

Make and break: Intentional fragmentation of copper flat axes as evidence for metallurgy in the Northern Group of the Early Neolithic Funnel Beaker societies

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Zusammenfassung

Vom Erschaffen und Zerstören. Intentionale Fragmentierung von kupfernen Flachbeilen als Nachweis von Metallurgie in der Nordgruppe der frühneolithischen Trichterbechergesellschaften

Dieser Beitrag betrachtet das Vorhandensein metallurgischer Aktivitäten in der Nordgruppe der frühneolithischen Trichterbechergesellschaften anhand der Untersuchung der intentionalen Fragmentierung von kupfernen Flachbeilen. Er prüft bekannte sowie neue Belege einer eigenständigen Kupfermetallurgie im westlichen Ostseeraum und beleuchtet das bisher unbeachtete Schadbild der Warmbrüchigkeit als Nachweis für metallurgisches Wissen in der Nordgruppe der Trichterbechergesellschaften. Vorgestellt werden drei Beispiele von Flachbeilen aus Neuenkirchen, Lkr. Mecklenburgische Seenplatte, Lackalända, Skåne (Schweden), und Nadrensee, Lkr. Vorpommern-Greifswald, mit solchen Warmbrüchen. Sie ermöglichen Einblicke in intentionale Zerstörungspraktiken und deuten auf die Anwesenheit von Metallurgen mit Kenntnissen in Pyrotechnologie hin. Die langdiskutierte Theorie von der »kleinen« Kupferzeit im westlichen Ostseeraum wird von der intentionalen Fragmentierung kupferner Flachbeile mittels Warmbrüchigkeit gestützt. Dieser Nachweis spricht zusammen mit den metallurgischen Werkzeugen aus Lønt, Haderslev Kommune (Dänemark), und Kotowo, Woi. Großpolen (Polen), für eine eigenständige Produktion von Kupferobjekten im Frühneolithikum (4100/4000–3300 v. Chr.), was bisherige Chronologien infrage stellt und die Bedeutung Mecklenburg-Vorpommerns für den Transfer metallurgischen Wissens zwischen den Trichterbechergesellschaften unterstreicht.

Schlagwörter Kupfer, frühe Metallurgie, Trichterbecher, Warmbrüchigkeit

Introduction

At the turn from the 6th to 5th millennia BC in parts of Europe, a Copper Age can be proposed that is defined by mining, smelting, and casting¹. From the early innovation

Summary

This paper explores the presence of metallurgical activities in the Northern Group of the Early Neolithic Funnel Beaker societies through an examination of the intentional fragmentation of copper flat axes. It reviews the existing and latest evidence for an independent copper metallurgy in the Western Baltic region and introduces the hitherto unnoticed damage pattern of hot-shorting as evidence for the metallurgical knowledge in the Funnel Beaker societies of the Northern Group. Three examples of flat axes that were subjected to hot-shorting are presented here; originating from Neuenkirchen, Mecklenburgische Seenplatte district, Lackalända, Scania (Sweden), and Nadrensee, Vorpommern-Greifswald district, they provide insight into intentional destruction practices and indicate the presence of metalworkers with knowledge of pyro-technology. The long-discussed existence of a »little« Copper Age in the Western Baltic region is supported by the intentional fragmentation of copper flat axes through hot-shorting. This evidence, coupled with metallurgical tools from Lønt, Haderslev Municipality (Denmark), and Kotowo, Greater Poland Voivodeship (Poland), suggests an independent production of copper objects during the Early Neolithic (4100/4000–3300 BC), challenging previous timelines and emphasizing the significance of Mecklenburg-Western Pomerania as a gateway for the transfer of metallurgical knowledge between Funnel Beaker societies.

Keywords copper, early metallurgy, funnel beaker, hot-shorting

centres in South-Eastern Europe, objects made of copper reach the Early Neolithic societies in Northern Germany and Southern Scandinavia roughly at the same time as the switch from a mobile to a sedentary lifestyle. While the initial numbers were rather low, one can observe a strong

