Abhandlung

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Local and non-local metal supply strategies in the Early Iron Age. Case study: the Wicina fortified settlement and the Bieszków hoard, western Poland

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Zusammenfassung: In der frühen Eisenzeit (750–450 v. Chr.) entstanden in Westpolen Siedlungszentren, die eine wichtige sozioökonomische Rolle in der lokalen Entwicklung spielten. Die befestigte Siedlung von Wicina (Powiat Żary, Woiwodschaft Lubuskie) in Westpolen, strategisch günstig auf einer natürlichen Düne über einem Sumpfgebiet gelegen, stellt ein solches Regionalzentrum dar.

In der vorliegenden Arbeit wird die Rolle dieses Siedlungsplatzes im überregionalen Metallaustauschnetzwerk mit Hilfe archäometallurgischer Analysen untersucht. Die Ergebnisse werden mit Artefakten verglichen, die wahrscheinlich aus der Siedlung von Wicina stammen und im nahe gelegenen Hortfund von Bieszków gefunden wurden. Die Ergebnisse der Isotopenanalysen deuten darauf hin, dass das Kupfer in den für die Untersuchung ausgewählten Artefakten (N=15) aus mehreren Quellen stammte. Der größte Teil des Metalls stammt aus dem Mittelmeerraum – von Sardinien, der südwestlichen Iberischen Halbinsel und Zypern. Eine einzelne Probe stammt aus alpinen oder slowakischen Kupfererzlagerstätten. Ein großes Fragment reinen Kupfers scheint auch aus lokalen Lagerstätten im Heiligkreuzgebirge in Südpolen zu stammen. Dies ist das erste Ergebnis, das darauf hinweist, dass Kupfer in der frühen Eisenzeit lokal in Polen gewonnen worden sein könnte.

Unsere Hypothese ist, dass das Kupfer entlang etablierter Handelsrouten (einschließlich der so genannten Bernsteinstraße) nach Westpolen gelangte und von dort aus weiter verteilt wurde. Ein kleiner Teil des in den Werkstätten von Wicina verwendeten Kupfers wurde durch lokale Kupfergewinnung im Heiligkreuzgebirge ergänzt.

Die Teilnahme am Fernhandel, die Kontrolle über einen Teil der Handelsroute und der Zugang zu den Gütern und deren mögliche Umverteilung beeinflussten die Entwicklung der Siedlung.

Schlüsselworte: Frühe Eisenzeit, Siedlungskomplex, archäometallurgische Analyse, Provenienzforschung, Strategien der Metallversorgung, archäologische Landschaft, günstige Lage, Fernhandel

Abstract: During the Early Iron Age (750–450 BC), settlement centres emerged in western Poland, playing a significant socio-economic role in local development. The fortified settlement of Wicina (Żary County, Lubusz Voivodeship) in western Poland, is an exemplar of such a regional center, strategically positioned on a natural dune above a marshland.

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In this study, we use archaeometallurgical analyses to shed light on the role of this settlement in the supra-regional metal exchange network. We compare the results with artifacts likely from the Wicina settlement found in the nearby Bieszków hoard.

The results of isotopic analyses indicate that the copper in the artifacts selected for study (n=15) originated from multiple sources. The majority of the metal came from the Mediterranean region – Sardinia, the southwestern Iberian Peninsula, and Cyprus. A single sample comes from Alpine or Slovak copper ore deposits. A large fragment of pure copper appears to have come from local deposits in the Holy Cross Mountains in southern Poland. This is the first result indicating that copper may have been mined locally in Poland during the Early Iron Age.

Our hypothesis is that copper reached western Poland along established trade routes (including the so-called Amber Route) and was then distributed further. A small portion of the total copper used in the workshops in Wicina was supplemented by local copper mining in the Holy Cross Mountains.

Control of a portion of the trade route, involvement in long-distance trade, access to goods, and its possible redistribution influenced the settlement's development.

Keywords: Early Iron Age, settlement complex, archaeometallurgical analysis, provenience studies, metal supply strategies, archaeological landscape, advantageous location, long-distance exchange

Streszczenie: We wczesnej epoce żelaza (750–450 p.n.e.) w zachodniej Polsce powstały ośrodki osadnicze, odgrywające znaczącą rolę społeczno-ekonomiczną w lokalnym rozwoju. Osada obronna w Wicinie (powiat żarski, województwo lubuskie) w zachodniej Polsce, strategicznie położona na naturalnej wydmie nad bagnami, stanowi jedno z takich regionalnych centrów.

W naszych badaniach wykorzystujemy analizy archeometalurgiczne, aby rzucić światło na rolę tej osady w ponadregionalnej sieci wymiany metali. Porównujemy wyniki z artefaktami prawdopodobnie pochodzącymi z osady w Wicinie odkrytymi w nieodległym skarbie z Bieszkowa.

Wyniki analiz izotopowych wskazują, że miedź w zabytkach wybranych do badania (n=15) pochodziła z wielu źródeł. Większość metalu pochodziła z regionu śródziemnomorskiego – Sardynii, południowo-zachodniego Półwyspu Iberyjskiego i Cypru. Pojedyncza próbka pochodzi z alpejskich lub słowackich złóż rudy miedzi. Duży fragment czystej miedzi wydaje się pochodzić z lokalnych złóż w Górach Świętokrzyskich w południowej Polsce. To pierwszy wynik wskazujący, że miedź mogła być wydobywana lokalnie w Polsce w okresie wczesnej epoki żelaza.

Nasza hipoteza zakłada, że miedź dotarła do zachodniej Polski ustalonymi szlakami handlowymi (włączając tzw. Szlak Bursztynowy), a następnie była dalej dystrybuowana. Niewielka część ogólnej ilości miedzi wykorzystywanej w warsztatach w Wicinie była uzupełniana przez lokalne wydobycie miedzi w Górach Świętokrzyskich. Kontrola nad częścią szlaku handlowego, udział w handlu dalekosiężnym, dostęp do towarów i ich ewentualna redystrybucja wpłynęły na rozwój osady.

Słowa kluczowe: wczesna epoka żelaza, kompleks osadniczy, analiza archeometalurgiczna, badania prowenienencji, strategie dostaw metalu, krajobraz archeologiczny, korzystna lokalizacja, wymiana na duże odległości

1 Introduction and the state of research

Comparative studies and mapping similar groups of archaeological objects have been fundamental methods in archaeology from its early days. The concentration of finds of similar style is typically evidence of local production, referring to regional styles and techniques. This is not necessarily based on locally accessible raw materials. When found outside their native regions, these objects, depending on their style, functions, or complexity, have been interpreted as personal items carried by the users. They are also seen as imports, indicating exchange-based contacts of various ranges and characters[1].

The distribution of selected raw materials has been studied to draw possible exchange directions and its intensity. Non-ferrous metal ores, amber, salt, obsidian, graphite, or ivory, to mention a few, have been found far from their sources. During the Bronze and Early Iron Ages, the circulation of these materials has been seen as evidence of well-organized exchange controlled by both paramount and minor chiefs of highly stratified societies[2]. While previous research has focused on long-distance trade connections between Mediterranean civilizations and central proto-states[3], we argue that interconnectedness may have also been practiced at sites beyond large civilization centers of the Early Iron Age.

In the Late Bronze Age and Early Iron Age (ca. 1300–750 BC and 750–450 BC), the Lusatian Urnfield Cultures, also named Lusatian or Lausitz Culture (hereinafter referred to

1 Pydyn 1999.
2 Gosden 2018.
3 Ibid.

as LUC) developed in the vast area of Central Europe, stretching from eastern Germany to western Ukraine and from the Baltic to the northern parts of the Czech Republic and Slovakia[4]. This culture was characterized by a cremation burial tradition typical of this prehistoric period across almost the entire territory of Europe. The local metal workers in their workshops produced a specific inventory of artifacts, including, for instance, socketed axes and knobbed sickles of a "Lusatian type"[5]. Additionally, there are numerous known imports, which suggests extensive exchange contacts.

In research on the origin of copper, the analysis of stable lead isotopes has been successfully used for many years[6]. This method is most often used for older periods, from the Neolithic to the end of the Bronze Age[7], but the comparative database for the Early Iron Age is relatively modest[8]. The question of the origin of copper in the territory of Poland in prehistory is still not well-researched compared to other parts of Europe. Based on the limited study to date[9], we can conclude that there has been a shift in the direction of metal inflow to the LUC area in its southwestern, highly developed part. The nearby sources of metal inflow– Alpine and Slovak– were replaced mainly by copper from more distant regions such as Iberia or Sardinia. This change requires further detailed exploration.

Our research is focused on gaining a better understanding of the involvement of LUC people in long-distance trade during the Early Iron Age. Based on a limited number of metal samples (n=15), our case study will examine the source of metal found at a remarkable Early Iron Age site in Wicina, located in western Poland. This site is unique due to its location and the wide variety of artifacts made from different materials that have been discovered there. We will also investigate the metal, likely from the Wicina settlement, which was found in the nearby Bieszków hoard. Considering the abundance of artifacts and hoards in the vicinity of the Wicina settlement[10], we believe that Wicina thrived during the Early Iron Age as a center of trade, and a possible trade hub, supplying metal artifacts and possibly ideas to neighboring regions and participating in long-distance networks. Using landscape archaeology analyses, we will determine whether the location of Wicina was advantageous and how this could have influenced its development.

To conclude, our study aims to determine the direction of copper inflow into the western LUC areas to the Wicina settlement and Bieszków hoard in the Early Iron Age. We will also investigate whether the development of western LUC societies, represented by Wicina, depended only on favorable access to trade routes and participation in the exchange or whether access to local raw materials was also possible.

2 The potential sources of copper and lead utilized in Europe during the 1st millennium BC

In the early 2nd millennium BC, copper metallurgy in Europe expanded across the continent, and the alloy of copper and tin – bronze – became the most sought-after metal for making tools and weapons[11]. During the 2nd millennium BC, copper and tin mining developed in different regions of Europe (Fig. 1). In the eastern Mediterranean, copper was mined in Cyprus and traded in the shape of oxhide ingots as far as Sardinia in the west[12]. The societies of the Bronze Age Aegean relied partly on copper from Cyprus, but mainly on copper, lead and silver from its own resources in Lavrion and the Cyclades[13]. In central Europe important copper mines were active in the Slovak ore Mountains[14] and in the Austrian Alps[15]. Copper and tin mining was a very important industry in the British Isles in the Late Bronze Age[16]. In the Cevennes and Montaigne Noir parts of the Massif Central in south-west France there are copper and lead-silver ores that might have been exploited in the Bronze and Iron Ages, but no strong evidence has been published as yet for such activity. In the Italian Alps an intensive copper mining produced throughout the Late 2nd millennium BC very high purity copper used for swords across Europe[17]. Sardinia played also an important role in the Bronze Age trade in copper; partly by producing this metal from the locally occurring ores, and partly by acting as a trade hub[18]. However, the largest multimetallic deposits in Europe are

4 Coles/Harding 1979; Probst 1996; Czebreszuk 2013; Kaczmarek 2017.
5 Gedl 1995; 2004; Kuśnierz 1998.
6 Radivojević *et al.* 2018.
7 Niederschlag *et al.* 2003; Ling *et al.* 2014; 2019; 2023; Kowalski *et al.* 2019; 2024; Nørgaard *et al.* 2019, 2021; Mödlinger/Trebsche 2020; Gavranović *et al.* 2022.
8 Melheim *et al.* 2018a; Thrane/Jouttijärvi 2020; Nowak *et al.* 2023a; Gavranović *et al.* 2025.
9 Nowak *et al.* 2023a; 2023b.
10 Maciejewski 2019a.
11 Earle *et al.* 2015.
12 Stos-Gale *et al.* 1997; Stos-Gale/Gale 1999; Gale 2011.
13 Stos-Gale 2000; Gale *et al.* 2009.
14 Schreiner 2007.
15 Pernicka *et al.* 2016; Höppner *et al.* 2005.
16 Williams/Le Carlier de Veslud 2019; Williams 2023.
17 Artioli *et al.* 2020; Ling *et al.* 2019.
18 Lo Schiavo *et al.* 2005; Stos-Gale 2023.

