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REFLECTIONS ON THE BEGINNINGS OF ANCIENT RUSSIAN GLASSMAKING[1]

Abstract: The origin of non-alkaline lead-silica ($PbO•SiO_2$) and lead-potassium-silica ($PbO•K_2O•SiO_2$) glass-forming technologies, which many Russian researchers believe to be typical of ancient Russian glassmaking and attesting to independent glassmaking in early 11th c. Rus', is discussed in this paper, limited to a few selected aspects of the issue. Research has proposed two sources of these technologies adopted in Rus': Byzantium (Shchapova, Noonan) and, in the case of the first one, the Far East (Brill). The number of discoveries of glasses of these two chemical types, both artifacts and production waste, from Europe as well as from the Far East in particular, has grown in the past few dozen years. New studies presenting the results of chemical composition analyses of glasses of these types have also increased exponentially. The growing body of data substantiates a return to the subject of the origins of ancient Rus' glassmaking. The research should be based on a comparative analysis of the results of laboratory tests of remains from workshops of type A (with full production cycles attested) as well as ready products found in ancient Rus' and in other regions, especially in the Far East.

Keywords: early medieval Rus', glassmaking, provenience of $PbO•SiO_2$ and $PbO•K_2O•SiO_2$ recipes

Abstrakt: Tematem rozważań jest pytanie o źródła pochodzenia technologii ołowiowo-krzemowej bezalkalicznej ($PbO•SiO_2$) i ołowiowo-potasowo-krzemowej ($PbO•K_2O•SiO_2$), które zdaniem wielu badaczy rosyjskich są charakterystyczne dla szklarstwa staroruskiego i świadczą o wykształceniu się na Rusi w początku XI w. samodzielnej szkoły szklarskiej. W artykule można było przedstawić tylko niektóre wątki z zakresu tej problematyki. W literaturze przedmiotu znajdujemy opinie, że znajomość wymienionych dwóch technologii Rusini przejęli z Bizancjum (Szczapowa, Noonan), lub pierwszej z nich z Dalekiego Wschodu (Brill). W ostatnich kilkudziesięciu latach wyroby ze szkła tych typów chemicznych, a także odpady ich produkcji, pojawiają się coraz częściej w różnych krajach europejskich, a przede wszystkim na Dalekim Wschodzie. Znacznie zwiększyła się też liczba publikacji wyników analiz składu chemicznego tych szkieł. W tej nowej sytuacji konieczne jest podjęcie na nowo studiów nad źródłami pochodzenia szklarstwa staroruskiego. Powinny one być oparte na analizie porównawczej rezultatów badań laboratoryjnych pozostałości warsztatów typu A (w których odbywał się pełny cykl produkcyjny) oraz gotowych wyrobów, występujących zarówno na terenie dawnej Rusi, jak i na innych terenach, zwłaszcza na Dalekim Wschodzie.

Słowa kluczowe: wczesne średniowiecze, Ruś, szklarstwo, pochodzenie receptur $PbO•SiO_2$ i $PbO•K_2O•SiO_2$

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Discovering the origins of glassmaking recipes used in different territories borders on the impossible when there are no written sources to go by. However, there is an extensive literature on the subject of the provenience of the non-alkaline lead-silica (high-lead silica) and lead-potassium-silica technologies[2] for melting glass that was used to make artifacts discovered in early medieval features and sites in Rus' territory. The following is a brief review of mainstream research on this issue. The focus here is on glassmaking in Kievan Rus'; data from later periods and other areas of old Rus' are cited only as comparative material.

1. STATE OF RESEARCH IN BRIEF

Interdisciplinary research on glass artifacts discovered in ancient Rus' territories started with Mikhail A. Bezborodov's work in the late 1940s. Taking into account the results of his extensive study of ready products, semi-products, waste products and fragments of furnaces, all of which he subjected to chemical, microscopic and other analyses, and his determinations of glass melting temperatures as well as crucible fabric microstructure, he was able to reconstruct the glass production and melting technologies that he believed were used by the ancient Russian glassmakers. Bezborodov established that the non-alkaline lead-silica ($PbO{\bullet}SiO_2$) and the potassium-lead-silica ($PbO{\bullet}K_2O{\bullet}SiO_2$ according to current nomenclature) glasses, found in assemblages from the 11th–13th centuries in the European part of the former Soviet Union, were produced by ancient Rus' glassmakers and that both technologies were typically employed in ancient Rus' glassmaking (Bezborodov 1956, pp. 173–174, 245, 259–261; *idem* 1969, pp. 160, 161, Table 23B 15, 16; Olczak 1964, p. 343, note 204). Moreover, he admitted that the two types of glass were known also outside of Rus': glass melted with the lead-silica technology has been found in Japan and the lead-potassium-silica technology was recorded in Germany, although the variant used in Rus' was improved by adding potassium as potash to the batch (Bezborodov referred to this as "potash" glass). In Germany, wood ash was used in the 11th–13th centuries ("ash" glass), but Bezborodov was of the opinion that "ash" glass was also produced in Rus' (Bezborodov 1956, pp. 90, 263, 265; *idem* 1969 – although here on p. 161 he says that the $K_2O{\bullet}PbO{\bullet}SiO_2$ type of glass has not been found anywhere outside the Soviet Union and Poland, not having much significance

withdraw it following the events of February 24, 2022, in accordance with the legal regulations of the Polish authorities on the discontinuation of scientific cooperation with the Russian Federation. The currently published version of the article contains changes with regard to the version edited in Moscow.

[2] Glass of the lead-potassium-silica type has been given different names in the literature. Russian researchers, for instance, refer to them as potassium-lead-silica, placing potassium oxide in first place ($K_2O{\bullet}PbO{\bullet}SiO_2$). Authors from a few other countries start off with silica first. Polish scholars (and others as well) tend to use a quantitative criterion. If the concentration of PbO exceeds that of alkali in the glass, then it is treated as a lead-alkali variant and then lead oxide is at the beginning, but if the glass contains less PbO than alkali, then it is designated as an alkali-lead variant and the alkali take first place in the designation (Dekówna 1980b, p. 283; on this issue, see also: Dekówna, Purowski 2019, p. 280, note 13).

in the latter place). The ancient Rus' provenance of glass of both chemical types was accepted in principle (see below) by most Soviet and later Russian researchers.

The prevailing view in Russian literature that glasses with the chemical composition $PbO•SiO_2$ known from Rus' were produced by Rus' glassmakers and that $PbO•K_2O•SiO_2$ glass was their invention was not generally questioned despite published information on single artifacts of these chemical types of glass occurring in other territories and written records noting lead recipes, which indicated that glass of these types was produced in different periods and regions (going beyond Bezborodov's work cited above, see Turner 1956, p. 47T; Caley 1962, p. 45, Table LVII 3, 4; Bakhtadze, Deopik 1963). Yulya L. Shchapova was aware of $PbO•SiO_2$ glass produced already in the ancient Near East, as well as in early medieval western Europe and Byzantium (Shchapova 1983, pp. 187 ff., Fig. 45), and seemed inclined to assume that the lead-silica recipe was adopted in Rus' from outside (Byzantium?) more or less in the end of the 10th c. (Shchapova 1972, pp. 188–193; *eadem* 1983, pp. 183–186). As for the $PbO•K_2O•SiO_2$ recipe, her opinion was that it was the effect of ancient Russian glassmakers' experience in adding potash to the lead-silica batch, which they had started doing in the first quarter of the 11th c. (Shchapova 1983, pp. 182, 184–185). In her words, "the world glass-making tradition does not know glass … of the composition" recorded as $PbO•K_2O•SiO_2$; and that these two types of glass are proof of an "independent glassmaking school" generically associated with Byzantine glassmaking, emerging in Rus' in the early 11th c. (Shchapova 1972, pp. 182–189; *eadem* 1978; 1983, pp. 183–191). A detailed study of the results of chemical composition analyses of glass of different colours (especially colourants, decolourants and opacifiers) in bracelets from Novgorod, Polotsk and Smolensk led her to assume the existence of glass workshops in these centres in the period from the middle to the end of the 12th c., where glassmakers coming from Kiev would have melted glass of the $PbO•SiO_2$ type, even as other glassmakers working in Novgorod at the turn of the 12th and in the beginning of the 13th c. produced $PbO•K_2O•SiO_2$ glass ($K_2O•PbO•SiO_2$ according to Shchapova 1972, pp. 119–142, 191).

Polish researchers had noted the presence, production and reworking of non-alkaline lead-silica glass in different parts of early medieval Europe earlier than in Rus': in Poland from the middle of the 10th c., in the northern Caucasus in the 8th–9th centuries, in Germany in the 9th c., in Sarkel on the Don in the 2nd half of the 9th–1st half of the 10th c. (Kaźmierczyk 1968, pp. 241–242; Olczak 1968, pp. 47 ff., Table 4; Dekówna 1980b, pp. 319, 320, 326, 327; *eadem* 1981, pp. 157–160). They also observed the production of this glass in broadly considered western Europe (Olczak 1968, pp. 206–208; Dekówna 1980b, p. 320; see below). The results of glass chemical composition analyses of non-alkaline lead glasses from Poland and Rus' demonstrated rather no similarity between the relevant technologies in the two regions (Dekówna 1980b, Tables 92; 93).

