KAMIL NOWAK · PAWEŁ GAN

THE EARLY IRON AGE HOARD FROM JODŁOWNO (POW. GDAŃSKI), NORTHERN POLAND

TECHNOLOGICAL STUDY OF THE METAL RAW MATERIALS

In the Early Iron Age, the areas bordering the southern shores of the Baltic Sea were characterized by increased development, and the communities occupying these areas began to have an increasing impact on those located in the midst of the North European Plain (Dzięgielewski 2017, 299). The bronze artifacts, characteristic only for this territory, provide evidence for local metallurgical production in Gdańsk Pomerania in the Early Iron Age (e. g. Waluś 1979, 219). Additional information on intensive metallurgical production is provided by finds related to the functioning of smelting workshops in Pomerania in Poland. Hundreds of finds of single-use casting moulds from the settlement in Juszkowo (pow. gdański / PL; Fudziński / Ślusarska 2017), or single artifacts and fragments of casting nozzles from the settlements in Luzino (pow. wejherowski / PL; Wiącek 1974, 271) and Widzino (pow. słupski / PL; Fudziński et al. 2009, 189 fig. 7), indicate that metallurgical activity in the Early Iron Age took place and was mainly concentrated in Gdańsk Pomerania. Additional evidence indicating the operation of intensive processing of copper alloys in this area is indicated by hoards containing raw material in the form of plano-convex ingots or bars (Dzięgielewski 2017, 305). Pomeranian hoards such as those from Swarzewo (pow. pucki / PL), Słupsk (pow. słupski / PL) or Szpęgawsk (pow. starogardzki / PL) provided finds of plano-convex ingots and metal bars counted in tens of kilograms (Kossinna 1919; La Baume 1931; Dzięgielewski et al. 2019, 32). Fragments of large, porous cast cakes also come from nearby Witkowo (pow. słupski / PL; Sprockhoff 1941, tab. 51). All these data indicate that the metal was imported and processed locally in eastern Pomerania.

The new find from Jodłowno (pow. gdański / PL), which the present article deals with, is another piece of evidence for the increased metallurgical production in Pomerania in Poland. A non-archaeologist found the hoard during prospection using a metal detector. The discoverer secured the area and the excavations carried out by archaeologists allowed the documentation of the deposit's context. The artifacts defined as raw material (bars / rods) may suggest that the deposit was a stock of raw material. The occurrence of grouped and tied bars inspired us to study this kind of objects within the technological and raw material context. Through archaeometallurgical analyses of the bars, we wanted to answer the question of the parameters and quality of the raw material transported and locally used in the Early Iron Age in northern Poland.

THE HOARD FROM JODŁOWNO – THE CONTEXT OF DISCOVERY AND ITS INVENTORY

The discovery using a metal detector was made in Jodłowno (**fig. 1**). The hoard was found in the forest, about 10 m from a meander of the former riverbed. The person, who found the artifacts, dug a large pit to a depth of about 70 cm, which damaged the deposit's upper layers, so the pit's original outline was illegible. He removed the first metal objects (three hollow ankle rings, fragments of bars and small ornaments) and stopped further »exploration«. One hollow ankle ring, six necklaces, slag, blade fragments and bars were

DOI: https://doi.org/10.11588/ak.2023.3.101725

Fig. 1 The location of the hoard discovery site Jodłowno (♦) on the map of Poland. – (Map K. Nowak).

Fig. 2 Lower part of the deposit lying *in situ* during the excavation. The ingots/rods in two groups, together with blade fragments, necklaces and one of the hollow ankle rings were left untouched. – (Photo M. Gólczyński).

discovered *in situ*. The deposit was buried in an organized form (**fig. 2**). The bars and fragments of blades were assembled together in two groups touching one another. The six necklaces stacked one above another and one hollow ankle ring lay in the centre. A vertical arrangement of the hollow ankle rings and their deposition in pairs should be considered. The stacked arrangement is very common in the case of hollow ankle rings[1]. The whole assemblage was covered with some organic material and a stone.

The Hoard's Inventory – Typology and Chronology

As a result of the excavation, 68 metal objects were obtained (**figs 3–4**). The inventory of the deposit includes 6 bow-shaped neck rings, 4 hollow ankle rings, half a hollow bracelet, 2 fragments of decorated necklaces, 4 forged blades 1 completely preserved and 3 in fragments, 2 casting jets and 49 bars (conventionally referred to as semi-finished products).

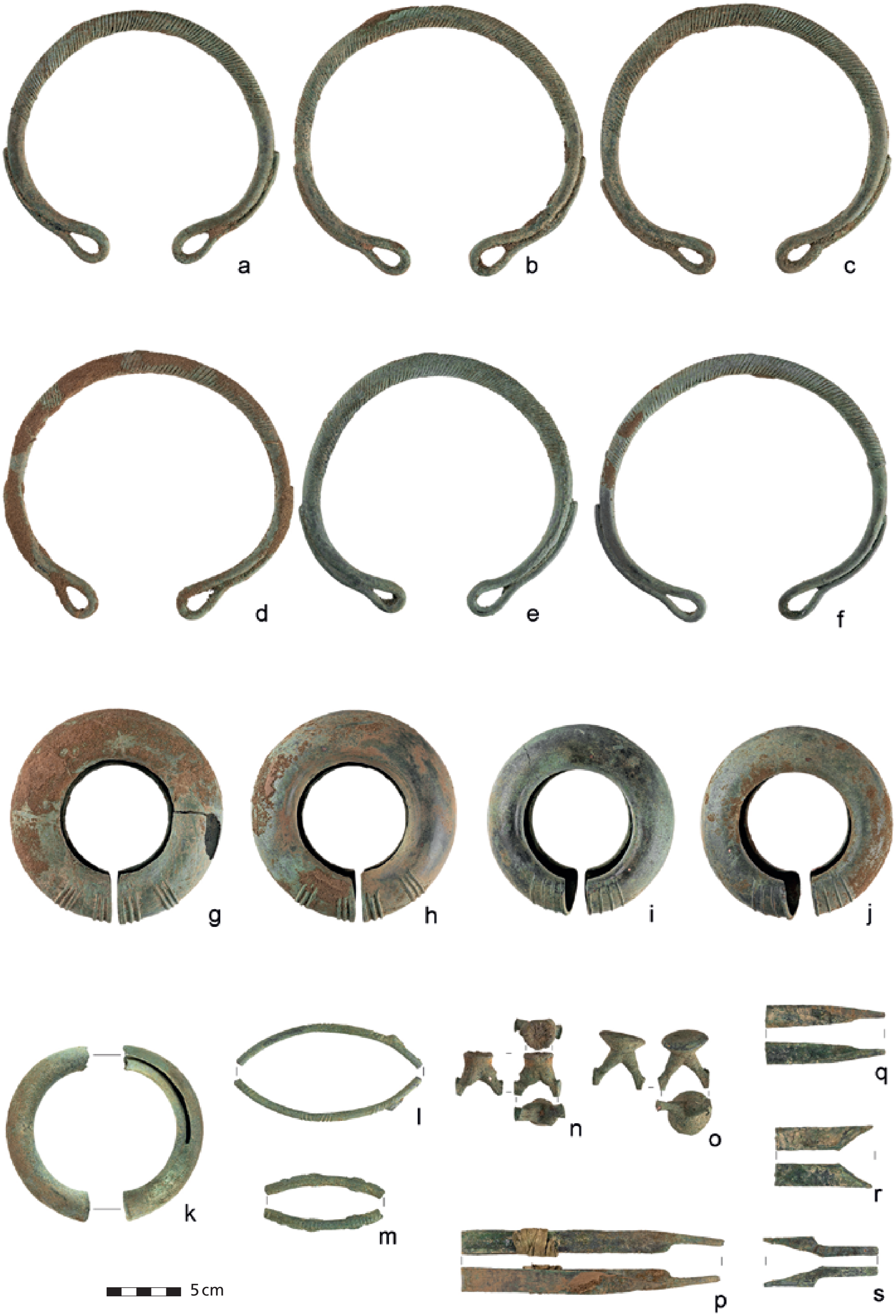

Fig. 3 The inventory of the hoard from Jodłowno: **a–f** bow-shaped necklaces of the western variant. – **g–j** two pairs of hollow ankle rings. – **k** a hollow bracelet. – **l–m** rod-shaped ornaments. – **n–o** casting waste. – **p–s** blades with traces of forging. – (Photos W. Ochotny). – Scale 1:4.

