

First Metallurgy in Northern Europe: An Early Neolithic Crucible and a Possible Tuyère from Lønt, Denmark

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In this article we present the fragments of a crucible and a possible tuyère that provide evidence of early copper metallurgy in Scandinavia at least 1500 years earlier than previously thought. The technical ceramics were found in a cultural layer containing Early Neolithic Funnel Beaker pottery dating to around 3800–3500 BC beneath a long barrow dating to 3300–3100 BC. The presence of a copper alloy in the crucible is confirmed by three independent X-ray fluorescence analyses using both a hand-held and a stationary instrument, SEM-EDS analysis of a cross-section, as well as a Bruker Tornado μ -X-Ray-fluorescence scanner (μ -XRF). The transmission of metallurgy to southern Scandinavia coincided with the introduction of long barrows, causewayed enclosures, two-aisled houses, and certain types of artefacts. Thus, metallurgy seems to be part of the new networks that enabled the establishment of a fully Neolithic society.

Keywords: metallurgy, copper, crucible, Early Neolithic Funnel Beaker culture, Denmark, X-ray fluorescence analysis

INTRODUCTION

Neolithic Denmark is exceptionally rich in copper artefacts from during the Early Neolithic period of the Funnel Beaker culture, dating to 4000–3300 BC (Klassen, 2000: fig. 111; Sørensen, 2014: 159; Price & Gebauer, 2017) (Figure 1). Copper artefacts were brought to southern Scandinavia in such large quantities that, in terms of weight, the quantity of metal found here far exceeds the amount found in the Alpine region and the areas between Scandinavia and the Alps (Klassen, 2000:

273, 2014a: 228). However, no evidence has been found so far that metallurgy was mastered and practised in southern Scandinavia before the Bronze Age. Actual smelting sites are missing, and neither slag nor technical ceramics such as furnaces, crucibles, or tuyères have been found (Vandkilde, 1996: 262; Sørensen, 2014: 175). Nevertheless, the possibility of local metalworking has been discussed for decades (Glob, 1952: 38; Midgley, 1992: 298; Klassen, 2000: 225; Melheim, 2015: 139). The discovery of some crudely-made copper flat axes, perhaps locally made in

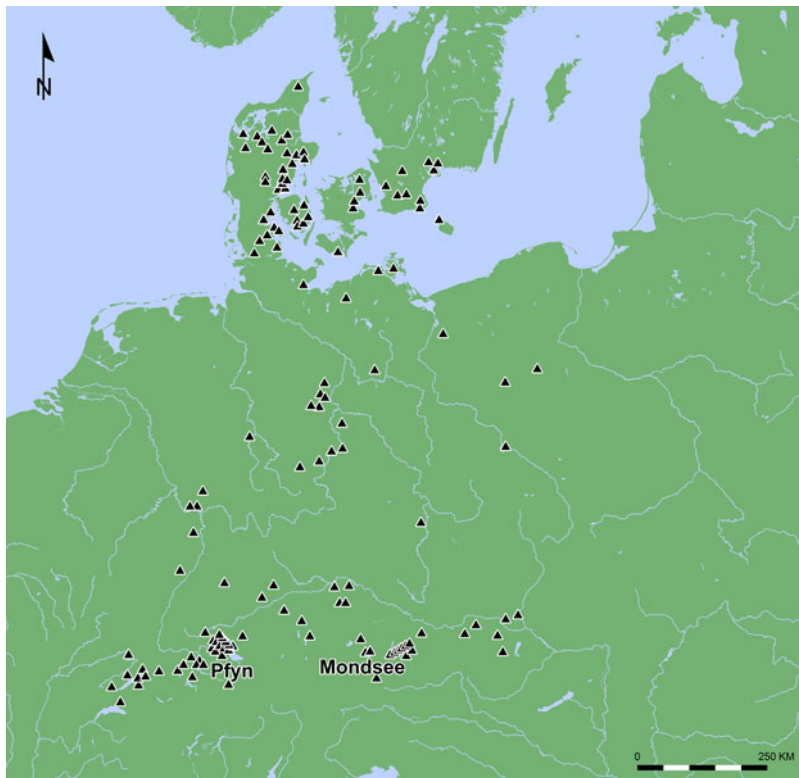


Figure 1. Distribution of artefacts made with Mondsee copper in central and northern Europe.

southern Scandinavia, suggest that pyro-technical knowledge may have followed the copper metal in long-distance movement to northern Europe along the river systems (Klassen, 2010: 40; Roberts & Frieman, 2015: 717). Furthermore, studies by Klassen show that many copper objects, especially the flat axes, were re-melted and cast into new shapes with the aim of creating larger and heavier axes, more impressive than the original imports (Klassen, 2010: 39). The average weight of copper flat axes in the northern Funnel Beaker culture is 381 g (range 100–1200 g), while the average weight of two groups of flat axes from the Alpine area are 222 g (range 50–650 g) and 151 g (range 50–250 g) respectively (Klassen, 2000: 227, fig. 105). Along with the demand for copper

adornments and expressions of identity, the potential of re-melting, re-casting, and re-modelling the metal objects may also have played an important role in the development of early metallurgy in southern Scandinavia.

The discovery of a crucible and a possible tuyère in a secure context dating to the Early Neolithic Funnel Beaker culture (3800–3300 BC) beneath a long barrow dating to 3300–3100 BC at Lønt in Haderslev in southern Jutland is the first evidence that melting of copper actually took place in the northern group of the Funnel Beaker culture. The two pieces of technical ceramics *predate* the previously known evidence for early Scandinavian metallurgy by more than 1500 years (Jensen, 2002: 117).

THE EARLY NEOLITHIC CONTEXT OF THE CRUCIBLE

The crucible and possible tuyère were found in a research excavation for the National Museum at Lønt in 1987 by Erik Jørgensen, but only recognized and interpreted as objects related to metallurgy by the current authors in relation to a new study of the material in 2012. Since 1987, the artefacts have been stored at the National Museum. Lønt is the site of a megalithic cemetery with eleven tombs and two causewayed enclosures located on the southern shore of Haderslev Fjord in south-eastern Jutland in Denmark (Jørgensen, 1983a & b, 1988a & b; Gebauer, 2016) (Figure 2). The Starup Langelandsvej enclosure is one of the oldest in the northern Funnel Beaker group with pooled average of ^{14}C dates at 3693–3526 cal BC (2σ) (Pedersen, 2008; Pedersen & Witte, 2012; Klassen, 2014a: 202; Sørensen, 2014: 224).