Lead-potassium-silica glasses first appeared in Poland in the 11th c., more or less at the same time as in the Rus' lands (Olczak 1968, pp. 218–219, but see below); they may have been melted or remelted in Wrocław in the 2nd half of the 11th c. (Kaźmierczyk 1970, p. 209; see below).

Development of research on levels of concentration of the principal glass-forming constituents, their proportions, as well as their totals and the relations between them has broadened significantly the body of data on ancient glassmaking. These research methods were used for a long time (for a review of the literature, see Dekówna 1980b, p. 30), but it was Shchapova who introduced them into research practice on a broader scale, especially in studies of alkaline glass. Shchapova established how the properties of the glass were impacted by the contents of principal glass-forming constituents and the relations between them. The content was established after first determining the level of concentration of these components in glasses of different types (Szczapowa/Ščapova 1973; 1975). These methods were adopted primarily by Polish researchers, who modified them somewhat, countering Shchapova's interpretation of some of the data (e.g., Dekówna 1980a; 1980b, who included in the last referenced study a proposal of rules for classifying the results of chemical composition analyses of non-alkaline lead-silica glasses, see Dekówna 1980b, pp. 313, 321, Table 92; see also Stawiarska 1984; 1988 and later work by these researchers, as well as the work of others, e.g. Olczak 1998). Methods of this kind are currently employed by many researchers worldwide.[3] They have come to represent standard research practice for historians of ancient glassmaking.

In the outcome of these research developments, a more orderly presentation of the results of chemical composition analyses of ancient glass became possible. Technological groups could be isolated and compared. Factors were identified to help determine, among others, glass-making recipes for the glass from which the examined artifacts were made. Raw resources used in the melting were examined and the nature of waste products described. Interpretative possibilities have also been broadened, greatly facilitating the provenancing of this material. The progress in research in ancient glassmaking has been considerable thanks to these procedures. They are also useful in addressing issues connected with the two types of glass, $PbO \bullet SiO_2$ and $PbO \bullet K_2O \bullet SiO_2$, addressed in this article (see below).

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[3] For example, in his monumental study Robert H. Brill published the results of laboratory analyses of glass from different regions of the world, adding in the case of the results for alkaline glass calculations of the sums and proportions of the following components: Na_2O+K_2O; $CaO+MgO$; $SiO_2+Al_2O_3+Fe_2O_3$; Na_2O/K_2O; CaO/MgO. He wrote: "Near the bottom of each table, several (usually five) ratios or sums of certain oxides are reported. These can be useful for comparing groups of glasses" (Brill 1999, p. 10). One should add that the results of calculations of sums and proportions of this set of components have been used and continue to be used by Polish researchers, among others (e.g. Dekówna 1980b; Olczak 1998; Dekówna, Purowski 2012; 2015; 2019; Wajda 2014).

Studying the proportions of the main glass-forming components, Julian Henderson isolated a few types of ancient glass, which he linked to specific centres (Henderson 1989; 2013, pp. 183 ff.). His conclusions in this regard are generally accepted.

These methods were used to study various issues connected with raw materials and technologies for melting the glass mass (e.g. Freestone 1994; Freestone *et al.* 2002; and many others).

Alexander N. Egor'kov presented an unusual dissenting opinion, negating the usefulness of the application of such methods due to the laboriousness of the process and the space that the results occupy in publications without, in his opinion, actually delivering any solutions (Egor'kov 2015, p. 233).

Year	Greeks in Kiev	Rus'	Rus'
1000	NaKCaSi/beads mosaics, bracelets	PbSi/Kiev/ beads, rings	
1025	*	*	KPbSi/Kiev/ glassware, window glass, beads, rings
1050	rings, vessels, window glass	declining production	increasing production
1075	*	*	*
1100	*	Kiev/glazing for ceramics, tiles, *pisanki;* smalt for mosaics	*
1125	*	*	Kiev/bracelets Kiev/new types of glassware
	*	Kiev/bracelets (briefly), Liubech/ bracelets	*
1150	*	Novgorod/ bracelets	*
	*	Smolensk/ bracelets	*
	*	Polotsk/ bracelets	*
		*	*
1175	sharp decline in production--some bracelets made	Voishchiny/ bracelets	*
	*	*	increasing production
	*	*	*
	*	*	Novgorod/Old Riazan'/Serensk/ bracelets, beads?, rings?
1200	*	Production of *pisanki* ceased	
1225	*	*	*

Fig. 1. The origins and development of glassmaking in Kievan Rus'.
After Noonan 1989, Table A

Ryc. 1. Pochodzenie i rozwój szklarstwa na Rusi Kijowskiej.
Wg Noonana 1989, tabela A

In 1989, Thomas Noonan presented a comprehensive summary of this stage of research on ancient Russian glassmaking (see Fig. 1). He based his article primarily on Shchapova's results, but he observed that the appearance of the lead-silica glass recipe in Rus' seemed to be of more interest to researchers abroad than to Russian scholars. He closed the discussion on the provenance of the two recipes with the following conclusions: glass-melting know-how came to Rus' with the Byzantine glassmakers invited around 980 by Grand Prince Vladimir to decorate two Kiev Orthodox churches with glass mosaics and glazed roof tiles. These master craftsmen were summoned repeatedly and rather did not settle permanently in Rus' (or if so, only some of them). The recipes used by the Russians consisted of the traditional soda recipe and its variants, as well as a variety of recipes for making lead glasses. The lead-potassium recipe that was most widespread in Rus' should be considered as a local variant of the potassium glass produced in Europe, in territories north of the Alps, starting roughly around 800–1000 (Noonan 1989, p. 25).

Noonan went on to devote a large part of his article to considerations on the origins of the lead-silica recipe in Rus'. His knowledge of early medieval European and Asiatic glassmaking permitted him to reject the possibility of the recipe coming from Bulgaria, the Baltic Slavs, Poland, central Asia and Japan. He repeated his conjectures about the lead recipe coming from the Byzantine masters invited to decorate the Kiev churches, who were not glassmakers strictly speaking (they did not produce vessels or ornaments), but craftsmen working in mosaics and glazes. Lead glaze was used to glaze ceramic vessels in the Roman period from Asia Minor to Britain, and also later, from the 7th/8th c., in Constantinople. In the 10th c., Byzantine craftsmen were undoubtedly highly experienced in the art of lead glazing. Noonan went on to cite T.I. Makarova's conclusion about a glazed pottery workshop working in Kiev in the 990s and 1040s, and glazed vessels being made on the side by the craftsmen producing glazed roof tiles. Analyses of the glaze demonstrated that the glass was of the $PbO \bullet CaO \bullet SiO_2$ type with a high content of aluminium; this type of glass was commonly used for glazing ceramics in Byzantium. Noonan quoted Makarova's opinion that Russian and Byzantine craftsmen working in the glazing workshops used Byzantine technology with local raw materials (Noonan 1989, pp. 26–32, with list of references to T. Makarova).

Noonan cited results published by Bezborodov and other authors regarding the glass chemical composition of the mosaic cubes from the earliest churches that the Byzantine masters had been asked to decorate in Kiev. The glass was melted according to different soda and lead recipes (non-alkaline and alkaline) and the conclusion was that: "…the adoption of PbSi and KPbSi glass recipes in Rus' can be seen as a logical development which took place as Byzantine and Rus' masters adapted the recipes used for glazed tiles and mosaics to the needs of glazed ceramics and glass goods. The adoption of lead silicate glass recipes was thus an integral part of the development of glass industry in Rus' based on Byzantine origins" (Noonan 1989, p. 37).

The growing number of finds of lead glasses from Asia, including the Far East, and the results of glass chemical composition analyses prompted Robert Brill to look for other sources of the lead recipe used in Rus'. In a paper published in the proceedings of the XV International Congress on Glass in Leningrad in 1989, he said: "Perhaps this high-lead technology moved along the river and overland systems linking Eastern Europe to that part of the world – but in which direction? One is reminded of the numerous precedents for heavily-leaded glasses in China and Japan. It is conceivable that the use of high-lead compositions could have moved westward through Central Asia along the Silk Road into Iran and Turkey and then into Eastern Europe" (Brill 1989, p. 22).

He returned to this issue in his later works: “The lead-silica family of glasses probably evolved from some technology closely related to glassmaking such as ceramic glazing, glass or metal enamelling, or the manufacture of imitation gems. Such glasses have been found in Viking and eastern European contexts. Trade with Turkey or northern Iran (along the Danube and Volga Rivers) could have been involved. Looking east, a lead-silica glass composition may have been brought westward across the Silk Road from westernmost China, where examples of lead-silica glasses from at least as early as the Tang Dynasty have been found. […] The notion of a long-distance technological glass connection that may have moved from East to West is intriguing” (Brill, Stapleton 2012, p. 430).

In a book published in 2001, V.A. Galibin opined that an independent glassmaking school, which could be called Russian, emerged in eastern Europe in the end of the first millennium; it was distinguished by glass of two chemical types: $PbO{\bullet}SiO_2$ and $K_2O{\bullet}PbO{\bullet}SiO_2$ ($PbO{\bullet}K_2O{\bullet}SiO_2$ according to the terminology explained above). This ancient Russian glass spread beyond the territory of Rus’ to northeastern Europe but did not penetrate south (Galibin 2001, pp. 81–82).

