The earliest traces of metallurgy in Greater Poland: tuyère from Kotowo, Poland

Danuta Żurkiewicz 1, Mateusz Stróżyk 2, Aldona Garbcz-Klemcka 3, Marzena Szmyt 1, and Patrycja Silska 2

1 Faculty of Archaeology, Adam Mickiewicz University in Poznań, Poznań; Archaeological Museum in Poznań, Poznań, PL; danuta@amu.edu.pl
2 Archaeological Museum in Poznań, Poznań, PL
3 AGH University of Science and Technology, Faculty of Foundry Engineering, Historical Layers Research Centre, Kraków, PL

ABSTRACT – During rescue excavations at Site 1 in Kotowo in 1958, a ceramic tube was discovered in a feature of the Funnel Beaker culture. Currently, XRF analysis suggests that it is a ceramic tuyère associated with copper processing. The feature, radiocarbon dated to 3911–3714 BC (68.3% probability), most likely housed a metalworking workshop. The artefact from Kotowo has several analogues in the Polish lands, mainly from sites of the Lengyel-Polgár culture. With a clear and well-documented cultural context, it testifies to the existence of the oldest metallurgical workshop so far known in the Funnel Beaker culture.

KEY WORDS – Funnel Beaker culture; Lengyel-Polgár complex; metalworking workshops; copper

Introduction

The advent of metallurgy to the Polish lands in the Oder and Vistula drainage basins dates back to the second half of the 5th millennium BC. Metallurgy was first practised by Lengyel-Polgár circle communities such as the Brześć-Kujawski and Lublin-Volhynia cultures or the Wyciąże-Złotniki group (Kadrow 2017. 84–86). In the early 4th millennium BC, interest in copper processing was taken over by the communities of the Funnel Beaker culture (FBC) (Novak 2017.155–156; see also Kosko, Szmyt 2019.233). A strong indication of the knowledge of metallurgy is given, it is believed, by the occurrence of metalworking production debris on archaeological sites such as slag, crucibles, various forms of raw material and
characteristic ceramic objects – blowpipes and their fragments interpreted to be tuyères. A single specimen of a tuyère, excavated on Site 1 in Kotowo, Kościan Commune, Greater Poland, is the subject of this article.

On this site, the staff of the Archaeological Museum in Poznań investigated a Lusatian culture cemetery in 1958. Besides Bronze Age graves, they also unearthed the remains of a Neolithic settlement left by FBC populations. The only Neolithic feature they identified yielded many material remains, including a pipe-like ceramic object, although its discoverer did not associate it with any function (Lipińska 1963). Attention was only drawn to a possible connection between this find and copper metallurgy in 1979. It was then that Tadeusz Wiślański included the Kotowo item in a set of remains of FBC copper metallurgy together with crucibles from Æmielów and Gródek Nadbużny, as well as a burnt tuyère from Janówek (Wiślański 1979.239, Fig. 138). A re-analysis of Neolithic pottery from Kotowo and 14C dates for the FBC feature (Żurkiewicz 2020) also provoked a re-examination of the ceramic tuyère. The main aim of this article is therefore to confirm the function of the Kotowo artefact through comparative research, and so place it in a broader cultural and spatial context.

**FBC sources from Kotowo, Site 1**

The site in Kotowo is located in central-western Poland on the Mogilnica River, a right-bank tributary of the Obra, in the Poznań Lakeland, central Greater Poland (Polish Lowland).

The FBC feature, designated as number 1, was discovered in the southern part of a narrow excavated strip of land, extending along the edge of a sand pit (Fig. 1.a). An oval feature ceiling, measuring 3.5×3.0m, was exposed at a depth of 0.70–0.95m below the ground level as it was at that time. The feature depth stayed below 0.5m, and inside the feature contour three smaller intensively coloured depressions were found that contained three clusters of archaeological material (Figs. 1.b, 2; Tab. 1).

