Metal casting moulds in bronze age and early iron age Poland. Current state of research

Author: Kamil Nowak

PL ISSN 0003-8180; e-ISSN 2719-7034

DOI: https://doi.org/10.23858/APol70.2025.002

https://rcin.org.pl/dlibra/publication/299387

Jak cytować:

Nowak, K. (2025). Metalowe formy odlewnicze z epoki brązu i wczesnej epoki żelaza z obszaru Polski. Aktualny stan badań. Archeologia Polski, 70, 17–54. https://doi.org/10.23858/APol70.2025.02

S T U D I A

„Archeologia Polski", t. 70: 2025, s. 17–54
PL ISSN 0003-8180; e-ISSN 2719-7034
https://journals.iaepan.pl/apol
DOI: 10.23858/APol70.2025.02

KAMIL NOWAK[a]

METAL CASTING MOULDS IN BRONZE AGE AND EARLY IRON AGE POLAND. CURRENT STATE OF RESEARCH

METALOWE FORMY ODLEWNICZE Z EPOKI BRĄZU I WCZESNEJ EPOKI ŻELAZA ODKRYTE NA OBSZARZE OBECNEJ POLSKI. AKTUALNY STAN BADAŃ

Abstract: This article presents the first comprehensive study of metal casting moulds from the Bronze Age and Early Iron Age discovered within present-day Poland. These artefacts, primarily made of tin bronze and unalloyed copper, were used in the direct casting of socketed axes, ornaments, and weapons. Drawing on recent discoveries, the study examines their technological characteristics, metal composition, and spatial distribution. Particular attention is given to manufacturing techniques of metal casting moulds, including lost-wax and ceramic mould-based methods. Comparative analysis places Polish finds within the broader Central European context, revealing shared technological traditions and regional variation. Experimental data support the interpretation that metal moulds were used for repeated direct casting, contradicting earlier views that they served only for model production. The concentration of finds in western Poland, often deposited in hoards of metals and in aquatic contexts, suggests diverse depositional practices of the metal moulds. This study not only expands the empirical base for understanding prehistoric metal casting in Poland but also contributes to ongoing discussions on metallurgical activities in Bronze and Early Iron Age Europe.

Keywords: Bronze Age, Early Iron Age, metallurgy, metal casting, casting mould

Abstrakt: Artykuł jest pierwszym, kompleksowym opracowaniem metalowych form odlewniczych z epoki brązu i wczesnej epoki żelaza, znalezionych na obszarze współczesnej Polski. Zabytki te, wykonane głównie z brązu cynowego oraz miedzi niestopowej, służyły do odlewania siekierek z tulejką, ozdób i broni. Na podstawie zebranych, najnowszych odkryć przeanalizowano ich cechy technologiczne, skład chemiczny metalu, z którego zostały wykonane, oraz dystrybucję przedmiotów. Omówiono techniki wytwarzania form, w tym metodę traconego wosku i odlewania w formach ceramicznych. Dokonano analizy porównawczej polskich znalezisk z zarejestrowanymi na terenie Europy Środkowej, ukazując podobieństwa (w zakresie tradycji wytwórczych) i różnice (regionalne) między nimi. W celu weryfikacji dotychczasowych interpretacji posłużono się danymi eksperymentalnymi. Świadczą one, że form metalowych używano wielokrotnie do bezpośrednich odlewów. To podważa wcześniejsze hipotezy, że stosowano je tylko do produkcji modeli. Koncentracja znalezisk w zachodniej Polsce, często w depozytach metali i w środowiskach wodnych, wskazuje na zróżnicowane praktyki deponowania takich wyrobów. Prezentowane badania nie tylko poszerzają zasób źródeł materialnych z zakresu pradziejowego odlewnictwa w Polsce, ale są też istotnym wkładem w dyskusję nad działalnością metalurgiczną w Europie epoki brązu i wczesnej epoki żelaza.

Słowa kluczowe: epoka brązu, wczesna epoka żelaza, metalurgia, odlewnictwo metalu, forma odlewnicza

[a] Dr. Kamil Nowak; Austrian Archaeological Institute, Austrian Academy of Sciences, Dominikanerbastei 16, 1010 Vienna, Austria; KamilLukasz.Nowak@oeaw.ac.at; ORCID iD: https://orcid.org/0000-0002-8137-0059.

INTRODUCTION

Metal casting is a technological process in which molten metal is poured into a cavity, formed by a casting mould, that reflects the desired shape of the final object. The process of obtaining a raw casting typically involves four successive stages: 1) pouring the molten metal into the mould; 2) cooling of the liquid metal; 3) solidification of the cast; and 4) cooling of the solidified casting (Szweycer, Nagolska 2002, p. 78). These stages leave characteristic physical traces that can be identified through macroscopic and microscopic analyses of archaeological artifacts (e.g. Gutiérrez Sáez, Lerma 2015; Nowak, Sych 2024).

Casting moulds can be categorized based on the durability of the material from which they are made. This typological framework, adapted from studies of historical casting practices (Szweycer, Nagolska 2002, p. 96), is applicable to prehistoric contexts. It includes:

1) Permanent moulds – fabricated from durable materials that can withstand repeated exposure to molten metal. These include stone and copper-based alloy moulds, which are distinguished by their strength and resistance to thermal and mechanical stress.

2) Semi-permanent moulds – made of ceramic masses, they are useful for a limited number of castings. They are not associated with the lost-wax method. Examples include moulds from Legnica (Lower Silesia) and Ruda (Grudziądz District, Kuyavia-Pomerania province) (Nowak, Stolarczyk eds 2016; Rembisz, Markiewicz 2007).

3) Disposable moulds – used only once, they include sand moulds and precision moulds employed in lost-wax casting. Although there is a lack of direct archaeological evidence for the use of casting sand, its role in prehistoric copper-alloy metallurgy has often been suggested (Goldmann 1981; Ottaway 1994, p. 117; Kuijpers 2008, p. 89).

This study focuses on the permanent casting moulds made of metal dating to the later part of the Late Bronze Age and Early Iron Age (HaA–HaD; ca. 1200–450 BC) that were found in present-day Poland. The number of such finds has increased in recent years, largely due to the widespread use of metal detectors by non-professionals. Although metal casting moulds are occasionally published as part of broader collaborative research projects, they seldom form the primary focus of scholarly enquiry, with notable exceptions (e.g. Kowalski *et al*. 2019; Baron *et al*. 2014). No comprehensive catalogue of metal casting moulds from Poland has yet been compiled, nor has there been a systematic analysis of their depositional contexts.

These moulds are a particularly intriguing aspect of prehistoric metallurgy. Discovered in various contexts dating to specific phases of the Bronze and Early Iron Ages, these artifacts have long sparked scholarly debate about their purpose. Were they fully functional tools designed for casting metal objects, or were they used exclusively to produce matrix using materials with lower melting points, such as wax or lead? This article analyses various aspects of this category of objects, based on a comprehensive list of all known examples of such moulds in Poland. It specifically addresses manufacturing methods, usage patterns, depositional contexts, and chronological and geographical distribution of these moulds in central Europe. This research constitutes the first comprehensive investigation of metal-casting moulds from Poland, contextualising the artifacts within broader regional and technological frameworks.

The earliest finds, from the end of the 19th century, are poorly documented, so little is known about the circumstances of their discovery. The majority, however, were unearthed during the second half of the 20th century and the early 21st, in controlled and well-documented archaeological contexts. The analysis in this article is based on published data on the discovery contexts, supplemented with the results of other analyses, such as elemental composition, casting-mould structure and technology. The discussion is situated within the broader context of central European Bronze Age finds, identifying certain similarities and differences in the deposition patterns of these objects across the region.

METAL CASTING MOULDS FROM POLAND – OVERVIEW

In 2014, Justyna Baron and her team (Baron *et al.* 2014) noted only five sites with metal-casting moulds from the Bronze and Early Iron Ages in Poland. However, this number has multiplied in recent years (**Table 1**; **Fig. 1**), leading to a better understanding of their discovery contexts.

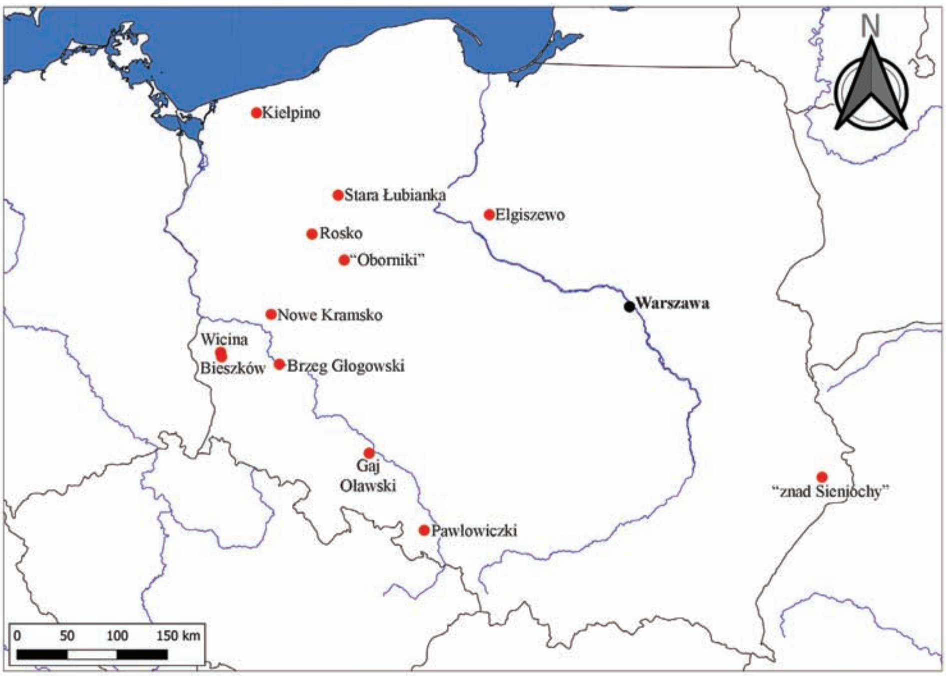


Fig. 1. Discovery sites of metal casting moulds dated to the Late Bronze Age and Early Iron Age in present-day Poland. Map source: SRTM project data; modified and prepared by K. Nowak.

Ryc. 1. Miejsca odkrycia metalowych form odlewniczych z późnej epoki brązu i wczesnej epoki żelaza na terenie obecnej Polski. Źródło mapy: dane misji SRTM; modyfikacja i oprac. K. Nowak.

CHARACTERISTICS OF METAL CASTING MOULDS

Currently, 28 parts of metal casting moulds are known from 12 archaeological sites (see **Table 1**). These represent ten complete sets: eight are bivalve (two-part) moulds (nos. 2, 3, 6, 7, 9, 10 in **Table 1**), and two are three-part moulds (no. 1). Five additional moulds are represented by single halves (nos. 4, 5, 8, 11, 12), and a specimen from Bieszków (no. 1) constitutes a fragment of a two- or possibly three-part mould.

In terms of structure, metal casting moulds are not significantly different from their stone counterparts. However, a key distinguishing feature is the presence of plastically formed alignment elements, such as centring pegs that fit into corresponding recesses in the other half of the mould. Some metal counterparts for socketed axes have special pegs in the upper section of the cavity to stabilise the casting core. This solution, not seen in the stone moulds, has been noted in finds from outside present-day Poland, for example, the hoard from Karbow (district Ludwigslust-Parchim, Mecklenburg-Vorpommern) (Sprockhoff 1956, pl. 5:10; Hundt 1997, pl. 35:1–29) and the Schinna hoard (district Nienburg/Weser, Lower Saxony) (Jacob-Friesen 1940, p. 113, fig. 2:a–b). Among the Polish finds, moulds for socketed axes from Brzeg Głogowski (**Fig. 2:d**), Elgiszewo (**Fig. 3:b**), and Rosko (**Fig. 3:a**) feature an all-around recess at the top of the cavity, designed to secure the casting core (Fleury 1991, fig. 3:b). In other cases, such as Gaj Oławski (**Fig. 2:a**), the "Sieniocha" hoard (**Fig. 3:c**), Pawłowiczki (**Fig. 2:c**), and Nowe Kramsko (**Fig. 2:b**), the core appears to have been wedged between the two halves of the mould. This interpretation is supported by the presence of pouring (or feeding) channels situated in the upper part of the mould. These channels allowed molten metal introduced above the core to flow downwards through lateral passages. The casting core itself was grooved or perforated to facilitate this flow. The technique is also evident in a core from Ķivutkalns in Lithuania (Podėnas, Čivilytė 2019, fig. 2). Conversely, the absence of such channels in the moulds from Nowe Kramsko and Brzeg Głogowski suggests that the metal was poured directly through an opening in the casting core (Drescher 1957, pl. 4; Fleury 1991, fig. 3:a).

The moulds from Kiełpino (**Fig. 4:a–b**) are technologically distinct. When assembled, the two halves of the mould create distinctive trapezoidal recesses at the upper edge, designed to hold the horizontal arm of a T–shaped casting core (Gedl 2004, p. 112). A comparable core, which is sometimes referred to in literature as an anvil (Sprockhoff 1956, p. 66), was found in the Witkowo hoard. Its function as a casting core has been discussed (Gedl 2004, pp. 113–114, pl. 31:558; Maciejewski, Nowak 2022).

Another notable feature of metal casting moulds is the absence of negatives on more than one side. This suggests that such moulds were not designed for multidirectional use. Although metal moulds with multiple negatives (on only one side) are rare, they do exist, as demonstrated by the Bieszków find (**Fig. 4:c–e**) and the mould from "Oborniki" (**Fig. 3:d**). Many of these moulds also feature cast loops on the exterior. These likely served a dual purpose: securing the mould halves during casting and facilitating separation afterwards (Mohen 1978, p. 29; Armbruster 2000, p. 41). Often, these loops are broken, suggesting that significant force was required to open the moulds, particularly if they had been thermally stressed or baked. Similar loop features are also observed on stone moulds from northern Germany, such as the socketed-axe mould from Medow (Vorpommern-Greifswald), as well

Table 1. Metal casting moulds from the Bronze Age and early Iron Age found in present-day Poland (prepared by K. Nowak).

Tabela 1. Metalowe formy odlewnicze z epoki brązu i wczesnej epoki żelaza znalezione na terenie dzisiejszej Polski (oprac. K. Nowak).