Fig. 4 The inventory of the hoard from Jodłowno: the ingots/rods deposited in two groups. Some of them were bent together (**a**). – (Photo W. Ochotny). – Scale 1:4.

The individual elements of the deposit were tied with a string made of organic material. Its remains have been largely preserved on some bars and in the loops of necklaces. Entire »packets« were bound in this way, composed, for example, of fragments of bars (**fig. 4, a**). There are also imprints of grass or reed on the hollow ankle rings (**fig. 3, g**), which may indicate that the entire deposit was covered with chaff or that the rings were wrapped in some organic material.

The hoard includes six bow-shaped neck rings of similar size and weight (**fig. 3, a–f**). The necklaces from the Jodłowno hoard belong to the Western variety, where the bent ends are permanently connected to the bow. In the Eastern variant the ends are unconnected. Based on his analysis, M. J. Hoffmann proposes to narrow down the chronology of this type of neck ring to the Ha D–Lt A period, suggesting that both varieties were contemporaneously in use (Hoffmann 2000, 125).

Four hollow ornaments, creating two pairs, belong to the type of hollow cast ankle rings known as *Nordische Hohlwulste*, *Hohlwulstringe* and *Wulstringe* (e.g. Schacht 1982; Schopper/Brather 2019, 66–70), as also found in the hoard inventory (**fig. 3, g–j**). The distribution of this type of objects reveals a clear concentration in northern Poland, northern Germany and Denmark (e.g. Dobrzany [pow. stargardzki/PL]; Gdynia-Karwiny; Reda Rekowo [pow. wejherowski/PL]; Stolpe auf Usedom [Lkr. Vorpommern-Greifswald/DE]; Ragow [Lkr. Dahme-Spreewald/DE] and Angermünde [Lkr. Uckermark/DE]; Mariesminde II [Kerteminde Komm./DK]; Bucka 2015, 467; Fudziński/Fudziński 2010; Schmidt 2014; Schopper/Brather 2019; Thrane/Juottijärvi 2020). Finds have also been reported in central and eastern Germany, Sweden and Belgium (e.g. Beerse [prov. Antwerpen/BE]; Scheltjens et al. 2013). In most studies, the northern hollow ankle rings are typically dated to the 6th Period of the Bronze Age/Ha D (e.g. Łuka 1966; Schacht 1982, 17; Jensen 1997, 75; Hoffmann 2000, 140; Heynowski 2006, 55–57; Thrane/Juottijärvi 2020, 30).

The hoard also contains fragments of artifacts and casting waste. One of the fragments is a cast, hollow bracelet with thickened ends (**fig. 3, k**). Additionally, two fragments originate from ornaments with a small rod diameter, commonly found in the Early Iron Age (**fig. 3, l–m**). These fragments are decorated with transverse or diagonal groups of grooves created during the casting process (e.g. Harding et al. 2004). The cast waste comprises two jets with two pouring channels (**fig. 3, n–o**). Furthermore, the hoard contains thin sheet metal objects. One well-preserved blade was bent U-shaped (**fig. 3, p**). The deposit also includes fragments of similar objects (**fig. 3, q–s**). These may have been semi-finished blades of knives or daggers. The largest group of metal artifacts are elongated bars (49 fragments; **fig. 4**).

Based on the above remarks and the presence of datable objects, such as hollow ankle rings and bow-shaped neck rings, the chronology of the hoard should be defined as the Early Iron Age. Based on the research of M. J. Hoffmann (2000, 125), the presence of bow-shaped neck rings dates the deposit to the late Early Iron Age (Ha D). In a work by K. Dzięgielewski (2017), the hollow ankle rings and bow-shaped neck rings are dated to the late Ha C. We want to assume a general deposit dating according to other authors to the late Early Iron Age (6th Bronze Age Period/Ha D).

ARCHAEOMETALLURGICAL ANALYSIS

The large collection of bars from the inventory is highly diversified, metrically and formally (**fig. 4**). However, two main groups can be distinguished – items with a D-shaped and ones with an oval cross-section. Most of them have an irregular shape and uneven surfaces, sometimes folded on one side. All bars from the collection are preserved in fragments, so the original length of the artifacts cannot be determined. They varied in weight. The entire collection weighs 5395 g.

Our goal was to determine the properties of the bars deposited in the hoard from Jodłowno and investigate, if the collection is homogeneous in terms of metal composition or not. To achieve this goal, we conducted elemental composition analysis (Energy-dispersive X-ray spectroscopy XRF) for all bar-shaped objects and internal microstructure analysis (scanning electron microscopy with the energy dispersive spectroscopy SEM-EDS) for selected artifacts.

The Chemical Composition of the Bars / Rods

The artifacts were transferred to the Laboratory of Bio- and Archaeometry of the Institute of Archaeology and Ethnology of the Polish Academy of Sciences to determine the elemental composition of the metal using non-invasive analytical methods. The Artax (Brucker Company) X-ray fluorescence spectrometer with polycapillary X-ray optics that produce a micro-spot of primary X-radiation with extremely high intensity, with a rhodium X-ray tube and a silicon drift detector (SSD) with 150 eV resolution for Mn-Kα and detection limits in the low ppm range was used. Each measurement lasted 100 seconds in the air atmosphere. Due to the non-homogenous nature of the metal, each measurement site was sampled several times to average the results, and the measurements were made on a surface that was locally cleaned of corrosion products. Dedicated Spectra software and the calibration curve of historic bronze standards developed in the laboratory were used to evaluate the results.

All bars from the hoard's inventory were examined. The results obtained are presented in **table 1**.

The analyzed collection is divided into several distinct material groups with different chemical profiles. A larger group of bars with 40 artifacts was made of metal characterized by significant impurities, most likely coming from the smelting of polymetallic copper ores. It can be said that it is a semi-finished metallurgical product partly corresponding to black copper and requiring further refining. The chemical composition results suggest that fahlores (German *Fahlerz*) of the tennantite-tetrahedrite with nickel series were used for smelting this group of ingots. The total level of impurities is, on average, 13.82 % (determination range 8.61–23.26 %), while the main impurities are arsenic (median 2.53 %, determination range 0.77–4.08 %), antimony (median 2.59 %, determination range 1.52–3.74 %). To determine the nature of the ore, it is also important to determine the content of silver (median 0.32 %) and nickel (0.30 %). Verification tests of several artifacts carried out using a scanning electron microscope (SEM-EDS) showed that the content of silver and nickel is higher and amounts of 1.34 % for Ni and 1.78 % for Ag on average. This corresponds to the known raw material profiles of fahlores with nickel (Höppner et al. 2005, 297; Lutz / Schwab 2014; Pernicka et al. 2016, 39). The lower markings obtained on the µXRF results were due to the limitations of the composition of the standards used. Applying standards that resemble the sampled material as closely as possible is important in such analytical methods.

