Archeologia Polski, LXVII: 2022
PL ISSN 0003-8180
DOI:10.23858/APol67.2022.003

TOMASZ PUROWSKI[a]

IDENTIFYING BRONZE AGE GLASS PRODUCTION CENTRES THROUGH BEAD-MAKING TECHNIQUES

Abstract: The assemblage of Bronze Age glass beads found in the territory of present-day Poland counts 3100 pieces. The earliest examples known from excavations in central Europe are dated most often to the BrB–HaA$_1$/A$_2$ phases of the Bronze Age (= BA II–III/IV); they are made of high magnesium glass (HMG), which is now most frequently corroded. In the HaA$_2$–HaB$_3$ phases (= BA IV–V), beads were produced of a "mixed alkali" glass, also called low magnesium and high potassium glass (LMHK), which is usually preserved in rather good condition. The oldest beads are large as a rule, well made, using, at least in some cases, the folding technique. Small, undecorated beads made of "mixed alkali" glass were produced by the winding technique.

Keywords: Poland, Bronze Age, glass beads, HMG, LMHK glass, folding technique, winding technique

Abstrakt: Z obszarów obecnej Polski znanych jest około 3100 paciorków szklanych datowanych na epokę brązu. Najstarsze okazy odkryte w środkowej Europie pochodzą z faz BrB–HaA$_1$/A$_2$ (= II–III/IV EB); wykonano je z tzw. szkła wysokomagnezowego (HMG), obecnie najczęściej skorodowanego. W fazach HaA$_2$–HaB$_3$ (= IV–V EB) paciorki robiono ze szkła „mieszanoalkalicznego", zwanego także szkłem niskomagnezowym i wysokopotasowym (LMHK), które zwykle zachowało się w dobrym stanie. Najstarsze paciorki są z reguły duże, dobrze wykonane, przy użyciu – przynajmniej w niektórych przypadkach – techniki zginania. Małe, niezdobione okazy zrobione ze szkła „mieszanoalkalicznego" zostały wyprodukowane metodą nawijania.

Słowa kluczowe: Polska, epoka brązu, paciorki szklane, HMG, szkło LMHK, technika zginania, technika nawijania

[a] Dr hab. Tomasz Purowski, prof. IAE PAN, Ośrodek Interdyscyplinarnych Badań Archeologicznych, Instytut Archeologii i Etnologii PAN, al. Solidarności 105, 00-140 Warszawa, tomasz@iaepan.edu.pl, ORCID iD: https://orcid.org/0000-0003-1916-7698.

1. INTRODUCTION

The oldest glass beads known from modern-day Poland are dated to the Bronze Age II (= phases BrB–C; that is, about 1650/1600–1300 BC) and Bronze Age III (= phases BrD–HaA_1; about 1300–1150/1100 BC).[1] They are found more frequently on archaeological sites from the Bronze Age IV (= HaA_2–B_1; about 1150/1100–1000/950 BC) and Bronze Age V (= HaB_2–B_3; about 1000/950–800/750 BC[2]). Altogether about 3100 glass beads have been recorded from 41 archaeological sites that are associated with communities of the Trzciniec, Tumulus and Lusatian cultures (Purowski 2019, p. 95).[3] Some impressive strings of beads have been found beside single finds; they count a few hundred beads each, and are combined with amber and metal (either gold or bronze) ornaments. No other categories of glass ornaments are known from Poland.

Glass artifacts were found in two hoards connected with Trzciniec communities (Błogocice; Wola Żydowska [Żydów]), discovered at two different cemeteries of this culture (Dacharzów; Żerniki Górne), as well as at two other cemeteries associated with a transitional phase between two cultures, Trzciniec and Lusatian (Bocheniec; Kębliny). Glass beads were also discovered at two burial grounds of the Tumuli culture (Ligota [Kruszyniec]; Kietrz) and, additionally, at 35 Lusatian culture sites from the Bronze Age: 30 cemeteries, four hoards (Będków; Pszczelnik; Rzędziny; Skórka), and one site (Targowisko) with a settlement and graveyard (Purowski 2019, pp. 95–96). Slightly over 20 glass beads are known from Tumuli culture graves, almost 20 from Trzciniec culture contexts and only three from the transitional Trzciniec-to-Lusatian phase. The bulk of the finds of glass beads from Polish territories were found in Lusatian contexts, especially five cemeteries of this culture: Domasław-Chrzanów (about 1000 complete beads and about 120 fragments of glass from beads), Kraków-Bieżanów (more than 350 beads; Purowski 2018), Kietrz (more than 500 beads and about 120 fragments of glass from beads), Targowisko (about 400 beads; Purowski 2014) and Samborowice (about 200 complete beads and about 50 fragments of glass from beads). Sets of bead finds more numerous than others have also been recorded at the burial grounds in Patrzyków (124 beads), Grobniki (about 70), Legnica (48) and Krzanowice (about 37), and in the hoard from Rzędziny (29) (Purowski 2019, p. 96).

Of the 3100 beads discovered in Poland, the author examined 85% directly, producing full descriptions of form, state of preservation and production technique. Moreover, 59 glass artifacts were studied with physico-chemical methods (Purowski, Kępa, Wagner 2018; Purowski 2019, pp. 116–144).

---

[1] Faience beads produced in Egypt and Mycenaean Greece are also known from Bronze Age II–III (= BrB–HaA_1) contexts in Poland (Purowski, Syta, Wagner 2019).

[2] Absolute dates after: K. Dzięgielewski 2017, p. 297.

[3] The burial ground at Lipniki (southeastern Poland) was not considered because the grave, which yielded six beads, is dated rather imprecisely to the end of the Bronze Age or the Hallstatt C period (Blajer, Przybyła 2006, p. 76).

The objective of the author's interdisciplinary research on glass products from the Bronze Age was to establish whether the form and production technique of beads known from Poland could be related to relevant glass-melting technologies and thus help to indicate the region(s) where the glass was melted and the beads produced. As discussed by M. Dekówna, the identification of production techniques, coupled with an understanding of the chemical composition of the glass and in some cases also without this knowledge, can help to determine the chronology and provenance of given artifacts. In light of this, glass finds take on added importance as dating material for other archaeological material and are a valuable source for studies of trade contacts and cultural relations between various peoples (Dekówna 2005, p. 19; Dekówna, Szymański 1971, p. 283).

2. CHEMICAL COMPOSITION OF THE GLASS

The total number of glass samples that was analysed is 63 (including the different-colour glass decoration on some of the 59 beads from the BA II–V [BrB–HaB] that have been subjected to analysis to date).[4] The sampled beads came from 14 archaeological sites associated with the Trzciniec culture from the BA II–1st half of BA III

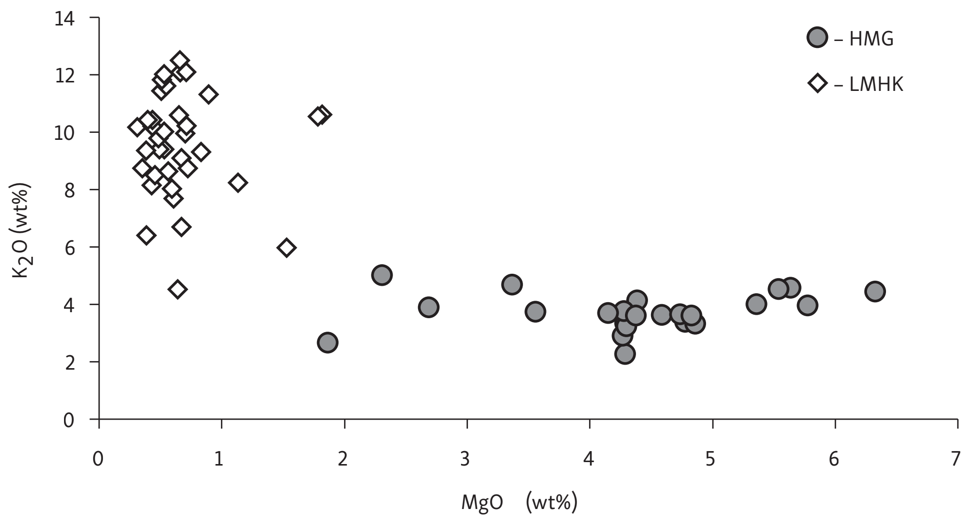


Fig. 1. MgO *vs.* K_2O in Bronze Age glass beads from Poland.
After Purowski 2019, Fig. 4.21

Ryc. 1. Korelacja zawartości MgO do K_2O w szkle paciorków z epoki brązu z Polski.
Wg Purowskiego 2019, ryc. 4.21

[4] The methods applied were LA-ICP-MS and EPMA; see: Purowski, Kępa, Wagner 2018; Purowski 2019, pp. 116–144.