No.	Discovery site				State of preservation	Item (negative)	Dimensions	Chronology	Literature	Figure (in the article)
	Site	District	Voivodeship	Date; context			L – length; W – width; T – thickness			
1	Bieszków	Żary	Lubusz	2011; hoard	Two completes (3 halves); one half	Knobs with loop; pin head	1st complete: L: 5.1 cm; W: 4.9–5.3 cm T: 1.8–2.7 cm 2nd complete: L: 3.9 cm; W: 3.5–4.9 cm; T: 1.0–1.6 cm half: L: 4.8 cm; T: 1.9 cm	HaD	Orlicka-Jasnoch 2013, pp. 506–507, 574, fig. 22:1, 2, fig. 23, photo 6, 20	4:c–f
2	Brzeg Głogowski (Brieg, Kr. Glogau)	Głogów	Lower Silesia	1921; probably damaged grave	Complete (2 halves)	Socketed axe	L: 12.9 cm; W: 4.2 cm	HaB2–HaB3	Seger 1927, p. 62; Seger 1936, p. 150; Gedl 2004, p. 113; Baron *et al.* 2014; Baron *et al.* 2015	2:d
3	Elgiszewo	Golub-Dobrzyń	Kuyavian-Pomeranian	2013; hoard in the bog on the lake shore	Complete (2 halves)	Socketed axe	L: 13.9 cm; W: 4.2 cm L: 13.8 cm; W: 4.3 cm	HaB2-HaB3	Gackowski 2016; Kowalski *et al.* 2019; Gackowski *et al.* 2024	3:b
4	„From the Sieniocha river area”	Tomaszów (?)	Lublin	2016; hoard	One half	Socketed axe	L: 13.0 cm; W: 4.9 cm; T: 2.0 cm	HaB3/HaC	Kłosińska, Sadowski 2017	3:c
5	Gaj Oławski	Oława	Lower Silesia	2012; stray find	One half	Socketed axe	L: 17.5 cm; W: 4.0–7.2 cm	HaB1 or HaB1/HaB2	Baron *et al.* 2013; Baron *et al.* 2014; Baron *et al.* 2015	3a

No.	Discovery site				State of preservation	Item (negative)	Dimensions	Chronology	Literature	Figure (in the article)
	Site	District	Voivodeship	Date; context			L – length; W – width; T – thickness			
6	Kiełpino (Kölpin, Kr. Kolberg--Körlin)	Gryfice	West Pomeranian	1884; hoard in the bog	Two completes (2 halves)	Socketed axe	<u>1st complete:</u> L: 8.0 cm; W: 4.0 cm <u>2nd complete:</u> L: 9.0 cm; W: 6.5 cm	HaC	Olshausen 1885, pp. 394–401, pl. 5; Ebert 1926, pp. 14–15, pl. 10; Gedl 2004, p. 112, pl. 28:545–546; Jantzen 2008, p. 354; Baron *et al.* 2014	4a–b
7	Nowe Kramsko	Zielona Góra	Lubusz	2015; hoard	Complete (2 halves)	Socketed axe	L: 17 cm; W: 5,2 cm × 5,4 cm (upper part of the assembled mould); 5,2 cm (lower part)	HaB1/ HaB2 (type of axe); HaB2/HaB3 (hoard)	Michalak, Orlicka-Jasnoch eds 2019; Nowak, Ialongo 2025	2:b
8	„Oborniki"	Oborniki	Greater Poland	2016 (given by the finder); unknown	One half	Two arrowheads	L: 9.0 cm; W: 4.4 cm	Late Bronze Age	Garbacz-Klempka 2018, pp. 51–52	3:d
9	Pawłowiczki (Gnadenfeld Kr. Cosel)	Kędzierzyn--Koźle	Opole	1869; unknown	Complete (2 halves)	Socketed axe	L: 12.7 cm; W: 5 cm; T: 1.8 cm	HaB2-HaB3	Seger 1909, p. 24; Seger 1922, p. 48; Kostrzewski 1953, p. 193; Gedl 2004, p. 113; Nessel 2013, p. 472; Baron *et al.* 2014; Baron *et al.* 2015	2:c

No.	Discovery site				State of preservation	Item (negative)	Dimensions	Chronology	Literature	Figure (in the article)
	Site	District	Voivodeship	Date; context			L – length; W – width; T – thickness			
10	Rosko	Czarnków- -Trzcianka	Greater Poland	1985; hoard near the stone mound	Two completes (2 halves)	Socketed axe	1st complete: L: 11.7 cm; W: 3.6 and 3.9 cm; 2nd complete: L: 12.9 cm; W: 3.7 and 4.3 cm	HaB2-HaB3	Machajewski, Maciejewski 2006; Maciejewski 2019; Baron *et al*. 2014; Baron *et al*. 2015	3:a
11	Stara Łubianka	Piła	Greater Poland	2015; stray find	One half	Knob	L: 5.9 cm; W: 3.5 cm	Late Bronze Age/Early Iron Age	Unpublished	–
12	Wicina	Żary	Lubusz	1996; Settlement	One half	Knob	L: 4,3 cm; W: 3,2 cm; T: 1,0 cm	HaD	Michalak 2011, p. 45; Michalak, Jaszewska 2011, p. 177, fig. 59:3	4:g

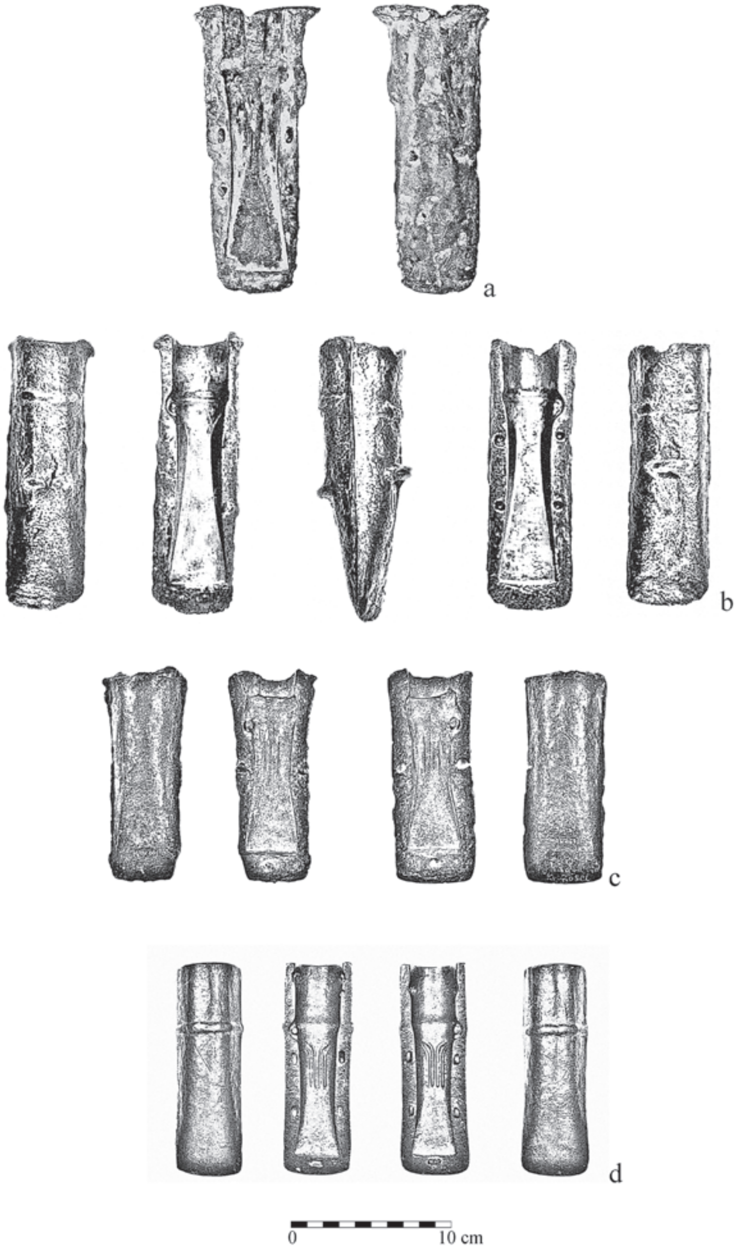


Fig. 2. Metal casting moulds found at the sites: a – Gaj Oławski (photo by Ł. Kapa; according to Baron *et al*. 2014, fig. 2); b – Nowe Kramsko (photo by M. Kusztelak; according to Orlicka-Jasnoch 2019, fig. 14); c – copy of a casting mould from Pawłowiczki (photo by K. Nowak); d – Brzeg Głogowski (photo by K. Nowak). Prepared by K. Nowak.

Ryc. 2. Metalowe formy odlewnicze znalezione na stanowiskach: a – Gaj Oławski (fot. Ł. Kapa; wg Baron i in. 2014, ryc. 2); b – Nowe Kramsko (fot. M. Kusztelak; wg Orlicka-Jasnoch 2019, ryc. 14); c – kopia formy odlewniczej z Pawłowiczek (fot. K. Nowak); d – Brzeg Głogowski (fot. K. Nowak). Oprac. K. Nowak.

Fig. 3. Metal casting moulds found at the sites: a – Rosko (photo by M. Maciejewski); b – Elgiszewo (according to Kowalski *et al*. 2019, fig. 1); c – "from the Sieniocha river area" (photo by S. Sadowski; according to Kłosińska, Sadowski 2017, fig. 5:5); d – "Oborniki" (photo by M. Frąckowiak). Prepared by K. Nowak.

Ryc. 3. Metalowe formy odlewnicze znalezione na stanowiskach: a – Rosko (fot. M. Maciejewski); b – Elgiszewo (wg Kowalski i in. 2019, ryc. 1); c – „znad Sieniochy" (fot. S. Sadowski; wg Kłosińska, Sadowski 2017, ryc. 5:5);); d – „Oborniki" (fot. M. Frąckowiak). Oprac. K. Nowak.

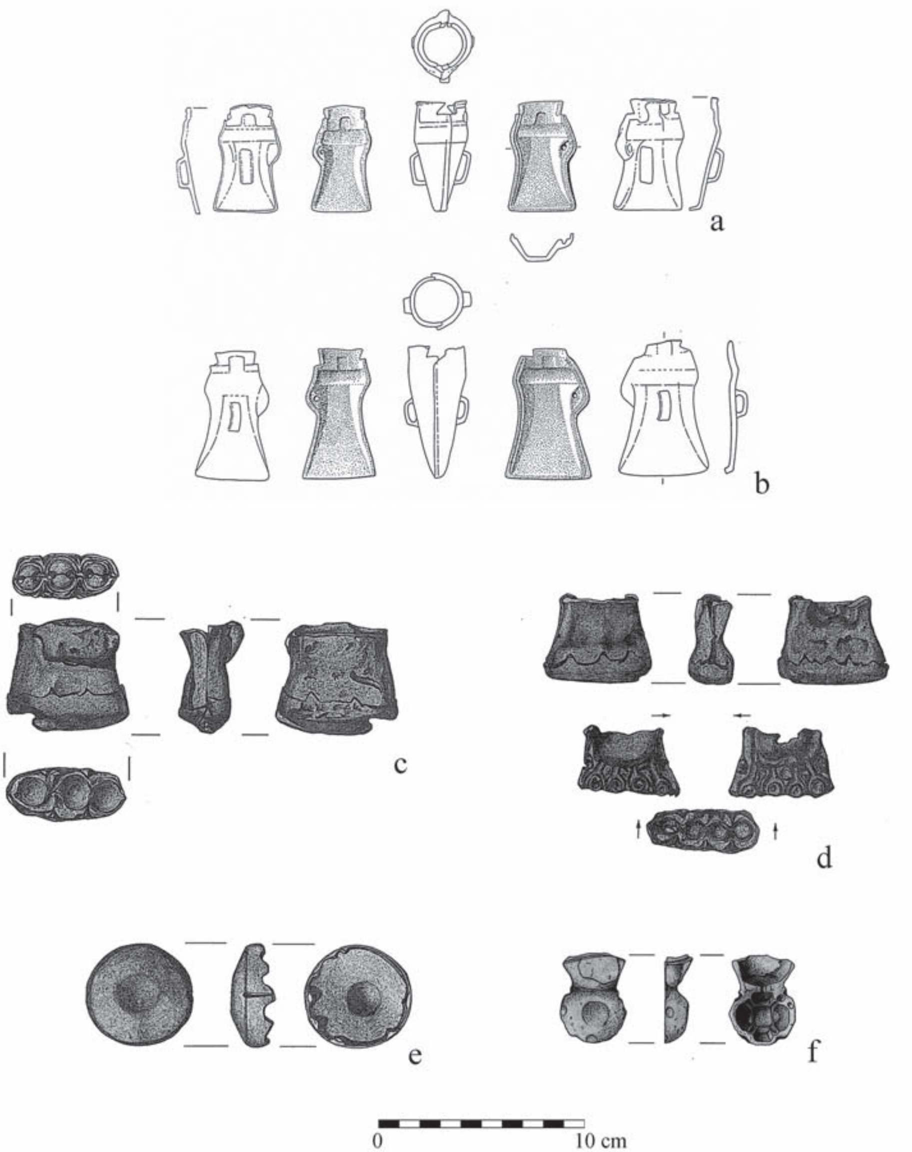


Fig. 4. Metal casting moulds dated to the Early Iron Age: a, b – Kiełpino (according to Gedl 2004, pls 28:545–546); c–e – Bieszków (according to Orlicka-Jasnoch 2013, figs 22–23); f – Wicina (according to Michalak, Jaszewska 2011, fig. 59.3). Prepared by K. Nowak.

Ryc. 4. Formy odlewnicze z wczesnej epoki żelaza: a-b – Kiełpino (wg Gedl 2004, pl. 28:545-546); c-e – Bieszków (wg Orlicka-Jasnoch 2013, ryc. 22–23); f – Wicina (wg Michalak, Jaszewska 2011, ryc. 59.3). Oprac. K. Nowak.

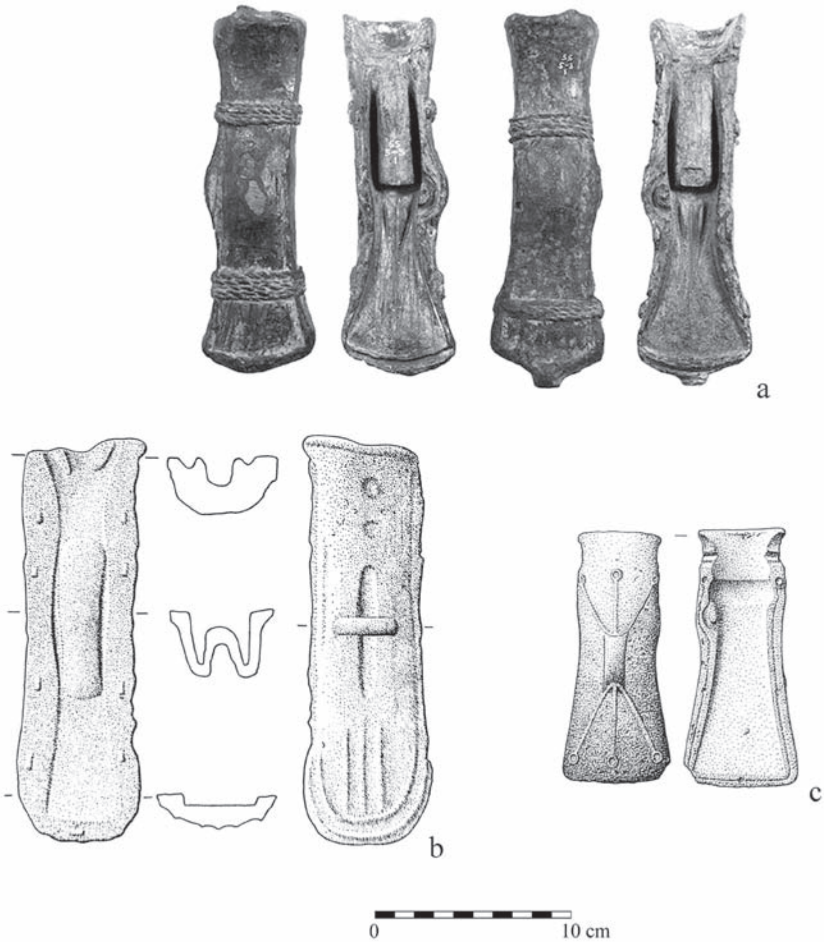


Fig. 5. Examples of decorated metal casting moulds: a – South Wiltshire palstave axe casting mould (according to Webley, Adams 2016, fig. 3:56); b–c – Gladbach Neuwied and Erkrath casting moulds for winged and socketed axes (according to Kibbert 1984, pl. 46:599; 71:a–b). Prepared by K. Nowak.

Ryc. 5. Przykłady dekorowanych metalowych form odlewniczych: a – forma odlewnicza do produkcji siekier z piętką z South Wiltshire (wg Webley, Adams 2016, ryc. 3:56); b-c – formy odlewnicze do produkcji siekier ze skrzydełkami środkowymi oraz siekier z tulejką z Gladbach Neuwied i Erkrath (wg Kibbert 1984, pl. 46:599; 71:a-b). Oprac. K. Nowak.

as in examples from Scandinavia, including those found "between Assens and Middelfart" and at Gamtofte (currently Region Syddanmark) (Jantzen 2008, p. 141, pls. 33:163; 34:164; see also Leube *et al.* 1967, p. 343, fig. 191:m; Schuldt 1968, pl. 25).