The results of the other determined elements on both instruments were very similar. The main addition is lead, whose median was 6.89 % (range of determination 4.12–19.27 %). Although known deposits of copper ore mixed with galena were mined in the Early Iron Age (Lutz / Pernicka 2013, 125), such a high content should probably be associated with an intentional action. Moreover, no positive correlation between Sb, As and Pb was observed, which could indicate the common material origin of these elements. Lead could have been added as a temperature-lowering flux, helpful in producing bars / rods with a standardized profile, and could have supplemented the shortages in accessing copper (Craddock 1977, 114–115). Products made with high-impurity copper rods should be expected to be quite brittle and porous. However, adding lead lowers the melting-point, increases the pourability of the alloy and allows a better representation of the negative of the casting mould, making it possible to create complex casts. The assumptions about the inten-

lab. no. CL	inv. no	Mn	Fe	Co	Ni	Cu	As	Ag	Sn	Sb	Pb	metal type
20936	5	0.07	0.03	0.00	0.16	91.39	0.84	0.19	0.07	1.68	5.59	CuAsSb AgNiPb
20937	6	0.00	0.13	0.62	0.49	84.22	3.73	0.30	0.08	2.27	8.15	CuAsSb AgNiPb
21110	29.1	0.11	0.03	0.00	0.42	87.53	3.14	0.35	0.11	3.18	5.13	CuAsSb AgNiPb
21111	29.2	0.25	0.05	0.00	0.22	86.32	1.14	0.26	0.28	2.14	9.36	CuAsSb AgNiPb
21112	29.3	0.14	0.02	0.00	0.14	87.29	0.05	0.08	11.85	0.27	0.16	CuSn
21113	29.4	0.07	0.11	0.40	0.46	83.78	3.57	0.34	0.13	2.70	8.45	CuAsSb AgNiPb
21114	29.5	0.13	0.06	0.00	0.14	88.36	0.04	0.06	10.97	0.13	0.12	CuSn
21115	29.6	0.08	0.02	0.00	0.43	86.53	3.45	0.37	0.18	3.11	5.83	CuAsSb AgNiPb
21116	29.7	0.44	0.13	0.00	0.34	86.05	3.42	0.33	0.17	3.15	5.99	CuAsSb AgNiPb
21117	29.8	0.14	0.05	0.00	0.38	87.88	3.59	0.43	0.15	3.07	4.32	CuAsSb AgNiPb
21118	29.9	0.06	0.02	0.04	0.26	88.19	3.24	0.39	0.10	3.01	4.69	CuAsSb AgNiPb
21166	30.1	0.02	0.01	0.07	0.38	87.51	2.84	0.30	0.07	2.64	6.16	CuAsSb AgNiPb
21167	30.2	0.02	0.21	0.09	0.32	83.71	2.65	0.26	0.14	2.59	10.01	CuAsSb AgNiPb
21168	30.3	0.02	0.03	0.04	0.37	87.39	2.90	0.32	0.18	3.37	5.39	CuAsSb AgNiPb
21169	30.4	0.04	0.01	0.04	0.43	86.52	3.32	0.33	0.06	2.76	6.49	CuAsSb AgNiPb
21170	30.5	0.02	0.02	0.07	0.18	90.60	1.05	0.30	0.18	3.46	4.12	CuAsSb AgNiPb
21171	30.6	0.02	0.10	0.07	0.22	88.98	0.77	0.26	0.39	2.32	6.89	CuAsSb AgNiPb
21172	30.7	0.04	0.03	0.08	0.30	87.67	2.45	0.29	0.06	2.73	6.36	CuAsSb AgNiPb
21173	30.8	0.02	0.01	0.04	0.19	87.62	0.84	0.20	0.22	1.87	8.99	CuAsSb AgNiPb
21174	30.9	0.04	0.02	0.08	0.34	86.36	2.64	0.31	0.07	2.93	7.21	CuAsSb AgNiPb
21175	30.10	0.01	0.01	0.03	0.39	77.00	4.08	0.44	0.07	3.74	14.22	CuAsSb AgNiPb
21176	30.11	0.03	0.01	0.06	0.19	87.80	0.83	0.21	0.15	1.81	8.92	CuAsSb AgNiPb
21177	30.12	0.04	0.03	0.06	0.30	84.12	2.96	0.38	0.07	3.19	8.86	CuAsSb AgNiPb
21698	19.4	0.04	0.02	0.00	0.10	87.80	0.18	0.07	10.80	0.29	0.69	CuSn
21699	19.A.1	0.03	0.01	0.00	0.08	96.23	0.36	0.27	0.04	2.70	0.29	CuSb

Tab. 1 A summary of the results of the chemical analyses of raw copper bars from Jodłowno obtained by the Artax X-ray fluorescence spectrometer. Results are given in weight percent (wt%). A »0.00« value means the result is below the detection limit of the method.

lab. no. CL	inv. no	Mn	Fe	Co	Ni	Cu	As	Ag	Sn	Sb	Pb	metal type
21700	19.A.2	0.00	0.04	0.00	0.09	96.98	0.27	0.21	0.07	2.09	0.25	CuSb
21701	19.A.3	0.03	0.02	0.00	0.07	94.76	0.45	0.34	0.06	3.94	0.35	CuSb
21702	16	0.03	0.02	0.02	0.38	86.99	2.60	0.32	0.06	2.71	6.88	CuAsSb AgNiPb
21704	29.10	0.01	0.01	0.09	0.07	89.36	0.18	0.05	9.69	0.21	0.34	CuSn
21705	29.11	0.02	0.02	0.07	0.23	86.61	2.16	0.32	0.08	2.35	8.13	CuAsSb AgNiPb
21706	29.12	0.03	0.01	0.06	0.06	91.05	0.12	0.04	8.17	0.19	0.26	CuSn
21707	29.13	0.06	0.10	0.50	0.37	82.48	3.59	0.35	0.07	2.04	10.44	CuAsSb AgNiPb
21708	29.14	0.04	0.01	0.08	0.24	89.97	2.28	0.33	0.04	1.88	5.13	CuAsSb AgNiPb
21709	29.15	0.01	0.12	0.61	0.37	84.28	3.33	0.34	0.09	2.02	8.83	CuAsSb AgNiPb
21710	29.16	0.03	0.13	0.73	0.38	81.88	3.28	0.36	0.13	2.25	10.83	CuAsSb AgNiPb
21711	29.17	0.05	0.02	0.08	0.37	88.48	2.59	0.32	0.07	2.78	5.23	CuAsSb AgNiPb
21712	29.18	0.01	0.02	0.06	0.33	87.35	2.46	0.33	0.00	2.53	6.90	CuAsSb AgNiPb
21713	29.19	0.04	0.02	0.05	0.31	86.98	2.55	0.36	0.05	2.80	6.84	CuAsSb AgNiPb
21714	29.20	0.02	0.02	0.08	0.22	90.96	4.32	0.46	0.04	3.39	0.48	CuAsSb AgNi
21715	29.21	0.03	0.10	0.11	0.24	80.07	1.50	0.23	0.24	2.45	15.03	CuAsSb AgNiPb
21716	29.22	0.03	0.01	0.07	0.25	88.33	2.74	0.40	0.07	2.59	5.51	CuAsSb AgNiPb
21717	29.23	0.02	0.07	0.09	0.29	85.88	2.19	0.27	0.68	2.86	7.64	CuAsSb AgNiPb
21718	29.24	0.03	0.01	0.08	0.30	86.81	2.91	0.34	0.07	2.32	7.13	CuAsSb AgNiPb
21719	29.25	0.03	0.02	0.07	0.22	84.18	2.64	0.25	0.08	1.91	10.60	CuAsSb AgNiPb
21720	4	0.04	0.02	0.09	0.25	88.84	2.84	0.37	0.08	2.56	4.90	CuAsSb AgNiPb
21721	7	0.02	0.08	0.16	0.22	76.74	1.57	0.17	0.26	1.52	19.27	CuAsSb AgNiPb
21722	8	0.03	0.01	0.08	0.23	89.02	1.95	0.34	0.05	2.17	6.13	CuAsSb AgNiPb
21723	9	0.06	0.01	0.08	0.26	87.97	2.29	0.30	0.07	2.28	6.67	CuAsSb AgNiPb
21724	10	0.02	0.01	0.05	0.29	87.16	2.39	0.30	0.08	2.75	6.95	CuAsSb AgNiPb