The fragments of the crucible and possible tuyère were found on the original Neolithic surface buried beneath the mound of the second dolmen in a long barrow that included four megalithic tombs (Jørgensen, 1988a: 204–07 a & b, 1988b, 2000: 95; Gebauer, 2014, 2016) (Figure 3). The Neolithic surface was primarily preserved beneath the two round dolmens in the middle of the long barrow. The first tomb, a closed dolmen chamber, is dated to an early part of period MN I by nine vessels placed in a circle around the circular mound. The construction of all four tombs dates from period MN I of the Danish Funnel Beaker period, around 3300–3100 BC (Dehn & Hansen, 2006: 22 fig. 9; Eriksen et al., 2014: 52; Hansen, 2016: 14). Based on the stratigraphic evidence, the tombs provide a *terminus ante quem* for the crucible and possible tuyère of the Early Neolithic

Funnel Beaker period, i.e. a period dated to 4000–3300 BC.

An Early Neolithic date is supported by the domestic pottery found together with the technical ceramics. A total of 889 sherds were found in the sealed Neolithic surface, including 146 decorated and 746 undecorated sherds. Due to fragmentation, only the shapes of five funnel neck beakers, four clay discs, a lug possibly from a lugged jar, and five flat bases were identified. Crusts of food were observed on five fragments. Only the ceramics were analysed; a small amount of flint debris was not available for this analysis (Jørgensen, 1988a: 204).

The dates and distribution of the domestic pottery indicate that two periods of activity are represented. The pottery found west of chamber II together with the crucible and possible tuyère is dated to EN Ib (3800–3650 BC) on the basis of funnel neck beakers of type III (Nielsen, 2009: 15), a Vølling-style beaker (Klassen, 2004: 246; Ravn, 2011), and decorated rim sherds associated with the Siggeneben Süd-Stengade II group (Madsen, 1994; Klassen, 2004: 241; Müller, 2011: fig. 4; Andersen, 2015: 120), alongside a number of undecorated body sherds (Figure 3, white squares).

The later pottery, dating to EN II (3500–3300 BC), was primarily found in the eastern part of the cultural layer around chamber I (Figure 3, green squares). This material included sherds of two vessels decorated in Fuchberg style, two clay discs, and thirty-six sherds with vertical belly striations (Andersen & Madsen, 1978; Jørgensen, 1988a: 204 fig. 14; Schirren, 1997: 178; Andersen, 1998: 145, 162). Two undecorated clay discs and the undecorated body sherds can only be dated to the Early Neolithic.

The crucible and the possible tuyère are dated to 3800–3500 BC based on their

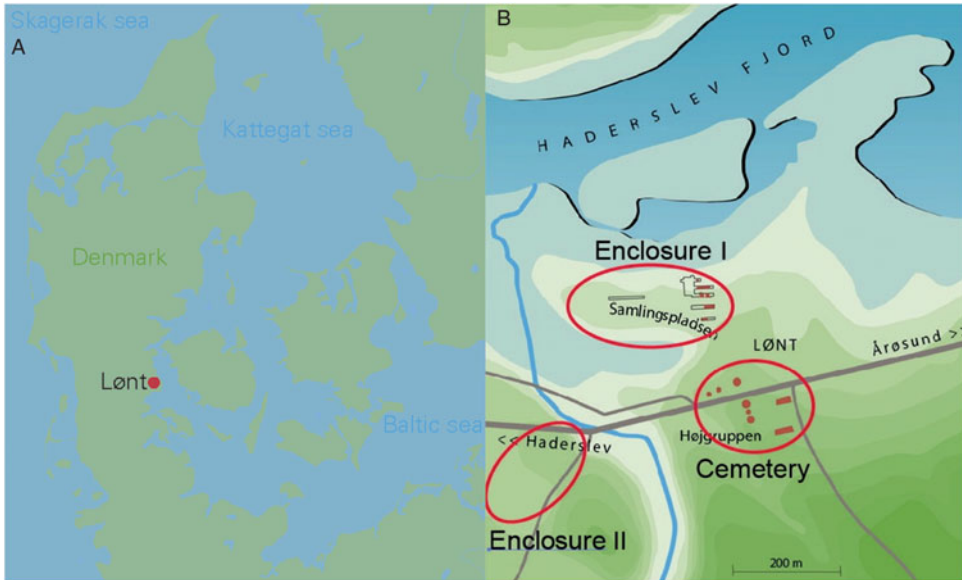


Figure 2. A. The location of Lønt in Denmark; B. Map of the Lønt area. The crucible was found beneath the southern long mound. The megalithic cemetery is located 250 m south and 600 m east of the two enclosures (after Gebauer, 2016, fig. 13.2).

association with pottery dating from late EN I and the absence of pottery from EN II in the area west of chamber II. The older part of the cultural layer represents the first activities at the Lønt cemetery and is coeval with the neighbouring Starup Langelandsvej enclosure.

THE CRUCIBLE

Nine fragments of a crucible were found, three of which conjoin (Figure 4). The vessel is made of lumps of clay pressed together with the fingers, unlike the coil-built domestic Funnel Beaker pottery. Despite its incomplete state, it is clearly a shallow vessel with a wide mouth, a form that allows the greatest area of contact between metal and charcoal. The shape is oblong oval and 10 cm minimum in length (Figure 4, B–D). No spout or handle was preserved. The base of the vessel is thick, measuring 3.6 cm, while

the thickness of the vessel wall tapers off to 0.8 cm at the rim. The shape with the heavy base is important for heat retention in crucibles that are heated from above (Martinon-Torres & Rehren, 2014: 120). The highly porous fabric of more than 75 per cent quartz (sand) tempered with burnt flint ensured the refractoriness of the crucible, i.e. the ability to withstand thermal shock and improved heat retention (Martinon-Torres & Rehren, 2014: 114; Vernon et al., 2019: 111).