It is worth noting that, unlike the finds from Poland, some metal-casting moulds from elsewhere in Europe are externally decorated. Examples of metal casting moulds from the British Isles in particular, dating to a period analogous to that of the Polish discoveries, frequently exhibit elaborate relief motifs formed during the casting process (e.g. South Wiltshire; Webley, Adams 2016, p. 327) (**Fig. 5:a**). Decorated specimens are also known from France (e.g. Thiais, Val-de-Marne; Mohen 1978, figs. 5–6), Germany (e.g., Gladbach Neuwied and Erkrath; **Fig. 5:b–c**; Kibbert 1984, pl. 46:599), Italy (Casaleccio di Reno; Le Fèvre-Lehöerff 1992, fig. 3), and the Czech Republic (hoard from Prague-Suchdol; Blažek *et al.* 1998, pls. 24:113; 24:114; 25–26).

The most common decorative motifs consist of various types of plastic projections, as well as point and linear elements. In finds from the British Isles, and to a lesser extent from France, these motifs often form patterns, occasionally of a complex nature (e.g., the specimen from Rothley, Leicestershire; Webley, Adams 2016, fig. 5:34). Elaborate decoration is also present on the only metal specimen discovered in Italy (Bietti Sestieri 1973, pl. 42). In some cases, cord motifs can be seen, as demonstrated by the aforementioned specimens from Thiais, Val-de-Marne, and South Wiltshire. An anthropomorphic motif appears in the decoration of the mould from Erkrath (Kibbert 1984, pl. 46:599) (**Fig. 5:c**).

PRODUCTION OF METAL CASTING MOULDS

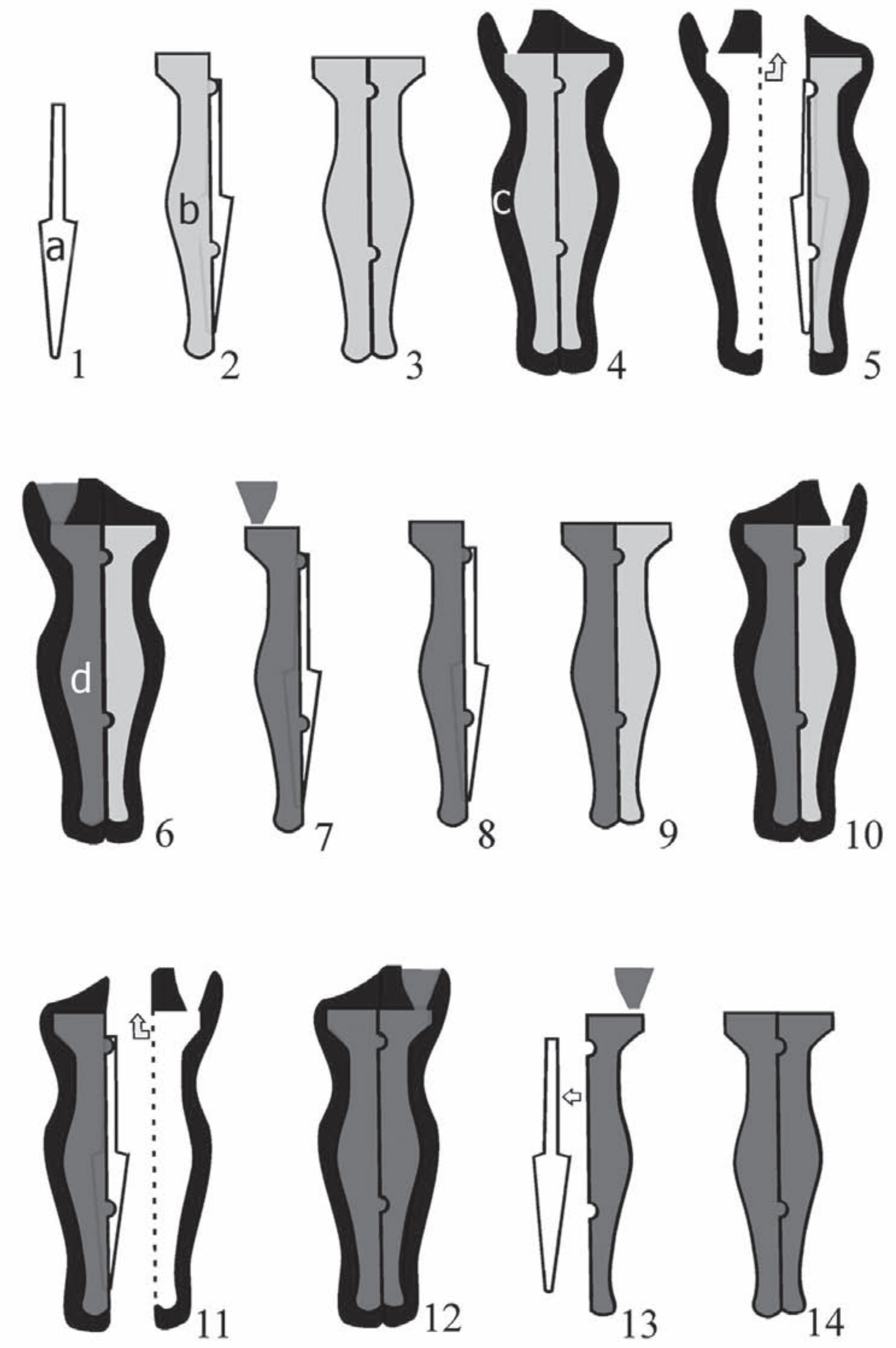
There are two principal methods of producing metal casting moulds, both of which require careful planning and a high degree of craftsmanship. These are the lost-wax technique and producing in a ceramic casting mould.

Fig. 6. Reconstruction of the production process of a metal casting mould using a two-part ceramic casting mould: a – model for the object to be cast in the mould; b – clay forming the ceramic mould; c – clay encasing the ceramic mould during the casting process; d – metal.

Suggested production stages: 1 – creating a pattern for the mould matrix; 2 – applying clay to one side of the pattern to form the first half of the mould; 3 – applying clay to the second side for the other half, aligning it with the form and fixings of the first half; 4 – wrapping the joined parts of the clay mould in clay, leaving an opening for the pouring basin; 5 – separating the two halves of the mould and removing one part; 6 – reassembling the two halves and pouring molten metal into the cavity; 7 – removing all clay components and the sprue from the cast mould; 8–9 – reusing the clay mould or creating a new one; 10 – wrapping the metal-and-clay mould assembly in another clay layer; 11 – removing the clay half of the mould, leaving the outer casing; 12 – rejoining the outer casing and pouring molten metal into the cavity; 13 – removing the outer clay casing, casting jet, and pattern from the second half of the mould; 14 – the finished metal casting mould. According to Webley, Adams 2016, p. 331, fig. 8; Hodges 1960. Prepared by K. Nowak.

Ryc. 6. Rekonstrukcja procesu produkcji metalowej formy odlewniczej przy użyciu dwuczęściowej ceramicznej formy odlewniczej: a – model przedmiotu, który ma zostać odlany w formie; b – glina tworząca kształt formy ceramicznej; c – glina otaczająca formę ceramiczną podczas odlewu; d – część metalowa.

Sugerowane etapy produkcji: 1 – wykonanie modelu tworzącego wnękę przyszłej formy; 2 – oklejenie jednej strony modelu gliną, w celu uformowania pierwszej połówki formy; 3 – oklejenie drugiej strony gliną, dopasowując ją do kształtu i mocowań pierwszej połówki; 4 – oklejenie złożonych glinianych połówek formy dodatkową warstwą gliny, pozostawiając otwór, który utworzy kanał wlewowy; 5 – rozdzielenie połówek formy i usunięcie jednej części glinianej formy; 6 – ponowne połączenie dwóch połówek i wlanie roztopionego metalu do wnęki; 7 – usunięcie wszystkich części glinianych oraz nadlewu kanału wlewowego od odlanej połowy metalowej formy; 8–9 – ponowne zastosowanie wcześniej użytej formy glinianej lub wykonanie nowej; 10 – oklejenie całego zestawu (połówki formy metalowej oraz połówki ceramicznej) nową warstwą gliny; 11 – usunięcie glinianej połówki formy, pozostawiając zewnętrzną warstwę; 12 – ponowne połączenie zewnętrznych warstw i wlanie roztopionego metalu do wnęki; 13 – usunięcie zewnętrznej warstwy gliny, nadlewu kanału wlewowego oraz modelu z drugiej połówki formy; 14 – gotowa metalowa forma odlewnicza. Wg Webley, Adams 2016, s. 331, ryc. 8; Hodges 1960. Oprac. K. Nowak.


a
b
c
d
1
2
3
4
5
6
7
8
9
10
11
12
13
14

The lost-wax (*cire perdue*) casting technique involves the creating of a wax model representing one half of the mould using a pattern which can be either a raw or unfinished axe or sickle, or a specially fabricated model. These models can be made of wood, metal, or clay (Ó Faoláin 2004, p. 192, fig. 3). It was also possible, but difficult to identify, to carve such a model in wax. The wax half-mould with the negative of the intended object is then coated with a clay slurry. Once this has dried and been fired, the wax is burned out, leaving a cavity into which molten metal is poured to produce one half of the final metal mould. To create the second half, the model (or original object) is placed in the newly cast half, and a corresponding wax model is shaped against it. This second wax half is then encased in clay, fired, and cast in metal. Special care is taken to ensure a precise fit between the two halves of the mould, particularly at the contact surfaces, to prevent misalignment or leakage during casting. External features such as loops, knobs, decorative elements, and the mould alignment system, including pegs and recesses, are added at the wax modelling stage. Therefore, all technical details and features of the final metal mould should be planned and executed in wax before casting.

Production using a ceramic casting mould, as proposed by Henry Hodges (Hodges 1960; cited in: Wirth 2003, pp. 87–89, fig. 4:2; Webley, Adams 2016, fig. 8), employs ceramic moulds as intermediaries in the production of metal casting moulds (**Fig. 6**). This technique involves forming a two-part ceramic mould around an original object or model. Once the ceramic halves have dried and been joined, a second layer of the clay mass is applied to the outside, producing a new outer shell. A pouring channel is then shaped into one side of the mould. Next, the outer shell is gently separated, and one of the ceramic halves, specifically the one on the side of the pouring channel, is removed, exposing the original model. The model remains embedded in the other half. The outer ceramic layers are then rejoined (one half now contains the model, while the other half is empty), and metal is poured through the channel to create the first half of the metal mould. This process is then repeated to create the second half. A new ceramic layer is formed on the completed half-metal mould with the original object still in place. Then is followed by the application of another external ceramic shell. The inner shell is then removed, the shells are reassembled, and the cavity is filled with molten metal. Once cooled, all ceramic residues are removed to create a complete two-part metal casting mould.

As the above illustrates, producing metal casting moulds was a complex, technically demanding, and time-consuming process. Specialised knowledge and refined manual skills were required. However, Monika Wirth observed through experimental archaeology that creating a metal casting mould would have been a standard workshop task for a skilled craftsman (Wirth 2003, p. 113). A notable feature is the high level of precision with which the internal cavity, which is the negative of the intended casting, was crafted, in contrast to the typically rough and porous outer surface of the mould (Wirth 2003, p. 90, fig. 4.3). In this case, utility was prioritized over aesthetics: as the external appearance of the mould was irrelevant to its function, it was not refined. Importantly, failed castings could easily be recycled and reattempted without significant material loss, thereby making the process more efficient over time. This was not the case with stone moulds, which could not be easily corrected, and any mistakes often resulted in the total loss of the raw material, making reproduction costly and impractical.

As Wirth argues (Wirth 2003, p. 113), the development of metal casting moulds should primarily be seen as a technical advancement that simplified the production process and reflected broader socio-technical progress. However, this transition was not necessarily driven by the higher material value of metal casting moulds. Instead, it highlights a shift in workshop practices and the organisation of metallurgical production.

RAW MATERIALS FOR PRODUCING METAL CASTING MOULDS

To date, metallurgical analyses have been carried out on 16 of the 28 metal casting mould artifacts discovered in Poland. Various analytical methods[1] were used to determine alloy composition. The results offer valuable insight into the diversity of raw materials selected for mould production in different regions and at different times.

Elemental composition analyses were conducted on a representative sample, including half-moulds from Gaj Oławski (Baron *et al*. 2014, table 1), and "Oborniki" (Garbacz--Klempka 2018, pp. 51–52, tab. 5.1), two mould parts from Nowe Kramsko (Kowalski, Garbacz-Klempka 2019, tab. 2), Rosko (Sałat *et al*. 2006, tab. 1) and Elgiszewo (Kowalski *et al*. 2019, tab. 1), as well as two complete three-part moulds and one fragment from Bieszków, and a half-mould from Wicina (Kucypera, Rybka 2013).

The ED-XRF (energy-dispersive X-ray fluorescence) method[2] was used for most of the analyses, with the exception of artifacts from Rosko, which were tested using an emission spectrometer. The results, summarised in **Table 2**, show that tin bronze was the most commonly used alloy for casting moulds in Poland. For Late Bronze Age artifacts, such as those from Gaj Oławski, Oborniki, and Rosko, the tin content ranged from 5.25% to 11.61%, which is consistent with widespread European practices (Webley, Adams 2016, supplementary material S4; Overbeck 2018). By contrast, moulds from the Early Iron Age, such as those from Bieszków and Wicina, exhibited a wider range of tin concentrations, from as low as 1.28% to as high as 24.28% (**Fig. 7**). This variation suggests evolving metallurgical strategies and possibly differing functional considerations.

Two of the moulds from the Late Bronze Age stand out for their use of unalloyed copper: the mould from Nowe Kramsko (specimens NK16A and B) and the complete mould from Elgiszewo. Trace elements such as silver (0.9–1.4%), arsenic (1.4–1.8%), and antimony (up to 5%) were identified in both cases, likely as natural impurities. The absence of deliberate

[1] The analyses were conducted by several research teams from different institutions. The mould from Gaj Oławski was examined by Beata Miazga at the Institute of Archaeology, University of Wrocław; the moulds from Elgiszewo, Nowe Kramsko, and Oborniki were analysed by Aldona Garbacz-Klempka at the Faculty of Foundry Engineering, University of Science and Technology in Kraków; the artefacts from Bieszków and Wicina were examined by Paweł Kucypera and Krzysztof Rybka; and the casting mould from Rosko was analysed by a team comprising Robert Sałat, Małgorzata Warmuzek, Stanisław Kozakowski, and Jacek Krokosz from the Foundry Research Institute in Kraków.

[2] In this article, the author draws on published results. For descriptions of analyses conducted on this material see: Gaj Ołwski (Baron *et al.* 2014, pp. 333–334), and "Oborniki" (Garbacz-Klempka 2018, pp. 79–80), bivalve moulds from Nowe Kramsko (Kowalski, Garbacz-Klempka 2019, pp. 140–141), Rosko (Sałat *et al.* 2006, p. 147) and Elgiszewo (Kowalski *et al.* 2019, p. 49), as well as two complete three-part moulds and one fragment from Bieszków, and a half-mould from Wicina (Kucypera, Rybka 2013, pp. 547–548).

Table 2. Differences in the chemical composition of metal casting moulds found in present-day Poland, based on published results (prepared by K. Nowak).

Tabela 2. Różnice w składzie chemicznym metalowych form odlewniczych znalezionych na terenie dzisiejszej Polski, na podstawie publikowanych wyników (oprac. K. Nowak).