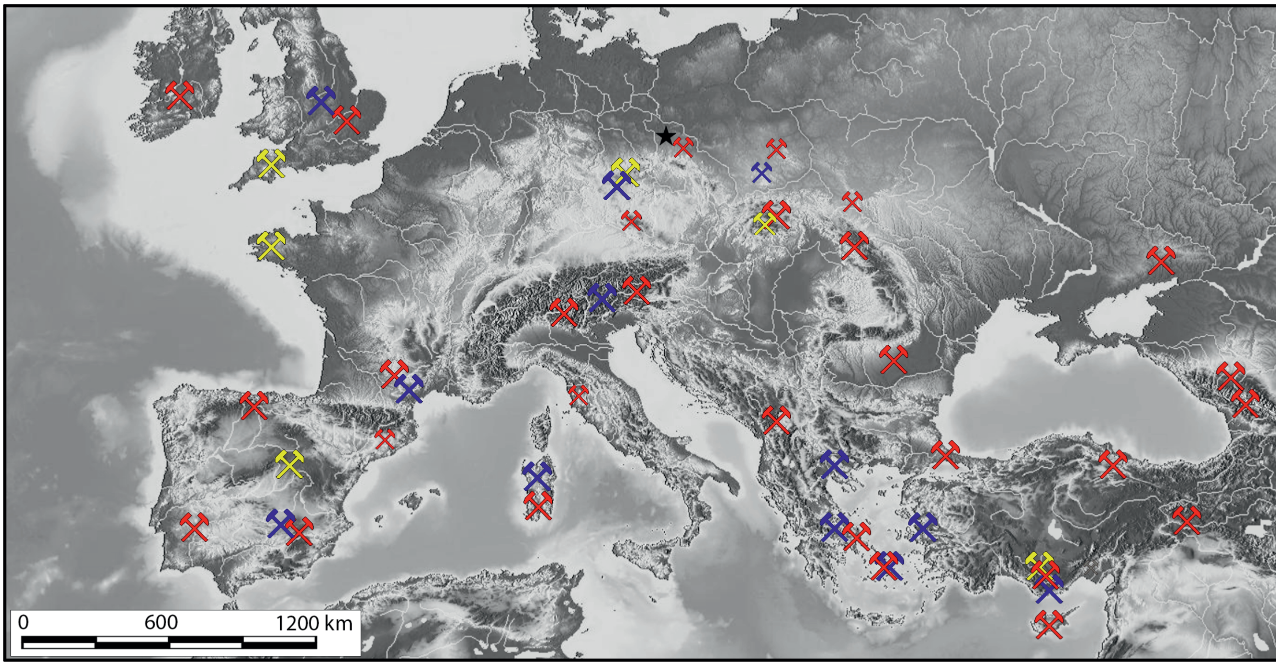

Fig. 1: Deposits of copper (red), tin (yellow) and lead (blue) ores that were or could be exploited in prehistory. The research area is marked with a star. The size of the mining symbol determines the size of the deposits (according to Niederschlag *et al.* 2003; Earle *et al.* 2015; Brügmann *et al.* 2017; Radivojević *et al.* 2018; Stos-Gale 2019; Brovender, Haiko, and Brovender 2021; Miśta-Jakubowska *et al.* 2024). Map source: https://maps-for-free.com/

in the Iberian Peninsula. They include copper, lead, silver, tin, and gold. The geologists and metallurgists have been writing about ancient mining in Spain for over a century. Oliver Davies wrote in his book on Roman mines in Europe: 'For about a century before and after the beginning of the Christian era Spain was the most important metal-producing country of the world; Pliny says, with some exaggeration, that nearly the whole land abounds in gold silver, lead copper and iron'[19]. Southwest Spain was also the focus of the first modern archaeometallurgical survey[20]. Some years later, Marcos Hunt surveyed and analyzed numerous ores and prehistoric metal artifacts from the region of Huelva[21]. The lead isotope analyses confirmed the use of copper from Spanish mines since the Chalcolithic period and throughout the Bronze Age[22]. In the archaeological literature concerning the origin of metals used in the Bronze Age Central Europe the copper and tin deposits in Spain and Sardinia traditionally have not been considered. However, the analytical programs in the last 10 years show more and more indications that the Iberian Peninsula and the western Mediterranean have been connected in the 2nd and 1st millennia BC with trade across Europe, supplying still copper and possibly tin[23].

Most of the copper and lead-silver mining sites listed above have been reasonably well characterized for their lead isotope ratios, but not all of them have a convincing geochemical 'fingerprint'. The presence of tetrahedrite minerals containing copper, antimony and silver (Fahlerz) is well attested for the North Tyrol Inn Valley mines[24] and it is known that a range of minerals – some with antimony and lead, some of pure copper – were exploited in the Slovak Ore Mountains[25]. Another two mines well characterized chemically are Mitterberg in Austria and the Great Orme in Wales. In the 1st millennium BC the production of copper for tools and weapons declined as iron took place of tin-bronze. However, tin bronze and copper still were used for vessels, jewelry, and other, mostly decorative, items. Without thorough research into the chronology of use of mining sites in all these major industrial centers, it is difficult to assess how much of bronze might have been re-used and how much of new copper and tin was entering the markets, but it seems most likely that the largest copper and tin producing regions did not go completely out of business in the Early Iron Age.

19 Davies 1935.
20 Rothenberg/Blanco-Freijeiro 1981.
21 Hunt-Ortiz 2003.
22 Stos-Gale 2001; Hunt-Ortiz 2003.
23 Berger *et al.* 2022; Melheim *et al.* 2018b.
24 Höppner *et al.* 2005.
25 Schreiner 2007.

2.1 Copper and lead ore deposits in Poland

Poland is currently a significant copper producer. The rich copper ore deposits in the so-called New Copper Basin in southwestern Poland are the best-known and are currently exploited on a large scale. However, the prehistoric exploitation of copper ore deposits has not been confirmed so far. It is argued that all metal processed in Poland was imported[26]. However, the archaeological and geological literature noted the possibility of exploiting easily accessible raw materials such as copper and lead in Poland in prehistory[27]. But there are no surveys of possible ancient copper smelting sites or reports of copper slag heaps.

Three main copper-bearing areas have been identified where probable prehistoric exploitation of copper ore or native copper could have occurred. These regions are marked in Fig. 1 and include:

1) the Zechstein ore deposits in the North Sudetic Basin in Lower Silesia, southwestern Poland[28];
2) the area of the Carpathian Flysch Belt in Subcarpathian Voivodeship, south-eastern Poland[29];
3) the copper mineralization in the Holy Cross Mountains in the Świętokrzyskie Voivodeship, southern Poland[30]. There was extensive early iron smelting[31], so it could be possible that some copper was also extracted there.

The copper minerals also occur in several areas in the Polish part of the Western Tatra Mountains[32]. These hydrothermal ore mineralizations bear mainly primary sulfide minerals tetrahedrite- (Zn), tetrahedrite- (Fe), and chalcopyrite. They were mined between the 16th and 18th centuries, but the exploitation was often stopped because of the low amount of copper. The Western Tatra Mountains deposits were never indicated as possibly exploited in prehistory.

The unprecedented accumulation of lead artifacts dated to the Early Iron Age (approximately 200 items, mostly grave finds[33]) in Upper Silesia in southern Poland, rich in lead ores, led researchers to hypothesize about the local lead exploitation in the prehistory[34]. Research results on lead provenance published recently[35] show convergence of lead isotope signatures of the Olkusz lead deposits in Silesian-Krakow Upland with the analyzed lead artifacts. It confirms the prehistoric exploitation of lead by the LUC communities in the Early Iron Age for the first time.

There are only a few lead isotope data for the copper and lead-silver ores from the mines in Poland. Much work is needed to characterize isotopically and chemically the occurrences of copper that might have been exploited in prehistory.

3 Archaeological context of the metals dated to the Early Iron Age period. The fortified settlement in Wicina and the Bieszków hoard

The fortified settlement in Wicina is located in western Poland in the Lubuskie Voivodeship, near the border with Germany (Fig. 2A). It is one of the sites clearly distinguished by the high level of metallurgical activity and the wealth of discovered artifacts. The settlement was built on a natural dune above a marshy area[36] (Fig. 2A). It was surrounded by a defensive wooden and earth rampart, which could have initially reached a height of 6 meters[37] (Fig. 2C). A bronze casting workshop, a blacksmith’s workshop, and at least two ceramic workshops were situated in the central part of the site[38].

Based on dendrochronological data from 1008 wooden samples, a defensive settlement began to be built around 754 BC. However, it was destroyed abruptly due to a Scythian raid. The latest dendrochronological date obtained from the site is 571 BC[39]. Referring to Reinecke’s system of relative chronology, this site’s dating is associated with the C and D sections of the Hallstatt Period (referred to as HaC and HaD), which is the Early Iron Age. After the Scythians completely burned the settlement, it was never resettled.

The Wicina settlement is a unique case of one of Poland’s longest-excavated archaeological sites. During the 38 research seasons, ca. 28.4 % of the site area was researched[40] (Fig. 2b–c). The vast amounts of obtained artifacts include ceramics, counted in millions of potsherds, as well as metals

26 Kostrzewski 1953; Gardawski 1979; Gedl 1982.
27 Witter 1938; Pyzik 1972; Ciurej *et al.* 2021; Nowak *et al.* 2023b.
28 Vaughan *et al.* 1989; Nowak *et al.* 2023b.
29 Kita/Ostrowicki 1959; Gedl 1988; Nieć *et al.*2016.
30 Ciurej *et al.* 2021.
31 Bielenin 2006; Przychodni 2002; Orzechowski 2013.
32 Sitarz *et al.* 2021.
33 Kowalczyk-Matys 2021; Miśta-Jakubowska *et al.* 2024.
34 Szydłowska 1982; 1988.
35 Nowak *et al.* 2023b; Miśta-Jakubowska *et al.* 2024.
36 Bugaj 2022; Sadowski/Kałagate 2013.
37 Kałagate/Jaszewska 2011.
38 Kałagate *et al.* 2011.
39 Kałagate 2013.
40 Kałagate *et al.* 2011.

