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A complex case of trade in metals: The origin of copper used for artefacts found in one hoard from a Late Bronze Age Lusatian Urnfield Culture in Poland

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ABSTRACT

Metal artefacts from Bronze Age hoards have routinely been used to study interregional contacts. Their stylistic and typological features helped distinguish local products and imports by appearance. In the last 40 years, combined lead isotope and chemical analyses of metals have been widely applied to verify hypotheses based on style and typology. This paper is a comprehensive typological and analytical study of a metal item hoard discovered in Paszowice, SW Poland. In the Bronze Age, the area was inhabited by the Lusatian Urnfield culture (ca. 1350/1300–800/750 BC) communities. We expected that at least some of the artefacts would be local products fashioned according to foreign stylistic patterns. The research aimed to determine whether a 'classical' stylistic analysis combined with provenance studies of metals would allow more decisive conclusions. This combination of methods could also show how the metal reached the Lusatian Urnfield culture settlement zone. We conducted a detailed typological and chronological analysis to map the distribution of similar artefact types. It demonstrated that stylistic matches for the artefacts from Paszowice occur mainly in NE Hungary, S Czech Republic, Slovakia, and Romania. Selected metal artefacts (both tin bronze items and raw copper objects) from Paszowice were also analysed for their chemical (EPMA) and lead isotope (MC ICP MS) compositions. The study revealed many copper sources used for their production, ranging from the nearest copper mines in the Slovak Ore Mountains, through Eastern Alps and mines in Sardinia, to possibly the Iberian Peninsula. In this way, we identified the potential trade routes by which metal could get to SW Poland: the southwestern and southeastern routes and the Mediterranean-Danube route. The Iberian metal might have also reached the study area from the north – through its redistribution by Scandinavian traders. Our results show that metal from many sources circulated in central Europe during the Late Bronze Age. The Lusatian Urnfield communities were part of a pan-European exchange network and maintained extensive long-distance contacts, allowing metal acquisition from various sources.

1. Introduction

The Lusatian Urnfield communities in present-day Poland belonged to a great circle of European Urnfield cultures that emerged in the Late Bronze Age (ca. 1350/1300–800/750 BC) and continued into the Early Iron Age and pre-Roman Iron Age (ca. 800/750–300/250 BC; Dzięgielewski, 2017). They inhabited mainly the Oder and Vistula river basins and the neighbouring regions of present-day Germany, Bohemia, Moravia, and Slovakia. These communities were not homogenous but rather clustered various Urnfield-type cultures developing regionally according to specific rules and influenced by various external and internal factors (Kaczmarek, 2017).

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The Lusatian Urnfield assemblages include many locally made metal artefacts, comprising, among others, the so-called Lusatian socketed axes and knobbed sickles (Gedl, 1995; Kuśnierz, 1998). The individual Lusatian groups interacted regularly, and there was a continuous exchange of goods and ideas, as the similarity of ceramic and bronze artefacts (e.g. Gardawski, 1979) shows. However, there is no doubt that the Lusatian Urnfield people participated in long-distance exchange since 'foreign types' of objects are also frequently discovered at their sites (imports or imitations).

The southwestern and western parts of the Lusatian Urnfield zone, including Silesia and Greater Poland, are associated with the so-called Oder Urnfield Culture (e.g. Kaczmarek, 2017). Typological studies show that the area maintained extensive long-distance contacts. The most common southern imports (from NE and E Carpathian Basin, Eastern Alpine zone) included tools, weapons, and dress accessories. There are also artefacts originating in the north and northwest (the Nordic zone with Mecklenburg and northern Brandenburg), the west (middle and the upper Elbe basin), S Germany, Italy, and the Mediterranean (Gediga, 1967; Blajer, 2001; Przybyła, 2009; Kaczmarek, 2012).

Trade routes visualised in archaeological studies are traditionally based on the distribution of stylistically, typologically and chronologically similar artefacts. Typological studies of metal artefacts have frequently been adopted as a primary criterion for determining the directions of long-distance contacts (Sprockhoff, 1930; Hansen, 1991; 1994). However, the development of chemical and lead isotope analyses in the last 40 years introduced a new tool for identifying metal exchange (Gale and Stos-Gale, 1982; Ling et al., 2019; Artioli et al., 2020; Berger et al., 2022). Combined lead isotope and chemical analyses have seldom been applied in metal provenance studies of Poland's Bronze and Early Iron Age artefacts. However, the number of such analyses is increasing, as several new papers show (Stos-Gale, 2019; Kowalski et al., 2019; Nowak et al., 2022). Five Bronze Age objects from Poland were also analysed and published in an article by Niederschlag et al. (2003).

This paper presents an artefact assemblage from the Oder Urnfield culture's southwestern part. In autumn 2015, a hoard of 34 metal items was discovered by chance in a freshly ploughed field near the village of Paszowice in Lower Silesia, SW Poland (Fig. 1), and handed over to the Regional Museum in Jawor. The site is situated on the edge of the Sudeten Foreland (Kondracki, 2009). The assemblage includes artefacts that have never co-occurred in a single hoard recorded in Poland. It contained, among other things, non-local types of axes and sickles, metal raw material and casting waste. Intriguingly, unworked metal is rarely found in Polish hoards (Blajer, 2001). The preliminary typological study indicated that the hoard includes artefacts that stylistically match the Central Danubian types. Visual inspection of these objects revealed casting jets and seams, indicating they had possibly never been used. As indicated above, the deposition model did not reflect local trends either.

To determine the geographical distribution of these specific items, we conducted a detailed typochronological study. The study was followed by lead isotope and chemical analyses of selected artefact types, as we intended to check if their typological features and the copper ore from which they were made originated in the same places. Our working hypothesis was that some artefacts (e.g. unfinished axes and sickles) were made locally near Paszowice. The raw metal would have been imported because Poland has no proven prehistoric copper and tin extraction sites. Our goal was to determine the possible sources of these metals and to trace the long-distance exchange network in which the Late Bronze Age Lusatian Urnfield communities participated. Another objective was determining if the stylistically exotic artefacts could be cast locally.

Based on the above, we can define the following research questions:

- Where are the closest typological matches to the selected artefact categories?

Fig. 1. Location of the Paszowice hoard.

- Where did the raw material come from?
- Does the state of the artefacts (lacking use-wear traces and visible casting nobs and pouring channels) indicate their local origin? Can we connect the presence of casting jets, metal lumps and a casting cake with the activity of the so-called "itinerant bronzesmiths"?
- Based on the results, can we identify the routes through which the metal reached central Europe?

2. Materials

2.1. Hoard inventory. Typological and chronological analyses

The hoard included 34 metal artefacts listed in Table 1 (Table 1). Most items were covered with an intense green patina, but their state of preservation was good.

2.2. Tanged sickles

In Poland, tanged sickles are relatively rare. These farming tools occurred in the local Late Bronze Age material between Period III (Br D/Ha A_1; ca. 1300–1150 BC) and Period V (Ha B_2/Ha B_3; ca. 900–700 BC). They were most common in the Upper and Middle Silesia and the western part of Greater Poland (Gedl, 1995, 79–80; Blajer, 1999, 45). The Paszowice hoard contains six new tanged sickles, two intact (Fig. 2.28, 21), two broken (Fig. 2.23–24), as well as a blade (Fig. 2.15) and a handle fragment with incisions (Fig. 2.16). The standard typological features of the sickles selected for the analyses (Fig. 2.21, 23–24) are their curved inner handle ribs, which terminate at the beginning of the blade. Based on their bases' shape and spurs' presence, they can be divided into two further typological groups: 1. V-shaped base with (Fig. 2.28) or without spur (Fig. 2.21); 2. straight base with spur (Fig. 2.23–24).

The distribution of sickles typologically similar to specimen no. 28 from Paszowice (Fig. 2.28) covers the present-day Czech Republic, Austria, Hungary, Croatia, Romania, and Transcarpathia, W Ukraine (Tarbay, 2018, 72, List 51, Map 85). Their design most likely originated within the Czech Republic, where the earliest specimens appeared in bronze hoards dated between Br D/Ha A_1 and the Ha A_2. Those hoards include: Bohunice, Ha A1; Plešivec 3, Br D/Ha A_1; Sobůlky, Ha A_1 and Železné, Ha A_2 (Říhovský, 1989, Pl. 22.343, 345–347, Pl. 23.350–351, 353, 355; Kytlicová, 2007, Pl. 34d.7). Examples from later Ha A_2/Ha B_1 hoards are also known: e.g. Praha–Suchdol 2, Ha A_2/Ha B_1; Štramberk 4, Ha B_1 (Říhovský, 1989, Pl. 23.358–359; Kytlicová, 2007, Pl. 53.42). In Austria (e.g. Grünbach am Schneeberg IIIa, Lauermann and Rammer, 2013, Pl. 40.2, Pl. 41.2), in the Carpathian Basin and northern Balkans, such sickles were in use later: between the Ha B_1 and the Ha B_2. They occurred most abundantly in the eastern part of the Carpathian Basin, in the so-called Hajdúböszörmény-type hoards from Transylvania (Romania) and E Hungary: Arad 2, Ha B_1; Ároktő–Tiszadorogma, Ha B_1; Hajdúsámson 4, Ha B_1; Hida, Ha B_2; Jászkarajenő, Ha B_1; Kapelna, Phase IV/Ha B_1/B_2; Karcag, Ha B_1; Mezőkövesd area, Ha B_1; Polgár–Folyás-Szilmeg, Ha B_1; Sălard, Ha B_1; Szombathely, Ha B_1; Zagon 2, Ha B_1; Zagon, stray find; Zsáka I/stray finds; Velikaya Began'/Zmeevka, uncertain hoard (Kemenczei, 1966, Pl. 13.4; Vinski-Gasparini, 1973, Pl. 110.19; Petrescu-Dîmbovița, 1978, Pl. 224.27, Pl. 239.13, Pl. 251a.15, Pl. 259c.11–13, Pl. 282.1061; Kobal', 2000, Pl. 91.5; Mozsolics, 2000, Pl. 38.13, Pl. 45.6, Pl. 53.7, 11–12, Pl. 74.11, 13; Tarbay, 2018, Pl. 122.54, Pl. 329.63, Pl. 457.44). All these matches suggest that discussed sickles circulated between Br D/Ha A_1 and Ha B_2. Specimens outside the Czech Republic, particularly the Carpathian finds, mainly represent the Ha B_1 period. At the same time, this typological sub-type seems absent in Poland (Gedl, 1995). Based on the relative chronological pattern discussed above and the find distribution, the Paszowice hoard is related to the sickle's later form.

No. 21 is an as-cast tanged sickle with an unremoved casting jet on its back (Fig. 2.21). It has a V-shaped base and a curved inner handle rib. Its

Table 1
The inventory of the hoard of metal items from Paszowice.

No.	Mus. inv. no.	Artefact	Size (cm)	Weight (g)	Analysis	Figure
1	MJ/2016/32	Metal lump	3 × 3.5	39	EPMA, MC ICP MS	2.1
2	MJ/2016/33	Metal lump	2.5 × 4	46	EPMA, MC ICP MS	2.2
3	MJ/2016/31	Metal lump	1.5 × 6	60	EPMA, MC ICP MS	2.3
4	MJ/2016/34	Metal lump/undefined metal object	L: 5; W: 3; thick: 2.5	146	EPMA, MC ICP MS	2.4
5	MJ/2016/3	Metal ring	⌀ 3.7	11	–	2.5
6	MJ/2016/4	Metal ring	⌀ 3.3	5	–	2.6
7	MJ/2016/5	Metal ring	⌀ 2.9	7	–	2.7
8	MJ/2016/6	Metal ring	⌀ 2.5	2	–	2.8
9	MJ/2016/7	Metal ring	⌀ 2.1	2	–	2.9
10	MJ/2016/8	Metal ring	⌀ 1.7	1	–	2.10
11	MJ/2016/9	Metal ring	⌀ 1.6 × 1.8	1	–	2.11
12	MJ/2016/10	Metal ring	⌀ 2.4	8	–	2.12
13	MJ/2016/29	Fragment of a mining pickaxe	L: 7; W: 2–3; thick: 1,5–2	254	–	2.13
14	MJ/2016/17	Casting jet	L: 3.5; ⌀ of the socket: 1.8 × 2.5	73	–	2.14
15	MJ/2016/24	Fragment of a tanged sickle	L: 4.5; W: 3.5; thick: 0.2–0.3	27	–	2.15
16	MJ/2016/26	Fragment of a tanged sickle	L: 2; W: 2.5; max. thick: 0.4	11	–	2.16
17	MJ/2016/27	Fragment of a sheet metal object	2.5 × 4; ⌀ of the hole: 1	4	–	2.17
18	MJ/2016/18	Fragment of a socketed axe	L: 7.2; W: 4.2; ⌀ of the socket: 2 × 2.4	89	–	2.18
19	MJ/2016/21	Socketed axe	L: 12; W of the blade: 5.5; ⌀ of the socket: 2.5 × 2.7	357	EPMA, MC ICP MS	2.19
20	MJ/2016/20	Socketed axe	L: 13.5; W of the blade: 5.5; ⌀ of the socket: 2.7 × 3.7	569	EPMA, MC ICP MS	2.20
21	MJ/2016/16	Tanged sickle	max W of the blade: 4.5; L: 14.2; height: 13 (14.5 with the pouring channel)	312	EPMA, MC ICP MS	2.21