Tab. 1 Continued.

tional introduction of lead may be strengthened by the discovery of a single bar (lab. no. CL21714) with a similar profile of chemical impurities CuAsSbAgNi visible in the main group but made without the addition of lead (measurement result 0.48 %). This issue will be the subject of further analytical research supplemented with lead isotope studies.

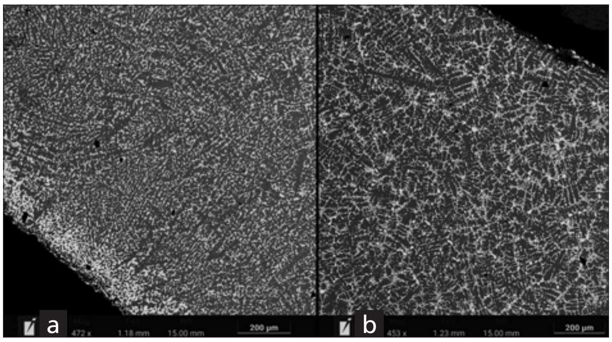

Fig. 5 Dendritic structures registered on one of the ingots (lab. no. CL20937). – (Photo P. Gan).

Another type of metal are three ingots tied together with a piece of string at the time of discovery. Analysis revealed they were made of antimony copper (lab. no. CL21699–21701 – medians of Sb 2.70 %; As 0.36 %; Pb 0.29 %). The likely source of this raw material would be tennantite deposits, different from those visible in the main group. Another explanation is the co-smelting of copper by adding the relatively pure antimony mineral. In any case, the ancient craftsman was aware of the different origins of this type of metal.

The last type of metal identified for five ingots is tin bronze with traces of impurities, mainly sulfur, iron and lead (lab. no. CL21112, 21114, 21698, 21704, 21706). The average tin content is 10.30 %. The chemical characteristics obtained indicate that chalcopyrite ores were the main source of copper for this separate group of ingots.

At this point, it should be emphasized that the observed impurities may be associated not only with various copper ores but also may »pass« into the alloy as a component of intentional alloy additives, such as tin or lead, added to improve the physical, functional or aesthetic properties of the metal. For example, antimony and silver are common components of galena. In addition, the content of impurities in the alloy depends on the level and quantity of the metallurgical processes (Pernicka 2014, 252–254; Garbacz-Klempka / Rzadkosz 2014, 507).

The Internal Microstructure Analysis (SEM-EDS)

A full metallographic analysis was performed on the cut sections from two samples (CL20937 and CL21114; **fig. 4, d. w**). The Neophot2 metallographic microscope and the TESCAN VEGA 4 scanning electron microscope were used to observe the microstructures, in which the electron excitation source is a tungsten cathode with thermoemission.

Our metallographic analyses made it possible to detail the internal microstructure of two types of identified raw material (CuAsSbAgNiPb and CuSn). **Figure 5** shows the dendritic microstructures formed during the slow solidification of the metal in the CL20937 sample. The element distribution mapping (**figs 6–7**) shows their heterogeneity. Visible differences in the size of the crystals located along the lower (**fig. 5, a**) and upper (**fig. 5, b**) edges, as well as near-surface enrichment of the spaces between the dendritic lead in the lower, rounded part of the product, indicate that the bar was cast in an open, unheated cavity form, or molten metal was poured into a gutter-shaped recess in the ground. Those observations correspond with the macroscopic ones, because sprues and shrinkage depressions are visible on the upper surfaces of the objects.

Dendritic microstructures were also documented in the case of sample CL21114 and a second type of raw material (CuSn). Chalcopyrite grains were observed among the uniform dendrite distribution (**fig. 8**). At the same time, there is a tin-saturated layer of varying thickness in the near-surface area, with a share of

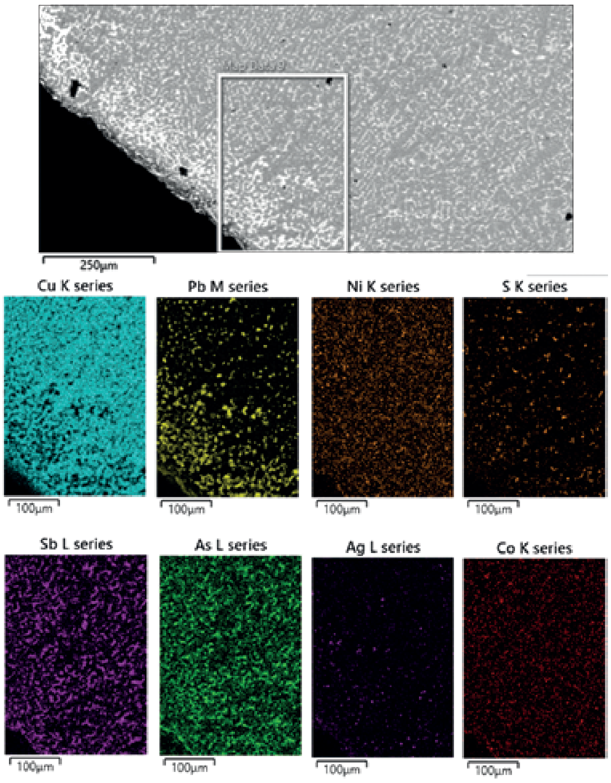

Fig. 6 Mapping of the near-edge dendritic structures of the ingot lab. no. CL20937. A differentiated lead distribution is visible. – (Photo and preparation P. Gan).