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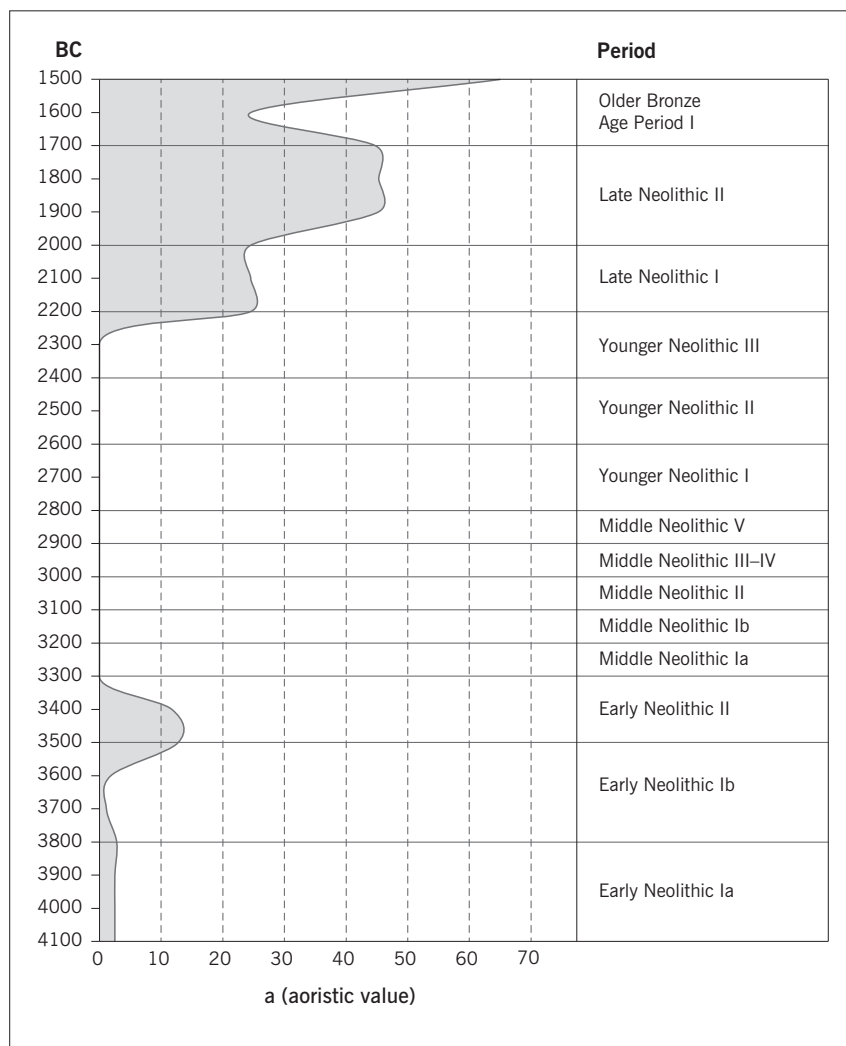


Fig. 1 Relative frequency of Neolithic copper objects in Northern Germany and Southern Scandinavia.

Abb. 1 Relative Häufigkeit neolithischer Kupferobjekte in Norddeutschland und Südschweden.

increase in copper artefacts starting around the beginning of the 2nd half of the 4th millennium (Fig. 1). The dominant object form in that isolated stage of Early Neolithic copper finds are flat axes. Limited numbers of daggers, arm spirals, hammer axes, and sheet-metal jewellery are also known. These objects are predominantly single depositions or single finds, although a number of multi-object depositions – such as the hoard finds from Bygholm, Horsens Kommune (Denmark), Neuenkirchen, Mecklenburgische Seenplatte district, and Riesebusch, Ostholstein district, – are also known (Fig. 2). Just as suddenly as it appeared, this increase in copper finds nearly completely vanished from the material culture at 3300 BC for the next 1000 years in the Western Baltic region. It is only in the Late Neolithic and Early Bronze Age that metal re-emerges (starting roughly at 2300 BC) and metallurgy is integrated permanently into the societies (Fig. 1). Whether this spike in numbers of Neolithic copper finds is due to an increased import of final products or the result of local production could not be ultimately determined. In very recent years, new discoveries are making the latter scenario more likely, and one could at least discuss the possibility of a »little« Copper Age in parts of Northern Europe. This paper summarises the available evidence and introduces further indications for the independent production of copper objects.

The question of an independent metallurgy in the Funnel Beaker North Group

In his comprehensive study of the copper finds of the Funnel Beaker North Group, L. Klassen (2000, 235–236) identified three main phases of metal use. The first phase (around 4000–3800/3700 BC) is primarily characterised by imports. In the 2nd phase (3800/3700–3500 BC), there is additional evidence of locally produced sheet-metal jewellery, and the mechanical treatment of objects forms part of the archaeological record. In the 3rd phase (3500–3300 BC), the archaeological evidence reveals the extensive mechanical and pyrotechnical treatment of objects as well as a wider variety of local types of flat axes and sheet-metal jewellery. Klassen (2000, 235–236) proposed that local, independent mining, smelting, and the production of copper objects took place in the Northern Group of the Funnel Beaker societies. This assumption is based on two major aspects:

Typological forms unique to the Funnel Beaker North Group. Klassen (2000, 233) identifies 13 different types that are specific to the Western Baltic region (Viborg, Ettrup, Pilegård, Riesebusch, Kieholm, Hyrup, Søby Hede, Avnslev, Vesterkobbøl, Kerteminde, Lackalånga, Fosie, and Nosaby). Also striking is that, even if there are typological equivalents in, for example, the northern Alpine region, the

Fig. 2 The Neuenkirchen hoard, Mecklenburgische Seenplatte district, with the hot-shorted flat axe; no scale.

Abb. 2 Hortfund von Neuenkirchen, Lkr. Mecklenburgische Seenplatte, mit dem warmbrüchigen Flachbeil; o. M.



examples from the Funnel Beaker North Group are significantly (up to 2.5 times) bigger and heavier. For example, the known representatives of the ›Ettrup‹ type are nearly two times bigger and four times heavier than their typological equivalent of the northern Alpine form-type ›Maurach‹ (Klassen 2000, 164).