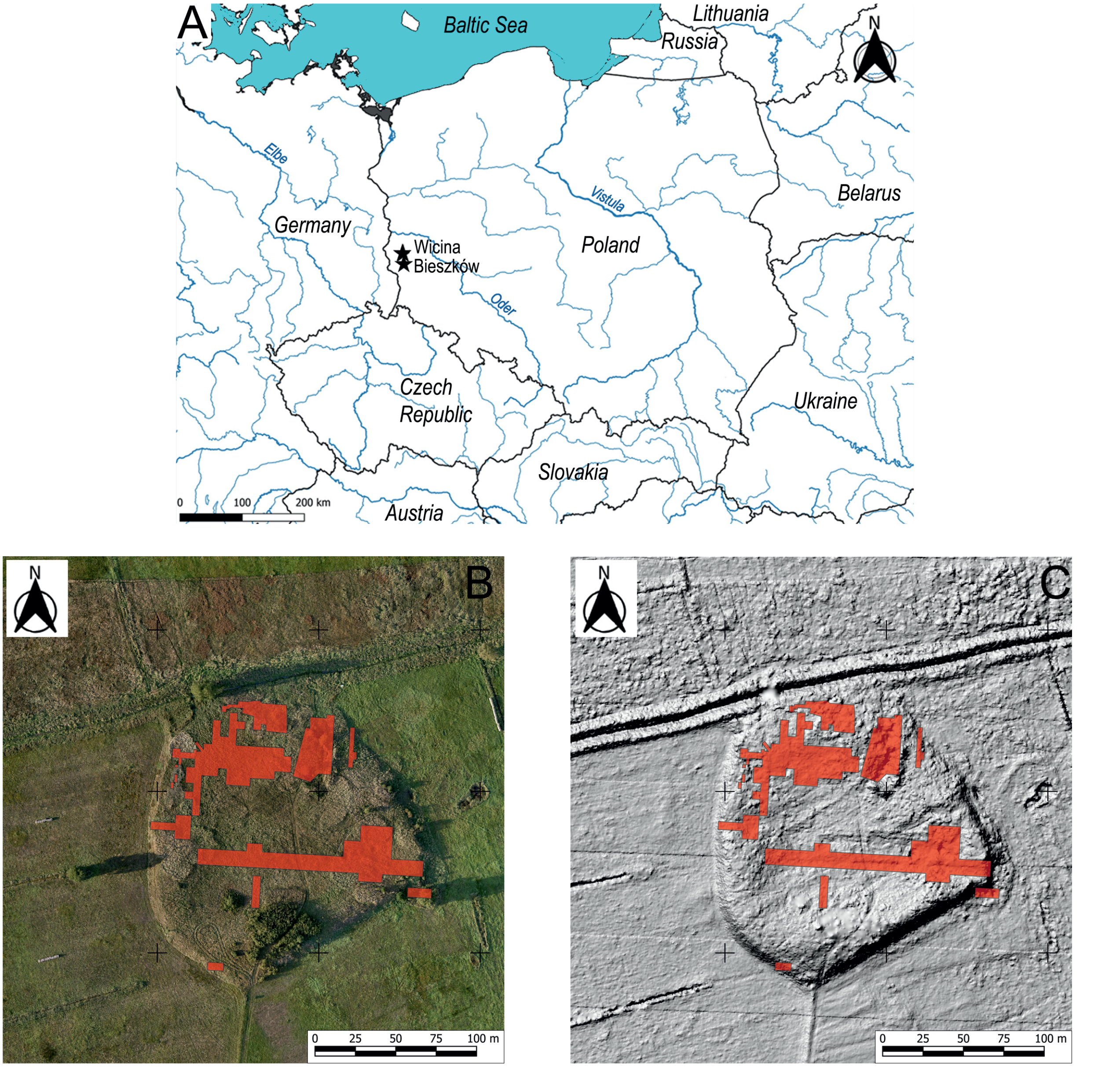

Fig. 2: A) Location of the settlement in Wicina and the Bieszków hoard on the map of Central Europe (source: GUGiK https://www.gov.pl/ and https://dane.gov.pl/); B-C) orthophoto map and the Digital Elevation Model (LIDAR based on UVA LIDAR) of the Wicina settlement with the area excavated during 38 research seasons marked (source: Bugaj 2022, Fig. 12, and by authors).

such as iron, gold, copper, and bronze; glass, amber and flint materials[41].

In the Wicina settlement and its close vicinity, at least 12 metal hoards with varied inventories were discovered[42] (Fig. 3). One of these deposits was found by chance in 2011 in Bieszków, 4 km south of Wicina (Fig. 2A). The hoard contains over 300 artifacts in a different state of preservation, weighing approximately 10 kg[43] (Fig. 2–24). Some of them were intentionally cut and partially melted. It includes ornaments, metal casting molds, lumps and droplets of metal, casting waste, iron and bronze elements of horse harnesses, iron elements of weapons, and bronze vessels. Typological and chronological analysis dates the hoard to the Early Iron Age (Reinecke HaD).

Based on the typological studies of the artifacts in the Bieszków hoard, it can be concluded that almost all items

41 Michalak 2011; Michalak/Jaszewska 2011; Purowski 2007; Przechrzta 2005; Garbacz-Klempka *et al.* 2024.

42 Maciejewski 2019a.

43 Orlicka-Jasnoch 2013.

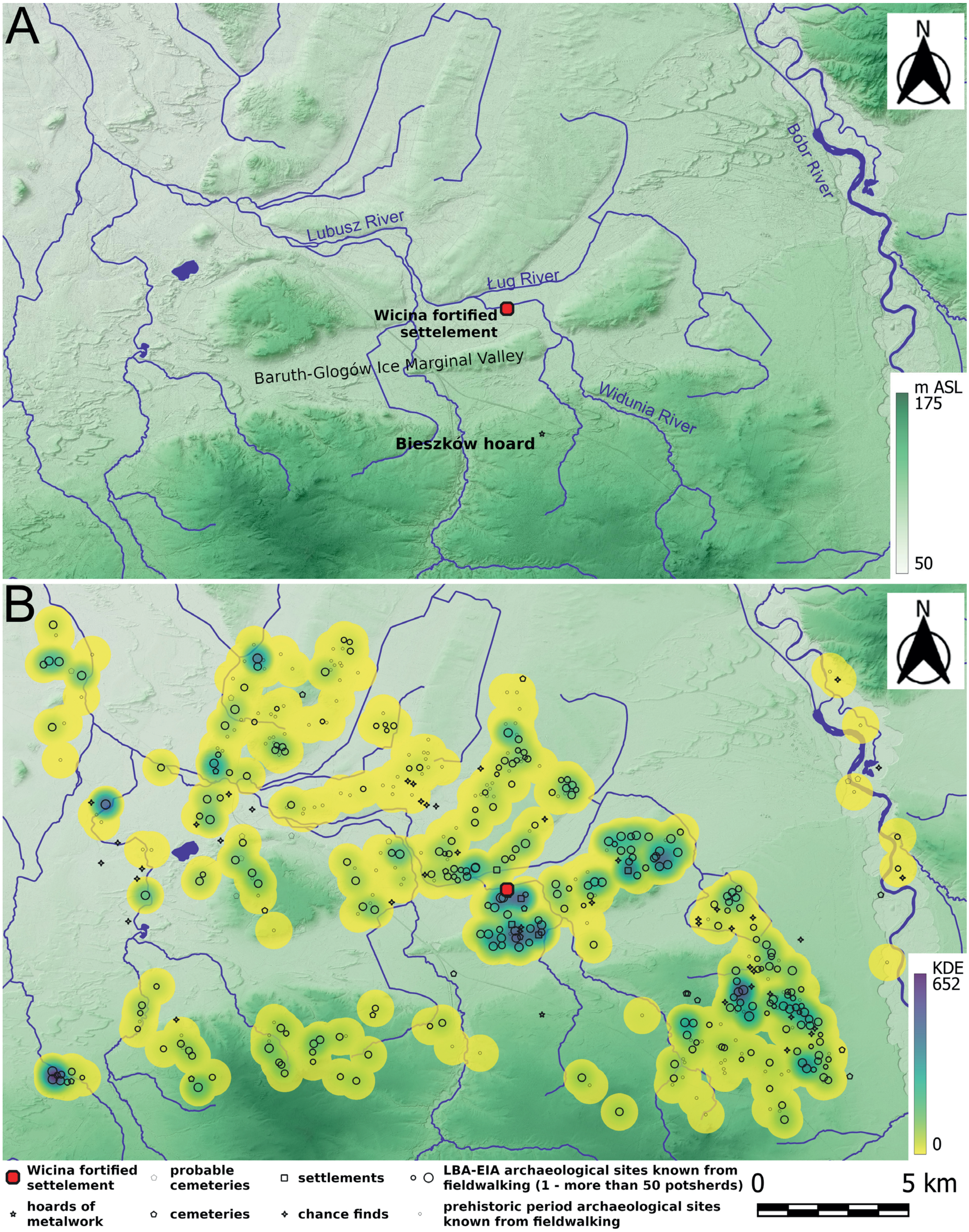

Fig. 3: A) Digital Elevation Model (DEM) of the area around the settlement in Wicina (GDAL Hillshade algorithm Z factor: 10; source: GUGiK and Wody Polskie WMS services), B) Archaeological sites dated to the Late Bronze Age and Early Iron Age around the Wicina settlement based on Polish Archaeological Record documentation and using Kernel Density Estimation.

have their counterparts in the Wicina settlement. We may assume the collection is representative of local metallurgy, probably made at least partially in the Wicina settlement.

4 The Wicina fortified settlement and Bieszków hoard in the natural and archaeological landscape

The fortified settlement is located in a prominent depression (Nowa Sól Depression), part of the Baruth-Głogów Ice-Marginal Valley (Fig. 3A). The depression mentioned above clearly separates the upland zones to the north and south, the natural landscapes of which are significantly different. The settlement is located on the border between an aeolian sand-covered dune area and the marshy areas of the peat plain (nowadays, this landscape is significantly altered; the marshy areas have undergone drainage sloughs) associated with the Ług River (or the Kanał Młyński) and its tributaries, including the Widunia (or Szyszyna) River, which flows at the foot of the settlement (Fig. 3A). The Ług River joins the Lubusz River, which is a tributary of the Nysa Łużycka River. The latest one flows into the Odra River, one of Central Europe's most important rivers. Quite characteristic formations in the described Nowa Sól Depression are erosion ostracods, which are dissected fragments of the Tertiary upland[44].

According to the Polish Archaeological Record data, a nationwide database containing data on traces of human activity in the past[45], a total of 516 archaeological sites from the Late Bronze Age, the Early Iron Age and generally dated to the Prehistoric period are located in approximately 450 km^2. The information about the sites has been chiefly drawn from field surveys. Therefore, we can only determine the function of some of the sites or their detailed chronology. Other limitations of using this database have been discussed in the cultural landscape studies of other areas in Poland[46]. The interrelationships between archaeological sites and relation to the relief, hydrological situation, and potential vegetation cover (based on maps of potential natural vegetation[47]) were analysed. Kernel Density Estimation (KDE) analyses with various parameters were also carried out. Free access QGIS software was used for the study, including the Heatmap algorithm (KDE) and the Visibility Analysis plug-in[48]. The most significant number of sites is concentrated around the Wicina fortified settlement (Fig. 3). This may be related to the intensive research carried out there since the 1960s. Another distinct cluster of human occupation is the sites located southeast of Wicina in a completely different, upland landscape. The areas on the Lubusz River and its tributaries were less intensive but probably steadily settled. It is enigmatical that the occurrence of archaeological sites is incidental to the Bóbr River (another tributary of the Odra River), located on the eastern border of the analyzed area. It can be related to the natural specifics of the area outside the Bóbr River valley itself (Fig. 3B). To understand the significance of Wicina settlement in the Early Iron Age landscape, it is necessary to locate the site in the natural landscape and in the context of the distribution of settlement points, i. e. settlement density. This information, combined with the results of archaeometallurgical analyses, will allow us to determine whether there is a correlation between factors such as location and access to goods.

5 Analysed metal artifacts

From the wealth of artifacts discovered in the Wicina settlement and Bieszków hoard, we were given permission to sample 15 metal artifacts (Table 1). As a result of a rigorous selection requested by the Central Odra Museum in Świdnica, which administrates both collections, only damaged objects and non-characteristic metal fragments were available for analysis. The selected artifacts included fragments of local types, lumps of metal, and pieces of small copper ingots (Fig.s 4–5).

It is possible that some of the selected artifacts were made in casting workshops in Wicina. The open armlet of wide sheet metal, with a slightly turned edge, profiled along with grooves with the ends decorated with an 'X' (Mus. inv. no. 1995:1217; Figure 4A), pin with vase-shaped heads decorated with grooves (Mus. inv. no. 1987:223; Fig. 4B), pin with straight stems, decorated with pseudo-twisting, and nail-shaped heads (Mus. inv. no. 1997:487; Fig. 4C) and cast necklaces decorated with pseudo-twisting with stamped ends (Mus. inv. nos. 2011:80; 2012:5; 2012:6; Fig. 4D–F) belong to this category[49]. Only an armlet (Mus. inv. no. 2012:64; Fig. 4G) of wide sheet metal with ends decorated typical for

44 Sadowski/Kałagate 2013.

45 Zabytek.pl.

46 Maciejewski 2016; Baron *et al.* 2019; Stolarczyk *et al.* 2020; Blajer *et al.* 2022.

47 Matuszkiewicz/Wolski 2023.

48 Čučković 2016.