The feature held a total of 318 FBC pottery shards. Most were found in Cluster 2, which held 144 pottery shards, including three partially preserved funnel beakers accompanied by ten bone fragments, small pieces of daub and a ceramic tuyère. Additionally, burnt pottery shards were recorded in Clusters 2 and 3, while in Cluster 2 char and burnt rocks were found. This led the researcher in charge of the excavations to conclude that Cluster 2 could have been a hearth, while the whole structure suggested a dwelling or an economic feature (Lipińska 1963.310).

The source materials from each cluster are shown in Table 1. A technological analysis of pottery from Feature 1 showed that pottery with a wall thickness of 5 to 8mm dominated in Clusters 1 and 2. These were vessels made of clay tempered with small amounts of fine sand and grog. There are a few vessels with walls 9–17mm thick in Clusters 1 and 2, but these are dominant in Cluster 3. The technology of most vessels in all clusters, regardless of wall thickness, is similar (for a detailed specification of technological traits see Żurkiewicz 2020). Technological differences are found only in plates.

Pottery from Feature 1 included six funnel beakers and three plates (Fig. 2) with noticeably raised edges and bowl-shaped. For two of these plates the diameter was estimated at approximately 28–29cm. The technology used for these items is distinctively different from that seen...
with the rest of the pottery assemblage. The plates are made of clay tempered with medium and coarse grog. Two plates are ornamented with finger imprints running around their edges. Additionally, on the inner surface of one plate, there runs a circumferential row of impressed pits. In the FBC’s Eastern group, such pottery is the most numerous in early phases. Beakers from Feature 1 are ornamented on the outside under the rim with simple single-element circumferential motifs and all were made of clay tempered with fine sand and grog. One, preserved best, may be counted among funnel beakers associated with the oldest FBC development phase in the Eastern group.

The pottery from Feature 1, in terms of its style, has been considered as settlement remains from the early (first) FBC development phase in Greater Poland (Żurkiewicz 2020:124–126). This claim is made more plausible by 14C dates obtained for the clusters of finds discovered in Feature 1.

The Poznań Radiocarbon Laboratory dated two animal bone fragments from Cluster 1 and two pottery shards (vessel bellies) from Cluster 1 and Cluster 2, in terms of technology unequivocally connected to the FBC, on which an organic residue was observed. Four determinations were obtained:

- Poz-102283 5080±40 BP – for the organic residue on a pottery shard from Cluster 2;
- Poz-139969 5015±35 BP – for a fragment of an unidentified animal bone from Cluster 1 (0.8%N, 5.4%C, 1.6% col);  
- Poz-101632 5000±40 BP – for a fragment of an unidentified animal bone from Cluster 1 (1.8%N, 6.4%C, d13C=–20.8‰, d15N=6.7‰);  
- Poz-102674 4960±40 BP – for the organic residue on a pottery shard from Cluster 1.

A combination of radiocarbon dates made using the ‘R_Combine’ function in the OxCal v4.4.4 software (Bronk Ramsey 2021), at the probability of 68.3%, rendered the time bracket of 3911–3714 BC for Fea-

---

Fig. 2. Kotowo, Site 1, Greater Poland. Selected materials from clusters found in Feature 1 (after Żurkiewicz 2020).
The earliest traces of metallurgy in Greater Poland: tuyère from Kotowo, Poland

Ceramic tuyère from an FBC feature in Kotowo, Site 1. Object description

The artefact found in Cluster 2 of Feature 1 was restored (glued together) from many fragments. Portions missing from its centre were filled with gypsum. Its inlet (wider end) has an edge broken off, while the mouth (narrower end) is chipped, perhaps with little being left of the original surface (Fig. 4a). Dimensions: total length: 8.4cm (judging by the state of preservation of its inlet and mouth, it can be assumed that this figure is close to the original total length); outer inlet diameter: max. 2.5cm, inlet opening diameter: 1.65cm; outer mouth diameter: 2.3×2.0cm, mouth opening diameter: 1.15×1.0cm.

The object is slightly asymmetrical. Its outer surface is smooth, even, hard, of a beige colour and bears traces of using a slick. Inside, along the object, some impressions are noticeable, perhaps left during its formation (Botevid 2020.238). The inner surface is dark, almost black, perhaps a result of sooting or smoking. The technology used to make it, judging by a small exposed surface on its outer wall, involved the use of a clay with a small amount of medium-grained grog. The fracture colour is dark, almost black. The artefact has no obvious burn marks on either end.