Bezborodov and Galibin reconstructed the composition of batches of both types. According to Bezborodov, the batch for melting non-alkaline lead glass in Rus’ from the $10^{th}/11^{th}$ centuries consisted of 2–4 parts lead (Pb) or 2.4–4.3 parts lead oxide (PbO) and 1 part sand (Bezborodov 1956, p. 183; *idem* 1969, p. 160, Table 23B15). For Galibin, the average lead content in glasses produced in Rus’ was 50–70%; glass of this kind melts in temperatures of 600–800°C (Galibin 2001, pp. 81–82).[4]

According to Bezborodov, the average chemical composition of $PbO{\bullet}K_2O{\bullet}SiO_2$ glasses produced in Rus’ is as follows: PbO 23.50–33.93%; K_2O 10.45–18.25%; SiO_2 52.80–62.20% (Bezborodov 1956, p. 239); according to Galibin it is: PbO 18–30%; K_2O 10–20%. This glass is more difficult to melt than the lead-silica type, because the temperature has to be 800–1000°C (Galibin 2001, p. 82).[5] Galibin pointed out a specific characteristic of the $PbO{\bullet}K_2O{\bullet}SiO_2$ glasses, namely, limited admixtures, unlike glasses melted in this period from batches following in their composition different recipes. This was due to the low iron content in the sand used by the ancient Rus’ glassmakers and the fact that when making potash from ash the iron remains in the insoluble sediments. It was also the reason why there was no need to use decolourants (manganese, antimony) for the production of glass of this type (Galibin 2001, pp. 82–83).

Russian researchers published the results of chemical composition analyses of glass objects discovered in Russian territory, finding for the most part that in the case of the $PbO{\bullet}SiO_2$ and $PbO{\bullet}K_2O{\bullet}SiO_2$ glass types, both the material itself and the objects made of it could have been made by the ancient Rus’ glassmakers.

[4] According to J. Olczak, batches for melting the glass used in artifacts coming from archaeological discoveries in Poland were composed of 3–4 parts Pb and 1 part sand (Olczak 1968, pp. 208–213). The study of glasses from Opole-Ostrówek and Wrocław-Ostrów Tumski demonstrated an average of 70–75% PbO and 23–26% SiO_2 in non-alkaline lead glasses (Pankiewicz *et al.* 2017, p. 70).

[5] Glasses of the $PbO{\bullet}K_2O{\bullet}SiO_2$ type from Opole-Ostrówek and Wrocław-Ostrów Tumski (Poland) contain an average of approximately 50% PbO; 9–12% K_2O and 30–35% SiO_2 (Pankiewicz *et al.* 2017, p. 70).

The question of the methodology of identifying glass production sites based on examples from the territory of ancient Rus' was addressed in an article by Ekaterina K. Stolyarova. There are two kinds of analyses: of archaeological sources and of laboratory results. In the former case, studies concern primarily different kinds of production remains, providing the grounds for identification of workshops with a full production cycle (from melting raw materials into glass to the ready product made of this glass), because only the physical presence of such workshops is evidence of local glass production. Stolyarova discussed the difficulties in discovering sites of this kind and ultimately, taking into consideration also the results of other researchers, concluded that remains of such workshops were recorded in southern Rus': in Kiev next to the church of St Sophia (which started to be constructed in 1037 and was completed in 1067), in the grounds of the Kiev Pechersk Lavra (1083), in Podolya and near the Mikhailovskii Cathedral (1108) (Bezborodov 1956, pp. 150, 154, 155; Lazarev 1986,[6] pp. 77, 99; Stolyarova 2015, p. 336). These workshops produced glass, which was used, among others, to make mosaic cubes for the decoration of the churches mentioned above. The results of the chemical composition analyses of the mosaic glass published by Bezborodov demonstrated that cubes of $PbO \bullet SiO_2$ glass and semi-products of $Na_2O \bullet CaO \bullet SiO_2$ glass melted according to ancient recipes occurred in the Kiev Pechersk Lavra workshops, that the cubes from the St Sophia Cathedral represented four types of glass: $PbO \bullet SiO_2$, $PbO \bullet K_2O \bullet SiO_2$, $Na_2O \bullet CaO \bullet SiO_2$ and $Na_2O \bullet PbO \bullet SiO_2$ and that those from the Mikhailovskii Cathedral three types: $PbO \bullet SiO_2$, $Na_2O \bullet CaO \bullet SiO_2$ and $Na_2O \bullet PbO \bullet SiO_2$. About half of the studied mosaics were made of lead-silica glass (Bezborodov 1956, pp. 159, 161, 163, 166). Bezborodov noted evidence of Byzantine craftsmen from Constantinople participating in the construction of the Church of the Tithes (989–996) and the Uspenskii Cathedral; he quoted written sources reporting large quantities of mosaic cubes being brought by merchants for the decoration of the Kiev churches under construction. This took place in the end of the 11^{th} c. when the Kiev Pechersk Lavra glass workshop was already operational. It was necessary to arrange glass production locally because of raiding nomads threatening the southern trade routes between Rus' and Byzantium and the lands of the East, which disorganized trade, including the import of mosaic components (Bezborodov 1956, pp. 149, 155, 158, 159, 161, 163, 166).

Discoveries made in the past several years of artifacts made of $PbO \bullet SiO_2$ and $PbO \bullet K_2O \bullet SiO_2$ types of glass and the growing number of publications of the results of glass chemical composition analyses have brought out a much more complex picture of the development of lead silica and lead-potassium-silica glass technology than assumed before.

Glasses of the first type are found in the Far East (China, 206 BC–AD 220; 7^{th}–8^{th} centuries AD; it is believed that they were produced here from the 6^{th}–7^{th} centuries, perhaps even earlier; Korea, 1^{st} c. BC–1^{st} c. AD and 4^{th}–7^{th} centuries AD; Japan, produced in the end of 7^{th} c. AD); they appeared in the northern Caucasus

[6] The author is grateful to Prof. E.K. Stolyarova for bringing this work to her attention.

in the 8th c., in Germany in the 8th–9th centuries, in the British Isles from the 10th c. (for the collected data, see Dekówna [2010] 2015, pp. 279–284), in Slovakia in the 10th c. (Staššíková-Štukovská, Plško 1997, pp. 270–272, Tables 4: 8, 9, 15–18, 20; 8; Plate 21: Stufe 6A, B).

As for the $PbO \bullet K_2O \bullet SiO_2$ type of glass, Shi Meiguang and co-authors consider them as apparently widespread in China in the 10th c., at the same time that they were being exported to Japan (Shi Meiguang *et al.* 1991, p. 28). According to Marta Żuchowska, the production of this type of glass (PbO 30–50%; K_2O 7–15%; SiO_2 30–60%; Na_2O <1%) developed in China already in the Six Dynasties period (222–589) (Żuchowska 2016, p. 80). Glasses of this kind have also been reported from western and central Europe. Smoothers made of lead-potassium-silica glass were discovered in the British Isles (10th–11th centuries; Bayley 2009, pp. 257–259). Objects made of this type of glass, dated to the 9th–10th and 12th centuries, were found in Germany (Wedepohl *et al.* 1995, p. 74, Table 2: Bru 9, 11; Hoex 9). Karl-Hans Wedepohl stated that in Central Europe "wood-ash-lead glass", that is, glass melted from a batch composed of wooden ash and lead (and sand – M.D.), occurred in the 8th–11th centuries; such are the smoothers found at Haithabu. In his opinion, these objects were widespread among the Vikings (Wedepohl 2001, pp. 262, 263; Krueger, Wedepohl 2003, p. 94). The presence of glass of this type has also been noted in North Africa (9th–10th centuries; Robertshaw *et al.* 2010, Table 3, no. 889).