Fig. 2. Glass beads from Poland.
a–g – high magnesium glass (HMG); h–o – low magnesium and high potassium glass (LMHK); a – Dacharzów; b–d, l, o – Kietrz; e, g – Błogocice; f – Targowisko; h, i, n – Domasław-Chrzanów; j – Górzyca; k, m – Rzędziny.
Photo T. Purowski

Ryc. 2. Paciorki szklane z Polski.
a–g – szkło wysokomagnezowe (HMG); h–o – szkło niskomagnezowe i wysokopotasowe (LMHK); a – Dacharzów; b–d, l, o – Kietrz; e, g – Błogocice; f – Targowisko; h, i, n – Domasław-Chrzanów; j – Górzyca; k, m – Rzędziny.
Fot. T. Purowski

(3 beads), Tumulus culture from the BA II–III (6 beads) and Lusatian culture from BA III–V (50 beads). Considering the K_2O and MgO content, the Bronze Age glass known from Poland can be divided into high magnesium glass (HMG) and low magnesium and high potassium glass (LMHK), which is also sometimes called "mixed alkali" glass (Fig. 1; Purowski, Kępa, Wagner 2018; Purowski 2019, p. 117).

2.1. HIGH MAGNESIUM GLASS (HMG)

High magnesium glass, which is characterized most often by a content of about 1–5% K_2O and about 2–6% MgO (seldom a little more or less), was melted in large amounts starting from about the 16th c. BC. It is characteristic of workshops from the Eastern Mediterranean (Henderson 1989, p. 38; Towle *et al.* 2001, p. 7; Gratuze, Billaud 2003, p. 13). In Europe, it is known from archaeological sites of the Bronze Age and the Hallstatt period, and can be encountered in eastern Europe as late as the 4th–3rd c. BC (Henderson 1989; Purowski *et al.* 2012, pp. 154, 156–157, Fig. 6).

Analyses of chemical content of high magnesium glass from finds discovered in Poland have totalled 23 samples to date. This glass is of either turquoise, blue or green colour (Fig. 2a–g). They contain relatively large amounts of alkali oxides (Table 1). The higher concentration of Na_2O, K_2O and MgO indicates that the glass was melted with soda-rich plant ash (E.g. Henderson 2000, pp. 57, 59, Fig. 3.28; Nikita, Henderson 2006, p. 73). A similar Na_2O/K_2O ratio in some samples of high magnesium glass could suggest that the alkali source in their case was either the same or came from a limited number of sources of similar chemical composition. The different ratio in other cases indicates that ash from different plants was used. The Na_2O/K_2O ratio results for a large part of glasses from Poland oscillates around 4 or 5. A similar ratio of these constituents is revealed in the ash of the *Anabasis syriaca* plant growing in Syria or the Osnun plant from Iran, as well as some plants from Israel, Iraq and Pakistan (see Brill 1999, p. 482; Barkoudah, Henderson 2006, Table 2; Purowski 2012, Table 13). At this point, however, one cannot indicate the specific halophyte plants the ash of which would have been used in this particular glass-melting process.[5]

Table 1. Main constituents (in wt%) in HMG and LMHK glass from the Bronze Age in Poland*

Tabela 1. Zawartość składników głównych (w % wagowych) w szkłach HMG i LMHK z epoki brązu z Polski*

Chemical group / Grupa chemiczna	No. of samples / Liczba próbek	Na_2O	K_2O	MgO	Na_2O/K_2O	Alkali flux / Źródło alkaliów
HMG	23	13.0–20.5 (16.3)**	2.3–5.0 (3.7)	1.9–6.3 (4.4)	2.9–8.2 (4.6)***	Soda-rich plant ash / Popiół roślin bogatych w sód
LMHK	40	0.6–7.9 (5.4)	4.6–12.5 (9.8)	0.3–1.8 (0.7)	0.1–1.2 (0.6)	Mixed-alkali / Mieszanoal-kaliczne

* Extreme values given first, followed by the average (in parentheses).
** In one sample, $Na_2O = 2.6\%$.
*** In one sample, $Na_2O/K_2O = 0.7$.

* W pierwszej kolejności podane są skrajne wartości, a następnie średnia (w nawiasie).
** W jednej próbce $Na_2O = 2,6\%$.
*** W jednej próbce $Na_2O/K_2O = 0,7$.

Various trace and rare earth minerals were introduced into the ready glass together with the raw minerals needed to melt it. An analysis of these extra elements is useful for tracing presumed glass-melting centres. Comparing amounts

[5] Ash from the same plant can have different sodium and potassium content depending on whether the parts burned were the stems or roots.

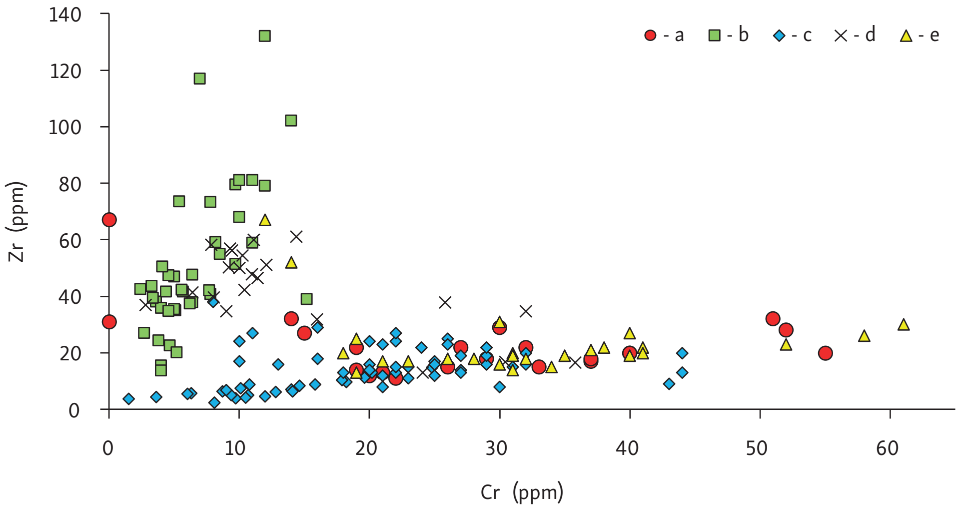


Fig. 3. Cr *vs.* Zr in Bronze Age high magnesium glass (HMG)
a – Poland; b – Egypt; c – Mesopotamia; d – Greece; e – Denmark.
After Shortland, Rogers, Eremin 2007; Smirniou *et al.* 2009; Walton *et al.* 2009; 2012; Varberg, Gratuze, Kaul 2015; Purowski 2019; processing T. Purowski

Ryc. 3. Korelacja zawartości Cr do Zr w szkle wysokomagnezowym (HMG) z epoki brązu
a – Polska; b – Egipt; c – Mezopotamia; d – Grecja; e – Dania.
Wg Shortlanda, Rogersa, Eremin 2007; Smirniou *et al.* 2009; Waltona *et al.* 2009; 2012; Varberg, Gratuze'a, Kaula 2015; Purowskiego 2019; opracował T. Purowski

of chromium, lanthanum, titan and zirconium in blue and colourless glass from the 2nd millennium BC from both Mesopotamia and Egypt, one is led to the conclusion that different sources were used for HMG production (Shortland, Rogers, Eremin 2007). Egyptian glass is characterized by a slightly higher content of Ti, Zr and La, and lower Cr compared to Mesopotamian glass. The bulk of HMG from Poland, especially when one looks at the Cr/La and Zr/Ti ratios (Table 2), resembles Mesopotamian glass in this respect, with singular examples being more like glass melted in Egypt (Purowski, Kępa, Wagner 2018). The same can be said of other high magnesium glass known from Europe (Figs 3 and 4).