49 Michalak 2011.

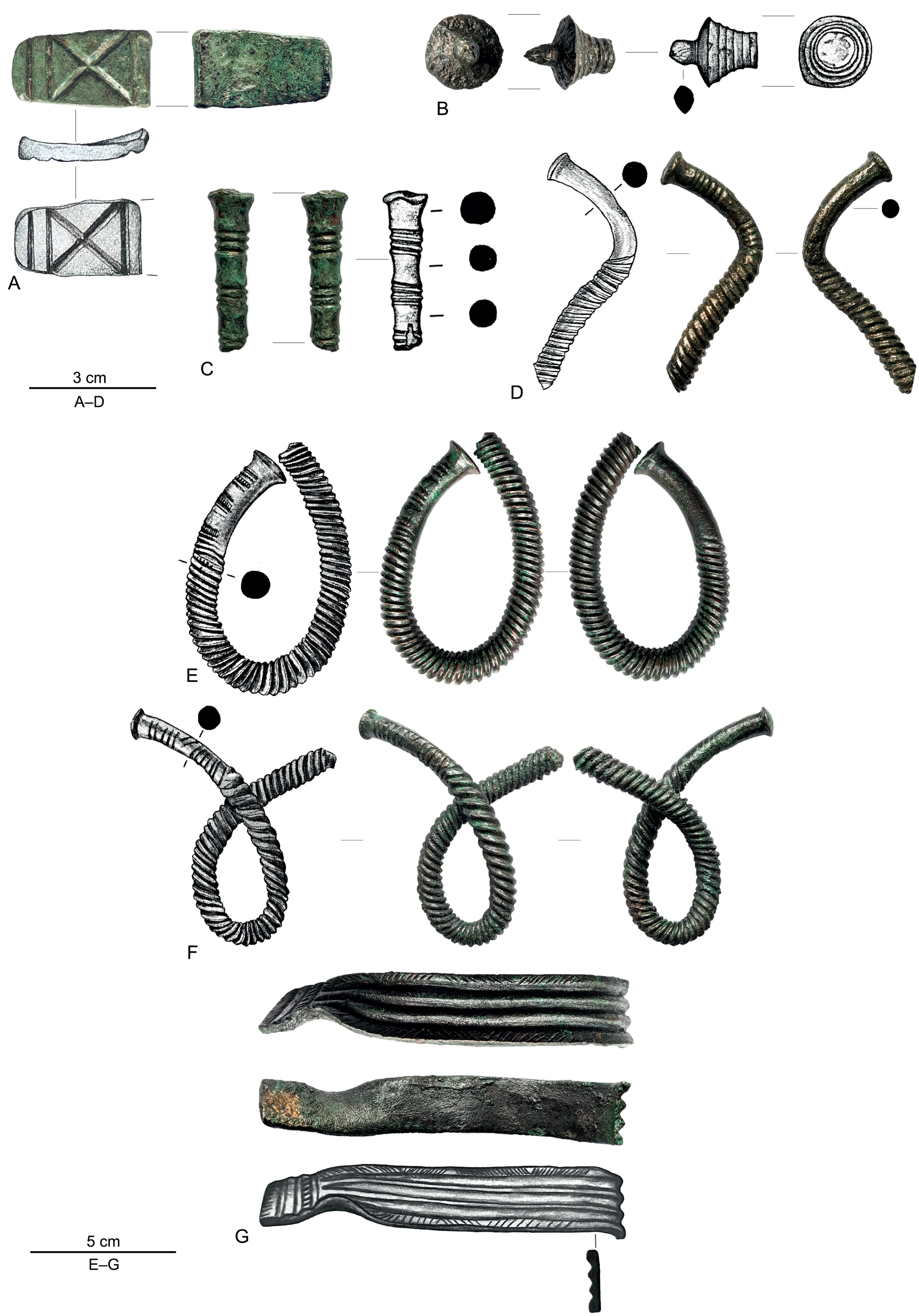

Fig. 4: Metalwork selected for analyses: A-D) from the Wicina settlement, E-G) from the Bieszków hoard (drawings source: Michalak, Jaszewska 2011, Fig. 20.6, 27.7, 42.6, 48.4; Orlicka-Jasnoch 2013, Fig. 13.1, 13.3, 11.1).

Tab. 1: Characteristics of metal objects selected for elemental composition analyses (LA ICP MS) and analyses of stable lead isotopes (MC ICP MS)

Site	Context	Museum Inv. No.	Sample no.	Artifact	Dimension [cm]	Weight [g]	Figure
Wicina	Fortified settlement	MAŚN 1995:1217 [271/95]	48	fragment of an armlet from sheet metal	3.4 × 1.9 × 0.4	14	4A
Wicina	Fortified settlement	MAŚN 1997:487 [15/97]	49	pin head fragment	3.8 × 0.8	11	4C
Wicina	Fortified settlement	MAŚN 1987:223 [23/87]	50	pin head fragment	2.2 × 1.9 × 0.5	15	4B
Wicina	Fortified settlement	MAŚN 2011:80 [119/80]	51	necklace fragment	7.6 × 0.8	42	4D
Wicina	Fortified settlement	MAŚN 1997:506 [154/97]	52	ingot fragment	2.0 × 1.5	20	5A
Wicina	Fortified settlement	MAŚN 1997:105 [105/97]	53	a metal lump or casting jet fragment	2.5 × 1.3	19	5C
Wicina	Fortified settlement	MAŚŃ 1995:1240 [300/95]	54	small plano-convex ingot	2.2 × 0.8	10	5B
Wicina	Fortified settlement	MAŚN 1997:454 [96/97]	55	ingot fragment	3.8 × 1.3	28	5D
Wicina	Fortified settlement	MAŚN 1995:1243 [169/95]	56	wire ornament from inside the ceramic casting mould	2.6 × 1.7	7	5E
Wicina	Fortified settlement	MAŚN 2011:157	57	fragment of large plano-convex ingot	15.2 × 10.3 × 5.1	2005	5H
Bieszków	Metal hoard	MAŚN 2012:5	58	necklace fragment	8.0 × 1.1–1.3	131.5	4E
Bieszków	Metal hoard	MAŚN 2012:6	59	necklace fragment	8.4 × 0.8–0.9	75.9	4F
Bieszków	Metal hoard	MAŚN 2012:64	60	fragment of an armlet from sheet metal	11.2 × 2.1 × 0.3	78.5	4G
Bieszków	Metal hoard	MAŚN 2012:258A	61	metal lump (droplet)	4.8 × 2.1 × 0.9	43	5F
Bieszków	Metal hoard	MAŚN 2012:258B	62	metal lump (droplet)	2.8 × 2.6 × 1,3	24	5G

finds further east, from Greater Poland (Orlicka-Jasnoch 2013) could be seen as an import.

We also selected eight artifacts that constitute the ingots, the fragments of ingots, or are casting production waste, such as metal droplets and casting jets (Fig. 5). Noteworthy is a large piece of metal weighing about 2 kilograms (Mus. inv. no. 2011:157; Fig. 5H). The direct evidence of local metal casting at the settlement is a ring-shaped metal item preserved inside the broken ceramic casting mold (Mus. inv. no. 1995:1243; Fig. 5E). It was also sampled for our studies.

Thanks to the selection of artifacts, we could study the types of alloys used, their chemical compositions, and the metal provenance of locally manufactured and non-local items.

6 Analytical methods

6.1 Elemental composition

Samples of the selected artifacts were analyzed for their chemical compositions using Inductively Coupled Plasma Mass Spectrometry (ICP-MS) at the University of Warsaw Biological and Chemical Research Centre. They were weighed and treated with an appropriate mixture of acids (4.0 mL 65 % HNO3, Merck Suprapur®, 0.5 mL 40 % HF, Merck Suprapur®). Next, the samples were digested using a microwave-assisted closed system (Milestone Ethos Up, 25 min ramping to 230 °C, 15 min hold at 230 °C). The resulting solutions were diluted by weight to about 50 g and subjected to elemental analysis. All solutions were measured by ICP MS (Perkin Elmer NexION300D). External calibration (Merck ICP Standard VIII, Merck Sn, Sb and Ti mono elemental ICP standards) with internal standard (Rh, Merck ICP standard) correction was used. The accuracy of the calibration has been verified using reference materials SPS SW1 and SPS SW2 (Spectrapure Standards, Norway).

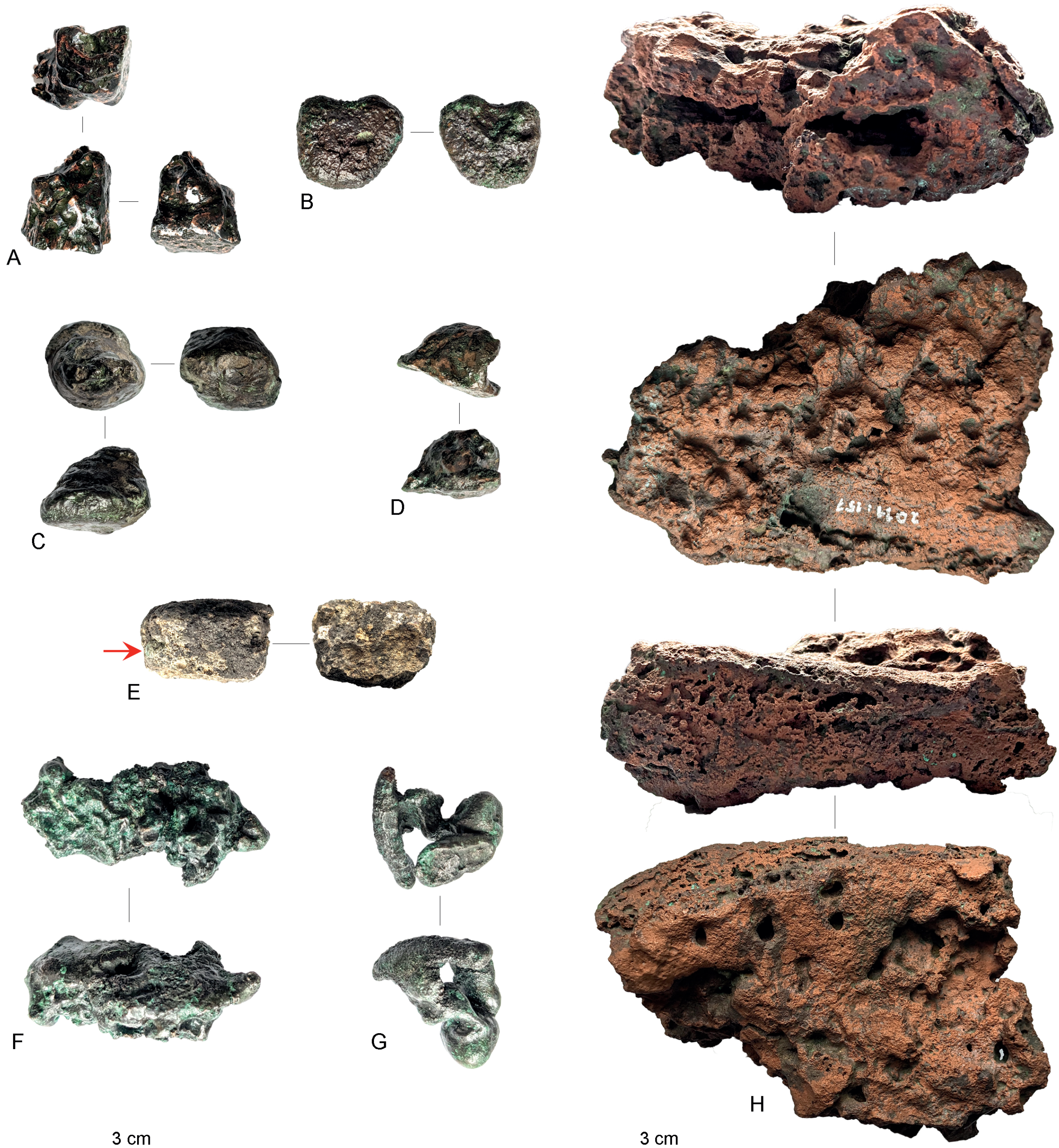

Fig. 5: Analyzed artifacts from the Wicina settlement and Bieszków hoard: A, D, H) fragments of ingots, B) an ingot), F-G) metal droplets, C) probable casting jet, E) a fragment of the disposable ceramic casting mold with the metal inside it. The red arrow shows the placement of metal wire ornament inside the casting mold.

