Abhandlung

Jacek Gackowski, Łukasz Kowalski*, Andrzej P. Kowalski, Aldona Garbacz-Klempka, Grzegorz Osipowicz, Albin Sokół, Mateusz Ćwiek, Mariusz Bosiak, Marek Kołyszko, Andrzej Krzyszowski, Maciej Markiewicz, Paweł Molewski, Agnieszka M. Noryśkiewicz, Małgorzata Perek-Nowak, Anna Rembisz-Lubiejewska, Tomasz Skorupka, Mateusz Sosnowski

A Late Bronze Age hoard from Elgiszewo reflects the complex interplay between bronzesmithing, metal hoarding and local identity

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Zusammenfassung: Im Jahr 2014 wurde im Dorf Elgiszewo in Nordzentralpolen beim illegalen Einsatz einer Metallsonde am torfigen Seeufer ein vielgestaltiger Hort aus Bronzeschmuck entdeckt und ausgegraben. Der Hort enthielt Pferdegeschirr, Körper- und Kleidungsschmuck und andere Metallgegenstände aus der späten Bronzezeit sowie eine Gussform und einen Kannelurenstein, der zur Ausrüstung eines Metallarbeiters gehört haben könnte. Im vorliegenden Artikel werden die Ergebnisse der archäologischen und metallographischen Untersuchungen des Hortes vorgestellt und diskutiert, unterstützt durch paläoökologische, petrographische und spurenbiologische Untersuchungen von Kannelurensteinen aus der Region. Die Ergebnisse werden

***Corresponding author: Łukasz Kowalski**, Institute of Archaeology, Centre for Applied Archaeology, Nicolaus Copernicus University in Toruń, Szosa Bydgoska 44/48, 87-100 Toruń, Poland. E-Mail: lukasz.kowalski@umk.pl. https://orcid.org/0000-0003-0647-826X
Jacek Gackowski, Institute of Archaeology, Centre for Applied Archaeology, Nicolaus Copernicus University in Toruń, Szosa Bydgoska 44/48, 87-100 Toruń, Poland. E-Mail: jacek.gackowski@umk.pl. https://orcid.org/0000-0002-5848-5771
Andrzej P. Kowalski, University of Gdańsk, Institute of Anthropology, Bielańska 5, 80-851 Gdańsk, Poland. E-Mail: andrzej.kowalski@ug.edu.pl. https://orcid.org/0000-0003-2009-2689
Aldona Garbacz-Klempka, AGH University of Krakow, Faculty of Foundry Engineering, Historical Layers Research Centre, Reymonta 23, 30-059 Kraków, Poland. E-Mail: agarbacz@agh.edu.pl. https://orcid.org/0000-0001-8417-6131
Grzegorz Osipowicz, Institute of Archaeology, Nicolaus Copernicus University in Toruń, Szosa Bydgoska 44/48, 87-100 Toruń, Poland. E-Mail: grzegorz.osipowicz@umk.pl. https://orcid.org/0000-0002-4393-655X
Albin Sokół, Archaeological Museum in Biskupin, Biskupin 17, 88-410 Gąsawa, Poland. E-Mail: a.sokol@biskupin.pl. https://orcid.org/0009-0000-0189-3603
Mateusz Ćwiek, Nicolaus Copernicus University in Toruń, Faculty of Earth Sciences and Spatial Management, Department of Geology and Hydrogeology, Lwowska 1, 87-100 Toruń, Poland. E-Mail: mateusz.cwiek@umk.pl. https://orcid.org/0000-0002-6172-3427
Mariusz Bosiak, Nicolaus Copernicus University in Toruń, Faculty of Chemistry, Department of Organic Chemistry, Gagarina 7, 87-100 Toruń, Poland. E-Mail: bosiu@chem.umk.pl. https://orcid.org/0000-0002-5505-3746
Marek Kołyszko, Institute of Archaeology, Nicolaus Copernicus University in Toruń, Szosa Bydgoska 44/48, 87-100 Toruń, Poland. E-Mail: marek.kolyszko@umk.pl. https://orcid.org/0000-0003-2631-8634
Andrzej Krzyszowski, Archaeological Museum in Poznań, Wodna 27 – Pałac Górków, 61-781 Poznań, Poland. E-Mail: andrzejkrzyszowski@wp.pl. https://orcid.org/0000-0003-4042-1064
Maciej Markiewicz, Nicolaus Copernicus University in Toruń, Faculty of Earth Sciences and Spatial Management, Department of Soil Science and Landscape Management, Lwowska 1, 87-100, Toruń, Poland. E-Mail: mawicz@umk.pl. https://orcid.org/0000-0002-1057-8776
Paweł Molewski, Nicolaus Copernicus University in Toruń, Faculty of Earth Sciences and Spatial Management, Department of Geomorphology and Paleogeography, Lwowska 1, 87-100, Toruń, Poland. E-Mail: molewski@umk.pl. https://orcid.org/0000-0002-7375-815X
Agnieszka M. Noryśkiewicz, Institute of Archaeology, Centre for Climate Change Research, Nicolaus Copernicus University in Toruń, Szosa Bydgoska 44/48, 87-100 Toruń, Poland. E-Mail: agnieszka.noryskiewicz@umk.pl. https://orcid.org/0000-0002-9481-8684
Małgorzata Perek-Nowak, AGH University of Krakow, Faculty of Non-Ferrous Metals, Historical Layers Research Centre, Mickiewicza 30, 30-059 Kraków, Poland. E-Mail: mperek@agh.edu.pl. https://orcid.org/0000-0003-0323-1624
Anna Rembisz-Lubiejewska, National Maritime Museum in Gdańsk, Ołowianka 9–13, 80-751 Gdańsk, Poland. E-Mail: a.rembisz-lubiejewska@nmm.pl. https://orcid.org/0000-0002-6105-1165
Tomasz Skorupka, Archaeological Museum in Poznań, Wodna 27 – Pałac Górków, 61-781 Poznań, Poland. E-Mail: tomasz.skorupka@muzarp.poznan.pl. https://orcid.org/0000-0003-3589-9098
Mateusz Sosnowski, Wdecki Landscape Park, Rynek 11A, 86-150 Osie, Poland. E-Mail: mateusz.sosnowski@wdeckipark.pl. https://orcid.org/0000-0003-1495-1627

anschließend in Verbindung zum breiteren sozioökonomischen Kontext der nordeuropäischen Bronzezeit gesetzt, einschließlich der Geographie der Metallhortung und der Verwendung von Metall im Rahmen wirtschaftlicher, sozialer und ritueller Aktivitäten während der Lausitzer Zeit in Polen.

Schlüsselworte: Späte Bronzezeit, Lausitzer Kultur, Mitteleuropa, Metallhortung, Pferdezaumzeug, Bronzeschmiede, Wanderschmied, Archäometallurgie, Spurenforschung, Petrographie

Abstract: In 2014, a multi-type hoard of bronze metalwork was unearthed as a result of illegal metal detection on the peaty lakeshore in the village of Elgiszewo, north-central Poland. The hoard contains horse gear items, body and dress ornaments and other metal objects dating back to the Late Bronze Age, accompanied by casting mould and a *Kannelurenstein* that could have once formed part of a metalworker's toolkit. This article presents and discusses the results of archaeological and metallographic examinations of the hoard, aided by paleoenvironmental, petrographic and traceological investigations of *Kannelurensteine* from the region. The results are then combined with the wider socio-economic context of the North European Bronze Age, including the geography of metal hoarding and the use of metal in the economic, social and ritual activities of the Lusatian period in Poland.

Keywords: Late Bronze Age, Lusatian culture, Central Europe, metal hoards, horse bridle, bronzesmithing, itinerant smith, archaeometallurgy, traceology, petrography

Introduction

Until recently, there has been little evidence of the prominent role of metal in the social and ritual activities of the Lusatian period in the region of Chełmno land (*Kulmerland*), north-central Poland. This region has yielded thirteen metal hoards dating to the later Bronze and Early Iron Age that are clustered near the local major settlements and mostly comprise up to ten metals[1]. However, the recent discoveries at Cierpice[2] and Papowo Biskupie[3] near Toruń have challenged this picture and shed some new light on the absorption of metal by the Lusatian people of Chełmno land. A multi-type hoard discovered in 2014 in the village of Elgiszewo on the Drwęca River (Fig. 1), which marks the southern border of the Chełmno group territory, provides evidence of a significant increase in metal consumption in the region. The same hoard follows hoarding patterns observed in other Lusatian regions that gravitated towards the Nordic zone. In these regions, female-gendered ornaments and horse bridle elements from the later Bronze Age to the Early Iron age were found to be frequently deposited together[4]. The choice of location for the Elgiszewo deposit also adheres to the overall topography of other North European Bronze Age metal hoards, which were often sunk or buried at the interface between wet and dry landscapes.

This paper considers a bronze hoard from Elgiszewo to be the materialisation of the complex interplay between bronzesmithing, metal hoarding and local identity. We present and discuss the results of archaeological and metallographic examinations of the hoard, which are aided by paleoenvironmental, petrographic and traceological investigations of *Kannelurensteine* from the region. An examination of bronze and stone artefacts from the hoard addresses the question of metalwork production during the Lusatian period in Poland and touches upon issues of metal commoditisation and weight standardisation in the North European Bronze Age. The contextual and paleoenvironmental evidence raises additional questions regarding both the geography of metal hoarding, and the use of metal in economic, social and ritual activities of the era.

The Elgiszewo hoard

The history and context of discovery

The hoard was unearthed in 2014 in the village of Elgiszewo near Toruń (Kuyavian-Pomeranian province) as a result of amateur and illicit metal detecting of the peaty shore of Lake Okonin (Fig. 2), although it was not initially reported. A few months later, the hoard's finders informed the Provincial Office for the Protection of Monuments in Toruń of the discovery. Soon after, a rescue dig was conducted by professional archaeologists at the find spot indicated by the finders; this dig revealed no additional metal objects or other archaeological material. A metal detector survey along the lake shore also revealed no signals relative to non-ferrous metal objects. During the exploration, soil samples for pedological analyses were taken from the trench. The finders claimed that the metal objects were located several dozen centimetres below the surface and were closely adjacent to

1 See, e. g. Gackowski/Kowalski 2019; Kowalski *et al.* 2020.

2 Gackowski *et al.* 2023.

3 Gackowski *et al.* 2024.

4 See, e. g. Kristiansen 1998; Sarauw 2015.

Fig. 1: The hoard from Elgiszewo (photographs: W. Ochotny; edited by Ł. Kowalski).

each other, suggesting that they may have originally been placed in an organic bag that had since decayed.

Visual examinations revealed that a substantial portion of the artefacts were badly damaged and firmly covered with a mixture of soluble corrosion products and soil particles from a well-aerated burial context (Fig. 3A). The metal artefacts were exposed to various types of corrosion, including pitting (Fig. 3C), cracking (Fig. 3D and 3E) and intergranular corrosion (Fig. 3F), which ultimately led to the failure of their structures, resulting in the occurrence of multiple perforations and ragged edges. Features of mechanical damage were also evident in some of the artefacts, possibly due to their use in the past. Six artefacts, including the casting mould and body ornaments, suffered further deterioration following the illegal excavation, as they were unprofessionally cleaned by the finders before being returned to archaeological officers. A detailed record of the treatment was kept, including photographs and written descriptions of the objects. Loose corrosion products and organic and mineral contaminants were carefully removed from the artefacts. Thereafter, actively corroding artefacts were exposed to a solution of 1.5 % w/v sodium hydroxide, 15 % w/v sodium potassium tartrate (Rochelle salt), and 83.5 % w/v water. Due to the porous structure of the metal objects, aqueous ultrasonic cleaning was carried out using cavitation bubbles and repeated to ensure the removal of salts and corrosion products. The artefacts were then dried with hot air and immersed in an ethanol bath to remove moisture before consolidation with acrylate resin. After gentle brushing, the artefacts were coated with 10 % w/v Paraloid B-72 in xylene and preserved with microcrystalline wax Cosmoloid H80 in xylene.

Geographical setting

The hoard is located in the Drwęca River Valley, which was formed during the last stage of the Pleistocene glaciation (the Weichselian glaciation) and the beginning of the Holocene[5] (Fig. 4A). The Drwęca River Valley cuts through the moraine plateau that covered predominantly of lessive soils formed

5 Kondracki 1998.

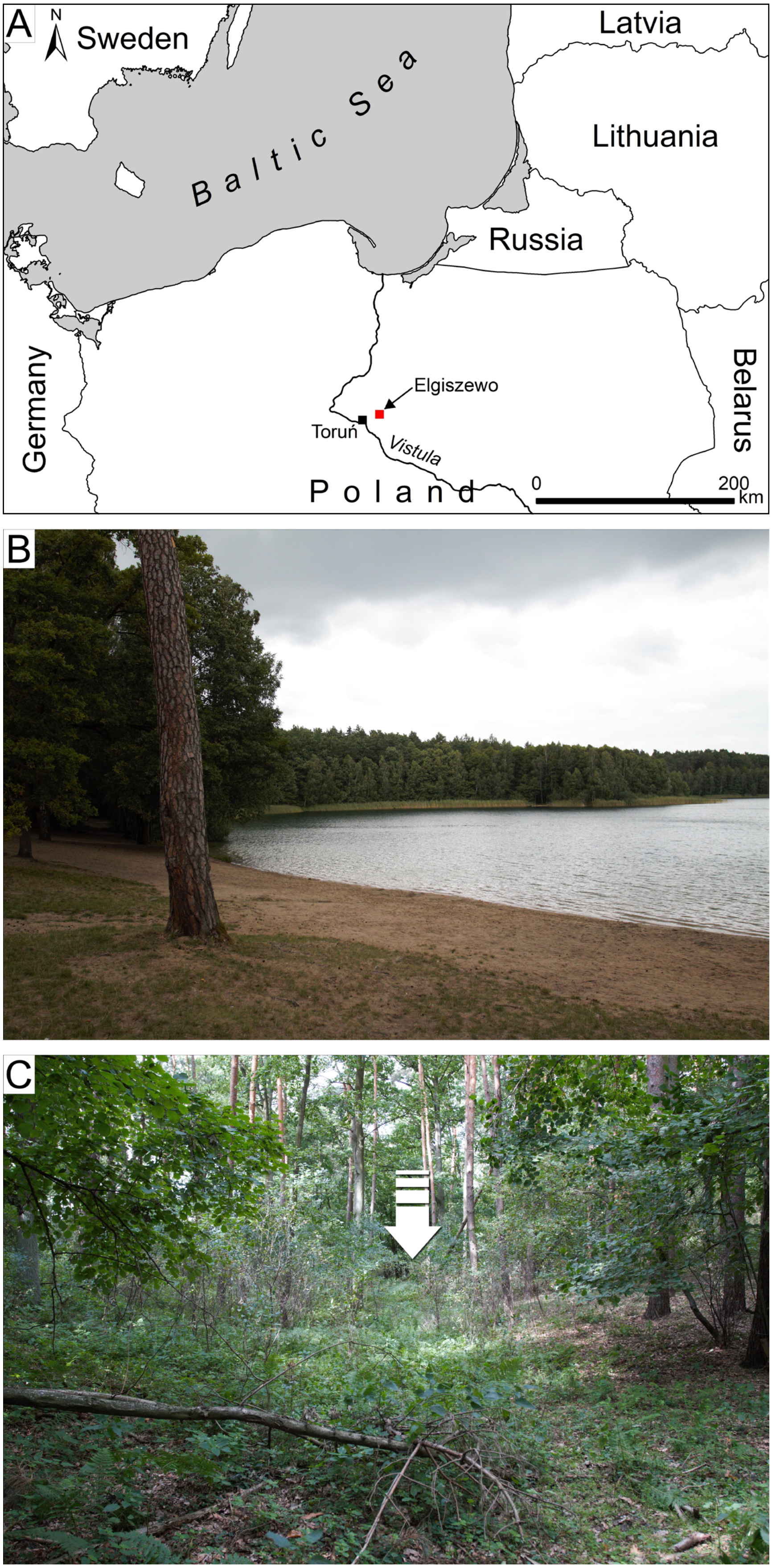

Fig. 2: A – Location map of Elgiszewo; B – general view of Lake Okonin from the find spot side; C – view of the find spot (photographs: M. Sosnowski; map background: P. Molewski).

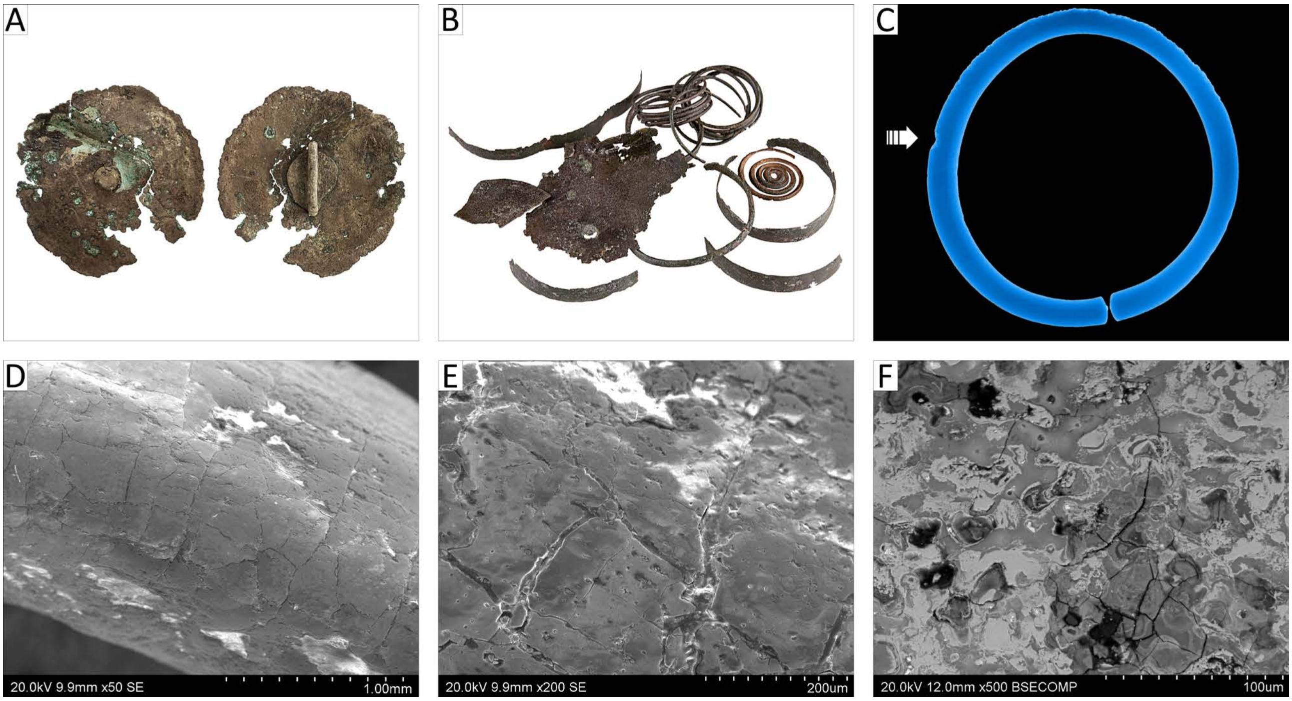

Fig. 3: Corrosion products and mechanical damage of the metal artefacts (photographs: W. Ochotny, M. Perek-Nowak, A. Garbacz-Klempka). See text for further details.

on till (Fig. 4B). With the recession of the ice sheet, sand and gravel ice-marginal and river terraces were formed that are now covered with forested rusty and podzolic soils. The floodplain occupies organic soil and winding and meandering main channel of the Drwęca River[6]. Tunnel valleys intersect the moraine plateau and terraces[7].

The hoard was buried in the forested shoreline zone of Lake Okonin, ca. 550 m north of the Drwęca River meander (Fig. 4B). Lake Okonin is in a kettle hole; the water level in the lake is 60.6 m a.s.l., the surface area is 35.0 ha and the average and maximum depth are 7.5 m and 11.5 m, respectively[8]. The findspot is located in a denudational trough valley with a depth of 6–7 m, stretching over a length of 100 m with an average width of 65 m (Fig. 4C). In the northern and southern parts of the lake basin are peat bogs located at 61.0 m a.s.l. – approximately 0.5 m above the current water level of Lake Okonin. A simulated increase in the water level of Lake Okonin by 0.5 m would result in flooding of the peat bogs, whereas an increase of 1–1.5 m would spread flooding to the beaches and exposed shoreline shallows (Fig. 4C). The climatic events at the turn of the Subboreal and Subatlantic periods in the Polish Lowland led to a gradual rise in lake water levels[9]. These fluctuations in Lake Okonin could have created a small wetland in the trough where the Elgiszewo hoard was located. Further to our recent study of the Cierpice hoard[10], this adds to a growing body of evidence that metal hoards of the North European Bronze Age were often buried at the interface between wet and dry environments.

Archaeological setting

Over the last few decades, the Elgiszewo region remained a blank spot on the map of Late Bronze Age settlement in Chełmno land[11], and the only evidence of Lusatian activity in the region was found at in nearby cemetery at Ciechocin, on the south side of the Drwęca River[12]. Subsequent prospections have revealed archaeological records that add more detail to the picture of the Lusatian settlement in the region (Fig. 5). A clear concentration of Lusatian dwellings on both sides of the Drwęca River was identified, indicating neighbourhood communities in the local settlement structure, as evidenced by the numerous open settlements in the

6 Szumińska 2002, 515–525.
7 Niewiarowski 1968, 59.
8 Atlas jezior Polski 1997; Mapa hydrograficzna 2015.
9 See, e. g. Niewiarowski 1995, 215–234; Kowalewski 2014, 71–76.
10 Gackowski *et al.* 2023.
11 Chudziakowa 1974, 83–88 mapy II–IV.
12 Zielonka 1959, 21; Chudziakowa 1974, 135.