A copper variety (Riesebusch) that is only prevalent in the Western Baltic region. The specific composition with dominant trace elements of arsenic followed by antimony as the only significant admixture, along with local distribution as well as the local forms, leads Klassen (2000, 212–213) to the conclusion that exploitation of middle Swedish ore sources is a likely possibility. This has not yet been confirmed by lead isotopes, though. On the contrary, the latest study by J.P. Brozio et al. (2023) showed that most of this arsenic copper originated from South-Eastern European sources such as the east Serbian mine at Madjanpek, Bor district. More striking, the flat axe and one band spiral from the eponymous hoard find for the copper variety Riesebusch (Ratekau, Ostholstein district) show a lead isotope signature consistent with Serbian ore sources; and two others, which are also part of Klassen's (2000) analysis group VIII (Riesebusch copper), match the lead isotope ratios from the eastern Slovakian Kremnica region (Brozio et al. 2023, 9). The rising number of lead isotope analyses also hints towards a South-Eastern European origin of the so-called Mondsee copper variety². This arsenic-rich copper, named after the metallurgy centre and archaeological culture at the eponymous lake Mondsee in Austria, has long been suspected to be from relatively close sources in the eastern Alpine region (Klassen/Stürüp 2001, 55–56). This was already controversially discussed by, e.g., C. Frank and E. Pernicka (2012, 131). More recent studies by J.P. Brozio et al. (2023), H. Skorna (2022), and H. Nørgaard et al. (2021) show that the lead isotope ratio of copper objects with this specific trace element composition are also consistent with sources from Serbia as well as Bulgaria. Thus, the overwhelming majority of the

analysed copper dating between 3800 and 3300 BC in the Western Baltic originated from South-Eastern European sources.

Although new lead isotope data does not support a Swedish origin for the Riesebusch copper, and therefore independent ore mining and smelting is highly unlikely, the variety of local forms still speaks for a local pyrotechnical production of copper objects in the Northern Group of the Funnel Beaker societies. As Frank and Pernicka (2012) already pointed out, the relatively higher arsenic content is likely the result of the introduction of a new technology in form of an intentional addition of arsenic into the copper using speiss (Rehren et al. 2012, 1717–1718; Nørgaard et al. 2021, 10). Objects made of this copper from South-Eastern European sources could then have travelled from or via the Mondsee Culture in Austria to the Western Baltic region early in the Funnel Beaker period (Nørgaard et al. 2021, 10) and were then (partially) recast/reworked into the local forms.

Evidence for metallurgy

Numerous discoveries revealing metallurgical activities are known from the material culture of the younger Neolithic societies in the northern Alpine region (Matuschik 1998, find list A). From the lakeside settlements at Mondsee and Atternsee alone, more than 160 metallurgical tools are known (Matuschik 1998; Klassen 2000, 283). These include finds such as crucibles, tuyères, casting residues, slags, and moulds. To a lesser extent, such evidence is known for the South, East, and South-Eastern Group of the Funnel Beaker societies (Klassen 2000, 284–285; Gebauer et al. 2021; Żurkiewicz et al. 2023). In contrast to this, the evidence in the Northern Group of the Funnel Beaker societies was absent until very recently. In the following, this evidence is compiled and complemented with new examples.

² Analysis of group VII after Klassen (2000).

Metallurgical tools from Lønt, Haderslev Municipality (Denmark)

The first hard evidence for metallurgy originates from the Danish site of Lønt. The site is a megalithic cemetery with eleven tombs and two causewayed enclosures (Gebauer et al. 2021, 29). Below a long barrow with two round dolmens from the early Middle Neolithic period I (around 3300–3100 BC), a Neolithic surface was preserved upon which fragments of a crucible and a tuyère were found. The pottery found in connection with both these objects can be dated to the Early Neolithic Ib (3800–3650 BC). An examination using scanning electron microscopy with energy dispersive analysis as well as with a μ -X-Ray-fluorescence scanner proved that the crucible had come into contact with molten copper (Gebauer et al. 2021, 32–33). Interestingly, the observed profile of the copper with predominant trace elements of arsenic and small amounts of nickel does not match the arsenic copper used to produce copper objects in the Northern Group of the Funnel Beaker societies within the Early Neolithic period. These objects made from this specific copper mostly also contain traces of antimony, silver, and small amounts of nickel in addition to the predominant trace element of arsenic.

Metallurgical tool from Kotowo, Greater Poland Voivodeship (Poland)

Due to the very close vicinity to other evidence from Nadrensee and Neuenkirchen (see below), the tuyère of Kotowo is included here as evidence for metallurgy, although, technically, the site belongs to the Eastern Group of the Funnel Beaker societies. The tuyère was found in a settlement feature with other pottery belonging to the earliest developmental phase of the Eastern Group of the Funnel Beaker

societies (Żurkiewicz et al. 2023). Energy-dispersive X-ray fluorescence spectroscopy performed on the inner surface of the tuyère showed considerable traces of copper, proving that the object was directly involved in metal working (Żurkiewicz et al. 2023, 424–425).

From the feature, which was at least temporarily used as a metal workshop, several samples for radiocarbon dating were obtained. The combined dates place the workshop activity in a time bracket between 3911–3714 cal BC (68.5 % probability; 3942–3708 cal BC, 95 % probability; Żurkiewicz et al. 2023, 423–424). These are not only the oldest dates for a Funnel Beaker community of the first developmental phase of the Funnel Beaker societies – the Eastern Group in Greater Poland (Żurkiewicz 2023, 11) – but also the oldest evidence of advanced metallurgy in close vicinity to the Northern Group of the Funnel Beaker societies. This hints towards an influx of the metalworking technology into the Funnel Beaker communities via the Lengyel-Polgár Circle (Żurkiewicz et al. 2023, 430).