Most HMG glass was coloured with copper compounds (Table 3; Purowski 2019, p. 130). Cobalt compounds for colouring were used most certainly in purple-blue glass (Kietrz, sample 144). The glass contains more CoO (0.086%) and NiO (0.053%) among others. A similar content of both oxides is recorded for Egyptian glass coloured with cobalt coming from alums (Fig. 5). The same raw material could have been used for colouring one of the turquoise glass samples (Kietrz, sample 142), which contains 0.027% CoO and only 0.05% CuO (Purowski 2019, p. 131).

Table 2. The Cr/La and Zr/Ti ratio in HMG glass from Poland. Calculations based on Purowski, Kępa, Wagner (2018)

Tabela 2. Proporcje Cr/La oraz Zr/Ti w HMG z Polski. Obliczenia na podstawie Purowski, Kępa, Wagner (2018)

Site / Stanowisko	Sample no. / Nr próbki	Cr/La	Zr/Ti*1000
Błogocice	112	12.33	29.31
Domasław-Chrzanów	119	7.25	33.71
Kietrz	129	12.33	29.51
Kietrz	130	13.00	32.18
Kietrz	132	10.67	28.28
Kietrz	134	3.75	55.90
Kietrz	138	17.00	53.07
Kietrz	139	9.00	34.32
Kietrz	142	4.75	34.76
Kietrz	145	10.00	29.70
Kietrz	146	10.00	26.08
Kietrz	148	3.50	52.81
Krzanowice	150	11.00	27.23
Krzanowice	151	8.67	29.41
Samborowice	158	10.50	32.18

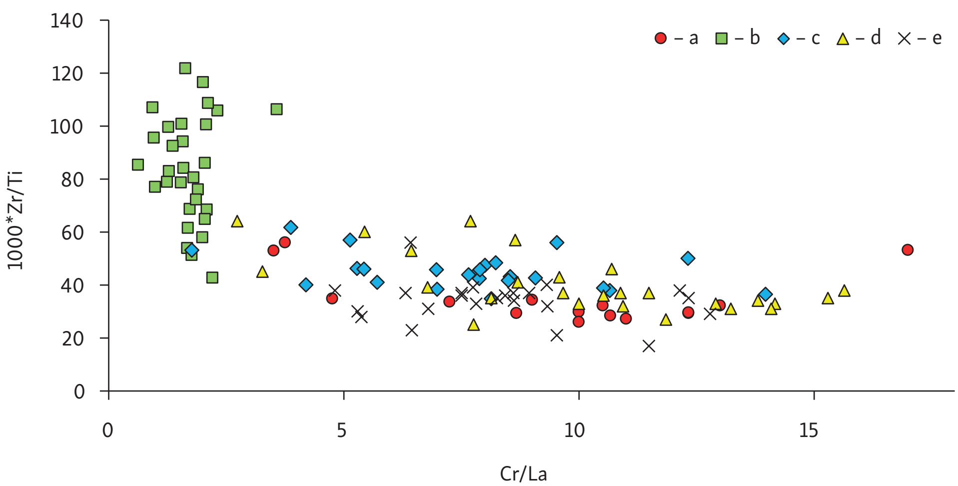


Fig. 4. Cr/La *vs.* Zr/Ti in Bronze Age high magnesium glass (HMG)
a – Poland; b – Egypt; c – Mesopotamia; d – Denmark; e – Corsica.
After Shortland, Rogers, Eremin 2007; Varberg, Gratuze, Kaul 2015; Peche-Quilichini *et al.* 2016; Purowski 2019; processing T. Purowski

Ryc. 4. Korelacja zawartości Cr/La do Zr/Ti w szkle wysokomagnezowym (HMG) z epoki brązu
a – Polska; b – Egipt; c – Mezopotamia; d – Dania; e – Korsyka.
Wg Shortlanda, Rogersa, Eremin 2007; Varberg, Gratuze'a, Kaula 2015; Peche-Quilichini'ego *et al.* 2016; Purowskiego 2019; opracował T. Purowski

Table 3. Selected constituents (in wt%) in HMG and LMHK glass from the Bronze Age in Poland coloured with copper compounds*

Tabela 3. Zawartość wybranych składników (w % wagowych) w szkłach HMG i LMHK z epoki brązu z Polski barwionych związkami miedzi*

Chemical group / Grupa chemiczna	No. of samples / Liczba próbek	Colour / Barwa	CuO	SnO_2
HMG	19	Turquoise, blue or green / Turkusowa, niebieska lub zielona	0.4–3.1 (1.1)	0.0003–0.003 (0.001)**
LMHK	31	Turquoise or green / Turkusowa lub zielona	2.0–5.3 (3.0)	0.001–0.52 (0.09)***

* Extreme values given first, followed by the average (in parentheses).
** In one sample, SnO_2 = 0.069%; in seven samples = below the detection limit of the method.
*** In four samples = below the detection limit of the method.

* W pierwszej kolejności podane są skrajne wartości, a następnie średnia (w nawiasie).
** W jednej próbce SnO_2 = 0,069%; w siedmiu próbkach = poniżej poziomu wykrywalności metody.
*** W czterech próbkach = poniżej poziomu wykrywalności metody.

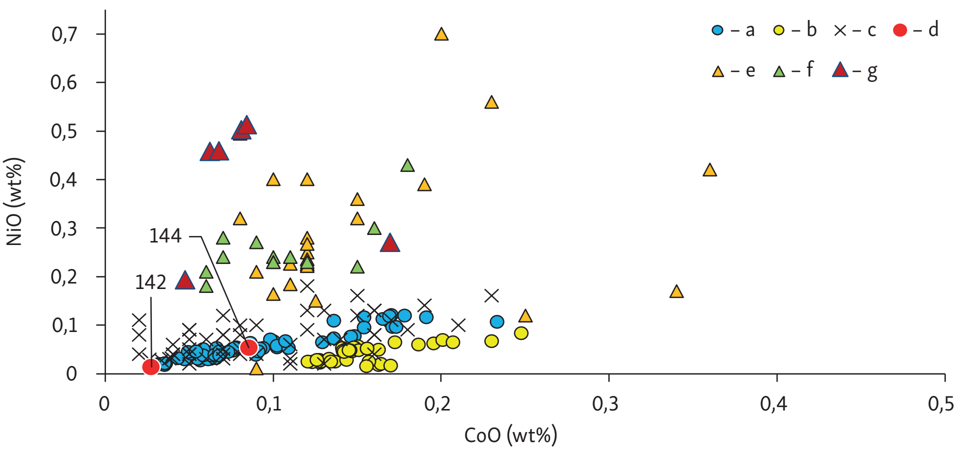


Fig. 5. CoO *vs.* NiO in Bronze Age high magnesium glass (HMG) and "mixed alkali" (LMHK) glass coloured with cobalt compounds
a–d – HMG (a – Egypt; b – Mesopotamia; c – Greece; d – Poland); e–g – LMHK (e – Italy; f – Greece; g – Poland). After Brill 1992; Towle *et al.* 2001; Nikita, Henderson 2006; Shortland, Rogers, Eremin 2007; Walton *et al.* 2009; 2012; Angelini *et al.* 2010; Croutsch *et al.* 2011; Abe *et al.* 2012; Henderson *et al.* 2015, Varberg, Gratuze, Kaul 2015; Purowski 2019; Conte *et al.* 2019; processing T. Purowski