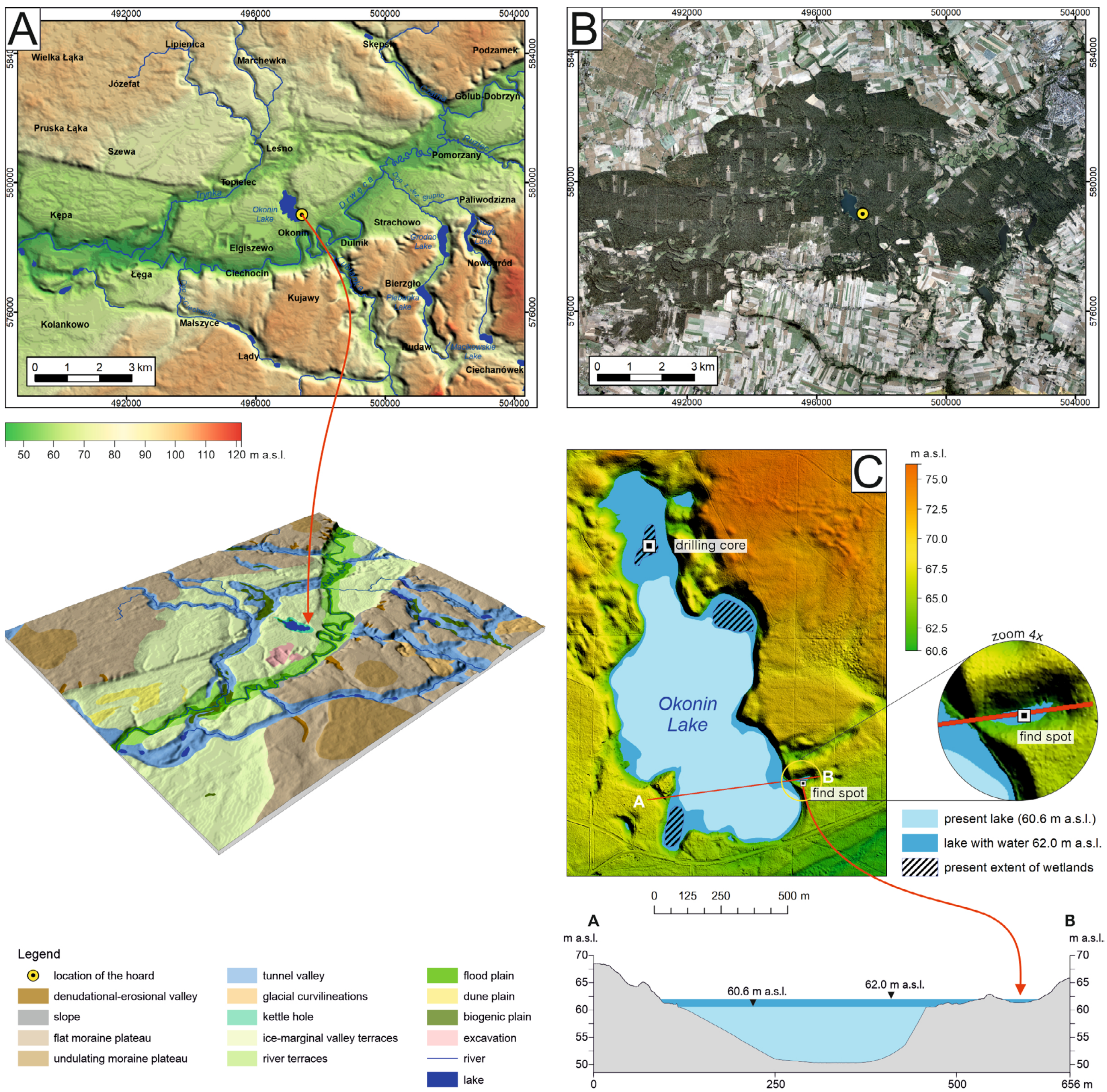

Fig. 4: Geographical setting for the Elgiszewo hoard. A – Hypsometry and geomorphology of the area surrounding the find spot (Niewiarowski 1965; Wysota 2007; Weckwerth *et al.* 2013, with changes); B – orthophotomap of the area surrounding the find spot; C – terrain model around the find spot with a simulated increase in the water level of Lake Okonin by 1.5 m and the location of drilling core for pollen analysis (figure by P. Molewski; orthophotomap and DTM data source: Head Office of Geodesy and Cartography (GUGiK); Lake Okonin bathymetric plan source: The Stanislaw Sakowicz Inland Fisheries Institute).

vicinity of Lake Okonin (e. g. sites at Elgiszewo and Ciechocin and bends of the Drwęca River); further west, along the Drwęca valley near the villages of Lubicz Dolny, Jedwabno, Młyniec Dolny and Młyniec Górny; and settlement traces in areas slightly further north-west, for example at Kamionki Małe near Łysomice[13]. In addition, the cremation cemeteries of Ha B3/Ha C are located south and southwest of Elgiszewo, including burial sites at Ciechocin, Jedwabno, Młyniec Dolny, and Młyniec Górny[14]. The cartography of ceramic finds and other archaeological records from the Drwęca Valley and adjacent areas offers evidence of stable Lusatian settlement

13 Gackowski 2012, 170–171.

14 Chudziakowa 1974, 148–149, 156–157; Dąbrowski 1997, 160–163 mapa 4.

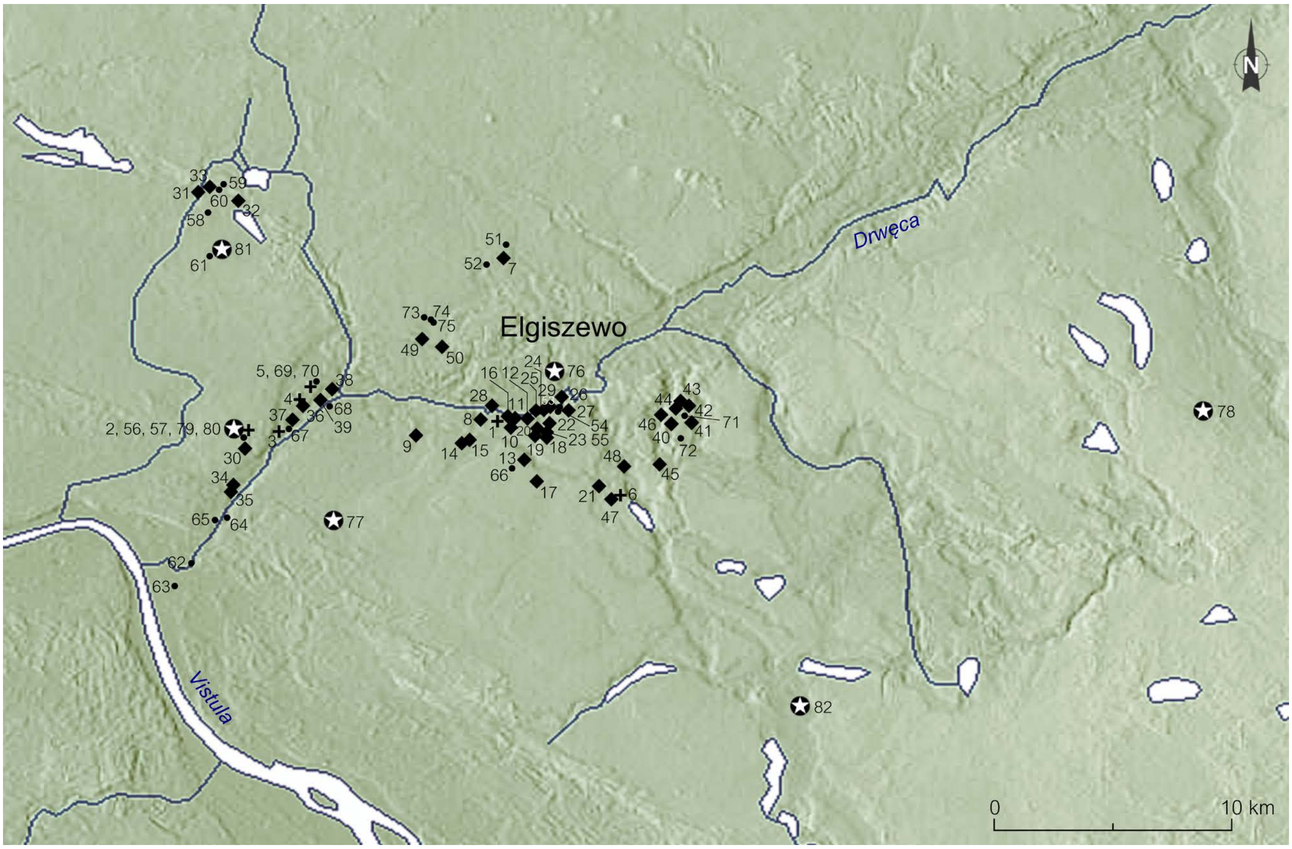

Fig. 5: The Elgiszewo hoard in the settlement landscape of the Chełmno group and the adjacent area in the later Bronze Age and Early Iron Age. The cartography includes the distribution of metal deposits, and identifies an important regional communication hub near the present-day Elgiszewo (map background: maps-for-free.com; edited by J. Gackowski, Ł. Kowalski). ✚ cremation cemeteries; ◆ open settlements; ● settlement traces; ✪ metal deposits. For more details see "List of sites from the studied area."

in the region as early as the Later Bronze Age that smoothly continued into the subsequent Early Iron Age – a period that saw the peaceful coexistence of the local Lusatian folks of the Chełmno group with migrating individuals and families of the Pomeranian culture. Archaeological evidence also points to existence of inter-tribal communication between the Lusatian settlers from the Elgiszewo region and their southern kinsmen from the Dobrzyń land (*Dobriner Land*), as exemplified by open settlements and cemeteries near the villages of Miliszew, Rudaw, Plebanka and Nowogród. This local settlement network was most likely extended through the Konstancjewo Basin to the Lusatian settlers from the areas adjacent to the edge of the Drwęca Valley near Białkowo, Płonka and Szafarnia[15], so it would be difficult to argue that the Drwęca River was a natural and cultural barrier separating these neighbouring Lusatian regions, as suggested by previous studies on this area[16].

This cultural landscape is complemented by a number of metals, demonstrating that local Lusatian power elites were parties to the widespread metal trade network connecting the Drwęca Valley with other regions of the European Late Bronze Age. The plate fibula from the cemetery of Jedwabno, which seems to originate from workshops operating in northern Germany is an example of this[17]. Similarly, the site of Głogów, on the southern bank of the Drwęca River and about 30 km east of Elgiszewo, had an antenna sword with all the characteristics of the *Flörsheim* type of the South European sword industry dating to the Ha B2 period[18]. Another example comes from Głowińsk, near Rypin, where a decorated bronze cauldron with cross attachments was discovered in 1940 connection with peat draining in Kościelny Las (*Kirchwalde*)[19]. The Głowińsk

15 Gackowski 2012, 172.

16 Chudziakowa 1974, 100; Dąbrowski 1997, 98.

17 Chudziakowa 1974, 59–60; Fogiel 1988, 44; Dąbrowski 1997, 62; Bukowski 1998, 229–230; Gedl 2004, 42–43; 47, 153 Taf. 23,87.

18 Müller-Karpe 1961, 55–56 Taf. 52,1–5; Bugaj 2005; Kucharski 2005, 168–169; Gackowski 2016, 14; 30; 36.

19 Heym 1942, 19–22; Gedl 2001, 31–32; 2003, 43–47.

cauldron is often cited as a luxury product of the Gáva-Holigrady culture workshops of the Carpathian region[20], and the discovery of a damaged but very similar cauldron at Elgiszewo attests to this pattern of metal movement and consumption in the region.

Typo-chronology of the hoard[21]

Body ornaments

The hoard comprises fragments of spiral bracelets (Plate 1,1–3) and armbands decorated with a zigzag motif (*Armspiralen mit Zickzackverzierung*) (Plate 1,4–9), made of sheet bronze and provided with narrowed endings. These pieces could originally have formed five different ornaments (see section "Elemental composition"). Each of the two categories has similar dimensions and shapes. Spiral bracelets and armbands are typical products of Lusatian workshops that operated over a wide geographical range from the lower Vistula westwards through the middle Warta and Oder regions, to the Saale basin throughout the later Bronze Age. A corpus of spiral hand ornaments also continued to be used in this zone at the beginning of the Iron Age[22].

There is also an undecorated bronze bracelet made of U-shaped sheet metal (Plate 1,10). Until now, such body ornaments had not been found and reported in Chełmno land. However, they are common in the Nordic zone and Pomerania[23], which appears to have been the metallurgical centre handling these types of bracelets and serving their clients in Greater Poland, the southern parts of East Prussia and Scandinavia[24]. This group of metals also includes three solid and undecorated bracelets made of round bronze rods (Plate 1,11.14.15). These artefacts appear to be related to the metal inventories of the later Bronze Age in Greater Poland[25] and their origins can be traced to either the region of Silesia or to Western Pomerania[26].

The two necklaces, both made of bronze rods, display similar diameters and no decorations (Plate 1, 16–17). One of these is provided with narrowed endings and a clasp (Plate 1,17), which has counterparts in Greater Poland[27] and appears to be related to necklaces from Mecklenburg-Vorpommern[28].

Dress ornaments

This group comprises a fragment of sheet bronze decorated with dotted circles and arches that can be added as a *Spindlersfeld*-type[29] fibula (Fig. 6A), more precisely the western Greater Poland variant *Chłopowo*[30] (Plate 1,13). This is the first archaeological evidence of a *Spindlersfeld* fibula from the Chełmno region. However, there is a reasonable basis for the conclusion that variants *Chłopowo*, *Wierzchowo*, *Kopaniewo* and *Piaszczyna*, known from the southern coast of the Baltic Sea[31], are local remakes of *Spindlersfeld* fibulae originating from Bohemia, Moravia and Lower Silesia, and continued to be used in the region of Pomerania at the beginning of the Iron Age[32].

The hoard contains a spiral coil that is likely to have formed the part of the *Spindlersfeld* fibula (Plate 1,12).

Phalerae

This is the largest group of metalwork from the hoard, containing nine bronze phalerae provided with one or two loops, which further proves that phalerae were frequently chosen by the Chełmno group to hoard[33]. Three phalerae are identifiable by their domed centre with flattened knob and a single loop (Plate 2,1–3), which places them within the *Kalisz* typological group[34]. One metal object from the

20 Gedl 2003, 45–47.

21 Typo-chronology of the hoard has already been analysed and discussed in Gackowski *et al.* 2021. For typo-chronological information of the hoard see also Gackowski 2016, Gackowski/Kowalski 2019 and Kowalski *et al.* 2019.

22 Kossina 1917, 51–57; Sprockhoff 1956a, 172–177; 1956b, 83–84 Karte 34, Taf. 36; Kostrzewski 1958, 134; Kostrzewski *et al.* 1965, 152–153; Bukowski 1998, 233; 345; Skrzypek 1999, 116–117; 2001, 170; Blajer 2001, 189–190, 194; 2013, 67–68; Gackowski/Rosołowski 2020, 88–89.

23 Sprockhoff 1956a, 206–208; 1956b, 141.

24 Szafrański 1955, 63–64.

25 Dąbrowski 1997, 67.

26 Szafrański 1955, 65–66.

27 Ibid. 69–70; Sprockhoff 1956a, 89–91; 154; 1956b, 135 Taf. 31,2–5; Kaczmarek 2002, 171–173 ryc. 67,6–7.

28 Sprockhoff 1956a, 155; 1956b, 135 Taf. 33,3.

29 Sprockhoff 1938, 205–233; Blajer 2001, 209.

30 Sprockhoff 1956a, 59; Skrzypek 1999, 110; Blajer 2001, 342; 344; 350; Gedl 2001, 28–30 tabl. 13.

31 Podgórski 1993, 305–311; Skrzypek 1999, 95–129; 2001, 169–184; Blajer 2001, 209–210, 350; 353; Rząska 2017, 38–39.

32 Bukowski 1998, 341–342.

33 Until now, more than twenty phalerae are known from Chełmno land, most of which are yielded by multi-type hoards from the beginning of the Iron Age in the region (Delekta 1935; Zielonka 1955; Chudziakowa 1974; Jędrzejewski 2009; Kowalski *et al.* 2020; Gackowski *et al.* 2023).

34 Sprockhoff 1956a, 263–269; Bukowski 1998, 295–297; Blajer 2001, 60; Kaczmarek 2005, 142; 2012, 318–319.

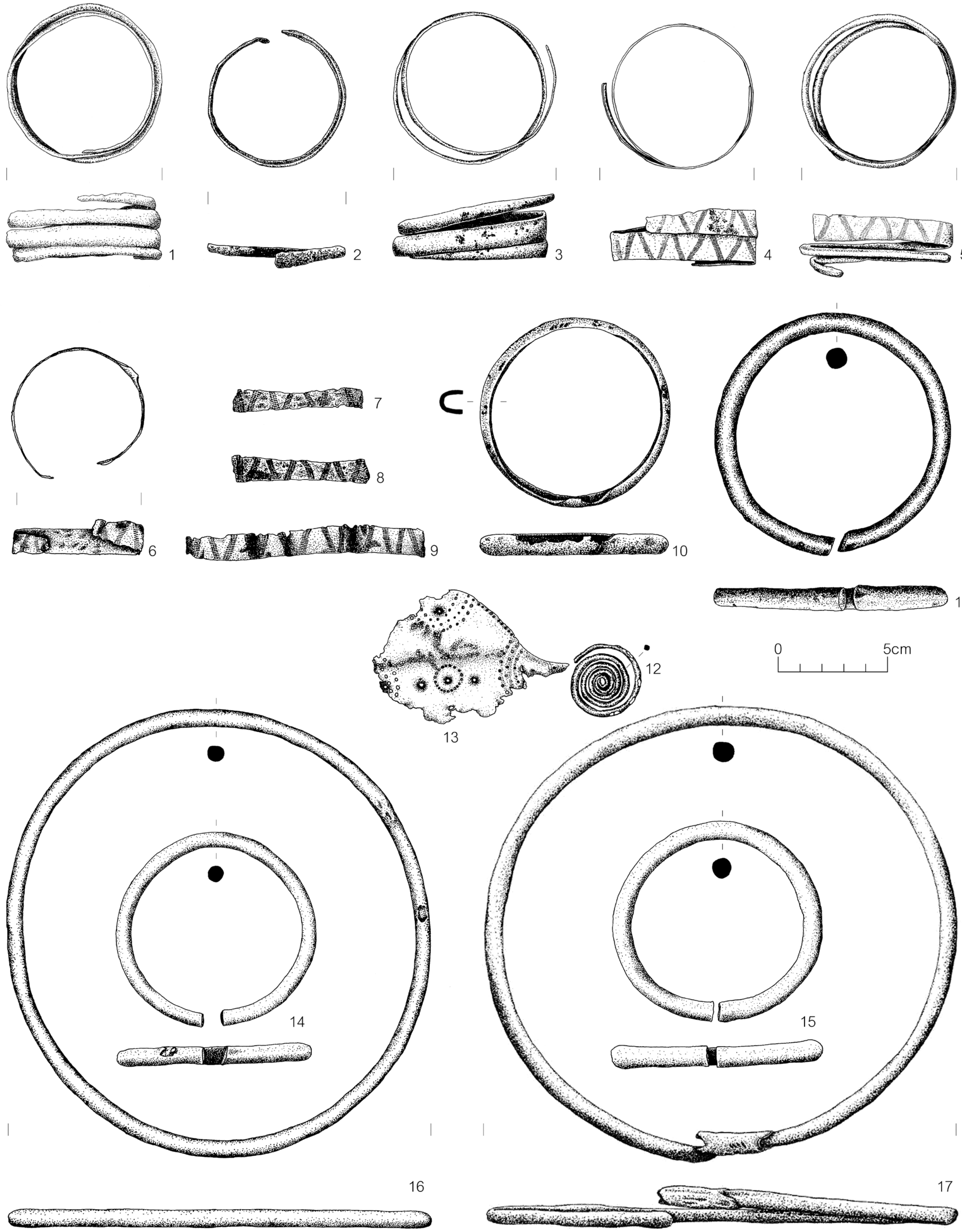

Plate 1: Metal hoard from Elgiszewo. 1–11, 14–17 body ornaments, 12–13 dress ornaments (drawings: M. Nowak).

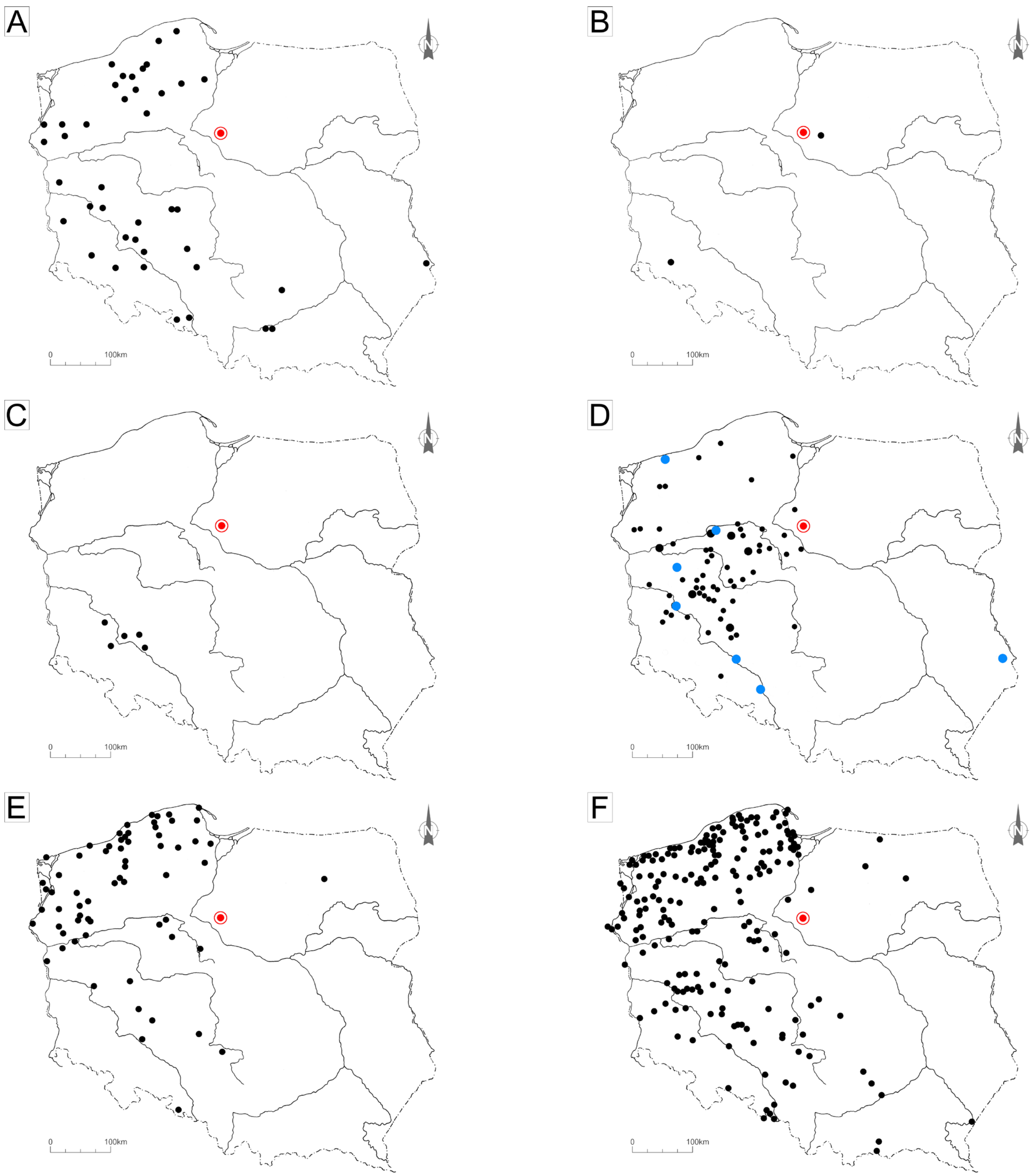

Fig. 6: Map of Poland showing distribution of the metal(work) from the Elgiszewo hoard. A – *Spindlersfeld* type fibulae; B – bronze cauldrons; C – antenna knives; D – *Przedmieście* type socketed axes and metal casting moulds; E – bronze waste; F – metal hoards of Ha B2–Ha B3. Large spots stand for three or more axes found together, blue spots stand for metal casting moulds, red spot stands for the Elgiszewo hoard (after Blajer 2001; Gedl 1984; 2001; 2004; Kaczmarek *et al.* 2021; Kowalski *et al.* 2019; Kuśnierz 1998; Szczurek/Kaczmarek 2022).