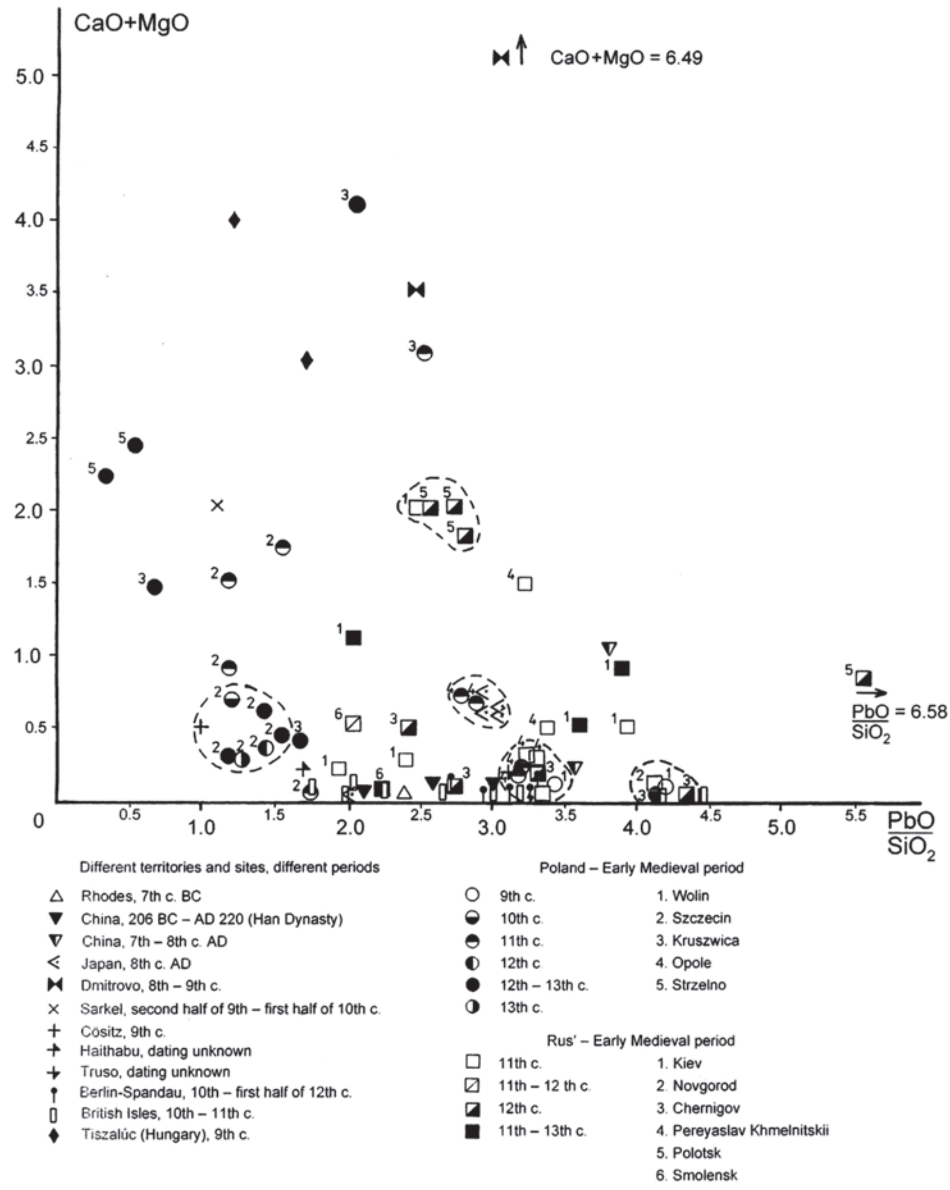
An effort was made to classify the growing body of data and to isolate technological properties in the glass chemical compositions of the two types of glass. These were subsequently used as a basis for identifying different groups among these glasses. The proportions of the principal glass-forming constituents constituted one of the criteria. And so, glasses of the $PbO \bullet SiO_2$ type from different regions and periods were grouped based on the relation of the PbO/SiO_2 (main characteristic) value to the summed up value CaO+MgO[7] (Fig. 2; Dekówna [2010] 2015, p. 284, Fig. 4). Glasses from ancient Rus' can be placed in two groups: 1. the most numerous group including examples from Rus' (11th and 12th centuries, Chernigov and Pereyaslav Khmelnitskii), Poland (9th and 11th centuries), China (206 BC–AD 220), Truso and Germany (10th–1st half of the 12th centuries) and British Isles (10th–11th centuries); 2. group composed of glasses found only in ancient Rus' territory (11th and 12th centuries; Kiev, Polotsk). The division derives from an analysis of the results of glass chemical composition studies of a relatively small set of finds, hence these data shall not be commented on here. One should point out that the finds from Rus' are dated rather late compared to other elements of the set.

The proportions of two components, K_2O/CaO or CaO/K_2O, was the criterion for dividing glasses of the $PbO \bullet K_2O \bullet SiO_2$ type. O. Mecking used it in her study of the remains of a workshop from the 13th c. in Erfurt, which produced beads and rings made of lead glass of different types. A detailed comparative analysis

[7] Analysing with his collaborators the chemical composition of $PbO \bullet SiO_2$ glasses from just one site (al-Basra, Morocco, AD 800–1100), P. Robertshaw divided the material according to the criterion of the PbO/K_2O ratio (Robertshaw *et al.* 2010, pp. 362 ff., Fig. 7).

of the lead-potassium-silica glasses, among others, which occurred here and the glasses found in eastern and central Europe, led the researcher to conclude that these glasses were widespread all over Europe, from England to Russia. She identified three groups: western German, Slavic and central European (eastern Germany, Poland, Slovakia, Czechia; Mecking 2013, pp. 651 ff.).

The current body of data, much more numerous and differentiated than the one available to Bezborodov, Shchapova, Galibin and other researchers, would require



new studies on the origins of ancient Russian glassmaking, especially the issue of the said two recipes for melting lead glasses. These studies, like the ones carried out until now, should be based on an examination of two main categories of data: 1. material sources (archaeological finds) and 2. results of laboratory analyses.

2. SOURCE BASE FOR FUTURE STUDIES. RESEARCH METHODS

2.1. MATERIAL SOURCES (ARCHAEOLOGICAL)

Research to date has demonstrated a large diversity of forms of glassmaking organization in antiquity and medieval times (perhaps only in some territories and in some periods of the indicated time) generally reflected as workshops of two types: A, producing glass from primary raw materials, and B, producing artifacts from already melted glass delivered from workshops of type A. Bezborodov pointed out the presence of both types in Rus', noting that the larger workshops were characterized by a full technological process, from melting the glass itself to crafting artifacts, while workshops with only simple furnaces engaged in forming objects

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Fig. 2. Glass chemical composition characteristic of non-alcaline lead silica glasses from different regions, sites and periods

Sources of analyses used for computation: Rhodes – Caley 1962, Table LVII 3; China, 206 BC–220 AD – Caley 1962, Table LVII 4; Brill 1999, Table XVA, nos 6771 and 6773; China, 7th–8th centuries – Brill 1999, Table XVA, nos 1587 and 1588; Japan – Bezborodov 1969, Table XXI, nos 652, 653, 656, 660, 671; Dmitrovo – Dekówna 1981, Table 4: 1, 2; Sarkel – Dekówna 1981, Table 4: 4; Cösitz – Dekówna [2010] 2015, Tables 1 and 2; Haithabu – Dekówna 1981, Table 4: 5; Truso – Dekówna and Purowski 2012, pp. 258–259, Table 28; Berlin-Spandau – Ullrich 1989, Table I, nos 3401, 3402, 3409, 3442, 3444; British Isles – Bayley 2009, Table 2, nos 2113-1b, 2113-1a, 2113-3b, 2113-3a, 2113-1d, 2113-3c, 3156, 4361, 4457; Tiszalúc – unpublished, analyses in the author's possession; Wolin – Olczak 1968, Table 2, nos 670, 671; Szczecin – Dekówna 1980b, Tables 87; 88: 1, 2; 99: 1–7; Kruszwica – Olczak 1968, Tables 22, nos 457, 520, 521, 933; 24: 480e; Opole – Olczak 1968, Table 8, nos 246, 247, 252, 253; Strzelno – Bezborodov 1969, Table XXI, nos 683, 684; Rus' – Bezborodov 1969, Table XXI, nos 643–650, 654, 657, 659, 664–670, 673–676.
Note: The numbers next to symbols in the chart refer to sites in Polish and Rus' territory listed in the legend.

After Dekówna [2010] 2015, p. 282, Fig. 4 updated

Ryc. 2. Charakterystyka składu chemicznego szkieł ołowiowo-krzemowych bezalkalicznych z różnych obszarów, stanowisk i okresów

Źródła informacji o wynikach analiz, które posłużyły za podstawę obliczeń: Rodos – Caley 1962, tabela LVII 3; Chiny, 206 r. p.n.e.–220 r. n.e. – Caley 1962, tabela LVII 4; Brill 1999, tabela XVA, nry 6771 i 6773; Chiny, VII–VIII w. – Brill 1999, tabela XVA, nry 1587 i 1588; Japonia – Bezborodov 1969, tabela XXI, nry 652, 653, 656, 660, 671; Dmitrovo – Dekówna 1981, tabela 4: 1, 2; Sarkel – Dekówna 1981, tabela 4: 4; Cösitz – Dekówna [2010] 2015, tabele 1; 2; Haithabu – Dekówna 1981, tabela 4: 5; Truso – Dekówna, Purowski 2012, s. 258–259, tabela 28; Berlin-Spandau – Ullrich 1989, tabela I, nry 3401, 3402, 3409, 3442, 3444; Wyspy Brytyjskie – Bayley 2009, tabela 2, nry 2113-1b, 2113-1a, 2113-3b, 2113-3a, 2113-1d, 2113-3c, 3156, 4361, 4457; Tiszalúc – niepublikowane, analizy w posiadaniu autorki; Wolin – Olczak 1968, tabela 2, nry 670, 671; Szczecin – Dekówna 1980b, tabele 87; 88: 1, 2; 99: 1–7; Kruszwica – Olczak 1968, tabele 22, nry 457, 520, 521, 933; 24: 480e; Opole – Olczak 1968, tabela 8, nry 246, 247, 252, 253; Strzelno – Bezborodov 1969, tabela XXI, nry 683, 684; Ruś – Bezborodov 1969, tabela XXI, nry 643–650, 654, 657, 659, 664–670, 673–676. Uwaga: cyfry przy symbolach na rycinie odpowiadają numerom stanowisk na terenie Polski i Rusi, według wykazu znajdującego się pod ryciną.