The vessel is covered by a slurry of fine-grained silt and sand that forms a 0.2 cm thick layer on the surface, especially on the inside (Figure 4, A). This layer enhances the refractory qualities of the crucible, reduces absorption of metal in the vessel wall, and enables reuse if the crucible remains intact (Martinon-Torres & Rehren, 2014: 124; Vernon et al., 2019: 113). The crucible is reddish with the lower part of the inside wall coloured white from high thermal impact (Figure 4, A). The centre of

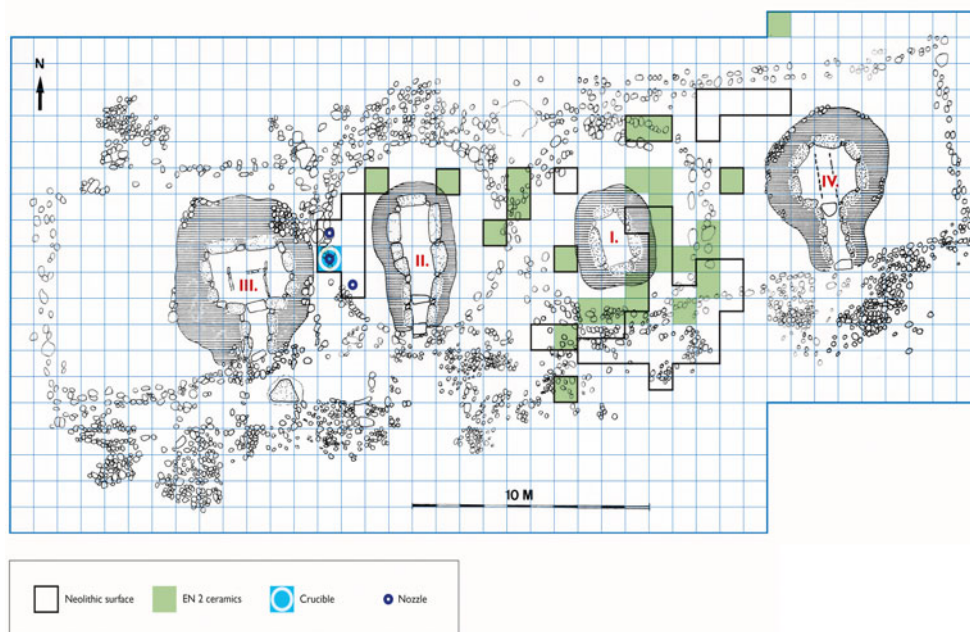


Figure 3. The long mound with four megalithic chambers at Lønt. The cultural layer was mainly below the two round dolmens in the middle, chambers I and II. The crucible and the putative tuyère were found beneath the mound covering chamber II (blue square). Only pottery dating from EN I was found in the immediate area around the crucible and possible tuyère. Pottery dating from EN II was distributed further east (green squares). Illustration by Frank Ruszkay.

the vessel wall is grey. There is no visible vitrification of the surface.

Based on the physical attributes alone—the shape of the vessel, the fabric, the coating with a slurry, as well as the heat impact on part of the interior—the crucible from Lønt was interpreted by Gebauer and Sørensen as a vessel for processing metal. Further verification of this interpretation came from comparison with other European finds and instrumental analyses.

European crucibles

Although the Lønt crucible is incomplete, the shape and measurements are compatible with contemporary crucibles found in continental Europe (Strahm, 1994, Strahm et al., 2013) (Figure 5). These crucibles are

round or oblong and may have a handle; measurements vary between 13 and 18 cm in length, 8 and 12 cm in width, and about 5 cm in height (Strahm, 2010: 378). A heavy base and porous, quartz-rich fabric is typical. The effect of high heat is visible in the interior of the vessel, with evidence of vitrification at the rim and transition to the handle due to the heat being provided from above (Martinon-Torres & Rehren, 2014: 113). Some crucibles show less thermal impact and not all crucibles show traces of metal (Strahm, 2010: catalogue no. 320), which perhaps suggests that they were not used (Melheim et al., 2016: 55). Most crucibles have been found in the Alpine area, only a few in central Europe, and none north of Harzen, Germany (Schlichterle & Rottländer, 1982).

The crucibles may have been used for smelting ore as well as melting metal for

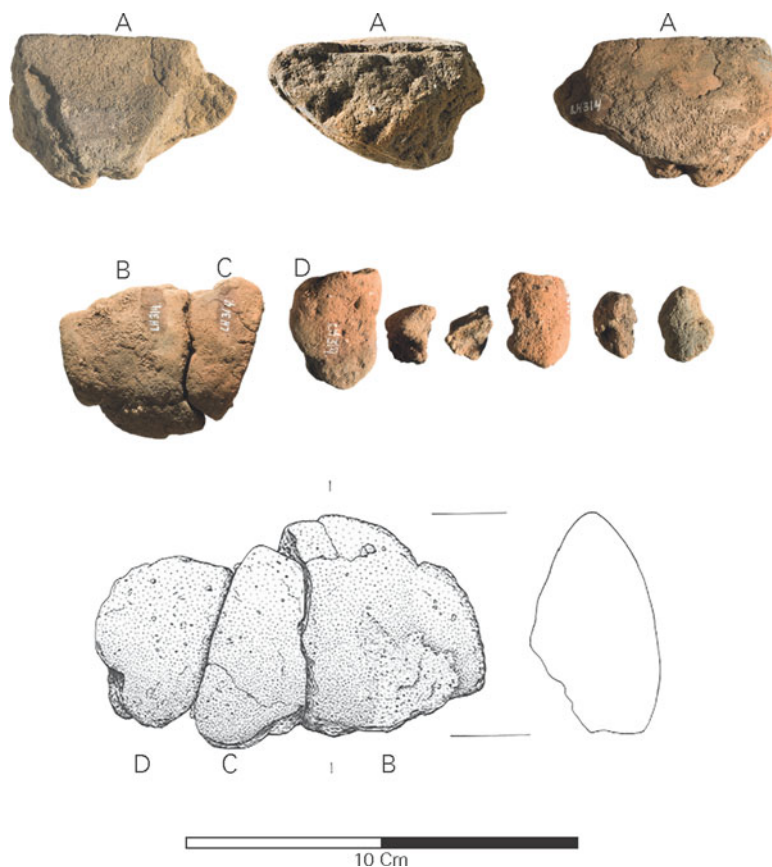


Figure 4. The nine crucible fragments from Lønt. *A.* The largest and best-preserved fragment with views of the interior with a whitish burnt area at the bottom, a cross-section, and the exterior showing its coating with a fine-grained slurry. The piece is lightly curved along the outer perimeter (9.1 cm long, 6.4 cm high, 0.7 cm thick at the rim and 3.6 cm thick toward the bottom of the object). *B.* The second-largest fragment has a stronger curvature (5.7 cm long, 5.7 cm high, 0.8 cm thick at the rim, maximum thickness 3.5 cm). The outer surface is only preserved on fragments *A* and *B*. Three matching fragments *B*, *C*, and *D* form a 10-cm-long curved piece (photographs by J. Lee, drawing by F. Oldenburg, illustration by M. L. Bendtsen, National Museum of Denmark).

casting (Martinon-Torres & Rehren, 2014: 111). The size of the crucibles was adequate for melting enough metal to produce common objects (Melheim et al., 2016: 62). For example, crucibles from the Pfyn culture hold 125–135 cm³ or the equivalent of 1.1–1.2 kg of copper, if filled to the brim (Schlichterle & Rottländer, 1982: 69). However, remnants of slag suggest that these crucibles were only filled halfway, to about 65 cm³ of copper, enough to produce two local copper flat axes weighing 295 g.