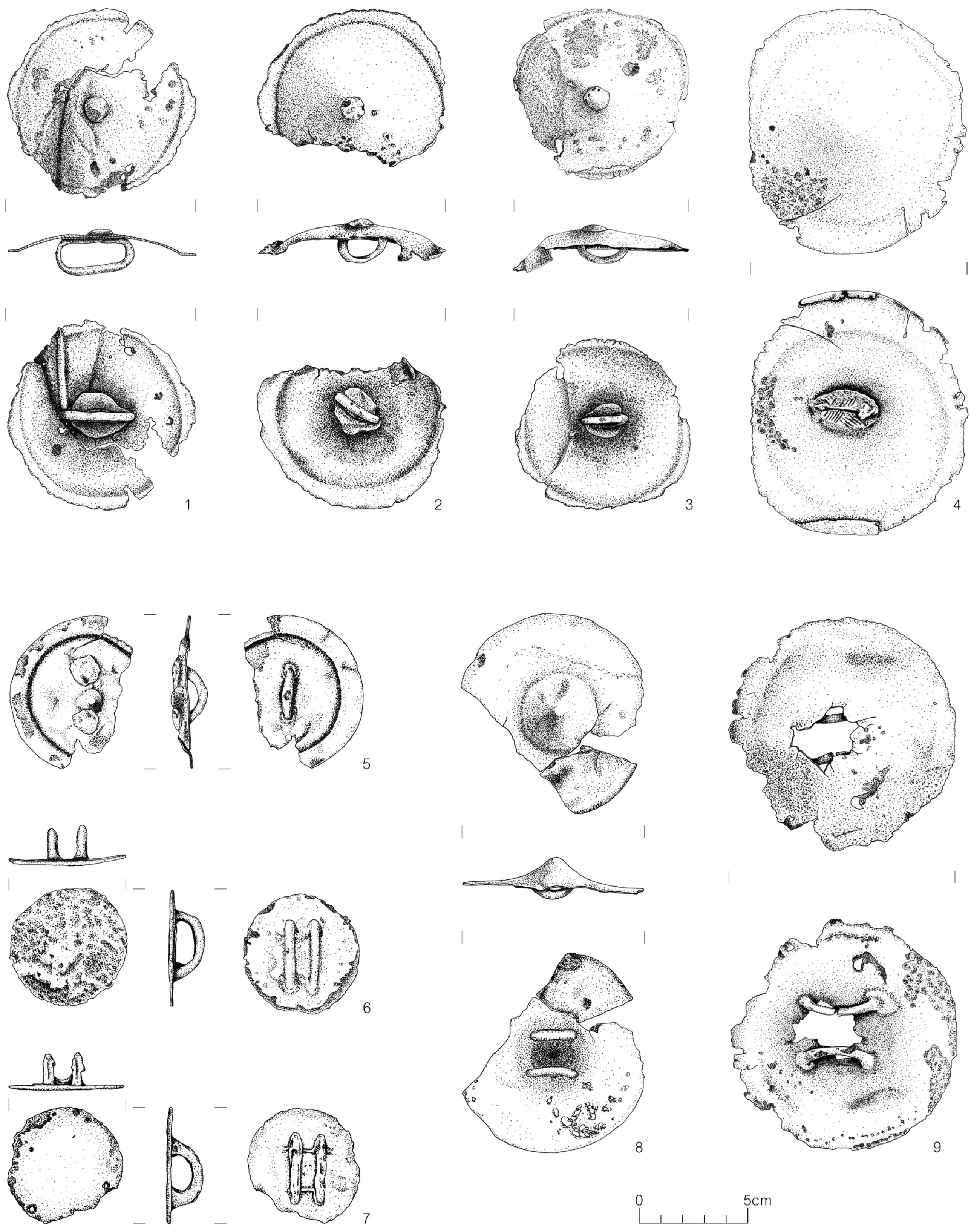

Plate 2: Metal hoard from Elgiszewo. 1–3 *Kalisz* type phalerae, 5 *Morgenitz* type phalera, 4, 6–9 other phalerae (drawings: M. Nowak).

hoard contains a flat rim and single loop endings and is flat hammered at the outer side of a dome (Plate 2,5) – this can considered a *Morgenitz*-type phalera. This type of phalerae is generally associated with the later stages of the North European Bronze Age[35]. Two additional phalerae are provided with two cast loops (Plate 2,8, 9) and have parallels in the Lusatian cemetery at Toruń-Kaszczorek[36] in Chełmno land. However, horse gear items of this type are much more prominent in the metal assemblages of Ha B2–Ha B3 in Greater Poland[37]. Two other phalerae with two loops of almost identical shape and dimensions (Plate 2,6, 7) appear to be related to examples produced by the Lusatian workshops of the Silesia region during the Ha B2–Ha B3 period[38]. Finally, this typological group contains a phalera that was originally provided with a single loop (Plate 2,4) and decorated at the base of the loop with a zig-zag motif.

Cauldron

Two similar twisted handles with looped and decorated cross attachments were originally riveted to a bronze cauldron (Plate 3,1, 2). Comparisons of the handles from Elgiszewo provide a very good match with the bronze cauldron from the Late Bronze Age hoard from Głowińsk near Rypin (Fig. 6B), which is presumed to represent a product of the Gáva-Holigrady culture workshops of the Ha B2–Ha B3 period[39].

Tools

The hoard includes a decorated knife (Plate 3,3) which has preserved a handle with a damaged blade part and a hilt ending in a pair of broken antennae. The Elgiszewo knife represents a significant expansion of *Szymocin*-type knives in Poland (Fig. 6C), extending its distribution beyond the previously limited range within the Silesian region[40] to encompass northern Poland.

The bipartite bronze casting mould included in the hoard (Plate 3,4) is characteristic of the socketed axes of the *Przedmieście* type, variant G[41], which are associated chiefly with the Late Bronze Age and the beginning of the Early Iron Age in southern and western Lusatian regions in Poland[42] (Fig. 6D). They are also found in the metal inventories of Pomerania, which may push the Elgiszewo hoard to the Ha B3/Ha C period, roughly corresponding to 800–700 BC. Metal casting moulds for socketed axes were relatively scarce in Late Bronze Age Poland. At the time of writing, ten examples have been reported, with the main distribution in western Poland[43].

The assemblage also comprised a lenticular-shaped stone artefact (Plate 4,1) with circular indentations on the upper and lower faces and an artificially flattened surface on the diameter (see section "*Kannelurensteine*").

Semi-products and waste

These comprise a fragment of sheet metal (Plate 3,5) and bronze wire coils (Plate 3,6–9). In Poland, bronze waste and semi-products have been identified in metal deposits of the later Bronze Age (Ha B2–Ha B3), but they more frequently featured in the final Bronze Age and the beginning of the Iron Age (Ha C)[44] (Fig. 6E). Similar artefacts can be traced to Chełmno land, where a hoard consisting of a socketed chisel, an armband and bronze wire spirals was found in 1891 in Chełmno[45], or to deposits of bronze semi-products found in Kałdus[46] and Lipienek[47].

Analytical methods

Initially, the metal artefacts were examined for casting defects and technological and use-wear traces using a Nikon SMZ 745Z stereoscopic microscope (OM) equipped with a Nikon Digital Sight DsFi1 microscope camera (magnification ×0.67). Then, the freshly exposed and cleaned surfaces of the metal artefacts were analysed for elemental concentrations using a Spectro Midex ED XRF spectrometer equipped with a molybdenum X-ray tube and a silicon Drift Detector (SDD), with a standardless mode using the fundamental parameters program (FP+) for correction of matrix effects, and a Hitachi S-3400N scanning electron microscope coupled with a BSE detector and an EDS NORAN 986B-1SPS spectrometer

35 Sprockhoff 1956b Taf. 62,4.5.8; Bukowski 1998, 296.
36 Delekta 1935; Chudziakowa 1974, 204 tabl. XXII,3.
37 Kaczmarek 2005, 142 tabl. XXV,7; XXVI,17.20.24.
38 Kaczmarek 2002, 137–138; 2012, 386; see also Blajer 2001, 54–57; 2013, 74–75.
39 Heym 1942, 19–22; Gedl 2001, 31–32; 2003, 43–47.
40 Gedl 1984; 1985; Bugaj 2005.
41 Kuśnierz 1998, 8–9.
42 Kuśnierz 1998, 33–53; Kaczmarek 2002, 98–99.
43 Baron *et al.* 2014; Kowalski *et al.* 2019; Orlicka-Jasnoch 2019.
44 Blajer 2001, 234–235.
45 Dąbrowski 1997, 71 ryc. 52,n; Gackowski/Kowalski 2019, 226–227.
46 Gackowski/Kowalski 2019, 228.
47 Kowalski *et al.* 2020.

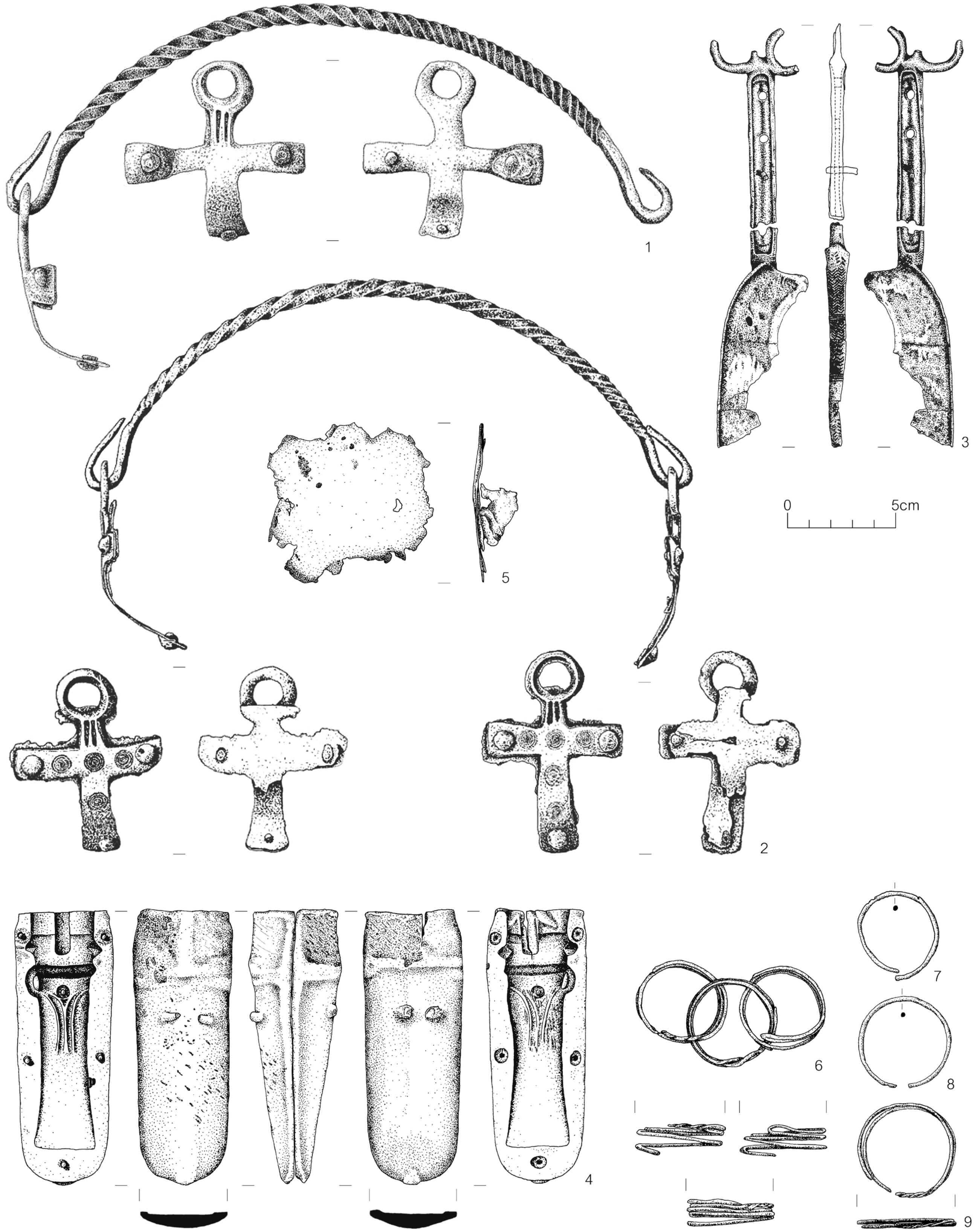

Plate 3: Metal hoard from Elgiszewo. 1–2 cauldron, 3–4 tools, 5–9 semi-products and waste (drawings: M. Nowak).

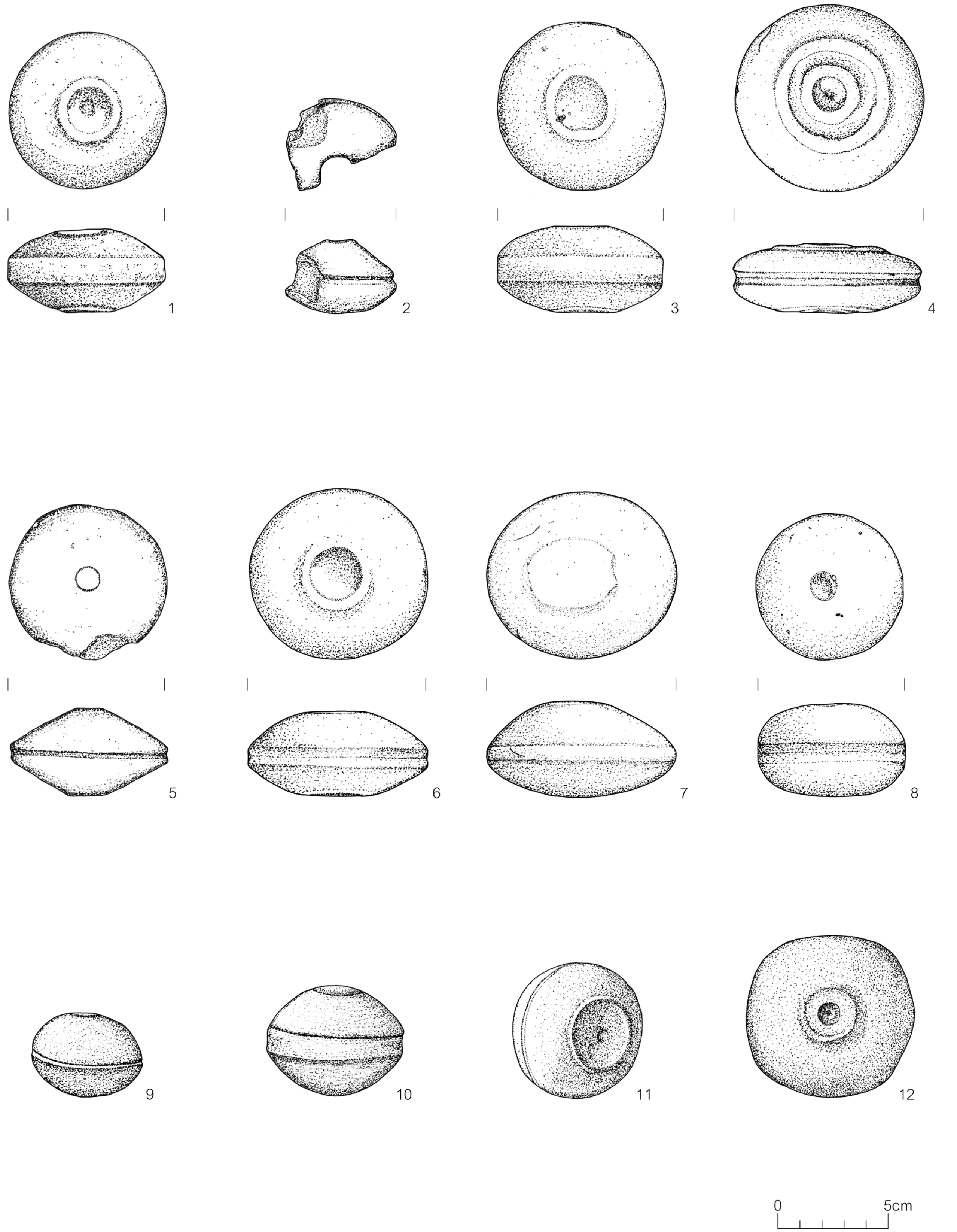

Plate 4: *Kannelurensteine* from the studied area (and the East Prussia). 1 – Elgiszewo, 2 – Głażewo, 3 – Gniewkowo-Zajezierze, 4 – Kałdus, 5 – Kijewo Szlacheckie, 6 – Ruda (site 3–6F), 7 – Ruda (site 3–6D), 8 – “Chełmno land”, 9, 10 – Mołtajny, 11 – Ogródki, 12 – Szczecinowo (drawings: Ż. Pankowska-Gajek; 9–12 adapted from Hoffmann 1999).

(Thermo Noran) operating at 20 kV accelerating voltage and chamber pressure of 50Pa. The analytical conditions used for ED XRF were 44.6 kV, 5.9 mA, 180 s of live time, and a spot size of 0.5 mm. The detection limits were established at 0.01 % for Ni, Cu, As and Bi; 0.02 % for Fe, Co, Ag, and Pb; and 0.05 % for Sn and Sb. The analytical error of ED XRF for trace elements in copper-based alloys is usually 10–15 %[48], and the accuracy of fundamental parameter methods is hampered when undetectable low-Z elements are present in the sample[49]. Five measurements were taken in different areas to optimise the ED XRF data reliability for each copper-based object. Selected metal objects were additionally examined using X-ray radiography using an industrial X-ray radioscopy Y.MU2000-D (YXLON) system, comprising an X-ray tube (160 kV) coupled with a digital panel detector and the YXLON Image 2500/3500 system for data imaging. Archaeometallurgical data are summarised in Tables 1 and 2 and in Figs. 7–11.

For the pollen analysis, a core was taken from the peat bog at the northern part of Lake Okonin (Fig. 4C) using an Instorf probe. The drilling depth was up to 7.0 m, and 550 centimetres of sediment were taken (from 1.5 m to 7.0 m). Samples of 1 cm^3 were taken at 2 cm intervals. In the sediment related to the Lusatian period in the region, samples were analysed at intervals of 2–4 cm, and the other periods were analysed at 2–40 cm intervals. A total of 76 samples (including 29 for the Lusatian period) were prepared following the standard pollen treatment (10 % KOH, 10 % HCl, 40 % HF) and Erdtman's acetolysis[50]. The glycerin-mounted slides were examined using a Zeiss Axioskop 2 Plus microscope equipped with a Jenoptik camera. For each sample, approximately 1000 AP grains were counted. Pollen and spore identification followed the method described by Hans-Jürgen Beug[51] and the Northwest European Pollen Flora[52]. A percentage pollen diagram was drawn using PolPal, which was then divided into four local pollen assemblage zones (LPAZ) and four assemblage subzones (LPASZ) using CONISS. The palynological data are summarised in Fig. 12.

A soil sample was taken from the find spot at a depth of 20 cm and analysed to quantify key soil properties: the pH of soil-to-solution ratio of 1 : 2.5 using 1 M KCl and distilled H_2O as the suspension medium. The contents of total carbon (TC) and nitrogen (TN) were also measured by dry combustion using the macro elemental analyser Vario Macro Cube.

A group of *Kannelurensteine* was analysed for petrography using a stereoscopic microscope, SteREO Discovery.V20 (Zeiss), with an Axiocam 305 Color camera and following the protocol for igneous (QAPF)[53] and sedimentary/clastic rocks[54]. The petrographic results are listed in Table 3 and Fig. 15. The selected stone artefacts were examined for technological and use-wear traces to reveal the manufacturing techniques and to identify their possible functions. A Nikon SMZ-745T optical microscope (magnification up to ×50) coupled with a Delta Pix Invenio 6EIII camera was first used to investigate the artefacts for technological traces as well as general characteristics of their surface and condition. The analysis of polish then used a metallographic microscope Zeiss Axioscope 5 Vario (magnification up to ×500) with an Axiocam 208 camera. Residues present on the stone artefacts were screened for elemental compositions using a low-vacuum (50 Pa) scanning electron microscope LEO 1430VP (Zeiss) coupled with the EDS spectrometer Quantax 200 with the XFlash 4010 detector (Bruker AXS). The results of the traceological analyses are shown in Figs. 16 and 18. The petrographic and traceological results were used to replicate several *Kannelurensteine* in full scale and with respect to the original raw material. The replicas were then tested for their possible use in metalworking. The experimental replicas were used against two different contact materials, and the resulting use-wear traces were documented with a metallographic microscope Zeiss Axioscope 5 Vario (magnification up to ×500) with an Axiocam 208 camera and then compared with the wear records of the original *Kannelurensteine*. The experimental data are presented in Table 4 and Figs. 17 and 18.

Results and discussion

Archaeometallurgy

Elemental composition

The results of the ED XRF analyses show that the artefacts represent three different alloy types (Table 1). The first group, which includes spiral armbands decorated with zig-zag motifs or their fragments, can be identified as relatively pure copper with a tin content between 8.5 % and 13 %, indicating the use of standard tin bronze. Five of the analysed fragments (El-2, 11, 12, 13 and 14) had identical

48 Lutz/Pernicka 1996.

49 Elam *et al.* 2004; Sitko 2007; 2008.

50 Berglund/Ralska-Jasiewiczowa 1986.

51 Beug 2004.

52 Punt 1976; Punt/Clarke 1980; Punt/Clarke 1981; 1984; Punt *et al.* 1988; 1995; 2003; Punt/Blackmore 1991.

53 Streckeisen 1974.

54 Wentworth 1922.

Tab. 1: Elemental composition of bronze artefacts from the Elgiszewo hoard. The ED XRF data are mean values of five measurements given as a percentage.