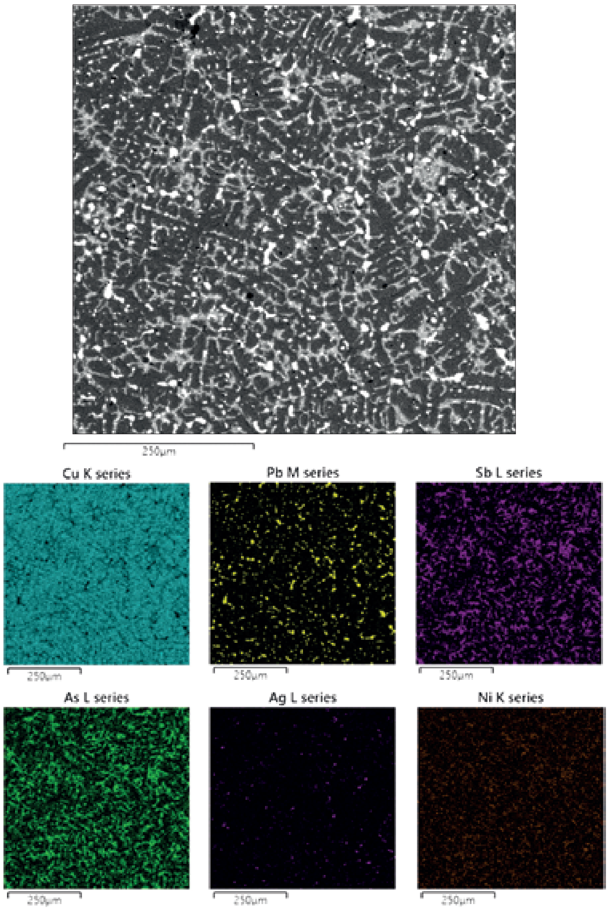

Fig. 7 Mapping of the dendritic structures of the middle part of the ingot lab. no. CL20937. Visible is an even distribution of lead. – (Photo and preparation P. Gan).

tin exceeding 30 % (**fig. 9**, linear measurement). This is probably related to the patination of the product's surface, but it also shows the need for proper preparation and research methodology.

DISCUSSION

In the light of the present state of research, the territory of Poland in the Bronze Age and the Early Iron Age did not possess a basis of copper as a raw material (Nowak et al. 2023) and the metal had to be imported from other areas. Do we have evidence from Poland for the importation and use of high-impurity copper in the Early Iron Age?

One of the closest raw material analogies for most of the bars from Jodłowno examined are the analyses made on two bars/ingots from a deposit (lost during World War II), weighing 27 kg and consisting of about 151 bars from Swarzewo (Kostrzewski 1953, 210; Bukowski 1998, 262; Dzięgielewski 2017, 305). Most likely, the titration method of the quantitative chemical analysis revealed the presence of antimony (3.40 %), arsenic (3.52–3.62 %), lead (5.86–14.12 %), nickel and silver (Kossina 1919, 166). It should be assumed that among the remaining hoards of raw material from the Early Iron Age found along the shores of the Baltic Sea, there will be bars/rods with a similar raw material profile. However, the number of such deposits has so far been relatively small. The significant and well-dated finds include the Słupsk deposit of over

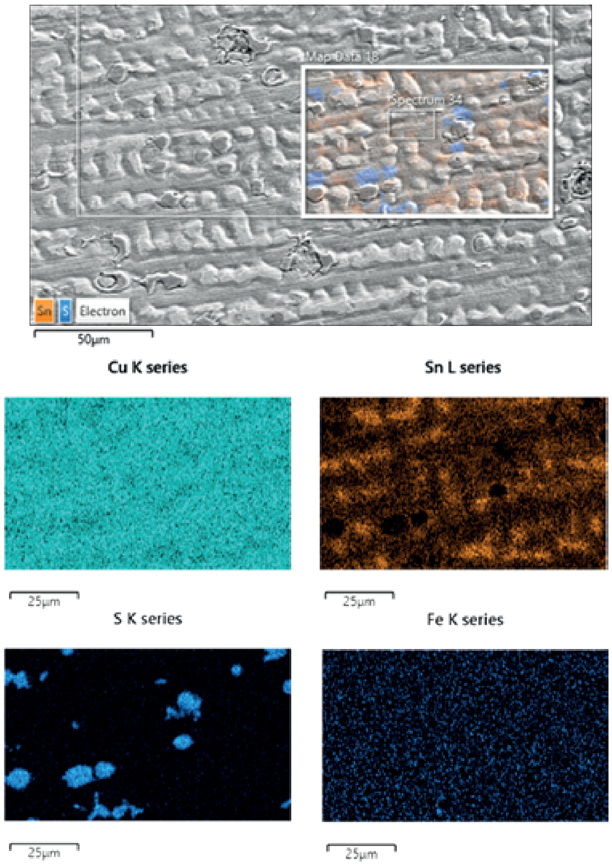

Fig. 8 Mapping of the dendritic structures of the ingot lab. no. CL2114. There is a visible lack of lead grains. – (Photo P. Gan).

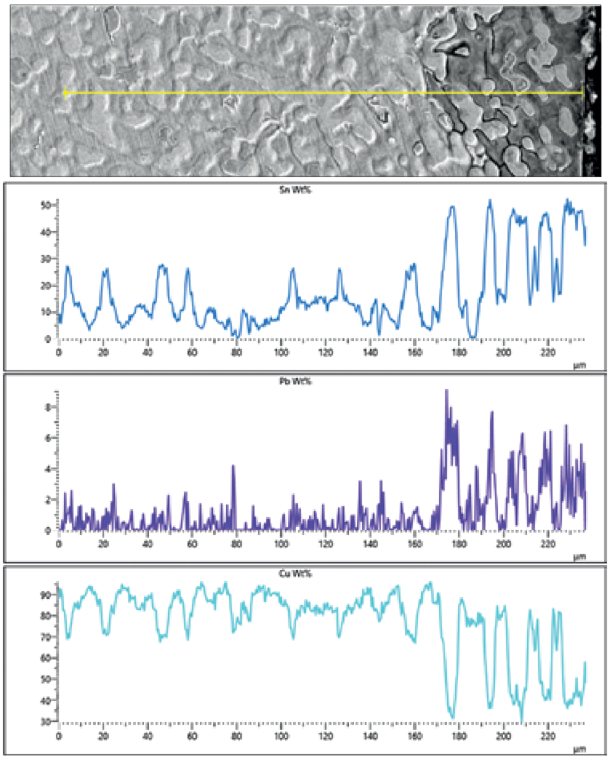

Fig. 9 Dendritic structures of the ingot lab. no. CL21114. – (Photo and preparation P. Gan).

100 bars (Dzięgielewski 2017, 305) and single finds of bars from Dargoleza (pow. słupski/PL) and Pękanino (pow. sławieński/PL) (Bukowski 1998, 262–263). Plano-convex ingots (cast cakes; bun ingots) and metal lumps of various shapes are more common but most likely made of almost pure copper, as in the case of the deposit from Swarożyn/Szpęgawsk (pow. tczewski/pow.starogardzki/PL; Kostrzewski 1953, 211). This group also includes similar discoveries from Gwiazdowo (pow. sławieński/PL), Polchówko (pow. pucki/PL) and Witkowo (Kostrzewski 1953, 210–211; Bukowski 1998, 262–264, La Baume 1931, 126–129). On the other hand, finds of bars/ingots made of tin bronze in Pomerania, similar to those from Jodłowno, are practically non-existent (Dzięgielewski 2017, 305). A few hoards containing such tin bronze ingots based on analyses performed in the 1970s were found in Wielkopolska in Łuszków (pow. kościański/PL), Słupy Duże (pow. aleksandrowski/PL) and Wacławów (pow. słupski/PL) (Dymaczewski 1961, 38–41. 55–61. 64–65)[2], as well as in Silesia in Bieszków and Wicina (both pow. żarski/PL) (Orlicka-Jasnoch 2013; Kucypera/Rybka 2013, tab. 1). Such metal could be widely distributed due to its very good functional properties and ease of production by smelting scrap metal. It is a universal raw material suitable for casting (approximate mould pouring temperature is about 1000 °C) and forming decorative features (Hensel 1996, 151–152).