Ceramic tuyère from an FBC feature in Kotowo, Site 1. Results of XRF analyses

The analyses were performed at the Faculty of Foundry Engineering, Stanisław Staszic AGH University of Science & Technology, Kraków, Poland. The chemical composition of the inner surface of the object at its inlet was examined, using energy-dispersive X-ray fluorescence spectroscopy (ED-XRF). For this purpose, a stationary spectrometer SPECTRO MIDEX, designed for metallic elements analyses, was used, fitted with an X-ray tube with an Mo anode and a semiconductor detector.

Table 1. Kotowo, Site 1, Greater Poland. Finds.

<table>
<thead>
<tr>
<th>Materials</th>
<th>Cluster 1</th>
<th>Cluster 2</th>
<th>Cluster 3</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>FBC pottery – number of shards</td>
<td>103</td>
<td>144</td>
<td>71</td>
<td>318</td>
</tr>
<tr>
<td>FBC pottery – weight of assemblage [g]</td>
<td>2847</td>
<td>3596</td>
<td>1893</td>
<td>8336</td>
</tr>
<tr>
<td>Number of FBC ornamented shards</td>
<td>17</td>
<td>9</td>
<td>3</td>
<td>29</td>
</tr>
<tr>
<td>Vessel forms</td>
<td>3 beakers, 3 plates</td>
<td>3 beakers</td>
<td>beaker fragments – stuck together with those from Cluster 2</td>
<td>9</td>
</tr>
<tr>
<td>GAC pottery</td>
<td>6</td>
<td>45</td>
<td>26</td>
<td>77</td>
</tr>
<tr>
<td>Bones</td>
<td>46 + fragment of a human skull</td>
<td>10</td>
<td></td>
<td>57</td>
</tr>
<tr>
<td>Daub</td>
<td>15</td>
<td>14</td>
<td></td>
<td>29</td>
</tr>
<tr>
<td>Rough-cast ware</td>
<td>6</td>
<td>2</td>
<td></td>
<td>8</td>
</tr>
<tr>
<td>Burnt pottery fragments</td>
<td>5</td>
<td>12</td>
<td></td>
<td>17</td>
</tr>
<tr>
<td>Others</td>
<td>bone chisel</td>
<td>ceramic tuyère</td>
<td>grindstone</td>
<td></td>
</tr>
</tbody>
</table>

Fig. 3. Kotowo, Site 1, Greater Poland. Joint calibration of 14C determinations in OxCal v4.4.4 (Bronk Ramsey 2021).
The chemical composition of the object interior was determined by making five measurements at the broken-off fragment of the tuyère inlet (Fig. 4b). These indicated a considerable amount of copper, from 1.19% to 5.46%, with the average of the measurements being 2.9%. The second largest share belonged to zinc (from 1.67% to 2.93%, with an average of 2.39%). However, this element should be linked to the material of which the tuyère was made, i.e. clay. There was relatively little tin on the surface (below 1.0%). Detailed percentages of the elements that were identified are shown in Table 2.

The usefulness of the XRF method for the examination of Neolithic ceramics has already been confirmed on many occasions (e.g., Menne 2020) and has also been found helpful in detecting traces of metallurgical processes on ceramic artefacts. Its application helped reveal traces of copper (up to 6.2%) on the surface of a crucible fragment linked to the FBC Northern group (Gebauer et al. 2021). A high proportion of silver and tin was also found on the related ore (Rostoker 1975.314).