Sample ID	Plate	Artefact	Microarea	Fe	Co	Ni	Cu	Zn	As	Ag	Sn	Sb	Pb	Bi
El-1	Pl. 1: 1	Spiral bracelet	...	<0.02	0.09	0.33	88	0.13	0.31	0.28	7.1	1.1	2.7	0.03
El-2	Pl. 1: 4	Spiral bracelet	...	0.07	0.06	0.09	90	0.13	0.00	0.01	8.5	0.06	1.2	0.06
El-3	Pl. 1: 3	Spiral bracelet	...	0.17	0.14	0.26	83	0.13	0.55	0.20	13	1.2	0.41	0.04
El-4	Pl. 1: 5	Spiral bracelet	...	0.28	0.06	0.09	89	0.13	0.11	0.38	8.5	0.10	1.4	0.04
El-5	Pl. 3: 6–9	Wire links	...	0.15	0.11	0.19	88	0.15	0.26	0.19	9.5	0.74	1.0	0.04
El-6	Pl. 1: 12	Spiral fragment	...	0.07	0.07	0.29	94	0.17	0.07	0.07	4.6	0.34	0.19	0.02
El-7	Pl. 1: 10	Bracelet	...	0.26	0.07	0.31	86	0.14	0.85	0.69	9.0	1.5	0.86	0.06
El-8	Pl. 1: 11	Solid bracelet	...	0.63	0.08	0.12	92	0.15	0.14	0.29	4.7	0.69	1.3	0.08
El-9	Pl. 1: 14	Solid bracelet	...	0.26	0.06	0.10	96	0.12	<0.00	0.12	2.7	0.36	0.19	0.01
El-10	Pl. 1: 15	Solid bracelet	...	0.70	0.08	0.14	92	0.14	0.18	0.32	4.2	0.87	0.85	0.09
El-11	Pl. 1: 6	Spiral bracelet	...	0.16	0.06	0.08	89	0.15	0.04	0.02	9.2	0.03	1.3	0.03
El-12	Pl. 1: 9	Spiral bracelet	...	0.12	0.06	0.07	89	0.13	0.02	0.03	9.0	0.05	1.2	< 0.00
El-13	Pl. 1: 8	Spiral bracelet	...	0.16	0.06	0.09	89	0.14	0.04	0.01	8.7	0.05	1.2	0.03
El-14	Pl. 1: 7	Spiral bracelet	...	0.27	0.08	0.10	86	0.15	0.07	0.02	11	0.06	1.8	0.09
El-15	Pl. 3: 3	Knife	...	0.27	0.09	0.07	77	0.11	1.1	1.8	13	4.8	1.3	0.09
El-16	Pl. 2: 1	Phalera	Dome	0.11	0.09	0.23	86	0.13	0.21	0.17	10	0.30	2.1	0.05
El-16			Knob	0.46	0.08	0.19	89	0.13	0.48	0.38	6.1	0.82	2.7	0.14
El-17	Pl. 2: 2	Phalera	Dome	0.03	0.09	0.26	90	0.13	0.22	0.20	7.3	0.47	1.2	0.04
El-17			Loop	0.03	0.09	0.30	90	0.13	0.29	0.22	6.2	0.67	1.9	0.04
El-18	Pl. 2: 9	Phalera	Dome	0.04	0.06	0.12	88	0.12	0.06	0.13	11	0.17	0.23	0.04
El-18			Loop	0.05	0.06	0.11	85	0.12	0.10	0.21	13	0.18	0.23	0.05
El-19	Pl. 2: 8	Phalera	Dome	0.62	0.07	0.12	75	0.27	5.1	2.8	3.3	5.9	6.2	0.27
El-19			Loop	0.40	0.08	0.15	81	0.25	3.1	1.6	2.1	4.6	6.4	0.12
El-20	Pl. 2: 3	Phalera	Dome	0.07	0.09	0.24	89	0.13	0.19	0.22	8.8	0.50	1.1	0.04
El-20			Loop	0.03	0.07	0.29	92	0.13	0.29	0.24	4.2	0.69	1.7	0.04
El-21	Pl. 2: 4	Phalera	Dome	0.16	0.07	0.31	84	0.12	0.15	0.09	14	0.28	1.0	0.03
El-21			Loop	0.11	0.07	0.28	86	0.12	0.09	0.08	13	0.29	0.58	0.02
El-22	Pl. 2: 5	Phalera	Dome	0.02	0.08	0.43	82	0.11	0.35	0.42	11	1.5	4.6	0.04
El-22			Loop	0.39	0.07	0.10	87	0.11	0.21	0.69	7.8	2.8	0.41	0.04
El-23	Pl. 2: 6	Phalera	Dome	0.09	0.08	0.27	80	0.12	0.12	0.10	13	0.76	5.4	0.04
El-23			Loop	0.09	0.08	0.26	80	0.12	0.14	0.11	13	0.76	5.8	0.04
El-24	Pl. 2: 7	Phalera	Dome	0.16	0.08	0.25	78	0.11	0.11	0.11	15	0.83	6.0	0.03
El-24			Loop	0.22	0.08	0.25	72	0.12	0.29	0.16	18	1.0	6.9	0.04
El-25	Pl. 3: 2	Cauldron	Handle	0.37	0.12	0.21	84	0.12	0.40	0.05	12	0.22	2.2	0.13
El-25			Attachment	0.14	0.25	0.42	84	0.13	0.72	0.35	9.1	1.2	3.5	0.15
El-25			Rivet	0.14	0.21	0.71	86	0.17	0.88	0.55	6.9	2.8	1.7	0.08
El-26	Pl. 3: 1	Cauldron	Handle	0.62	0.41	0.24	83	0.12	0.70	0.12	12	0.20	2.3	0.25
El-26			Attachment	0.45	0.09	0.32	88	0.14	0.49	0.48	7.0	1.4	1.3	0.09
El-26			Rivet	0.06	0.22	0.74	87	0.14	0.77	0.54	6.5	2.3	1.4	0.07
El-27	Pl. 1: 16	Necklace	...	0.05	0.07	0.36	89	0.12	0.83	0.73	4.9	1.9	2.2	0.06
El-28	Pl. 1: 17	Necklace	...	1.0	0.07	0.19	85	0.12	0.60	1.1	9.1	2.0	0.92	0.07
El-29	Pl. 3: 5	Bronze destruct	...	0.24	0.12	0.32	85	0.13	0.27	0.05	12	0.20	2.1	0.04
El-30	Pl. 1: 13	Fibula	...	0.62	0.08	0.22	89	0.15	0.26	0.10	8.0	0.49	0.75	0.06
El-31M	Pl. 3: 4	Casting mould	Male part	0.04	0.06	0.59	93	0.12	0.83	1.4	0.36	3.1	0.55	0.04
El-31F			Female part	0.06	0.06	0.58	93	0.13	0.81	1.4	0.36	3.4	0.52	0.04
El-32	Pl. 1: 2	Spiral bracelet	...	0.31	0.08	0.09	84	0.16	0.02	0.01	13	<0.05	2.0	0.04

Tab. 2: Results of the SEM-EDS analyses of bronze artefacts from the Elgiszewo hoard. The SEM-EDS data are normalised to 100 wt.%.

Sample ID	Artefact	Microarea	S	Fe	Ni	Cu	As	Ag	Sn	Sb	Pb
El-1	Spiral bracelet	...	0.40	...	...	89.07	...	...	7.32	...	3.20
			...	...	...	82.14	...	...	13.42	...	4.44
			...	...	...	74.08	...	7.96	13.59	...	4.36
			...	...	...	73.02	...	3.90	16.28	...	6.80
			3.23	...	...	67.28	...	...	29.49	...	...
			0.21	...	...	50.94	0.72	...	38.29	...	9.84
			...	...	...	23.38	...	30.31	19.11	...	27.20
El-4	Spiral bracelet	...	...	...	...	91.55	...	...	8.45	...	...
			...	...	...	87.42	...	...	9.05	...	2.29
			7.75	...	...	80.46	...	...	9.96	...	...
			...	...	...	74.30	...	...	19.05	...	2.91
El-8	Bracelet	...	...	...	...	100	...	...	...	...	...
			8.04	0.56	...	68.02	...	19.83	3.54	...	...
			10.02	...	...	65.55	...	22.12	2.30	...	...
			4.94	3.17	...	55.91	...	9.91	20.76	...	5.30
			17.57	...	...	53.95	...	28.48	...	...	...
			16.96	...	...	39.98	...	43.06	...	...	...
El-9	Bracelet	...	...	...	...	100	...	...	...	...	...
			...	...	...	100	...	...	...	...	...
El-10	Bracelet		...	...	...	100	...	...	...	...	...
			...	...	...	98.27	...	...	1.73	...	...
			...	...	...	91.85	...	...	8.15	...	...
			...	...	...	76.38	...	...	20.19	...	3.42
			...	...	...	61.11	...	3.15	12.25	23.48	...
			...	...	...	57.15	...	15.31	...	...	27.53
El-31	Casting mould	Male part	...	...	...	100	...	...	...	...	...
			...	...	1.31	98.69	...	...	...	...	...
			...	...	1.53	94.62	1.16	...	...	2.69	...
			...	...	1.36	93.98	...	1.28	...	3.38	...
			...	...	...	93.21	...	2.59	...	4.19	...
			...	...	...	71.35	...	...	...	28.65	...
			...	...	...	62.88	...	37.12	...	...	...
			...	...	9.02	56.33	...	...	...	34.65	...
		Female part	...	...	...	100	...	...	...	...	...
			...	...	...	95.51	...	...	...	4.49	...
			...	...	1.52	95.36	1.54	...	...	1.59	...
			...	...	1.36	93.30	...	1.55	...	3.78	...
			1.52	...	...	90.66	2.98	1.18	...	3.66	...
			17.93	...	...	82.07	...	...	...	...	...
			...	...	...	72.87	...	...	...	...	27.13
			...	...	8.20	55.32	...	...	...	36.47	...

Tab. 3: Petrographic characteristic of *Kannelurensteine* from the studied area, following classification for igneous (QAPF; Streckeisen 1974) and sedimentary/clastic rocks (Wentworth 1922). Except for the *Kannelurenstein* from Gniewkowo-Zajezierze, all other specimens can be linked to the Chełmno group. See text and Fig. 15 for further details.

Location	Raw material						Weight (g)	Use-wear	Plate	Additional information
	Colour	Mineral composition	Crystal/grain diameter (mm)	Texture	Parent rock	Type				
Elgiszewo (Ciechocin commune)	Reddish/brown	95 % quartz, 5 % opaque minerals, sericite, silica matrix	0.5	Medium grained sand, well sorter, very low porosity	Sedimentary (clastic)	Quartz/quartzite sandstone	251	Yes	Pl. 4: 1	Malachite and azurite residues, which are corrosion products of bronze metalwork deposited with the stone artefact; see Fig. 15A
Głażewo (Unisław commune)	Black	Pyroxene, plagioclase in unknown ratio	…	Aphanitic, massive	igneous	Basalt	60	No	Pl. 4: 2	Preserved partially
Gniewkowo-Zajezierze (*loco* commune)	Black and white	50 % pyroxene, 45 % plagioclase, 5 % biotite	0.1–1	Phaneritic, fine crystalline, massive	Igneous (subvolcanic)	Diabase	302	…	Pl. 4: 3	0.5 mm thick plagioclase dyke; see Fig. 15B
Kałdus (Chełmno commune)	Light-yellow	Quartz, clay minerals, feldspar, silica matrix	0.001–0.1	Coarse silt to clay, very low porosity	Sedimentary (clastic)	Mudstone	240	…	Pl. 4: 4	See Fig. 15C
Kijewo Szlacheckie (Kijewo Królewskie commune)	Pinkish/reddish	70 % feldspar, 15 % biotite, 15 % quartz	0.1–4	Phaneritic, fine to medium crystalline, massive	Igneous (plutonic)	Granite	230	Yes	Pl. 4: 5	…
Ruda (site 3–6F) (Grudziądz commune)	White	95 % quartz, 5 % feldspar, silica matrix	0.1–0.2	Very fine to fine grained sand, well sorted	Sedimentary (clastic)	Quartz sandstone	259	Yes	Pl. 4: 6	Accessory garnet; dark blue residues with linear traces, which can be related to the parent rock material; see Fig. 15D
Ruda (site 3–6D) (Grudziądz commune)	White	98 % quartz, 2 % opaque minerals, garnet, silica matrix	0.05–0.1	Very fine grained sand, well sorted, very low porosity	Sedimentary (clastic)	Quartz sandstone	286	No	Pl. 4: 7	Cavity with quartz crystals; see Fig. 15E
"Chełmno land"	Brown	95 % quartz, 5 % feldspar, opaque minerals, silica matrix	0.3–0.5	Medium grained sand, well sorted, very low porosity	Sedimentary (clastic)	Quartz sandstone	220	Yes	Pl. 4: 8	Cavity with quartz crystals; black residues, which are post-depositional contaminant; see Fig. 15F

Tab. 4: Experimental data for bronze pins and replicas of *Kannelurensteine* from the studied area. The weight loss of the objects was quantified at the beginning and end of each step. Specimen No. 4 is made of the same raw material (granite) as specimen No. 2 and was thus excluded in the experiment.

Experimental bronze pin (sample ID)	Experimental *Kanelurenstein* (raw material)	Pin weight (g)	Step 1	Step 2	Step 3	Step 4	Weight lost (g)	Average weight lost per step (g)
1A	Quartz sandstone	72.95	72.84	72.65	72.47	72.27	0.68	0.17
1B	Quartz sandstone	49.35	49.14	48.91	48.73	48.58	0.77	0.19
2	Granite	55.00	54.83	54.68	57.49	54.33	0.67	0.16
3	Quartz sandstone	73.40	73.18	72.95	72.78	72.60	0.80	0.20
5	Basalt	52.08	52.05	52.02	51.99	51.96	0.12	0.03
6	Mudstone	60.90	60.94	60.71	60.48	60.24	0.66	0.16
7	Basalt	55.83	55.77	55.75	55.72	55.68	0.09	0.02
8	Diabase	63.00	62.88	62.78	62.66	62.57	0.43	0.11

chemical compositions within the analytical errors, suggesting that they may have originated from the same object.

The level of impurities is significant among the metalwork from the other alloy group, which is mainly controlled by antimony (1.5–5.9 %), arsenic (0.35–5.1 %) and silver (0.42–2.8 %). This indicates the use of copper smelted from fahlores, which adds to a growing body of evidence supporting a substantial influx of fahlore copper during the Lusatian period in northern Poland[55]. To some extent, this is confirmed by the SEM-EDS data (Table 2), which show a significant amount of sulphur in the spiral bracelet El-1 (3.2 %), the bracelet El-8 (4.9–17.6 %) and the casting mould (1.5–17.9 %), which can be taken as the remnants of the roasting (oxidation) of fahlores[56]. The considerable quantity of sulphur present in the spiral armband El-4, amounting to up to 7.7 %, may be indicative of the use of chalcopyrite. The tin content in this group is not homogeneous, with values ranging from 0.36 % to 13 %. The tin content is markedly lower in both parts of the casting mould, making a mere 0.36 % – and is much lower than the content observed in the metalworking of the North European Bronze Age. However, the chemistry of the Elgiszewo mould is comparable to other metal moulds known from Bronze Age Poland – casting moulds from Rosko[57], Gaj Oławski[58] and Nowe Kramsko[59] also exhibit low tin content, and there are strong archaeometallurgical indications that these tools were used for direct casting[60].

Some of the metal objects show a diluted fahlore copper pattern. For instance, phalerae El-17 and El-20 have an antimony (0.47–0.69 %) and silver (0.20–0.24 %) content that is much higher than expected for chalcopyrite but clearly too low to have been derived from copper smelted from fahlores. It is assumed that fahlore copper is disadvantageous due to its high arsenic and antimony content, and therefore it was often mixed with copper smelted from chalcopyrite[61]. The archaeometallurgical data from the region indicats that the use of diluted fahlores was commonplace during the Lusatian period in Poland. This can be evidenced, for example, by a metal hoard from Kaliska in Pomerania[62]. Moreover, there are many archaeological indications that a large portion of metal went to northern Lusatian regions through the trading route (*Handelskorridor*) that powered the flow of Tyrolean copper fahlores to Scandinavia[63]. The ongoing lead isotope analysis of the Elgiszewo hoard and other bronzes from the Chełmno land will help to determine the origin of the metal used for their production and identify the trading network that safeguarded the metal supply to Lusatian clients in northern Poland.

55 See, e. g. Hensel 1996; Garbacz-Klempka *et al.* 2016; 2017; Kowalski/Garbacz-Klempka 2019a; Kowalski/Niedzielski 2021; 2022; Kowalski *et al.* 2019; 2020; 2021; Gackowski *et al.* 2023; Nowak/Gan 2023.
56 Tylecote *et al.* 1977; Pernicka 2014.
57 Machajewski/Maciejewski 2006.
58 Baron *et al.* 2014; 2016.
59 Kowalski/Garbacz-Klempka 2019b.
60 Kowalski *et al.* 2019.
61 Lutz/Pernicka 2013; Melheim *et al.* 2018; Grutsch *et al.* 2019.
62 Kowalski/Niedzielski 2021.
63 Kaczmarek 2012; Ling *et al.* 2014; O'Brien 2015.

Except for phalera El-18 (a phalera with a damaged dome), the signals for lead are significantly high for the other phalerae with two cast loops, i. e. El-19 (6.2–6.4 %), El-23 (5.4–5.8 %) and El-24 (6.0–6.9 %), suggesting a deliberate addition of lead[64] to improve the castability of the alloy. There are some differences in the lead (and tin) content in the domes and loops of these phalerae, although this can be taken as a compositional variation resulting from surface enrichment, sample geometry or intergranular corrosion that may limit the accuracy of the ED XRF[65]. The pair of phalerae El-23 and El-24, which display very similar shapes and dimensions, and their chemical compositions are identical within the analytical errors. This may indicate that the two objects were cast from the same alloy and used similar wax models (see section "Technological characterisation"). The ED XRF results also suggest the manipulation of lead content in the elements of the *Morgenitz* type phalera (El-22) to control the castability of the alloy, as evidenced by the different lead content in the dome and loop parts, averaging at 4.6 % and 0.41 %, respectively. The bronzes from Elgiszewo contain much higher amounts of lead than bronzes produced in more northern regions of the European Bronze Age, for example metals from Sweden and Denmark, which have lead concentrations mostly below 0.5 %[66].

It is notable that the two twisted handles of a bronze cauldron are separated from the other parts of the cauldron by significantly lower amounts of antimony, arsenic, silver and nickel. The rationale behind the diluted copper fahlore and increased tin content in the alloy used for the handles is evident – this was done to improve the modulus of elasticity of a bronze rod that was cast and twisted to form the handles. Here, it is also interesting to see that the antenna knife and the casting mould have very similar ratios of Sb/As (4.4 and 4.0), Sb/Ag (2.7 and 2.4) and Ag/As (1.6 and 1.7), indicating the possibility that the copper smelted for their production comes from the same batch of fahlores and perhaps the same workshop. Finally, three solid bracelets made of a bronze rod (El-8, 9 and 10) are separated from the other metalwork by their relatively low amount of tin, ranging between 2.7 % and 4.7 %, accompanied by a significantly low lead amount of 0.19–1.3 %. There is no clear technological rationale for the tin depletion observed in these objects. However, their chemistry and shape align well with a group of ring ornaments from the region that may have served as semi-products (*Barrenringe*) or commodity money (*Gerätegeld*)[67]. The discovery of a *Kannelurenstein* in the Elgiszewo hoard adds further dimension to the study, as these stone items are now widely accepted as balance weights characteristic of continental Europe during the Urnfield era[68] (see section "*Kannelurensteine*").

Technological characterisation

Photomacrographs suggest that the solid bracelets were cast using the lost-wax technique, yet the fact that bracelets E1-9 and E1-10 were formed from a cast bronze rod cannot be denied, as evidenced by the irregularities in their diameters (Fig. 7I and 7K). On Fig. 7E and 7F it is clearly visible that the closed bracelet El-7 involved the lost-wax casting. This is well evidenced by the presence of casting jets on the inner and outer sides that were not completely removed and trimmed. Porosity near the feeding channel (Fig. 7F), which is due to the gaseous melt that was used for casting, was also identified. A closer examination of the spiral armband fragment El-13 shows that a decorative zig-zag motif could have been carved on the wax model using a comb (Fig. 8A).

As can be seen in Fig. 7C and 7D, bronze wire coils with twisted or recurrent endings went through a *chaîne opératoire* that involved plastic forming, plaiting and hammering. The geometry of the antenna knife and the visible drafts on both sides suggest the use of split-mould casting with four cores centred within the mould to produce holes in the tang part of the knife. A decorative herringbone notching is present on the antenna knife (Fig. 8D and 8F), and very similar traces can be observed in the broken loop base of the phalera El-21 (Fig. 9K). The notching on these two objects was made on the final castings through the use of the same tool and probably by the same craftsperson. The chemical composition of the knife and phalera El-21 indicates that the presumed workshop operated with both fahlores and diluted fahlore copper.

Macroscopic observations confirm that similar technology was to produce three *Kalisz*-type phalerae: El-16, El-17 and El-20. A loop was formed from a bronze wire (Fig. 9D) and was then welded to a dome (Fig. 9A) that was cut from sheet metal and provided with profiled edges by plastic forming (Fig. 9C). As Fig. 9B clearly shows, the flattened knob crowning the dome is an imitation rivet that was formed on a wax model. The *Morgenitz*-type phalera is notable for having a loop that was riveted on the outer side

64 Liversage 2000.
65 Pollard/Heron 1996.
66 Liversage 2000; Ling *et al.* 2014.
67 Blajer 1992; 2001; Garbacz-Klempka *et al.* 2016; see also Garbacz-Klempka *et al.* 2017; Kowalski *et al.* 2020.
68 Ialongo/Rahmsdorf 2019; 2021.

Fig. 7: Photomacrographs of the artefacts showing the macrostructures typical of casting and plastic forming. A–B – spiral bracelet El-1; C–D – wire coils El-5; E–F – bracelet El-7; G–H – solid bracelet El-8; I–J – solid bracelet El-9; K–L – solid bracelet El-10 (photographs: P. Jurecki). See text for further details.

of the dome (Fig. 10D-F). The photomacrographs demonstrate that the El-21 phalera featuring a single loop (not preserved) was cast in a reusable mould[69], as evident from the casting flash in the middle of the loop base. Furthermore, the notching discernible in Fig. 9K indicates that during the finishing of the cast object, the flash was chiselled smoothly.

Further macroscopic observations confirm that reusable mould and one-piece casting were employed for phalerae El-18 and El-19. This is clearly demonstrated by the presence of casting flashes on the loop's base (Fig. 9I) and the regular shape of the domes (Fig. 9E and 9G). In contrast,

69 Reusable casting moulds for phalerae are known from the Lusatian assemblages, for example the site of Łojewo in the Kuyavia region (Cofta-Broniewska 1996, 10 ryc. 4,1).