(*continued on next page*)

Table 1 (*continued*)

No.	Mus. inv. no.	Artefact	Size (cm)	Weight (g)	Analysis	Figure
22	MJ/2016/30	1/2 of a casting cake	⌀ 9.1; W: 4.5; max thick: 1.5	253	EPMA, MC ICP MS	2.22
23	MJ/2016/15.23	Tanged sickle (in two fragments)	L: 14; W: 2.2–4; thick: 0.1–0.3; height: 10.7	80 and 48	EPMA, MC ICP MS	2.23
24	MJ/2016/13.25	Tanged sickle (in two fragments)	W: 2.5–3.1; L: 13.5; height: 10.2; thick: 0.2–0.4	98 and 22	EPMA, MC ICP MS	2.24
25	MJ/2016/28	Casting jet	height: 3.5; ⌀ of the upper part: 2.5 × 3	62	EPMA, MC ICP MS	2.25
26	MJ/2016/19	Socketed axe	L: 11,6; W of the blade: 5.5; ⌀ of the socket 3.2 × 3.6	261	–	2.26
27	MJ/2016/22	Socketed axe	L: 12; W of the blade: 4; ⌀ of the socket: 3 × 3.3	310	–	2.27
28	MJ/2016/14	Tanged sickle	W of the blade: 2.1–3.1; L: 13.5; height: 11.8	130	–	2.28
29	MJ/2016/1	Spearhead	L: 13.5; W: 4; ⌀ 2.3	86	–	2.29
30	MJ/2016/2	Fragment of a plate	⌀ 11; thick: 0.1	48	–	2.30
31	MJ/2016/11	Fragment of a wire	L: 5.5; ⌀ 0.7	9	–	2.31
32	MJ/2016/12	Fragment of a wire	L: 6.5; ⌀ 0.7	12	–	2.32

shape is comparable to no. 28 but lacks the spur on the handle. Such tanged sickles are rare in central Europe. In Slovakia, a similar specimen was recorded in Zemplínske Kopčany as a stray find. A local study linked it stylistically to the Ha B_1 (Furmánek and Novotná, 2006, 102–104, Pl. 29.459). Matching tanged sickles are also found in the Czech Republic, in hoards dated to the Ha B_1 period: Chloumky 1, Hemže (Kytlicová, 2007, 258, 261, Pl. 181B.8, Pl. 186B.2).

Tanged sickles nos. 23–24 (Fig. 2.23–24) have similar typological parallels to no. 21. Except for one specimen from Jevičko (Ha A), Czech Republic, most of their counterparts come from Ha B_1 hoards discovered in the E Carpathian Basin, particularly the Great Hungarian Plain: Hajdúsámson 4, Ha B_1; Mezőkövesd area, Ha B_1; Szendrőlád, Ha B_1; Szentes–Nagyhegy 3, Ha B_1; Rohod 4, Ha B_1 (Mozsolics, 2000, Pl. 38.13, Pl. 53.10, Pl. 82.7, Pl. 93.10–11; Tarbay, 2018, Pl. 207.13). A sickle found in a multi-period hoard in Lovasberény, within the Transdanubian Urnfield culture zone, is an exception. However, it was also deposited in the Ha B_1 period (Tarbay, 2018, Pl. 168.70).

2.3. Spearhead

The spearhead has a relatively long socket and an almond-leaf-shaped blade (Fig. 2.29). Its midrib is diamond-shaped. The narrow sides of its socket feature two holes which are the remains of the casting core's fixing system (Bingelli, 2011, Fig. 1.3; Trommer and Bader, 2013; Nowak, 2016, 79, Fig. 2.1). They also play a role in the hafting of the bronze part to the wooden shaft, usually with wooden pegs (see Tarbay et al., 2021). This type of spearhead frequently occurs with materials dated between Bronze Age Period III (Br D/Ha A_1) and V (Ha B_2/Ha B_3) (Gedl, 2009, 50–52). In Polish contexts, most such spearheads were discovered in Silesia and Greater Poland, but several specimens come from Lesser Poland and Pomerania. At the same time, they rarely appear in Lower Lusatia, Warmia and Masuria (Gedl, 2009, 52–53). Typologically comparable spearheads were also found in the Carpathian Basin. Their production and deposition chronology is extensive, covering approximately the same time as in Poland (see Bader, 2015, 376–377, Tab. 1). Being a common and widely distributed type across time and space, it cannot be dated precisely. Based on the chronological position of other finds in the Paszowice hoard, this spearhead may stylistically represent the latest part of the Ha B period.

2.4. Socketed axes

The Paszowice hoard contained four completely preserved socketed axes and one axe fragment. While they represented various types (Fig. 2.18–20, 26–27), they were all characteristic of the Carpathian Basin and its neighbouring areas.

No. 19 (Fig. 2.19) might be classified as a Palotabozsok-type socketed axe, according to Valentin Dergačev (Dergačev, 2002). This unique object has an emphasised collar, one loop, and a narrow body that terminates in a fan-shaped blade with a straight cutting edge. The wider sides of the axe are decorated with identical cast ribs consisting of one horizontal rib, one V-shaped rib, one curved Y rib, and four curved side ribs. Palotabozsok-type axes date back to between the Ha A_1 and Ha B_1 periods. The pattern on the axe from Paszowice is unique, with only a few distant matches among the Debrecen-type axes dated around the Ha B_1 period (e.g. Dergačev, 2002, 174–176; Tarbay, 2018, 40–41, Fig. 31.14, 15, 20).

Axe no. 26 has a thick rim, a hexagonal-sectioned body, and one loop. Its blade is fan-shaped and has a curved cutting edge. The axe is decorated with two curved side ribs; one terminates below the loop, and the other is below the rim (Fig. 2.26). The tool belongs to the so-called socketed axes with beaked mouths. Its rim part broke, but, likely, it had an asymmetrical rim originally. Identical socketed axes have recently been discussed by J. G. Tarbay (Tarbay, 2019, 289, Fig. 8, Fig. 11.1, Appendix List 3). The core distribution area of this type is NE Hungary, W Ukraine, and Transylvania (Romania). Such axes were also found in Moravia, Slovakia, and Serbia (Tarbay, 2019, 289, Fig. 8, Fig. 11.1, Appendix List 3). Such artefacts might generally be dated to the Ha B_1 period in their core distribution area. In W Ukraine, their chronology covers the Ha A_2/Ha B_1 and Ha B_2/Ha B_3 periods. Poland's best match to the Paszowice specimen is perhaps a stray axe with a symmetric mouth found in Kraków (Kuśnierz, 1998, 12, Pl. 1.9).

The no. 27 socketed axe (Fig. 2.27) can be classified as a Debrecen-type axe after Valentin Dergačev's typological scheme (Dergačev, 2002, 174–176). The tool has a straight, emphasised collar, a socket with a lenticular cross-section, and one loop. It is decorated with three cast parallel ribs and two V-shaped ribs. Debrecen-type axes with identical decorative combinations (Wanzek, 1989, Fig. 9.2f) are mainly present in Transylvania (Romania), Hungary, W Ukraine, and the Czech Republic. Their deposition lasted between the Ha A_1 and Ha B_2 periods but peaked in Ha B_1 (Wanzek, 1989, Fig. 9.2f; Tarbay, 2018, 41, List 16.6, Map 22): Delniţa, Ha B_2; Corneşti, Ha B1; Gyöngyössolymos 1, Ha A_1; Jászkarajenő, Ha B_1; Jupalnic, Ha A_2; Krekhov, Period V (Ha B_1/Ha B_2), Letovice (uncertain hoard); Nagykálló 1, Ha B_1; Nyíregyháza 4, Ha B_1; Regöly 3, Ha A_1; Plăieşti, Ha B_1; Şpălnaca 1, Ha B_1; Şoarş, Ha B_1; Tăuteu, Ha B_1; Transylvania 1 (stray find); Ţelna, Ha B_1; Zaliztsi, Period IV/V (Ha A_2–Ha B_2) (Żurowski, 1949, Pl. 7.1, Pl. 11.7; Kemenczei, 1972, Pl. 5.2; Petrescu-Dîmboviţa, 1978, Pl. 220b.1, Pl. 237C.7, Pl. 243b.2, Pl. 244.15, Pl. 247b.10, Pl. 248B.4, Pl. 255c.5, Pl. 276b.2; Mozsolics, 1985, Pl. 29.1; Říhovský, 1992, Pl. 52.761; Mozsolics, 2000, Pl. 61.6; Kacsó, 2010, Fig. 1.4; Tarbay, 2018, Jászkarajenő no. 9). A casting mould for producing this particular axe type was identified at the Regöly-Földvár settlement in southern Transdanubia, W Hungary (Kőszegi, 1988, 175, Pl. 8F.33).

Artefact no. 20 (Fig. 2:20) also belongs to the group of Debrecen-type axes. The tool has a nearly hexagonal-sectioned body. It features a thick rim, one loop, and one horizontal rib along its wider sides. Among Poland's Late Bronze Age finds, perhaps the axe from the Witów hoard (Ha A), Lesser Poland, can be considered matching. It should be noted, however, that it is slightly different as it has a beaked mouth (Kuśnierz, 1998, 12–13, Pl. 1.13). Axes similar to no. 20 occurred in Ha A_1–Ha B_1 contexts in Austria, the Czech Republic, Slovakia, Romania, Bosnia and Hercegovina, W Ukraine, W Hungary, and N Croatia: Austria (stray find); Bizovac, Phase II; Boković, Ha B_1; Budinšćina, Phase II; Bystřice pod Hostýnem, stray find; Čajkov (stray find); Domažlice (stray find); Frost im Weißenbachtal (uncertain hoard); Gemer (stray find); Hummersdorf (stray find); Kamena Gorica, Phase IV; Konrádovce (stray find); Mačkovac, Ha B_1/Ha B_2; Malé Kršteňany (stray find); Sazovice, Ha A_1; Slovakia (stray find); Niederwegscheid (stary find); Suskovo 1, Ha A_2; Szentgáloskér, Ha A_1; Uioara de Sus, Ha A_1; Uherské Hradiště (stray find) (Novotná, 1970, Pl. 39.702, 706, 708, Pl. 40.727, 728; Vinski-Gasparini, 1973, Pl. 37.9, Pl. 81.A.3, Pl. 126.7; Mayer, 1977, Pl. 73.1005–1007; Petrescu-Dîmboviţa, 1978, Pl. 162.40–41; Mozsolics, 1985, Pl. 113.19; Říhovský, 1992, 196, Pl. 46.688–690; Pászthory and Mayer, 1998, Pl. 69.1025; Kobal', 2000, Pl. 74.19; König, 2004, Pl. 40.42, Pl. 49B.6; Salaš, 2005, Pl. 269.1).

The Paszowice hoard also contains a small axe fragment with a loop, a thick collar, and a blade emphasised with a thick rib at the section of the blade-socket interface (Fig. 2.18). It is decorated with a so-called pseudo-wing and three horizontal ribs immediately below the rim. Such axes are known from Hungary, Slovakia, and Italy: 'Abruzzi' (stray find); Boutigny, Bronze Final II; 'Italy' (stray find); central Italy (stray find); Cluj (stray find); Csorvás (stray find); Duchcov casting mould, Ha A; Gąsawa (stray find); Ljubljana marshes (stray find); Ohrazenice (stray find); Mahrersdorf, Ha B_1/Ha B_2; Mezőkövesd vicinity, Ha B_1; Miljana, Phase IV; Mukachevo II, Ha A_2; Příštpo (stray find); Ripatransone (stray find); Rybna (stray find); Stična area (stray find); Szajla, Ha B_1; Szendrőlád, Ha B_1; Székesfehérvár-Szedreskert (stray find); Nitra County (stray find); Žitný Ostrov (stray find); Viničky 2, Ha B_1 (Schmidt, 1875, Fig. 6; Hampel, 1877, Pl. 9.16; 1896, 46–47; Szendrei, 1888, Pl. 4.1; Smodić, 1956, Pl. 2.1; Novotná, 1970, Pl. 38.683; Mohen, 1977, 119, 137, 428/Chalo-Saint-Mars/91-I; Carancini, 1984, Pl. 132.3894–3895, 3898; Kemenczei, 1984, Pl. 122.5; Mozsolics, 1985, Pl. 243.27; Koštuřík and Kovárník, 1986, no. 101, 232, Fig. 32; Říhovský, 1992, Pl. 61.871; Kacsó, 1994, Fig. 4.4; Šinkovec, 1995, Pl. 17.95, 101; Blažek et al., 1998, Pl. 3.12; Kuśnierz, 1998, Pl. 4.48, Pl. 4.52; Kobal', 2000, Pl. 77c.5; Lauermann and Rammer, 2013, Pl. 45.1; Tarbay, 2019, 289–292, Pl. 5.9, Pl. 8.12–13, List 4). Finds resembling the axe from Paszowice originated mainly between Ha A and Ha B_1/Ha B_2, and the discussed specimen is most characteristic of Ha B_1.