Ryc. 5. Korelacja zawartości CoO do NiO w szkłach wysokomagnezowym (HMG) i „mieszanoalkalicznym" (LMHK) z epoki brązu barwionych związkami kobaltu
a–d – HMG (a – Egipt; b – Mezopotamia; c – Grecja; d – Polska); e–g – LMHK (e – Italia; f – Grecja; g – Polska). Wg Brilla 1992; Towlego *et al.* 2001; Nikity, Hendersona 2006; Shortlanda, Rogersa, Eremin 2007; Waltona *et al.* 2009; 2012; Angelini *et al.* 2010; Croutsch *et al.* 2011; Abe *et al.* 2012; Hendersona *et al.* 2015, Varberg, Gratuze'a, Kaula 2015; Purowskiego 2019; Conte *et al.* 2019; opracował T. Purowski

2.2. LOW MAGNESIUM AND HIGH POTASSIUM GLASS (LMHK)

Low magnesium and high potassium glass (LMHK) is characterized by a low content of MgO (mainly < 1%; Fig. 1) and CaO (about 1–3%). This is commonly called "mixed alkali" glass owing to the high content of both Na_2O (most often about 4–9%) and K_2O (most frequently about 6–13%) (Henderson 1988, Figs. 6.13, 6.14, 6.16 and 6.17; Towle *et al.* 2001, Tables 1 and 3; Angelini *et al.* 2004, Tables 2 and 3; Venclová *et al.* 2011, p. 573, Table 1; Mildner *et al.* 2014; Purowski, Kępa, Wagner 2018, Fig. 4). LMHK glasses were manufactured in Europe, most probably in Italy. In the Late Bronze Age, primary production centres melting glass and making glass jewellery were located most probably in Frattesina (Henderson *et al.* 2015, p. 3). Research by J. Henderson and others points to yet another primary production site or zone in Italy (perhaps an ultrapotassic volcanic province near Rome) manufacturing LMHK glasses (Henderson *et al.* 2015, p. 7). Beads made of "mixed alkali" glass are known also from outside Italy: Switzerland, Germany, France, Ireland, England, Greece, Czechia and Poland (Venclová *et al.* 2011, Fig. 1; Bellintani 2014, Fig. 6; Conte *et al.* 2019; Purowski, Kępa, Wagner 2018).

To date, 40 samples of LMHK glass discovered in Poland have been analysed (Purowski 2019, p. 132). They are turquoise, blue, green or white in colour (Fig. 2h–o).

LMHK glass has less Na_2O and MgO, and more K_2O compared to HMG (Table 1; Fig. 1). The amounts of these constituents are not instructive in terms of the kind of alkali material that was used in melting LMHK glass. A likely hypothesis is that it was leached plant ash (Hartmann *et al.* 1997, p. 554; Angelini *et al.* 2004, pp. 1175, 1179). The Na_2O/K_2O ratio in glass from Poland is in most cases about 0.4–0.7; it is rarely higher (up to 1.2) and in one case significantly lower (= 0.1). It could mean that there were at least two different sources of alkali material (Angelini *et al.* 2004, p. 1183).

There is more rubidium in LMHK glass than in HMG. It is well correlated with potassium (Purowski 2019, Fig. 4.45), hence the assumption that it was introduced into the glass with the alkali material. According to G. Hartmann *et al.* (1997, p. 554), leaching of plant ash enriched the potash with rubidium as well as potassium and sodium compounds.

Copper compounds constituted the main colourant in the case of 28 glasses of turquoise colour[6] as well as three of green colour (Table 3). Five blue glasses and one dark blue one owed the colour to cobalt presence. The minerals presumably used to colour the glasses can be found in the territories of modern Germany, Switzerland, Austria and Czechia (Henderson 1985, p. 280). Other compounds introduced with the colourant into LMHK glass from Poland included, among others, compounds of nickel, copper, arsenic and antimony (Purowski 2019, p. 142). A similar cobalt and nickel content occurs in some European LMHK glass; lower levels of NiO are recorded in Egyptian and Mesopotamian HMG glass (Fig. 5).

[6] The presence of CoO > 0.005% (see *Principes*… 2002, Table 3) in four samples of turquoise glass suggests that cobalt could have also had an influence on the colour (Purowski 2019, p. 141).

3. BEAD-MAKING TECHNIQUES

Observation of traces of technical treatment on the beads from Poland revealed two techniques, winding and folding, used in their production (Purowski 2022).

Winding calls for a hot glass thread to be applied on a heated metal mandrel (Dekówna, Szymański 1972, pp. 339–340; Gam 1993, Fig. 1; Siegmann 2006, p. 928). Variants used in the past have included:

1. Dipping the tip of a mandrel in the glass mass; in this case, either 1.1. the mass was formed on a slab and a thread was subsequently drawn from it and wound on the mandrel by whirling it around, or 1.2. a thread was drawn from the viscous glass on the tip of one mandrel and wound onto another mandrel (Fig. 6a).

2. Heating the semi-product in the shape of a glass rod and winding the softened end onto a mandrel (Fig. 6b).

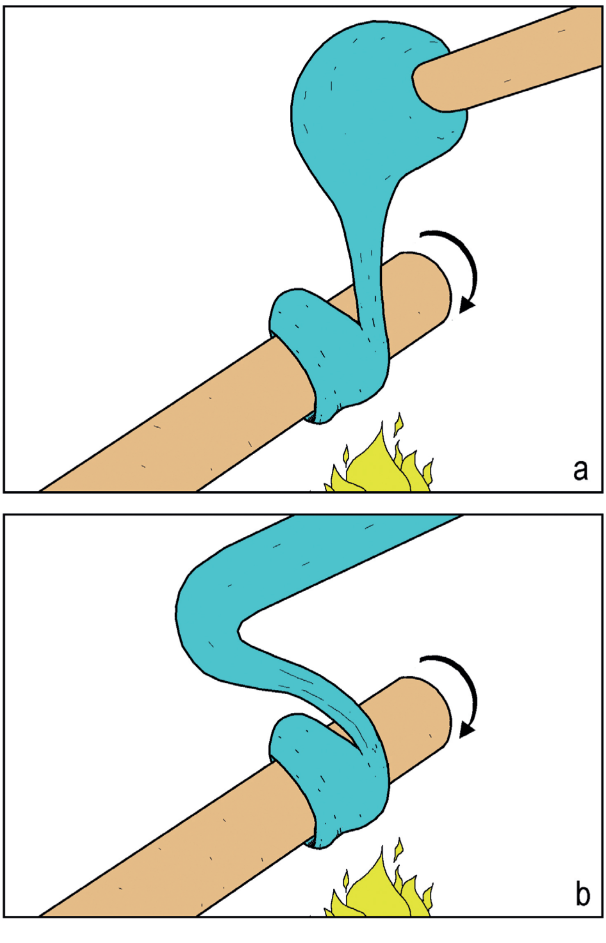


Fig. 6. Schematic model of the winding technique in bead-making
a – variant 1; b – variant 2.
Drawing T. Purowski

Ryc. 6. Schemat wykonania paciorków techniką nawijania
a – wariant 1; b – wariant 2.
Rys. T. Purowski

3. Dipping a mandrel with conical tip in a crucible and drawing a small amount of glass mass by direct winding onto the mandrel; a second mandrel was applied to the formed bead and, by winding between these two mandrels, an hourglass-shaped threading channel was formed (Stawiarska 1974, Table I 1B).[7]

The third variant was used primarily for single beads (with a single corpus). In the case of variants 1 and 2, a longer tube could be formed (but not drawn as in the drawing technique) in order to cut segments, a few or more, from it.