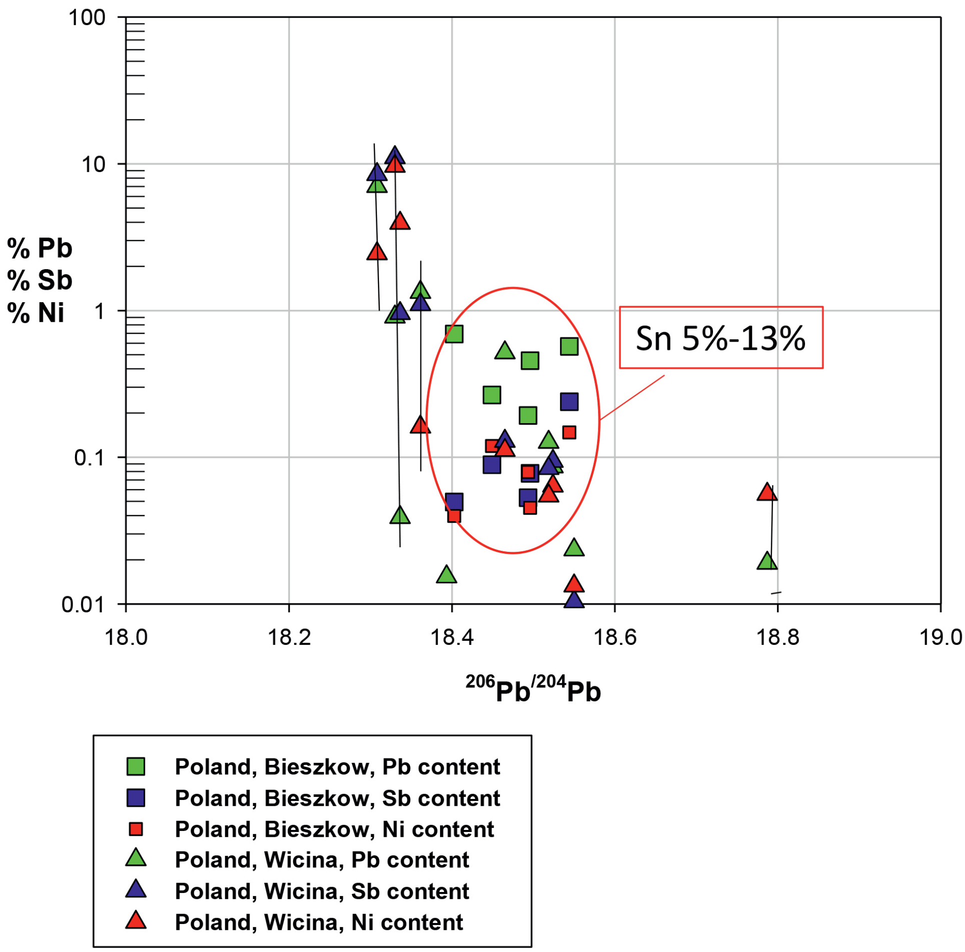

Fig. 6: Comparison of main impurities in copper-based artifacts from west Poland and one of their lead isotope ratios.

6.2 Stable lead isotope analyses

The lead isotope analyses of the same artifacts were performed using Multicollector-Inductively Coupled Plasma Mass Spectrometry (MC-ICP-MS) at the University of Warsaw Biological and Chemical Research Centre following the methodology described in more detail[50]. Isotopic data were obtained on a Nu Plasma 3 instrument equipped with an Aridus-3 desolvation nebulizer system. The Pb-rich samples (>880 mg/kg) were analyzed without Pb separation. After dilution with 2 % HNO3 to ~30 µg/L Pb the solution was spiked with thallium NIST SRM997 isotopic standard (~15 µg/L Tl) and aspired into the instrument.

50 Karasiński *et al.* 2023.

7 Results of lead isotope and chemical analyses

The analyses of 15 copper-based artifacts from the Wicina settlement and hoard from Bieszków dated to the early 1st millennium BC show varied elemental compositions (Table 2) and lead isotope characteristics (Table 3). Perhaps the most striking feature of this group of artifacts is the differences in their chemical compositions, from very pure copper and tin-bronze to copper with high lead, antimony, and nickel contents.

The five copper-based artifacts from the Bieszków Hoard and two pins and a necklace from Wicina (MAŚN 15/97, MAŚN 119/80, MAŚN 23/87; MAŚN 2012:258A, MAŚN 2012:258B, MAŚN 2012:6, MAŚN 2012:64, MAŚN 2012:5; Table 1) form a group with quite similar chemical and lead isotope characteristics. All of the artifacts have been made of copper smelted from copper ores with impurities below 0.5 %, only concentrations of lead and iron are in some of them a little higher (Fig. 6 and Table 2).

Tab. 2: Results of the total contents of selected elements. The results are presented in mg/kg. They refer to the dry weight of the samples and take into account all dilutions. Cu is a main component of the investigated artifacts (matrix)

Site	Museum Inv. No.	Sample no.	Fe%	Co%	Ni%	Zn%	As%	Ag%	Sn%	Sb%	Au%	Pb%	Bi%
Wicina	MAŚN 1995:1217 [271/95]	48	0.20	0.03	0.01	0.01	0.09	0.03	6.21	0.01	<LOD	0.02	<LOD
Wicina	MAŚN 1997:487 [15/97]	49	0.05	0.02	0.05	0.04	0.29	0.05	9.73	0.08	<LOD	0.13	<LOD
Wicina	MAŚN 1987:223 [23/87]	50	5.72	0.04	0.11	0.06	0.41	0.10	13.35	0.13	<LOD	0.52	0.02
Wicina	MAŚN 2011:80 [119/80]	51	0.33	0.03	0.06	0.01	0.30	0.08	10.51	0.09	<LOD	0.09	0.01
Wicina	MAŚN 1997:506 [154/97]	52	0.32	0.02	0.06	0.01	0.11	0.03	0.01	0.01	<LOD	0.02	0.23
Wicina	MAŚN 1997:105 [105/97]	53	0.31	2.15	9.65	<LOD	9.97	0.31	0.38	11.03	<LOD	0.91	0.07
Wicina	MAŚŃ 1995:1240 [300/95]	54	0.45	0.01	0.16	<LOD	0.35	0.44	8.68	1.10	<LOD	1.34	0.02
Wicina	MAŚN 1997:454 [96/97]	55	0.13	0.02	2.44	0.01	2.56	0.60	0.05	8.46	<LOD	7.03	0.03
Wicina	MAŚN 1995:1243 [169/95]	56	2.88	0.44	3.95	0.02	0.35	0.20	0.03	0.96	<LOD	0.04	0.02
Wicina	MAŚN 2011:157	57	0.47	<LOD	<LOD	0.01	0.06	0.01	0.02	0.01	<LOD	0.02	0.01
Bieszków	MAŚN 2012:5	58	0.19	0.02	0.12	0.27	0.15	0.09	5.43	0.09	<LOD	0.27	0.01
Bieszków	MAŚN 2012:6	59	0.17	0.02	0.08	0.01	0.24	0.07	7.32	0.05	<LOD	0.19	0.02
Bieszków	MAŚN 2012:64	60	0.39	0.02	0.05	0.01	0.24	0.07	12.74	0.08	<LOD	0.45	0.02
Bieszków	MAŚN 2012:258A	61	0.11	0.03	0.04	0.02	0.20	0.05	8.23	0.05	<LOD	0.69	0.01
Bieszków	MAŚN 2012:258B	62	0.48	0.02	0.15	0.01	0.33	0.18	12.33	0.24	<LOD	0.57	0.02

Tab. 3: Lead isotope analysis for artifacts from the Wicina settlement and Bieszków hoard

Sample no.	Museum Inv. No.	Site	208Pb/ 206Pb	207Pb/ 206Pb	206Pb/ 204Pb	207Pb/ 204Pb	208Pb/ 204Pb
48	MAŚN 1995:1217 [271/95]	Wicina	2.07963	0.84252	18.550	15.629	38.577
49	MAŚN 1997:487 [15/97]	Wicina	2.08903	0.84607	18.519	15.668	38.686
50	MAŚN 1987:223 [23/87]	Wicina	2.09268	0.84856	18.465	15.669	38.641
51	MAŚN 2011:80 [119/80]	Wicina	2.08738	0.84549	18.524	15.662	38.667
52	MAŚN 1997:506 [154/97]	Wicina	2.07232	0.83549	18.787	15.696	38.933
53	MAŚN 1997:105 [105/97]	Wicina	2.10194	0.85484	18.330	15.669	38.528
54	MAŚŃ 1995:1240 [300/95]	Wicina	2.09398	0.85237	18.361	15.650	38.447
55	MAŚN 1997:454 [96/97]	Wicina	2.10353	0.85552	18.308	15.663	38.512
56	MAŚN 1995:1243 [169/95]	Wicina	2.10108	0.85453	18.336	15.669	38.525
57	MAŚN 2011:157	Wicina	2.08586	0.84930	18.393	15.622	38.366
58	MAŚN 2012:5	Bieszków	2.09232	0.84929	18.449	15.669	38.601
59	MAŚN 2012:6	Bieszków	2.09002	0.84766	18.493	15.677	38.651
60	MAŚN 2012:64	Bieszków	2.09226	0.84760	18.496	15.677	38.698
61	MAŚN 2012:258A	Bieszków	2.09499	0.85140	18.403	15.668	38.553
62	MAŚN 2012:258B	Bieszków	2.08843	0.84536	18.544	15.677	38.729

All of these artifacts are tin bronzes, with tin content between 5–12 % and very low contents of antimony (<0.3 %). Numerical comparisons for this group of artifacts (using TestEuclid) with lead isotope ratios in the database representing about 10 000 ores from Europe and the Near/Middle East indicate that they are consistent with the ores from north and east Sardinia (regions of Sassari and Nuoro)[51]. These bronzes are consistent mainly with the ores from the copper mine in Calabona near Sassari (Fig. 7). Their lead isotope ratios are also consistent with the ores from the Cevennes in the Massif Central in south France, but these lead isotope data are for samples from a Mediaeval silver extraction site (Baron *et al.* 2006), so they cannot provide comparative material with tin-bronzes.