No.	Site and marking of find (inventory number)	Analysed chemical elements (wt%)											Literature
		Cu	Sn	Sb	As	Pb	Ni	Ag	Co	Fe	Bi	Zn	
1	Bieszków, 247 (MAŚN 2012:246)	92.72	6.27	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	0.82	*NA*	0.14	Kucypera, Rybka 2013, tab. 1
2	Bieszków, 248/1 (MAŚN 2012:247)	88.48	10.04	*NA*	0.64	0.46	0.03	*NA*	*NA*	0.17	*NA*	0.16	
3	Bieszków, 248/2 (MAŚN 2012:247)	88.78	9.98	*NA*	0.51	0.23	0.04	*NA*	*NA*	0.2	*NA*	0.21	
4	Bieszków, 248/3 (MAŚN 2012:247)	88.70	9.68	*NA*	0.5	0.17	0.08	*NA*	*NA*	0.35	*NA*	0.46	
5	Bieszków, 249/1 (MAŚN 2012:248)	96.36	2.16	*NA*	0.45	0.3	0.06	*NA*	*NA*	0.48	*NA*	0.08	
6	Bieszków 249/2 (MAŚN 2012:248)	96.66	1.86	*NA*	0.66	0.28	0.04	*NA*	*NA*	0.41	*NA*	0.06	
7	Bieszków 249/3 (MAŚN 2012:248)	95.83	2.24	*NA*	0.77	0.41	0.09	*NA*	*NA*	0.45	*NA*	0.09	
8	Elgiszewo, "Male" part (WKZ/T/31.1/2015)	93.00	0.36	3.1	0.83	0.55	0.59	1.4	0.06	0.04	0.04	*NA*	Kowalski *et al.* 2019, tab. 1
9	Elgiszewo, "Female" part (WKZ/T/31.1/2015)	93.00	0.36	3.4	0.81	0.52	0.58	1.4	0.06	0.06	0.04	*NA*	
10	Gaj Oławski	87.54	6.89	2.06	0.67	0.12	0.47	*NA*	*NA*	*NA*	*NA*	*NA*	Baron *et al.* 2014, tab. 1
11	Nowe Kramsko, NK16A (MAŚN-2015:18)	91.00	0.03	4.6	1.8	0.45	0.47	1.2	0.06	0.16	0.05	*NA*	Kowalski, Garbacz--Klempka 2019, tab. 2
12	Nowe Kramsko, NK16B (MAŚN-2015:18)	91.00	0.04	5.0	1.4	0.46	0.9	0.9	0.06	0.02	0.04	*NA*	
13	Oborniki, OB-1 (MAP DEP 2017)	90.2	8.44	0.17	0.26	0.24	0.14	0.08	0.08	0.2	0.08	0.11	Garbacz-Klempka 2018, tab. 5.1
14	Rosko, "ONA"	87.02	11.61	0.44	0.18	0.22	0.27	*NA*	*NA*	0.01	<LOD	0.01	Sałat *et al.* 2006, tab. 1
15	Rosko, "ON"	90.05	5.25	2.3	1	1.1	0.26	*NA*	*NA*	<LOD	0.01	<LOD	
16	Wicina (MAŚN 1996:701)	71.03	24.28	0.35	0.32	0.99	0.18	0.32	0.04	1.71	0.15	0.26	Kucypera, Rybka 2013, tab. 1

Key: MAŚN – Archaeological Museum of the Middle Odra River in Zielona Góra; WKZ/T – Kuyavian-Pomeranian Provincial Conservator of Monuments in Toruń; MAP – Archaeological Museum in Poznań; DEP – deposit; "NA" – not analysed (there is no relevant data in the literature); "<LOD" – below the detection limit of the method.

Objaśnienia: MAŚN – Muzeum Archeologiczne Środkowego Nadodrza w Zielonej Górze; WKZ/T – Kujawsko-Pomorski Wojewódzki Konserwator Zabytków w Toruniu; MAP – Muzeum Archeologiczne w Poznaniu; DEP – depozyt; „NA" – nie analizowane (brak odpowiednich danych w literaturze); „<LOD" – poniżej granicy wykrywalności metody.

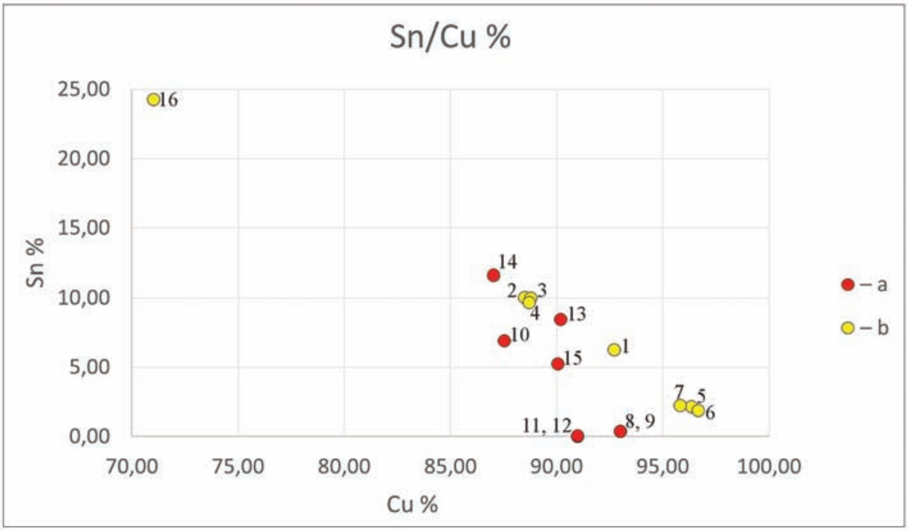


Fig. 7. Copper and tin content in the analysed metal casting moulds, based on published data (numbering from **Table 2**). Prepared by K. Nowak.

Ryc. 7. Zawartość miedzi i cyny w analizowanych metalowych formach odlewniczych, na podstawie publikowanych danych (numeracja wg **tab. 2**). Oprac. K. Nowak.

tin alloying in these examples appears to have been intentional. As Łukasz Kowalski and Aldona Garbacz-Klempka (Kowalski, Garbacz-Klempka 2019, p. 142) and Kowalski and his team (Kowalski *et al.* 2019, p. 51) have noted, this choice may have been intended to enhance the thermal resistance of the material from which the mould was made and raise its melting point, thereby improving its performance during repeated metal casting processes.

Noteworthy findings emerged from the analysis of casting moulds from Bieszków and Wicina (Kucypera, Rybka 2013). The mould from Wicina contained over 24% tin, combined with approximately 71% copper and minor impurities (e.g. 0.32% silver), indicating a high-tin bronze alloy. Seven of the Bieszków mould elements were analysed: a pinhead mould (inv. no. MAŚN 247) with a tin content of 6.27%, a three-part mould for four buttons (no. 248) with a consistent tin content of ~10%, a three-part mould for three buttons (no. 249), made of bronze demonstrating a similar composition, but with a significantly lower tin content ranging from 1.86% to 2.24%. Despite their structural similarity and identical use for casting buttons, the different tin contents suggest that these moulds were likely produced during separate casting events using distinct crucible charges. Notably, all Bieszków artifacts exhibited low levels of metallurgical impurities, such as antimony, nickel, silver, arsenic, and lead, indicating the use of relatively refined raw materials.

These variations raise some crucial questions: Why were moulds for the same casting purpose made from alloys with such different properties? Since alloys with low tin content (~2%) have inferior casting properties compared to those with ~10% tin, it is puzzling that suboptimal alloys were used for some moulds. Given the complexity and precision required when making metal casting moulds, it seems logical that more suitable alloys would have been preferred.

USING METAL CASTING MOULDS IN THE DIRECT METAL CASTING PROCESS

In earlier literature, researchers have commonly assumed that metal casting moulds were used solely to produce wax or lead models for the fabrication of ceramic moulds. It was believed that these moulds were too susceptible to thermal damage, deformation, or metal adhesion when molten bronze was cast (Kostrzewski 1953, p. 193; Dobrzańska 1959, p. 90; Tylecote 1986). This interpretation was reinforced by the frequent discovery of casting moulds alongside finished products made from nearly identical copper-tin alloys, seemingly excluding their use in direct casting processes (Machajewski, Maciejewski 2006, p. 145).

Experimental archaeology has substantially revised this view. Studies conducted in Germany and Great Britain (Drescher 1957; Wirth 2003; Wang, Ottaway 2004) have demonstrated that direct casting in metal moulds is not only feasible but also repeatable. These experiments confirmed that the structural integrity of bronze moulds could be preserved during casting, provided that the following conditions were met: 1) preheating the moulds to avoid thermal shock; 2) ensuring proper positioning during pouring; 3) controlling the temperature of the molten metal; 4) coating the interior of the mould with protective layers, such as soot, powdered charcoal, clay, or mixtures of charcoal with animal fat and ash (Armbruster 2000, p. 42; Webley, Adams 2016, p. 332; Kowalski *et al.* 2019, p. 57). These protective measures helped prevent alloy adhesion and mould degradation, enabling the same alloy to be used for both the mould and the cast object. One example is the $CuSn_{10}$ alloy from Wirth's experimental series (Wirth 2003).

Subsequent research has confirmed that metal casting moulds were indeed used for the direct production of artifacts made from copper and its alloys, rather than just producing the wax models. Furthermore, Leo Webley and Sophia Adams (Webley, Adams 2016, p. 332) note that some moulds from the Late Bronze Age contain traces of lead residues, suggesting the use of a broader range of casting materials. Additionally, Justyna Baron and her team (Baron *et al.* 2014; Baron *et al.* 2015) traced beeswax residues inside a casting mould from Gaj Oławski, suggesting that the moulds may have been used for non-metallic casting processes or that they had a dual purpose.

Metal and stone moulds are classified as permanent casting moulds that can withstand multiple casting cycles. Their durability and reusability make them especially effective for mass production, particularly of standardised tools and weapons, such as axes. While the exact number of castings that can be achieved per mould is uncertain, experimental data suggest that a single mould could sustain at least a dozen castings without significant damage (Drescher 1957, p. 59; Webley, Adams 2016, p. 332). Evidence of repeated use is visible on several artifacts. For instance, the casting mould from Rosko (**Fig. 8:a–b**) exhibits pronounced abrasions on its exterior, likely resulting from repeated placement in sand during casting cycles. Similarly, broken loops, which were used to fasten or stabilise the mould halves, have been observed on artifacts from Elgiszewo and Gaj Oławski. This may indicate long-term or intensive use. The Elgiszewo mould also bears fractures within the mould cavity, which is suggestive of thermal shock or mechanical stress sustained during repeated metal pourings (**Fig. 8:c–d**) (Kowalski *et al.* 2019, p. 60).

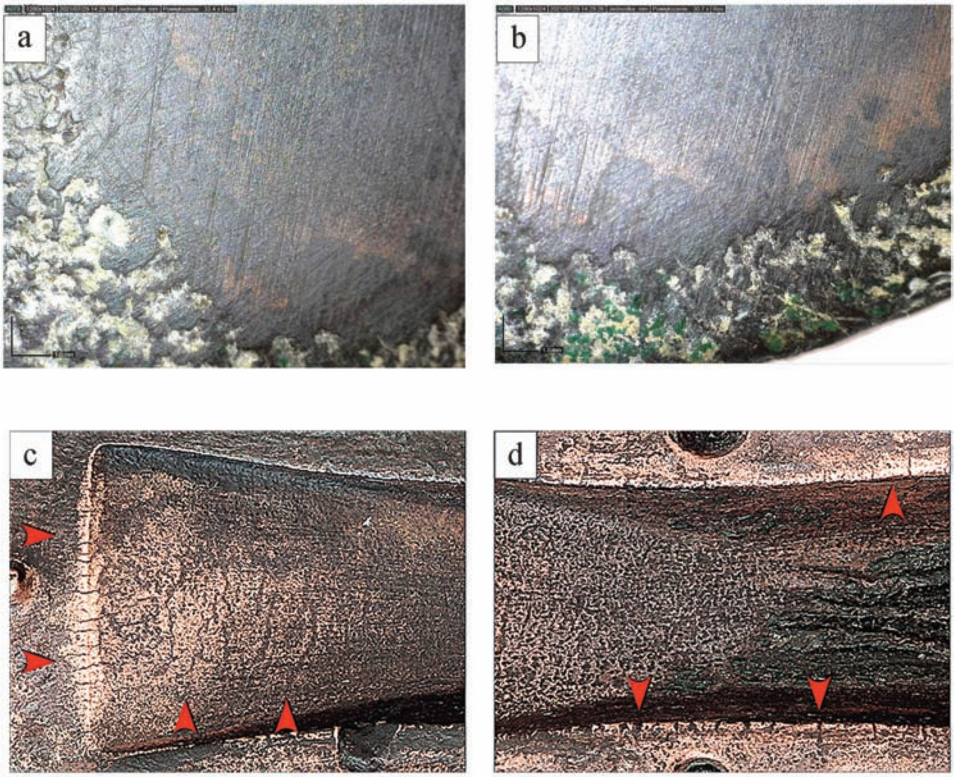


Fig. 8. Traces of wear on the analysed metal casting moulds: a–b – microscopic images showing abrasion on the outer surface of the casting mould from Rosko (photo by K. Nowak); c–d – thermal fatigue cracks resulting from high-temperature exposure (according to Kowalski *et al.* 2019, fig. 8:a–b). Prepared by K. Nowak.

Ryc. 8. Ślady zużycia na analizowanych metalowych formach odlewniczych: a-b – obrazy mikroskopowe pokazujące ścieranie powierzchni zewnętrznej formy z Roska (fot. K. Nowak); c-d – pęknięcia termiczne spowodowane działaniem wysokiej temperatury (wg Kowalski i in. 2019, ryc. 8:a-b). Oprac. K. Nowak.

CONTEXTUALIZING THE METAL CASTING MOULD DISTRIBUTION AND DEPOSITION PATTERNS IN POLAND WITHIN CENTRAL EUROPE

The majority of metal casting moulds discovered in Poland and in adjacent regions date to the Late Bronze Age, particularly within the cultural horizon associated with the Urnfield tradition (**Figs 9–10**). The spatial distribution of these moulds reveals a clear imbalance between western and eastern Poland. While most finds are concentrated in the west of the country, only isolated examples have been identified in the east, such as the specimen "from Sieniocha river area" near the present-day border with Ukraine. A notable outlier is the casting mould from Elgiszewo, located in the Kuyavian-Pomeranian province.

In terms of depositional context, the most of casting moulds in Poland are associated with hoard inventories (**Table 1**). However, many examples are isolated finds or originate from contexts with unclear provenance. Some hoards, such as those from Elgiszewo and

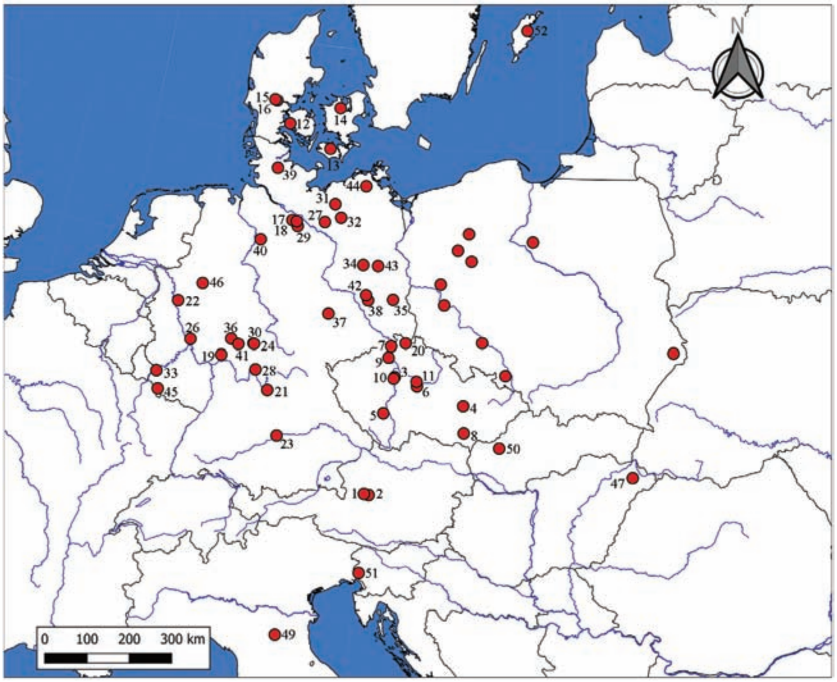


Fig. 9. Distribution of Bronze Age metal casting moulds found in Central Europe (numbering from **Table 3**); finds Nos 3 and 47 – approximately indicated (according to publications) because their exact location is unknown. Map source: SRTM project data; modified and prepared by K. Nowak.