An average Scandinavian flat axe weighs 381 g, requiring 43 cm³ of copper.

Scientific analyses of the crucible

Several independent analyses demonstrate the presence of traces of copper (Cu) and arsenic (As) on/in the interior surface of the crucible. Copper was mainly detected in the whitish area with the most heat impact on the interior surface, but not in the rim area



Figure 5. Crucibles of the Pfyn culture from the sites of Zürich-Rentenanstalt, Wetzikon, and Robenhausen (after Strahm, 1994, fig 8). The crucible from Lont resembles the oval example, whose length is 17 cm. Reproduced by permission of Helvetia Archaeologica.

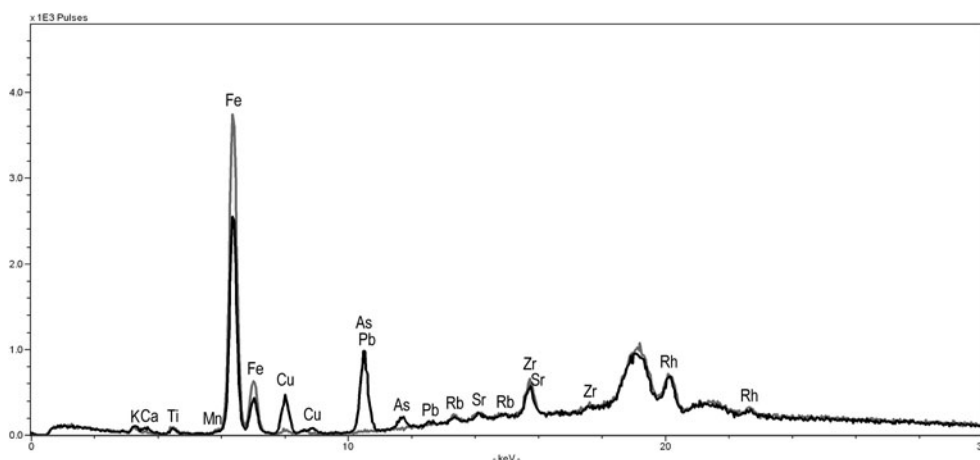


Figure 6. XRF spectra of the thin crust on the exterior of the crucible (grey line) and the whitish area on the interior (black line). Copper (Cu) and Arsenic (As) was found in the whitish area of the interior where the thermal impact was also most pronounced.

or on the outside of the object. In 2013, an X-ray fluorescence (XRF) analysis with a hand-held instrument was undertaken by Michelle Taube at the Laboratory for Environmental Archaeology and Material Science at the National Museum of Denmark (case no. 11042003) (Figure 6). In 2014, Arne Jouttijärvi at the Heimdal Archaeometry Laboratory carried out a scanning electron microscopy with energy dispersive analysis (SEM-EDS) on a cross-

section of the crucible and an XRF analysis with a stationary instrument (Jouttijärvi, 2014). The degree of penetration into the ceramic was low with a content of copper at about 0.1 per cent Cu in the thin surface layer, but no copper beyond a depth of 2 mm. Compared with Bronze Age crucibles, the lack of fractures in the grains of sand in the temper suggest a lower heat impact.

The third analysis, by Daniel Wielandt, involved a Bruker Tornado μ -X-Ray-

fluorescence (μ -XRF) scanner, hosted at the Quadlab research group of the Natural History Museum of Denmark, to map the elements present on the entire presumed inner surfaces of three of the fragments. Given the peculiarities of this type of instrument, as compared to, for example, an SEM, which is typically used for microanalytical studies, a description of the operating principles is warranted.

The Tornado provides comparatively rapid and high sensitivity mapping by scanning the sample stage under an intense and focused primary X-ray beam, generated by a rhodium X-ray tube. The primary X-rays are focused by polycapillary optics to an approximately $\approx 25 \mu\text{m}$ spot at the focal point on the sample, where they generate fluorescent X-rays from a comparable or larger region, providing an upper limit on the achievable resolution that is lower than an SEM. The resulting fluorescent X-rays are detected by a 30 mm^2 silicon drift detector energy dispersive spectrometer, which is capable of effectively identifying K-alpha and L-alpha emission from elements of interest for cuprolithic alloys, such as copper, arsenic, tin, antimony, and lead. Of critical importance for studies of rare, fragile, and irreplaceable materials, the sample preparation requirements are significantly relaxed compared to those of traditional electron microscope and microprobe analysis, at least for semi-quantitative mapping applications. The Tornado does not require destructive cutting and/or polishing, and the sample chamber can operate at atmospheric pressure and accommodates comparatively large, uncoated samples.

The mapping revealed enhanced levels of Cu in two of the three measured fragments (fragments A and B), with one fragment in particular showing significant coupled enrichment of Cu and As in a number of hotspots present on the most heat-affected area (fragment A) (Figure 7).