Beads made by folding started out as rectangular plaques or rods of glass (of a cooled down but still plastic glass mass), which were folded around a mandrel and sealed at the edges (Fig. 7; Stawiarska 1974, Table I 2). Once the two meeting edges were pressed together, the obvious seam on the surface was either left there or smoothed by rubbing the re-heated surface on a slab. This technique has been classified by some glass historians as a variant of the winding technique (Dekówna, Szymański 1972, p. 339; Siegmann 2006, p. 929), while others distinguish it as a separate technique (Stawiarska 1974, pp. 185–186), rightly pointing out that the glass mass undergoing folding was in a semi-liquid state (great viscosity), whereas the glass used for winding was liquid (low viscosity).

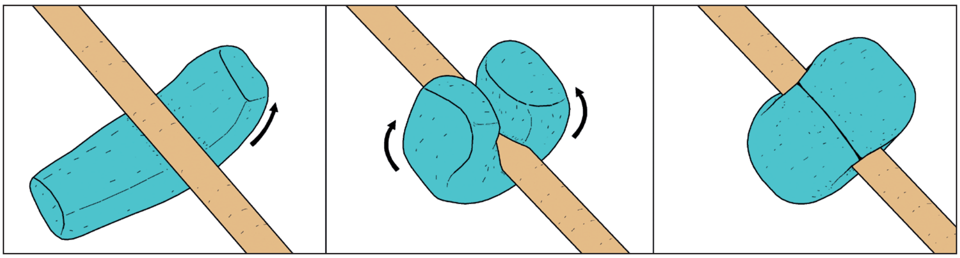


Fig. 7. Schematic model of the folding technique in bead-making.
Drawing T. Purowski

Ryc. 7. Schemat wykonania paciorków techniką zginania.
Rys. T. Purowski

Analyses of Bronze Age artifacts made of LMHK glass have demonstrated the use of either the first or the second variant of the winding technique for their production[8]. The prime evidence for this determination comes from traces of winding on the body of a bead (Fig. 8d), unmelted end(s) of a glass thread (Fig. 8a–b), unmelted side(s) of the glass thread (Fig. 8c), as well as ellipsoid air bubbles in either concentric or spiral arrangement (Purowski 2018, Fig. 4e). Unmelted ends of threads are the most common traces. They were observed on more than a thousand beads. In most cases, the end(s) projects distinctly from the surface around

[7] One of the anonymous reviewer of this text pointed out that the third variant of the winding is very difficult to implement in practice.

[8] The beads have a cylindrical or slightly conical threading channel (not of hourglass shape), which excludes the application of the third variant described above.

the threading hole. Sometimes there is only a small protuberance with evidence of breaking (where the projecting fragment was broken off after the glass had cooled down). The profusion of technical traces indicates that in the case of these beads no complementary technique for improving the overall shape of these adornments was applied (Purowski 2022).

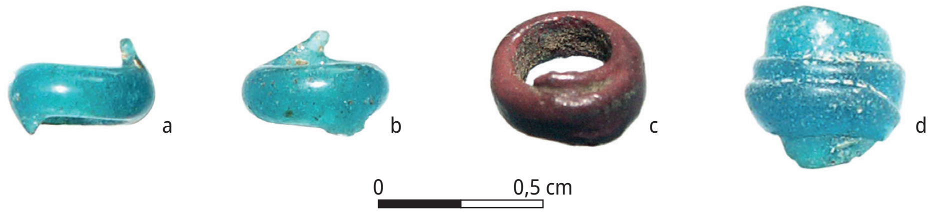


Fig. 8. Beads made by the winding technique using "mixed alkali" (LMHK) glass
a, b – Targowisko; c – Kietrz; d – Kraków-Bieżanów.
Photo T. Purowski

Ryc. 8. Paciorki wykonane techniką nawijania ze szkła „mieszanoalkalicznego" (LMHK)
a, b – Targowisko; c – Kietrz; d – Kraków-Bieżanów.
Fot. T. Purowski

Fig. 9. Beads made by the folding technique using high magnesium glass (HMG)
a, b – Kietrz; 1 – seam; 2 – break; 3 – ellipsoid bubbles.
Photo T. Purowski

Ryc. 9. Paciorki wykonane techniką zginania ze szkła wysokomagnezowego (HMG)
a, b – Kietrz; 1 – szew; 2 – przerwa; 3 – pęcherze elipsoidalne.
Fot. T. Purowski

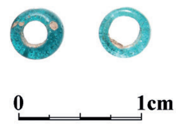
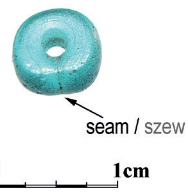
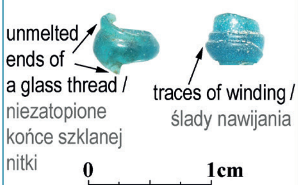
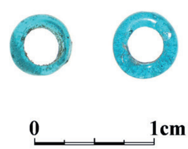
Traces of technical treatment on beads made of HMG glass are much less frequent than on specimens of LMHK glass. They do not have the unmelted thread end(s) sticking out from the surface and at least some of them show a seam (Fig. 9a), indicating that a glass plaque or rod was folded to make them (see Fig. 7). Singular examples of beads with an evident seam are present in the assemblage from Poland (Purowski 2022). More often, beads made of HMG feature a break in the body (Figs 2d; 9b), which may also be proof of the application of the folding technique. Ellipsoid air bubbles in the glass of some of the beads are also noteworthy, especially the way in which they are arranged concentrically around the threading hole (Fig. 9b); these bubbles must have formed in the process of drawing the plaque or rod from the glass mass to prepare a half-product.

4. GLASS BEAD FORM

The glass beads known from Poland are for the most part undecorated. They are either oblate or annular in shape, made of clearly translucent glass of a turquoise colour, less often green or blue (Fig. 2a–l). The size differs (maximum diameter between about 0.3–0.4 cm and 1.5 cm) and so does the state of preservation of the glass (corroded outer surface or no substantial traces of corrosion). Similar finds are very numerous from other European territories.

Ornamented beads from Poland can be classified as so-called Pfahlbauperlen (Haevernick 1978). Six large cylindrical or biconical specimens, decorated with a glass thread winding spirally around the body of the bead (so-called Pfahlbautönnchen mit Spirale), were discovered in the cemeteries at Domasław-Chrzanów (Fig. 2n) and Kietrz (Fig. 2o), in graves dated to the BA IV (HaA_2–HaB_1) or 1st half of BA V (HaB_2). The specimens under discussion are on the whole slightly distorted (burned through), taking on today a dark blue or black colour; the better preserved examples are of glass of turquoise colour (glass chipped from the ornament) or white-green. T.E. Haevernick counted some 300 specimens of Pfahlbautönnchen mit Spirale (Haevernick 1978, p. 145), numerous finds coming from Italy, Switzerland and Germany, but some also found in France, Austria, Belgium, Croatia, Greece and Czechia (Haevernick 1978, pp. 148–156; Bellintani 2011, p. 269, Fig. 5; Croutsch *et al.* 2011, p. 98, Fig. 23; Venclová *et al.* 2011, pp. 567, 569, Fig. 3; Mildner *et al.* 2014, Fig. 1.14–17; Bellintani, Saracino 2015, Fig. 3).