Hot-shorting as evidence for metallurgical activities

In addition to the hard evidence in the form of metallurgical equipment from Lønt and Kotowo, a specific damage pattern called »hot-shorting,« introduced here, is interpreted as proof of metallurgical activity. From the copper object inventory of the Funnel Beaker North Group, a number of damaged objects can be observed. Although damage also occurs in other object types³, it is best observable in flat axes, which are generally better preserved due to their massiveness. For nearly 14 % of the 118 known pieces, different damage patterns such as bending, weakening of the structural integrity of the axe body, and blows against the neck have been documented (Fig. 3; Klassen 2000, 278–279). Other examples are known from the band spiral, sheet-metal fragment, and the



Fig. 3 Damage types observed on flat axes of the Funnel Beaker societies (Northern Group) and sites with evidence of metallurgy.

Abb. 3 Schadensarten an Flachbeilen der Trichterbechergesellschaften (Nordgruppe) und Fundorte mit Nachweisen von Metallurgie.

³ E.g., daggers or band spirals; Skorna 2022, 57.

dagger of Neuenkirchen (Skorna 2022, 53–54), but also from the dagger of Bygholm (Klassen 2000, Pl. 94F).

Although these damage types have already been described in the existing literature⁴, a unique and specific type of damage has remained unnoticed in relation to the inventory of copper objects from the Funnel Beaker societies of the Northern Group: the so-called hot-shorting. Hot-shorting, also known as »Warmbrüchigkeit« in German, refers to a phenomenon observed in copper(-alloy) objects when they are heated beyond a specific temperature (usually up to 600–700°C, and higher in the case of bronze). This extreme heat generates significant thermal stress within the material, causing it to fracture even under minimal pressure⁵. Depending on the temperature, even a slight touch leads to separation into pieces with no or only marginal deformation or further fragmentation (Knight 2019, 252). This can be caused by several elements which are either added to improve the workability or the general properties of the copper(-alloy). For example, in the British Late Bronze Age, the bronze is alloyed with tin and lead (Knight 2019, 252; Knight 2022, 16). As the segregated lead has a lower melting point than the copper/tin alloy, it increases the chance of a fracture when (over-)heated and worked. Certain other elements can also increase the likelihood of fractures. These elements do not have to be necessarily deliberately added during the production but can also be already present in the mined ore. Already 0.005% bismuth can result in hot-shorting, as the melting of the bismuth along grain boundaries destroys the internal structure of the copper (Stahl 1925, 421–422; Dies 1967, 676; Junk 2003, 29–30). Moreover, antimony is known to cause brittleness and red-fracture (breaking when red-hot). Copper with an antimony level of 1% is also reported to be extremely prone to hot-shorting. K. Dies (1967, 676) even calls it a harmful element to copper and copper alloys. While certain trace elements increase the likelihood of an axe hot-shorting, the main reason is that the work piece is being annealed

too intensely or worked in a red-hot state (Kuijpers 2018, 122). This is usually considered to be a mistake made by an inexperienced metal worker (Kuijpers 2018, 220; 232). More importantly, deliberately destroyed objects exploiting the hot-shorting of copper(-alloys) are also known. M. Kuijpers (2018) lists several examples of the Early Bronze Age and the Copper Age, with one example being possibly hot-shorted deliberately (Axe 329, Kuijpers 2018, 181). M.G. Knight (2022, 66; 105) lists several examples of deliberately hot-shorted objects originating from Late Bronze Age depositions in southern Britain. So far, most of the cases are known from the Bronze Age. This is probably due to the smaller number of early copper objects but also to a research desideratum. In general, the number of hot-shorted objects seems to be rather low, but the damage pattern may also have been overlooked or not recognised, as in the case of the Northern Group Funnel Beaker societies and probably also in the remaining Funnel Beaker groups.

Hot-shorting examples in the Northern Group of the Funnel Beaker societies

As shown above, the access to metallurgical knowledge can be evaluated using damage analysis, which can confirm the presence of hot-shorting. In the following, three examples of hot-shorted flat axes are described (Fig. 3).

Neuenkirchen, Mecklenburgische Seenplatte district

The flat axe of Neuenkirchen is part of an ensemble of five copper objects found during construction work. The hoard consists of a dagger, a large arm spiral, a band spiral, a sheet-metal fragment probably belonging to a pendant, and the aforementioned fragment of a flat axe (Fig. 2–6) and can be dated to around 3800/3700 BC (Skorna 2022, 135). All