Artefact no. 14 (Pl. 2.14) is likely a casting jet fragment from a narrow axe similar to no. 19 (Pl. 2.19). Matching axe jet fragments occurred in Lovasberény (Ha B_1) and Beremend (Ha B_1) (e.g. Tarbay, 2018, Pl. 165.58–59, Pl. 259.10).

2.5. Mining pickaxe

The Paszowice hoard yielded an unusual tool fragment in the shape of an oblong bar, widening towards one end (Fig. 2.13). It has a quadrangular cross-section with slightly rounded edges. The object's surface on one side is smoother and has more rounded edges than on the other side, which is uneven, "rough," and with traces of metal solidification. At the narrow end, the metal has cracks. Apart from the "raw" side, all sides have traces of plastic working (forging).

The artefact is a Mitterberg-type copper mining pickaxe, distinguished by a quadrangular cross-section and lack of wings (Mayer, 1977, 226–233). The second popular type usually has a hexagonal cross-section and wings: e.g. Hallstatt, Holašovice, Uioara de Sus, Szentendre (Drescher, 1968, 135; Vulpe, 1975, Pl. 45.457–459, Pl. 46.460–464; Mayer, 1977, Tab. 92.1357–1358; Boroffka, 1995, 81, 103, Tab. D; Chvojka, 2010; Windholz-Konrad, 2012, Figs. 4–5; Nessel, 2013, 427, 173:1).

The discussed tool fragment broke off just below the socket base. The lower part is also missing. The artefact is the northern- and easternmost located evidence of a Mitterberg-type pickaxe. Such pickaxes are predominantly recorded in the Austrian mining areas, including Mitterberg Mine 27, Paß Lueg (hoard, Ha A_1), Töging a. Inn, and Mahrersdorf (Ha B_1/Ha B_2) (Mayer, 1977, 226–227, Pl. 90.1342–1344, Pl. 91.1345–1352, Pl. 92.1353–1355; Pászthory and Mayer, 1998, 177, Pl. 76.1175–1175A; Stöllner and Schwab, 2009, 151; Mödlinger and Trebsche, 2020, Fig. 3.3; Thomas, 2022, Fig. 3, Fig. 5). A fragmented specimen similar to the Paszowice pickaxe was found in the Ha A_1 mega-hoard from Márok, southern Transdanubia (Mozsolics, 1985, Pl. 90.11). The site of Sebechleby in Slovakia yielded a complete pickaxe associated with the Mitterberg type (Hampel, 1896, 32, Fig. 3; Nevizánsky and Prohászka, 2019, Fig. 5). Pickaxe fragments were also identified by Josip V. Kobal' in Transcarpathian (W Ukraine) hoards like 'Velikaja Began/Zmeevka/Orosievo' and Boržavskoe, Ha A_1 (Kobal', 2000, 76, 98, Pl. 51.25, Pl. 94.5).

The dating of mining pickaxes matching the Paszowice find is not entirely secure, as they represent a long tradition of standard mining tools. Two of them (Paß Lueg, Márok) were found in a context dated to Ha A_1 (first half of Period III) (Mayer, 1977, 227; Mozsolics, 1985, 146–149), while Mahrersdorf was associated with Ha B_1 (Mödlinger and Trebsche, 2020). According to Peter Thomas, the oldest variants of Mitterberg-type pickaxes were most likely long and massive, followed by the short and massive Paß Lueg variant and the latest Mahrerdorf variant, which was long and thin (Thomas, 2018, Fig. 218). The fragment from Paszowice probably comes from a massive pickaxe of the older type.

2.6. Small rings

The hoard found in Paszowice contained eight small, annular rings (Fig. 2.5–12), mainly with a circular or quadrangular cross-section. One ring has a U-shaped cross-section. The artefacts have undecorated surfaces. Similar rings were used in southwestern Poland throughout the Bronze Age until the Early Iron Age (Baron et al., 2019).

2.7. Unclassifiable artefacts

Among the unclassifiable artefacts is a disc fragment with a rectangular hole in its centre (Fig. 2.30). The function of this object is unclear. A similar artefact is known from Liptovská Mara (SK) (Novotná, 1981, 312–313, Fig. 2). A small, bent sheet metal fragment with a perforated hole is also an unclassifiable artefact (Fig. 2.17). Additionally, the assemblage contains two fragments of thick, bent wires (Fig. 2.31–32), which may have belonged to rings or bracelets with circular cross-sections.

2.8. By-products and ingots

The hoard contained two casting jets (Fig. 2.14, 25), three irregular metal lumps (Fig. 2.1–4), as well as half of a plano-convex ingot (Fig. 2.22). These objects lack typo-chronological value.

2.9. Typochronological character

Most chronologically sensitive artefacts from the Paszowice hoard might be dated to the Ha B_1 period (second half of Period IV). It applies to tanged sickles (nos. 21, 23–24, and 28) and some socketed axes (nos. 18, 26–27). The Palotabozsok-type socketed axe no. 19 might have originated between Ha A_1 and Ha B_1. Similarly decorated Debrecen-type axes link it to the latter period. The shapes of the remaining finds did not change through the ages (e.g. spearhead no. 29, pickaxe no. 13) or are unsuitable for a typochronological analysis (e.g. annular rings nos. 5–12, lumps and plano-convex ingots nos. 1–4, sheet metal no. 17, casting jet nos. 14, 25, sheet disc no. 30, bracelets nos. 31–32).

The distributions of the typologically characteristic artefacts, including socketed axes, pickaxes, and tanged sickles matching those from the Paszowice hoard, are highlighted in Fig. 3. The results of the typochronological analysis demonstrate that the hoard represented the metalworking tradition from the Carpathian Basin, particularly S Slovakia, N Hungary, and Transylvania. Moreover, considerable quantities of similar artefacts were found in the Czech Republic, especially in Moravia. Typologically similar finds also come from the northern Balkans and the eastern Alps. No significant typological similarities exist with the contemporaneous metalwork found in Poland or other regions close to Paszowice.

3. Metal analysis methods

As the sampling permit limited the number of artefacts we could examine, only eleven specimens were selected for chemical and lead isotope analyses. Some were picked because their shape possibly indicated local casting (casting jet no. 25; axes and sickles in the as-cast form – nos. 19–21, 24). The plano-convex ingot no. 22 and metal lumps (nos. 1–4) might have been imported raw materials, so we sampled them to compare with finished as-cast products and casting waste. In this way, we intended to find out what raw material was used by the local Lusatian Urnfield communities. For further comparisons, we also analysed the finished sickle no. 23. The tests aimed to determine the casting alloy's chemical composition and whether the assemblage is chemically homogeneous. The second goal was to determine the provenance of copper using lead isotope analysis. We also wanted to check whether items of typologically southern provenance displayed a specific chemical and lead isotope profile.

3.1. Electron probe microanalyses (EPMA)

Eleven artefacts from the hoard were sampled to analyse their elemental compositions (the selected items are marked with a red circle in Fig. 2). The samples were taken using a micro-drill and HSS drills with 1–2 mm diameters.

Samples were embedded in epoxy resin and polished with diamond paste until a perfectly flat surface was obtained. Photographs of the polished samples were taken with an optical microscope and a Scanning Electron Microscope (SEM). EPMA were carried out at The Polish Geological Institute – National Research Institute (PIG-PIB) in Warsaw using the Cameca SX100 microprobe. Electron beam parameters were set to 15 kV accelerating voltage and 20nA beam current. The electron beam diameter (spot size) was set to 50 µm (samples 1, 3, 4, 19, 20, 24, 25) and 10 µm (2, 21, 22, 23), depending on the available surface area of the sample. Information on standards, X-ray lines and other analytical conditions is shown in the supplementary material.

In most cases, samples were not completely homogenous. In order to obtain statistically relevant values, approximately 20 areas (15 to 22) per sample were analysed.

3.2. The lead isotope analyses

Eleven metal artefacts from the hoard found in Paszowice were analysed for their stable lead isotope ratios (marked with the red circle on the figure No. 2). The analyses have been made at the Isotope Laboratory, School of Earth Sciences of the University of Melbourne, using a MC ICP MS (Multi-collector Inductively Coupled Plasma Mass Spectrometry). Powdered samples as submitted were weighed into 12 ml Savillex beakers and reacted with 2 ml of hot 7 M HNO_3 overnight. The blue solutions (with occasional undissolved specks) were dried in HEPA-filtered air. Pb was extracted using a single pass on a 0.2 ml bed of AG1-X8 (100–200 mesh) anion resin, with the HBr-HC_l technique.

After strong dilution, Pb isotope ratios were measured on a Nu Plasma MC-ICP-MS over the course of 2 separate sessions, using thallium doping to correct for instrumental mass bias (Woodhead, 2002). The thallium doping technique is expected to yield iPb/204Pb results that have an external precision of 0.04–0.08% (2std dev). This is confirmed by the results for the SRM981 Pb standard done in the same sessions. Seven analyses of Pb extracted from the BCR-2 reference basalt show greater variability but the average is in excellent agreement with the GeoREM-preferred compositions (https://georem.mpch-mainz.gwdg.de) and are consistent with the long-term laboratory average and with TIMS (Thermal Ionisation Mass Spectrometry) reference data. Estimated Pb concentrations (ppm Pb*) are based on sample weights, dilutions and signals in the mass spectrometer. They are minimum values (some Pb lost during processing) and of low precision (R. Maas and J. Woodhead, University of Melbourne, personal communication).

4. Results

4.1. Chemical composition

The average chemical composition is shown in Table 2. Based on the analysis of the chemical composition using the EPMA method, two categories of samples can be clearly distinguished (Fig. 4): copper (1–4 and 22) and bronze (19–25). Copper samples contained between 95 and 99 wt% of Cu (97.2% on average). Numerous impurities containing sulphur and other elements, i.e. melt exsolutions (alloy droplets of a different composition than the bulk sample) and/or ore residues, are visible in the SEM-BSE (Backscattered Electron) images. Average sulphur content in copper samples ranged from 0.5 to 2.0 wt% (1.2% on average), while the remaining elements are antimony, arsenic and nickel, respectively 0.04–1.32% (0.42% on average), 0.03–1.84% (0.48% on average) and 0.02–0.61% (0.35% on average) with traces (often below limits of detection) of Co, Ag, Pb, Fe and Zn. It should be noted that the content of minor and trace elements varied substantially between samples.

Bronze samples contained between 1.3 and 5.5% Sn (3.5% on average) and from 90.6 to 97.1% Cu (94.0% on average). The SEM-BSE images show that the alloy structure is not homogenous (Sn–rich and Sn–poor zones). Both melt exsolutions and residual ore impurities were present. In total, bronze samples contained slightly fewer impurities than copper samples but of similar composition: mainly Sb, S, As and Ni – 0.11–2.7% (0.8% on average), 0.18–0, 9% (0.54% on average), 0.05–0.63 (0.19% on average), 0.09–0.31% (0.18% on average) respectively with a smaller proportion of Ag, Co, Zn and Pb. As in the copper samples, the composition of the minor and trace elements varied between the samples.

4.2. Interpretation of lead isotope analyses

Eleven fragments of copper-based metals from a hoard in Paszowice, including fragments of unalloyed copper, some of them ingots with gas holes, and three sickles and two axes alloyed with small amounts of tin have a considerable range of lead isotope and elemental compositions.

The four shapeless lumps of unalloyed copper that seem to be fragments of copper ingots (nos. 1, 2, 3) and a casting cake no. 22 have a range of lead isotope and elemental compositions that can imply a different origin for each of them. All four contain small amount of impurities that most likely indicate the geochemistry of the ores that were used for smelting copper. The contents of lead in all of them are below 0.2%. The contents of antimony and silver, the elements associated with the tetrahedrite copper ores, known also as Fahlerz, are below 0.1% in nos. 3 and 4, but no. 2 contains more than 1% of antimony and 0.1% of silver. Nos. 22 and 1 contain silver below 0.1% and antimony between 0.1 and 0.5%. The shapeless lump no. 4 is of very pure copper with arsenic and nickel below 0.2% and some sulphur.

Fig. 2. The Paszowice hoard inventory. The sampled objects are marked with red circles (photos by A. Muła).