Although the heterogeneous nature, high X-ray penetration, and non-ideal geometry of the sample limits the accuracy and application of quantitative analysis, the built-in data reduction software suggests a substantial copper and arsenic component, summarized and illustrated in Table 1 and Figure 7. The Ob1-5 regions mark areas with significant Cu and As, while the Ob6-7 regions probe the composition of comparatively unaffected areas of the surface, reflecting a manner of background determination for the instrument and crucible material. Although Cu and As enrichments are coupled, the As is generally less variable at ≈ 1 per cent in the affected areas as opposed to Cu that varies between 6 per cent and 1 per cent. Elevated levels of nickel (Ni) also occur in the hotspot area with the highest apparent Cu concentration. The optical depth at Cu-K α X-ray energies is ≈ 50 microns, and the resulting large interaction volume would appear to dilute the elemental abundance; it is therefore possible that the Cu is in fact present as thinner flakes or particles of Cu metal close to the surface. These particles could have been transferred by direct contact. The As could be alloyed into these materials but given its more uniform distribution and the volatility of As, it could also have evaporated and then condensed in a more uniform pattern on the crucible surface during processing of the metal. Since an accurate quantitative measure of the amount of the individual minerals is not provided by the analysis, we cannot define a lower limit where the occurrence of other minerals may be excluded. However, it seems likely that the metal used in the crucible derives from a different type of arsenic copper than the copper used in trinkets and flat axes in southern Scandinavia during the Early Neolithic period. All these artefacts contain an amount of antimony (Sb) and silver (Ag) (Klassen, 2004: 66; Liversage,

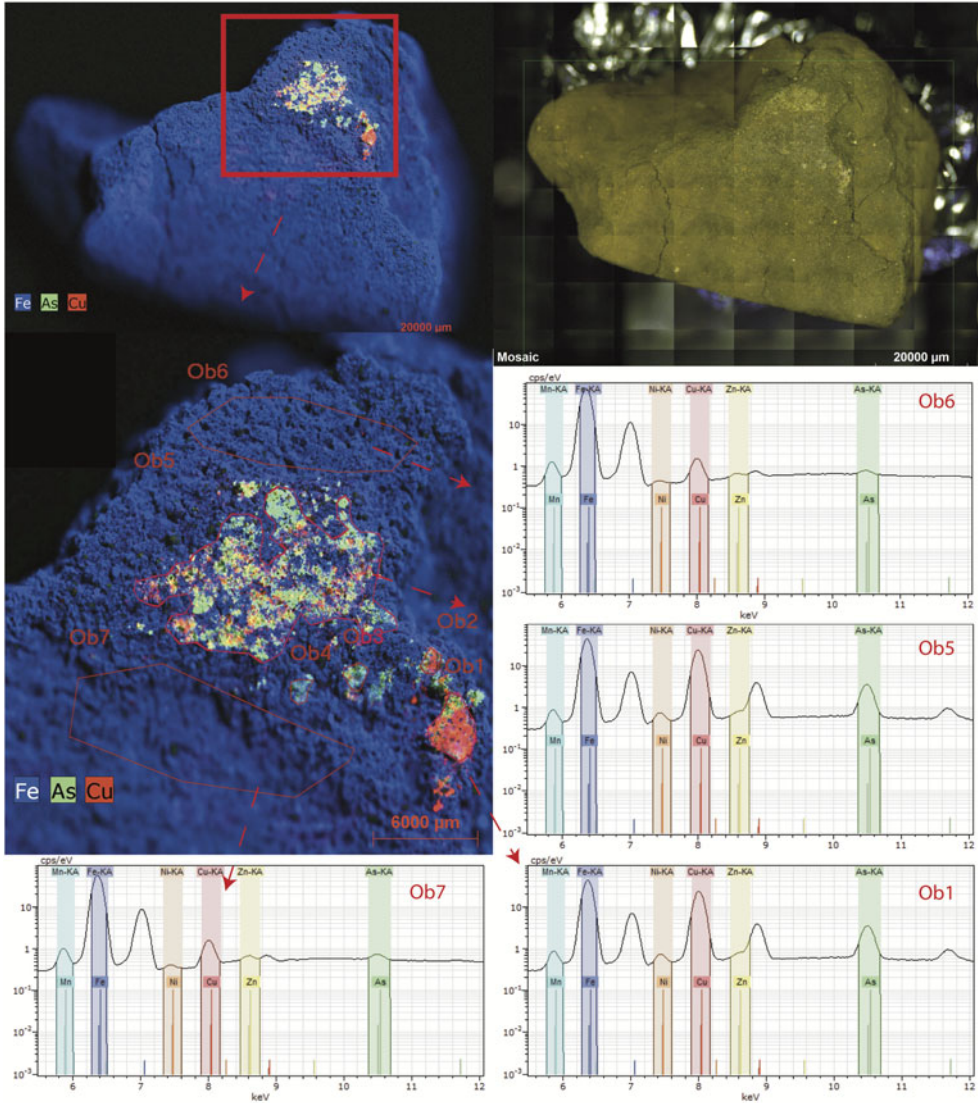


Figure 7. Optical mosaic image and FeAsCu (blue-green-red) K-alpha XRF maps and spectra generated with the Quadlab Tornado μ -XRF. The red-boxed area in the overview XRF (upper left) is shown in more detail in the middle left. The areas of interest with concentration data (Ob1–Ob7) are shown alongside logarithmic-scale spectra of selected areas. The heights of the multiple thin lines rising from the abscissa denote the approximate relative intensity of the various K-alpha and K-beta emission lines, coloured according to the general spectra scheme. Fe traces the shape of the crucible fragment, and the maps and spectra clearly reveal a number of superimposed Cu (red) and As (blue) hotspots. Background spectra collected in Ob6 and Ob7 show no or minor Cu, As and Ni K-alpha peaks, while Ob5 and Ob1 show significant increases above these levels (D. K. P. Wielandt).

1992: 97). An analysis of lead isotopes was not carried out due to difficulties in separating lead from the copper residue and the fabric of the crucible itself.