One large bead, which could be classified as a so-called Pfahlbaunoppenperlen (or Pfahlbau-Noppenperlen), is known from a hoard that was hidden at Rzędziny in the 2nd half of BA IV (HaB_1) (Fig. 2m). The matrix glass is a poorly translucent blue and the four 'horned eyes' are from an opaque white or poorly translucent blue. Analogous specimens were found in Switzerland, Italy, Germany, Austria, Croatia, Czechia and Greece, among others (Haevernick 1978, p. 146; Bellintani 2011, pp. 269–270, Fig. 5; Venclová *et al.* 2011, p. 569, Fig. 3; Mildner *et al.* 2014, Fig. 1.9, 10; Blečić Kavur, Kavur 2015, p. 42, Fig. 5).

	Group I / Grupa I	Group II / Grupa II
Chemical group / Grupa chemiczna	HMG (high magnesium glass) / (szkło wysokomagnezowe)	LMHK (low magnesium and high potassium glass) / (szkło niskomagnezowe i wysokopotasowe)
Raw materials / Surowce	pebbles or sand / kamienie kwarcowe lub piasek + soda-rich plant ash / popiół roślin bogatych w sód + CuO or CoO / CuO lub CoO	sand / piasek + mixed alkali / mieszanoalkaliczny + CuO or CoO / CuO lub CoO
Glass preservation / Stan zachowania szkła	frequent corrosion of the outer surface / częsta korozja powierzchni zewnętrznej 	good / dobry 
Bead-making technique / Technika wykonania paciorków	folding technique / technika zginania 	winding technique / technika nawijania 
Size / Rozmiar	large (Ø about 0.8–1.3 cm) / duże (Ø około 0,8–1,3 cm) 	small (Ø about 0.4–0.5 cm) / małe (Ø około 0,4–0,5 cm) 
Glass-melting centre / Miejsce wytopu szkła	Mesopotamia or Egypt / Mezopotamia lub Egipt	Europe (most probably Italy) / Europa (prawdopodobnie Italia)

5. CONCLUSIONS

About 3100 glass beads of Bronze Age date were discovered in southern and western Poland. Some of these formed strings of more than 300 pieces. Most of the beads are made of glass that is of turquoise colour, less often blue or green. Taking into consideration glass-melting technology, glass preservation which is connected with the nature of the raw glass materials, execution technique and size of the beads, the collection of undecorated glass beads from Polish territory can be broken down into two groups (Fig. 10). The groups reflect different production centres and different chronologies.

5.1. GROUP I

The oldest beads, which first appeared in central Europe in BA II–III/IV (BrB–HaA_1/A_2), were made of high magnesium glass (HMG). The glass was melted in Mesopotamia and Egypt using a pure source of silica and halophyte plant ash, and coloured with copper or cobalt compounds. The beads themselves were made most probably in the same two regions. The jewellery made of HMG could have reached the territories of present-day Poland via the regions of Italy and Moravia (so-called Amber Road). In some cases, however, an eastern route cannot be excluded (Venclová *et al.* 2011, p. 579; Varberg, Gratuze, Kaul 2015, p. 174; Purowski, Kępa, Wagner 2018, p. 1300).

The oldest beads are large as a rule (about 0.8–1.3 cm in diameter). They were well made using, at least in some cases, the folding technique, as attested by the seam that shows where the ends of the glass plaque or rod were joined. Presumably a gap in the body of a bead may also be an indication of this technique.

HMG glass is most frequently corroded today.

5.2. GROUP II

In Poland, most of the finds of low magnesium and high potassium (LMHK) glasses come from BA IV and the 1st half of BA V (= HaA_2–HaB_2), and only a few from the 2nd half of BA V (= HaB_3). No LMHK glass from the Hallstatt C phase has been found. Beads made of LMHK glass made their way into southern Poland most probably from Italy, up the Amber Road and through the Moravian Gate, as

Fig. 10. The most important characteristics of undecorated glass beads from the Bronze Age discovered in Poland.

Processing T. Purowski

Ryc. 10. Najważniejsze cechy niezdobionych paciorków szklanych z epoki brązu odkrytych w Polsce.

Opracował T. Purowski

indicated by the large numbers of beads discovered along the upper reaches of the Oder River. Single artifacts, found in western Poland, could have been brought from the west by way of eastern Germany (Purowski 2019, p. 144).

Undecorated beads, which are made of a mixed alkali glass (LMHK), are small (their outer diameter being mostly about 0.4–0.5 cm).[9] These objects were produced with less care, using the winding technique. Technical evidence of this treatment, in the form of unmelted end(s) or side(s) of the glass thread, abounds on the surface of these beads. LMHK glass is usually preserved in rather good condition.

5.3. CLOSING REMARKS

As shown in Fig. 10, beads of group I are distinguished from the undecorated specimens of group II not only by a different glass chemical composition (that is, different glass-making raw materials, mainly alkali, hence the division into HMG and LMHK), but also execution, form (primarily size) and state of preservation of the glass. Therefore, a correct identification of the technique used to make Bronze Age beads (taking into account the other discussed properties) makes it possible to suggest production centres where glass could have been melted and the beads produced. These findings can be useful in the future for determining chronology and provenance in the case of objects, which cannot be subjected to a physico-chemical study of the glass from which they were made.

Translated by Iwona Zych

Acknowledgments:

The author would like to thank the following for making material available for study: Prof. Jan Chochorowski and Karol Dzięgielewski (Institute of Archaeology, Jagiellonian University in Kraków); Adam Golański and Bartłomiej Konieczny (Kraków Unit for Motorway Research); Julia Orlicka-Jasnoch (Archaeological Museum of the Middle Oder Region in Świdnica); Dr. hab. Jacek Górski (Archaeological Museum in Kraków); Ewa Matuszczyk (Museum of Opole Silesia); Dr. Dominik Abłamowicz and Monika Bajka (District Museum in Sandomierz); Marian Pawliński (Upper Silesian Museum in Bytom); Krzysztof Socha (Fortress Museum Kostrzyn); Romuald Turakiewicz (Museum in Racibórz); Krzysztof Kowalski and Dorota Kozłowska (National Museum in Szczecin); and Tomasz Stolarczyk (Copper Museum in Legnica). The project was financed by the National Science Centre of Poland (DEC-2013/09/D/HS3/04464).

BIBLIOGRAPHY OF WORKS CITED

Abe Y., Harimoto R., Kikugawa T., Yazawa K., Nishisaka A., Kawai N., Yoshimura S., Nakai I. 2012, *Transition in the use of cobalt-blue colorant in the New Kingdom of Egypt*, "Journal of Archaeological Science", 39, pp. 1793–1808.

[9] Decorated beads, the so-called Pfahlbautönnchen mit Spirale and Pfahlbaunoppenperle, have large dimensions.

Angelini I., Artioli G., Bellintani P., Diella V., Gemmi M., Polla A., Rossi A. 2004, *Chemical analyses of Bronze Age glasses from Frattesina di Rovigo, Northern Italy*, "Journal of Archaeological Science", 31, pp. 1175–1184.

Angelini I., Cupitò M., Bettineschi C., Leonardi G., Molin G. 2010, *Cronologia di vetri protostorici veneti. mediante indagini archeometriche*, [in:] *Atti del Convegno "Riflessioni e Trasparenze. Diagnosi e conservazione di opere e manufatti vetrosi" (Ravenna, 24–26 febbraio 2009) dell'Associazione Nazionale di Archeometria*, M. Vandini ed., Bologna, pp. 71–86.