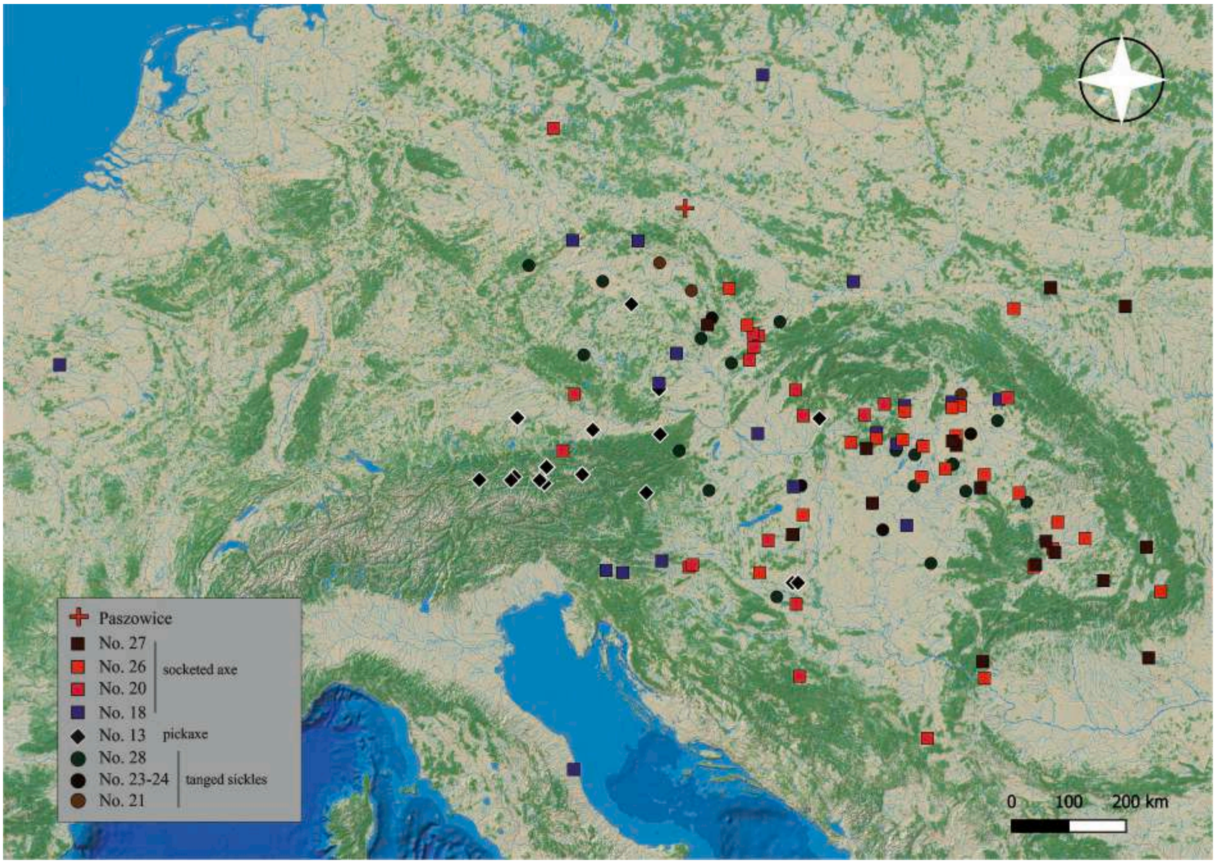

Fig. 3. Distribution of artefacts typologically similar to those found in the Paszowice hoard.

Table 2
Chemical compositions (EPMA). Results are in weight %, values in italics are below the limit of detection, "total" values contain some elements – e.g. Si, Fe – excluded from this table – complete data and detection limits are shown in supplementary material).

Sample	Cu	Sn	S	Sb	As	Ni	Fe	Co	Ag	Zn	Pb	Au	Total
1	94.73	*<0.1*	1.88	0.57	1.84	0.61	0.11	*<0.1*	*<0.1*	*<0.2*	*<0.2*	*<0.2*	100.12
2	96.51	*<0.1*	1.56	1.32	*<0.2*	0.18	0.24	0.12	0.11	*<0.2*	*<0.2*	*<0.2*	100.48
3	98.26	*<0.1*	1.32	*<0.1*	*<0.2*	0.31	0.31	*<0.1*	*<0.1*	*<0.2*	*<0.2*	*<0.2*	100.64
4	98.93	*<0.1*	0.55	*<0.1*	*<0.2*	0.11	*<0.1*	*<0.1*	*<0.1*	*<0.2*	*<0.2*	*<0.2*	100.24
19	90.61	5.14	0.30	2.70	0.63	*<0.1*	*<0.1*	*<0.1*	0.29	*<0.2*	*<0.2*	*<0.2*	100.09
20	92.28	5.51	0.90	0.16	*<0.2*	0.13	0.13	0.10	*<0.1*	*<0.2*	*<0.2*	*<0.2*	99.56
21	97.07	1.29	0.39	0.94	0.22	0.31	*<0.1*	*<0.1*	*<0.1*	*<0.2*	*<0.2*	*<0.2*	100.64
22	97.66	*<0.1*	0.60	0.14	0.20	0.55	1.00	0.15	*<0.1*	*<0.2*	*<0.2*	*<0.2*	100.58
23	95.15	3.60	0.18	0.79	*<0.2*	0.27	*<0.1*	*<0.1*	*<0.1*	*<0.2*	*<0.2*	*<0.2*	100.54
24	93.71	4.76	0.88	0.12	*<0.2*	0.14	0.19	0.10	*<0.1*	*<0.2*	*<0.2*	*<0.2*	100.22
25	95.01	3.97	0.59	0.11	*<0.2*	0.13	0.19	0.10	*<0.1*	*<0.2*	*<0.2*	*<0.2*	100.38

The casting jet no. 25 and the sickle no. 24 have identical lead isotope compositions and the chemical compositions within the analytical errors – therefore it seems certain that they originated from the same piece of metal. The sickle no. 21 contains more antimony and arsenic (0.94% and 0.22%) than the sickle no. 24, but very similar lead isotope composition. The piece of copper no. 2 is not alloyed with tin, but its elemental and lead isotope composition resembles closely that of the low tin bronze sickle no. 21. Two axes (nos. 20 and 19) and the sickle (no. 23) form isotopically close group, but have somewhat varied elemental compositions.

The lead isotope compositions of the analysed metals from Paszowice hoard are given in Table 3 and their lead isotope ratios are plotted on Fig. 5. The analysed metals from Paszowice are dated to the beginning of the first millennium BC (Ha B_1, c. 1000–900 B.C.) when in Europe the use of bronze for tools and weapons was in decline (Liversage and Pernicka, 2002). Therefore, a possibility that the bronze sickles and axes in this hoard have been made from re-melted bronze needs to be taken into account. In principle, the lead isotope ratios of the copper smelted from two different ore deposits with different lead isotope ratios would fall on a line joining these ratios measured for each deposit. Because of different amounts of lead in the original pieces of metal the points representing the artefacts made from re-melted metals would be expected to be scattered randomly along these lines. The pattern of lead isotope ratios observed in metal artefacts from Paszowice suggests they were not made of remelted copper pieces from isotopically different sources. Thus, we hypothesise that the discussed artefacts were made of the initially smelted copper originating in a single source.

The interesting point, clearly visible on this figure, is a difference between the lead isotope ratios of the fragments of copper ingots (nos. 22, 1, 3, 4), and the tin-bronze artefacts and the copper fragment no. 2. It is therefore clear that these pure copper ingots Nos. 1 and 3 and pieces nos. 4 and 22 could not have been used as the main metal for casting the

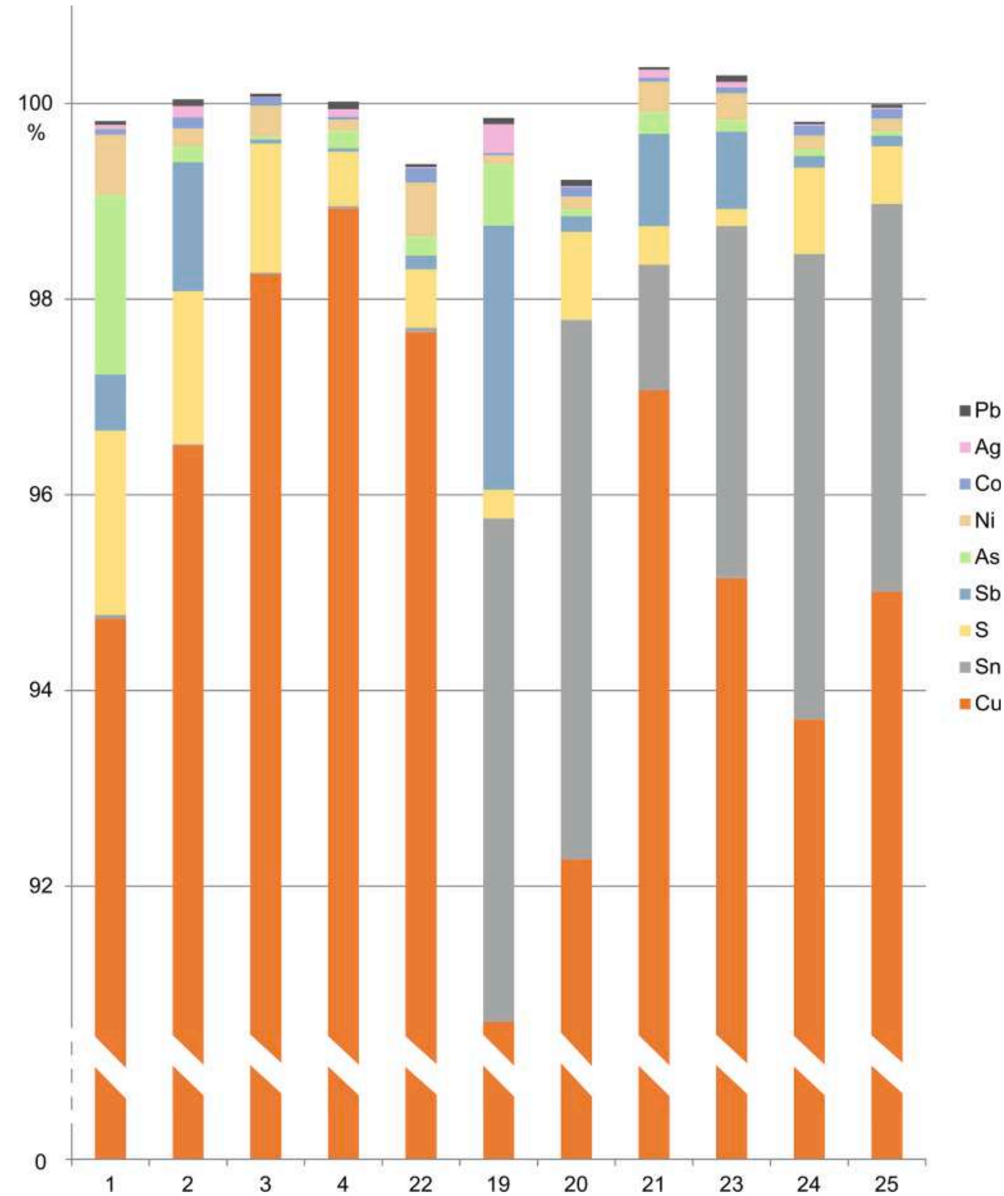

Fig. 4. Main elements in the chemical compositions of copper (1–4, 22) and bronze (19–25) samples (values in weight %).

Table 3
Lead isotope analyses.

Sample	Object	$^{208}Pb/^{206}Pb$	$^{207}Pb/^{206}Pb$	$^{206}Pb/^{204}Pb$	$^{207}Pb/^{204}Pb$	$^{208}Pb/^{204}Pb$
1	Metal lump	2.08200	0.84280	18.609	15.683	38.743
2	Metal lump	2.09634	0.85300	18.366	15.666	38.499
3	Metal lump	2.08824	0.84359	18.586	15.679	38.812
4	Metal lump	2.08393	0.84697	18.427	15.607	38.401
19	Socketed axe	2.10270	0.85430	18.348	15.675	38.581
20	Socketed axe	2.10141	0.85394	18.330	15.653	38.519
21	Sickle	2.09506	0.85195	18.375	15.655	38.498
22	Casting cake	2.07422	0.83082	18.883	15.689	39.168
23	Sickle	2.10321	0.85489	18.333	15.673	38.558
24	Sickle	2.09625	0.85015	18.421	15.661	38.615
25	Casting jet	2.09600	0.85008	18.423	15.661	38.615