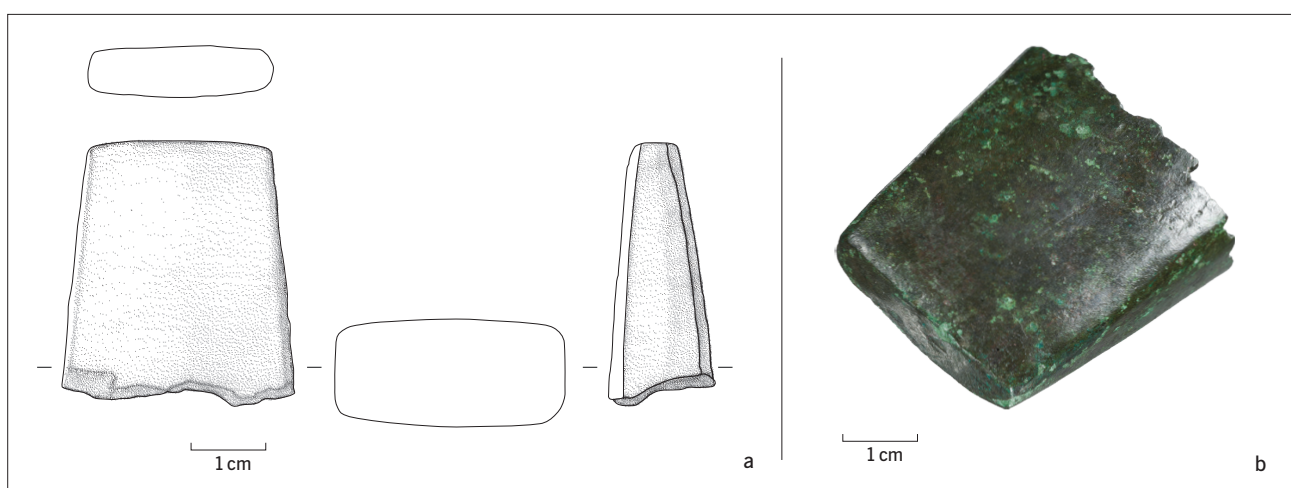


Fig. 4a–b The hot-shorted flat axe from Neuenkirchen, Mecklenburgische Seenplatte district.

Abb. 4a–b Das warmbrüchige Flachbeil von Neuenkirchen, Lkr. Mecklenburgische Seenplatte.

4 Amongst others, Klassen 2000 and Skorna 2022.

5 Untracht 1969, 18; Jantzen 2008; Kuijpers 2018, 127; Knight 2019, 252.



Fig. 5a–c Possible hammer mark and detailed fracture line on the flat axe of Neuenkirchen, Mecklenburgische Seenplatte district (b–c 60x magnification); no scale.

Abb. 5a–c Mögliche Hammerspuren und Details der Bruchlinie am Flachbeil von Neuenkirchen, Lkr. Mecklenburgische Seenplatte (b–c 60-fache Vergrößerung); o. M.

a	b
	c

objects appear to have been intentionally destroyed before they were deposited. The dagger, the flat axe fragment, and the band spiral exhibit clear signs of the destruction process. Due to their fragile nature and limited material thickness, this cannot be determined for certain for the sheet fragment and arm spiral.

A lead isotope analysis of the flat axe fragment has shown that the metal that was used to produce the object most likely originates from the eastern Serbian mines in Madjanpek, where mining during the Chalcolithic period has been proven (Pernicka et al. 1993; Antonović 2018). The use-wear analysis revealed several scratches, indentations, and dents on the object. Some of these can be attributed to the manufacturing process: for example, some of the grinding marks, which are evidence of the effort to work out superficial casting defects (Skorna 2022, 60–61). Others can be interpreted as signs of use: for example, the smaller indentations and isolated deeper scratches. One long oval indentation on one side of the flat axe blade stands out in particular, as it can be interpreted as a hammer blow (Fig. 5; Skorna 2022, 60; 84). The most prominent feature is the hot-short fragmentation pattern, which is clearly visible through the clean and sharp

break without any signs of bending of the flat axe (Fig. 5–6). Together with the hammer blow, this can be interpreted as a deliberate hot-short to fracture the flat axe before deposition. Other objects such as the dagger and the band spiral of the hoard find of Neunkirchen were also intentionally destroyed (Skorna 2022, 56–57), underlining the argumentation that the flat axe met the same fate.

Lackalända, Scania (Sweden)

Two other possible examples of hot-shortening originate from a two-piece hoard from Swedish Lackalända (Fig 3; 7), where two flat axes were deposited in a fragmented state. As these flat axes could not be examined in person by the author, one has to rely on the published illustration by Klassen (2000, Pl. 27,100A–B). Judging from the drawings, a clear fracture typical for hot-shortened objects can be observed. As this is the only example where both fragments of a hot-shortened flat axe were preserved, it is clearly visible that no bending along the longitudinal axis is present. Furthermore, there is no observable displaced material at the fracture lines, as