The crucible is interpreted as a vessel for processing metal based on the shape of the vessel, the fabric, the coating with a slurry, as well as the heat impact on the lower part

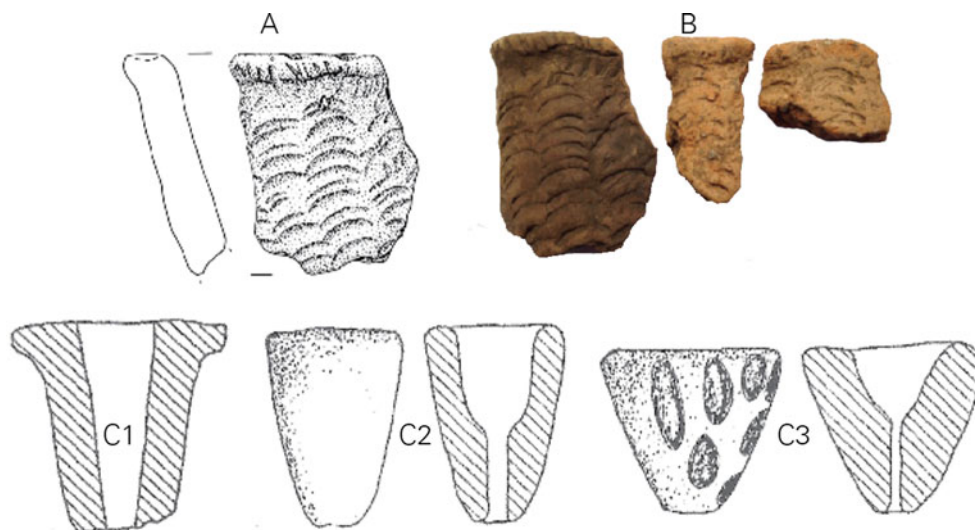


Figure 8. A and B: The possible tuyère from Lønt. Length and maximum diameter: 5 cm (drawing: F. Oldenburg; photograph: A.B. Gebauer, National Museum of Denmark). C: Examples of complete tuyères: Haid, Austria (C1; length: 4.6 cm); Sendschirli, Turkey (C2; length: 4.2 cm); Sialk, Iran (C3; length: 3.6 cm) Roden 1988: fig. 6.5; fig. 7, 1 and 3. Reproduced by permission of Der Anschnitt (illustration by M.L. Bendtsen, National Museum of Denmark).

Table 1. Abundance of selected elements in regions of interest, as suggested by the Tornado μ -XRF analysis (see Figure 5 for location of fragments and EDS spectra). Given the heterogenous nature of the sample and software limitations, these data are provided without individual error estimates. We estimate that the relative pure counting statistical error is always better than $\approx 10\%$ 2 sigma.

Element/Region	Ob1	Ob2	Ob3	Ob4	Ob5	Ob6	Ob7
Copper	6.2%	3.3%	1.1%	0.9%	1.6%	0.29%	0.4%
Arsenic	1.1%	0.93%	1.2%	1%	1%	0.056%	0.082%
Nickel	0.055%	0.016%	0.017%	0.013%	0.01%	0.016%	0.024%

of the interior. The scientific analyses confirm that the vessel has been in contact with molten copper. Substantial amounts of copper were found on fragment A by using an μ -X-Ray-fluorescence scanner. Some copper was also detected on fragment B, while no traces were found on the remaining fragments where the outer surface is eroded. According to Jouttijärvi (2014), the thermal impact was relatively modest given the lack of heat fractures and vitrification. The limited impact of heat may be explained by the thermal conductivity of the crucible, the amount of metal, the length of

the period of use, as well as control of the melting process. The content of arsenic may somewhat lower the melting point of the copper. Perhaps technological differences, e.g. using bellows rather than blow pipes, mean that heat fractures are more likely to occur in Bronze Age crucibles. Furthermore, parts of a crucible may not be vitrified, and vitrification is not seen in all Neolithic crucibles elsewhere in Europe.

Alternatively, the crucible may have been a 'holding crucible' used for excess metal in a casting process or for cooling the metal into an ingot (Vernon et al.,

2019: 110). The first option would be more likely as no evidence of ingots has been found in Scandinavia. The crucible is not considered to be a mould because of the heavy base, where the thickness of the vessel wall of moulds is more even (Winiger, 1971: pl. 79, 24–27). The shape of the rounded, oblong interior of the Lønt crucible is also different from the outline of known copper flat axes or trinkets from southern Scandinavia. One possible exception is the unique copper axe from Bedeager, Bornholm, that imitates a jadeite axe and is thought to be a local product, possibly from Zealand, Denmark (Klassen, 2010: fig. 1.40). However, this axe is one of a kind. Thus, the crucible from Lønt is interpreted as a vessel for melting copper or as a ‘holding crucible’ used for excess metal.

THE POSSIBLE TUYÈRE

A tuyère is a nozzle or ceramic tip protecting a blowpipe or a bellows of organic material from heat. The end of the tuyère facing the fire has a stricture that allows manipulation of the direction and quantity of the airflow in the crucible (Martinon-Torres & Rehren, 2014: 110). A socket-like piece with an almost bell-shaped outline is tentatively interpreted as a tuyère for a blow pipe (Jørgensen, 1988a: 204, fig. 14h; Roden, 1988: 68), although the end with the narrow air channel is missing (Figure 8). The surviving length of the artefact is 5 cm. The vessel wall is quite thick at 1 cm, while the diameter of the rim is 5 cm and 3 cm at the exterior and interior respectively. No indication of exposure to high heat was found, but that is usually not the case (Roden, 1988: 72; Bourgarit, 2007: 7). The dimensions and funnel-shape of the object indicate that it is not part of other Funnel Beaker objects with a similar restricted diameter and

strong curvature, such as collared flasks, clay ladles, biberons, or handles of vessels (Bakker, 1979: 57; Knöll, 1981: 26; Andersen, 2000: 35 fig. 14, 36 fig. 15; Wunderlich, 2012).

Almost no finds of tuyères predate the Bronze Age and very little is known about the kind of air supply used in early metallurgy. However, blow pipes are often suggested as the means of delivering air in small-scale crucible production (Roden, 1988; Thrane, 2006: 271; Krismer, 2013: 943; Vernon *et al.*, 2019: 122). In experimental work and Egyptian wall paintings, two to six pipes were used (Roden, 1988: fig. 1; Hauptmann, 2007: 221; Hamilton, 2018: 176). Small bell-shaped tuyères are usually associated with blow pipes. This kind of tuyère dates from the third millennium BC in the eastern Mediterranean and the Levant and the middle of the second millennium in central Europe around the middle Danube (Roden, 1988; Thrane, 2006: 271). Small bell-shaped tuyères have not been found previously in Denmark, but a larger type of tuyère with a perpendicular bend was introduced around 1300 BC in the late Bronze Age (Thrane, 2006: 271). Before the Bronze Age, only a few tuyères of unknown shape are associated with the Bell Beaker, Złota and Funnel Beaker cultures in Poland (Roden, 1988: 71; Midgley, 1992: 295). Two other cases of tube-like objects in Funnel Beaker contexts in the north are not considered to be tuyères since the interior diameter is the same along the whole length of the objects without the defining stricture at the end which, if they were nozzles, would face the fire (Andersen, 1999: fig. V.93.5; Hage, 2012, 235–39, 2016, fig. 132).