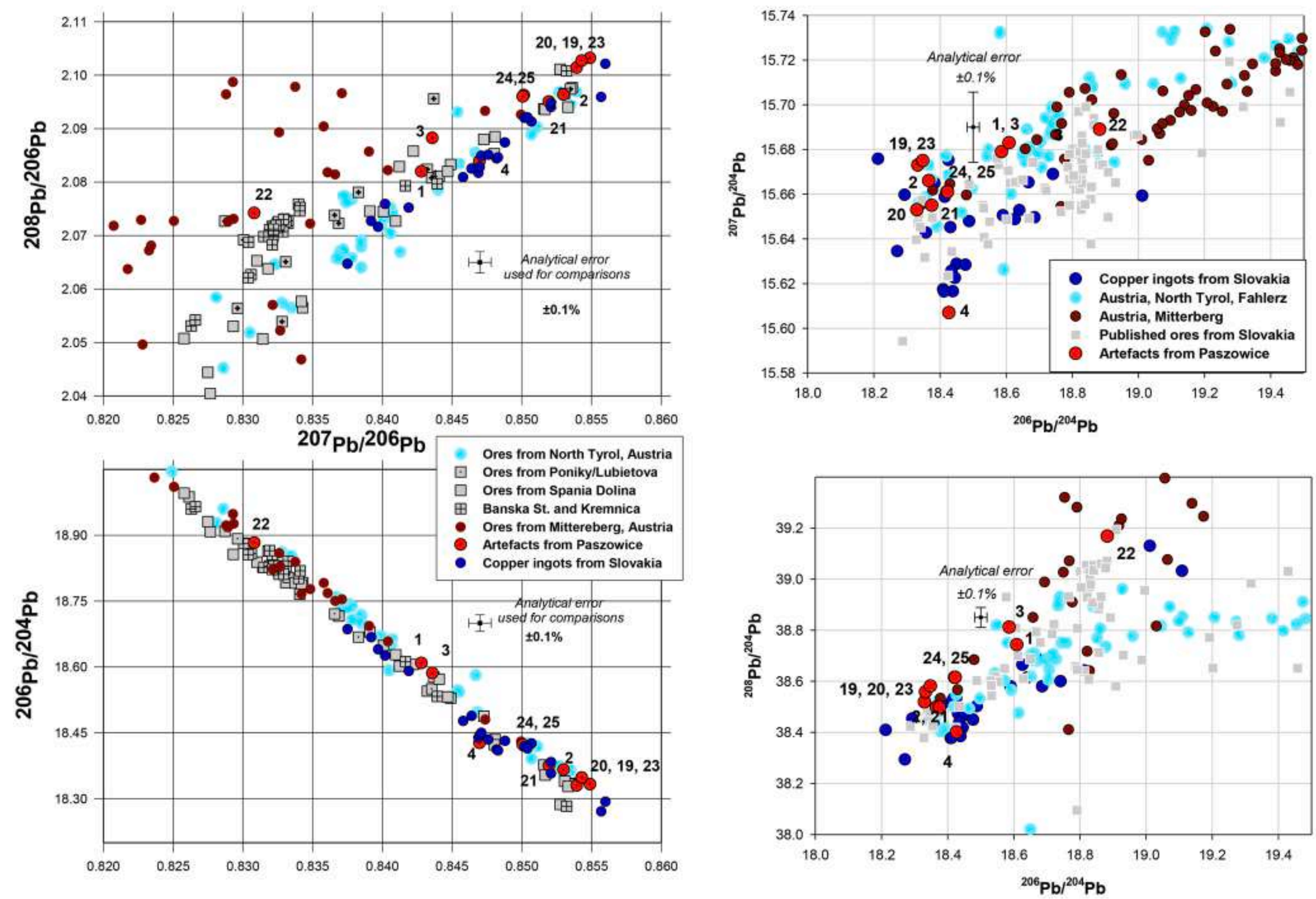

Fig. 5. Lead isotope data for the analysed metals from Paszowice compared with the published data for the ores from the Austrian Alps and the Slovak Ore Mountains. On the plot on the left the ores form Slovakia are identified as to their specific mining region.

bronze sickles and axes.

On Fig. 5 the lead isotope ratios for the metals from Paszowice are compared with the data for the ores from the regions in central Europe closest to the Polish territory, where copper is known to have been exploited in the Bronze and possibly the Iron Ages. These are the copper ores in the Slovak Ore Mountains (Schreiner, 2007) and prehistoric copper ingots found there (Modarressi-Tehrani et al., 2016), and two regions in the Austrian Alps: North Tyrol (Höppner et al., 2005) and Mitterberg (Pernicka et al., 2016). These four plots show that the partial overlaps of the lead isotope ratios of these three deposits on the plot $^{208}Pb/^{206}Pb$ versus $^{207}Pb/^{206}Pb$ can be resolved when compared with the plots to the ^{204}Pb ratios.

Out of these three ore deposits the most extensively researched is the region of Mitterberg with extensive ^{14}C dating of prehistoric mining activities, chemical and lead isotope analyses. The main copper mining activity in prehistory in Mitterberg has been identified as 18th–9th centuries BC, with the peak of production in the 16th–13th centuries (Pernicka et al., 2016, Table 2). The lead isotope ratios of the ores from Mitterberg are quite distinctive, so usually it is quite easy to eliminate this copper source when interpreting the lead isotope data of ancient metals. Amongst the copper-based metals from Paszowice the casting cake no. 22 seem to be consistent with the samples from the Winkel lode in Mitterberg, but also its lead isotope ratios are consistent marginally with the ores from Banská Štiavnica in the Slovak Ore Mountains. The antimony, cobalt and nickel in this casting cake are at the levels that can be within the range of these elements in copper smelted from the ores from Mitterberg (Pernicka et al., 2016, Tables 3 and 4).

Research into mining in the Slovak ore Mountains is not as complete as for Mitterberg. However, the abundance of the multimetallic ores in the Slovak Ore mountains is very impressive: they include exploitable occurrences of antimony, copper gold, iron, lead, zinc and silver amongst others (Balaž, 2015). There is an abundance of evidence of Bronze Age copper production in the Špania Dolina-Piesky, including hundreds of stone hammers and there is evidence of iron smelting from about 700 BC (Kúšik, 2015). In view of this evidence it seems very likely that copper was still produced in this region in the early 1st millennium BC. The publications by Schreiner (2007) focus on the earliest mining in this region in the Copper and early Bronze Ages. The publication by Modarressi-Tehrani et al. (2016) promises further research, but as far as we know this work has not yet been published. The new lead isotope data published by them is from a large group of copper ingots found in the mining regions of the Slovak Ore Mountains. On Fig. 5 only the copper fragments nos. 4 and 2, and the sickle 21 have lead isotope ratios closely similar to some of these ingots. The sickle 21 and the fragment no. 2 have very similar lead isotope and chemical compositions, apart from tin added in a small quantity to the sickle, to the bar no. 935 found in Roštovňa, Riečka Village with an Br C_2–Ha A_1 bronze axe (Modarressi-Tehrani et al., 2016, tables 1 and 2, 114-115) and also their elemental contents fit into the cluster for the ores from Slovakia presented in this paper (Fig. 7, 120). The copper lump no. 4 from Paszowice has also very similar lead isotope and elemental composition to two undated copper bars with higher antimony contents nos. 958 and 928 from Podkonice and Špania Dolina. The no. 4 from Paszowice has also very similar lead isotope ratios to the ores from the Harz mountains, but in view of the lack of information of copper mining in the Harz mountains in the early 1st millennium BC, Slovak Ore Mountains seem a more

Table 4
A list of identified possible sources of copper used to produce selected items from the Paszowice hoard. Yellow colour + – entirely consistent with the lead isotope and chemistry of the ores; grey colour ±– marginally consistent.

No.	Item	Copper ore source							
		Slovak Ore Mountain	Austrian Alps		Germany, Harz	Italy		Spain	
		Špania Dolina/Poniky/Banská Štiavnica/Kremnica/L'ubietova	North Tyrol Brixlegg	Mitterberg	Lautenthal/ Clausthal	Sardinia, Calabona/ Ozieri	Italian Alps	Menorca	Betic Cordilliera/Jaen / Sierra Alhamilla/ Almagrera mine
1	Shapeless lump	+	-	-	-	-	-	-	-
2	Shapeless lump	+	±	-	-	-	-	-	-
3	Shapeless lump	±	-	-	-	+	-	-	-
4	Shapeless lump	+	-	-	±	-	-	-	-
19	Socketed axe	-	-	-	-	-	-	-	+
20	Socketed axe	-	-	-	-	-	±	-	+
21	Sickle	+	-	-	-	-	-	-	-
22	Casting cake	±	-	+	-	-	-	-	-
23	Sickle	-	-	-	-	-	-	-	+
24	Sickle	-	-	-	-	+	-	±	-
25	Casting jet	-	-	-	-	+	-	±	-

likely origin for this piece of copper. Also the lump of copper no. 1 is consistent with the geochemical characteristics of the copper smelted from the ores in Špania Dolina. All these four artefacts consistent with the origin from Slovakia (nos. 1, 2, 4 and 21) have very low tin content, only the sickle contains about 1.5% of added tin and varied amounts of antimony (0.04–1.3%). It should be mentioned here, that the artefacts 1 and 21 also have lead isotope and, within the analytical error, chemical data consistent with some ores from the Swiss mines in La Valais (Cattin et al., 2011). However, for the mines in this high mountains (c. 2000 m.) there is no clear evidence of copper extraction in the early 1st millennium BC. Also, the comparisons with lead isotope and chemical data for bronzes dated to this period from the Swiss sites (Rychner and Stos-Gale, 1998) do not show similarities with the copper from Paszowice. One more shapeless lump of copper, no. 3, has lead isotope ratios different from all published data for the ores from the Slovak Ore Mountains by more than 2 analytical errors and is of a very pure copper with comparatively high sulphur, nickel and iron. The most similar ores geochemically and isotopically to this fragment of copper metal are from the region of Capo Morargiu and Calabona on Sardinia (Stos-Gale et al., 1995; Begemann et al., 2001). This observation makes it stand out from other pieces of copper in this hoard that might have been part of the trade in ingots. Some metals discussed above have lead isotope compositions consistent with ore samples from the North Tyrol (Höppner et al., 2005). The latest research results and radiocarbon and dendrochronological dating confirm the operation of mines in the 1st millennium BC (Staudt et al., 2019; Goldenberg, 2021). However, given the purity of copper used for these artefacts we can dismiss these deposits as possible source of metals found in Paszowice.

The remaining metals from the Paszowice hoard that have been analysed for this project consist of two sickles and two axes and a casting jet no. 25 which is chemically and isotopically identical with the sickle no. 24. These two metals have tin content between 4 and 5% and otherwise all other impurities below 0.2%. their lead isotope compositions also are consistent with the ores from Sardinia. There is plentiful evidence of the copper metallurgy in Sardinia dated from the 13th–9th centuries BC (Lo Schiavo et al., 2005; Sabatini and Lo Schiavo, 2020). The production of copper did not stop during the Phoenician period in the early 1st millennium BC and there is strong evidence of an important role of Sardinia in trade with Italy, Iberia, Southern France, eastern Mediterranean and north Africa (Webster and Teglund, 1994). Trading contacts between Sardinia and Italy can have significant implications on the LBA–EIA trade in metals in south-east Europe. Gerhard Tomedi (2017) discussed at length the contacts between the south-east Hallstatt cultures and Etruscans from Northern Italy. It has also been noted that the copper either from the Italian Eastern Alps in the region of Trentino-Bolzano or from Sardinia has been traded as far as Bulgaria in the form of sickles and axes found in the site of Varbitsa (Chernykh, 1978 and unpublished data from the Isotrace Laboratory, Oxford). Fig. 6 shows comparisons of the lead isotope data for the metals from Paszowice and from Varbitsa with the data for the ores from Sardinia and the Italian Eastern Alps (Trentino-Bolzano). The copper ores in these two mining regions are not of the tetrahedrite (Artioli et al., 2008, Addis et al., 2016; Valera et al., 2005) type and therefore artefacts from Paszowice that contain more than 0.2% of antimony (nos. 1, 2, 21, 19, 23) in spite of apparently lead isotope ratios similar to the ores from these locations could not have been smelted from these ores.

The three remaining pieces of low-tin bronze (two unfinished axes and a broken sickle (nos. 19, 20 and 23) have similar lead isotope ratios, but one of the axes (no. 19) and the sickle no. 23 contain higher antimony than the other axe (no. 20). The axe no. 19 also contains about