The next research step and an extremely interesting issue will be the correlation of the results obtained for the ingots with the chemical analyses of the other artifacts from the hoard. At least some of them could have been cast using the above material or could have been forged (semi-finished blades). Using such raw material is indirectly indicated by the finds of two hollow ankle rings from the Gdynia-Karwiny hoard found nearby (Dzięgielewski et al. 2019, 32 tab. without no.). Both artifacts were made from a raw material with a high content of lead (4.27–7.05 %), antimony (about 3.80 %), arsenic (1.9 %), silver (1.5 %), nickel (0.6 %) and very little tin (about 0.58–0.92 %). Analyses of several of the over 250 hollow ankle rings deposited on the southern coast of the Baltic Sea, carried out in the 1970s using the spectrographic method in the Institute of Archaeology and Ethnology of the Polish Academy of Sciences Laboratory, show that a similar chemical composition of the casting alloy was also present in the artifacts from the collection of the National Museum in Szczecin from Żelisławiec (pow. gryfiński / PL; lab. no. CL2746: Sb 2.2 %, As 3 %, Pb 1.4 %, Ag 1.8 %, Ni 1 %, Sn 0.39 %) and Mosina (pow. szczecinecki / PL; lab. no. CL3653: Sb 2.5 %, As 1.85 %, Pb 2.1 %, Ag 1.38 %, Ni 1.42 %, Sn 0.27 %). The same raw material profile but with a smaller share of lead and other impurities, suggesting an increased number of metallurgical activities (raw material refinement), are characteristic of the hollow ankle rings from the collection of the Museum in Koszalin from Pieszcz (pow. sławieński / PL; lab. no. CL1976: Sb 0.94 %, As 1.98 %, Pb 0.51 %, Ag 1.42 %, Ni 0.82 %, Sn 0.15 %; lab. no. CL1977: Sb 0.88 %, As 1.2 %, Pb 0.43 %, Ag 1.21 %, Ni 0.70 %, Sn 0.43 %) and Trąbki Wielkie (pow. gdański / PL; lab. no. CL4010: Sb 1.72 %, As 1.90 %, Pb 0.88 %, Ag 0.78 %, Ni 1.22 %, Sn 0.46 %) from the collection of the Archaeological Museum in Gdańsk. Nevertheless, some hollow ankle rings were made of tin-lead bronze, such as the ones from Redostowo (pow. goleniowski / PL; lab. no. CL2873: Sb 0.21 %, As 0.25 %, Pb 1.12 %, Ag 0.19 %, Ni 0.17 %, Sn 5.1 %) and from Gozd-Wybudowanie (pow. koszaliński / PL; lab. no. CL1654: Sb 0.43 %, As 0.70 %, Pb 1.45 %, Ag 0.03 %, Ni 0.15 %, Sn 4.6 %), or metal combining both types of raw material identified in a ring from Stęszyce (pow. kołobrzeski / PL; lab. no. CL3720: Sb 1.45 %, As 1.65 %, Pb 1.48 %, Ag 1.52 %, Ni 1.41 %, Sn 4.20 %). The use of this type of raw material could be possible in the case of bow-shaped necklaces. The chemical profile of the object from Podwilczyn (pow. słupski / PL; lab. no. CL3628) corresponds to the impure copper bars / ingots discussed above. All the aforementioned objects are in the collection of the National Museum in Szczecin. On the other hand, the one from Gniewino (pow. wejcherowski / PL; lab. no. CL4006) from the collection of the Archaeological Museum in Gdańsk was made by mixing tin bronze with 10 % Sn content with heavily impure lead-free copper.

CONCLUSION

Based on the above finds, it is clear that the raw material identified in Jodłowno was widely used in the Early Iron Age. Analyses of other artifacts with equivalents in the hoard not only repeat the raw material profile of the bars / ingots from Jodłowno and Swarzewo but also show their gradual refining and mixing of two types of metal. Our research on the elemental composition of the bars / ingots indicates the probable origin of the metal used in their production. The presence of characteristic impurities (As, Sb, Ni, Ag) may indicate two main areas related to the prehistoric exploitation of copper ore deposits – the Western Carpathian and the Eastern Alpine regions. Our results fit the research on objects from the Eastern Baltic Region and Scandinavia, where the presence of metal from fahlore and chalcopyrite ores was confirmed (e. g. Ling et al. 2019; Thrane / Juottijärvi 2020; Nørgaard et al. 2021; Čivilytė et al. 2023). However, a large amount of lead indicates the intentional addition of this alloying element. The presence of lead points out that material from another unspecified mining area was also used. It indicates developed circum-Baltic contacts and the participation of the Baltic area communities in the interregional exchange network.

While not prejudging the origin of the raw material without comparison with the provenience analysis using stable lead isotopes, we can initially agree with the western and / or south-western direction of the metal inflow. In this context, information about finding axes made in the Lower Saxony style, which were thought to accompany the aforementioned hoard of bars from Słupsk, should be recalled. However, the results of the chemical analyses of the deposit from Słupsk are unknown (Dziegielewski et al. 2019, 33). There are also Early Iron Age hoards containing bars and hollow ankle rings from central Germany (Hoffmann 1959). In addition, it is worth mentioning a hollow ankle ring from the hoard from Środa Wielkopolska (pow. śremski / PL) from the collection of the Archaeological Museum in Poznań (Dymaczewski 1961, 63), which both typologically and in terms of elemental composition corresponds to the objects in question (lab. no. CL5518: Sb 1.25 %, As 2.3 %, Pb 2 %, Ag 1.05 %, Ni 1.1 %, Sn 1.4 %) and may indicate the circulation of the metal, as well the possibility of the mobility of the metalsmiths, which produced specific sets of high-quality items.

All the above remarks make the discovery of the hoard from Jodłowno an interesting and extremely important contribution to our expanding knowledge about the circulation of metal in northern Poland in the Early Iron Age.

Acknowledgments

We thank Ms Monika Kwiatkowska and the Provincial Office for the Protection of Cultural Property in Gdańsk for making the artifacts available for analysis and for the partial financing of the research. This work received financial support from the National Science Centre, Poland (project no.: 2021/40/C/HS3/00097). Research is also part of the activities of the research group »Centre of Applied Archaeology«, University Centre of Excellence, Nicolaus Copernicus University in Toruń.

Notes

1) See, e. g. Pluckow (Lkr. Vorpommern-Rügen / DE); Gdynia-Karwiny site 1, Pomerania; Petzsch 1933, 11; Dzięgielewski et al. 2019, 69.

2) Unpublished reports from the Institute of Archaeology and Ethnology Laboratory database: numbers of chemical analyses CL6064–68, 6154–55, 6157–61, 6163–64, 9471–74.

References

Bucka 2015: K. Bucka, Dobrzany, miasto, okolice, gm. loco, pow. stargardzki, stan. nieokreślone. Stargardia 10, 2015, 467.

Bukowski 1998: Z. Bukowski, Pomorze w epoce brązu w świetle dalekosiężnych kontaktów wymiennych. Ser. Monogr. 104 (Gdańsk 1998).

Craddock 1977: P. T. Craddock, The Composition of the Copper Alloys Used by the Greek, Etruscan and Roman Civilisations. Journal Arch. Scien. 3, 1977, 103–123.