Decoration of the nozzle

The lip of the possible tuyère is decorated with fingertip imprints and vertical strokes

incised along the edge. The side is covered by curved strokes reminiscent of fingernail impressions but incised with a sharp tool and a few vertical strokes impressed with a short, curved tool with very fine teeth. The overall impression is that of a scaly skin (Figure 8, A and B).

The decoration is atypical of the Funnel Beaker culture, and no parallels have been found. Fingernail impressions were used in a few all-over designs dating from period EN I or early EN II in Denmark and Poland (Skaarup, 1975: 72–73 fig. 29.8, 80 fig. 36.2, 145 fig. 61.2; Meurers-Balke, 1983: pl. 22, 3; Pedersen, 2008: vessel 81; Papiernik, 2012: 222, 224 pl. II). However, fingernail impressions are commonly used in the Pfyn culture when this culture served as a secondary production centre of metallurgy between 3800 and 3650 BC (Winiger, 1971: pls. 8, 26, 73, 74, 77, 78, 84; Mainberger, 1998: pls. 2, 13).

Decoration on a tuyère is rare, but a few objects are covered in carpet-like designs (Roden, 1988: fig. 5.2, fig. 7.1–2 and fig. 8) (Figure 8, C3). The roughening of the vessel surface with an all-over design may have served practical purposes, providing a more secure grip and a better heat absorption due to the greater surface area of the uneven exterior (Müller, 1906: 212; Rice, 1987: 232). Additionally, the decoration may have had a symbolic significance, marking the boundary between the craftsman and the powers and dangers of the melting process (Hodder, 1982: 191; Melheim, 2015: 101, 2016: 61).

METALLURGY IN THE FUNNEL BEAKER CULTURE

Metallurgy was invented in the Near East, with the first copper smelting in Europe documented at Belovode in eastern Serbia in the early fifth millennium (Roberts et al., 2009: 1014; Radivojevic et al., 2010:

2776). In central Europe, the earliest evidence of copper metallurgy is found at Mariahilfberg in Brixlegg (Tyrol, Austria) associated with the Münchhöfen culture and dated to the second half of the fifth millennium (Höpner et al., 2005). From around 3800 BC, extensive production of copper artefacts took place in the north Alpine region and pyrotechnical knowhow reached western and northern Europe in the fourth and third millennia BC (Dolfini, 2013; Bartelheim & Pearce, 2015: 694; Roberts & Frieman, 2015). However, evidence of metallurgy in the form of ceramics from technical processes, such as furnaces, crucibles, moulds, and tuyères are not found in the Nordic region before the Bronze Age in the second millennium BC aside from a few finds in the northern Fenno-Scandian area and finds associated with the Rhomp-Pit Ware and Typical Comb Ware in the eastern Baltic area in the first half of the fourth millennium BC (Vandkilde, 1996: 262; Nordqvist et al., 2011, 2012; Hage, 2012: 238; Melheim, 2015: 139; O'Brien, 2015: 155). Thus, the crucible and possible tuyère from Lønt represents the only evidence so far of local metallurgy in the fourth millennium (Figure 9).

Scandinavian copper objects were imported from secondary production centres in the Alpine region related to the Mondsee, Altheim, and Pfyn cultures dating to 3800–3300 BC (Klassen, 2000, 2010: 228). The source of the arsenical copper, so-called Mondsee copper, used in most objects found in Scandinavia has yet to be identified, but may be located further east or south-east of Mondsee in the eastern Alpine area (Frank & Pernicka, 2012: 127; Klassen, 2014a: 228). Local Scandinavian sources of copper were probably not exploited at this time. The chemical composition of copper ore from Helgoland is different from the patterns seen in southern Scandinavian copper

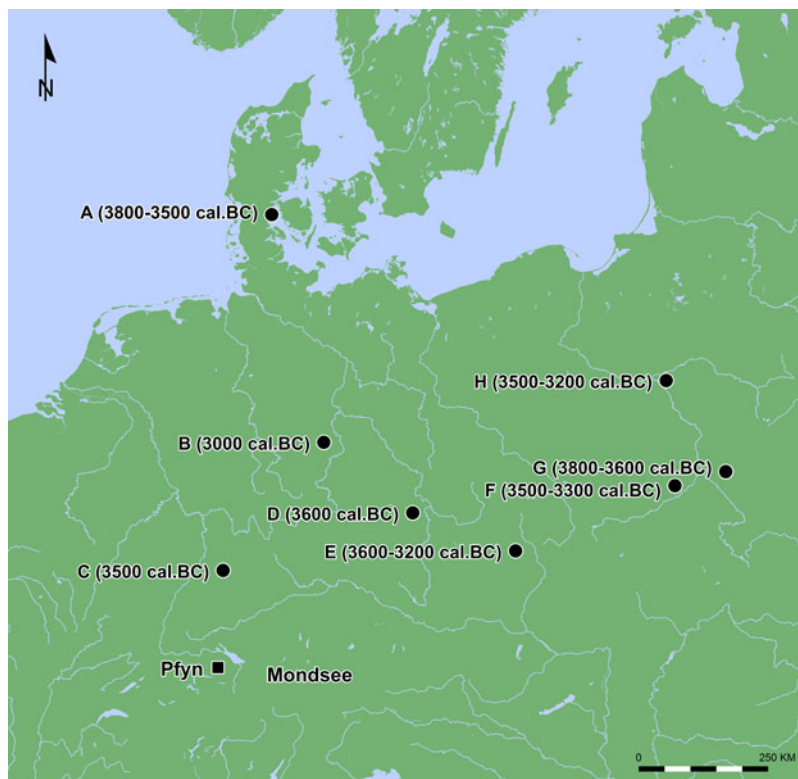


Figure 9. Finds of crucibles and other indications of metallurgy in groups belonging to the wider TRB culture as well as contemporary groups in the Alpine forelands. A. Lønt, Denmark (Funnel Beaker): crucible, possible tuyère. B. Grossbrömmen, Thüringen (Bernburg): crucible. C. Klingenberg bei Heilbronn, Baden-Württemberg (Michelsberg): several crucibles. D. Makotracz, Bohemia (Baalberg): crucible, slag. E. Laskov, Moravia, Czech Republic (Funnel Beaker): crucible, slag. F. Cmielów, southern Poland (Funnel Beaker): crucible, slag. G. Grodek Nadbuzny, southern Poland (Funnel Beaker): crucible, slag. H. Janówek, southern Poland (Funnel Beaker): crucible, nozzle, slag (L. Sørensen based on Klassen 2014a, 231 fig. 135).

artefacts including the crucible from Lønt (Klassen, 2000: 211–17, catalogue nos. T1–14). An origin in Sweden is unlikely because of differences in the lead isotopes (Klassen & Stürup, 2001). No evidence supports connections between the southern Scandinavian Funnel Beaker culture and the Rhomp-Pit Ware or Comb Ware culture in the northern Fenno-Scandinavian area (Melheim, 2015: 11). Recent research into the possible sources of southern Scandinavian Neolithic copper points to central Europe as a likely source (Frank & Pernicka, 2012: 131).