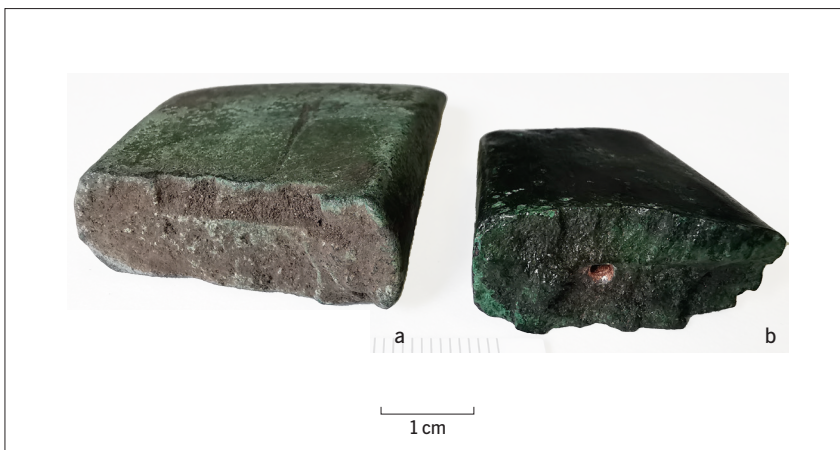
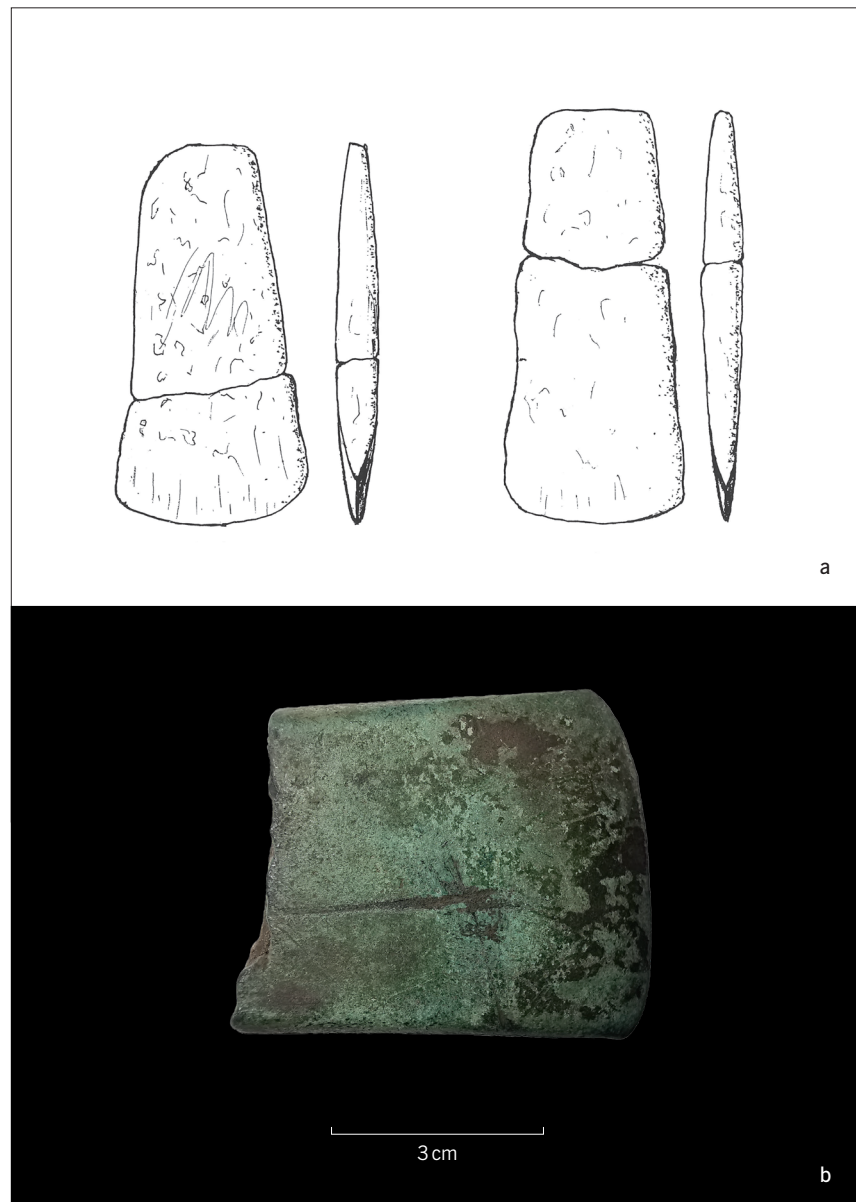


Fig. 6a–b The flat axe fragments of Nadrensee, Vorpommern-Greifswald district (a), and Neuenkirchen, Mecklenburgische Seenplatte district (b), exhibiting the clear sharp fracture of hot-shorts

Abb. 6a–b Flachbeilfragmente von Nadrensee, Lkr. Vorpommern-Greifswald (a), und Neuenkirchen, Lkr. Mecklenburgische Seenplatte (b), mit der klaren, scharfen Bruchkante eines Warmbruchs.

Fig. 7a–b The possible hot-shorts from Lackalända, Scania (a), and Nadrensee, Vorpommern-Greifswald district (b).

Abb. 7a–b Mögliche Warmbrüche von Lackalända, Skåne (a), und Nadrensee, Lkr. Vorpommern-Greifswald (a).



was the case, for example, with a flat axe from South Funen (Klassen 2000, Pl. 4,19). One would expect such observable displaced material if bending or forceful impacts caused the breakage. With some caution, both pieces from Lackalända can thus be classified as hot-shorts.

Nadrensee, Vorpommern-Greifswald district

The flat axe fragment from Nadrensee was found by a metal detectorist (Schirren 2008, 265). The site is roughly 70 km south-east of the site of the hoard find from Neuenkirchen (Fig. 3). The fragment likely belonged to a formerly trapezoid axe with an asymmetric cutting edge and slightly pronounced cutting corners. A clear typological classification is not possible due to the fragmented nature of the find, but several comparable examples of trapezoid axes are known from the Northern Group of the Funnel Beaker societies (e.g., from Kulebjerg Skov, Sorø Municipality [Denmark]; Klassen 2000, Pl. 7,30). Although, unfortunately, the fragment has

not yet been subjected to a detailed use-wear analysis, several deeper and shallower scratches can be observed already with the naked eye. Other damage patterns, which could indicate hammer blows or other forceful impacts, are not visible. As with the flat axe from Neuenkirchen, the flat axe fragment from Nadrensee exhibits a clear and sharp fracture of a typical hot-short without visible bending along the longitudinal axis or further damage (Fig. 6–7).