Ryc. 9. Rozmieszczenie form odlewniczych z epoki brązu znalezionych w środkowej Europie (numeracja wg **tab. 3**); zabytki nr 3 i nr 47 – oznaczone orientacyjnie (wg publikacji), ponieważ ich dokładna lokalizacja jest nieznana. Źródło mapy: dane misji SRTM; modyfikacja i oprac. K. Nowak.

Kiełpino, were found in wetland or peatland environments, which suggests that they were intentionally deposited in liminal landscapes. In contrast, others, such as the Rosko hoard, were discovered in association with structural remains, possibly indicating ritual or utilitarian deposition within settlement contexts.

This diversity of deposition types is consistent with the patterns observed across central Europe (**Table 3**). In Germany and the Czech Republic, the majority of metal moulds also originate from hoard contexts. Pure mould hoards, albeit rare, are known from the Czech Republic, as evidenced by three sets from Prague-Suchdol (Blažek *et al.* 1998, pp. 171–172). Another unique example is the hoard from Velím, containing three mould sets, eight gold spirals, an anvil, and a palstave (Blažek *et al.* 1998, pp. 178–179). An intriguing find comes from Brzeg Głogowski, where a casting mould was reportedly deposited alongside a matching axe, likely in a burial context, although this is uncertain (Seger 1936, p. 150). If confirmed, this would be the only known example of a metal casting mould found in a grave in central Europe.

Finds of Bronze Age metal moulds from Poland include six sets and three half-moulds, totalling 15 parts, which were discovered at eight sites. In contrast, metal moulds have been found at 30 sites in Germany, comprising 26 sets and eight half-moulds. In the Czech Republic, ten sites (including "Bohemia") have yielded eight sets and four halves. When these

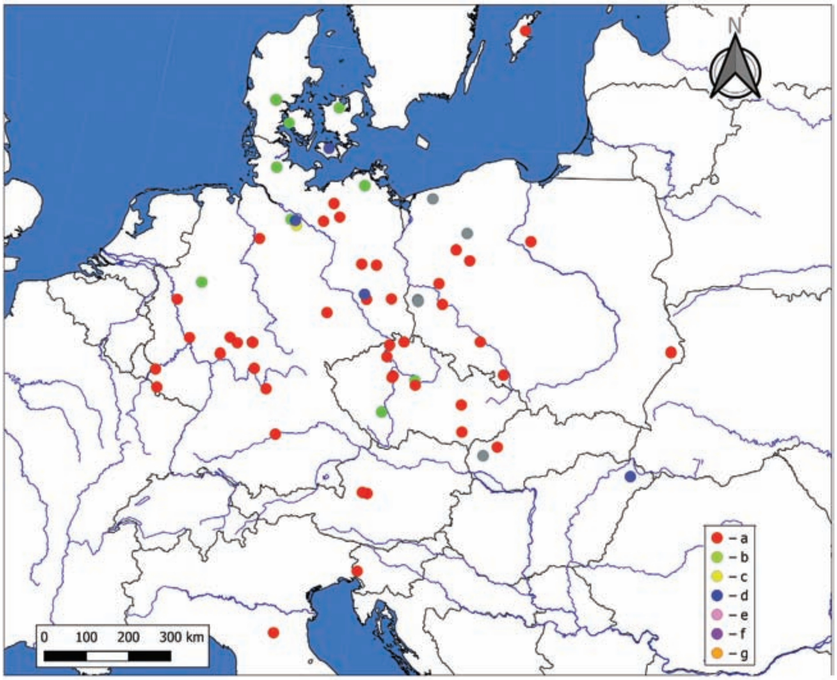


Fig. 10. Chronological distribution of metal casting moulds found in Central Europe: a – Bronze Age I; b – Bronze Age II; c – Bronze Age III–V (Urnfields); d – Early Iron Age; e – Bronze Age in general. Map source: SRTM project data; modified and prepared by K. Nowak.

Ryc. 10. Rozmieszczenie metalowych form odlewniczych znalezionych w środkowej Europie według chronologii zabytków: a – I okres epoki brązu; b – II okres epoki brązu; c – III–V okres epoki brązu (kultura pól popielnicowych); d – wczesna epoka żelaza; e – ogólnie epoka brązu. Źródło mapy: dane misji SRTM; modyfikacja i oprac. K. Nowak.

numbers are compared to larger collections, such as those from France (over 60 moulds; Mohen 1990, p. 129; Fleury 1991, p. 274) or Britain (55–57 moulds; Webley, Adams 2016, p. 324), an evident decline in the number of metal moulds towards the southeast of Europe emerges. Two metal casting moulds are known from Austria and possibly two from Hungary (**Table 3**). Most of these finds come from hoards; in one notable case, a hoard was discovered within a settlement context (Gladbach; Kibbert 1984, p. 62, pl. 71:167). Stray finds typically comprise mould halves, while complete sets are less common (e.g., Erkrath, Werne; Kibbert 1980, pp. 216–217, pl. 35:526; Nessel 2019, p. 615). Metal casting moulds deposited in hoards are generally complete and unfragmented. A rare exception includes a mould fragment from Brandgraben (Kainischtal; Nessel 2019, p. 633). Most finds outside of Poland date to the Late Bronze Age, mirroring the chronology of similar discoveries within Poland. However, the use of metal casting moulds predates this period: such moulds appear as early as the Bronze Age II (BrC in Reinecke's scheme), particularly in Denmark and Germany. These earlier moulds were used to cast palstave-type axes. Notably, no examples of this mould type have been found in Poland. The complete absence of metal casting moulds in the southeastern region of Europe, the western Balkans for example (Gavranović 2013),

Table 3. The Bronze Age metal casting moulds from Central Europe (prepared by K. Nowak).

Tabela 3. Metalowe formy odlewnicze z epoki brązu z terenu środkowej Europy (oprac. K. Nowak).

No.	Discovery site			State of preservation	Dimensions	Item (negative)	Chronology	Literature
	Country	Site	Context		L – length; W – width; Wt: weight			
1	Austria	an der Traun Hallstatt- -Seeufer", Bez. Gmunden	Hoard	Half	L: 5.8 cm; W: 3.8 cm; Wt: 164.8 g	Flat axe (?)	Urnfields	Nessel 2019, p. 654
2	Austria	Brandgraben (Kainischtal), Styria	Hoard	Fragment of a one half	L: 5.35 cm; W: 2.65 cm; Wt: 32.7 g	Flat axe (?)	BzD/HaA (stilistically), 940–780 BC (^{14}C)	Nessel 2019, p. 633
3	Czech Republic	„Bohemia"	Stray find, unknown	Half	L: 25 cm; W: 4.5 cm; Wt: 775 g	Winged axe	HaA	Nessel 2019, p. 741
4	Czech Republic	Borotín, Okr. Blansko, South Moravian Region	Hoard	Half	L: 10.8 cm	Socketed axe (?); casting core	HaA1	Nessel 2019, pp. 700–701
5	Czech Republic	Bošovice (Čížová), Okr. Písek, South Bohemian Region	Hoard	Complete	1a: L: 28 cm 1b: L: 24 cm	Palstave axe	BzC2/BzD	Kytlicová 2007, p. 254; Blažek *et al*. 1998, p. 188, pl. 37:171–172; Nessel 2019, p. 701
6	Czech Republic	Chotouchov, Okr. Kolín, Central Bohemian Region	Hoard	Half	L: 25 cm; W: 7.2 cm	Winged axe	HaA1–A2	Blažek *et al*. 1998, p. 167, pl. 27:103; Kytlicová 2007, p. 258, Pl. 163A:1–4; Nessel 2019, p. 703
7	Czech Republic	Děčín, Okr. Děčín, Ústecký Region	Hoard	Complete	1a: L: 19.0 cm; W: 5.1 cm; Wt: 620 g 1b: L: 18.9 cm; W: 5.1 cm; Wt: 621 g	Winged axe	BzD-HaA	Chvojka *et al*. 2017, p. 78, pl. 90:1–2; Nessel 2019, p. 703
8	Czech Republic	Hradisko u Křepic, Okr. Břeclav, South Moravian Region	No data	No data	No data	No data	Late Bronze Age	Podborský 1974, p. 69
9	Czech Republic	„Litoměřice", Okr. Litoměřice, Ústecký Region	Stray find	Half	L: 12.4 cm; W: 6.2 cm	Winged axe	HaA	Blažek *et al*. 1998, p. 163, pl. 20:96; Nessel 2019, p. 745

No.	Discovery site			State of preservation	Dimensions	Item (negative)	Chronology	Literature
	Country	Site	Context		L – length; W – width; Wt: weight			
10	Czech Republic	Praha-Suchdol (Praha 6), Okr. Praha, Central Bohemian Region	Hoard	Three complete sets	1st complete: 1a: L: 22 cm; W: 8.1 cm 1b: L: 22.8 cm; W: 8.2 cm 2nd complete: 2a: L: 20.6 cm; W: 7.8 cm 2b: L: 19.9 cm; W: 7.8 cm 3rd complete: 3a: L: 22 cm; W: 8.4 cm 3b: L: 21.6 cm; W: 8.3 cm	3 × Winged axe	BzD–HaA1	Blažek *et al*. 1998, pp. 171–172, pl. 24:113–114; 25:115–116; 26:117–-118; Kytlicová 2007, p. 254, pl. 50B:51; Nessel 2019, p. 726
11	Czech Republic	Velim, Okr. Kolín, Central Bohemian Region	Hoard	Three com-plete sets	1st complete: 1a: L: 24.3 cm; W: 6.5 cm 1b: L: 23.6 cm; W: 6.4 cm; Wt: 1700 g 2nd complete: 2a: L: 18.7–19.0 cm; W: 4.5–5.5 cm 2b: L: 23.8 cm; W: 6.5 cm; Wt: 900 g 3rd complete: 3a: L: 14.7 cm, 14.3 cm; W: 5.5–6.8 cm 3b: L: 18.8 cm; W: 5.6 cm	3 × Palstave axe	BzC–D	Blažek *et al*. 1998, p. 178, pl. 30:132–133; 31:134–137; Kytlicová 2007, p. 312, pl. 159–160 A; Nessel 2019, p. 735
12	Denmark	Assens, Båg Hd., Region Syddanmark	Stray find	Half	L: 22.8 cm; W: 5.9 cm; Wt: 620 g	Palstave axe	II Bronze Age Period	Aner, Kersten 1977, p. 106, pl. 64:1736; Jantzen 2008, p. 171, pl. 42:183; Nessel 2019, p. 549
13	Denmark	Bandholm, Nørvang Hd., Region Syddanmark	Stray find	Complete	L: 20.0 cm; W: 7.0 cm	Sickle	Bronze Age	Aner, Kersten 1990, p. 56, pl. 24; Nessel 2019, p. 550

No.	Discovery site			State of preservation	Dimensions	Item (negative)	Chronology	Literature
	Country	Site	Context		L – length; W – width; Wt: weight			
14	Denmark	„Holbæk", Merlose Hd., Region Sjælland	Stray find from the bog	Quarter (half of the half)	Wt: 180 g	Palstave axe	II Bronze Age Period	Aner, Kersten 1976, p. 31, pl. 18:700; Jantzen 2008, p. 172, pl. 42:184; Nessel 2019, p. 552
15	Denmark	Nørup, Tørrild Hd., Region Midtjylland	Hoard (?)	Complete	L: 21.8 cm; W: 5.3 cm	Palstave axe	II Bronze Age Period	Aner, Kersten 1990, p. 104, pl. 54:4567; Nessel 2019, p. 539
16	Denmark	Nørup, Tørrild Hd., Region Midtjylland	Stray find	Complete	No data	Palstave axe	II Bronze Age Period	Jantzen 2008, p. 172, pl. 43:185; Nessel 2019, p. 554
17	Germany	„aus dem Lüneburgi-schen I"	Stray find	Complete	1a: L: 20 cm; Wt: 670 g 1b: L: 20.8 cm; Wt: 710 g	Palstave axe	II Bronze Age Period	Drescher 1957, pp. 52–75; Jantzen 2008, p. 353; Nessel 2019, p. 622
18	Germany	„aus dem Lüneburgischen II"	Hoard (?)	Two halves (not a set)	No data	2 x Palstave axe	Bronze Age	Drescher 1957, pp. 52–75, pl. 1 and 2; Jantzen 2008, p. 353; Nessel 2019, p. 579
19	Germany	Bad Homburg v. d. Höhe (Bleibeskopf), Lkr. Hochtaunuskreis, Hessen	Hoard	Complete	1a: L: 18.8 cm; Wt: 900 g 1b: L: 18.8 cm; Wt: 740 g	Winged axe (+ raw cast of winged axe)	Late Bronze Age	Nessel 2019, p. 558
20	Germany	Buchberg (Zittau Moun-tains), between Jonsdorf and Waltersdorf, Saxony	Stray find	Half	L: 18.6 cm; W: max. 5.2 cm	Winged axe	Middle Bronze Age	Coblenz 1961, p. 369, fig. 6:3; Coblenz 1984, pp. 93–123, fig. 2; Bar-telheim, Niederschlag 1992, p. 85; Jantzen 2008, p. 354; Nessel 2019, p. 613
21	Germany	Bullenheimer Berg (Seinsheim and Ippesheim-Bullenheim), Bavaria	Stray find or hoard, fortified settlement	Complete	No data	Winged axe	HaB3	Wirth 2003; Overbeck 2018, p. 80, pl. 7:17

No.	Discovery site			State of preservation	Dimensions	Item (negative)	Chronology	Literature
	Country	Site	Context		L – length; W – width; Wt: weight			
22	Germany	Erkrath, Lkr. Mettmann, North Rhine-Westphalia	Stray find	Complete	No data	Winged axe	Urnfields	Nessel 2019, p. 615
23	Germany	Erlingshofen, Lkr. Eichstätt, Bavaria	Hoard	Complete (3 items) with the metal casting core	L: 11.5 cm; W: 10.7 cm; Wt: 555 g (1a), 580 g (1b), and 132 g (1c: casting core)	Sword handle (Möringen type)	HaB3	Drescher 1958, p. 78, pl. 14 and 17; Overbeck 2018, pp. 81–82, pl. 10; Nessel 2019, p. 564
24	Germany	Fulda-Haimberg, Lkr. Fulda, Hessen	Hoard (?)	Complete	L: 19.9 cm; W: 5.15 cm; Wt: 802 g (two parts: 1600 g)	Winged axe	HaB	Jockenhövel 1986, pp. 213–234; Nessel 2019, p. 568
25	Germany	„Germany”	Stray find	Complete	No data	No data	Bronze Age (?)	Jantzen 2008, p. 353; Nessel 2019, p. 614
26	Germany	Gladbach (Neuwied), Lkr. Neuwied, Rhineland--Palatinate	Hoard, settlement	Complete	1a: L: 20.5 cm; W: 5.6 cm; Wt: 996 g 1b: L:19.5 cm; W: 6 cm; Wt: 994 g	Winged axe	HaB1	Kibbert 1984, p. 62, pl. 71:167; Overbeck 2018, pp. 77–78, pl. 3:13
27	Germany	Grabow, Lkr. Ludwigslust--Parchim, Mecklenburg--Vorpommern	Stray find	Half	No data	Socketed axe	Late Bronze Age	Keiling 1987, fig. 2; Jantzen 2008, p. 352; Nessel 2019, p. 618
28	Germany	Gössenheim, Lkr. Main--Spessart, Bavaria	Hoard	Complete	No data	Winged axe	HaB3	Pászthory, Mayer 1998, p. 140, pl. 63:908a-c; Overbeck 2018, pp. 80–81, pl. 8:18
29	Germany	Haaßel, Lkr. Uelzen, Lower Saxony	Hoard	Two completes	<u>1st complete:</u> 1a: L: 21.4 cm; Wt: 330 g 1b: L: 22 cm; Wt: 420 g <u>2nd complete:</u> 2a: L: 23.1 cm; Wt: 830 g 2b: L: 23.1 cm; Wt: 980 g	Palstave axe	I Bronze Age Period	Drescher 1957, pp. 52–75; Jantzen 2008, p. 352–353; Nessel 2019, p. 570