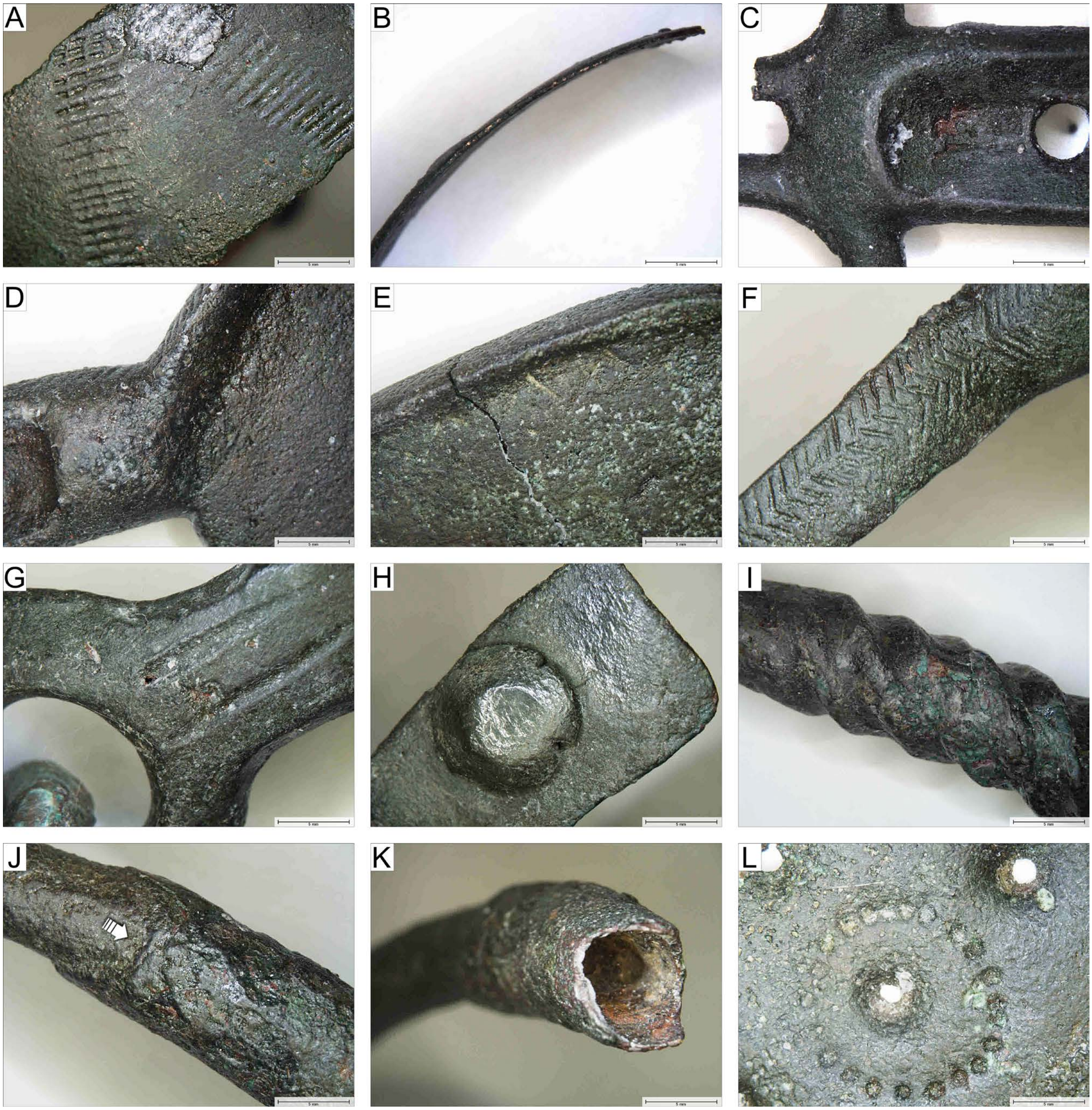

Fig. 8: Photomacrographs of the artefacts showing the macrostructures typical of casting and plastic forming. A–B – spiral armband El-13; C–F – antenna knife El-15; G–I – cauldron handle El-26; J–K – necklace El-28; L – fibula El-30 (photographs: P. Jurecki). See text for further details.

the pair of phalerae El-23 and El-24, which have two loops, went through a chain of production involving lost-wax and one-piece casting. It can be seen from Fig. 10G-H and 10J-K that the loops have different shapes and thicknesses; therefore, it is unlikely that they came from the same mould. The flashes preserved between the loops (Fig. 10J and 10L) may point to the lost-wax casting technique. The supporting evidence from the chemical data shows that the objects contain significant lead concentrations between 5.4 % and 6.9 % (see section "Elemental composition"), which would increase the castability of the alloy used for these decorative elements.

The photomacrographs provide support for the assumption that the mould could be used for direct metal casting. In Fig. 11B, a split is discernible in the feeding channel of the mould, and it is possible (as seen in Fig. 11F) that a broken knob is also a mechanical defect produced the mould was exposured to molten metal. Evidence in support of this finding is provided by the presence of slight cracks on the

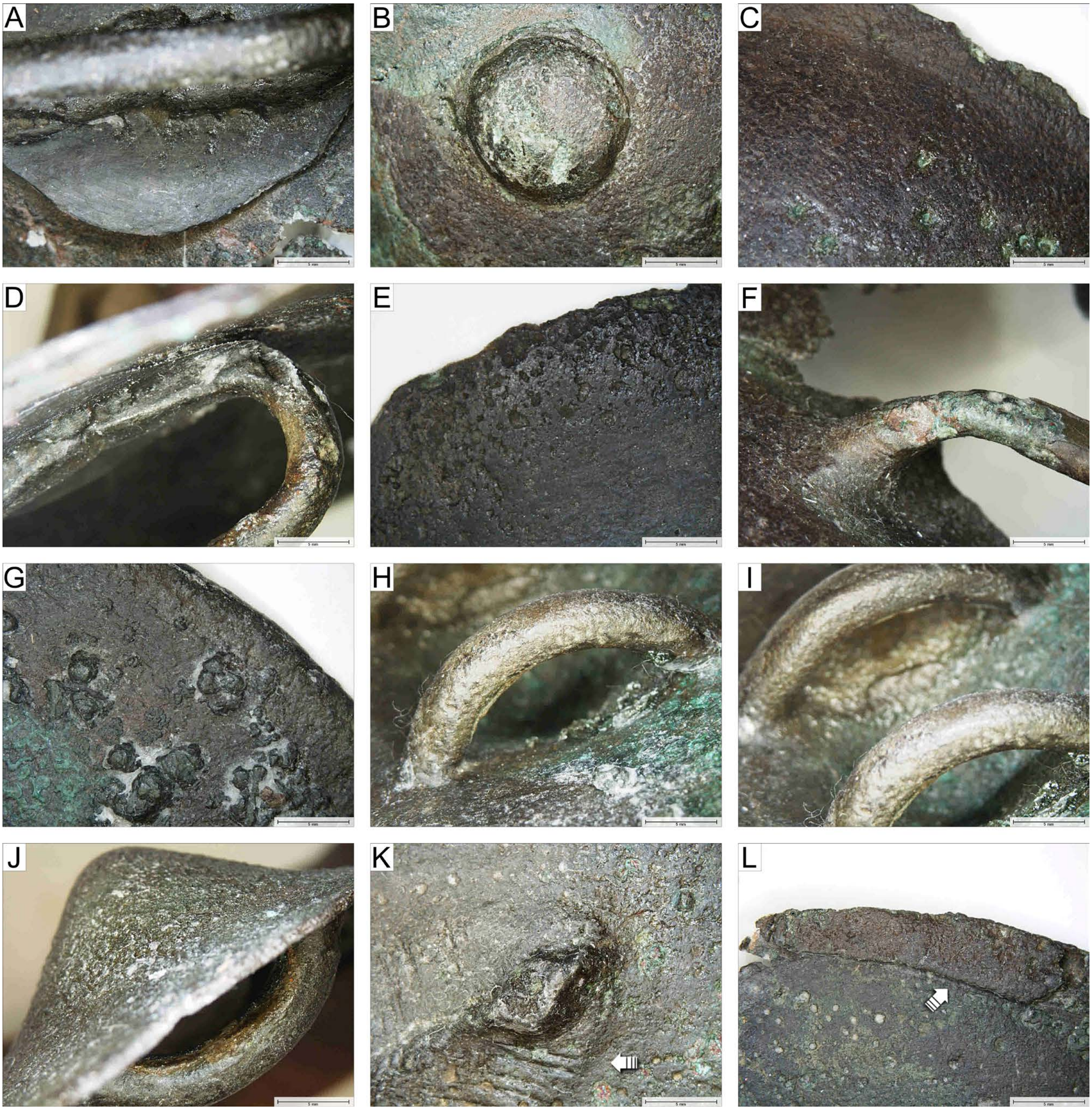

Fig. 9: Photomacrographs of the phalerae. A–D – phalera El-16; E–F – phalera El-18; G–J – phalera El-19; K–L – phalera El-21 (photographs: P. Jurecki). See text for further details.

inner side of the blade and socket part (Fig. 11K), which are the most probable locations for higher thermal stress concentrations during direct casting[70]. The experimental data indicate that a metal mould for socketed axes will last for fifteen cycles without any apparent damage to the mould[71].

The 3D visualisations and reverse engineering of the Elgiszewo mould revealed that a socketed axe that could have been cast in the mould was 10.8 cm long, 3.2 cm wide and had a socket diameter of ca. 3 cm (Fig. 11L)[72]. However, a compatible socketed axe of the *Przedmieście* type has not yet been reported from the Chełmno land.

70 Kowalski *et al.* 2019.

71 Drescher 1957; Kuijpers 2008, 89; Baron *et al.* 2016, 188.

72 Kowalski *et al.* 2019.

Fig. 10: Photomacrographs of the phalerae. A–F – phalera El-22; G–I – phalera El-23; J–L – phalera El-24 (photographs: P. Jurecki). See text for further details.

Palynology

The pollen diagram (Fig. 12A) demonstrates local vegetation development and human activity in the vicinity of the hoard findspot over an extended timescale, spanning the Neolithic to the late medieval period[73]. The pollen diagram has been divided into five phases of human activity, based on the AP/NAP[74] ratio and anthropogenic indicators developed by Karl-Ernst Behre[75].

A phase related to the Lusatian period (420–316 cm) is well evidenced by the anthropogenic indicator curves in the

73 A detailed description of full pollen profile can be found in Noryśkiewicz/Kamiński 2022.

74 AP/NAP value is the ratio of total counts of Arboreal Pollen grains (AP) to Non-Arboreal Pollen grains (NAP).

75 Behre 1981.

Fig. 11: Photomacrographs and X-ray images of the casting mould, with the 3D visualization of a compatible socketed axe. A – feeding channel; B – split in the feeding channel; C–D – peg; E – peg hole; F – broken knob; G – casting porosity; H – loop negative; I – orante motif negative; J – X-ray recordings showing the presence of a split in the feeding channel; K – thermal fatigue cracks on the inner side of the mould; L – 3D visualization of a socketed axe compatible with the mould (photographs: P. Jurecki, A. Garbacz-Klempka, W. Ochotny; 3D visualisation by D. Ścibior). See text for further details.

pollen diagram, suggesting that there are four different subphases (3A–3D) of human activity in the Elgiszewo region. The substantial decline of hornbeam (*Carpinus betulus*), oak (*Quercus*), linden (*Tilia*), elm (*Ulmus*) and hazel (*Corylus*) throughout this phase, accompanied by rising values of pine (*Pinus sylvestris*) and birch (*Betula*), indicates woodland clearance in the vicinity of Lake Okonin. Following an initial decline, *Pinus sylvestris* has been observed to increase in the pollen record for the final two subphases (3C and 3D). This is not, however, the result of woodland regeneration at this time; rather, this indicates that local growing conditions were favourable for the high production and long-distance transport of pine pollen.

Subphase 3A (420–404 cm). In general, anthropogenic indicator taxa demonstrate minimal fluctuation during this subphase, as evidenced by an increase in mugwort (*Artemisia*) and sorrel (*Rumex*). This subphase also saw the increase of *Corylus*, coeval with the single appearance of pollen from the goosefoot family (*Chenopodiaceae*) and plantain (*Plantago lanceolata*, *Plantago major/media*). The increasing values of *Artemisia* and *Rumex* may suggest the appearance of routes and tracts connecting the Lusatian hamlets in the region and beyond.

Subphase 3B (404–396 cm). A decline in human activity in the vicinity of Lake Okonin is observable in this subphase. Woodland regeneration appears to have occurred at that time, as evidenced by the expansion of *Carpinus* and *Ulmus*.

Subphase 3C (396–358 cm). This subphase saw the greatest development of Lusatian settlements in the study area. The substantial decline of components of a mixed deciduous forest (*Carpinus betulus*, *Tilia*, *Ulmus* and *Corylus*), accompanied by rising values for ruderals (*Artemisia*, *Rumex*, *Urtica*, *Chenopodiaceae*) and taxa typical of meadows and pastures (*Calluna vulgaris*, *Plantago lanceolata*, *Plantago major/media* and *Ranunculaceae*) and crops (*Cerealia*-type), implies a great level of human impact on vegetation in the vicinity of Lake Okonin, including both pastoral and arable farming. The low but constant presence of Common bracken (*Pteridium aquilinum*) may suggest that forest burning was still used in the study area to obtain land for cultivation. An increasing participation of ferns (*Filicales monolete*) and the appearance of pollen from the aquatic floating-leaf plants in the diagram, suggest a lowering of water levels in Lake Okonin and a transition to drier conditions in the region.

Subphase 3D (358–316 cm): Economic activity was reduced in this subphase, as evidenced by a drop in anthropogenic indicators. However, some level of cereal-based agriculture was evident in the region, which is inferable from the presence of *Cerealia*-type pollen in the diagram.

The pollen evidence from this study provides a broader context for understanding the Elgiszewo hoard within a wider framework of anthropogenic interventions in the natural landscape and cultural change that accompanied the end of the Bronze Age in the region. The pollen record indicates that the hoard was buried at a time of increased human activity in the area surrounding Lake Okonin and the increasing inter-group and inter-tribal communication in the region, as evidenced in the appearance of routes and the expansion of the Lusatian settlement network, accompanied by forest burning and the introduction of pastoral and arable farming and a pronounced pick-up in metal movement and consumption in the region.

Pedology

The results reveal a significant content of organic matter in the sample exceeding 25 % (TC=13.9 %) and a pH(H_2O) of 5.2, which indicates that the soil bulk sampled in the findspot was acidic. These observations are strongly correlated with processes of peat formation (humification processes are dominant over mineralization) in the northern and southern parts of the denudation basin of Lake Okonin in waterlogged conditions.

The prevailing environmental conditions in Lake Okonin currently favour a reduction in the water level in the reservoir. The associated peat decomposition and mineralisation, which result in depletion of soil organic matter content, are closely link to the stoichiometric changes between carbon and nitrogen and the C/N ratio, which decreased in the analysed sample to a value of 21.

Kannelurensteine

Archaeological background

A lenticular-shaped stone with circular indentations and an artificially flattened surface on the diameter (Plate 4,1) was part of the Elgiszewo hoard. Similar stone objects, labelled *Kannelurensteine* (sometimes also referred to as *Rillensteine*), are typically provided with a groove or flattened surface on the diameter (circular indentations on the upper and lower faces have also been frequently observed) and are well attested in the settlement contexts of many Urnfield regions across Europe[76] (Fig. 13), as demonstrated by Fritz Horst[77]. In Poland, these objects are dated to the Montelius period IV and V (and VI)[78] of the Northern Bronze Age, with a distribution between Pomerania, Greater Poland and Silesia. They have also been found in Kuyavia, region

76 Kostrzewska 1953, 249; Kostrzewski 1958, 153–156; Dąbrowski 2009, 206; Woźny 2011, 43–45; 2014, 220–227; Rembisz-Lubiejewska 2017, 54; Ialongo/Rahmsdorf 2021, 146–147.

77 Horst 1982.

78 Two examples of *Kannelurensteine* from the lake settlement of the West Baltic Barrow culture at Mołtajny near Kętrzyn are dated to 550–120 BC, roughly corresponding to the Ha D2–La Tène C2 period (Hoffmann 1999, 101; Gackowski 2000, 43–48; Krąpiec 2000, 71–73; see “List of *Kannelurensteine* from the studied area (and the East Prussia)”.

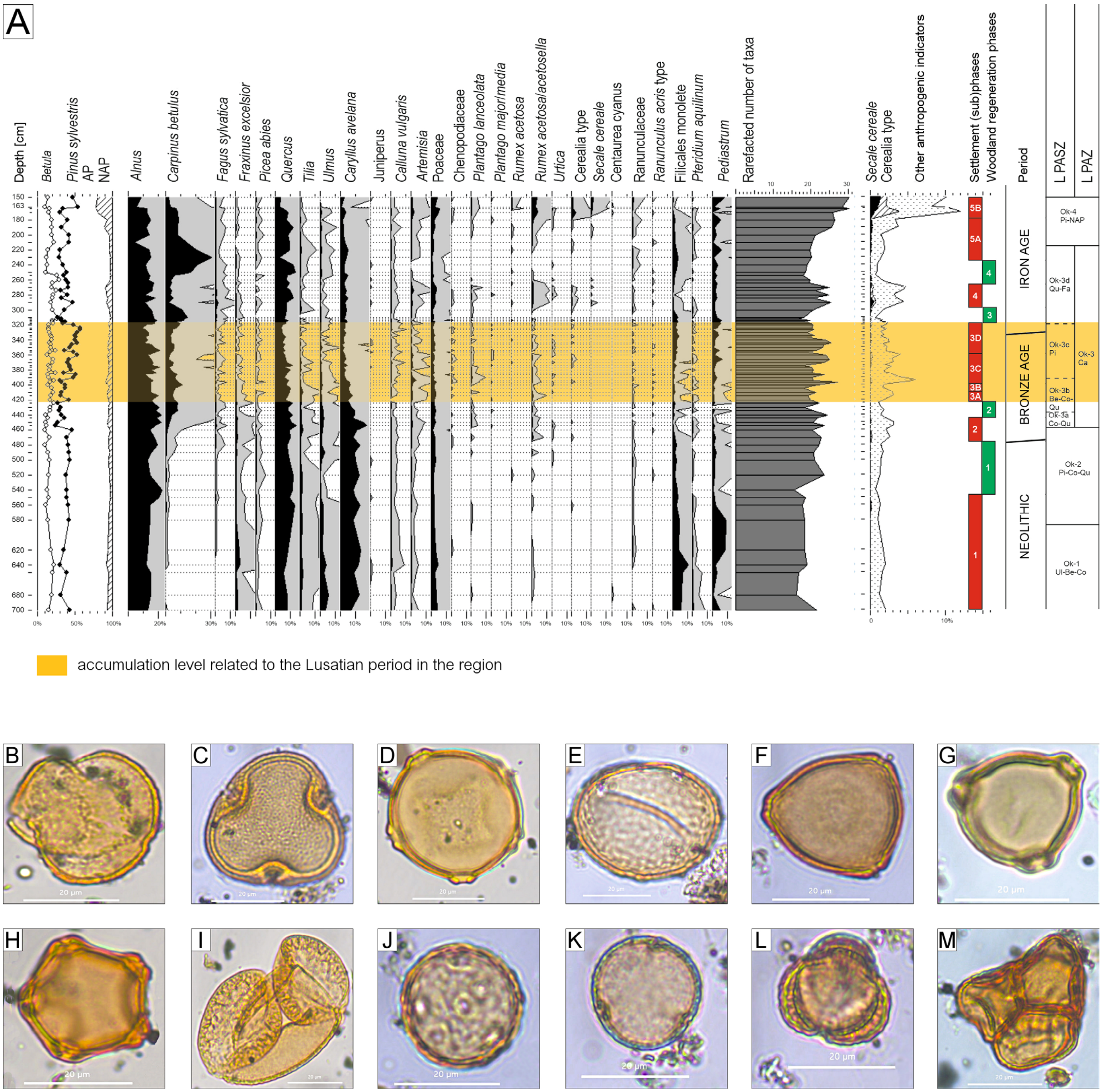

Fig. 12: A – Palynological diagram of selected taxa identified in the peat bog in the northern part of Lake Okonin, with selected pollen grains identified in pollen spectra of the Okonin peat bog related to the Lusatian period in the region. B – oak (*Quercus*); C – linden (*Tilia*); D – hornbeam (*Carpinus betulus*); E – elm (*Ulmus*); F – hazel (*Corylus*); G – birch (*Betula*); H – alder (*Alnus*); I – Scots pine (*Pinus sylvestris*); J – plantain (*Plantago lanceolata*); K – sorrel (*Rumex*); L – mugwort (*Artemisia*); M – heather (*Calluna vulgaris*) (photographs and figure by A. M. Noryśkiewicz). Scale bars equal 20µm. See text for further details.

of Świecie and the adjacent Chełmno land (Elgiszewo, Głażewo, Kałdus, Kijewo Szlacheckie and Ruda; Table 3). Four further examples from the Masurian Lake District[79] (Plate 4; see “List of *Kannelurensteine* from the studied area (and the East Prussia)”) can be included as the easternmost points in the distribution of *Kannelurensteine*.