Three artifacts from Wicina stand out from the rest with their very high nickel content and lead isotope ratios consistent with the copper ores of the Paleozoic age (about 600–500 Ma). They are two fragments of a metal lump/ cake and a fragment of wire (MAŚN 96/97, MAŚN 105/97 and MAŚN 169/95). They have very similar lead isotope ratios, but very different chemical compositions. The composition

51 Stos-Gale *et al.* 1995; Begemann *et al.* 2001; Lo Schiavo *et al.* 2005; Stos-Gale 2023.

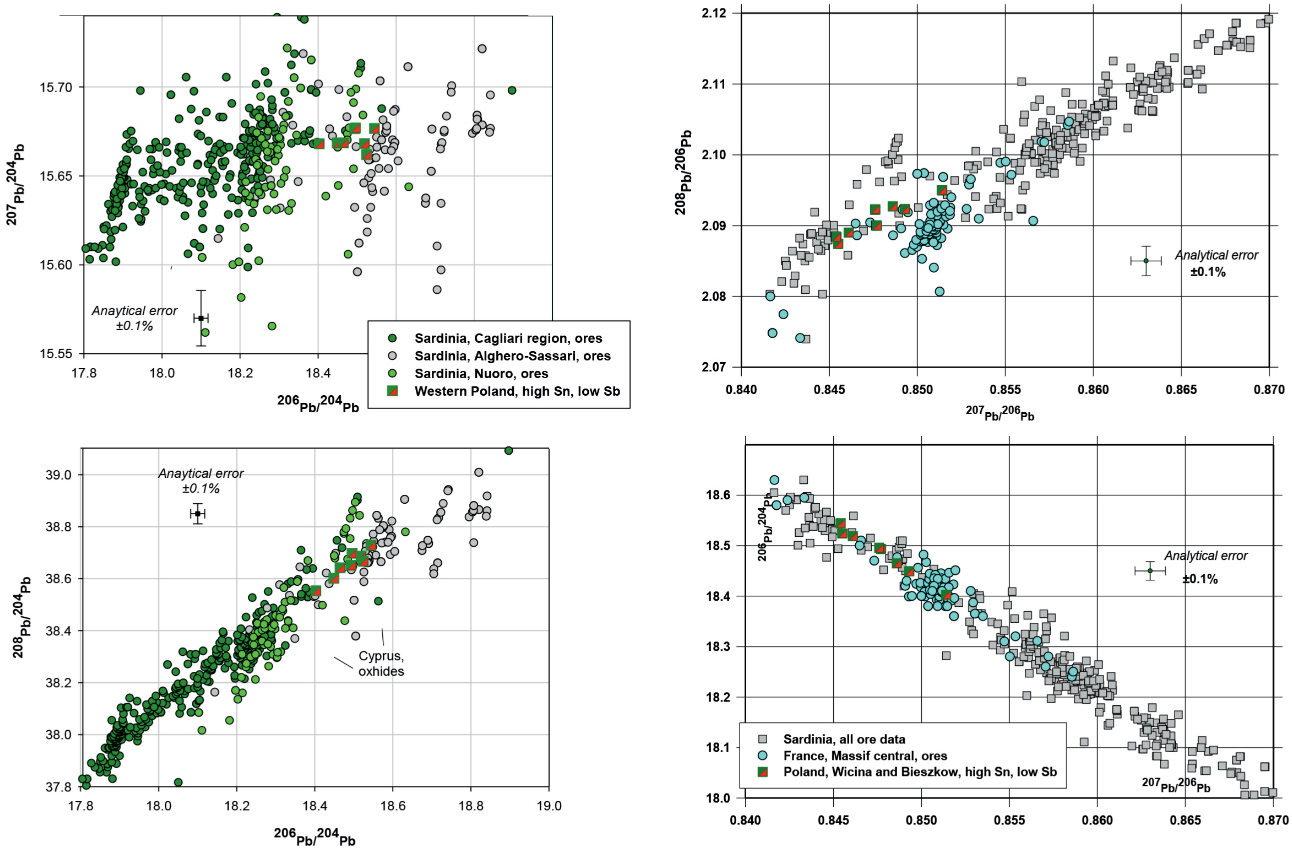

Fig. 7: Comparison of lead isotope ratios of bronzes from western Poland with the data for the Sardinian copper and lead/silver ores.

of the metal fragment 105/97 indicates copper smelted from a very complex mixture of minerals resulting in very high contents of arsenic and antimony (9 % and 11 %, respectively), about 1 % of lead and very unusual 2 % of cobalt and 10 % of nickel. All other elements are present in quantities below 0.5 %. The other two artifacts in this group also have high nickel content (2 % and 4 %), but while the lump 96/97 contains about 8 % of antimony and 7 % of lead, the wire contains about 1 % of antimony and less than 0.1 % of lead. So, if these three pieces of copper originated from the same copper mineralization it must have been a complex multimetallic outcrop of copper ore. The elemental compositions of these three artifacts are in Fig. 6 to the left of the ^{206}Pb/^{204}Pb=18.4.

The lead isotope ratios of these three metal fragments are consistent with the multimetallic ores from the mines located in the Guadalquivir Valley in southern Spain[52] (Metallogenetic map of Spain) (Fig. 8). Some bars/ingots from Jodłowno, northern Poland, dated to a similar period, have the same lead isotope ratios[53]. They also contain several percent of antimony and lead, but much lower contents of nickel.

Two artifacts from Wicina stand out isotopically from the other analyzed metals. They are a 'metal lump' MAŚN 154/97 made of pure copper with all impurities below 0.3 % and a fragment of bracelet made of pure copper with an addition of about 6 % of tin (MAŚN 271/95). Their chemical and lead isotope compositions are consistent with the copper ores from Cyprus (Fig. 8).

The most interesting artifact in this group is the huge lump of metal from Wicina (MAŚN 2011:157). It was made of very pure copper, with about 0.5 % of iron and all other impurities below 0.1 % and rather unusual lead isotope ratios that seem consistent with the copper ores from the Holy Cross Mountains in central-south Poland (Figs. 8 and 9). This region has been well-researched as a center of early iron smelting[54], but there are also copper ores in this region, and very little is known about their earliest exploitation[55]. There are only 16 lead isotope analyses of copper ores from

52 Sáez *et al.* 2021.

53 Nowak *et al.*, in prep.

54 Bielenin 2006; Przychodni 2002; Orzechowski 2013.

55 Osika 1986.

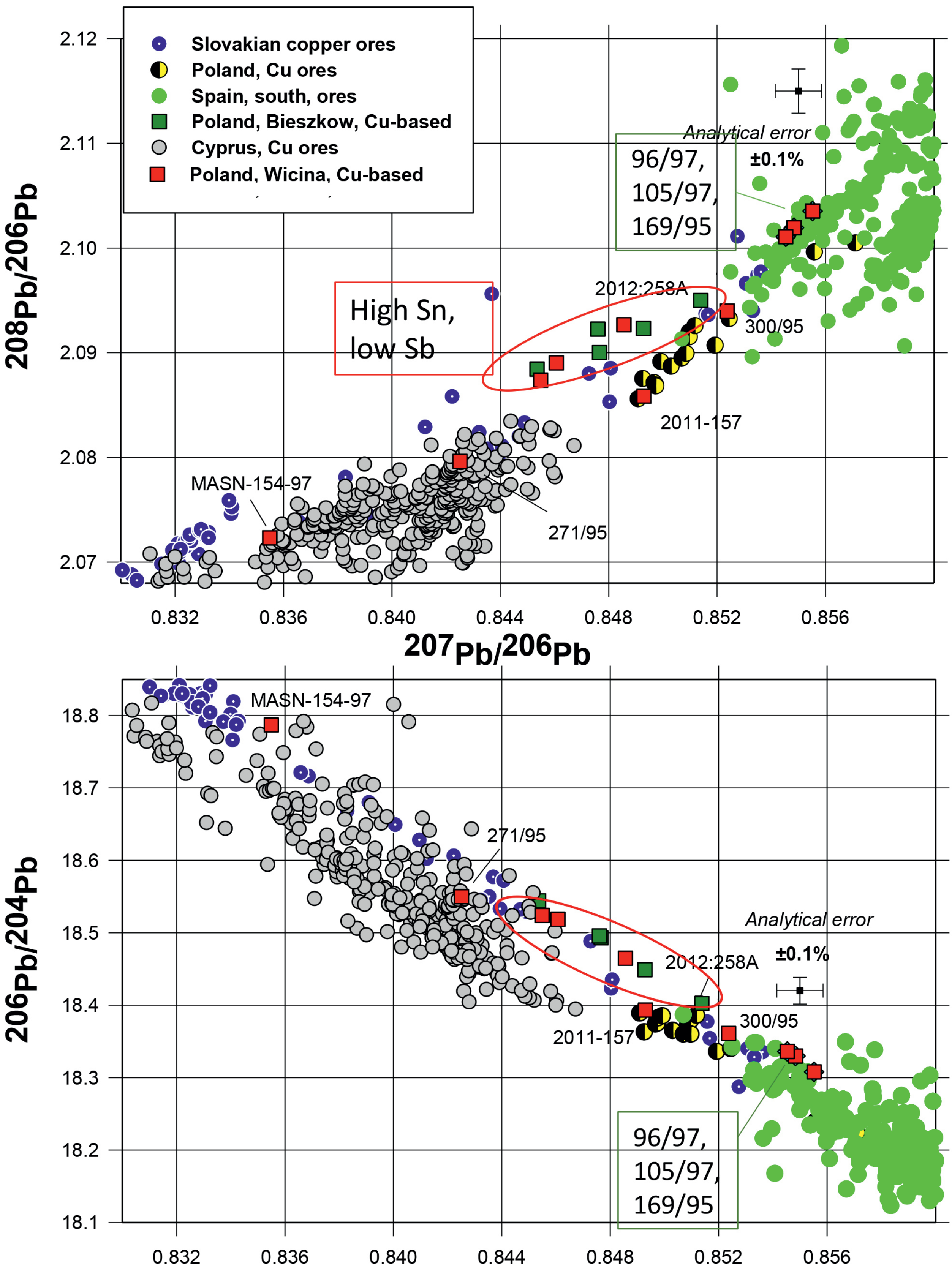

Fig. 8: Comparison of lead isotope ratios of copper-based artifacts from southwest Poland with the copper ores from Poland, Cyprus, the Slovak Ore Mountains, and southern Spain.

central Poland[56], and nothing is known about the copper mining activities so the consistency of this copper cake with the ores from the Holy Cross Mountains needs to be treated as a tentative hypothesis.

A tin-bronze cake from Wicina MAŚŃ 300/95 has a chemical composition typical of copper smelted from tetrahedrite ores (Fahlerz) with silver and antimony minerals because it contains nearly 0.5 % Ag and 1 % Sb. Its lead isotope ratios are consistent with the ores from the Austrian mines in North Tyrol and also, to a smaller degree, with the ores from the Spania Dolina in the Slovak Ore Mountains (Fig.s 8 and 9). On Fig. 10 it seems that this metal has lead isotope ratios also very similar to one of the copper ingots from Slovakia analyzed in 2016[57] (bar from Rostovna, Riecka Village found with a BC2–HaA1 bronze axe), but the find spot of this artifact does not guarantee that it was made from copper ores found in Slovakia, so perhaps the origin of this artifact should remain open for now.

8 Discussion

8.1 The role of the settlement in Wicina in the archaeological landscape and its influence on the development of the local community

The fortified site in Wicina, surrounded by open settlements and nearby cemeteries, formed a cooperating and interacting complex that developed and thrived in the Early Iron Age. Archaeological finds (information collected within the Polish Archaeological Record; Fig. 2) and palynological analyses[58] show little evidence of older and younger occupations. Due to its location, massive wooden fortifications, rich evidence of metallurgy, and unique objects made of glass and amber, the settlement is considered a political and economic center[59].

Our research revealed that the site held considerable significance in the region despite not being ideally situated for farming. This importance is demonstrated by the presence of numerous hoards of metals in the vicinity and the discovery of objects made from both local and non-local materials.

The archaeological artifacts in this area, obtained during years of excavations, indicate extensive supra-regional contacts. The site's exceptional richness is evident in the collection of 3617 metals[60] and approximately 900 glass items[61]. When comparing the natural landscape around the Wicina settlement with other cultural landscapes of the Late Bronze Age and Early Iron Age in Poland, it is evident that the studied area only partially aligns with the settlement strategies of Central European communities during this period. Only small plots of land could have been effectively used for growing cereals in the area surrounding the site. The published results of pollen analyses do not suggest that intensive agriculture was practiced there[62]. The archaeozoological data also deviate from the patterns recorded at other Early Iron Age sites. A significantly lower proportion of cattle was recorded, which may have also been used for agricultural work[63].