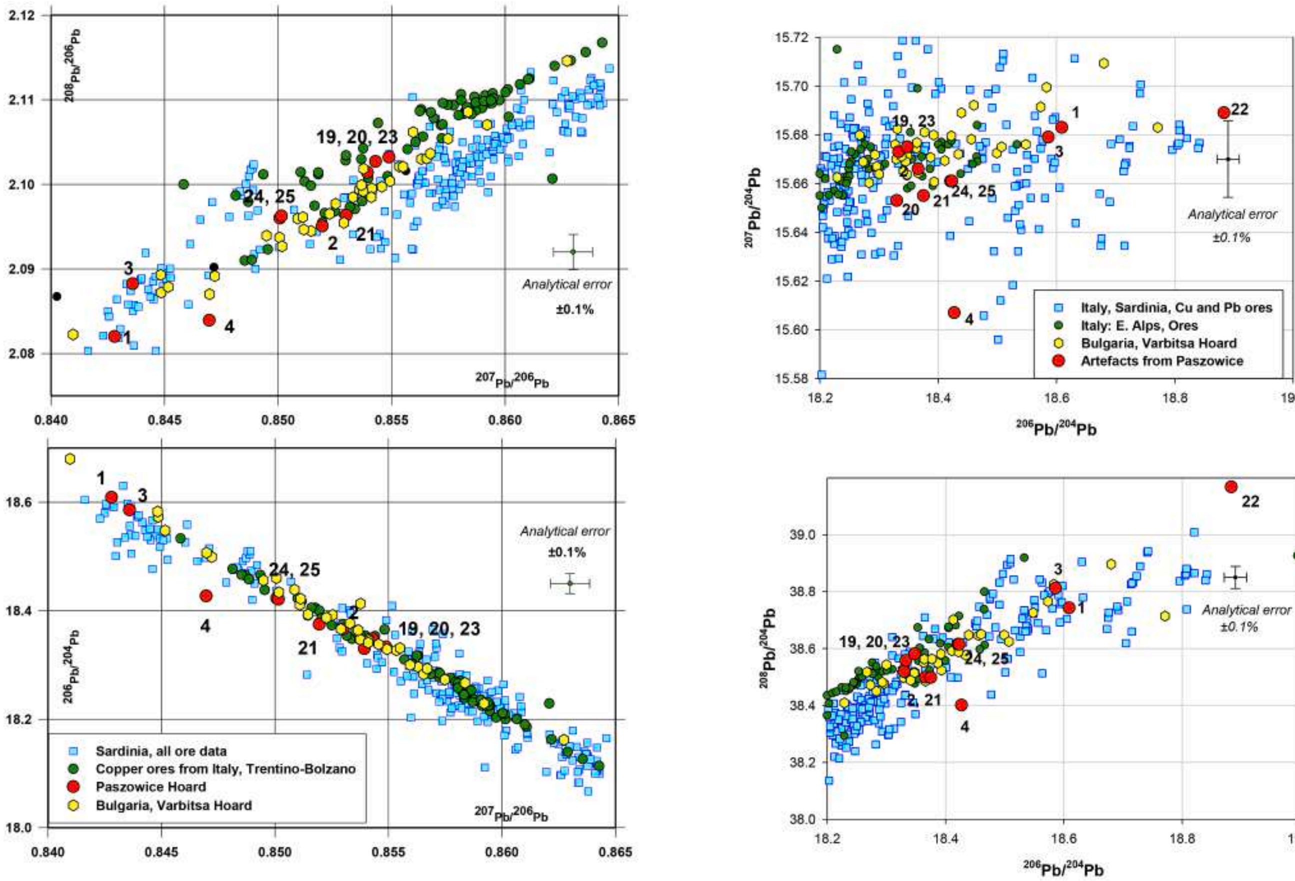

Fig. 6. Comparison of the lead isotope data of the copper-based artefacts from Paszowice with the Bulgarian hoard of sickles and axes rom Varbitsa (unpublished data from the Isotrace Laboratory, Oxford) and the ores from Sardinia in S-E Alps near Italian Eastern Alps (Trentino-Bolzano).

0.3% of silver, which is higher than in any other artefact from this hoard. It is possible that these metals originate from a deposit where both, the tetrahedrite ores and sulphides were used for smelting copper resulting with chemically different batches of metal, as it could be the case, for example in the Austrian Alps and in the mines in Sierra Morena in south Spain. However, it is equally possible that these metals have different origin from deposits of very similar geological age (300–600 my). In this case it is possible that the axe (no. 20) might have been cast from a metal originating in the Italian Eastern Alps in the region of Trentino-Bolzano, where at least in some localities copper was smelted until 9th c. BC. Also, isotopically and chemically, it is possible that all three, or just two, of these artefacts originated from the mines in the Iberian Peninsula. While culturally and typologically there is at present no clear indication of the contacts of this region with central Europe, Iberia has very rich metal deposits, including, gold, silver and tin, which have been exploited throughout the Bronze Age and could have been traded since the Bronze Age across Europe. The western Mediterranean had contacts with the eastern Mediterranean at least since the second half of the 2nd millennium BC (Stos-Gale and Gale, 1992; Hauptmann, 2009) and in the early 1st millennium BC the Phoenicians have been involved in the trade of metals from the western Mediterranean (Renzi et al., 2009; Eshel et al., 2019; Stos-Gale, 2001). That the copper, and possibly tin from the Iberian Peninsula was also traded to northern Europe is indicated by the lead isotope ratios of a group of artefacts contemporary with the metals from Paszowice: the bronzes from Scandinavia dated to the periods V–VI (Ling et al., 2014). These large group of copper-based artefacts also has lead isotope and chemical compositions very similar to the metals from Paszowice indicating a common source of copper. Sardinia might have played a 'middle man' in this trade towards the north and the east. Additionally it must be said that the chemical and lead isotope compositions of the copper-based artefacts found in Spain and dated to the early 1st millennium BC (data source: https://oxalid.arch.ox.ac.uk; https://www.ehu.eus/ibercron/iberlid) are remarkably similar to the tin bronzes from Paszowice and the Scandinavian bronzes from that period as illustrated on Fig. 7.

Another multimetallic deposits where copper might have been exploited in the 1st millennium BC and with similar lead isotope ratios to some of these artefacts from Paszowice are the deposits in the south-west France in Massif Central (Baron et al., 2006; Brevart et al., 1982; Prange and Ambert, 2005). However, at present there is no evidence for the exploitation of these ores in the 2nd and early 1st millennia BC.

5. Discussion

5.1. *A metalworker's hoard?*

The phenomenon of hoarding (its economic, political, ritual and sociological significance) already has buoyant literature (cf. e.g. Blajer, 2001; Hansen et al., 2012; Maciejewski, 2016; Brandherm, 2018), and it is impossible to even briefly present it here. Based on our multi-faceted study (typology, lead isotopes, elemental composition, use-wear) and the context, we shall discuss different interpretation scenarios for the Paszowice hoard.

The researchers often take up the issue of the so-called 'founders' hoards'. The association of specific hoards with the activities of metallurgical workshops dates back to the end of the 19th century. The recent use of the term 'founder's hoard' (Ger. *Gießerfund, Handwerkerdepot*; Pol. *skarb odlewcy*; Hung. *öntőműhely* or *fémhulladék depó*) and papers related

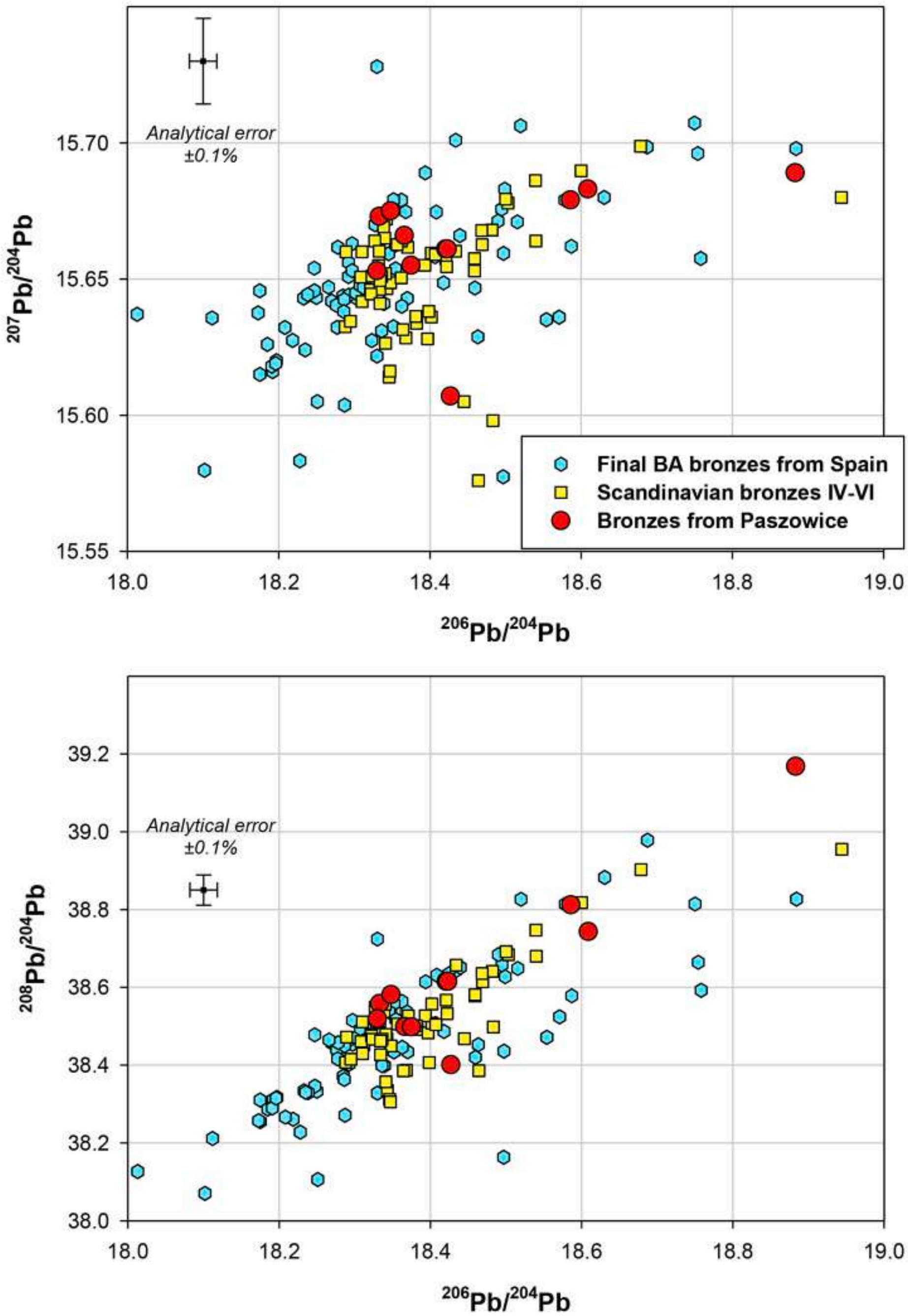

Fig. 7. Comparisons of lead isotope ratios for chemically similar copper based artefacts dated to the beginning of the 1st millennium BC from Spain, Scandinavia and Paszowice (data source for Spain: IBERLID https://www.ehu.eus/ibercron/iberlid and unpublished lead isotope and chemical data from Ignacio Montero Ruiz; for Scandinavia: Ling et al., 2014, Melheim et al., 2018).

to this phenomenon were discussed in greater detail, among others, in the works by D. Jantzen (2008, 281–282), B. Nessel (2010, 1), B. Rezi (2011, 303, footnote no. 1), and A. Mozsolics (Mozsolics, 1984). The term ‘founder’s hoard’ usually refers to a specific set of items in the deposit. In most publications, the term is unexplained and used automatically if the hoard contains the following:

– ‘scrap metal’, i.e. items preserved in fragments, damaged, with visible casting defects or with traces of heavy wear;
– various types of metal bars, ingots, parts of casting cakes or lumps, as well as casting waste (jets);
– tools related to casting; mainly metal casting moulds and cores but also anvils, hammers and chisels indicating that the hoard belonged to the person (or persons) involved in metallurgy;
– a series of objects made in the same casting mould, items with preserved casting jets or distinct casting seams, indicating local casting activities.

One of the main components of the 'founder's hoards' is the so-called scrap metal, i.e. fragmented, sometimes heavily damaged items. The presence of such fragments in hoards is not only related to their purely functional role as a raw material (cf. e.g. Chapman, 2000; Brandherm, 2018; Fontijn, 2020). As B. Rezi points out, they might be recycled metal, pre-monetary currency, products of ritual destruction, or have links with social activities indicating intergroup relationships ('enchainment theory'; Sommerfeld, 1994; Nebelsick, 2000; Rezi, 2011; pages 303–306 clearly explain these interpretations, there is also a wealth of literature on fragmentation). Thus, on the one hand, fragments in hoards are interpreted as reusable raw material or as a medium of exchange having a particular weight and value. On the other hand, they have a specific symbolic function in the social, cult and ritual spheres. All interpretations emphasise that the fragmentation was intentional (Knight, 2019; 2020), but verifying this hypothesis is challenging.

In light of this discussion, the hoard from Paszowice has classic determinants of being a 'founder's hoard', including the casting waste (jets), the raw material (metal lumps and metal ingot), the evidence of unsuccessful castings with misruns and casting nobs, the objects cast in a single mould, and the metal fragments.

In selected categories of items, we can trace the entire operational chain related to their biography (manufacturing and use). For sickles, we can distinguish four production stages represented by:

1) an unsuccessful as-cast item with removed casting jet (no. 24; Fig. 2.24);
2) a successful as-cast item with removed casting jet (no. 28; Fig. 2.28);
3) a successful as-cast item with a preserved casting jet and traces of being preliminarily prepared for use (peening; no. 21; Fig. 2.21); traces preserved on the tip of the blade indicate that peening of its surface began but was not finished (interestingly, the peening began before removing the pouring basin);
4) an item with traces of manufacturing, use-wear (see Nowak et al., 2019; 2022) and damage (bending; no. 23; Fig. 2.23).

Similarly, the hoard's socketed axes also represent several production stages:

1) an as-cast item with casting defects and removed casting jet (no. 20; Fig. 2.20);
2) a good-quality as-cast item with preserved pouring channel (no. 19; Fig. 2.19);
3) a ready product with mechanical damage (broken or bent loops), manufacturing and use-wear traces (nos. 26 and 27; Fig. 2.26, 27).

The items from Paszowice bear traces reflecting the entire metallurgical operational chain. The hoard provides much valuable information about metal manufacturing and casting. But was the production local, or were the as-cast items transported as ready products?

5.2. Or the hoard of an itinerant bronzesmith?

Sometimes the hoards (mainly 'founder's hoards') are associated with 'itinerant bronzesmiths'. Recently, M. Maciejewski presented an extensive criticism of the sources, arguing that perceiving a hoard as a private property of an itinerant bronzesmith/trader is groundless (Maciejewski, 2016, 42–45). The work on 'itinerant craftsmen' (Ger. *Wanderhandwerker*) by M. Neipert presents the results of her archaeological and ethnographic studies (2006). The extensive analysis of ethnological sources proves, at least temporarily, the existence of mobile producers in non-industrial communities. However, it is impossible to identify an itinerant metalworker as an independent entity (economically and socially) through analysing archaeological sources (Neipert, 2006, 123-25). Thus, it is risky to conclude that the hoards belonged to itinerant artisans who travelled around without permanent casting workshops, selling finished products and replacing or buying old and broken ones.