The literature has extensively discussed the function of *Kanneleurensteine*, resulting in a range of proposed interpretations. These include their use as fixed pulleys or, more generally, as working tools. This latter interpreta-

79 Dąbrowski 1997, 77; 164; Hoffmann 1999, 270; 285; Gackowski 2012, 205; 2016, 168–171; Rembisz-Lubiejewska 2017, 54.

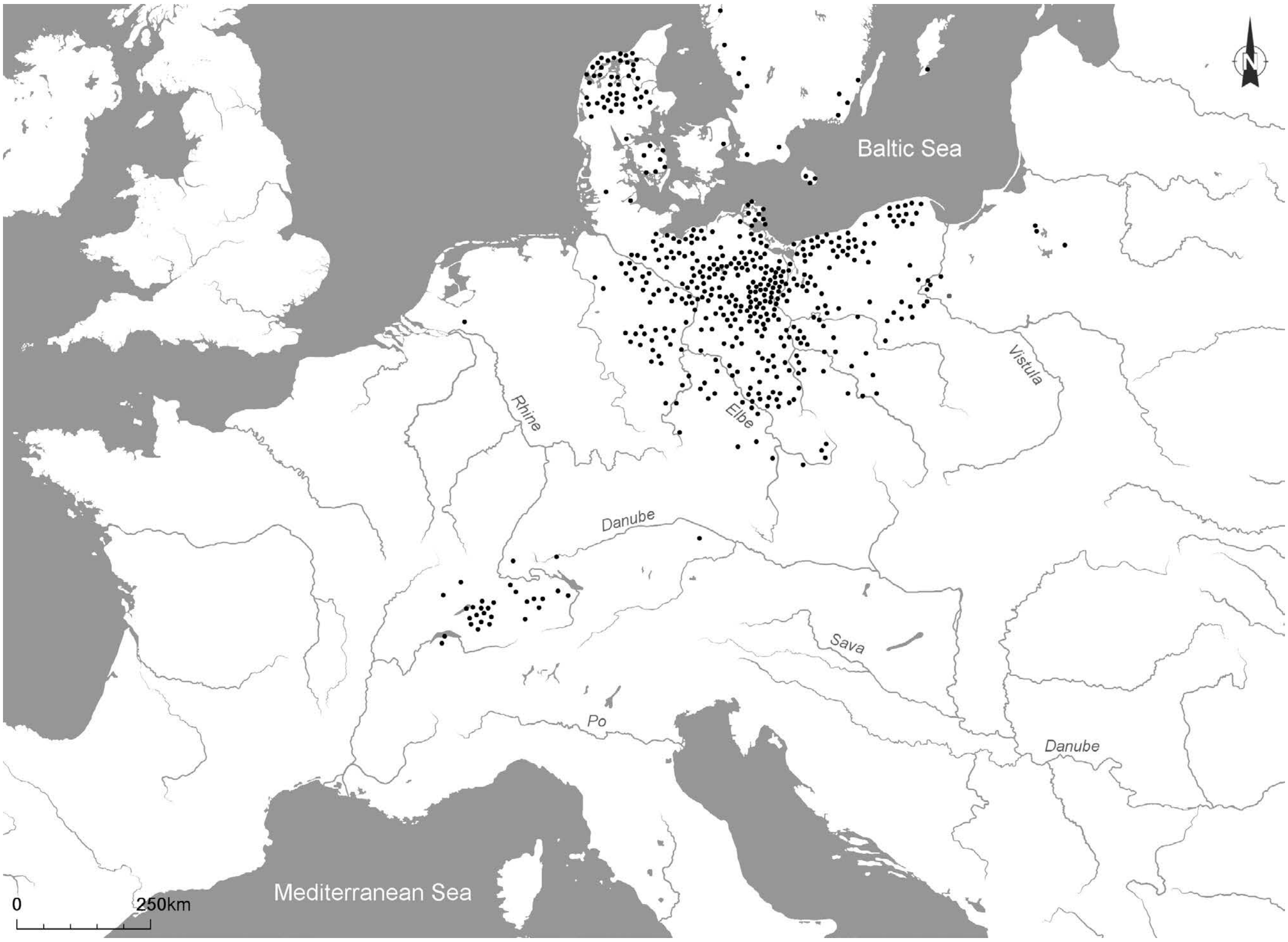

Fig. 13: Map of Europe showing the possible overall spread of distribution of *Kannelurensteine* in Europe. Red spot stands for the Elgiszewo hoard (adapted from Horst 1982, with changes; map background: brichuas/Shutterstock.com).

tion encompasses their application in cold forging[80]. Some interpretations viewed these objects as symbolic food[81], fishing net weights[82], slingshot stones[83], or door holders[84]. The extensive European Research Council (ERC) grant "*WEIGHTANDVALUE: Weight metrology and its economic and social impact on Bronze Age Europe, West and South Asia*" (2015–2022) has produced the most convincing and coherent interpretation of *Kannelurensteine* to date[85]. A broad consensus has now emerged that *Kannelurensteine* were used as balance weights in the Urnfield weight system and that these objects were regulated based on a quantum of ca. 450 g[86].

Kannelurensteine are known only from grave contexts in the geohistorical range of the Lusatian culture in eastern Germany and western Poland[87]. To date, only two hoards have been discovered that contain these types of artefacts: Potsdam-Krampnitz[88] in Brandenburg and the Elgiszewo hoard. Moreover, the association of *Kannelurensteine* with metalworking recurred in different parts of Europe[89]. In Poland, two such objects were found at the Lusatian settlement of Ruda near Grudziądz, which also yielded ovens, clay moulds, bronze ready- and semi-products, and other

80 Horst 1982, 54 and refs; 1986, 82–91; Dąbrowski 1997, 77; 2009, 206; Bukowski 1998, 347–348; see also Woźny 2011; 2014.

81 Kostrzewska 1953, 251–252; Kaczmarek 2002,121.

82 Horst 1982; Dąbrowski 2009, 206;.

83 Kostrzewski 1958, 153–156; Horst 1982.

84 Ialongo/Rahmsdorf 2021, 148, and refs.

85 Ialongo 2018; Ialongo/Rahmsdorf 2019; 2021; see also Bouzek 2007, 23–25.

86 Ialongo/Rahmsdorf 2021, 154–155.

87 Horst 1982, 33–83; 1986; 82–91; Bukowski 1998, 347–348; Kaczmarek 2002, 121–122; Woźny 2014, 222, 227; Nowak 2016; Alagierski 2018; Krzyszowski/Kowalski 2019, 80–82; Ialongo/Rahmsdorf 2021, 147–149.

88 Horst 1982, 53.

89 Ialongo/Rahmsdorf 2021, 155.

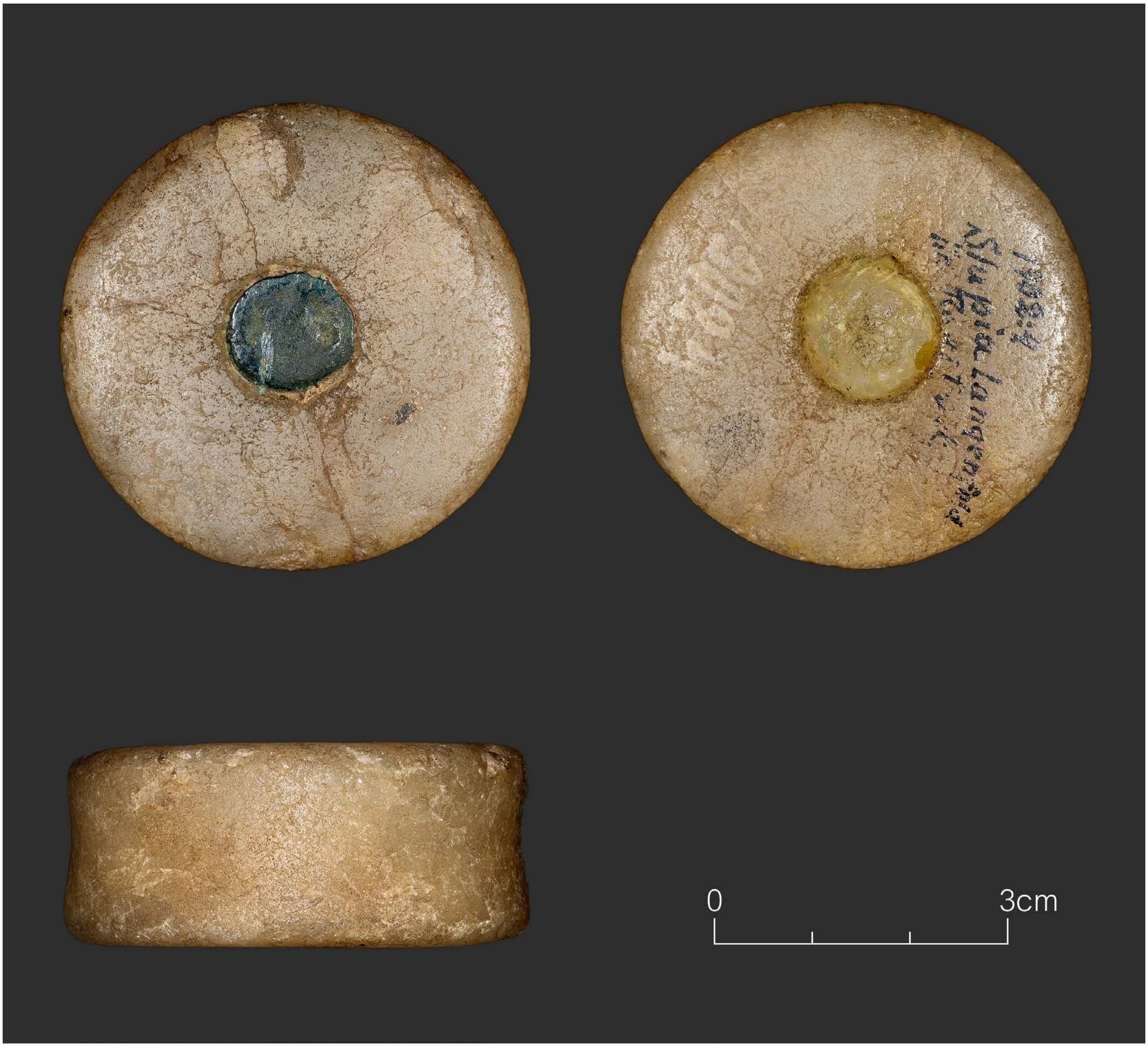

Fig. 14: *Kannelurenstein* from Słupia, Greater Poland. Note that the molten bronze was originally poured into two circular indentations on the upper and lower faces of the stone object (photograph: T. Skorupka; courtesy of Archaeological Museum in Poznań).

artefacts related to bronzesmithing[90]. In the cemetery of Legnica[91] in Lower Silesia, a *Kannelurenstein* was part of the furnishing of a smith's burial dating to 1100–750/700 BC. A similar pattern can be traced to the Lusatian necropolis at Wartosław in Greater Poland, which yielded several *Kannelurensteine*[92]. One of these was placed with a stone casting mould in a cremation grave (1100–1000 BC) that could have been the burial place of members of a lineage or clan associated with metal production and/or metalworking[93]. A *Kannelurenstein* from the Lusatian cemetery at Słupia[94] in Greater Poland (Fig. 14) represents a particularly eloquent example of the association of *Kannelurensteine* with metalworking. The stone object is made of polished quartzite and has a flattened surface on its diameter. However, the most distinctive feature of the object is its two circular indentations on the upper and lower faces, into which a small portion of molten bronze was poured.

90 Gackowski 2005; 2012.
91 Nowak 2016.
92 Krzyszowski 2019.
93 Krzyszowski/Kowalski 2019; Kowalski *et al.* 2021.
94 Kostrzewski 1923, 77 ryc. 250; Kostrzewska 1953, 229–254 ryc. 19.

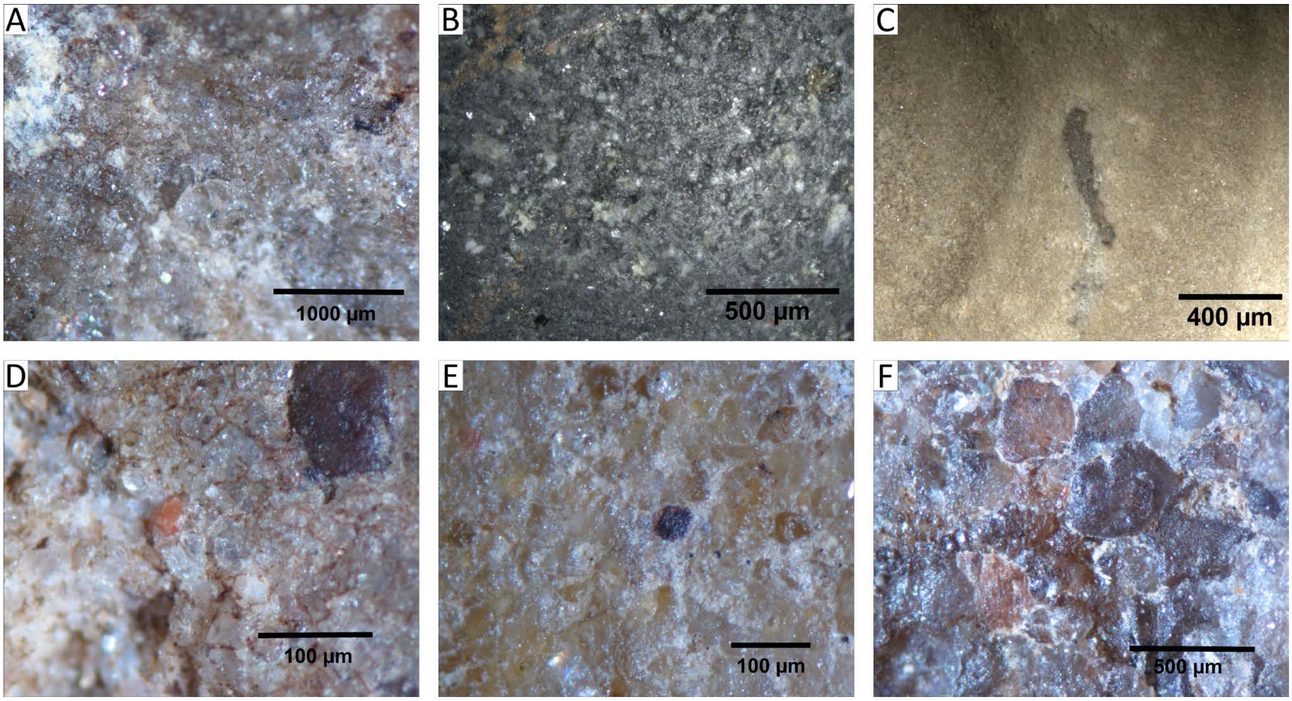

Fig. 15: Microphotographs of *Kannelurensteine* from the studied area (photographs: M. Ćwiek). See text and Table 3 for further details.

Petrography

Table 3 lists the petrographic characteristics of the *Kannelurensteine* from the studied area. Microscopic observations of the analysed stone artefacts indicate that the starting material used for their production represents a variety of igneous and sedimentary rocks, consisting of generally hard minerals (5–7 on the Mohs hardness scale). The identified sedimentary rocks have a hard matrix composed mainly of silica (Fig. 15). This fact can be taken as evidence of the deliberate selection of rock material that was not related to the general accessibility of rocks but rather their physical properties. The petrography of the *Kannelurensteine* indicates that their lithology roughly corresponds to the erratic structure of the Polish Lowland region, suggesting that the rock material used to produce the artefacts was sourced from the studied area.

For example, the *Kannelurenstein* from Kijewo Szlacheckie has a similar texture and crystal composition to Smaland granite[95], while the Kinne diabas is a likely candidate for the starting material used for the artefact found at Gniewkowo-Zajezierze[96]. The specimen from the Elgiszewo hoard is composed of rock material that was most likely chipped from Jotnian sandstones[97]. Half of the examined artefacts are made of quartz/quartzite sandstone, which appears to be a frequently selected raw material for the European *Kannelurensteine*[98].

Traceology

Traceology reveals that three manufacturing techniques were used for the analysed *Kannelurensteine*. The flat surfaces of the artefacts were formed by grinding (Fig. 16A). There is also evidence of surface polishing visible on the artefact from Kijewo Szlacheckie (Fig. 16B). The final shaping of the circular indentations on the upper and lower faces was done by nicking, which is a percussion technique that involves the use of a sharp-edged tool (Fig. 16C–F). It may be assumed that the same technique was used to flatten the surface on the diameter. A nicking technique could also have been employed to form the grooves running around the diameter of the artefacts (at least to some extent). However, manufacturing traces were largely obliterated by use and post-depositional alteration. The geometry of the artefact from Głażewo, with its central hourglass perforation created using a core drill bit and abrasive sand mate-

95 Czubla *et al.* 2006.
96 Ibid.
97 Górska-Zabielska 2008.
98 Ialongo/Rahmdtorf 2021, 146.

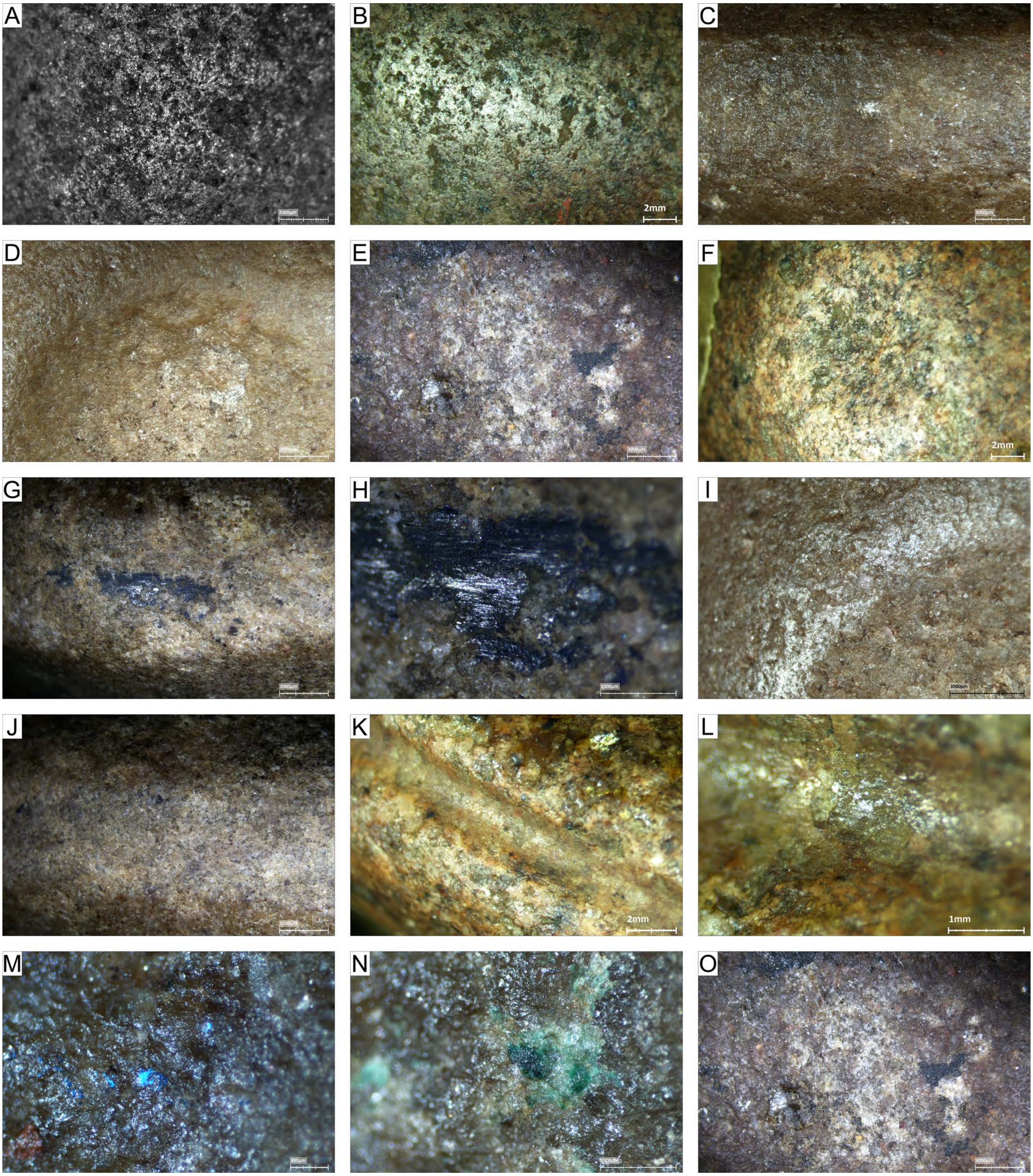

Fig. 16: A–F – Technological traces on the *Kannelurensteine* from the studied area; G–L – wear traces; M–O – residues (photographs: G. Osipowicz). Lens magnification ×0.67–5. See text for further details.

Fig. 17: Experimental *Kannelurensteine* used in this study (photograph: A. Sokół).

rial, suggests that it may perhaps have been later customised to serve as a stone mace head.

Wear traces identified on the analysed stone objects vary from piece to piece. The polish and parallel linear traces visible on the flattened surfaces on the objects' diameters are the result of wear from use. The circular indentations on the upper and lower faces display polished surfaces (Fig. 16I), which may be evidence that the items were made for handheld use or that they were in long-term contact with soft materials such as leather. The items' flattened surfaces are abrasive and contain multiple chipping marks (Fig. 16J and 16C). The occurrence of these traces does not necessarily indicate the use of the objects (e. g. as pounders); they may instead be the result of wear from surface forming. Finally, clear evidence of smoothing (Fig. 15K) and linear polish (Fig. 16L) is visible in the groove of the *Kannelurenstein* from Kijewo Szlacheckie, and similar use-wear can be observed on one of the specimens found at Ruda (Fig. 15G and 15H).

Microscopic observations also revealed the presence of numerous green–blue spots (Fig. 16M) and dispersed green precipitates (Fig. 16N) on the surface of the artefact from Elgiszewo. The SEM-EDS investigation identified these residues as azurite and malachite, which are corrosion products of bronze metalwork deposited with this stone artefact. Furthermore, signals from zinc and copper, alongside noticeable amounts of sulphur and calcium, were detected in the EDS spectra for the dark blue residues with linear traces on the specimen from Ruda (Fig. 16G and 16H), which can be related to the parent rock material. Similarly, the black substance preserved on the artefact from "Chełmno land" (Fig. 16O) appears to be unrelated to the stage of use of the object and may be a contaminant from the burial conditions.

Experimental study

The experimental copies of *Kannelurensteine* from the studied area (Fig. 17) were first tested for their use in metalworking as tools for removing casting seams, flashes and debris on replica bronze pins, and surface smoothing or polishing. The raw materials used for the stone replicas were sourced from the local geologic reservoir and corresponded to the petrography of the original artefacts. The grooves running along the diameter of the replicas were used against bronze pins to remove excess metal with an oscillatory motion in four steps of 5 minutes each. The weight loss of the experimental pins was monitored at the beginning and at the end of each step (Table 4). Initially, one of the experimental stones was tested against two bronze pins to eliminate any possible influence of casting seam or flash topography on experimental work efficiency. The results were comparable in both cases.

A difference in the abrasive properties of rock material used against the bronze replicas was observed. However, the evidence produced by the experiment was inconclusive with regard to the potential usefulness of *Kannelurensteine* for metalworking. This assumption is supported by the petrographic characteristics of *Kannelurensteine*, which indicate that the raw material used for their production is disadvantageous for metal smoothing or polishing. Additionally, the geometry of the working edges of the investigated objects limits their use for metalwork of a specific shape, such as rods or wires. The circular indentations on the upper and lower faces of the experimental tools provide a reliable grip but do not facilitate grinding, which is difficult due to the unstable workpiece. Burnishes made of medium- to coarse-grained sandstone are a much better choice for metal rubbing to obtain a smooth surface on a final product, which is well attested to in stone assemblages from the Lusatian period in Poland[99].