Interestingly, the community appeared to be prosperous based on the abundance of metal and glass artifacts, suggesting that other contributing factors to the local wealth were also present. Why was this spot chosen for settlement? Some sites located in a similar landscape may help answer this question. Rosko and Karmin (western Poland) were situated in longitudinal depressions of glacial origin: the Baruth-Glogów and Toruń-Eberswald Ice Marginal Valleys[64]. The archaeological evidence proves intense occupation near the sites including numerous deposits of metal objects. In both areas, settlements were situated at the bottoms of the depressions[65]. Their environmental and archaeological background is similar. The Wicina settlement is also located in the Baruth-Glogów Ice Marginal Valley, situated in a depression that separates the northern and southern upland zones, each with distinct natural landscapes. The site is positioned on the border between an aeolian sand-covered dune area and the marshy areas of the peat plain associated with watercourses occurring here. The natural conditions suggest that the Wicina, Rosko, and Karmin complexes were conveniently situated to navigate the obstacles related to the Ice Marginal Valley landscape. The Wicina fortified settlement was strategically located at the border of a wetland area, positioned on a watercourse flowing north between erosion spurs. This location served as a potential route connecting the densely populated areas of Upper Lusatia and western Lower Silesia with the Middle and Lower

56 Church *et al.* 1996; Zartman *et al.* 1979.
57 Modarressi-Tehrani *et al.* 2016.
58 Milecka 2013.
59 Kałagate/Jaszewska 2011.
60 Michalak/Jaszewska 2011.
61 Purowski 2007.
62 Milecka 2013.
63 Osypińska 2013.
64 Maciejewski 2019b, Fig. 1; 2020; Baron *et al.* 2019, Fig. 77.
65 Maciejewski 2024.

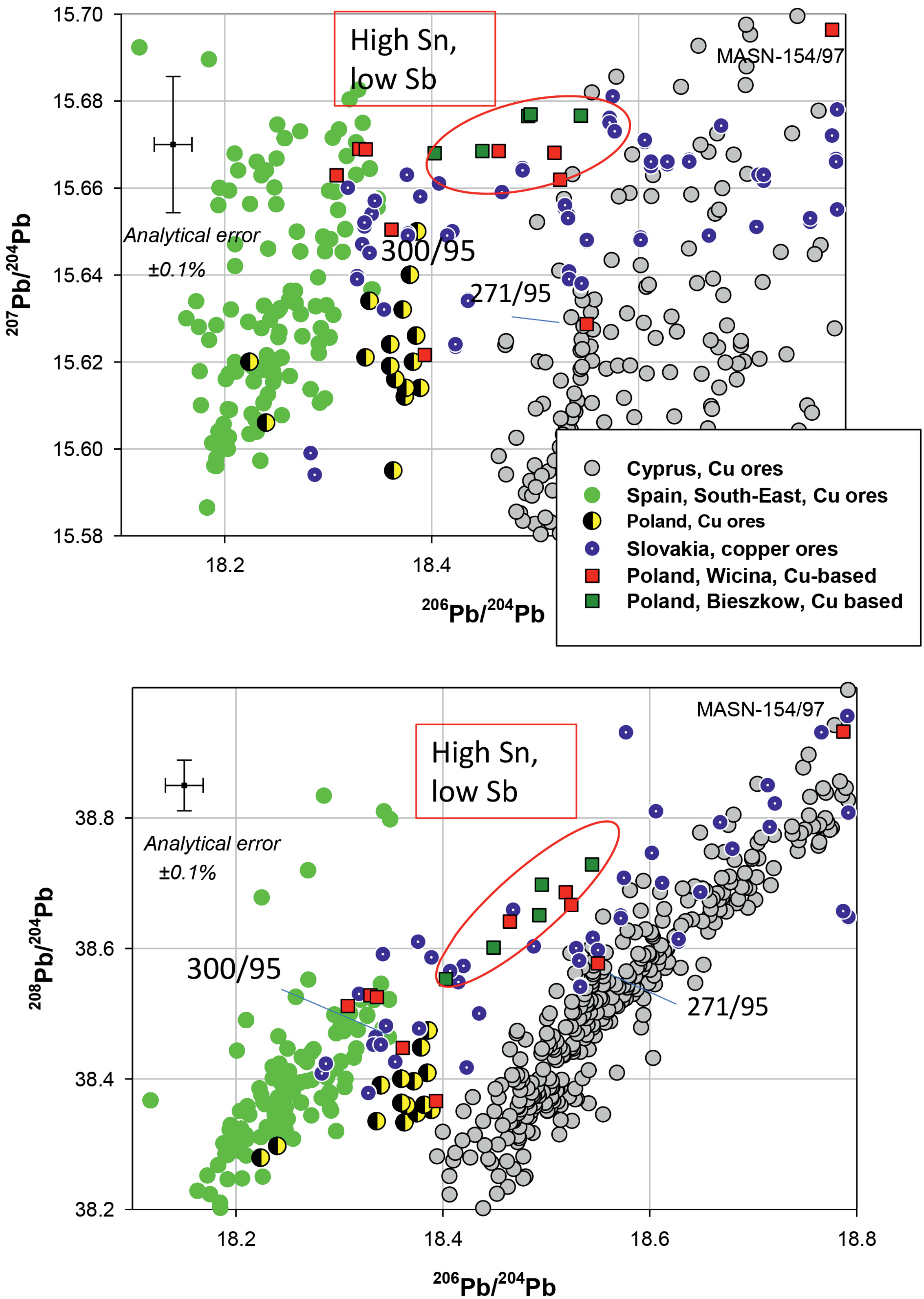

Fig. 9: Comparison of lead isotope ratios of copper-based artifacts from southwest Poland with the copper ores from Poland, Cyprus, the Slovak Ore Mountains, and southern Spain with respect to 204Pb.

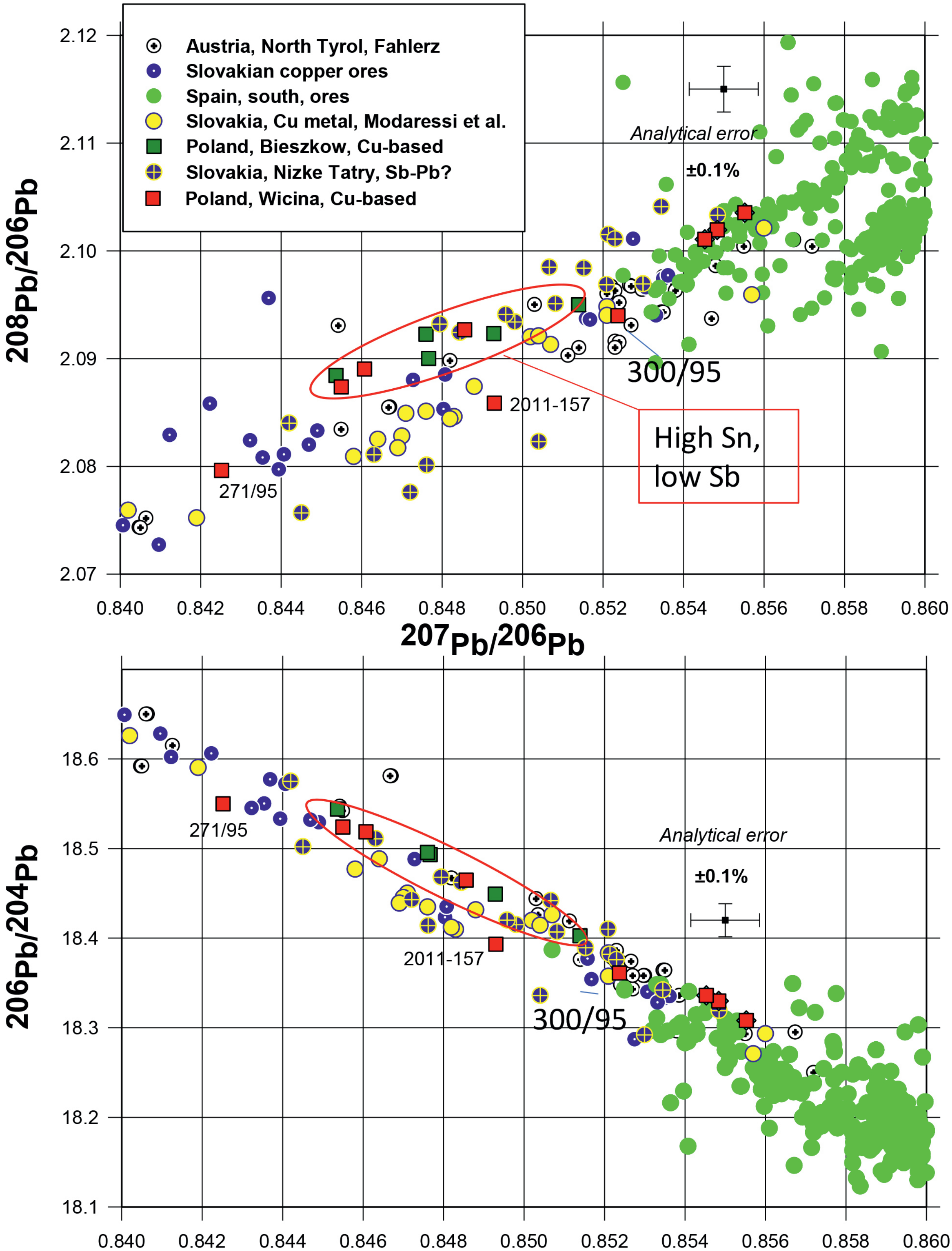

Fig. 10: Comparison of lead isotope ratios of copper-based artifacts from southwest Poland with the copper ores from the Slovak Ore Mountains, Austrian Alps, and southern Spain.

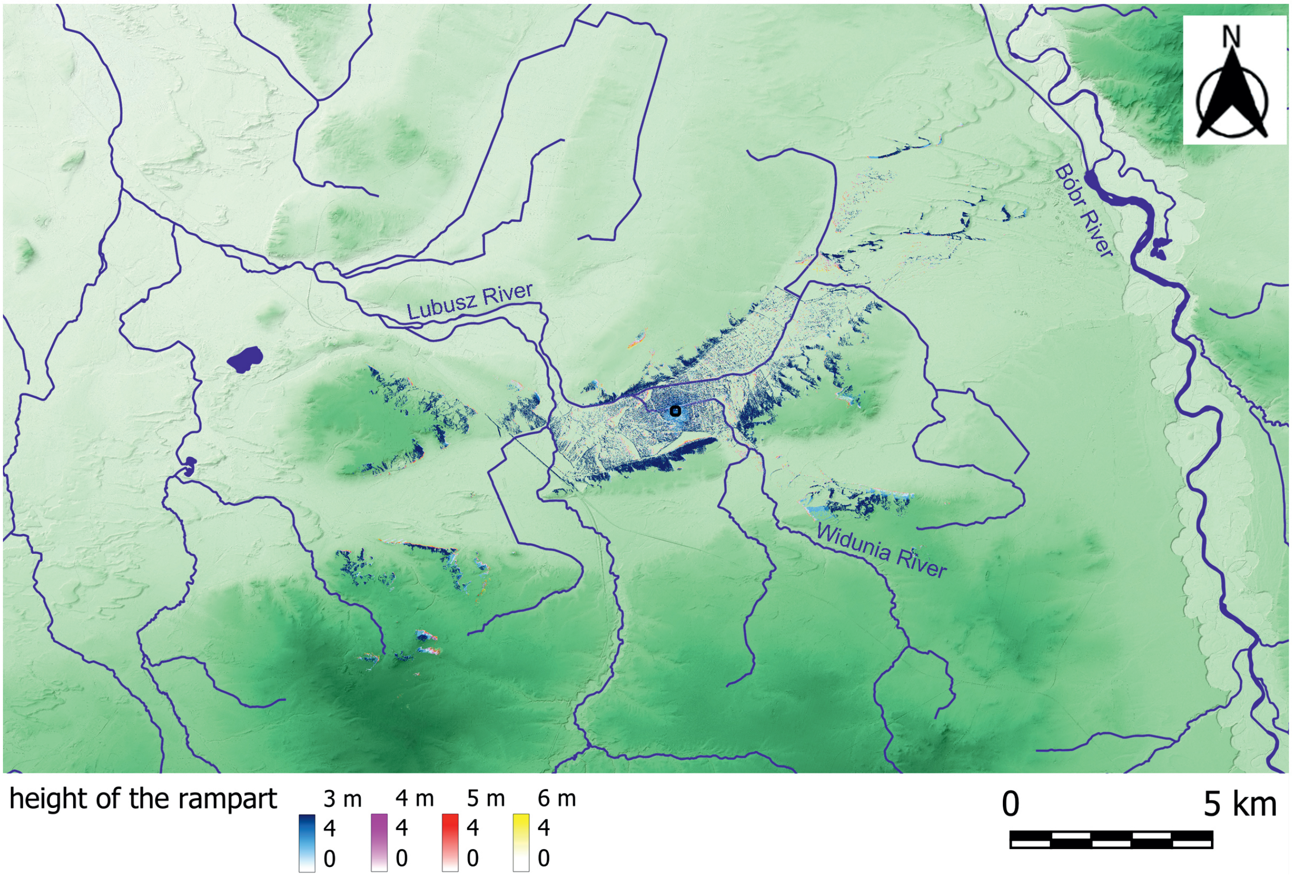

Fig. 11: Visibility from the ramparts of the Wicina fortified settlement. Binary viewshed analysis for four observers positioned on the ramparts on the N, E, W and S sides of the settlement, for the assumption that the ramparts were 3, 4, 5 and 6 m high above modern terrain, and in addition, the observer was 1.6 m high, radius of analyses was 10 km.