Wg Dekówny [2010] 2015, s. 282, ryc. 4 ze zmianami from semi-products and glass cullet delivered from workshops of type A, among others (Bezborodov 1956, pp. 267–268).

R.H. Brill and J.P. Wosinski suggested a similar model of glassmaking in antiquity and medieval times: "Glassmaking can be divided into two operations: an engineering stage, producing the material from its ingredients (primary production), and a handcrafting stage (secondary production), fashioning the material into objects" (Brill, Wosinski 1988, pp. 283–284, cited after Henderson 2013, p. 307). On this, Henderson: "Primary production centres can be defined as locations where the glass was fused from primary raw materials; secondary production centres imported raw glass, its colour may have been modified and then beads, windows and vessels manufactured from it" (Henderson 2013, p. 307), and: "Evidence for primary glass production can consist of evidence of fritting, including overheated frit and fritting ovens […]. If a fritting oven is discovered, then this is clear evidence for primary production. Even though frit could potentially also be imported, this does not detract from the evidence of primary production" (Henderson 2013, p. 18).

The present author is of the opinion that each type presumably encompassed at least a few variants. Type A would have included workshops where the full process was implemented, from preparing the batch out of primary raw materials, through its melting to the stage of crafting artifacts and their full treatment, as well as workshops where only the glass was melted to be sold in the form of blocks or semi-products, or frit. There could have also existed workshops crafting artifacts from glass melted in these workshops, but without final crafting (e.g., decoration), which would have been done in other workshops. As for the type B workshops, they would have encompassed variants of processing workshops, both re-melting glass brought from outside in the form of blocks, "cakes", ingots and cullet and crafting objects from this glass, as well as workshops which produced ready objects only from half-products or crushed glass (Figs 3; 4; Dekówna 1987, p. 208; *eadem* 1988, p. 6). Workshops in ancient and early medieval times could have also combined features of types A and B, meaning they were crafting products from glass melted on the spot as well as from raw glass brought from outside (Dekówna 1988, p. 16).

There are several reasons why finds from this group are such a difficult topic to study and require a special research approach. First, the material remains of glassmaking are hugely diverse and they often constitute a spotty record of the production process, there is a great diversity of forms of glassmaking organization as indicated above and some of these, especially type B, leave very meagre material evidence. The author has separately presented a proposal for characterizing workshop remains of each type and subtype by standardizing principles of description, classification of characteristics and interpretation (Fig. 3; see Dekówna 1988, pp. 16, 18, Fig. 6; *eadem* 2009).

Research on the origins of ancient Russian glassmaking should be based on an analysis of remains of workshops of type A of the earliest date. As indicated above, testimony of local glassmaking in Rus' was noted by Ekaterina K. Stolyarova, who distinguished workshops with a production cycle that was complete (type A) or incomplete (type B), and determined the existence of specialist workshops (for one

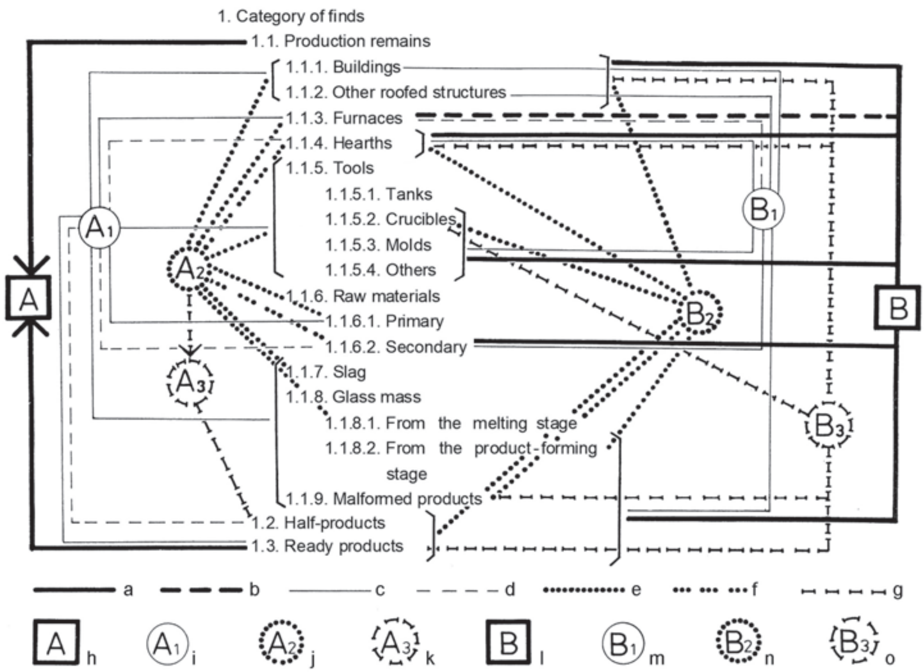

Fig. 3. Model scheme of the relations between categories of finds representing glassmaking and different kinds of glassmaking workshops

a, h – workshops of type A with elements of type B: c, i, e, j, g, k – variants of type A workshops (A_1, A_2, A_3); a, 1 – workshops of type B: c, m, e, n, g, o – variants of type B workshops (B_1, B_2, B_3). Dashed symbols (b, d, f) mark presumed attribution of finds from a given category, sub-category or group to a specific workshop variant.

After Dekówna 1988, Fig. 6, updated

Ryc. 3. Schemat obrazujący związek kategorii znalezisk dotyczących szklarstwa z różnymi odmianami warsztatów szklarskich

a, h – warsztatów typu A z elementami typu B: c, i, e, j, g, k – warsztatów odmian typu A (A_1, A_2, A_3); a, 1 – warsztatów typu B: c, m, e, n, g, o – warsztatów odmian typu B (B_1, B_2, B_3). Symbolami przerywanymi (b, d, f) oznaczono prawdopodobną przynależność znalezisk danej kategorii, podkategorii lub grupy do określonej odmiany warsztatów.

Wg Dekówny 1988, ryc. 6, ze zmianami

or more kinds of production employing a single technology) as well as universal ones (crafting a few kinds of objects using different technologies) and workshops where all the tasks were carried out by one or more master craftsmen, or where there was an inner division of tasks with hired masters of glassmaking, glassblowing, heat-treatment and decoration of the glass products with cold techniques (polishing, painting). Stolyarova did not identify any criteria for distinguishing remains of the last four categories (specialist and universal workshops, workshops with or without task division) in the archaeological record. However, she did identify workshops with a full production cycle (see above and Stolyarova 2015, pp. 336–339). She also

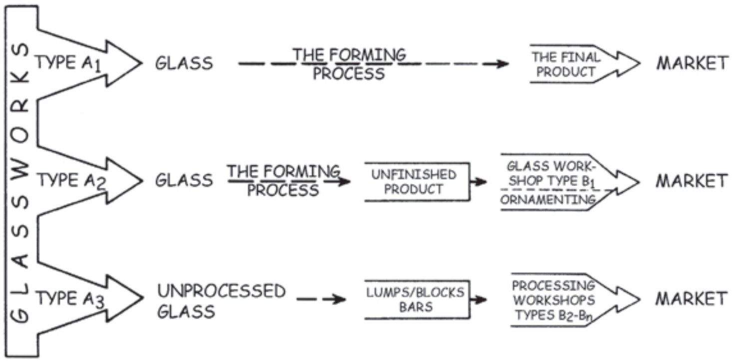

Fig. 4. Ideal model of organization of glassmaking in antiquity and early medieval times.
After Olczak 1998, Fig. 2, updated

Ryc. 4. Schemat organizacji produkcji szklarskiej w starożytności i wczesnym średniowieczu – założenia idealne.
Wg Olczaka 1998, ryc. 2, ze zmianami

quoted Shchapova's conclusions regarding the origins of the glassmakers working in the workshop at the Uspenskii Cathedral in the Pechersk Lavra. Based on the results of a glass chemical composition analysis of ready artifacts and waste products, Shchapova identified glassmakers from both Byzantium and Rus' (Stolyarova 2015, p. 340). Glass from Kiev with the following composition: K-Na-Pb-Si, K-Mg-Ca-Si, K-Ca-Mg-Pb-Si Shchapova considered as evidence of Russian glassmakers repeatedly testing recipes and raw materials used by the Byzantine masters (Shchapova 1998, pp. 81, 82; *eadem* 2008, pp. 81, 82). However, glass of the same and similar chemical composition have been found also in other territories (for further reading see Dekówna 2000, p. 191).