As was shown above, the practice of destroying metal objects before depositing them into the ground is well known within the Funnel Beaker communities. We can therefore assume that the knowledge about the properties of copper as well as the skill of hot-working the metal were used to deliberately destroy objects, exploiting the hot-shortening of copper. Hot-shortened flat axes are therefore a telltale sign for metallurgical knowledge in the Northern Group of the Funnel Beaker societies. These hot-shortened objects implicate the presence of a metalworker with a command of pyro-technology, the necessary equipment, and sound material knowledge (Knight 2022, 158).

Conclusion – A »little« Copper Age?

The deliberate fragmentation of copper flat axes by hot-shortening constitutes compelling evidence for metallurgy in the Early Neolithic Northern Group of Funnel Beaker societies. In addition, with the metallurgical tools from Lønt and Kotowo, the evidence deepens the impression of an independent production of copper objects in the Western Baltic region during the Early Neolithic (4100/4000–3300 BC). The radiocarbon dates from Kotowo and stratigraphical and typological evidence from Lønt, as well as the typological information gathered from the hoard find of Neuenkirchen, push the start of this development back into the first centuries of the 4th millennium BC – far earlier than previously thought. The hot-shortened flat axes from Neuenkirchen and Nadrensee, and the metallurgical activities they involve, close the gap in metallurgical knowledge between Lønt and Kotowo. Mecklenburg-Western Pomerania thus appears to have served as the gateway for the transfer of knowledge as well as transformational ideas between the Eastern Group and the Northern Group of the Funnel Beaker societies. This observation strengthens the idea of the influx of such technological innovations via the Lengyel-Polgar Circle, as Žurkiewicz et al. (2023, 430) have proposed. The scarcity of metallurgical evidence is most likely due to the lack of sources, as not many larger settlements with multi-

ple house plans (as in the Alpine pile dwellings) are known from the Western Baltic, where one would expect to find metal workshops. For example, from Mecklenburg-Western Pomerania only seven house plans are known, and the research has to rely on rare cases of good preservation such as in Lønt, where Neolithic strata were preserved under megalithic graves. Another factor could be that hot-shortened objects have perhaps not been identified as such and that, therefore, evidence for the metallurgical practice has not been recognised. Lately this hypothesis has gained more attention through the works of Kuijpers (2018) and Knight (2018), and more examples of hot-shortened material are being identified that were previously overlooked, as in the cases of Neuenkirchen, Nadrensee, and Lackalända. The variety of local forms, the growing evidence in the form of tools, and the hot-shortened flat axes point to the fact that one has to expect lively metallurgical activity, especially in the »boom time« between 3500 and 3300 BC. The evidence for mining ore and smelting is missing for the Funnel Beaker societies of the Northern Group, and they most likely had to rely on imports in the form of readymade products from the metallurgical centre of the Mondsee Group or directly from the sources in South-Eastern Europe. Nevertheless, the proven metallurgical activities are enough to propose a Copper Age in the Western Baltic region starting no later than 3500 BC and lasting only until 3300 BC.

Bibliography

Antonović 2018

D. Antonović, Eneolithic copper mines in the Balkans. In: J. Balen/I. Migolav/D. Rajković (eds.), *Back to the past. Copper Age in Northern Croatia* (Zagreb 2018) 187–209, doi:10.17234/9789531758185.

Brozio et al. 2023

J. P. Brozio/Z. Stos Gale/J. Müller/N. Müller-Scheeßel/H. Skorna et al., The origin of Neolithic copper on the central Northern European plain and in Southern Scandinavia: Connectivities on a European scale. *PLOS ONE* 18,5, e0283007, doi:10.1371/journal.pone.0283007.

Dies 1967

K. Dies, *Kupfer und Kupferlegierungen in der Technik* (Berlin, Heidelberg, New York 1967).

Frank/Pernicka 2012

C. Frank/E. Pernicka, Copper artifacts of the Mondsee group and their possible sources. In: M. S. Midgley/J. Sanders (eds.), *Lake Dwellings after Robert Munro. Proceedings from the Munro International Seminar: The Lake Dwellings of Europe 22nd and 23rd October 2010*, University of Edinburgh (Edinburgh 2012) 113–138.

Gebauer et al. 2021

A. B. Gebauer/L. V. Sørensen/M. Taube/D. K. P. Wielandt, First Metallurgy in Northern Europe. Early Neolithic Crucible and a possible Tuyère from Lønt, Denmark. *European Journal Arch.* 24,1, 2021, 1–21.

Jantzen 2008

D. Jantzen, *Quellen zur Metallverarbeitung im nordischen Kreis der Bronzezeit*. PBF 19,2 (Stuttgart 2008).

Junk 2003

M. Junk, Material properties of copper alloys containing arsenic, antimony, and bismuth.

The material of Early Bronze Age ingot torques. Unpubl. Diss. TU Bergakademie Freiberg (Freiberger 2003), <https://nbn-resolving.de/urn:nbn:de:swb:105-1299566> (31.05.2024).