Čivilytė et al. 2023: A. Čivilytė / V. Podėnas / K. Minkevičius / H. Luik, New Insights on Bronze Age Metallurgy in the Eastern Baltic Region: Archeometallurgical Investigations Based on EDXRF and Lead-Isotope. Arch. & Anthr.: Open Access 4(4), 2023, 000608. DOI: 10.31031/AAOA.2023.04.000608.

Dymaczewski 1961: D. Dymaczewski, Skarby halsztackie z Wielkopolski. Przegląd Arch. 13, 1961, 7–109.

Dzięgielewski 2017: K. Dzięgielewski, Late Bronze and Early Iron Age Communities in the Northern Part of the Polish Lowland (1000–500 BC). In: U. Bugaj (ed.), The Past Societies. Polish Lands from the First Evidence of Human Presence to the Early Middle Ages. 3: 2000–500 BC (Warszawa 2017) 295–340.

Dzięgielewski et al. 2019: K. Dzięgielewski / A. Longa / J. Langer / M. Moskal-del Hoyo, Contextualisation of the Early Iron Age Hoard of Bronze Objects Discovered in Gdynia-Karwiny, Site 1. Rech. Arch. 10, 2018, 21–78. DOI: 10.33547/RechACrac.NS10.02.

Fudziński et al. 2009: M. Fudziński / Z. Ratajczyk / A. Ostasz / P. Fudziński, Nowe materiały kultury łużyckiej i pomorskiej z badań na obwodnicy słupskiej. In: M. Fudziński / H. Paner / S. Czopek (eds), Nowe materiały kultury łużyckiej i pomorskiej z Pomorza (Gdańsk 2009) 187–196.

Fudziński / Fudziński 2010: P. Fudziński / M. Fudziński, Skarb przedmiotów brązowych z Redy-Rekowa stanowisko nr 19. Pomorania Ant. 23, 2010, 209–214.

Fudziński / Ślusarska 2017: P. Fudziński / K. Ślusarska, Ośrodek starożytnego brązownictwa pomorskiego we wczesnej epoce żelaza w Juszkowie, gmina Pruszcz Gdański (Gdańsk 2017).

Garbacz-Klempka / Rzadkosz 2014: A. Garbacz-Klempka / S. Rzadkosz, Charakterystyka składu chemicznego i struktury zabytków metalowych z osady kultury łużyckiej w Grzybianach. In: T. Stolarczyk / J. Baron (eds), Osada kultury pól popielnicowych w Grzybianach koło Legnicy (Legnica, Wrocław 2014) 507–538.

Harding et al. 2004: A. Harding / J. Ostoja-Zagórski / C. Palmer / J. Rackham, Sobiejuchy: A Fortified Site of the Early Iron Age in Poland. Polskie Badania Arch. 35 (Warszawa 2004).

Hensel 1996: Z. Hensel, Metalurgia brązu pradziejowych społeczeństw Kujaw (Poznań 1996).

Heynowski 2006: R. Heynowski, Randbemerkungen zum Hortfund von »Schlöben«. In: W.-R. Teegen / R. Cordie / O. Dörrer / S. Rieckhoff / H. Steuer (eds), Studien zur Lebenswelt der Eisenzeit. Festschrift für Rosemarie Müller. Ergbd. RGA 53 (Berlin, New York 2006) 49–68.

Hoffmann 2000: M. J. Hoffmann, Kultura i osadnictwo południowowschodniej strefy nadbałtyckiej w I tysiącleciu p. n. e. (Olsztyn 2000).

Hoffmann 1959: W. Hoffmann, Ein Bronzefund aus der jüngsten Bronzezeit aus Calbe, Kr. Schönebeck. Jahresschr. Mitteldt. Vorgesch. 43, 1959, 222–227.

Höppner et al. 2005: B. Höppner / M. Bartelheim / M. Huijsmans / R. Krauss / K. P Martinek / E. Pernicka / R. Schwab, Prehistoric Copper Production in the Inn Valley (Austria), and the Earliest Copper in Central Europe. Archaeometry 47, 2005, 293–315.

Jensen 1997: J. Jensen, Fra Bronze- til Jernalder en kronologisk undersøgelse. Nordiske Fortidsminder 15 Ser. B (København 1997).

Kossinna 1919: G. Kossina, Meine Reise nach West- und Ostpreußen und meine Berufung zu Generalfeldmarschall von Hindenburg im August 1915. Mannus 9, 1919, 119–195.

Kostrzewski 1953: J. Kostrzewski, Wytwórczość metalurgiczna w Polsce od neolitu do wczesnego okresu żelaznego. Przegląd Arch. 9, 1953, 177–211.

Kucypera / Rybka 2013: P. Kucypera / K. Rybka, Analiza składu chemicznego przedmiotów zabytkowych z Bieszkowa i z Wiciny. In: A. Jaszewska / S. Kałagate (eds), Wicina. Badania archeologiczne w latach 2008–2012 oraz skarb przedmiotów pochodzących z Wiciny. Bibl. Arch. Środkowego Nadodrza 7 (Zielona Góra 2013) 547–558.

La Baume 1931: W. La Baume, Zur Kenntnis der Metall-Technik in der Bronzezeit und älteren Eisenzeit. In: 50 Jahre Museum für Naturkunde und Vorgeschichte (Westpreußisches Provinzial-Museum) in Danzig 1880–1930 (Danzig 1930) 123–151.

Ling et al. 2019: J. Ling / E. Hjarthner-Holdar / L. Grandin / Z. Stos-Gale / K. Kristiansen / A. L. Melheim / G. Artioli / I. Angelini / R. Krause / C. Canovaro, Moving Metals IV: Swords, Metal Sources and Trade Networks in Bronze Age Europe. Journal Arch Scien.: Reports 26, 2019, 101837. DOI: 10.1016/j.jasrep.2019.05.002.

Lutz / Pernicka 2013: J. Lutz / E. Pernicka, Prehistoric Copper from the Eastern Alps. Open Journal Archaeometry 1, 2013, 122–127.

Lutz / Schwab 2014: J. Lutz / R. Schwab, The Early Iron Age Hoard from Fliess in Tyrol and Ore Resources in the Eastern Alps. In: E. Pernicka / R. Schwab (eds), Under the Volcano. Proceedings of the International Symposium on the Metallurgy of the European Iron Age (SMEIA) Held in Mannheim, Germany, 20–22 April 2010. Forsch. Archäometrie u. Altwiss. 5 (Rahden / Westf. 2014) 25–34.

Łuka 1966: L. J. Łuka, Kultura wschodniopomorska na Pomorzu Gdańskim (Gdańsk 1966).

Nowak et al. 2023: K. Nowak / T. Stolarczyk / Z. Stos-Gale / J. Baron / K. Derkowska / P. Derkowski / B. Miazga / J. Woodhead / J. Karasiński / R. Maas, Question of Local Exploitation of Copper Ore Deposits in the Urnfield Time in Poland. Frontiers Earth Scien. 11, 2023, 1184949. DOI: 10.3389/feart.2023.1184949.

Nørgaard et al. 2021: H. W. Nørgaard / E. Pernicka / H. Vandkilde, Shifting Networks and Mixing Metals: Changing Metal Trade Routes to Scandinavia Correlate with Neolithic and Bronze Age Transformations. PLoS ONE 16(6), 2021, e0252376. DOI: 10.1371/journal.pone.0252376.