No.	Discovery site			State of preservation	Dimensions	Item (negative)	Chronology	Literature
	Country	Site	Context		L – length; W – width; Wt: weight			
30	Germany	Haimbach (Fulda), Lkr. Fulda, Hessen	Hoard	Complete	No data	Winged axe	HaB2/B3	Kibbert 1984, pp. 89–90, pl. 25:322, pl. 72:322; Overbeck 2018, pp. 78–79, pl. 4:14
31	Germany	Holzendorf, Lkr. Parchim, Mecklemburg-Vorpommern	Hoard in the bog	Complete	L: 8.5 cm	Socketed axe	V Bronze Age Period	Hundt 1997, p. 60, pl. 35:18; Jantzen 2008, p. 364; Maciejewski, Nowak 2022; Nessel 2019, pp. 573–574
32	Germany	Karbow, Lkr. Ludwigslust--Parchim, Mecklemburg--Vorpommern	Hoard	Complete	L: 12.5 cm	Socketed axe	V Bronze Age Period	Sprockhoff 1956, p. 125; Keiling 1987, fig. 1; Hundt 1997, pl. 42:1–2; Jantzen 2008, p. 353; Nessel 2019, p. 575
33	Germany	Konz, Lkr. Trier-Saarburg, Rhineland-Palatinate	Hoard	Half	L: 19.3 cm; W: 5.5 cm	Winged axe	HaB3	Kibbert 1984, p. 83, pl. 22:285; 72:285; Overbeck 2018, p. 81, pl. 9:19
34	Germany	Krampnitz (Fahrland--Potsdam), Lkr. Potsdam--Mittelmark, Brandenburg	Hoard	Complete	L: 19.6–20.3 cm; W: 5.7–6.0 cm; Wt: 909.1 g	Winged axe	III Bronze Age Period	Gandert 1961, p. 54, fig. 4; Jantzen 2008, p. 353; Nessel 2019, p. 583 (as Neufahrland, Kr. Potsdam)
35	Germany	Krieschow, Lkr. Spree--Neiße	Hoard	Complete	No data	„Beil”	III Bronze Age Period	Jentsch 1894, p. 308; Bönisch 2000, p. 80
36	Germany	Lindenstruth, Lkr. Gießen, Hessen	Hoard	Complete	1a: L: 21.4 cm; W: 5.2 cm; Wt: 1182 g 1b: Wt: 1037 g	Winged axe	HaB1	Kibbert 1984, pp. 62–63, pl. 12:168, pl. 71:168; Overbeck 2018, pp. 76–77, pl. 2:12; Nessel 2019, p. 578

No.	Discovery site			State of preservation	Dimensions	Item (negative)	Chronology	Literature
	Country	Site	Context		L – length; W – width; Wt: weight			
37	Germany	Merseburg, Lkr. Saale-kreis, Saxony-Anhalt	Stray find	Half	No data	Winged axe	III Bronze Age Period	Jantzen 2008, p 354; Nessel 2019, p. 623
38	Germany	Polzen (Kremitzaue), Lkr. Elbe-Elster, Branden-burg	Hoard	Half	No data	Winged axe	III Bronze Age Period	Bastian, Voss 1878, pp. 63–64, pl. 14:9; Voss 1881, p. 108; Wanzek 1989, p. 33; Jantzen 2008, p. 354; Nessel 2019, p. 587
39	Germany	Rendsburg, Lkr. Rendsburg-Eckernförde, Schleswig-Holstein	Hoard	Two com-pletes	1a-b: L: 24.8 cm; Wt: 1625 g 2a-b: L: 22.0 cm; Wt: 910 g	Palstave axe	II Bronze Age Period	Aner, Kersten 1978, p. 215, pl. 82–83; Jantzen 2008, p. 172, pl. 44; 45:187; Nessel 2019, p. 587
40	Germany	Schinna, Lkr. Nienburg/ Weser, Lower Saxony	Hoard	Complete and half (sickle)	Complete: 1a: L: 11.5 cm; Wt: 282 g 1b: L: 11.7 cm; Wt: 300 g Half: 2: L: 13.7 cm; Wt: 230 g	Socketed axe; sickle	V Bronze Age Period	Jacob-Friesen 1940, pp. 108–110, figs 1–7; Drescher 1957, pp. 52–75; Jantzen 2008, p. 363; Nessel 2019, p. 589
41	Germany	Schotten, Lkr. Vogelsbergkreis, Hessen	Hoard	Complete	1a: L: 20.5 cm; W: 4.3–6.0 cm; Wt: 903 g 1b: L: 20.2 cm; W: 4.3–6.0 cm; Wt: 898 g	Winged axe	HaB2/B3	Kibbert 1984, p. 89; pl. 25:321, pl. 72:321; Overbeck 2018, p. 79, pl. 5:15; Nessel 2019, p. 589
42	Germany	Schönewalde, Lkr. Elbe--Elster, Brandenburg	Hoard	Complete	No data	Winged axe or Palstave axe	Bronze Age	Voss 1881, p. 110; Bönisch 2000, p. 80
43	Germany	Spindlersfeld (Berlin), Treptow-Köpenick, Brandenburg	Hoard	Complete	1a: L: 15.3 cm; W: max 3.2 cm; Wt: 181 g 1b: L: 14.8 cm; Wt: 181 g	Pin	III Bronze Age Period	Friedel 1893; Reich 1991; Reich 1997; Probst 1996, pp. 375–376; Jantzen 2008, p. 352; Nessel 2019, p. 590

No.	Discovery site			State of preservation	Dimensions	Item (negative)	Chronology	Literature
	Country	Site	Context		L – length; W – width; Wt: weight			
44	Germany	Vorland, Lkr. Vorpommern-Rügen, Mecklenburg-Vorpommern	Hoard	Complete	1a: L: 22.5 cm; Wt: 820 g 1b: L: 23.6 cm; Wt: 998 g	Palstave axe	II Bronze Age Period	Reich 1991, p. 57; Wiegmann 1997, pp. 216–217; Jantzen 2008, p. 353; Nessel 2019, p. 594
45	Germany	Wallerfangen, Lkr. Saarlouis, Saarland	Hoard	Complete	L: 20 cm; W: 4.4 cm	Winged axe	HaB2/B3	Kibbert 1984, pl. 25:320; Overbeck 2018, pl. 6:16; Nessel 2019, p. 595
46	Germany	Werne, Kr. Unna, North Rhine-Westphalia	Stray find	Complete	L: 19 cm; W: 5.7 cm; Wt: 445 g (1a) and 373 g (1b)	Palstave axe	II Bronze Age Period	Kibbert 1980, pp. 216–217, pl. 35:526; Jantzen 2008, p. 354; Nessel 2019, p. 630
47	Hungary	Komitat Szabolcs-Szatmár	Stray find, no data	Half?	No data	Socketed axe	Bronze age	Mozsolics 1985, p. 188; Nessel 2019, p. 825
48	Hungary	Localisation unknown	No data	Complete	No data	Three pins	Bronze age	Hampel 1886, pl. IV.7–8; Tarbay 2018, fig. 67
49	Italy	Casaleccio di Reno, region Emilia-Romania, Bolonia	Hoard	Complete	No data	Winged axe	Urnfields	Bietti Sestieri 1973, pl. 42; Le Fèvre-Lehöerff 1992, p. 134, 170, 178, fig. 3; Nessel 2019, p. 675
50	Slovakia	Hrádok nad Váhom, Trenčín Region	Hoard	Complete	ca. 6.5 × 6.5 cm	Hoop (chain links)	BrD–Ha A1	Ondrkál 2024
51	Slovenia	Šempeter pri Goric, municipality of Šempeter--Vrtojba	Hoard	Complete	L: 20.5 cm; Wt: 1020 g	Winged axe	HaA	Teržan (ed.). 1995, pl. 135:48; Furlani 1996, p. 73–88; Nessel 2019, p. 910
52	Sweden	Gothem, Gotlands län, Gotland	Stray find	Half	No data	Socketed axe	IV–V Bronze Age Period	Jantzen 2008, p. 353; Nessel 2019, p. 526

raises important questions. This may be due to regional technological traditions, the use of alternative casting technologies (e.g. ceramic or stone moulds), the availability of raw materials, or perhaps the historical practice of remelting metal moulds in later periods. The latter must obviously remain a speculative theory for now.

REPERTOIRE OF OBJECTS PRODUCED IN METAL CASTING MOULDS

The typological range of objects produced using metal casting moulds appears to be more limited than that cast in stone moulds. In Poland, the most common moulds are those used for socketed axes, of which there are eight complete sets and two half-moulds (**Table 1**; **Fig. 11**). Moulds for ornaments are less frequently encountered, as seen in finds from Bieszków, Wicina, and Stara Łubianka. The only known Polish example of a mould for weaponry is a half-mould for a spearhead from the Oborniki region. A similar prevalence of (palstave, winged, socketed) axe production is also observed outside of Poland, in France, Germany, the British Isles, and the Iberian Peninsula. Moulds for other tools, ornaments, or weapons

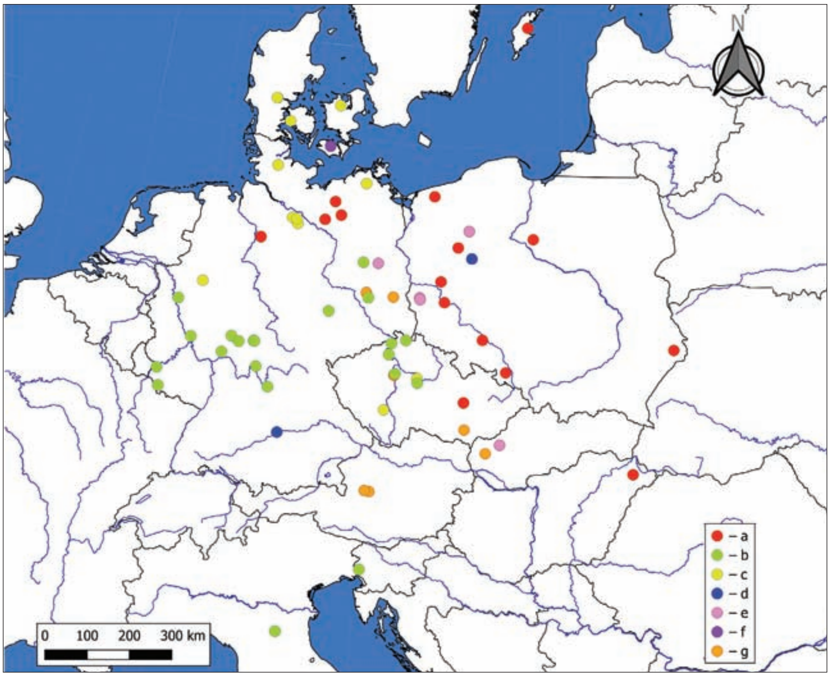


Fig. 11. Typological distribution of metal casting moulds found in Central Europe: a – socketed axe; b – winged axe; c – palstave axe; d – weaponry; e – ornament; f – sickle; g – unknown type of axe/unknown item. Map source: SRTM project data; modified and prepared by K. Nowak.

Ryc. 11. Rozmieszczenie metalowych form odlewniczych znalezionych w środkowej Europie według typów odlewanych przedmiotów: a – siekierka z tulejką; b – siekierka ze skrzydełkami środkowymi; c – siekiera z piętką; d – broń; e – ozdoba; f – sierp; g – nieokreślony typ siekiery/nieznany przedmiot. Źródło mapy: dane misji SRTM; modyfikacja i oprac. K. Nowak.

are considerably rarer. The Schinna hoard (Nienburg/Weser, Lower Saxony) is exceptional for its precisely modelled mould for a knobbed sickle found alongside moulds for a socketed axe (Jacob-Friesen 1940, p. 113, fig. 2:a–b). This sickle mould differs substantially from the object described as a "mould" for sickles from Nowe Kramsko. Another extraordinary find is a multi-part metal mould for casting the hilt of a Mörigen-type sword from Erlingshofen (district Eichstätt, Bavaria). This is a rare example of high-quality mould-making for weaponry (Pola *et al*. 2015, pp. 1637–1638; Overbeck 2018, pp. 81–82). A comparable find from East Pennard in Somerset (Great Britain) comprises a metal casting mould for a basal-looped spearhead (Knight *et al*. 2015, p. 65, fig. 9, pl. 27:389). A metal casting mould for pins with a head profiled with discs was discovered in the hoard from Berlin-Spindlersfeld (Friedel 1893, unnumbered plate; Helmbrecht 1997, p. 205). A metal mould for three pins was found in Hungary (the context and place of discovery are unknown; Hampel 1886, pl. IV.7–8; Tarbay 2018, p. 116, fig. 67), and a unique casting mould for producing a chain of rings was discovered in Slovakia (Hrádok nad Váhom, Trenčín Region; Ondrkál 2024, fig. 2:3–4).

Despite the variety of objects represented by the moulds, the surviving collection probably does not reflect the full extent of past metallurgical activity. As Jean-Pierre Mohen (Mohen 1978, p. 30) notes, many metal moulds were probably remelted after periods of use, particularly during times of metal scarcity or technological transition. The potential recycling of these artefacts could mean that the original prevalence and typological diversity of metal casting moulds in prehistoric Europe is significantly underrepresented.

CONCLUSION

The study of metal casting moulds from the Bronze Age and Early Iron Age found in Poland provides insights into the technological practices of prehistoric metalworking communities. The proliferation of such finds, particularly in recent decades, has significantly broadened our understanding of these artifacts, which were once considered rare and marginal within the wider field of metallurgical studies.

The evidence presented in this study demonstrates that metal casting moulds in Poland were primarily used in the production of socketed axes, although moulds for ornaments and weapons have also been attested. The prevalence of bivalve and three-part moulds, coupled with features such as alignment pegs, core stabilisation systems, and feed channels, indicates a high level of technical expertise.

Compositional analyses confirm that both tin bronze and unalloyed copper were used for mould production. The choice of alloy appears to have been driven by functional considerations, such as thermal resistance and casting precision. However, variations in alloy content, even among moulds used for casting similar types of objects, suggest a lack of single raw material standards, likely reflecting decisions made at the workshop level rather than adhering to standard protocols.

The contextual and spatial distribution of the moulds, which are most commonly found in hoards but also as individual finds, suggests a variety of deposition patterns. This variability likely reflects the diverse approaches to these artifacts. While they certainly played a utilitarian role, it is highly possible that they may have been imbued with additional meanings. The presence of moulds in liminal landscapes, such as wetlands, also suggests a connection with votive practices.

Experimental and analytical research supports the conclusion that metal casting moulds were used in direct metal casting processes and not just for producing wax or lead models. Their construction, the fact that they show evidence of repeated use, and the technological parallels that can be seen across Europe all affirm their role as durable, reusable components of metallurgical toolkits.

Despite the growing number of discoveries, the collection of metal casting moulds known from Poland is modest compared to regions such as France and the British Isles. This disparity could be due to differential preservation, recovery practices, or recycling patterns.

ACKNOWLEDGEMENT

I would like to express my sincere gratitude to Dr. Jarosław Rola of the District Museum in Piła for providing information on the casting mould from Stara Łubianka and for granting permission to include it in this study. I would also like to thank Dr. János Gábor Tarbay of the Hungarian National Museum for providing information on the metal casting moulds from Hungary. I also extend my thanks to Dr. Marcin Michalski of the Pracownia Badań Historycznych i Archeologicznych Pomost for permission to use in this article photographs of the find from the Oborniki region, taken by Dr. Maksymilian Frąckowiak. Furthermore, I am grateful to Dr. Radosław Jarysz of the Archaeological Museum in Wrocław and to Ewa Matuszczyk of the Opole Silesia Museum in Opole, for access to the artefacts from Brzeg Głogowski and Pawłowiczki for research purposes.