The analysis results of the Kotowo tuyère suggest that it should be directly linked to metalworking. Being a qualitative confirmation of contact with molten metal, the results of analogous analyses made on casting moulds (Garbacz-Klempka, Dziegielewski 2021; Garbacz-Klempka et al. 2016) make the percentages for the Kotowo tuyère appear surprisingly high. In the case of casting moulds from a Bronze Age cemetery in Gogolin-Strzebniew, the copper content ranges from 2% to 18% (Garbacz-Klempka, Dziegielewski 2021). Tuyère, unlike moulds, rarely show traces of direct contact with molten metal (cf. Dziekoński 1962; closest analogy from Cyprus, Tylecote 2002.22). However even if the tuyère did not come into direct contact with molten metal, a closed hearth system
The earliest traces of metallurgy in Greater Poland: tuyère from Kotowo, Poland

Possible uses of the Kotowo tuyère

The results of physicochemical analyses show that the tuyère was a fireproof ending of an installation supplying air to a copper smelting reactor. The purpose of blowpipes and tuyères was to aid the burning of charcoal with an additional air blast that helped ensure the right temperature. Hence, they are believed to be proof of local metalworking (Garbacz-Klempka 2018.20; Höppner et al. 2005.299; Carozza, Mille 2009.143). The relatively large diameters of the Kotowo tuyère inlet and mouth suggest that the object could not have been used as a blowpipe because its diameters should not have been greater than 10mm. Instead, it must have ended in bellows that effectively supplied oxygen to the reactor charge (Bourgarit 2007). Experiments have shown that the use of human breath through a blowpipe, ending in a clay element or bellows with a tuyère, ensures the right temperatures and conditions for liquefying, melting or smelting copper (Rehder 1994). Furthermore, it is suggested that the local topography and natural conditions were taken advantage of when places for metalworking workshops were selected. This shows that wind was harnessed to supply air to furnaces (Bourgarit 2007; Martinón-Torres, Rehren 2014.110).

In the light of available information, the morphology of Eneolithic metalworking features can be characterized as varied (Bourgarit 2007). What draws attention in this context is a particular type of structure, using bowl-like ceramic vessels (Bourgarit 2007.Tab. 1). The list of relevant sites given in the cited publication (Bourgarit 2007.Tab. 1) is supplemented by a site at Belovode (Serbia) where Europe’s oldest traces of copper processing have been documented, attesting to the advanced skills of Eneolithic metallurgists (Radivojević et al. 2010; Radivojević, Rehren 2021; Radivojević et al. 2021). The discoveries made there prompted researchers to carry out an experiment to find out whether such vessels and ceramic tuyères with bellows could be used to process copper, and the results showed that they could.

As known from various European Eneolithic sites, vessels used in metalworking installations (Cadet et al. 2021) find counterparts in the Kotowo plates/bowls. Interestingly, they also have uncertain analogies in other FBC settlement contexts on the Polish Lowland. What attracts attention is their technology because, as the only ones on this site, they were made of clay tempered with medium- and coarse-grained grog. This may indicate that they were designed for other purposes than those of the other vessels. Admittedly, no traces of use for metallurgical purposes have been found on the Kotowo plates/bowls, but the same is true for the Belovode vessel artefacts. Experiments carried out on them have not found any such traces on the vessels that were examined, and neither have the spectrographic analyses of original reactor remains on the Belovode site revealed any substantial residues of slag or copper on the vessel surfaces (Radivojević, Rehren 2021.128).

The advent of metallurgy in the Vistula and Oder drainage basins

In the lands of present-day Poland, we now know of nine fragments of potential ceramic tuyères, originating with five Eneolithic sites of which only three may be linked to FBC communities. The others are