Recently Ukrainian researchers have conducted a detailed study of the surviving field documentation and numerous finds from excavations carried out by V.A. Bogusevych within the city of Kiev in 1950 and 1951. This extensive material has been published for the first time and with a new interpretation, according to which it cannot be confirmed that glassmaking existed in Podolya. No evidence of a glass furnace nor any production waste has been recorded. Rare finds of bricks with vitreous drippings and glass products suggest the kind of production that was practiced in the neighbourhood in the 12th–13th centuries (Khamaiko *et al.* 2022, pp. 50, 62, 64). However, the discovery *in situ* of remains of furnaces and production waste in the area of the Metropolitan Garden of Kiev Pechersk Lavra attests to the operation of a glassworks here in the 12th c. Also, "[T]he location of another glassmaking workshop to the North of the Trinity Gate Church was determined and its existence dates back to the 12th–13th centuries" (Khamaiko *et al.* 2021, pp. 121, 148). The authors recommend further detailed analyses of these finds using well-dated comparative material (Khamaiko *et al.* 2021, pp. 148).

As postulated above, a verification of the sources of the $PbO \bullet SiO_2$ and $PbO \bullet K_2O \bullet SiO_2$ recipes penetrating into Rus' should be undertaken in view of the much larger body of data now available. A comparative analysis should be carried out of the chemical composition of production remains as well as ready products which researchers (Bezborodov, Shchapova, Stolyarova) have identified as representing workshops of type A functioning in Rus' (it is frequently difficult to be certain because, as stated above, objects from other ateliers could have found their way into these workshops) and finds of this kind revealed in other regions, best if from functioning workshops. In this research, it is essential to take into account numerous finds from the Far East (see references cited above and Brill 1999, Table XVA; and, e.g., papers published in collective volumes: Brill, Martin eds 1991; Zorn, Hilgner eds 2010; Gan Fuxi *et al.* eds 2009; esp. Gan Fuxi 2009, pp. 99–101, Fig. 2.6), as well as new finds from Europe: Great Britain, Germany (e.g. Wedepohl *et al.* 1995; Wedepohl 2001; Gratuze *et al.* 2017; see below), and Poland (Rzeźnik, Stoksik 2017; Siemianowska *et al.* 2019, Tables 1: 1669/54, 2233/54; 2: 8/52, 25/68; 5: 1/66, 2577/54, 2764/54).[8] In Czech territory, glasses of the two types do not appear until the 11th–12th centuries (Černá *et al.* 2001, pp. 64, 65, 67, 70, Fig. 3: B, C; Černá, Tomková 2017, pp. 204, 206–207).[9]

Finds of smoothers merit note in this context. Artifacts of this kind were recorded already in 3rd c. AD assemblages from the British Isles and in Merovingian and Carolingian contexts in Britain and France. They were the most numerous from the 9th–10th centuries through modern times in Britain, France, the Netherlands, Germany, Denmark, the region of northern Elbe, Sweden and Norway (Dekówna 1980b, p. 152 with earlier references; and Schuld 1967, p. 36; Arwidsson 1984, pp. 199, 200, 202; Thénot 1985; Macquet 1990, pp. 324–327; Stephan *et al.* 1992, p. 100; *iidem* 1997, pp. 690–693; Steppuhn 1999; Caune 2003 detailed earlier references; Gratuze *et al.* 2017, pp. 92–93). Singular smoothers have been recorded from Spain (Clop *et al.* 1998), Czechia: Moravia (10 examples; Mikulčice, 9th c., Himmelová 1995, pp. 91–92, 101), Břeclav-Pohansko – nine examples, 9th–

[8] A glass-processing workshop operating after 970–975 was discovered in Poland in the locality of Obiszów (Grębocice commune, Lower Silesia) (Rzeźnik, Stoksik 2017). Non-alkaline lead silica glass of different chemical types (Rzeźnik, Stoksik 2017, Fig. 6: 13, 15, 16, 17) and glass of the $PbO \bullet K_2O \bullet Al_2O_3 \bullet SiO_2$ type (Rzeźnik, Stoksik 2017, Fig. 6: 14) were remelted in this workshop. The aluminium in the composition of the latter type of glass probably penetrated from the fabric of the crucible in which the glass was remelted. S. Siemianowska and associates have published finger rings from Opole-Ostrówek in Silesia, including examples of lead-silica or lead-potassium-silica glass from the 10th c., made, in the opinion of the authors, out of semi-products in glass-processing workshop(s) (Siemianowska *et al.* 2019, p. 643).

[9] In the 11th–13th centuries, the number of glasses of the two types discussed here grows substantially in different parts of Europe. In view of the focus of this article, the author has concentrated on the earliest dated finds, citing primarily the oldest among these.

Lead glasses have been reported from the Iberian peninsula, from territories occupied by the Arabs in the 8th c., but since the authors (e.g., Schibille *et al.* 2020) do not present the results of chemical composition analyses, it is impossible to tell whether there are any glasses of the two chemical types discussed here among the finds.

2nd half of the 10th centuries, Olomouc – one and Prague – one example, 11th–1st half of the 13th centuries (Ježek, Zavžel 2022, pp. 327, 329–330), Poland (three examples: Wrocław, 1st half of the 13th c., Kaźmierczyk 1970, p. 294, Fig. 47f; Żnin, Bydgoszcz province, 12th c., Olczak 1999, pp. 32–33, Fig. 5; Poznań, Middle Ages, Olczak 1999, pp. 31–32), Russia (a few examples: one each from Novgorod, 1st half of the 10th c., Ščapova [1991] 1992; Gnezdovo, 10th–early 11th centuries; Moscow, 10th c., Rostov, Suzdal, Stolyarova 2014; and a few fragments from Stara Ladoga, 10th–12th centuries?, Grigor'eva, Lesman 2012), Latvia (eight examples, different sites, mainly Riga, 10th–13th centuries and two examples from the 17th c., Caune 2003).

The function of smoothers is not clear. Based on late medieval and modern written attestations and ethnographical evidence earlier researchers suggested an utilitarian use for these objects, namely, "pressing" and smoothing of dried textiles and robes, mainly the hems and seams; they also seemed to be used to treat animal skins (Dekówna 2000, with references). It is also believed that they were used in the making of jewelry (Ježek, Zavžel 2022, pp. 339–341). An example from Styrmen in Bulgaria was used in a highly unique manner: as an ornament in a building (Dekówna 1980b, pp. 153–154). However, in recent years, evidence against an "utilitarian" function has mounted, smoothers beginning to be considered as formed pieces of raw glass ("Glassbaren", ingots) intended for trade (e.g. Ščapova [1991] 1992, p. 242; Stephan *et al.* 1997, pp. 692–693). Examination of the concave part of these smoothers has been suggested as a way of resolving this interpretative issue: scratches or streaks on this surface favoured the tool hypothesis (e.g. Steppuhn 1999, Figs 4; 5; 7), while a smooth and glossy surface indicated raw glass. In the latter case, the object needed to be broken into pieces (smaller chunks were easier to remelt and use in portions for the production of a variety of minor objects, such as ornaments). Consequently, smoother fragments could be interpreted as raw glass (Grigor'eva, Lesman 2012, p. 68). The present author is inclined to agree with the view of some researchers (e.g. Stephan *et al.* 1997, pp. 692–693) that smoothers were used for different purposes and these can be adjudicated based primarily on an examination of the archaeological context of discovery.

The glass of smoothers which has been subjected to chemical composition analysis, represented two variants: 1. potassium-lime, and 2. lead-lime-aluminium-silica. Lead glass is considered foremost in this article.

Lead glass, which occurred in different variants, was used in objects interpreted as smoothers discovered in France, Germany, the British Isles, Norway and Russia (Gratuze *et al.* 2017, pp. 92–93 with references). Summing up the results of their research, Bernard Gratuze and his co-authors argued that there is an undisputed similarity of composition between lead slag and the lead silica glass of the smoothers, and that it is very probable that the glass of smoothers were melted from a batch containing lead slag from the mine at Melle (southwestern France) (Gratuze *et al.* 2017, p. 105).

In an earlier study, these researchers compared their results with those from an analysis of the glass of smoothers from Novgorod, Haithabu, Kaupang, York and

Dublin, and found the chemical composition of the glass of artifacts from France and Ribe to have the same specific characteristics. They concluded that all the artifacts were produced of glass of the same type and have in all likelihood a common origin, and that the smoothers of lead glass discovered in York, Dublin and Ribe, like those from France, Haithabu and Kaupang, were produced using lead slag from the Melle mine. The smoother from Novgorod is also very likely of the same provenance[10] (Gratuze *et al.* 2014b, pp. 217, 220, 222).

These conclusions can be disambiguated based on the principles of classification of ancient glass proposed by Shchapova (1983, Table 2).[11] Applying these principles, the present author has concluded that the published results of Gratuze and his collaborators indicate the presence of smoothers of the $PbO{\bullet}K_2O{\bullet}CaO{\bullet}MgO{\bullet}Al_2O_3{\bullet}SiO_2$ glass type with higher iron and phosphorus content at Bressuire and Melle (Gratuze *et al.* 2014a, Fig. 5). Two smoothers from Haithabu are also made of glass of similar composition[12] (Wedepohl 2001, pp. 262–263, Table 3D, E), while examples from York and Dublin are of glass of the following types: $PbO{\bullet}K_2O{\bullet}CaO{\bullet}Al_2O_3{\bullet}SiO_2$ and $PbO{\bullet}K_2O{\bullet}Na_2O{\bullet}CaO{\bullet}Al_2O_3{\bullet}SiO_2$ with higher iron, phosphorus and barium content (Bayley 2009, pp. 257–258, Table 3); as for the smoother from Novgorod, it is of glass of the $PbO{\bullet}K_2O{\bullet}CaO{\bullet}MgO{\bullet}Al_2O_3{\bullet}SiO_2$[13] or $PbO{\bullet}K_2O{\bullet}CaO{\bullet}Al_2O_3{\bullet}SiO_2$ type with raised iron, phosphorus and barium content (Ščapova [1991] 1992, Table 1). Research has thus shown that the composition of the glass from which these objects are made demonstrates considerable similarity. The insignificant differences in the content of some of the components are due mainly to differences in the composition of the ash used for melting the glass.