FUNDING

The article forms part of the author's research and did not receive separate funding. Library queries were conducted as part of previous research projects (National Science Centre, Poland, grants nos. 2017/27/N/HS3/01097 and 2021/40/C/HS3/00097).

BIBLIOGRAPHY

Aner E., Kersten K. 1976. *Die Funde der älteren Bronzezeit des nordischen Kreises in Dänemark, Schleswig-Holstein und Niedersachsen*, 2: *Holbæk, Sorø und Præsto Amter*, Neumünster.

Aner E., Kersten K. 1977. *Die Funde der älteren Bronzezeit des nordischen Kreises in Dänemark, Schleswig-Holstein und Niedersachsen*, 3: *Bornholms, Maribo Odense und Svendborg Amter*, Neumünster.

Aner E., Kersten K. 1978. *Die Funde der älteren Bronzezeit des nordischen Kreises in Dänemark, Schleswig-Holstein und Niedersachsen*, 4: *Südschleswig-Ost*, Neumünster.

Aner E., Kersten K. 1990. *Die Funde der älteren Bronzezeit des nordischen Kreises in Dänemark, Schleswig-Holstein und Niedersachsen*, 9: *Vejle Amt*, Neumünster.

Armbruster B.R. 2000. *Goldschmiedekunst und Bronzetechnik: Studien zum Metallhandwerk der Atlantischen Bronzezeit auf der Iberischen Halbinsel*, Monographies instrumentum, 15, Montagnac.

Baron J., Konczewski P., Nowak K. 2013. *Brązowa forma odlewnicza z Gaju Oławskiego, pow. oławski*, „Śląskie Sprawozdania Archeologiczne", 55, pp. 161–167.

Baron J., Miazga B., Nowak K. 2014. *Functions and contexts of Bronze Age metal casting moulds from Poland*, „Bulletin de la Société préhistorique française", 111(2), pp. 325‑338.

Baron J., Miazga B., Ntaflos T., Puziewicz J., Miazga B. 2015. *Beeswax remnants, phase and major element chemical composition of the bronze age mould from Gaj Oławski (SW Poland)*, „Archaeological and Anthropological Sciences", 8(1), pp. 187–196, https://link.springer.com/article/10.1007/s12520-014-0225-0

Bartelheim M., Niederschlag E. 1992. *Untersuchungen zur Buntmetallurgie, insbesondere des Kupfers und des Zinns, im sächsisch-böhmischen Erzgebirge und dessen Umland*, „Arbeits- und Forschungsberichte zur sächsischen Bodendenkmalpflege", 35, pp. 8–87.

Bastian A., Voss A. 1878. *Die Bronzeschwerter des Königlichen Museums zu Berlin*, Berlin.

Bietti Sestieri A.M. 1973. *The metal industry of continental Italy, 13th to the 11th century BC, and its connections with the Aegean*, „Proceedings of the Prehistoric Society", 39, pp. 383–424.

Blažek J., Ernée M., Smejtek L. 1998. *Die bronzezeitlichen Gußformen in Nordwestböhmen*, Beiträge zur Ur- und Frühgeschichte Nordwestböhmens, 3, Nordböhmische Bronzefunde, 2, Most.

Bönisch E. 2000. *Bestattung in aller Form – Das Grab eines Bronzegießers aus der Niederlausitz*, Ausgrabungen im niederlausitzer Braunkohlenrevier, 1999, pp. 67–84.

Chvojka O., Jiráň L., Metlička M. [*et al.*] 2017. *Nové české depoty doby bronzové. Díl 1*, České Budějovice–Praha–Plzeň.

Coblenz W. 1961. *Böhmisch-sächsische Kontakte während der Lausitzer Kultur*, „Památky Archeologické", 52(2), pp. 362–373.

Coblenz W. 1984. *Bronzezeitliche Höhensiedlung auf dem Oybin mit Zugangssperre*, „Arbeits- und Forschungsberichte zur sächsischen Bodendenkmalpflege", 27/28, pp. 93–123.

Dobrzańska E. 1959. *Przyczynek do znajomości metalurgii brązowej w epoce brązu i okresie halsztackim w dorzeczu górnej Wisły i górnej Odry*, „Silesia Antiqua", 1, pp. 83–102.

Drescher H. 1957. *Der Bronzeguß in Formen aus Bronze*, „Die Kunde", 8(1–2), pp. 52–74.

Drescher H. 1958. *Der Überfangguss. Ein Beitrag zur vorgeschichtlichen Metalltechnik*, Mainz.

Ebert M. 1926. *Reallexikon der Vorgeschichte*, 7, Berlin.

Fleury L. 1991. *Les moules de l'Âge du Bronze en France atlantique et dans les îles Britanniques: aspects techniques et culturels*, [in:] C. Chevillot, A. Coffyn (eds), *L'Âge du Bronze atlantique: ses faciès, de l'Ecosse à l'Andalousie et leurs relations avec le Bronze continental et la Méditerranée*, Beynac-et-Cazenac, pp. 267–276.

Friedel E. 1893. *Der Bronzefund von Spindlersfeld bei Coepenick, Brandenburgia*, „Monatsblatt der Gesellschaft für Heimatkunde der Provinz Brandenburg zu Berlin", 1(1892/1893), pp. 37–38, and an unnumbered plate.

Furlani U. 1996. *Depojska najdba it Šempetra pri Gorici–II ripostiglio di San Pietro presso Gorizia*, [in:] B. Teržan (ed.), *Depojske in posamezne kovinske najdbe bakrene in bronaste dobe na Slovenskem II*, Katalogi in monograije, 30, Ljubljana, pp. 73–88.

Gackowski J. 2016. *The Younger Bronze Age and the beginning of the Iron Age in Chełmno Land in the light of the evaluation of selected finds of metal products*, „Analecta Archaeologica Ressoviensia", 11, pp. 165–190, https://doi.org/10.15584/anarres.2016.11.8

Gackowski J., Kowalski Ł., Kowalski A.P., Garbacz–Klempka A., Osipowicz G., Sokół A., Ćwiek M., Bosiak M., Kołyszko M., Krzyszowski A., Markiewicz M., Molewski P., Noryśkiewicz A.M., Perek-Nowak M., Rembisz-Lubiejewska A., Skorupka T., Sosnowski M. 2024. *A Late Bronze Age hoard from Elgiszewo reflects the complex interplay between bronzesmithing, metal hoarding and local identity*, „Praehistorische Zeitschrift", 99, 1–49, https://doi.org/10.1515/pz-2024-2049

Gandert O.-F. 1961. *Ein Hortfund der Mittleren Bronzezeit aus Berlin–Charlottenburg*, „Berliner Blätter für Vor– und Frühgeschichte", 9, pp. 47–58.

Garbacz–Klempka A. 2018. *Synteza badań archeometalurgicznych artefaktów z epoki brazu. Eksperymentalna rekonstrukcja stopów miedzi i technologii*, Kraków.

Gavranović M. 2013. *Urnenfelderzeitliche Gussformen aus dem westlichen Zentralbalkan*, [in:] B. Rezi, R.E. Németh, S. Berecki (eds), *Bronze Age crafts and craftsmen in the Carpathian Basin. Proceedings of the International Colloquium from Târgu Mureş, 5–7 October 2012*, Târgu Mureş, pp. 149–166.

Gedl M. 2004. *Die Beile in Polen IV. Metalläxte, Eisenbeile, Hämmer, Ambosse, Meißel, Pfrieme*, Prähistorische Bronzefunde, 9(24), Stuttgart.

Goldmann K. 1981. *Guß in verlorener Sandform – Das Hauptverfahren Alteuropäischer Bronzegießer?*, „Archäologisches Korrespondenzblatt", 11, pp. 109–116.

Gutiérrez Sáez C., Lerma I.M. 2015. *Traceology on metal. Use wear marks on copper based tools and weapons,* [in:] J.M. João Manuel Marreiros, J.F. Gibaja Bao, N. Ferreira Bicho (eds), *Use-wear and residue analysis in archaeology*, Basel, pp. 171–188.

Hampel J. 1886. *A bronzkor emlékei Magyarhonban. I. rész: Képes atlasz*, Budapest.

Helmbrecht M. 1997. *Spindlersfeld, Kr. Teltow, Prov. Brandenburg*, [in:] A. Hänsel, B. Hänsel (eds), *Gaben an die Götter. Schätze der Bronzezeit Europas*, Berlin, pp. 204–206.

Hodges H. 1960. *The Bronze Age moulds of the British Isles. Part 2: England and Wales – moulds of stone and bronze*, „Sibrium", 5, pp. 153–62.

Hundt H.–J. 1997. *Die jüngere Bronzezeit in Mecklenburg*, Lübstorf.

Jacob–Friesen K.H. 1940. *Der Bronzegießerfund von Schinna, Kr. Nienburg*, „Die Kunde", 8, pp. 108–118.

Jantzen D. 2008. *Quellen zur Metallverarbeitung im Nordischen Kreis der Bronzezeit*, Prähistorische Bronzefunde, 19(2), Stuttgart.

Jentsch H. 1894. *Bronzedepotfund von Krieschow Kr. Cottbus und Urnen von Wiesendorf gl. Kr.*, „Niederlausitzer Mittheilungen", 3(5–7), pp. 308–309.

Jockenhövel A. 1986. *Struktur und Organisation der Metallverarbeitung in urnenfelderzeitlichen Siedlungen Süddeutschlands*, [in:] D.-W.R. Buck, B. Gramsch (eds), *Siedlung, Wirtschaft und Gesellschaft während der jüngeren Bronze– und Hallstattzeit in Mitteleuropa. Internationales Symposium Potsdam 25. bis 29. April 1983*, „Veröffentlichungen des Museums für Ur- und Frühgeschichte Potsdam", 20, pp. 213–234.

Keiling H. 1987. *Die Kulturen der mecklenburgischen Bronzezeit*, Archäologische Funde und Denkmale aus dem Norden der DD, Museumskatalog Schwerin, 6, Schwerin.

Kibbert K. 1980. *Die Äxte und Beile im mittleren Westdeutschland I*, Prähistorische Bronzefunde, 9(10), Münich.

Kibbert K. 1984. *Die Äxte und Beile im mittleren Westdeutschland II*, Prähistorische Bronzefunde, 9(13), Münich.

Kłosińska E.M., Sadowski S. 2017. *Long-distance connections of the south-eastern peripheries of the Lublin region at the time of the Lusatian Culture in the light of archival and newly discovered materials*, „Sprawozdania Archeologiczne", 69, pp. 391–408, https://doi.org/10.23858/SA69.2017.016

Knight M.G., Ormrod T., Pearce S. 2015. *The Bronze Age Metalwork of South–Western Britain. A corpus of material found between 1983 and 2014*, BAR British Series, 610, Oxford.

Kostrzewski J. 1953. *Wytwórczość metalurgiczna w Polsce od neolitu do wczesnego okresu żelaznego*, „Przegląd Archeologiczny", 9, pp. 177–211.

Kowalski Ł., Garbacz–Klempka A. 2019. *Badania metaloznawcze skarbu z Nowego Kramska*, [in:] A. Michalak, J. Orlicka-Jasnoch (eds), *Skarb z Nowego Kramska. Analizy. Konteksty*, Zielona Góra, pp. 139–178.

Kowalski Ł., Garbacz-Klempka A., Gackowski J., Ścibior D., Perek-Nowak M., Adamczak K., Długosz P. 2019. *Towards direct casting: Archaeometallurgical insight into a bronze mould from Elgiszewo,* *Poland, 900–700 BC*, „Archeologické rozhledy", 71(1), pp. 45–66, https://doi.org/10.35686/AR.2019.3

Kucypera P., Rybka K. 2013. *Analiza składu chemicznego przedmiotów zabytkowych z Bieszkowa i Wiciny*, [in:] A. Jaszewska, S. Kałagate (eds), *Wicina. Badania archeologiczne w latach 2008–2012 oraz skarb przedmiotów pochodzących z Wiciny*, Zielona Góra, pp. 547–562.

Kuijpers M.H.G. 2008. *Bronze Age metalworking in the Netherlands (c. 2000–800 BC). A research into the preservation of metallurgy related artefacts and the social position of the smith*, Leiden.

Kytlicová O. 2007. *Jungbronzezeitliche Hortfunde in Böhmen*, Prähistorische Bronzefunde, 20(12), Stuttgart.

Leube A., Hollnagel A., Schocknecht U. 1967. *Kurze Fundberichte. Medow, Kr. Anklam*, „Bodendenkmalpflege in Mecklenburg", p. 343.

Le Fèvre–Lehöerff A. 1992. *Les moules de l´Age du Bronze dans la plaine orientale du Po: vestiges de mise en forme des l´alliages base cuivre*, „Padusa", 28, pp. 131–243.

Machajewski H., Maciejewski M. 2006. *Skarb ludności kultury łużyckiej z Roska nad Notecią*, [in:] H. Machajewski, J. Rola (eds), *Pradolina Noteci na tle pradziejowych i wczesnośredniowiecznych szlaków handlowych*, Poznań, pp. 127–146.

Maciejewski M. 2019. *The Rosko hoard – a road sign? Research and its perspectives: mass deposition of metal objects, Late Bronze and Early Iron Ages in Poland*, „Praehistorische Zeitschrift", 94(1), pp. 233–251, https://doi.org/10.1515/pz-2019-0012

Maciejewski M., Nowak K. 2022. *Hoards, metallurgy and points. Proposal of an analytical tool for the description hoards with elements of a metallurgical workshop*, [in:] D. Hofmann, F. Nikulka, R. Schumann (eds), *The Baltic in the Bronze Age. Regional patterns, interactions and boundaries*, Leiden, pp. 123–144.

Michalak A. 2011. *Zabytki metalowe z grodziska ludności kultury łużyckiej w Wicinie*, [in:] A. Jaszewska (ed.), *Wicina. Katalog zabytków metalowych*, Biblioteka Archeologii Środkowego Nadodrza, 5, Zielona Góra, pp. 21–53.

Michalak A., Jaszewska A. 2011. *Katalog zabytków metalowych. VI. Przedmioty związane z metalurgią*, [in:] A. Jaszewska (ed.), *Wicina. Katalog zabytków metalowych*, Biblioteka Archeologii Środkowego Nadodrza, 5, Zielona Góra, pp. 177–199.

Michalak A., Orlicka–Jasnoch J. (eds.), 2019. *Skarb z Nowego Kramska. Analizy. Konteksty*, Zielona Góra.

Mohen J.P. 1978. *Moules en bronze de l'Âge du Bronze*, „Antiquités Nationales", 10, pp. 23–32.

Mohen J.P. 1990. *Métallurgie préhistorique: introduction à la paléométallurgie*, Masson.

Mozsolics A. 1985. *Bronzefunde aus Ungarn. Depotfundhorizonte von Aranyos, Kurd und Gyermely*, Budapest.

Nessel B. 2013. *Gussformen und Schmiedegeräte aus Mitteleuropa*, [in:] *Bronzezeit. Europa ohne Grenzen. 4.-1. Jahrtausend v. Chr. Ausstellungskatalog*, St. Petersburg, pp. 470–472.

Nessel B. 2019. *Der bronzezeitliche Metallhandwerker im Spiegel der archäologischen Quellen*, 1–2, Universitätsforschungen zur Prähistorischen Archäologie, 344, Bonn.

Nowak K., Ialongo N. 2025. *Late Bronze Age hoard from Nowe Kramsko. Is there a method in fragments?*, [in:] M. Maciejewski, J.G. Tarbay, K. Nowak (eds), *Hoards from the European Bronze and Iron Ages. Current research and new perspectives*, New Approaches in Archaeology, 4, Turnhout, pp. 131–148.