<table>
<thead>
<tr>
<th>Analysis no.</th>
<th>Co</th>
<th>Ni</th>
<th>Cu</th>
<th>Zn</th>
<th>As</th>
<th>Ag</th>
<th>Sn</th>
<th>Sb</th>
<th>Au</th>
<th>Pb</th>
<th>Bi</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAP_Kot_58_1009_01</td>
<td>&lt;0.02</td>
<td>&lt;0.015</td>
<td>1.19</td>
<td>2.15</td>
<td>0.05</td>
<td>0.34</td>
<td>0.65</td>
<td>0.18</td>
<td>&lt;0.02</td>
<td>0.01</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>MAP_Kot_58_1009_02</td>
<td>&lt;0.02</td>
<td>&lt;0.015</td>
<td>2.18</td>
<td>2.03</td>
<td>0.05</td>
<td>0.41</td>
<td>0.50</td>
<td>0.16</td>
<td>&lt;0.02</td>
<td>0.02</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>MAP_Kot_58_1009_03</td>
<td>&lt;0.02</td>
<td>&lt;0.015</td>
<td>2.71</td>
<td>2.93</td>
<td>0.00</td>
<td>0.48</td>
<td>0.49</td>
<td>0.01</td>
<td>&lt;0.02</td>
<td>0.20</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>MAP_Kot_58_1009_04</td>
<td>&lt;0.02</td>
<td>&lt;0.015</td>
<td>2.96</td>
<td>2.82</td>
<td>0.06</td>
<td>0.42</td>
<td>0.53</td>
<td>0.12</td>
<td>&lt;0.02</td>
<td>0.08</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>MAP_Kot_58_1009_05</td>
<td>&lt;0.02</td>
<td>&lt;0.015</td>
<td>5.46</td>
<td>1.67</td>
<td>0.00</td>
<td>0.48</td>
<td>0.94</td>
<td>1.15</td>
<td>&lt;0.02</td>
<td>0.01</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Medium</td>
<td>&lt;0.02</td>
<td>&lt;0.015</td>
<td>2.90</td>
<td>2.32</td>
<td>0.03</td>
<td>0.43</td>
<td>0.62</td>
<td>0.32</td>
<td>&lt;0.02</td>
<td>0.07</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Tab. 2. Kotowo, Site 1, Greater Poland. Results of the chemical composition analysis of the ceramic tuyère, using X-ray fluorescence spectroscopy (ED-XRF) in wt%.

1 For a slightly different opinion on the function of differences in tuyère diameters see Marcos Martinón-Torres and Thilo Rehren (2014.111).
associated with the groups of the Lengyel-Polgár circle. However, the list of Eneolithic finds from the Polish lands, attesting to the knowledge of copper processing skills, is a little longer. In it, one may include fragments of vessels in the categories of crucibles, semi-finished products, raw-material bits or slag. Below, in chronological order, the other finds are described, being the oldest known testimony to the knowledge of copper smelting in the lands of present-day Poland. At this juncture, one should caution that where hypothetically finds could be linked with metal processing but the link has not been substantiated by specialist analyses (e.g., Opatowice, Site 42, Kujawy-Pomerania Province – Kośko, Szmyt 2007.247) or a context is uncertain, such finds have not been considered. Furthermore, as part of the project named “The catalogue of the oldest metal object from Wielkopolska”, analyses have been carried out of potential crucibles and ladles from Neolithic sites in Greater Poland (Śrem, Site 8, Mrowino, Site 3). The results in this instance, however, have been negative.

The oldest finds, attesting to the knowledge of metallurgy that have been discovered in the Polish lands and documented in reliable archaeological contexts, come from Brześć Kujawski culture settlements, Brześć Kujawski, Sites 3 and 4, Kujawy-Pomerania Province. On Site 3, in the ceiling of a settlement feature, a discovery was made of a slag lump fused with a crucible fragment (Grygiel 2008.208, Fig. 184). Site 4, in turn, yielded miniature ingots, in the form of elongated bands and rods with a rectangular cross-section (Jażdżewski 1938.53, Fig. 38). On the same site, in the cultural layer, underneath a grave, a ceramic tuyère was found. It tapered towards one end and had its thicker end broken off similarly to the Kotowo specimen (Fig. 5.e; Jażdżewski 1938.15, Fig. 35:5). All these finds are connected to the classic phase of the Brześć Kujawski culture and roughly dated to 4500–4300 BC (Grygiel 2008.1992).

Slightly younger Lublin-Volhynia culture finds were unearthed in Złota – Grodzisko I and II sites, Świętokrzyskie Province. The finds comprised five remains of ceramic tuyères (Fig. 5.c,d,f,g,h), fragments of 22 crucibles for smelting copper and many raw material lumps and metal ornaments (Dziekoński 1962). Unfortunately, the dating of these finds cannot be narrowed down, and thus they can be only generally assigned to the horizon of the Lublin-Volhynia culture, coinciding with the period 4300/4200–3800 BC (Zakościelna 2006.80–88). This is the same time bracket to which the Kotowo tuyère is assigned.