The results of this research indicate that smoothers of the second variety of glass mentioned above were made of lead-potassium "ash" glass (wood-ash-lead glass according to K.-H. Wedepohl 2001, p. 262), which is different from the "potash" glass of this variant that according to Russian researchers was melted in Rus'.[14]

[10] Shchapova is inclined to associate it with Egyptian or, more broadly, Near Eastern glassmaking (Ščapova [1991] 1992, pp. 233–242).

[11] The researcher distinguished the following degrees of concentration of principal glass-forming constituents in potassium-lead glasses constituting the criteria for dividing into chemical types: Na_2O 1.5 – <4; K_2O <13; $CaO+MgO$ 2 – <4; PbO <21; SiO_2 45–55 (Shchapova 1983, Table 2).

[12] In need of correction is a remark made by the author regarding data on the smoothers from Haithabu made of the lead-potassium-silica type of glass in Dekówna [2010] 2015, p. 274, note 3. The relevant mention, which is based on information from Karl-Hans Wedepohl (2001), is included in Gratuze *et al.* 2003, pp. 103, 104.

[13] Glass of an analogous composition was used to make an artifact, a smoother most likely, a fragment of which was discovered at Cösitz (Zörbig) in Germany (10th c.; Dekówna 2000, Figs 4; 5; *eadem* [2010] 2015, p. 274).

[14] To conclude this chapter, it is worth mentioning that a fairly in-depth study of the production technology of $PbO{\bullet}SiO_2$ and $PbO{\bullet}K_2O{\bullet}SiO_2$ glasses has recently been published by Polish researchers. It is based on the results of a chemical composition analysis of the glass used to make bracelets found at Czermno (early medieval Polish–Rus' borderland), dated however not earlier than the 11th–13th centuries (Wajda *et al.* 2023, pp. 11–13).

2.2. LABORATORY ANALYSES

Research into the origins of the two recipes believed by Russian scholars to have been used by local glassmakers in Rus' must be based primarily, as explained above, on comparative analyses of the chemical composition of waste from glass production discovered in relics of workshops of type A as well as ready products from the territory of ancient Rus' and the glass of finds of the same kind from other territories. The analytical methods used for the purpose may differ, but the objective should be to receive quantitative results. Methods used most often recently include EPMA and LA-ICP-MS. Isotope analyses have also started to be performed.

Comparative research should be performed on the quantitative outcomes of the principal glass-forming constituents as well as components occurring in small amounts and even those recorded as trace elements (which, for example, could point to the kind of raw material used for melting the glass under analysis and its provenience), but also on the proportions of the main constituents. The literature on the subject characterizes many different research methods of this kind and the nature of the ensuing results.[15] The choice of methods is left to the researcher undertaking studies of this kind.

3. CLOSING REMARKS

The discussion presented in this paper covers only a few selected aspects of the issue in question. As indicated, the search for the origins of glassmaking recipes in use in given territories/centres in the past encounters serious difficulties. Foremost, researchers have repeatedly remarked on the rarity in the archaeological record of remains of fully equipped workshops of type A, evidencing different stages of the process (e.g. Dekówna 1987; 1988; Stolyarova 2015). Moreover, it is not easy to differentiate between remains of primary glass melting and cullet and/or semi-products brought from outside for processing in the workshop (some places could have combined different features of the two types of workshops [A and B] as signalled above). Despite this, in view of the recently growing number of finds associated with glassmaking from Europe and Asia (especially in the Far East) and the development of research methods and incremental accretion of laboratory results concerning the chemical composition of glass and, to a lesser degree, the fabric of the various elements of glass workshop equipment (furnaces, crucibles and others), it would be worthwhile under these new conditions to resume interdisciplinary studies on the origins and beginnings of glassmaking in Rus' and to present their results in the form of a monograph which would include (in a single work) a discussion of all (or most) aspects of this problem.

Major international trade routes passed through Rus' in early medieval times. Craftsmen of different specialties, glassmakers included, brought the technological know-how of their trade to the new places of their professional activity.

[15] A listing of the most important methods in Polish archaeological literature on the subject is to be found in: Stawiarska, Bis 2022.

It is currently understood that Rus' glassmakers had more sources than previously thought from which to draw glass-melting know-how. Contacts with the Byzantine Empire brought Byzantine glassmaking recipes to Kiev (see above). Many glassmaking workshops, including Stara Ladoga on the Russo-Finnish border, sprang up around the Baltic Sea in the 8th–9th/10th centuries in the wake of Arab trade. According to Russian researchers, the technology used at Stara Ladoga came in its entirety from the East (Rjabinin, Galibin 1995, pp. 111–112; Ryabinin 1997, p. 49; see also Dekówna, Purowski 2012, pp. 95–96). Robert H. Brill, an expert on ancient and medieval glassmaking, may well be right conjecturing a Far Eastern source (see above) for the lead glass melting technologies adopted in Rus' (and in other parts of Europe? – M.D.). After all, a major intercontinental route from Volga Bulgaria to Spain through Rus' and southern Poland was connected to the Silk Road by a network of smaller roads and trails. Glassmakers with the technological know-how to produce $PbO{\bullet}SiO_2$ and $PbO{\bullet}K_2O{\bullet}SiO_2$ glass could have followed these routes west.

Pioneering studies on ancient Russian glassmaking in the 1950s, Bezborodov based his theory on the limited data available in the 1950s. His hypothesis has now been corroborated by a much larger set of evidence: in Rus', $PbO{\bullet}K_2O{\bullet}SiO_2$ glass was melted from batches with potash as the alkaline constituent, while the glass produced in western Europe was an "ash" variant (see above). Objects of "potash"-type glass discovered outside ancient Rus' should be considered as imports in their place of finding.[16] The "potash" variant of the lead-potassium-silica recipe (but only this variant) appears to be a specific characteristic of ancient Rus' glassmaking; however, it is unclear who was the author, whether Rus' glassmakers or foreign specialists working in Rus'.

For the time being it is still not clear what triggered the introduction of melting technology for these two glass types ($PbO{\bullet}SiO_2$ and $PbO{\bullet}K_2O{\bullet}SiO_2$) in Europe, including Rus', and from where had these impulses come.[17] One possibility is that instead of coming directly from a distant centre, the know-how was passed on from one centre to the next centre by the glassmakers themselves or various foreigners from the different intermediary centres for instance. Potential differences of chemical composition of glasses from these different centres could have been due to different raw materials found locally and/or technological changes introduced by the local glassmakers. Producing lead-potassium glass with potash in Rus' could reflect a change of this kind.

These questions still await resolution.

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[16] For example, graves from the 11th c. in the cemetery of Dziekanowice, Wielkopolskie province (Poland), yielded beads made of "potash" glass of the $PbO{\bullet}K_2O{\bullet}SiO_2$ type. They are very well preserved (while beads made of glass of a different chemical type are very heavily corroded), featuring a regular shape and fine finishing (Dekówna, Purowski 2019, pp. 281–282, 304, Table 13: 1, 2).

[17] Apart from the undoubted taking over in Rus' of soda recipes from Byzantium. But could both the lead recipes have come from the same source as suggested by some researchers (e.g. Yu. Shchapova, P. Noonan). Perhaps there was more than one source of these recipes?

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MARIA DEKÓWNA

REFLEKSJE NA TEMAT POCZĄTKÓW SZKLARSTWA STARORUSKIEGO

Streszczenie

Wykrycie źródeł pochodzenia receptur szklarskich stosowanych na różnych terytoriach jest niezwykle trudne, lub wręcz niemożliwe, gdy brak jest poświadczających je źródeł pisanych.

W literaturze przedmiotu znajdujemy jednak opinie na temat pochodzenia technologii ołowiowo-krzemowej bezalkalicznej i ołowiowo-potasowo-krzemowej, według których wytapiane było szkło, z jakiego wykonano przedmioty znajdowane na wczesnośredniowiecznych obiektach na terenie dawnej Rusi.