Barkoudah Y., Henderson J. 2006, *Plant ashes from Syria and the manufacture of ancient glass: ethnographic and scientific aspects*, "Journal of Glass Studies", 48, pp. 297–321.

Bellintani P. 2011, *Progetto "Materiali vetrosi della protostoria italiana". Aggiornamenti e stato della ricerca*, "Rivista di Scienze Preistoriche", 66, pp. 257–282.

Bellintani P. 2014, *Baltic amber, alpine copper and glass beads from the Po plain. Amber trade at the time of Campestrin and Frattesina*, "Padvsa", 50, pp. 111–139.

Bellintani P., Saracino M. 2015, *Rivers, human occupation and exchanges around the Late Bronze Age settlement of Frattesina (ne Italy)*, [in:] *Rivers in Prehistory*, A. Vianello ed., Oxford, pp. 77–87.

Blajer W., Przybyła M. 2006, *Die Notgrabungen an der Fundstelle 5 in Lipnik, Kr. Przeworsk in den Jahren 1999–2003 (2.–6. Grabungssaison)*, "Recherches Archéologiques de 1999–2003", pp. 66–79.

Blečić Kavur M., Kavur B. 2015, *The game of glass beads in the attire of the cultures of Caput Adriae and its hinterland*, [in:] *Annals du 19e Congres de l'Association Internationale pour l'Histoire du Verre, Piran 2012*, I. Lazar ed., Koper, pp. 39–47.

Brill R.H. 1992, *Chemical analysis of some glasses from Frattesina*, "Journal of Glass Studies", 34, pp. 11–22.

Brill R.H. 1999, *Chemical analyses of early glasses*, 2, *Tables of analyses*, New York.

Conte S., Matarese I., Vezzalini G., Pacciarelli M., Scarano T., Vanzetti A., Gratuze B., Arletti R. 2019, *How much is known about glassy materials in Bronze and Iron Age Italy? New data and general overview*, "Archaeological and Anthropological Sciences", 11, pp. 1813–1841.

Croutsch C., Tegel W., Nicolas T., Pascutto É., Leprovost C., Billot M., Gratuze B., Logel T., Putelat O. 2011, *Les sites protohistoriques d'Erstein « Grasweg-PAE » (Alsace, Bas-Rhin) : l'occupation Rhin-Suisse-France-Orientale*, « Revue Archéologique de l'Est", 60, pp. 83–146.

Dekówna M. 2005, *Rozwój metod badania znalezisk szkła w Polsce*, "Acta Universitatis Nicolai Copernici, Archeologia", 29, "Archeologia szkła", 9, s. 3–40.

Dekówna M., Szymański A. 1971, *Badanie technik produkcji wczesnośredniowiecznych paciorków szklanych metodami petrograficznymi*, "Slavia Antiqua", 18, pp. 283–309.

Dekówna M., Szymański A. 1972, *Recherches sur les techniques d'exécution des objets de verre anciens par les méthods pétrographiques*, [in:] *Annales du 5e Congrès de l'Association Internationale pour l'Histoire du Verre*, Liège, pp. 337–351.

Dzięgielewski K. 2017, Late *Bronze and Early Iron Age communities in the northern part of the Polish Lowland (1000–500 BC)*, [in:] *The past societies. Polish lands from the first evidence of human presence to the Early Middle Ages*, P. Urbańczyk ed., v. 3, *2000–500 BC*, U. Bugaj ed., Warszawa, pp. 295–340.

Gam T. 1993, *Experiments in glass: present and future*, [in:] *Annales du 12e Congrès de l'Association Internationale pour l'Histoire du Verre*, Amsterdam, pp. 261–270.

Gratuze B., Billaud Y. 2003, *La circulation des perles en verre dans le Bassin Méditerranéen, de l'Âge du Bronze moyen jusqu'au Hallstatt*, [in:] *Échanges et commerce du verre dans le monde antique. Actes du colloque de l'Association Française pour l'Archéologie du Verre Aix-en-Provence et Marseille 7–9 juin 2001*, D. Foy, M.-D. Nenna eds., Monographies instrumentum, 24, Montagnac, pp. 11–15.

Haevernick T.E. 1978, *Urnenfelderzeitliche Glasperlen: eine Bestandesaufnahme*, "Zeitschrift für schweizerische Archäologie und Kunstgeschichte", 35/3, pp. 145–157.

Hartmann G., Kappel I., Grote K., Arndt B. 1997, *Chemistry and technology of Prehistoric glass from Lower Saxony and Hesse*, "Journal of Archaeological Science", 24, pp. 547–559.

Henderson J. 1985, *The raw materials of early glass production*, "Oxford Journal of Archaeology", 4/3, pp. 267–291.

Henderson J. 1988, *Glass production and Bronze Age Europe*, "Antiquity", 62, pp. 435–451.

Henderson J. 1989, *The scientific analysis of ancient glass and its archaeological interpretation*, [in:] *Scientific analysis in archaeology and its interpretation*, J. Henderson ed., Oxford, pp. 30–62.

Henderson J. 2000, *The science and archaeology of materials*, London–New York.

Henderson J., Evans J., Bellintani P., Bietti-Sestieri A.-M. 2015, *Production, mixing and provenance of Late Bronze Age mixed alkali glasses from northern Italy: an isotopic approach*, "Journal of Archaeological Science", 55, pp. 1–8.

Mildner S., Schüssler U., Falkenstein F., Brätz H. 2014, *Bronzezeitliches Glas im westlichen Mitteleuropa – Funde, Zusammensetzung und die Frage nach seiner Herkunft*, [in:] *Ressourcen und Rohstoffe in der Bronzezeit. Nutzung – Distribution – Kontrolle*, B. Nessel, I. Heske, D. Brandherm eds, Wünsdorf, pp. 100–108.

Nikita K., Henderson J. 2006, *Glass analyses from Mycenaean Thebes and Elateia: compositional evidence for a Mycenaean glass industry*, "Journal of Glass Studies", 48, pp. 71–120.

Peche-Quilichini K., Cesari J., Leandri F., Bellot-Gurlet L., Canobbio E., Gratuze B., Leandri C., Paris C. 2016, *Étude de provenance et implications économico-culturelles des parures vitreuses et résineuses du Bronze moyen de l'abri 1 de Campu Stefanu (Sollacaro, Corse-du-Sud)*, "ArcheoSciences", 40, pp. 65–81.

Principes… 2002, *Principes de description des verres anciens depuis les temps les plus reculés jusqu'au XIII^{e} siècle de n.è.*, M. Dekówna, J. Olczak eds, Warszawa–Toruń.

Purowski T. 2012, *Wyroby szklane w kulturze łużyckiej w międzyrzeczu Noteci i środkowej Odry. Studium archeologiczno-technologiczne*, Warszawa.

Purowski T. 2014, *Bursztynowy rozdzielacz i szklane paciorki odkryte w obiektach kultury łużyckiej w Targowisku, pow. wielicki*, [in:] *Kompleks osadniczy kultury łużyckiej w Targowisku, stan. 10–12, pow. wielicki*, J. Górski ed., Via Archaeologica. Źródła z badań wykopaliskowych na trasie autostrady A4 w Małopolsce, Kraków, pp. 289–306.

Purowski T. 2018, *Paciorki bursztynowe i szklane z cmentarzyska ludności kultury łużyckiej w Krakowie-Bieżanowie, stan. 30*, "Archeologia Polski", 63, pp. 99–117.