Among the materials of the Wyciąże-Złotniki group, dated to 3700–3600 BC (Włodarczak 2006.33), discovered at a site in Złotniki, Małopolskie Province, crucible fragments were identified that bore copper residues on the inside (Dzieduszycka-Machnikowa 1964). In this context, a crucible found in Złota – Nad Wawrem site can be considered as a continuation of interest in metallurgy among FBC communities. It is a small vessel with an opening next to its base from which a pipe-like mouth protrudes. However, a qualitative analysis carried out at the Spectrography Laboratory, State Archaeological Museum, has not found any traces of copper on its surface (Matraszek 2001.151). An object similar to this find, from Cmicłów and discussed below, was taken to be the remains...
of a smoking pipe (Matraszek 2001.151). Importantly, these finds are associated with FBC communities, while the settlement phase of the site in Z³ota supposedly corresponds to Phase BR II dated to 3750/3700–3500/3400 BC (Matraszek 2001.167; Kruk et al. 2018.40).

From a site at Gródek Nadbużny, Lublin Province, a number of varied artefacts were recovered, attesting to advanced and intensive copper processing. Among them are 22 crucible fragments with fused metal or residue, pointing to contact with copper, 25 lumps of strongly burnt daub and five lumps identified as ore or slag (Gumiński 1989.166–169). For Feature 18, from which one crucible fragment with fused metal came, the 14C date GrN-16125 4665±40 BP (Gumiński 1989.173) was obtained, assigning the feature, at a probability of 68.2%, to the time bracket of 3513–3372 BC. Prior to the FBC settlement, the site was occupied by a Lublin-Volhynia culture community, although it did not practise metallurgy (Kadrow 2015.203).

At an FBC settlement in Cmielów, Świętokrzyskie Province, dating to 3600–3400 BC (Włodarczak 2006.Fig. 16), in addition to a ‘smoking pipe’ similar to that found in Z³ota, a discovery was made of fragments of over a dozen crucibles that bore visible traces of copper on the inside (Krzak 1963).

Finds from the FBC Southern group from Janówek, Lower Silesia Province, represent the two youngest specimens of hypothetical ceramic tuyères, found in the Polish lands in an FBC context (Wojciechowski 1973.40). Both objects were found in two economic features, holding rich materials stylistically dated to the younger (Luboni) FBC phase. Unfortunately, there are no 14C determinations available for the site, hence its chronology can be only generally described as coinciding with the Luboni phase that is roughly dated to 3400–2700 BC in Wielkopolska (Wierzbicki 2013.156). The FBC settlement at Janówek was preceded by settlement remains from the early phase of the Lengyel culture (Wojciechowski 1973.4). However, we have little information about these remains.

**The advent of metallurgy, and tuyères in Eneolithic communities**

Copper minerals and native copper were first used in the Middle East as early as the 8th millennium BC (O’Brien 2014; Roberts et al. 2009; Maddin et al. 1999). It was there that early agrarian communities appreciated the aesthetic value of native copper fragments encountered on the ground. What they also found attractive was the possibility of shaping such pieces by cold forging. In turn, copper thermal processing is first evidenced in 7th millennium BC Anatolia (Pernicka, Anthony 2010), although serious reservations have recently been raised about this (Radivojević et al. 2017). By the 6th millennium BC, the skills and expertise of copper processing were advanced enough to melt and shape it in moulds (O’Brien 2014).

A more recent series of radiocarbon dates shows metallurgy in the Balkans predates that known from the Aegean. This, however, does not allow one to simply deduce that knowledge of metallurgy from the Middle East was imported to Europe, but rather tends to support the hypothesis that metallurgy was invented independently in the two regions (Renfrew 1969; O’Brien 2014.38; Rosenstock et al. 2016.106; Radivojević et al. 2010; Radivojević 2015). Additional support for this hypothesis comes from Serbia and Bulgaria, where traces of copper mining and processing were founded, dated to 5200–4500 BC and tied to the Vinča culture (Marić et al. 2021; O’Brien 2014.40; Rosenstock et al. 2016.75–76).