The extensive typological and chronological studies showed that some of the studied artefacts from the Paszowice hoard are non-local and come from at least two directions: the southwest (mining pickaxe – eastern Alps) and the southeast (tanged sickles, Middle Danube-type socketed axes – Moravia, Slovakia, Hungary, Romania; Fig. 3). Until recently, the scholars assumed that items with preserved casting jets, in the as-cast state, with casting defects and casting waste (removed casting jets) were produced in the vicinity of the deposition site (on this topic see von Brunn, 1981, 120). In our study, we could determine how some artefacts were produced and whether they followed local production patterns. Sickle no. 21 was manufactured in a casting mould typical of western and southern Germany, the Czech Republic, Slovakia, and other places. Its ridge features a massive casting nob – a pouring basin remnant and an approximately conical casting sprue. Thus, the second part of the mould (the so-called cover) must have had a modelled pouring basin. Other sickles were made in casting moulds with a pouring channel on the ridge. These sickles have an additional spur at the handle (Primas, 1986, Fig. 2; Jahn, 2013, 39, Fig. 2.1). Macro- and microscopic investigation of surfaces in sickles nos. 24 and 28 demonstrated that they could potentially originate in the same mould (Nowak et al., 2022). However, the runner's location slightly differs in both specimens (Fig. 2.24 and 28). It indicates that the sickles were not cast in the same mould, but a single solid model had been used to produce at least two moulds (e.g. of clay or moulding sand), and the runners were later modelled by hand (compare to suggestions by Jahn, 2013, Fig. 2.10).

Tanged sickles were most likely not locally cast since Poland's Lusatian cemeteries and settlements yielded only a few such specimens. At the same time, they were recorded in several metal hoards and as stray finds. Furthermore, Poland evidently lacks finds of moulds for producing tanged sickles, which dramatically contrasts the relatively numerous moulds for knobbed sickles. M. Gedl indicates areas south of the Carpathians as tanged sickles' production zone (1995, 77). Areas west of Oder with evidence of casting moulds and finished products may also be considered (Saxony, Bavaria, Austria; e.g. Bierbaum, 1942; 1956; Overbeck, 2018).

The analysed axes from Paszowice differ from the local production patterns regarding their decorations and the pouring channel's location in the casting mould. Most of the casting moulds for socketed axes found in Poland were used to produce the so-called Lusatian axes with a characteristic decoration (parallel ribs) and a relatively homogeneous system of pouring metal into the mould (the pouring channel located in the mould's side wall). The only exceptions are the moulds from Śrem and Pawłowiczki in Silesia (S Poland). The former is a stone mould fragment designed to cast the so-called pseudo-winged axe. Its pouring channel is located at the loop's upper base (Seger, 1909, Fig. 23). The latter is a metal mould for producing Lusatian axes with a similarly located pouring channel (Seger, 1909, Fig. 29; Baron et al., 2014, Fig. 4a). Such a technological solution is typically expected in moulds from SE Europe (e.g. Wanzek, 1989). In the Paszowice hoard, using a mould with such a design is confirmed by the casting nob in axe no. 26. At the same time, we might also observe similarities to local manufacturing patterns. Axe no. 19, with the pouring channel in the casting mould's side wall, reflects a local tradition, a technological solution typical of Poland's Bronze Age finds.

We must also consider that the items in the Paszowice hoard did not follow the local deposition pattern. Depositing the raw material and unfinished products was rare here (Blajer, 2001), and there are no known examples of either plano-convex ingots with traces of dividing or pickaxes. No other hoard from Poland contained Central Danubian axes, tanged sickles, mining tools (the pickaxe), weapons (the spearhead), artefact fragments, casting waste, dress accessories, and raw material. Instead, the hoard reflects southern traditions. Hoards containing such items (mainly fragments of casting cakes with tanged sickles and socketed axes) are characteristic of the areas south of Paszowice – the Czech Republic (cf. e.g. Paseky 6 hoard – Fröhlich et al., 2015; Paseky 3 hoard –

Chvojka, 2015; Pětipsy, Nechranice, Březovice – Kytlicová, 2007), Moravia (hoards from Blučina 18, Borotín, Drslavice 2, Mušov 2, Boskovice 3–4 – Salaš, 2005), Austria (Enzersdorf im Thale – Lauermann and Rammer, 2013) and Hungary (e.g. Lovasberény, Biatorbágy-Herceghalom, Velem 1 – Mozsolics, 1985, Pls. 228–231B; Pls. 337–239, Pls. 244–246). The closest matches to sickles with preserved casting jets come from Moravia (Velká Roudka hoard – Salaš, 2005, Table 286). In the hoards from Blučina 17 and Přestavlky, the Middle Danubian axes were deposited with bent (similarly to the broken sickle no. 23 from Paszowice; Salaš, 2005, Tables 89B, 255) tanged sickles. In this light, the Paszowice hoard clearly follows foreign, southern deposition patterns.

The artefacts, including those with casting defects, casting jets, fragmented specimens, and raw material, were probably transported to S Poland as they were. However, we cannot exclude that some items from the Paszowice hoard were of local origin. The two twin sickles with different runners' locations indicate using a solid mould-making model. Was a solid sickle model (made of wood or imported metal object) of foreign provenance used for local production? Finding a casting mould for pseudo-winged axes in SW Poland may also indicate that this foreign axe type was produced locally. The same applies to axe no. 19, in which a foreign solid model was used, but the pouring channel was formed according to local traditions (skills?). Concluding that the metal artefacts were brought to Paszowice by a travelling metallurgist and that he made a few more items on the spot would be pretty daring. A more likely scenario is that while some items came from the south via a trade route, a local metallurgist might have cast other objects.

To verify this possibility, we must investigate the evidence of local metalworking and consider whether there are traces of increased exchange between the Paszowice area and the south. Near the field where the hoard was discovered were three Lusatian Urnfield sites (two settlements and a cemetery) from the Bronze and the Early Iron Ages. The multi-phase cemetery came to light in 2015 during rescue excavations preceding a motorway construction. The investigations revealed traces of intensive and long-lasting prehistoric occupation, including 672 features from the Middle and Late Bronze Age and the Early Iron Age (Janczewski and Sielicka, 2018). The finds were typical of the local Lusatian Urnfield culture. No ceramic or metal artefacts of southern origin (Bohemia, Moravia, Slovakia, or Hungary) occurred. Dark blue glass beads found in some Early Iron Age graves were the strongest evidence of long-distance exchange. Judging by the matching finds from the cemetery in Domasław (about 70 km to the east), they originated in the Balkans (cf. Purowski, 2013).

Apart from the Paszowice hoard, the neighbouring area has no traces of intense metalworking activities. However, a Late Bronze and Early Iron Age settlement located 5 km west of the hoard deposition place yielded some evidence of casting: a half-of-a-stone, bi-valve casting mould used to produce a spearhead and an arrowhead (Jarysz, 1997, 157, Fig. 13). The mould was made of amphibolite of glacial origin, and the spearhead negative resembles the spearhead from Paszowice but differs slightly regarding the socket's proportions and the width of the almond-shaped blade. Thus, metalworkers were active in the area, and some items in the hoard might have been produced locally. If we accept that the hoard was a deposit of raw metal material used by the local communities, we might hypothesise that metal of non-local origin (sickles, axes, raw material, pickaxe fragment) and the so-called scrap metal was imported for further remelting. Part of the metal owned by the local community, and possibly the metallurgist, was intended for the deposition.

5.3. Provenance studies – The possibility of metal influx to the Lusatian Urnfield zone

Our study identified the closest analogues to items from Paszowice (Fig. 3). The traditional methods of stylistic provenance determination – typology and distribution studies of the matching artefacts – demonstrated that the Paszowice collection did not consist of artefacts typical of the local Lusatian context. The hoarding pattern also differed. Thanks to the analyses of lead isotopes carried out for selected items, the sources of the metal used in the production of these items were determined (Table 4). Only the metal lumps 1, 2, 4, and sickle no. 21 indicate an origin in the Slovak Ore Mountains. A large number of sickles and axes analogous to those in the Paszowice hoard have been found in these areas. The raw copper casting cake no. 22 indicates East Alpine origin, which is also evidenced by the characteristic chemical composition. The results indicate that there are also extended contacts with the Mediterranean basin. The unworked lump (no. 3) and the sickle, along with the pouring channel (nos. 24 and 25), most probably removed from it, indicate the origin from Sardinia. The finished axes nos. 19 and 20 in as-cast conditions and the used and most likely ritually bent sickle 23 could have been made of metal of Iberian origin. The identification of tin bronze from Iberia and Sardinia as far east as Poland could be a controversial hypothesis and requires further research, but this possibility needs to be included for future consideration, in spite of the current lack of archaeological evidence for Iberian exports to central Europe at that time.

The current hypothesis presented here is shown schematically in Fig. 8. The main directions of the metal imports to south-west Poland are from the Slovak Ore Mountains, Mitterberg, Sardinia, and the Iberian Peninsula. The less likely sources are in the Italian Alps, North Tyrol, and Menorca. The fundamental question that needs to be discussed is how this metal was transported to the territory of today's south-western Poland. The data indicate that it is possible to propose several scenarios of the influx of metal to the area of southern Lusatian Urnfield Culture. Theoretically, the metal could have been transported in separate shipments from several different sources (south-eastern – Slovak Ore Mountains, southern – Alpine region, and south-western – western Mediterranean; Fig. 8) to the vicinity of today's Paszowice.

Another likely possibility is the transport of metal along a long trade route across Europe. It is possible to indicate several options (Figs. 9-11). The first option is the Mediterranean route, which channelled the metals from Spain and Sardinia to northern Italy, where it was joined by metal from eastern Alpine mines and continued North. The transport of metal from this direction to the Central Europe is confirmed by the research of the Late Bronze Age copper ingots from the Staré Hodějovice hoard in South Bohemia (Kmosek et al., 2020). Kmosek and his colleagues proved contacts with alpine area and importing copper from various sources (Mitterberg, Trentino and possibly Valais regions). In this theory, Slovak ore deposits were the second supplier of the metal (Fig. 9). Metal from the western part of Europe and the Slovak deposits reached the area of the Lusatian Urnfields by separate transports. Then, it was cast on site.

The second possibility may point to the transport via Mediterranean and the Danube, through which the metal from the western Mediterranean reached the Balkans and then supplied, among others, the territories of today's Bulgaria (Fig. 10). This may be indicated by the presence of the Iberian or Italian metal in the hoard discovered in Varbitsa. The intensive activity of the Phoenician traders in the western Mediterranean in this period could have resulted in the spread of tin-bronze into northern Europe, possibly from northern Italy via the Danube into Serbia and Bulgaria and from there further northwest. Contacts between the central-western Mediterranean and the Balkans in the earlier period have been discussed by Molloy (2019) and Tomedi (2017). This type of contact may also be indicated by the presence of the double-axe ingots, related to the Mediterranean, in NE Carpathian Basin (Tarbay, 2019, Fig. 10). This course of the trade route is supported by the distribution of similar sickles and axes in eastern Hungary, Slovakia, and Moravia. Mediterranean metal reaching these areas was used to produce local items. Then, the transport was supplemented with local metal from Slovak ore deposits. At the next stage, artefacts made locally from the incoming metal were transported further. This may be indicated by the isotopic composition of typologically local axes no. 19 and 20 and sickles 23 and 24 (along with a casting jet 25). In the northwest direction, Slovak metal was also transported in the form of fragments of