Orlicka-Jasnoch 2013: J. Orlicka-Jasnoch, Skarb przedmiotów brązowych i żelaznych z Bieszkowa, gm. Jasień. In: AA. Jaszewska / S. Kałagate (eds), Wicina. Badania archeologiczne w latach 2008–2012 oraz skarb przedmiotów pochodzących z Wiciny. Bibl. Arch. Środkowego Nadodrza 7 (Zielona Góra 2013) 491–537.

Pernicka 2014: E. Pernicka, Provenance Determination of Archaeological Metal Objects. In: B. Roberts / C. Thornton (eds), Archaeometallurgy in Global Perspective (New York 2014) 239–268.

Pernicka et al. 2016: E. Pernicka / J. Lutz / Th. Stöllner, Bronze Age Copper Produced at Mitterberg, Austria, and Its Distribution. Arch. Austriaca 100, 2016, 19–55.

Petzsch 1933: W. Petzsch, Ein Depotfund der VI. Periode der Bronzezeit von Pluckow (Jasmund). In: W. Petsch (ed.), Der Depotfund von Pluckow (Rügen) und andere bronzezeitliche Funde aus Vorpommern. Schr. Ges. Freunde u. Förderer Univ. Greifswald. Mitt. Slg. Vorgesch. Alt. Univ. Greifswald H. 6 (Greifswald 1933) 9–32.

Schacht 1982: S. Schacht, Die Nordischen Hohlwulste der frühen Eisenzeit. Wiss. Beitr. Martin-Luther-Univ. Halle-Wittenberg 18 (Halle [Saale] 1982).

Scheltjens et al. 2013: S. Scheltjens / G. Bervoets / S. Hertoghs / S. Delaruelle, Bewoning uit de late bronstijd en de vroege ijzertijd aan de Beekakkers in Beerse. ADAK Rapport 47 (Antwerpen 2013).

Schmidt 2014: J.-P. Schmidt, Der spätbronzezeitliche Hortfund von Stolpe auf Usedom, Lkr. Vorpommern-Greifswald. Bodendenkmalpfl. Mecklenburg-Vorpommern 62, 2014, 27–80.

Schopper / Brather 2019: F. Schopper / S. Brather, Wuchtige Pracht. Neue Hohlwulstringe aus Ragow, Lkr. Dahme-Spreewald. Arch. Berlin u. Brandenburg 2019, 66–70.

Sprockhoff 1941: E. Sprockhoff, Niedersachsens Bedeutung für die Bronzezeit Westeuropas. Zur Verankerung einer neuen Kulturprovinz. Ber. RGK 31(2), 1941, 1–138.

Thrane / Juottijärvi 2020: H. Thrane / A. Juottijärvi, A New Bronze Age Hoard from Mariesminde at Langeskov on Funen, Denmark. Acta Arch. 91(2), 2020, 11–45. DOI: 10.1111/j.1600-0390.2020.12226.x.

Waluś 1979: A. Waluś, Wytwórczość metalurgiczna kultury pomorskiej a kultury kurhanów zachodniobałtyjskich. In: T. Malinowski (ed.), Problemy Kultury Pomorskiej. Muzeum Okręgowe w Koszalinie (Koszalin 1979) 219–227.

Wiącek 1974: B. Wiącek, Odkrycie dłubanki z wczesnej epoki żelaza na stanowisku produkcyjnym w Luzinie, pow. Wejherowo. Pomorania Ant. 5, 1974, 253–274.

Zusammenfassung / Summary / Résumé

Der früheisenzeitliche Hort aus Jodłowno (pow. Gdański/PL), Nordpolen. Technologische Untersuchung der metallischen Rohmaterialien

Dieser Artikel befasst sich mit archäologischen Objekten aus dem Hortfund von Jodłowno in Nordpolen, die mit dem Metalldetektor entdeckt wurden. Einige der Artefakte wurden *in situ* belassen; daher ist die Anordnung der meisten Objekte bekannt. Der Hortfund wird in die frühe Eisenzeit datiert, wahrscheinlich in Ha D (ca. 650/600–500/450 v. Chr.). Der größte Teil des Inventars besteht aus Barrenfragmenten. Jeder der 49 Barren wurde auf seine chemische Zusammensetzung hin untersucht. Es wurden vier Rohstoffgruppen unterschieden, wobei Kupfer mit einem hohen Anteil an Verunreinigungen die größte darstellte. Auch Blei war ein wichtiger Zusatz. Die erzielten Ergebnisse bereichern unsere Kenntnisse über die Rohstoffe in Nordpolen, Pommern, Großpolen und Schlesien in solchen Objektkategorien wie Barren, Hohlwulstringen und bogenförmigen Halsringen.

The Early Iron Age Hoard from Jodłowno (pow. Gdański), Northern Poland. Technological Study of the Metal Raw Materials

This article deals with archaeological objects from the Jodłowno deposit in northern Poland. They were discovered using a metal detector. Some of the artifacts were left *in situ*; therefore, the arrangement of most objects is known. The assemblage dates to the Early Iron Age, probably Ha D (ca. 650/600–500/450 BC). The largest part of the inventory comprises the bar/ingot fragments. Each of the 49 ingots has been tested for its chemical composition. Four groups of raw materials were distinguished, whereby copper with a large amount of impurities was the largest. Lead was also an important addition. The results obtained enrich our knowledge of raw materials in northern Poland, Pomerania, Wielkopolska and Silesia in such categories of objects as ingots, hollow ankle rings and bow-shaped necklaces.

Le dépôt de Jodłowno (pow. Gdański) du premier âge du Fer. Examen technologique du métal brut

Cet article traite d’objects archéologigues du dépôt de Jodłowno dans le Nord de la Pologne. Ils ont été découverts à l’aide d’un détecteur de métaux. Certains des artefacts étant encore *in situ*, on connaît ainsi la disposition de la plupart des objets de ce dépôt. La découverte est datée du premier âge du Fer, très probablement Ha D (environ 650/600–500/450 av. J.-C.). Les fragments de lingots constituent la plus grande catégorie de cet inventaire. L’analyse de la composition chimique des 49 lingots a permis d’isoler quatre groupes de matières premières. Le cuivre avec une grande quantité d’impuretés domine. Le plomb était également un ajout important. Les résultats obtenus enrichissent notre connaissance des matières premières pour des objets tels que les lingots, anneaux creux et torques aux extrémités repliées dans le Nord de la Pologne, en Poméranie, Grande Pologne et Silésie.

Traduction: Y. Gautier

Schlüsselwörter / Keywords / Mots-clés

Frühe Eisenzeit / Metallhort / Rohstoff / Spurenelemente / Mikrostruktur / Produktionstechnologie
Early Iron Age / metal hoard / raw material / trace elements / microstructure / technology of production
Premier âge du Fer / dépôt de métal / matière première / oligo-éléments / microstructure / technologie de production

Kamil Nowak
Nicolaus Copernicus University in Toruń
Institute of Archaeology
Faculty of History
Centre of Applied Archaeology
Szosa Bydgoska 44/48
PL - 87-100 Toruń
kamil.nowak@umk.pl
ORCID: 0000-0002-8137-0059

Paweł Gan
Polish Academy of Sciences
Institute of Archaeology and Ethnology
Bio- and Archaeometric Laboratory
Długa 24/26
PL - 00-950 Warszawa
pawel.gan@gmail.com
ORCID: 0000-0002-1679-0989