Klassen 2000

L. Klassen, Frühes Kupfer im Norden. Untersuchungen zu Chronologie, Herkunft und Bedeutung der Kupferfunde der Nordgruppe der Trichterbecherkultur. *Jutland Arch. Soc.* 36 (Aarhus 2000).

Klassen 2004

L. Klassen, Jade und Kupfer. Untersuchungen zum Neolithisierungsprozess im westlichen Ostseeraum unter besonderer Berücksichtigung der Kulturentwicklung Europas 5500–3500 BC (Højbjerg 2004).

Klassen/Stürüp 2001

L. Klassen/S. Stürüp, Decoding the Riesebusch-copper. Lead-isotope analysis applied to early neolithic copper finds from south Scandinavia. *Prähist. Zeitschr.* 76,1, 2001, 55–73.

Knight 2019

M. G. Knight, Going to Pieces: Investigating the Deliberate Destruction of Late Bronze Age Swords and Spearheads. *Proc. Prehist. Soc.* 85, 2019, 251–272, doi:10.1017/ppr.2019.3.

Knight 2022

M. G. Knight, Fragments of the Bronze Age. The Destruction and Deposition of Metalwork in South-West Britain and its Wider Context. *Prehist. Soc. Research Paper* 13 (Oxford, Philadelphia 2022).

Kuijpers 2018

H. G. Kuijpers, An archaeology of skill. Metalworking skill and material specialization in early Bronze Age Central Europe. *Routledge Stud. Arch.* 29 (Abingdon, Oxon, New York 2018).

Liversage 1992

D. Liversage, Barkær. Long barrows and settlements. *Ark. Stud.* 9 (København 1992).

Matuschik 1998

I. Matuschik, Kupferfunde und Metallurgie-Belege, zugleich ein Beitrag zur Geschichte der kupferzeitlichen Dolche Mittel-, Ost- und Südosteuropas. In: M. Mainberger (ed.), *Das Moordorf von Reute. Archäologische Untersuchungen in der jungneolithischen Siedlung Reute-Schorrenried* (Staufen 1998) 207–261.

Nørgaard et al. 2021

H. Nørgaard/E. Pernicka/H. Vandkilde, Shifting networks and mixing metals: Changing metal trade routes to Scandinavia correlate with Neolithic and Bronze Age transformations. *PLOS ONE* 16,6, 2021, 1–42, doi:10.1371/journal.pone.0252376.

Pernicka et al. 1993

E. Pernicka/F. Begemann/S. Schmitt-Strecker/G. A. Wagner, Eneolithic and Early Bronze Age copper artefacts from the Balkans and their relation to Serbian copper ores. *Prähist. Zeitschr.* 68,1, 1993, 1–54, doi:10.1515/prh.1993.68.1.1.

Rehren et al. 2012

T. Rehren/L. Boscher/E. Pernicka, Large scale smelting of speiss and arsenical copper at Early Bronze Age Arisman, Iran. *Journal Arch. Scien.* 39,6, 2012, 1717–1727, doi:10.1016/j.jas.2012.01.009.

Rosenstock et al. 2016

E. Rosenstock/S. Scharl/W. Schier, Ex oriente lux? – Ein Diskussionsbeitrag zur Stellung der frühen Kupfermetallurgie Südosteuropas. In: M. Bartelheim/B. Horejs/R. Krauß (eds.), *Von Baden bis Troia. Ressourcennutzung, Metallurgie und Wissenstransfer. Eine Jubiläums-*

schrift für Ernst Pernicka. *Orient. European Arch.* 3 (Rahden/Westf. 2016) 59–122.

Schirren 2008

M. Schirren, *Kurze Fundberichte. Stichwort Nadrensee, Lkr. Uecker- Randow. Jahrb. Bodendenkmalpfl. Mecklenburg* 55, 2008, 265.

Skorna 2022

H. Skorna, *The life and journey of Neolithic*

copper objects. Transformations of the Neuenkirchen hoard, North-East Germany (3800 BCE). Scales Transformation 15 (Leiden 2022).

Stahl 1925

W. Stahl, *Über wismuthaltiges Kupfer. Metall u. Erz* 22,17, 1925, 421–422.

Untracht 1969

O. Untracht, *Metal techniques for craftsmen.*

A basic manual for craftsmen on the methods of forming and decorating metals (London 1969).

Żurkiewicz et al. 2023

D. Żurkiewicz/M. Stróżyk/A. Garbacz-Klempka/M. Szmyt/P. Silska, *The earliest traces of metallurgy in Greater Poland. Doc. Praehist.* 50, 2023, 420–433, doi:10.4312/dp.50.9.

Source of figures

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|---|--|---|--|
| 1 | after Brozio et al. 2023, 3 Fig. 1 | 5 | Skorna 2022, 61 Fig. 21 |
| 2 | Skorna 2022, 49 Fig. 17 (Photo A. Heitmann, Kiel University) | 6 | author |
| 3 | author; made with Natural Earth CC0 public domain | 7 | a Klassen 2000, Pl. 27,100A–B;
b author |
| 4 | a Skorna 2022, 192 Pl. 2a;
b Skorna 2022, 194 Pl. 4c | | |

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