The second stage of the experiment was set up to test the experimental grooved *Kannelurensteine* (made of quartz sandstone) against two different contact materials (leather and cord) and to determine whether the findings can be linked to the obtained traceological evidence. Initially, wear traces that formed on the inner surfaces of the stone replicas during their production and handling were removed by grinding with fine-grained sandstone. One of the experimental products was exposed to an oscillatory motion of a lime tree bark cord in a groove for a period of 20 minutes, while other replica was used against a vegetable-tanned cowhide under the same conditions.

Wear traces obtained during the experiment were documented (Fig. 18) and compared with the wear records of the original *Kannelurensteine*. A lab detergent–water solution was used to clean the two experimental replicas. In both examples, the wear record was poorly developed. Wear was observed on only very small fragments of the grooves, measuring approximately 0.5–1 cm, and it was characterised mainly by the darkening of the surface and the gentle smoothing of raw-material crystals. Wear records of this type on the original *Kannelurensteine* would probably be unidentifiable and impossible to interpret. The organic residues resulting from the use of the leather strap and cord as experimental contact materials are well-preserved within the grooves.

A matt polish observed on the stone replica tested against the leather strap has a homogeneous and domed topography (Fig. 18B–D). The microrelief in this case was quite irregular, with a smooth texture and no linear traces. Gentle linear smoothing of the microrelief was only found locally, with a pale polish covering its higher parts, which are rounded. As can be seen in Fig. 18B–D, the motion of the cord produced a polish with characteristics generally comparable to those observed for the leather contact material, although the former is far brighter and has high points that are much more smoothened. Overall, the polish of the product is far from linear (Fig. 18H), yet linearity can be observed in some mineral crystals (Fig. 18F and 18G). However, the traceological evidence is not conclusive enough to confirm whether these are the result of wear from use, surface forming, or perhaps the crystal structure of the raw material used.

A comparison of the wear records produced by the two experimental contact materials revealed some differences that could not be adequately discerned in the original artefacts. Future experimental work and statistical validations of microscopic data are required to accurately determine the character of wear traces observed on the *Kannelurensteine* from the studied area. Despite the limitations of this experiment and the consequently poor reference traceological data for further comparisons, our findings may address the previous results reported in the literature. In fact, in contrast to previous thinking, we found that the distinct use wear characteristics observed in the groove of the artefacts from Kijewo Szlacheckie and Ruda cannot be explained by the frequent use of a cord or strap to keep the grooved *Kannelurenstein* weight hanging from one extremity of an equal-arm balance[100].

Discussion

The *Kannelurensteine* from the Chełmno group have a remarkable unimodal weight distribution, with a peak value of 220–250 g (Fig. 19). The groove and the indentations are not present on all objects from the studied area and it seems likely that they may have been carved to obtain the desired mass of ca. 250g[101]. One of the stones from Ruda (Plate 4,7) is much heavier (286 g) than other examples from Chełmno land, but its proportions suggest that it may have been intended for further carving. Remarkably, the Elgiszewo *Kannelurenstein* is exactly the same weight as one of the accompanying waste handles of the bronze cauldron, which lends support to the hypothesis that *Kannelurensteine* were most often used as single weights to weigh amounts of material of similar magnitude[102] (Fig. 20). The traceological evidence from this study is important in this context by demonstrating that the *Kannelurenstein* from the Elgiszewo hoard displays polish that may be suggestive of prolonged contact with leather, which may have been utilised as a material for pouches holding the stone weight hanging on the balance scale.

99 See, e. g. Kowalski *et al.* 2021.

100 Ialongo/Rahmstorf 2021, 154–155.

101 Ibid. 155.

102 Ibid. 155–156.

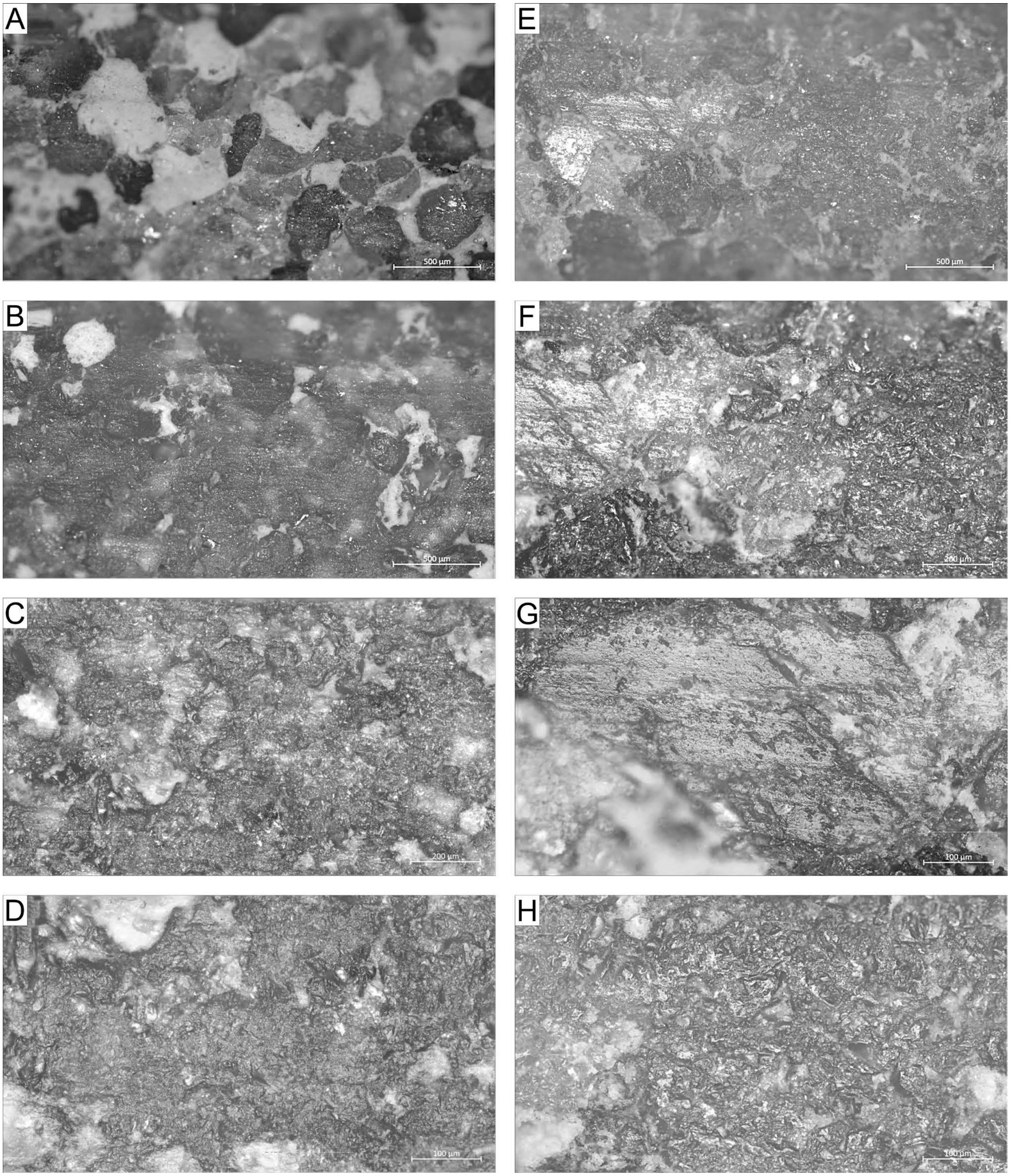

Fig. 18: Wear traces observed in the grooves of the experimental *Kannelurensteine*. B–D – product of experimental surface treatment using a leather strap; A – shows an area with no wear traces; E–H – product of experimental surface treatment using a cord (photographs: G. Osipowicz). Lens magnification ×5–20. See text for further details.

Fig. 19: *Kannelurensteine* from the Chełmno land and the selected metalwork from the Elgiszewo hoard that may have served as semi-products or commodity money. The *Kannelurensteine* from the studied area exhibit remarkable unimodal weight distribution with a peak value of 220–250 g (photographs: W. Ochotny, K. Deczyński). See text for further details.

Fig. 20: Suspended replica antler balance scale with flax strings and leather pouches, holding the original *Kannelurenstein* (251 g) and the waste handle (250 g) of the bronze cauldron from the Elgiszewo hoard in equilibrium (photograph: S. Rosołowski).

A closer examination of the weight of the *Kannelurenstein* and the metalwork from the Elgiszewo hoard reveals that some of the ring ornaments and cauldron handles can be organised along a sequence of multiples of ca. 50 g. This sequence can be roughly arranged as 2 : 3 : 4.5 : 5 (Fig. 19). It is interesting to see these figures in relation to a multiple cremation burial from the Lusatian cemetery at Wartosław, which yielded metalworking tools and more than 30 lithic artefacts dating to 1100–1000 BC[103]. The stone assemblage included a *Kannelurenstein* with two circular indentations, an ovoid artefact with crossing grooves and other stone objects that could have once formed a scale weight set. Here, two weight peaks of 120–100 g and 50–40 g can be observed, which can also be expressed as multiples of 50 g (Fig. 21). Other examples of *Kannelurensteine* from the cemetery at Wartosław have weights between 72–120 g[104], which alligns well with the cluster of *Kannelurensteine* around ca. 100–130 g and coincide with the cluster of *Kannelurensteine* around 100 to 130 grams that has been distinguished mainly from German finds[105]. This geohistorical association is not unexpected given that the pottery from the Wartosław grave perfectly matches the late Urad ceramic style that developed in the region of Brandenburg and Lubusz Land (*Land Lebus*) during the Montelius IV period.

These figures are encouraging and may have exciting implications for further investigation into the use of weighing equipment in Lusatian regions. However, the analysed assemblage is far too small to merit *a priori* assumptions, and it would therefore be beneficial to have more comparable data for *Kannelurensteine* from the southern Baltic region to reinforce the interpretation of the weight system in that region during the later Bronze Age.

103 Krzyszowski/Kowalski 2019; Kowalski *et al.* 2021.
104 Krzyszowski 2019.
105 Ialongo/Rahmstorf 2021, 152.

Fig. 21: Stone assemblage from a cremation grave at the Lusatian cemetery of Wartosław that could have once formed a scale weights set. Two weight peaks of 120–100 g and 50–40 g are evident that can be expressed as multiples of 50 g (photographs: K. Kucharska; courtesy of Archaeological Museum in Poznań). Below are the *Barrenringe* and *Halsringe mit Vogelkopfenden* from northern Poland, which may give a hint of weight regulation in the Early Iron Age of the southern Baltic region (adapted from Gackowski/Dąbrowski 2020; Nowak/Gan 2023; https://poznan.wuoz.gov.pl/skarb-z-grabionnej). See text for further details.

Combining content and context: possible interpretations of the Elgiszewo hoard

Much effort has been put into discussing whether hoards containing metalworking tools and scrap metal should be seen as the materialisation of economic, social or ritual events[106]. This polarised perspective has been widely contested and many prehistorians now agree that such an approach is unproductive for developing a better understanding of the contexts, motivations and meanings of metal hoarding. We must assume that metal hoarding permeated not only the economic sphere, but also the social and ritual realms, which are in fact inseparable in primitive mentalities. Lene Melheim grasps this, claiming that "(...) hoarding was a flexible method for handling objects with particular histories or values which would apply to a number of different aims, ranging from conspicuous consumption, storage, sacrifice, memory practice and the removal of valuables or objects with powerful life-stories from circulation"[107].

Economic context and meanings

Economic models often explain metal hoards through thesaurisation by merchants or itinerant smiths[108]. This concurs with the hypothesis that the number of metal objects could have served as commodity money[109] in the metal trading networks of Bronze Age Europe. The deposits of bronze sickles[110] or bronze ingots with D-shaped cross-sections, which are known chiefly from the Lusatian metal industry in northern Poland[111], may serve to illustrate this, and three solid bracelets from the Elgiszewo hoard, accompanied by *Kannelurenstein*, seem to fit this pattern as well. The economic interpretations of metal hoards are typically based on the assumption that the items were hidden for safekeeping in response to danger or fears with the intention of later retrieval. The widespread metal hoarding seen in the European Bronze Age has led some scholars to speculate about the controlled distribution of metal goods and hypothesise that hoarding was used to regulate wealth accumulation and prevent metal prestige capital outflow to commoners[112].

The Elgiszewo hoard – comprising a mix of items related to bronzesmithing and metal goods from Silesia and Pomerania – may also be interpreted as a deposit by a travelling smith and/or trader[113]. The hoard contents may represent the metal trade route connecting the Lusatian power elites from Chełmno land with other Lusatian regions of Poland. This scenario resonates with the pollen record, which indicates that the hoard was buried at a time of increased human activity in the area surrounding Lake Okonin and the increasing inter-group and inter-tribal communication in the region (see section "Palynology"). However, this interpretation is less convincing when set against the deposition context of the Elgiszewo hoard, which is located in a boggy and waterlogged area. Such a location is not a reasonable place to hide valuable metalworking or trade stock, as it would be extremely difficult to retrieve these materials in the future.

Social context and meanings

The social (institutional) interpretations of events that led to metal hoarding often relate to *non-domestic rituals* that were aimed at exercising power and prestige through a public display or consumption of bronze metalwork. The display of status by power elites was a prominent feature of public space throughout the later Bronze Age. This included water places, which frequently hosted ostentatious displays of valuable metal goods. A potential social agenda for such a form of potlatch could be the balancing of the extensive accumulation of bronze wealth, as described by Georges Bataille, who defined the disposal of the accursed share (*la partie maudite*)[114]. Upon further examination of pre-capitalist societies, it becomes evident that the circulation of bronze surpluses was problematic. Consequently, a form of destruction of a portion of metal wealth was exercised to regulate social relations within the group and to balance internal conflicts. In contrast to modern economies, the economy of the European Bronze Age was not characterised by significant avenues for the accumulation of wealth. The disposal of wealth in pre-industrial societies can be better approached by gift-giving obligations, as defined by Marcel Mauss[115] or Karl Polanyi's account of substantivism[116], which postulates that in non-market societies, the

106 See, e. g. Torbrügge 1971; Bradley 1990; 2005.
107 Melheim 2015, 85.
108 Cf. Hansen 2013, 372.
109 Briard 1997; Hansen 2002, 93; see also Pare 2013.
110 Sommerfeld 1994.
111 Kossinna 1919; La Baume 1930; Kostrzewski 1953; Kowalski *et al.* 2020.
112 Pennors 2000, 205–206; Kowalski *et al.* 2019.
113 For the concept of itinerant smiths in the Lusatian culture see Maciejewski 2016; Nowak 2016; 2022; Kowalski *et al.* 2021; Stróżyk *et al.* 2023; see also Kristiansen 2019.
114 Bataille 2014.
115 Mauss 2001.
116 Polanyi 2001.

consumption of goods and services is embedded in non-economic kinship and captured in social relations and religious beliefs.

The display of social status and the valorisation of spaces for public rituals appear to be closely interrelated in the Urnfield period[117]. Historical sources have demonstrated that aquatic deposits required the sacralisation of watery places that were selected for deposition. For instance, Strabo in *Geographica* (IV,1,13) notes that the Gauls deposited metals in sacred lakes (*limnais hierais*). Additionally, the possibility exists that a body of water may have been a duplicate of a burial furnished with weapons, ornaments and tools. The deliberate sinking of the paraphernalia would thus have been the result of an eschatological reform that was extended throughout Urnfield culture: The souls of the household communities continued to exist in the grave, while the souls of the chosen few would only go to the afterlife through a metonymic chain linking their personal belongings with water[118].

The points raised thus far demonstrate that the social motivations behind the accumulation of metal in watery locations are intertwined with religious beliefs[119]. The legacy of Oscar Montelius has long set the course for the interpretation of aquatic deposits from the Bronze Age as a votive offering[120], although it may be equally argued that these same deposits could also reflect water animisation and fertility rites. Moreover, farming communities could have deposited metal goods into the water as part of a contract with their gods; in return, they could have expected good health, a successful harvest and the promise of crossing the water to the world of the dead[121]. The argument here is less persuasive because the Elgiszewo hoard contains damaged and fragmented metalwork, whereas objects dedicated to deities were typically required to be undefiled, without any signs of use or violence[122]. This is well attested in the religions of the ancient world and Barbaricum. For example, linguistic evidence comes from the Germanic word *heilagaz* meaning both something sacred and healthy, and the related Polish word *cały*, which also derives from the Indo-European root *koilo*-[123], refers to something healthy, complete and intact.

The deposition of metal in aquatic environments is frequently explicable by reference to the concept of *ouk ekphora* rule, which refers to the taboo against removing certain objects[124]. Diodorus Sicilus touched upon this in *Bibliotheca historica* (5.27), noting that the Gauls were prohibited from retrieving gold from offering places once it had been dedicated to the gods (*anatetheimenos tois theois*). The deposition of the casting mould in the Elgiszewo hoard, along with all the metal objects, adds a new dimension to the interpretation of the hoard in terms of *ouk ekphora*. Evidence of the ecumenical treatment of metal accessories used for casting and smithing can be found throughout the Lusatian period in Poland. These items were excluded from settlement and funeral realms and deposited in watery places without any intention of future retrieval[125]. This social strategy of engaging metal depositions may be to some extent representative of a form of inalienable possession, which functions as an instrument of keeping, securing objects that are symbolically identified with a social group and preventing them from entering into gift-giving obligations and exchange[126].

The Elgiszewo hoard can also be approached from a different social angle. There are good reasons to believe that metal became significant in political negotiations during the Late Bronze Age in Poland, and thus may have influenced interactions between the Lusatian power elites from the Chełmno land and nearby regions[127]. The distribution pattern of metal hoards in the geopolitical range of Chełmno group may provide insight. These hoards are clustered near major settlements and are deposited along the Vistula, Drwęca and Osa, which were the border rivers of Chełmno folks' territory[128]. The Elgiszewo hoard would thus mark an important regional communication hub in the southern border of Chełmno group (see Fig. 5). The hoard may also demonstrate how social groups constituted and represented their local identities by ordering the landscape that shaped their existence. Metal hoarding was, after all, an act in and upon the landscape[129]. This spatial patterning of metal hoards and settlement also indicates the increasing external tensions and atomisation of the Lusatian societies in the region at the dawn of the Hallstatt period. This was followed by the appearance of fortified settlements in the local landscape and the consolidation of local power elites that shifted towards more territorial strategies[130].

117 Bradley 1990.
118 Roymans/Kortlang 1999, 55–57; Pennors 2000, 206.
119 Hansen 1997.
120 Hansen 2002, 91–92.
121 Stjernquist 1998, 172–176.
122 For different opinion, see e. g. Sommerfeld 1994.
123 Kroonen 2013, 200.
124 Hansen 2012, 27.
125 Baron *et al.* 2014; Kowalski *et al.* 2021; cf. Fontijn 2008, 12.
126 Kristiansen 2012, 383.
127 Kowalski *et al.* 2020.
128 Gackowski/Kowalski 2019; Kowalski *et al.* 2020; Gackowski *et al.* 2023.
129 Melheim 2015, 85; see also Fontijn 2002; Bradley 2017.
130 Kowalski *et al.* 2020.

Ritual context and meanings

The Elgiszewo hoard contains female ornaments, a fragment of a cauldron, a knife and horse-related elements, which makes it challenging to determine with certainty whether it can be classified as a votive offering. Luxury objects were deposited in watery places as part of a *devotio hostium* dedicated to chthonic deities. According to Livius, Decius devoted both himself and the opposing enemy forces to the gods of the Underworld in return for saving the Romans by addressing the words *deis Manibus Tellurique devoveo*[131]. The same spell appears in the Gaulish inscription from the tablet of Chamalières as *briχtía anderon*, which has been translated as "magic of the underworld"[132]. In accordance with traditional narratives, aquatic spirits, such as the proto-Germanic *nikwas*, have occasionally been associated with a water horse[133], which could potentially shed light on the horse harness fittings present in the Elgiszewo hoard and other similar metal deposits from watery places. One noteworthy aspect of the Nordic and Baltic regions is the frequent occurrence of horse-related accessories accompanied by female-gendered items[134], which has led to the hypothesis that the North European Bronze Age saw the ecumenical ritual events and ceremonies led by priestesses using two-horse team wagons[135].

The fragmentation of metals and the destruction of other artefacts from the Elgiszewo hoard may be viewed as a materialising transformation. It is possible that the image we observe here is the result of ritual violence directed towards the metal object, which mirrors the destructive disposition of a dead body through the cremating inferno[136]. Indeed, the hoarding of damaged metals parallels the cremation rite in terms of its structural composition[137] and may therefore be deemed a variant of a burial of the objects belonging to the deceased. Anthropology recognises such a pattern as the exclusion not of the objects themselves but of their non-spatial associations, meanings and functions, etc. The Gundestrup cauldron offers a remarkable illustration of this pattern. Moreover, such objects are not typically *external symbolic storage*[138]. It is likely that these objects were not symbolic agents – their users could have considered them real embodiments of the true meanings and functions associated with these objects, supporting the idea of parallelism in the biographies of objects and humans. This is not a novel argument. Indeed, Richard Thurnwald's account of the *Zubehör* demonstrates this, as do the non-spatial relations that Lucien Lévy-Bruhl calls *appurtenances*[139]. It would therefore be reasonable to define aquatic deposits as *les depôts des appurtenances*[140]. The primitive mentality holds that the physical elimination of such objects cancels all their associations. However, it is evident that this process was highly structured[141] and required the appropriate method and place to succeed. Furthermore, the ritual killing of objects might be seen to echo the triad of punishment for an offence against the three functions of Indo-European society. The punishments for crimes against rulers were death from strangulation and hanging, crimes against the heroic code were punished by beating, mutilation and burning, and crimes against the rules of commoners were punished by drowning. These punishment methods were used either selectively or in combination[142]. This line of reasoning may suggest that cremation of bronzes would not be sufficient to erase their attributes, as splitting, bending and burning is, after all, part of the transformation of metal that heralds its new form, or rebirth. Accordingly, the only way to break the chain of possible incarnations of metal and annihilate its appurtenances is to sink a metal deposit in a watery place that would prevent the future retrieval of the deposit and ensure its ultimate consumption by an animated body of water or aquatic spirits. This *modus operandi* presents a promising avenue for understanding a vast array of metal hoards from the European Urnfield period through to the Early Iron Age.

List of finds

Body ornaments

1. Spiral bronze bracelet with narrowed endings, coiled (3.5 coils) from sheet metal, undecorated. Size: coil ∅ 6.5 cm, coil width 0.8 cm, coil height 2.8 cm, sheet metal thickness 0.20 cm, weight 53 g. Inv. No. WKZ/T/1/2015. Plate 1,1.
2. Spiral bronze bracelet with narrowed endings, fragment. Preserved one coil with narrowed ending, made of sheet metal, undecorated. Size: coil ∅ 6.0 cm, coil width 0.80 cm, sheet metal thickness 0.20 cm, weight 10 g. Inv. No. WKZ/T/32/2015. Plate 1,2.