Oder River basins. Although wetlands are not impassable boundaries, being familiar with these areas makes crossing them much safer. In Mauss's[66] system of total services, this knowledge of crossing wetlands safely could be considered valuable. An analysis of visibility shows that an entire depression, surrounded by erosion spurs, was visible from the settlement's ramparts (Fig. 11). The site could be, therefore, considered a point of control along the route. Still, it is unlikely to be viewed as an oppressive authority ruled by force. Instead, it is about guiding potential Early Iron Age travelers, gaining their knowledge, (material) gratitude, and favor. We assumed earlier that the settlement served as a hub for long-distance trade, acquiring metal and distributing it to nearby regions. The inhabitants oversaw a portion of the trade route, facilitating passage through difficult terrain.

8.2 Local and non-local metal supply strategies in the Early Iron Age. Tracing the interconnectivity

Multi-directional connections of various scales and intensities between various LUC societies are evident at many sites. Similarities are apparent in funeral rituals, settlement forms, economy, ceramic forms, and metal inventories. At the start of the Iron Age, the significant social and cultural changes in the western part of the LUC area were influenced by interactions with the Hallstatt culture, which developed under the considerable influence of the Mediterranean and Pontic world[67]. In southwestern Poland, the contacts, ranging from stylistic adaptations to social changes, are also noted in archaeological evidence[68]. They included new settlement patterns, grave goods customs, and the appearance of imported objects, mainly from the Hallstatt culture

66 Mauss 1924.

67 Metzner-Nebelsick 2018.

68 Gedl 1991; Gediga 1992; Baron 2017.

zone and cultures north of the Italian Peninsula[69]. Social transformations are reflected in richly-furnished chamber burials of noblemen unprecedented in the Bronze Age[70]. Hallstatt imports and local imitations indicate, therefore, that the LUC community in southwest Poland underwent a profound social and economic transformation in the late 7th and early 6th centuries. Gediga[71] states that large parts of western Poland were not only influenced but were also among the Hallstatt culture's north-eastern groups; this, however, is disputed[72]. The LUC communities in the southwestern part of present-day Poland actively participated in the trade route that connected the Baltic Sea with the South. During the Hallstatt period, amber was quite common, as indicated by maps showing the distribution of amber discoveries in the Early Iron Age[73]. There has been much discussion about trade along the Amber Road. Recently, Golec *et al.*[74] presented detailed descriptions of the opportunities for trade along the Amber Road during the European Iron Age. These descriptions included the main route and its branches, from the south Baltic coast through central Europe to the Adriatic Sea and the Po River. The authors state that there was an exchange system along a route consisting of regional social centers. These centers were based on stable social organization and involved the redistribution of goods to subcenters. Therefore, the fortified Wicina settlement can be defined as one of these regional centers.

Unlike the place of extraction, where amber was common and treated mainly as a raw material intended for exchange[75], in the Hallstatt culture, considered a transit zone[76], its importance changed and increased. Golec *et al.*[77] explain that amber was retained in the transit zone and used for trading between different centers. The Hallstatt culture became a hub for exchanging goods from various Hallstatt centers and southern regions. Through the Amber Road, goods from the southern Baltic coast were transported south to northern Italy. In the opposite direction, raw materials and items that were scarce in central European centers, such as metal, glass, and other goods, were transported.

Our research shows that the Wicina settlement and the Bieszków hoard contained metal from many potential sources. Most of the metal comes from the Mediterranean – Sardinia, the southwestern Iberian Peninsula, and Cyprus. This is the first time that the presence of Cypriot copper deposits in Poland has been identified. A single sample is associated with Alpine or Slovak copper ore deposits. Additionally, a large fragment of pure copper appears to come from local deposits in the Holy Cross Mountains in south Poland.

The consistency of the lead isotope ratios measured for the copper raw material fragment (MAŚN 2011:157) with the few lead isotope data for the copper ores from the Holy Cross Mountains in south Poland, over 400 km away from Wicina, was the most surprising result of our research. The exact location and context of the discovery are not documented. However, it should be assumed that the metal fragment is of the same chronology as the settlement, considering that the settlement area was not resettled after the destruction caused by the Scythian invasion.

Even though there is a limited comparative lead isotope database for copper ore from Poland, and the context of the find is not well-known at this stage of the research, this analytical evidence suggests that there might have been copper exploitation in this region in the Early Iron Age. As mentioned earlier, some authors suggest that copper exploitation in the Holy Cross Mountains area may have begun as early as the Bronze Age[78]. Obtaining copper ores by the rift method, i. e., reaching mineral deposits along karst crevices, could be the easiest and most efficient way of prehistoric exploitation. These easily accessible deposits could have been mined in prehistory using mining tools typical of that period. However, much more analytical data combined with the site survey is needed to progress with this hypothesis.

It's interesting to note an issue related to the origin and distribution of metal. Eight items represent the metal associated with Sardinian ore deposits, including locally defined artifacts and casting waste. The local artifacts mainly consist of necklaces decorated with pseudo-twisting, a common form found in many sites on both sides of the Oder River[79]. This type of necklace is present in hoard inventories and has been discovered in other settlements from this period. Fragments of these necklaces are often found, as seen in the Bieszków hoard and other hoards near the Wicina settlement. It's likely that we're witnessing the use of raw metal sourced from abroad and its redistribution in the form of necklaces. Both casting waste and artifacts are made of tin bronze. The metal was either mixed in a local workshop in Wicina or imported as is.

69 Łuka 1959.
70 Gediga 2007; 2010.
71 Gediga 2010.
72 Baron 2017.
73 Dulęba/Markiewicz 2023, Fig. 1.
74 Golec *et al.* 2023, extensive additional literature therein.
75 Dzięgielewski 2017.
76 Golec *et al.* 2023.
77 Ibid.
78 Pyzik 1972; Gedl 1988; Kowalczewski 1993; Ciurej *et al.* 2021.
79 Michalak 2013.

Fig. 12: Highly schematic route of metal inflow into western Poland in the Early Iron Age (according to Ling *et al.* 2014, Fig. 21; with further literature therein). Map source: https://maps-for-free.com/, with modifications.

From the remaining probable sources of the raw material (Cyprus, Iberia, Alps/Slovakia), ingots and local-style artifacts were identified, indicating the use of the imported raw material in casting production.

Metal from Cyprus could have reached western Poland via the southern Carpathian route (Fig. 12). It is well known, however, that Sardinia has been trading with Cyprus since the Bronze Age[80]. Also, the Phoenicians were sailing to the western Mediterranean in search of metals[81]. Therefore, the metal from Cyprus, Sardinia, and Iberia was most probably transported either as one cargo or via separate routes to the north of the Italian Peninsula (Fig. 12). In such a scenario, metal coming from several sources in the Mediterranean reached the main branch of the Amber Road. Then, through long-distance trade, either direct, barter, or exchange between neighboring centers[82], it reached the Hallstatt world to the areas of today's western Poland. Other luxury items were transported together with the metal, mainly glass[83], numerous finds of which are known from this part of Poland, including the settlement in Wicina.

Artifacts proving contacts (most probably indirect) of LUC communities with the Mediterranean world include an amulet with the image of Pataikos-Pantheos modeled in so-called Egyptian faience. An amulet was discovered in 1981 in a child (3–4 year old) grave no. A in the Late Bronze Age-Early Iron Age cemetery in Cieszków, southwestern Poland[84]. Amulets with the image of Pataikos-Pantheos were quite popular in Egyptian civilization. As a sign of Egyptian influences, similar amulets were also found in other regions of the Mediterranean basin, mainly in Italy (Etruria) and the Phoenician civilizations such as Carthage or Sardinia[85]. An amulet from Cieszków is the only confirmed Egyptian artifact discovered in Polish lands dating back to the Late Bronze Age and Early Iron Age. It is worth noting that artifacts such as amber, blue glass beads, and a likely local imitation of an Etruscan bronze scoop were also unearthed in the same cemetery[86].

The possibility of local exploitation of Polish copper deposits was discussed above. It is possible that locally available copper ore deposits were penetrated in the Late Bronze Age and Early Iron Age. The exceptional quality and purity of the copper raw material indicate outstanding knowledge of the ore and the process of extracting and refining metallic copper. An exchange of specialists and knowledge through the existing trade routes could have influenced the development of local mining. It is worth recalling here the

80 Gale/Stos-Gale 1987; 2002; Stos-Gale/Gale 1992; Stos-Gale 2023.
81 Stos-Gale 2001; Eshel *et al.* 2019.
82 Golec *et al.* 2023.
83 Purowski *et al.* 2020.
84 Kosiński/Śliwa 1984
85 Kosiński/Śliwa 1984; Śliwa 2000.
86 Kosiński/Śliwa 1984.

recently isotopically confirmed local exploitation and processing of lead deposits in the area of LUC in the Early Iron Age[87]. The highest quality local raw materials obtained on a small scale could be redistributed between Early Iron Age social centers. The possibility of supplementing copper resources from long-distance exchange with locally obtained metal is highly tempting. However, to cool down the enthusiasm, it should be noted that confirmation of local copper extraction requires further long-term research, including extensive study of metal artifacts and copper ore mineralizations in the Holy Cross Mountains.

9 Conclusions

Our research has shown that the so-called Lusatian Urnfield Culture communities participated in long-distance trade of goods in the Early Iron Age. Exchanges related to Amber Road involved specific communities assuming the role of a center, intermediating in the exchange, and redistributing goods circulating between the north – the Baltic Sea- and the South – the Mediterranean world.

One prominent center was the fortified settlement in Wicina, along with the surrounding sites such as cemeteries, settlements, and hoards. The settlement was strategically positioned in an advantageous location, allowing for the regulation of movement through marshy and swampy areas. The significant amount of metal found in both the settlement and nearby hoards indicates the unique and stable development of the community's social structure. Our research shows that Wicina's prosperity was linked to three main factors: 1) the use of its strategic location to control a portion of the trade route, 2) involvement in long-distance trade and distribution of goods, and 3) access to metals (from both foreign and local sources) and luxury items.

This area, represented by the Wicina settlement and Bieszków hoard, acted as a transit area where various goods were exchanged and redistributed within the local market. Elemental and lead isotope analyses revealed that raw metal material from distant sources was being processed into local products.

The research results gained by using various analytical methods indicate that metal from multiple Mediterranean sources, including Sardinia, Cyprus, and Iberia, was distributed throughout Central Europe during the Early Iron Age. It is possible that this metal reached Central Europe through merchants controlling Mediterranean trade or through separate events. The exchange system during the Early Iron Age was complex and likely institutionalized but varied in character in different regions along the trade route.

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