In the early 5th millennium BC, knowledge of copper metallurgy is observable among the communities of the Lengyel and Tisza cultures and other Carpathian Basin groups. The region’s oldest metallurgical workshop was identified on the site of Slovenské Pravno, okr. Turčianske Teplice, north-central Slovakia. There, at a settlement of the Ludanice culture, dated to 4100–3800 BC, a roasting furnace was found holding slag and copper lumps (Czajlik 2014).

Finds interpreted to be ceramic tuyères are known from Eneolithic sites stretching from the Caucasus to Iberia (Gailhard et al. 2021; Murillo-Barroso et al. 2017). However, it must be noted that on the oldest European site, where all the major elements of the metallurgical chaîne opératoire are recorded at Belovode, Petrovac county, Serbia, dated to 5000–4600 BC, the remains of ceramic tuyères have not been found yet. Nonetheless, experiments attempting to reconstruct local metalworking assume that such objects were used (Radivojević, Rehren 2021.128).

In central Europe, the oldest known site evidencing copper metalworking skills is located in the Tyrole-
Danuta Żurkiewicz, Mateusz Stróżyk, Aldona Garbacz-Klempka, Marzena Szmyt, and Patrycja Silska

was carried out. This is seen in separate concentrations within the feature, having clearly distinct fills in which most of the movable finds were found.

Furthermore, the content of individual concentrations attests to the economic purpose of the feature. They were found to contain animal bone fragments, daub, a bone awl and a grindstone but the most numerous remains were pottery shards, both thin- and thick-walled ones. Some of the shards have been visibly refired. Archival descriptions mention visible layers of char in Cluster 2, i.e. where the tuyère was found. Moreover, the fact that some thick-walled ware had rough surfaces indicates its functional, probably, economic purpose.

Among the pottery, small fragments of three plates deserve special attention. Plates are common among the early material of the FBC Eastern group. What makes the Kotowo ones different is their raised edges, making them look somewhat like bowls. What’s more, the best preserved plate was probably made using an atypical technology: by impressing its form in a kind of basket, the structure of which is still visible on the outside surface of the plate (Fig. 2.a). Finally, all the plates were made following a potter’s recipe that was different from that used for the other vessels from this site. Here, the clay of which the plates were made was tempered with medium and coarse grog. However, the rarest artefact found in the feature in question is a fragment of a pipe-like artefact that

Discussion and conclusions

The archival discoveries listed above and the new examinations of the Kotowo tuyère justify the inclusion of the Vistula and Oder drainage basins among the lands where early knowledge of advanced copper processing has been identified among FBC communities.

The feature found on Site 1 at Kotowo may be interpreted as the remains of economic activity, which is indicated by its size and form, an elongated oval with a flat bottom, as well as internal organization, the division into three zones in which economic activity

Fig. 6. FBC ceramic tuyères. a Podoli, okr. Brno-Venkov; b Cimburg, okr. Kutná Hora; c Lønt, comm. Haderslev. After Petr Kos and Miloslav Šmíd (2013), Milan Zápotocký (2000), and Anne Brigitte Gebauer et al. (2021).
The earliest traces of metallurgy in Greater Poland: tuyère from Kotowo, Poland

should be interpreted, on the strength of specialist analyses and the analogies referred to above, as a ceramic tuyère used in copper processing. In conclusion, it can be claimed that the tuyère was found in a feature that, at least during a part of the time it functioned, was a metalworking workshop.

An attempt was made to specify more precisely the time the feature was used by carrying out a number of $^{14}$C determinations. Unfortunately, the unfavourable course of the calibration curve prevented any narrowing down of the period when the feature was used by indicating a relatively broad interval of 3911–3714 BC (probability of 62%). At present, this series of dates comprises the oldest determinations made for an FBC community in Greater Poland that coincide with the first development horizon of the FBC Eastern group (Kozłowski, Nowak 2019.107).

The Kotowo tuyère proves that already in the early FBC advanced metalworking skills were present (for an opposite opinion see Kowalski et al. 2016.196).