131 Livius 2008, 140.
132 Koch 2003, 2.
133 Lühr 2017, 956–959.
134 See, e. g. Sarauw 2015; Kaczmarek *et al.* 2021; Szczurek/Kaczmarek 2022; Gackowski *et al.* 2023.
135 Kristiansen 2012; Varberg 2013.
136 Nebelsick 1997; 2016, 75–85.
137 Ibid, 75–85.
138 Renfrew 1998.
139 Lévy-Bruhl 1963.
140 Kowalski 2001, 20–21.
141 Cf. Fontijn 2002; 2008.
142 Ward 1970.

3. Spiral bronze bracelet with narrowed endings, coiled (2.5 coils) from sheet metal, undecorated. Size: coil ∅ 6.5 cm, coil width 1.0 cm, coil height 3.0 cm, sheet metal thickness 0.20 cm, weight 51 g. Inv. No. WKZ/T/3/2015. Plate 1,3.
4. Spiral bronze armband with narrowed endings, fragment. Preserved 1.5 coil, made of sheet metal, decorated with a zig-zag motif. Size: coil ∅ 6.5 cm, coil width 1.2 cm, sheet metal thickness 0.20 cm, weight 19 g. Inv. No. WKZ/T/2/2015. Plate 1,4.
5. Spiral bronze armband with narrowed endings, fragment. Preserved 2.5 coils with narrowed ending, made of sheet metal, decorated with a zig-zag motif. Size: coil ∅ 5.5 cm, coil width 1.2 cm, sheet metal thickness 0.20 cm, weight 32 g. Inv. No. WKZ/T/4/2015. Plate 1,5.
6. Spiral bronze armband with narrowed endings, fragment. Preserved one coil, made of sheet metal, decorated with a zig-zag motif. Size: coil ∅ 6.2 cm, coil width 1.2 cm, sheet metal thickness 0.20 cm, weight 6 g. Inv. No. WKZ/T/11/2015. Plate 1,6.
7. Spiral bronze armband with narrowed endings, fragment. Preserved half of coil, made of sheet metal, decorated with a zig-zag motif. Size: coil length 6.0 cm, coil width 1.1 cm, sheet metal thickness 0.20 cm, weight 3 g. Inv. No. WKZ/T/14/2015. Plate 1,7.
8. Spiral bronze armband with narrowed endings, fragment. Preserved half of coil, made of sheet metal, decorated with a zig-zag motif. Size: coil length 6.5 cm, coil width 1.3 cm, sheet metal thickness 0.20 cm, weight 5 g. Inv. No. WKZ/T/13/2015. Plate 1,8.
9. Spiral bronze armband with narrowed endings, fragment. Preserved half of coil, made of sheet metal, decorated with a zig-zag motif. Size: coil length 11.5 cm, coil width 1.2 cm, sheet metal thickness 0.20 cm, weight 7 g. Inv. No. WKZ/T/12/2015. Plate 1,9.
10. Bronze bracelet, closed, made of U-shaped sheet metal, undecorated. Size: hoop ∅ 7.8 cm, width 1.0 cm, height 1.0 cm, sheet metal thickness 0.20 cm, weight 50 g. Inv. No. WKZ/T/7/2015. Plate 1,10.
11. Bronze bracelet with bevelled endings, open, made of round rod, undecorated. Size: hoop ∅ 9.0 cm, rod ∅ 1.0 cm, weight 155 g. Inv. No. WKZ/T/8/2015. Plate 1,11.
12. Bronze bracelet with straight endings, open, made of round rod, undecorated. Size: hoop ∅ 7.8 cm, rod ∅ 0.70 cm, weight 92 g. Inv. No. WKZ/T/9/2015. Plate 1,14.
13. Bronze bracelet with straight endings, open, made of round rod, undecorated. Size: hoop ∅ 7.8 cm, rod ∅ 0.90 cm, weight 144 g. Inv. No. WKZ/T/10/2015. Plate 1,15.
14. Bronze necklace, closed, made of round rod, undecorated. Size: hoop ∅ 18 cm, rod ∅ 0.75 cm, weight 247 g. Inv. No. WKZ/T/27/2015. Plate 1,16.
15. Bronze necklace with narrowed endings and a clasp, made of round rod, undecorated. Size: hoop ∅ 18 cm, rod ∅ 0.70 cm, clasp ∅ 0.90 cm, clasp length 3.3 cm, weight 232 g. Inv. No. WKZ/T/28/2015. Plate 1,17.

Dress ornaments

16. Spiral fragment, presumably the part of the *Spindlersfeld* fibula; see below. Preserved spiral coil made of rod square in cross section. Size: ∅ 3.5 cm, rod width 0.20 cm, weight 11 g. Inv. No. WKZ/T/6/2015. Plate 1,12.
17. Bronze fibula, type *Spindlersfeld*, fragment. Preserved central part of lenticular plate (bow) made of sheet metal, decorated with dotted circles and arches. Size: length 9.2 cm, width 6.3 cm, weight 14 g. Inv. No. WKZ/T/30/2015. Plate 1,13.

Phalerae

18. Bronze phalera with a domed centre and a single loop, type *Kalisz*, damaged. Provided with a flattened knob and profiled edges, undecorated. Size: ∅ 9.0 cm, knob ∅ 1.2 cm, height 2.0 cm, loop width 3.3 cm, weight 32 g. Inv. No. WKZ/T/16/2015. Plate 2,1.
19. Bronze phalera with a domed centre and a single loop, type *Kalisz*, damaged. Provided with a flattened knob and profiled edges, undecorated. Size: ∅ 9.0 cm, knob ∅ 1.2 cm, height 2.0 cm, loop width 3.5 cm, weight 33 g. Inv. No. WKZ/T/17/2015. Plate 2,2.
20. Bronze phalera with a domed centre and a single loop, type *Kalisz*, damaged. Provided with a flattened knob and profiled edges, undecorated. Size: ∅ 8.3 cm, knob ∅ 1.2 cm, height 1.8 cm, loop width 2.5 cm, weight 30 g. Inv. No. WKZ/T/20/2015. Plate 2,3.
21. Bronze phalera with a single loop (broken off), notching around the loop base, damaged. Size: ∅ 11.5 cm, weight 63 g. Inv. No. WKZ/T/21/2015. Plate 2,4.
22. Bronze phalera with a domed centre and a single loop, type *Morgenitz*, damaged. Provided with a knob and profiled edges, undecorated. Loop endings flat hammered at the outer side of the dome. Size: ∅ 7.5 cm, height 1.8 cm, loop width 2.8 cm, weight 24 g. Inv. No. WKZ/T/22/2015. Plate 2,5.
23. Bronze phalera with two cast loops, undecorated. Size: ∅ 5.5 cm, height 2.0 cm, loop width 3.0 cm, loop span 1.5 cm, weight 30 g. Inv. No. WKZ/T/23/2015. Plate 2,6.
24. Bronze phalera with two cast loops, undecorated, damaged. Size: ∅ 5.5 cm, height 1.8 cm, loop width 3.0 cm, loop span 1.5 cm, weight 30 g. Inv. No. WKZ/T/24/2015. Plate 2,7.

25. Bronze phalera with a domed centre and two cast loops, undecorated, damaged. Size: ∅ 9.0 cm, height 2.0 cm, loop width 2.5 cm, loop span 2.0 cm, weight 43 g. Inv. No. WKZ/T/19, 33/2015. Plate 2,8.
26. Bronze phalera with two cast loops, undecorated, damaged. Size: ∅ 11 cm, loop width 3.5 cm, loop span 2.0 cm, weight 59 g. Inv. No. WKZ/T/18/2015. Plate 2,9.

Cauldron

28. Bronze cauldron, fragment. Preserved a handle with two looped cross attachments that were originally riveted to the metal body. A handle made of a twisted bronze rod with hammered and looped endings. Attachments decorated with vertical grooves and concentric circles. Preserved fragments of metal body. Size: handle height 10 cm, handle span 30 cm, handle thickness 0.30–0.80 cm, attachments height 9.0 cm, attachments width 7 cm, attachments loop ∅ 3.0 cm, weight 250 g. Inv. No. WKZ/T/25/2015. Plate 3,2.
27. Bronze cauldron, fragment. Preserved a handle with one looped cross attachment that was originally riveted to the metal body. A handle made of a twisted bronze rod with hammered and looped endings. Attachment decorated with vertical grooves. Preserved fragments of metal body. Size: handle height 9 cm, handle span 31 cm, handle thickness 0.30–0.80 cm, attachment height 8.5 cm, attachment width 8.2 cm, attachment loop ∅ 2.5 cm, weight 209 g. Inv. No. WKZ/T/26/2015. Plate 3,1.

Tools

29. Bronze antenna knife, type *Szymocin*, fragment. Preserved a handle with a damaged blade part and hilt ending in a pair of damaged antennae. The back part decorated with incised double herringbone motif interspersed with triple grooves. The tang has four rivet holes, one bronze rivet preserved. Size: length 20 cm, blade part length 9 cm, blade part width 2.5 cm, back part width 1.2 cm, blade width 0.2 cm, handle part length 11 cm, grip length 9 cm, grip width 1.3 cm, grip thickness 0.7–1.0 cm, weight 77 g. Inv. No. WKZ/T/25/2015. Plate 3,3.
30.1–2. Bipartite bronze casting mould for socketed axes, type *Przedmieście*. Male part provided with four pegs fitting into holes in the female part. Two damaged knobs visible on the outer side. The split with a total length of 2.5 cm is discernible on the feeding channel. Size: male part: length 13.9 cm, width 4.2, weight 298 g. Inv. No. WKZ/T/31.1/2015; female part: length 13.8 cm, width 4.3, weight 314 g. Inv. No. WKZ/T/31.1/2015. Plate 3,4.
31. Lenticular-shaped stone object with circular indentations on the upper and lower faces and flattened surfaces on the diameter. Size: ∅ 7 cm, height 3.7 cm, flattening on the diameter width 1.2 cm, weight 251 g. Inv. No. WUOZ/T/34/2015. Plate 4,1.

Semi-products and waste

33. Bronze wire joined coils with twisted or recurrent endings. Size: coil ∅ 3.5 cm, wire ∅ 0.15 cm, weight 36 g. Inv. No. WUOZ/T/5/2015. Plate 3,6–9.
32. Bronze destruct, originally made of metal sheet. Size: length 8.0 cm, width 7.8 cm, weight 16 g. Inv. No. WUOZ/T/29/2015. Plate 3,5.

All artefacts are held in the Archaeological Museum in Biskupin, Poland.

List of *Kannelurensteine* from the studied area (and the East Prussia)[143] (see Fig. 13 and Plate 4):

1. Elgiszewo, Ciechocin commune. Context: metal hoard, Ha B3/Ha C. Size: ∅ 7.1 cm, height 3.8 cm, weight 251 g. Archaeological Museum in Biskupin, Inv. No. WUOZ/T/34/2015. Plate 4,1.
2. Głażewo, Unisław commune. Context: stray find, Ha B2–Ha B3/Ha C. Size: ∅ 7.1 cm, height 3.3 cm, weight 60 g, preserved partially with a central hourglass perforation. District Museum in Toruń, Inv. No. MT/A/240. Plate 4,2.
3. Gniewkowo-Zajezierze, *loco* commune. Context: defensive settlement, Lusatian culture, Ha B2–Ha B3/Ha C. Size: ∅ 6.9 cm, height 3.5 cm, weight 302 g. Provincial Office for the Protection of Monuments in Toruń. Plate 4,3.
4. Kałdus, Chełmno commune. Context: defensive settlement, Lusatian culture, Ha B2–Ha B3/Ha C. Size: ∅ 7.6 cm, height 2.8 cm, weight 240 g. Museum of Chełmno land, Inv. No. MZCH/A/26. Plate 4,4.
5. Kijewo Szlacheckie, Kijewo Królewskie commune. Context: stray find, Ha B2–Ha B3/Ha C. Size: ∅ 7.2 cm, height 3.9 cm, weight 230 g. District Museum in Toruń, Inv. No. MT/A/519. Plate 4,5.

143 Prinke/Skoczylas 1980; Dąbrowski 1997; Hoffmann 1999; Gackowski 2012; Bielińska-Majewska 2015; Rembisz-Lubiejewska 2017; Oliwkowski 2021; Wyrzykowski 2021.

6–7. Ruda, Grudziądz commune. Context: open settlement, Lusatian culture, Ha B2–Ha B3. Site 3–6 D: size: ∅ 7.7 cm, height 3.9 cm, weight 286 g. Institute of Archaeology, NCU in Toruń, Inv. No. 15/01; Site 3–6 F: size: ∅ 7.0 cm, height 3.4 cm, weight 259 g. Institute of Archaeology, NCU in Toruń, Inv. No. 123/02. Plate 4,6, 7.
8. "Chełmno land". Context: stray find, Ha B2–Ha B3/Ha C. Size: ∅ 6.0 cm, height 3.8 cm, weight 220 g. Institute of Archaeology, NCU in Toruń. Plate 4,8.
9–10. Mołtajny, Barciany commune. Context: lake settlement, West Baltic Barrow culture, Ha D – La Tène C. Archival. Size: ∅ ca. 5.1 cm, height ca. 3.4 cm. Archival. Size: ∅ ca. 6.3 cm, height ca. 4.9 cm. Formerly Königsberg City Museum. Plate 4,9.10.
11. Ogródki, Miłki commune. Context: stray find, Ha B2–B3. Archival. Size: ∅ ca. 5.7 cm. Formerly Königsberg City Museum. Plate 4,11.
12. Szczecinowo, Stare Juchy commune. Context: lake settlement, West Baltic Barrow culture, Ha C – Ha D. Archival. Size: ∅ 7.5 cm. Formerly Königsberg City Museum. Plate 4,12.

List of sites from the studied area[144] (see Fig. 5):

Cremation cemeteries of Ha B3–Ha D

1. Ciechocin, *loco* commune, Ha C–Ha D
2. Jedwabno (site 110), Lubicz commune, Ha B3/Ha C
3. Młyniec Dolny[145] (site 4), Lubicz commune, Ha B3/Ha C
4. Młyniec Dolny (site 12), Lubicz commune, Ha C–Ha D
5. Młyniec Górny (site 98), Lubicz commune, Ha B3/Ha C
6. Rudaw (site 10), Ciechocin commune, Ha B3/Ha C

Open settlements of Ha B–Ha D

7. Chełmonie (site 6), Kowalewo Pomorskie commune, Ha C–Ha D
8. Ciechocin (site 3), *loco* commune, Ha C–Ha D
9. Ciechocin (site 5), *loco* commune, Ha C–Ha D
10. Ciechocin (site 7), *loco* commune, Ha C–Ha D
11. Ciechocin (site 9), *loco* commune, Ha C–Ha D
12. Ciechocin (site 11), *loco* commune, Ha C–Ha D
13. Ciechocin (site 14), *loco* commune, Ha C–Ha D
14. Ciechocin (site 16), *loco* commune, Ha C–Ha D
15. Ciechocin (site 17), *loco* commune, Ha C–Ha D
16. Ciechocin (site 21), *loco* commune, Ha C–Ha D
17. Ciechocin (site 27), *loco* commune, Ha C–Ha D
18. Ciechocin (site 30), *loco* commune, Ha C–Ha D
19. Ciechocin (site 31), *loco* commune, Ha C–Ha D
20. Ciechocin (site 32), *loco* commune, Ha C–Ha D
21. Ciechocin (site 34), *loco* commune, Ha C–Ha D
22. Ciechocin (site 37), *loco* commune, Ha C–Ha D
23. Ciechocin (site 38), *loco* commune, Ha C–Ha D
24. Ciechocin (site 39), *loco* commune, Ha C–Ha D
25. Ciechocin (site 40), *loco* commune, Ha C–Ha D
26. Ciechocin (site 46), *loco* commune, Ha C–Ha D
27. Ciechocin (site 47), *loco* commune, Ha C–Ha D
28. Elgiszewo (site 7), Ciechocin commune, Ha C–Ha D
29. Elgiszewo (site 9), Ciechocin commune, Ha C–Ha D
30. Jedwabno (site 4), Lubicz commune, Ha C–Ha D
31. Kamionki Duże (site 15), Łysomice commune, Ha C–Ha D
32. Kamionki Małe (site 1), Łysomice commune, Ha B3/Ha C
33. Kamionki Małe (site 4), Łysomice commune, Ha B3/Ha C
34. Lubicz Dolny (site 1), *loco* commune, Ha B
35. Lubicz Dolny (site 2), *loco* commune, Ha B3/Ha C
36. Młyniec Dolny (site 2), Lubicz commune, Ha C–Ha D
37. Młyniec Dolny (site 6), Lubicz commune, Ha C–Ha D
38. Młyniec Dolny (site 10), Lubicz commune, Ha C–Ha D
39. Młyniec Górny (site 8), Lubicz commune, Ha C–Ha D
40. Nowogród (site 1), Golub-Dobrzyń commune, Ha C–Ha D
41. Nowogród (site 5), Golub-Dobrzyń commune, Ha C–Ha D
42. Nowogród (site 6), Golub-Dobrzyń commune, Ha C–Ha D
43. Nowogród (site 7), Golub-Dobrzyń commune, Ha C–Ha D
44. Nowogród (site 10), Golub-Dobrzyń commune, Ha C–Ha D
45. Nowogród (site 13), Golub-Dobrzyń commune, Ha C–Ha D
46. Nowogród (site 18), Golub-Dobrzyń commune, Ha C–Ha D
47. Rudaw (site 9), Ciechocin commune, Ha C–Ha D
48. Rudaw (site 18), Ciechocin commune, Ha B3/Ha C
49. Szewa (site 4), Kowalewo Pomorskie commune, Ha C–Ha D
50. Szewa (site 7), Kowalewo Pomorskie commune, Ha C–Ha D

Settlement traces of Ha B–Ha D

51. Chełmonie (site 9), Kowalewo Pomorskie commune, Ha C–Ha D

144 Jakimowicz 1925; Heym 1942; Zielonka 1959; Chudziakowa 1974; Fogel 1979; Dąbrowski 1997; Blajer 2001; Gedl 2001; 2003; Gackowski 2012; 2016; Kucharski 2015; Gackowski/Rosołowski 2022. Archaeological Record Survey data: The Provincial Office for the Protection of Monuments in Toruń (WUOZ).
145 The identified site may be the cemetery at Jedwabno (site 110), Lubicz commune.

52. Chełmonie (site 61), Kowalewo Pomorskie commune, Ha B3/Ha C
53. Elgiszewo (site 8), Ciechocin commune, Ha C–Ha D
54. Elgiszewo (site 12), Ciechocin commune, Ha C–Ha D
55. Elgiszewo (site 13), Ciechocin commune, Ha C–Ha D
56. Jedwabno[146] (site 115), Lubicz commune, Ha B3/Ha C
57. Jedwabno, Lubicz commune, Ha B3/Ha C
58. Kamionki Małe (site 2), Łysomice commune, Ha B3/Ha C
59. Kamionki Małe (site 3), Łysomice commune, Ha B3/Ha C
60. Kamionki Małe (site 5), Łysomice commune, Ha B3/Ha C
61. Kamionki Małe (site 8), Łysomice commune, Ha B3/Ha C
62. Lubicz Dolny (site 14), *loco* commune, Ha C–Ha D
63. Lubicz Dolny (site 15), *loco* commune, Ha C–Ha D
64. Lubicz Górny (site 1), *loco* commune, Ha B3/Ha C
65. Lubicz Górny (site 2), *loco* commune, Ha B3/Ha C
66. Miliszewy (site 3), Ciechocin commune, Ha B3/Ha C
67. Młyniec Dolny (site 20), Lubicz commune, Ha C–Ha D
68. Młyniec Dolny (site 101), Lubicz commune, Ha C–Ha D
69. Młyniec Górny[147] (site 106), Lubicz commune, Ha C–Ha D
70. Młyniec Górny[148] (site 108), Lubicz commune, Ha C–Ha D
71. Nowogród[149], Golub-Dobrzyń commune, Ha B
72. Plebanka, Golub-Dobrzyń commune, Ha C–Ha D
73. Szewa (site 2), Kowalewo Pomorskie commune, Ha C–Ha D
74. Szewa (site 9), Kowalewo Pomorskie commune, Ha C–Ha D
75. Szewa (site 10), Kowalewo Pomorskie commune, Ha B

Metal deposits of Ha B2–Ha D

76. Elgiszewo, Ciechocin commune (hoard), Ha B3/Ha C
77. Głogowo, Obrowo commune (bronze antenna sword, type Flörsheim), Ha B2
78. Głowińsk, Rypin commune (bronze cauldron), Ha B2–Ha B3
79. Jedwabno[150] (site 118), Lubicz commune (bronze eyelet pin, plate fibula), Ha B
80. Jedwabno[151], (site 117) Lubicz commune (bronze spearhead), Ha B3/Ha C
81. Kamionki, Łysomice commune (bronze necklace), Ha B3/Ha C
82. Lubin, Kikół commune (hoard), Ha D

Authorship contribution statement

JG: Writing – original draft, Settlement analysis, Typo-chronological analysis. **ŁK**: Conceptualization, Writing – original draft, Investigation, Metallographic data curation, Visualization, Funding acquisition, Supervision. **APK**: Writing – original draft. **AGK**: ED XRF analysis, Writing – original draft, Visualization. **GO**: Writing – original draft, Traceological analysis, Visualization. **AS**: Writing – original draft, Archaeological experiment, Visualization. **MĆ**: Writing – original draft, Petrographic analysis, Visualization. **MĆ**: Writing – original draft, Petrographic analysis, Visualization. **MB**: SEM-EDS analysis. **MK**: Conservation treatment. **AK**: Resources, Visualization. **MM**: Pedological analysis. **PM**: Paleogeographical analysis, Visualization. **AMN**: Visualization. **MPN**: SEM-EDS analysis. **ARL**: Typo-chronological analysis. **TS**: Resources, Visualization. **MS**: Visualization.

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146 The identified ceramic urn may originally come from the cremation cemetery at Jedwabno (site 110), Lubicz commune.
147 The Bronze/Early Iron Age chronology of an antler cheekpiece from Młyniec Górny near Toruń (Sulimirski 1948, 80–89 ryc. 2) has been contested by some authors (e. g. Bukowski 1977, 94).
148 The identified ceramic urn may originally come from the cremation cemetery at Młyniec Górny (site 98), Lubicz commune.
149 The identified site may be the open settlement at Młyniec Górny (site 98), Lubicz commune.
150 The identified bronze eyelet pin and plate fibula may originally come from the cremation cemetery at Jedwabno (site 110), Lubicz commune.
151 The identified bronze spearhead may originally come from the cremation cemetery at Jedwabno (site 110), Lubicz commune.

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