1. PRZEGLĄD WYNIKÓW DOTYCHCZASOWYCH STUDIÓW

Dwudziestowieczni główni badacze rosyjscy dziejów szklarstwa we wczesnośredniowiecznej Rusi – Michaił A. Biezborodow, Julia Szczapowa i W.A. Galibin – stwierdzili, że szkła ołowiowo-krzemowe bezalkaliczne ($PbO•SiO_2$) i ołowiowo-potasowo-krzemowe ($PbO•K_2O•SiO_2$)[18] znajdowane w zespołach archeologicznych z XI–XIII w. na obszarze europejskiej części byłego ZSRR są wyrobem

[18] Zob. przypis 1 w tekście angielskim w sprawie nazewnictwa szkieł tego drugiego typu.

szklarzy ruskich oraz że obie technologie są charakterystyczne dla szklarstwa staroruskiego i świadczą o wykształceniu się na Rusi w początku XI w. samodzielnej szkoły szklarskiej. Teza ta oparta była na przeprowadzonej przez tych naukowców analizie rezultatów badań laboratoryjnych, przede wszystkim składu chemicznego szkła wielu przedmiotów różnej kategorii (Bezborodov 1956; 1969; Shchapova 1972; 1978; 1983; Galibin 2001). Analizę tę znacznie ułatwiły wprowadzone na szeroką skalę przez J. Szczapową metody określania stopni koncentracji głównych składników szkłotwórczych mających wpływ na własności szkła, a także obliczanie ich proporcji i sum oraz proporcji sum owych komponentów (Szczapowa/Ščapova/Shchapova 1973; 1975; 1983)[19]. Obszernego podsumowania tego etapu badań (1956–1989) nad początkami szklarstwa na Rusi dokonał Thomas Noonan w pracy opublikowanej w 1989 r. (por. ryc. 1).

Wymienieni badacze, przypominając fakt zaproszenia około 980 r. przez Wielkiego Księcia Włodzimierza szklarzy bizantyńskich do ozdobienia mozaikami i szkliwionymi dachówkami dwóch cerkwi kijowskich, są zgodni, że dzięki temu Rusini przejęli od Bizantyńczyków umiejętność wytopu szkła – przede wszystkim technologii wytopu szkieł sodowych różnych typów chemicznych. Natomiast w literaturze toczy się dyskusja, czy mogli zapożyczyć od nich także receptury wytopu szkieł ołowiowych: $PbO{\bullet}SiO_2$ i $PbO{\bullet}K_2O{\bullet}SiO_2$. Zwraca się uwagę, że szkła obu typów występują także na innych terenach (europejskich, azjatyckich); na niektórych z nich wcześniej niż na Rusi (zob. ryc. 2 oraz np. Olczak 1968, s. 47 nn.; Dekówna 1981; Brill, Martin eds 1991; Gan Fuxi i in. eds 2009). Ale stwierdza się też, że technologia wytopu szkieł typu $PbO{\bullet}K_2O{\bullet}SiO_2$ rozpowszechnionych na terenie dawnej Rusi (są to szkła „potażowe") różni się od tej, według której wytopione są szkła znajdowane w zachodniej Europie, zwłaszcza w Niemczech (są to szkła „popiołowe") (Bezborodov 1956; 1969; Galibin 2001). Robert H. Brill przypuszcza, że znajomość recept produkcji szkieł ołowiowych mogła przeniknąć do wschodniej Europy z Dalekiego Wschodu (Brill 1999; Brill, Stapleton 2012).

2. BAZA ŹRÓDŁOWA PRZYSZŁYCH STUDIÓW

W związku z dużym przyrostem w ostatnich dziesięcioleciach znalezisk związanych ze szklarstwem na terenie Europy i Azji (zwłaszcza na Dalekim Wschodzie), rozwojem metod badawczych i znacznym zwiększeniem liczby wyników analiz składu chemicznego szkła, warto byłoby podjąć ponownie, w tych nowych warunkach, interdyscyplinarne studia nad pochodzeniem i początkami szklarstwa na Rusi i ich wyniki przedstawić w formie monografii zawierającej omówienie wszystkich (lub większości) aspektów tego problemu. Studia te powinny być oparte na analizie źródeł głównie dwóch kategorii: 1. materialnych; 2. wyników badań laboratoryjnych.

2.1. Źródła materialne

Już dawno stwierdzono, że w starożytności i we wczesnym średniowieczu funkcjonowały warsztaty szklarskie dwóch typów: A – w których produkowano szkło z surowców wyjściowych; B – w których wyrabiano przedmioty ze szkła już wytopionego, sprowadzanego z warsztatów typu A (Bezborodov 1956, s. 267–268; Henderson 2013, s. 18, 307). W ramach tych dwóch typów istniało wiele odmian (ryc. 3; 4; Dekówna 1987; 1988; 2009). Studia nad pochodzeniem omawianych w niniejszym artykule technologii wytopu dwóch typów szkieł ołowiowych trzeba opierać przede wszystkim na badaniu pozostałości warsztatów typu A. W odniesieniu do wczesnośredniowiecznej Rusi warsztaty takie wyodrębniła ostatnio E.K. Stolyarowa, wykorzystując również ustalenia Biezborodowa i Szczapowej. Zdaniem tych badaczy działały one w Kijowie: na terenie Kijowsko-Pieczerskiej Ławry, przy soborze św. Zofii, na „Podole" i koło soboru Michajłowskiego (Stolyarova 2015, s. 336). Opublikowane przez M.A. Biezborodowa wyniki analizy składu chemicznego szkła kostek mozaikowych znalezionych w tych obiektach świadczą, że były one zrobione ze szkła sodowego różnych typów chemicznych, ale też ołowiowego (Bezborodov 1956, s. 159, 161, 163, 166).

[19] Tego rodzaju wskaźniki były stosowane, w mniejszym zakresie, już wcześniej przez różnych badaczy, a później – rozwijane (zwłaszcza przez badaczy polskich).

Ostatnio badacze ukraińscy podjęli szczegółowe studia nad zachowaną obecnie dokumentacją polową i licznymi znaleziskami ujawnionymi w czasie wykopalisk prowadzonych w latach 1950 i 1951 na terenie Kijowa przez W.A. Bogusiewicza. Po raz pierwszy został przez nich opublikowany ten bogaty materiał oraz nowa jego interpretacja. I tak, stwierdzają, że nie mogą potwierdzić, by na „Podole" istniała wytwórczość szklarska (Khamaiko i in. 2022, s. 50, 62, 64), natomiast odkryte *in situ* pozostałości pieców i odpadów produkcyjnych świadczą, że huta szkła funkcjonowała w XII w. na terenie Kijowsko-Pieczerskiej Ławry (Khamaiko i in. 2021, s. 121, 148).

Poszukując źródeł pochodzenia technologii wytopu szkieł ołowiowych będących tematem niniejszych rozważań, i podejmując próbę weryfikacji dawnych ustaleń, konieczne jest oparcie tych działań na studiach porównawczych nad wynikami badań znalezisk z terenów dawnej Rusi z rezultatami analogicznych badań przeprowadzonych nad znaleziskami z innych obszarów (najlepiej – w ujawnionych tam reliktach warsztatów szklarskich). W studiach tych niezbędne jest wykorzystanie w szerokim zakresie wyników analiz składu chemicznego szkieł dalekowschodnich.

2.2. Badania laboratoryjne

Do tych celów mogą być wykorzystane różne metody analityczne, ale tylko takie, za pomocą których uzyskuje się wyniki ilościowe. Ostatnio najczęściej są wykorzystywane metody: EPMA i LA-ICP-MS. Zaczynają też być stosowane analizy izotopowe. Badaniom porównawczym powinny być poddawane zarówno wyniki ilościowe głównych składników szkłotwórczych i komponentów występujących w małych ilościach w tym śladowych, jak i proporcje składników głównych. W literaturze przedmiotu znajdujemy opisy różnych rodzajów metod badawczych oraz rezultatów uzyskanych dzięki ich zastosowaniu (zob. np. Stawiarska, Bis 2022). Wybór należy do badacza, który podejmie takie studia.

3. UWAGI KOŃCOWE

O ile przyjęcie przez Rusinów receptur sodowych z Bizancjum nie budzi wątpliwości, to problem źródeł pochodzenia omawianych tu dwóch receptur na wytop szkieł ołowiowych nadal czeka na rozwiązanie. Można się liczyć z możliwością, że nie zostały one bezpośrednio zapożyczone z odległego jakiegoś ośrodka, lecz mogły być przejmowane przez kolejne ośrodki jedne od drugich i przenoszone przez szklarzy – cudzoziemców różnego pochodzenia, na przykład z ośrodków pośredniczących w przekazywaniu ich dalej. Mogło też być kilka źródeł ich pochodzenia.

Natomiast hipoteza M.A. Biezborodowa, który sformułował ją na podstawie niewielkiej serii danych istniejących na początku lat pięćdziesiątych XX w., sprawdza się obecnie na znacznie zwielokrotnionym ich zasobie: na Rusi szkła typu $PbO \bullet K_2O \bullet SiO_2$ były wytapiane z zestawu, w którym składnik alkaliczny występował w postaci potażu (szkła takie Biezborodow określa jako „potażowe"), podczas gdy szkła produkowane w zachodniej Europie były wytapiane z zestawu zawierającego popiół drzew (szkła te nazywa „popiołowymi"). Wyroby ze szkła tego typu („potażowe") znajdowane poza terytorium dawnej Rusi są importami na tych obszarach.

Odmiana „potażowa" receptury ołowiowo-potasowo-krzemowej zdaje się więc stanowić cechę specyficzną szklarstwa staroruskiego; nie wiadomo jednak, kto był jej twórcą: szklarze staroruscy, czy obcy, pracujący na Rusi.