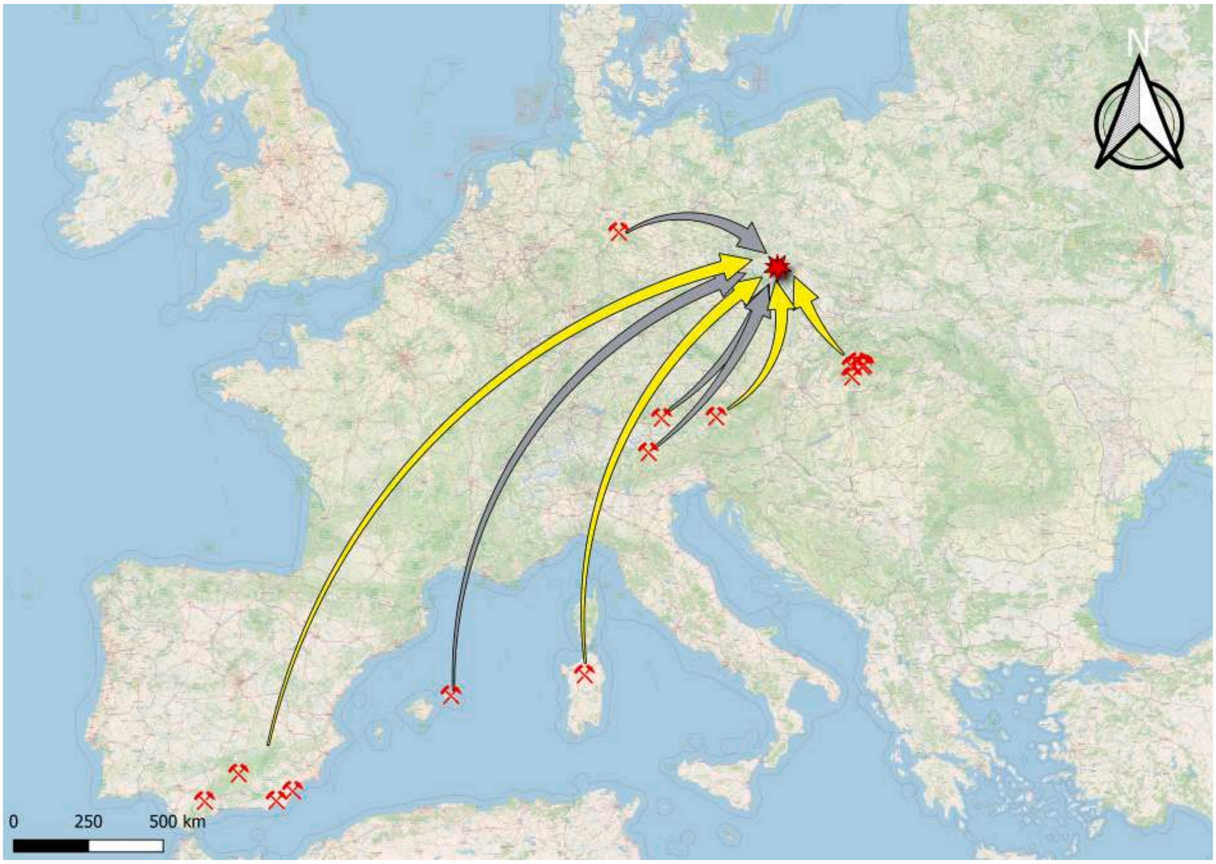

Fig 8. All identified metal sources, including those entirely consistent with the lead isotope and chemistry of the ores (in yellow) and marginally consistent (in grey). OpenStreetMap® licensed under the Open Data Commons Open Database License (ODbL) by the OpenStreetMap Foundation (OSMF).

Fig. 9. Two hypothetical metal transport routes to the southern Lusatian Urnfield zone – from SW Europe and Slovakia. OpenStreetMap® licensed under the ODbL by the OSMF.

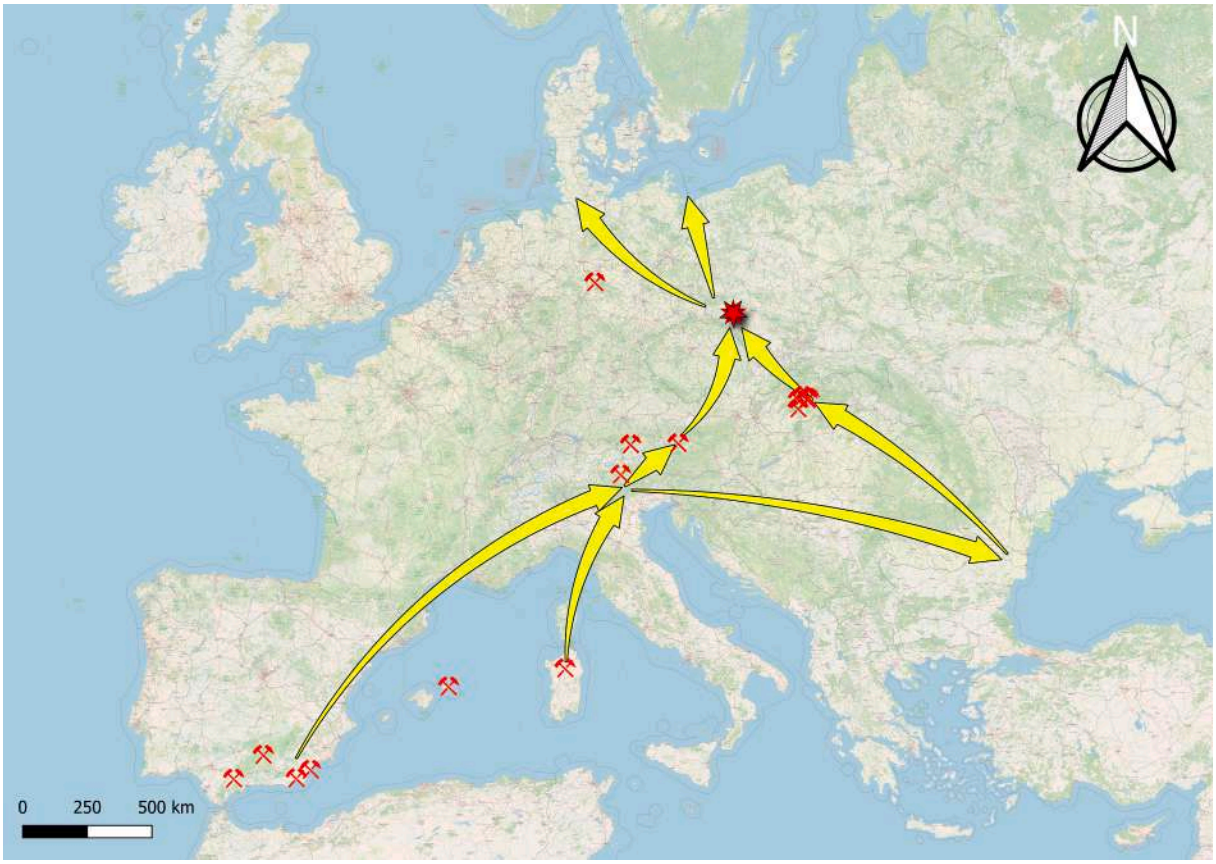

Fig. 10. Hypothetical metal transport route through the Danube, Oder and Elbe. Some metal items, like casting cake no. 22 or metal lump no. 3, came from the south, others from the southeast. OpenStreetMap® licensed under the ODbL by the OSMF.

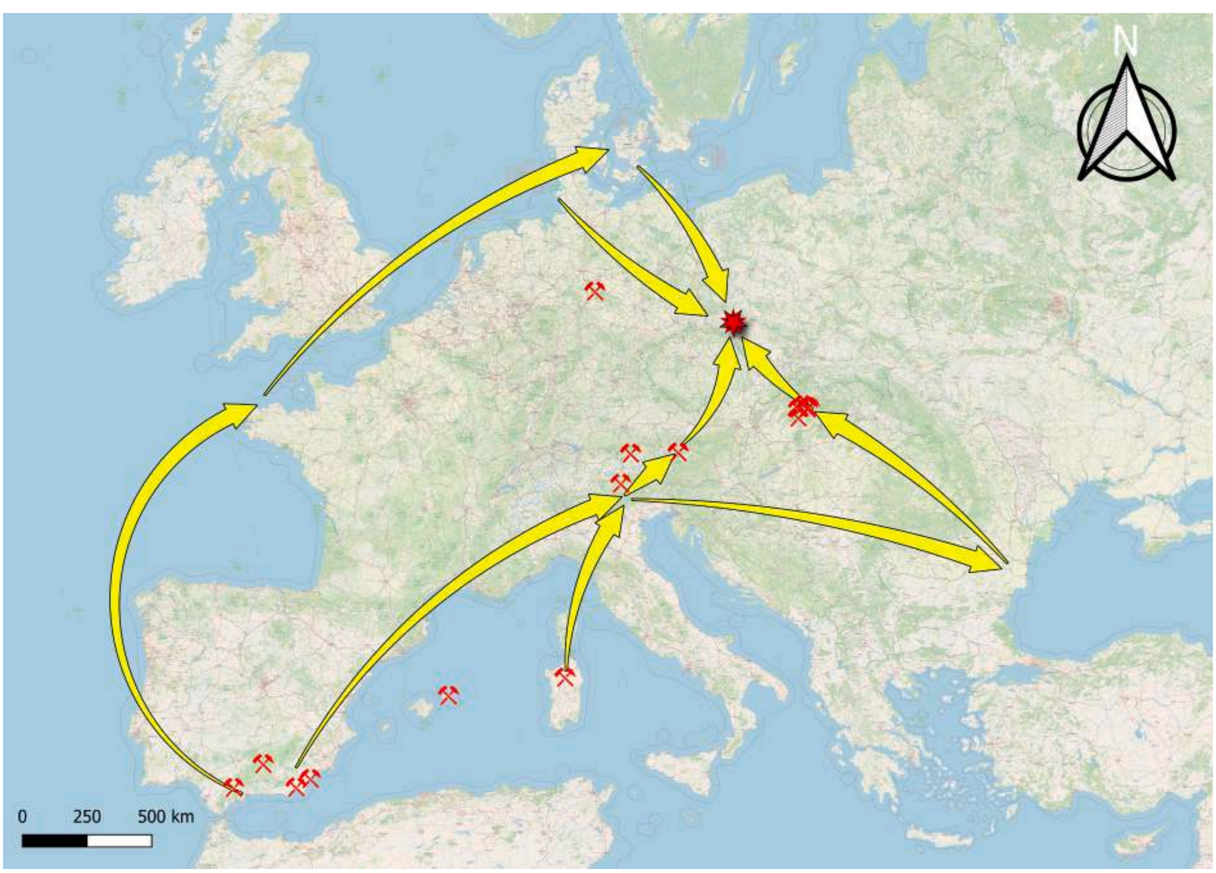

Fig. 11. Hypothetical possibilities of metal influx into central Europe. Lusatian Culture communities included in the long-distance exchange. OpenStreetMap® licensed under the ODbL by the OSMF.

casting cakes and possibly other types of ingots. At this point, we should mention sickle no. 21 with an extremely low tin content, different from the classic alloy used in producing these items (cf. Jahn, 2013; Trampuž Orel et al., 1996). It cannot be ruled out that for the local community in Slovakia, it had the function of a raw material ingot, as it is indicated for other 'ingot-like' objects, e.g., from the Carpathian Basin (halves of the axes or hammers; Tarbay, 2014, 213-217). In the case of sickle no. 21, probably, at the destination, attempts were made to prepare the sickle for regular use, as evidenced by the forging marks of the blade.

An additional interesting issue is the matter of contact with the North – with the Nordic Bronze Age societies. Research shows (Ling et al., 2014; Melheim et al., 2018) that the Nordic zone had lively contact with the Iberian Peninsula, acquiring metals from Iberian mines. A theoretical possibility is the redistribution of metal obtained by Nordic traders from the Iberian Peninsula (Fig. 11). This theory opens the possibility that Nordic traders obtained metal not only for their own use, but also for trade into northern and central Europe, including the communities of Lusatian Urnfields. For contacts and transport, they could use the rivers – the Elbe and the Oder. In this theory, we would have to assume that the Nordic traders transported to the south not only amber, but also copper.

6. Conclusions

The type of the deposited items, their typological relations, elemental composition, and the provenance of raw materials make the hoard from Paszowice unique for SW Poland. The hoard includes a set of artefacts never found together in a single Polish deposit and reflecting the hoarding pattern prevalent in the Czech Republic, Moravia, Slovakia, Austria and Hungary.

A detailed typochronological analysis determined the geographical distribution of the specific artefact types. Most matches come from the NE Carpathian Basin, Moravia near the Moravian Gate, and S Slovakia. The distribution area of these characteristic items stretches along the NW-SE axis with finds from Paszowice at its northernmost end.

Our studies of metal provenance based on lead isotope analyses showed a multidirectional influx of metal to the Lusatian Urnfield zone. Based on a comprehensive analysis of artefacts from the Paszowice hoard – pioneering for Poland's LBA metals – we concluded that the metal came both from the nearest mining regions (Slovak Ore Mountains, Mitterberg) and those very distant (Spain, Italy).

We cannot unambiguously determine whether the hoard's owner was a so-called itinerant bronzesmith. However, we concluded that items of non-local type were imported and used on-site by a local metallurgist to produce new tools according to local patterns. How many 'biographies' the metal had along its way, we cannot say. As indicated by the as-cast state of the items and the presence of casting waste, local imitations of foreign items were also produced.

We have identified the possible northern or southern directions of metal influx to Poland. Our research demonstrated that central Europe, represented in this case by the communities of the Lusatian Urnfield Culture in SW Poland, participated in the long-distance exchange, in which one of the main goals was to obtain a metal supply.

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CRediT authorship contribution statement

Kamil Nowak: Conceptualization, Project administration, Funding acquisition, Investigation, Visualization, Writing - original draft, Writing - review & editing. **János Gábor Tarbay:** Conceptualization, Visualization, Writing - original draft, Writing - review & editing. **Zofia A. Stos-Gale:** Data curation, Visualization, Writing - original draft, Writing - review & editing. **Paweł Derkowski:** Formal analysis, Investigation, Data curation, Writing - original draft. **Katarzyna Sielicka:** .

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

All data used can be found in the figures, tables and supplementary materials.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jasrep.2023.103970.

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