Purowski T. 2019, *Od fajansu do szkła. Kontakty ziem polskich z głównymi centrami cywilizacyjnymi w II–I tys. p.n.e. w świetle badań archeometrycznych tworzyw szklistych*, Warszawa.

Purowski T. 2022, *Glass beadmaking techniques from the Bronze Age based on finds from Poland*, "Journal of Glass Studies", 64, pp. 249–253.

Purowski T., Dzierżanowski P., Bulska E., Wagner B., Nowak A. 2012, *A study of glass beads from the Hallstatt C-D from Southwestern Poland: implications for glass technology and provenance*, "Archaeometry", 54, pp. 144–166.

Purowski T., Kępa L., Wagner B. 2018, *Glass on the Amber Road: the chemical composition of glass beads from the Bronze Age in Poland*, "Archaeological and Anthropological Sciences", 10, pp. 1283–1302.

Purowski T., Syta O., Wagner B. 2019, *Mycenaean and Egyptian faience beads discovered in southern Poland*, "Journal of Archaeological Science: Reports", 28, https://doi.org/10.1016/j.jasrep.2019.102023.

Shortland A.J., Rogers N., Eremin K. 2007, *Trace element discriminants between Egyptian and Mesopotamian Late Bronze Age glasses*, "Journal of Archaeological Science", 34, pp. 781–789.

Siegmann M. 2006, *Bunte Pracht – die Perlen der frühmittelalterlichen Gräberfelder von Liebenau, Kreis Nienburg/Weser, und Dörverden, Kreis Verden/Aller*, 5, Beiträge zur Ur- und Frühgeschichte Mitteleuropas, 28, Langenweissbach.

Smirniou M., Rehren T., Adrymi-Sismani V., Asderaki E., Gratuze B. 2009, *Mycenaean beads from Kazanaki, Volos: a further node in the LBA glass Network*, [in:] *Annales du 18e Congrès de l'Association Internationale pour l'Histoire du Verre*, D. Ignatiadou, A. Antonaras eds, Thessaloniki, pp. 11–18.

Stawiarska T. 1974, *Paciorki szklane z okresu wpływów rzymskich występujące w kulturze zachodniobałtyjskiej*, "Archeologia Polski", 19/1, pp. 177–233.

Towle A., Henderson J., Bellintani P., Gambacurta G. 2001, *Frattesina and Adria: report of scientific analyses of early glass from the Veneto*, "Padvsa", 37, pp. 7–68.

Varberg J., Gratuze B., Kaul F. 2015, *Between Egypt, Mesopotamia and Scandinavia: Late Bronze Age glass beads found in Denmark*, "Journal of Archaeological Science", 54, pp. 168–181.

Venclová N., Hulínský V., Henderson J., Chenery S., Šulová L., Hložek J. 2011, *Late Bronze Age mixed-alkali glasses from Bohemia*, "Archeologické rozhledy", 63, pp. 559–585.

Walton M., Eremin K., Shortland A., Degryse P., Kirk S. 2012, *Analysis of Late Bronze Age glass axes from Nippur – a new cobalt colourant*, "Archaeometry", 54, pp. 835–852.

Walton M.S., Shortland A., Kirk S., Degryse P. 2009, *Evidence for the trade of Mesopotamian and Egyptian glass to Mycenaean Greece*, "Journal of Archaeological Science", 36, pp. 1496–1503.

TOMASZ PUROWSKI

IDENTYFIKACJA SZKLARSKICH OŚRODKÓW PRODUKCYJNYCH Z EPOKI BRĄZU NA PODSTAWIE ROZPOZNANIA TECHNIK WYKONANIA PACIORKÓW

Streszczenie

Na obszarze południowej i zachodniej Polski odkryto około 3100 paciorków szklanych datowanych na epokę brązu. Niektóre z nich tworzyły kolie złożone z ponad 300 egzemplarzy. Najczęściej omawiane przedmioty znajdowane są na cmentarzyskach, rzadziej w skarbach, a tylko jeden odkryto w jamie osadowej. Większość paciorków wykonano ze szkła barwy turkusowej, rzadziej niebieskiej lub zielonej (ryc. 2a–l). Szkło dekoracji ma barwę białą (linia spiralna; ryc. 2o) lub niebiesko-białą (guzy; ryc. 2m).

Biorąc pod uwagę technologię wytopu, stan zachowania szkła, który jest wynikiem zastosowanych surowców, technikę wykonania przedmiotów i ich wielkość, można podzielić niezdobione paciorki szklane z Polski na dwie grupy. Przedmioty obu grup wykonano w różnym miejscu i czasie (ryc. 10).

Najstarsze paciorki szklane – zaliczone do grupy I – pojawiły się w środkowej Europie, w tym w Polsce, w fazach BrB–HaA_1/A_2 (= II–III/IV EB). Wykonano je z tzw. szkła wysokomagnezowego (HMG; ryc. 1), wytapianego w Mezopotamii i Egipcie przy pomocy popiołu roślin halofitowych, a barwionego związkami miedzi lub kobaltu (ryc. 3–5; tabele 1–3). Biżuteria zrobiona z HMG mogła trafić na obszary obecnej Polski za pośrednictwem obszarów Italii i Moraw (tzw. szlakiem bursztynowym). W niektórych przypadkach nie można jednak wykluczyć trasy wschodniej („bałkańskiej").

Najstarsze paciorki szklane odkryte w Polsce są najczęściej duże (maksymalna średnica wynosi ok. 0,8–1,3 cm; ryc. 2a–g). Zostały starannie wykonane przy użyciu, przynajmniej w niektórych przypadkach, techniki zginania (ryc. 7), o czym świadczy szew, który wskazuje miejsce połączenia końców szklanej pałeczki (ryc. 9a). Być może przerwa widoczna w przypadku niektórych paciorków (ryc. 2d; 9b) jest również śladem po zastosowaniu wspomnianej metody. Obecnie szkło HMG jest najczęściej skorodowane.

Paciorki grupy II datowane są na obszarze obecnej Polski przeważnie na HaA_2–HaB_2 (= IV–1 poł. V EB), a rzadziej na HaB_3 (= 2 poł. V EB). Wykonano je z tzw. szkła mieszanoalkalicznego, zwanego również szkłem niskomagnezowym i wysokopotasowym (LMHK; ryc. 1). Najprawdopodobniej omawiana biżuteria trafiła w międzyrzecze Odry i Wisły z Italii. Paciorki odkryte w Polsce południowej sprowadzono tzw. szlakiem bursztynowym (przez Bramę Morawską), natomiast znalezione w Polsce zachodniej – przez wschodnie Niemcy.

Niezdobione paciorki wykonane ze szkła mieszanoalkalicznego (LMHK) są małe (ich maksymalna średnica wynosi najczęściej ok. 0,4–0,5 cm; ryc. 2h–l). Liczne ślady zabiegów technicznych (np. niestopiony koniec lub bok nici szklanej; ryc. 8) wskazują jednoznacznie, że zrobiono je techniką nawijania (ryc. 6). Szkło LMHK zachowało się do naszych czasów w dobrym stanie (na powierzchni zewnętrznej nie obserwujemy korozji, tak częstej w przypadku HMG).

Jak widać na ryc. 10, paciorki grupy I odróżniają się od niezdobionych okazów grupy II nie tylko innym składem chemicznym szkła (czyli zastosowaniem różnych surowców szklarskich, głównie alkalicznych; stąd podział na HMG i LMHK), ale też techniką wykonania, formą (przede wszystkim wielkością) oraz stanem zachowania szkła. Cechy te mogą być więc w przyszłości pomocne przy określaniu chronologii i miejsca wykonania tych przedmiotów, których tworzywa nie można przebadać metodami fizykochemicznymi.