---

**Fig. 7. Chronology of finds attesting to copper processing within the entire FBC oecumene and the dating of ceramic tuyères from the Lengyel-Polgár circle found on the Polish lands. Sites on which ceramic tuyères were found are marked in yellow, and sites that yielded other finds attesting to the knowledge of metallurgy are marked in white. 1 Łent, 2 Kotowo, 3 Brześć Kujawski, 4 Janów, 5 Cimburg, 6 Podoli, 7 Zlotniki, 8 Cmielow, 9 Złota – Grodzisko I and II, 10 Złota – Nad Wawrem, 11 Gródek Nadbużyń.**
Its design suggests that it was used with bellows rather than as a fireproof ending of a simple blowpipe to be blown by a person, which could be re-used many times until it was damaged, perhaps by a fragment breaking off at its inlet. Similar types of damage are noticeable on other Eneolithic tuyères (Fig. 5.a,e; 6.a). Unfortunately, metalworking in Kotowo cannot be tied now to any specific copper goods. Eneolithic metal goods from central Greater Poland are finds of uncertain archaeological contexts for the most part and are mostly believed to have been influenced by the Baden culture in the second half of the 4th millennium BC. A hoard from Rudki, Greater Poland, is a good example of this (Kowalski et al. 2019).

Ceramic tuyères on central European Eneolithic sites make up a rather small set. Perhaps they were not indispensable for successful copper smelting. In this set, only the Kotowo specimen has been confirmed by spectrographic analyses to have been used in metallurgy. Moreover, the results suggest that it may have been used for purifying, or refining metal that was procured earlier.

The form of the Kotowo specimen, however, does find analogies on other archaeological sites, and the closest specimens in terms of form come from Złota-Grodzisko I (Fig. 5.d) or Podoli, Moravia (Fig. 6.a).

The information presented above justifies the cautious conjecture that there were three types of Eneolithic tuyères:

Type 1. Simple ceramic endings of blowpipes with the diameter of the inner channel not exceeding 10mm, represented by a specimen from Brześć Kujawski (Fig. 5.e).

Type 2. Ceramic tuyères used with single bellows, and this is the type of the Kotowo specimen and most other finds. Its characteristic may be a smaller (by 1/3?) diameter of the mouth than that of the inlet. Admittedly, the current data are too few, making any generalizations of observations from Kotowo almost impossible.

Type 3. Short specimens with a broad inlet that could have been used in a more advanced smelting technology with two bellows ensuring a continuous supply of oxygen and thus a stable and high temperature (Dziekoński 1962). Tuyères of this type could have prevented hot embers from being drawn inside in-flammable bellows, and it is to this type that the Łont specimen may belong (Fig. 6.c).

It is difficult to claim that these types of tuyères evolved from each other, with Type 1 being the oldest and Type 3 the youngest, since we still have only a few relevant specimens. Moreover, tuyères of Type 2 and Type 3 are encountered among materials associated with an earlier stage of the FBC (Kotowo and Łont) and dated to the first half of the 4th millennium BC (Fig. 7).

Finds documenting early manifestations of the knowledge of metallurgy in the Polish lands accumulate in the south and for the most part concern Lengyel-Polgár communities. In fact, most FBC sites where metalurgical relics were recovered were settled earlier by Lengyel-Polgár communities. The sites at Złota (Grodzisko I and II, and Nad Wawrem) provide attestations of metalworking that are close in both time and space. Metalworking was begun there by the populations of the Lublin-Volhynia culture and later continued by FBC communities. Although a more accurate dating of local settlement by the Lublin-Volhynia culture and FBC is not forthcoming, the Złota metalworking attestations are chronologically the closest to the finds from Kotowo (Fig. 7).

A cautious conjecture can be thus made that metalworking skills among FBC populations could have been acquired from the communities of the Lengyel-Polgár circle and that both communities had close relations. This brings us to a broader issue – the nature of cultural change between the two groups (Kadrow 2015; Kośko, Szmyt, Żurkiewicz 2022).

The information set out above therefore allows us to picture how Eneolithic innovations and accompanying social and economic changes spread, taking into account lands east of the Oder River, which has not always been the case until now (e.g., Strahm et al. 2014, Abb. 4).


https://doi.org/10.2478/bps-2019-0004