Nowak K., Stolarczyk T. (eds), 2016. *Metalurdzy znad Kaczawy. Cmentarzysko ciałopalne z epoki brązu odkryte w Legnicy przy ul. Spokojnej*, Legnica.

Nowak K., Sych D. 2024. *Traceology of metalwork – limitations and new perspectives*, „Sprawozdania Archeologiczne", 76(1), pp. 99–121, https://doi.org/10.23858/SA/76.2024.1.3569

Olshausen O. 1885. *Broncefund von Kölpin, Kreis Colberg-Cörlin*, „Baltische Studien", 35(4), pp. 394–401.

Ondrkál F. 2024. *Hrádok nad Váhom. Bronzeworking equipment from an Urnfield Culture site in the Carpathians*, „Dissertationes Archaeologicae", 3(12), pp. 149–166, https://ojs.elte.hu/dissarch/article/view/8444

Orlicka–Jasnoch J. 2013. *Skarb przedmiotów brązowych i żelaznych z Bieszkowa, gm. Jasień*, [in:] A. Jaszewska, S. Kałagate (eds), *Wicina. Badania archeologiczne w latach 2008–2012 oraz skarb przedmiotów pochodzących z Wiciny*, Zielona Góra, pp. 491–537.

Orlicka–Jasnoch J. 2019. *Skarb ludności kultury łużyckiej z Nowego Kramska. Aspekt archeologiczny*, [in:] A. Michalak, J. Orlicka-Jasnoch (eds), *Skarb z Nowego Kramska. Analizy. Konteksty*, Zielona Góra, pp. 17–138.

Ottaway B.S. 1994. *Prähistorische Archäometallurgie*, Leidorf.

Overbeck M. 2018. *Die Gießformen in West– und Süddeutschland (Saarland, Rheinland-Pfalz, Hessen, Baden-Württemberg, Bayern) mit einem Beitrag von A. Jockenhövel, Alteuropäische Gräber der Kupferzeit, Bronzezeit und Älteren Eisenzeit mit Beigaben aus dem Gießereiwesen (Gießformen, Düsen, Tiegel)*, Prähistorische Bronzefunde, 19(3), Stuttgart.

Ó Faoláin S. 2004. *Bronze artefact production in Late Bronze Age Ireland. A survey*, BAR British Series, 382, Oxford.

Pászthory K., Mayer E.F. 1998. *Die Äxte und Beile in Bayern*, Prähistorische Bronzefunde, 9(20), Stuttgart.

Podėnas V., Čivilytė A. 2019. *Bronze casting and communication in the southeastern Baltic Bronze Age*, „Lietuvos archeologija", 45, pp. 169–199, https://doi.org/10.33918/25386514–045005

Podborský V. 1974. *Na okraj výroby bronzových předmětů staršího metalika na Moravě*, [in:] L. Wiegandová (ed.), *Archeologický sborník*, Ostrava, pp. 66–78, pl. VIII–XII.

Pola A., Mödlinger M., Piccardo P., Montesano L. 2015. *Casting Simulation of an Austrian Bronze Age Sword Hilt*, "JOM. The Journal of The Minerals, Metals & Materials Society (TMS)", 67, pp. 1637–1645, https://doi.org/10.1007/s11837-015-1464-y

Probst E. 1996. *Deutschland in der Bronzezeit: Bauern, Bronzegießer und Burgherren zwischen Nordsee und Alpen*, Münich.

Reich C. 1991. *Der Hortfund von Spindlersfeld*, [in:] J. Blischke (ed.), *Prähistorische Archäologie im Raum Berlin*, Berlin, pp. 57–79.

Reich C. 1997. *Von nah und fern. Der Hortfund von Spindlersfeld*, [in:] A. Hänsel, B. Hänsel (eds), *Gaben an die Götter. Schätze der Bronzezeit Europas, Bestandskataloge*, 4, Berlin, pp. 67–69.

Rembisz A., Markiewicz M. 2007. *Pozostałości domostwa ludności kultury łużyckiej w Rudzie (stan. 3–6), gm. Grudziądz, woj. kujawsko–pomorskie w świetle wyników analiz archeologiczno–przyrodniczych*, [in:] G. Nawrolska (ed.), *XV Sesja Pomorzoznawcza, materiały z konferencji 30 listopada – 02 grudnia 2005*, Elbląg, pp. 41–52.

Sałat R., Warmuzek M., Kozakowski S., Krokosz J. 2006. *Badania metalograficzne przedmiotów brązowych pochodzących z Roska, gmina Wieleń*, [in:] H. Machajewski, J. Rola (eds), *Pradolina Noteci na tle pradziejowych i wczesnośredniowiecznych szlaków handlowych*, Poznań, pp. 147–152.

Schuldt E. 1968. *Mecklenburgische Altertümer. Neue Funde*, Schwerin.

Seger H. 1909. *Beiträge zur Vorgeschichte Schlesiens: 3. Gussformen*, „Schlesiens Vorzeit in Bild und Schrift, Neue Folge", 5, pp. 16–27.

Seger H. 1922. *Vermehrung der vorgeschichtlichen Sammlung des Schlesischen Museums für Vorgeschichte und Altertümer*, „Altschlesien", 1, pp. 37–50.

Seger H. 1927. *Vermehrung der vorgeschichtlichen Sammlung des Schlesischen Museums für Kunstgewerbe und Altertümer*, „Altschlesien", 2(1), pp. 59–68.

Seger H. 1936. *Schlesische Hortfunde aus der Bronze– und frühen Eisenzeit*, „Altschlesien", 6(1), pp. 85–182.

Sprockhoff E. 1956. *Jungbronzezeitliche Hortfunde der Südzone des nordischen Kreises (Periode V)*, 1–2, Moguncja.

Szweycer M., Nagolska D. 2002. *Metalurgia i odlewnictwo*, Poznań.

Tarbay J.G. 2018. *A gyermelyi típusú kincsek és koruk*, Budapest, PhD thesis, ELTE University, http://hdl.handle.net/10831/40535
Teržan B. (ed.), 1995. *Depojske in posamezne kovinske najdbe bakrene in bronaste dobe na Slovenskem I*, Katalogi in monografije, 29, Ljubljana.
Tylecote R. 1986. *The Prehistory of metallurgy in the British Isles*, London.
Voss A. 1881. *Über spiralig gedrehte Arm– und Halsringe, einhenklige (tassenförmige), getriebene Bronzeschalen und buckelförmige Bronzezierrathen (Schildbuckel?)*, „Verhandlungen der Berliner Gesellschaft für Anthropologie, Ethnologie und Urgeschichte", pp. 107–127.
Wang Q., Ottaway B.S. 2004. *Casting experiments and microstructure of archaeologically relevant bronzes*, BAR British Series, 1331, Oxford.
Wanzek B. 1989. *Die Gussmodel für Tüllenbeile im südöstlichen Europa*, Universitätsforschungen zur prähistorischen Archäologie, 2, Bonn.
Webley L., Adams S. 2016. *Material genealogies: bronze moulds and their castings in Later Bronze Age Britain*, „Proceedings of the Prehistoric Society", 82, pp. 323–340, https://doi.org/10.1017/ppr.2016.8
Wiegmann U. 1997. *Vorland, Kr. Grimmen, Prov. Pommern*, [in:] A. Hänsel, B. Hänsel (eds), *Gaben an die Götter. Schätze der Bronzezeit Europas*, Berlin, pp. 216–217.
Wirth M. 2003. *Rekonstruktion bronzezeitlicher Gießereitechniken mittels numerischer Simulation, gießtechnologischer Experimente und werkstofftechnischer Untersuchungen an Nachguss und Original*, Aachen, PhD thesis, Faculty of Georesources and Materials Engineering, 5, Rheinisch-Westphalian Technical University, https://publications.rwth-aachen.de/record/59228/files/Wirth_Monika.pdf

STRESZCZENIE

Metalowe formy odlewnicze odkrywane na obszarze obecnej Polski stanowią unikalną kategorię zabytków. Dostarczają cennych informacji o technologii odlewniczej stosowanej przez społeczności zamieszkujące teren środkowej Europy w późnej epoce brązu i we wczesnej epoce żelaza (czyli ok. 1200–450 p.n.e.). W Polsce odnotowano dotychczas łącznie 28 takich znalezisk, na 12 stanowiskach archeologicznych (**ryc. 1**; **tab. 1**). Celem niniejszego artykułu jest kompleksowe zaprezentowanie tych przedmiotów, a także analiza technologii ich produkcji, funkcji, jaką pełniły, oraz kontekstów, w których je deponowano.

Omawiane formy odlewnicze znaleziono w postaci dwu- lub trzyczęściowych, pełnych zestawów albo osobnych połówek (**ryc. 2–4**). Ich konstrukcja jest podobna do form kamiennych, lecz ich wyróżnikiem są specjalne elementy pozycjonujące, takie jak wymodelowane kołki centrujące i odpowiednie zagłębienia w przeciwległych częściach form. W wielu przypadkach stosowano również stabilizację rdzenia odlewniczego, co umożliwiało precyzyjne ukształtowanie pustych przestrzeni wewnątrz odlewu, tak jak w formach pozyskanych w Brzegu Głogowskim, Elgiszewie i Rosku. Część egzemplarzy miała zewnętrzne uchwyty, które pełniły dwojaką funkcję: stabilizowały złożoną formę podczas procesu odlewania oraz ułatwiały jej rozdzielenie po wystygnięciu metalu. Powierzchnia zewnętrzna form odkrytych w Polsce jest niezdobiona. Egzemplarze dekorowane znane są natomiast z innych krajów europejskich: z Wysp Brytyjskich, Francji, Niemiec, Włoch, a także z Czech (**ryc. 5**).

Analizowane formy wykonane zostały dwiema metodami: traconego wosku oraz odlewania przy użyciu ceramicznych form odlewniczych (**ryc. 6**). Oba procesy wymagały fachowej wiedzy i doświadczenia, w tym precyzyjnego przygotowania modeli, wieloetapowego formowania glinianych warstw oraz starannej kontroli parametrów podczas odlewania. Formy metalowe produkowane były prawdopodobnie przez wyspecjalizowanych metalurgów, którzy przede wszystkim umieli skorygować błędy technologiczne spowodowane przetapianiem wadliwych odlewów. W przeciwieństwie do form z kamienia, metalowe egzemplarze mogły być przetwarzane wielokrotnie (przez przetapianie), co pozwalało ograniczyć zużycie surowców.

W wyniku analiz składu chemicznego, które przeprowadzono dla 16 wybranych egzemplarzy (spis zabytków poddanych analizom w **tab. 2**), wykazano, że do ich wyrobu zastosowano głównie brązy cynowe, a tylko w niektórych przypadkach również czystą miedź (Cu) z domieszkami naturalnymi: srebra (Ag), arsenu (As) i antymonu (Sb). W składzie metalu, z którego zrobiono formy datowane na późną epokę brązu, zawartość cyny (Sn) mieści się w granicach 5,25–11,61%, natomiast w tych z wczesnej epoki żelaza zawartość tego pierwiastka wykazuje znacznie większe wahania – od 1,28% do 24,28% (**ryc. 7**). W metalu, jakiego użyto do odlania zabytków z Elgiszewa i Nowego Kramska, celowo zastosowano miedź (Cu), bez dodatku cyny (Sn). Zabieg ten zapewne miał na celu zwiększenie odporności termicznej wykonywanych form. Zróżnicowany udział procentowy stwierdzono nawet w przypadku form przeznaczonych do odlewania przedmiotów tego samego typu. Świadczy to o odmiennych praktykach warsztatowych i modyfikacji przez wytwórców parametrów sporządzanych stopów.

W wielu publikacjach, przede wszystkim wcześniejszych, twierdzono, że metalowe formy służyły jedynie do wytwarzania modeli z wosku lub z ołowiu. Współczesne eksperymenty archeologiczne wykazały jednak, że za ich pomocą możliwe było odlewanie stopionego brązu, pod warunkiem uprzedniego nagrzania form, kontrolowania temperatury metalu oraz stosowania odpowiednich powłok ochronnych we wnętrzu formy (z sadzy, gliny, węgla drzewnego). Uzyskane w ten sposób odlewy charakteryzowały się dużą precyzją wykonania. A same formy metalowe mogły być stosowane nawet kilkanaście razy. Ślady eksploatacyjne, takie jak przetarcia powierzchni zewnętrznych, pęknięcia lub uszkodzenia uchwytów, świadczą o intensywnym użytkowaniu niektórych badanych egzemplarzy, np. form z Roska, Elgiszewa i Gaju Oławskiego (**ryc. 8**).

Metalowe formy odlewnicze zostały odkryte głównie w zachodniej części kraju, przy czym dominują wśród nich znaleziska wchodzące w skład skarbów. Niektóre z nich pozyskano na terenach podmokłych (zabytki z miejscowości Elgiszewo i Kiełpino), co może wskazywać na ich intencjonalne zdeponowanie w rejonie przygranicznym, być może w kontekście rytualnym. Nieliczne okazy odnotowano zaś w centralnej i wschodniej Polsce („znad Sieniochy").

Liczba krajowych znalezisk, w porównaniu z tymi z innych regionów środkowej Europy (**ryc. 9**; **tab. 3**), jest zbliżona do zarejestrowanej w Niemczech (gdzie znanych jest 30 stanowisk). W Czechach odnotowano ich znacznie mniej (10), zaś na terenie Francji, Wielkiej Brytanii i Hiszpanii – znacznie więcej. Tej kategorii wyrobów nie stwierdzono natomiast w południowo-wschodniej części kontynentu. Przypuszczalnie jest to spowodowane odmiennymi tradycjami technologicznymi, jak również wtórnym przetapianiem form metalowych. Zabytki z obszaru dzisiejszej Polski pochodzą z końca epoki brązu i z wczesnej epoki żelaza. Na terenach sąsiednich wytwarzano je znacznie wcześniej (**ryc. 10**).

Większość analizowanych form przeznaczona była do odlewania siekier z tulejką; do wykonania takich przedmiotów służyło osiem pełnych zestawów i dwie połówki. Rzadziej miały one zastosowanie do produkcji ozdób (zabytki z Bieszkowa, Starej Łubianki, Wiciny) lub broni (połówka formy do odlewania grotu włóczni pochodząca z okolicy Obornik). Przy użyciu form metalowych wykonywano podobny asortyment wyrobów w całej środkowej i zachodniej Europie, w badanym okresie. Ustalono, że najczęściej służyły do odlewania siekier zaopatrzonych w piętkę, w skrzydełka środkowe oraz w tulejkę. Znacznie rzadziej używano ich do wytwarzania innych przedmiotów metalowych: narzędzi (sierpów), części broni ręcznej (rękojeści mieczy), a także szpil oraz łańcuchów złożonych z kółek (**ryc. 11**).

Omawiane w artykule formy metalowe stanowiły ważny element wyposażenia warsztatu odlewniczego w epoce brązu i wczesnej epoce żelaza w międzyrzeczu Odry i Wisły. Zrobione zostały przy zastosowaniu zaawansowanej technologii. Ich zaletą była możliwość wielokrotnego użycia. Stanowiły też zasób cennego surowca, który można było przetopić i ponownie wykorzystać. Chociaż zbiór opisywanych przedmiotów z ziem polskich jest skromny w stosunku do liczby znalezisk zachodnioeuropejskich, niewątpliwie jest on ważnym źródłem wiedzy na temat pradziejowego odlewnictwa i metalurgii w środkowej Europie.

Kamil Nowak

*

Received: 17.05.2025; **revised:** 04.08.2025; **accepted:** 13.08.2025.

The author declares that he has no conflicts of interest arising from competition, collaboration or other personal or financial relationships that could affect the research and results described in the article.

Nadesłano: 17.05.2025; **zrewidowano:** 04.08.2025; **zaakceptowano:** 13.08.2025.

Autor oświadcza, że nie ma konfliktu interesów wynikającego z konkurencji, współpracy lub innych relacji, powiązań osobistych lub finansowych, które mogły mieć wpływ na badania i wyniki opisane w artykule.