Cultural and social norms rather than accessibility appear to regulate the presence of copper items north of central Europe; a regular tapering-off pattern in the distribution is not observed (Bogucki, 1988: 190). Copper trinkets and axes are known throughout the area of the Funnel Beaker culture, but in limited numbers and with an uneven distribution. Copper ornaments were deposited in megalithic tombs in the Netherlands, north-western and central Germany, and Denmark, while axes are mainly found in Denmark and Poland (Schlicht, 1973; Midgley,

1992: 294, 2008: 144; Klassen, 2014a: 229 fig. 134). Additionally, a limited number of copper objects, such as needles, awls, spirals, rings, and axes, are found on Polish Funnel Beaker settlements. The Danish and Polish trinkets and most of the axes are made from arsenical copper and seem unrelated to the Polish copper artefacts from late Lengyel (4250–3800 BC) that were cold-hammered and made from non-arsenical copper (Midgley, 1992: 299). Likewise, the copper from the western Funnel Beaker culture comes from a different source of mainly non-arsenical copper and dates from MN I–II (Schlicht, 1979).

Smelting and melting of copper is associated with the southern Funnel Beaker culture from 3800 BC onwards, coeval with the production centres in the Alpine area (Schlichterle & Rottländer, 1982; Midgley, 1992: 296; Klassen, 2000: 283) (Figure 9). Evidence of metalworking in the form of crucibles as well as copper slag has been found at Makotracz in Bohemia, Laskov in Moravia, and Grodek Nabudzny, Janówek, and Cmielow in southern Poland (Klassen, 2000: 284 fig. 125) (Figure 9). At the site of Janówek, fragments of tuyères were found as well as arsenical copper, crucibles, and slag (Wisłanski, 1979: 237; Midgley, 1992: 295). Preconditions for local metallurgy in the form of raw materials and knowledge of copper imports was likewise available in central Germany, where production of copper artefacts has been found in a few cases (Klassen, 2000: 285; Müller, 2011: 296), although local production, for instance in the Salzmünde group, has been disputed by others (Strahm et al., 2013: 72).

DISCUSSION

The adoption of metallurgy by early farmers in southern Scandinavia raises a number of questions about the role of metal and metalworking in society.

The fact that metal objects were remelted and re-created according to regionally and locally desirable forms suggests that copper objects were perceived in the same way as other exotic and visually distinct objects, such as jadeite axes, amber, and polished stone axes. Metal in itself was not conceptually different from other shiny objects with distinctive colours and limited accessibility. Indeed, the re-creation of copper axes to conform to local fashions in southern Scandinavia only produced larger axes, not axes of superior quality or new types of artefacts (Klassen, 2010). The potential of metal for tool production may not have been fully appreciated in the region during the Early Neolithic (Bray, 2012). The question may also be raised whether the axes were initially made for utilitarian purposes, e.g. as weapons or tools, or as a valuable. The axes may have circulated in a rough form as cast until someone decided not to recast them and turned them into a finished axe through forging, hammering, and grinding (Kienlin & Stöllner, 2009). Furthermore, the mastering of pyrotechnology has been associated with the ritual sphere and is thought to have contributed to the prestige and social control by the elite (Kaul, 2006: 107f; Midgley, 2008: 176; Klassen, 2010: 40; Nielsen & Sørensen, 2018: 23). On the other hand, the role of copper in social differentiation in Neolithic society is debated (Roberts & Frieman, 2015: 719; White & Hamilton, 2018: 125); the copper objects may have functioned as valuables in reciprocity/gift exchanges in a more group-oriented society. A striking number of copper axes are stray finds; only trinkets were used in graves, perhaps indicating that they played another role in society than as the exclusive property of the elite (Price & Gebauer, 2017: 148).

According to Klassen (2014a: 246), the spread of metallurgy north of the Alpine production centres appears to follow in the

wake of the tradition of enclosure construction, with both features forming a part of the establishment of fully Neolithic societies in the Funnel Beaker area around 3800–3700 BC (Furholt, 2011; Gron & Sørensen, 2018: 969). The transmission of metallurgy to southern Scandinavia is coeval with the introduction of long barrows, causewayed enclosures, and two-aisled houses (Sørensen, 2014: 148, 178; Gron & Sørensen, 2018: fig. 7). Such long-distance connections to central Europe and the Alpine area are visible in the distribution pattern of point-butted stone axes with a perforated butt of type Zug that had a limited occurrence in Switzerland and a number of imitations in southern Scandinavia, as well as the presence of some early types of polygonal battle axes in the Michelsberg and Baalberg culture groups, and southern Scandinavia (Klassen, 2014b; Sørensen, 2014: 148 fig. V.88, 177). Apparently, metallurgy was one of the components of these new networks that transformed Scandinavian society into a fully Neolithic community.

The reasons why the ceramics from technical processes were found in the cultural layer at Lønt remain obscure, but depositions of objects related to metallurgy in the Bronze Age are often assumed to represent special events (Kaul, 1987: 43; Bradley, 2005: 164; Melheim, 2015: 131). The presence of such exotic objects at Lønt is less surprising. Lønt is located in a prosperous and fairly densely populated region, as reflected in the high number of megalithic tombs (Klatt, 2009: fig. 12; Ebbesen, 2011: maps 1 and 2). The location is optimal in terms of communication and transport by sea and land (Klassen, 2014a: 72 fig. 34, 79 tb. 7). Evidence of long-distance contacts and exchange is provided by the finds of copper flat axes and trinkets in the surrounding area (Madsen, 1978; Vandkilde, 1996: 401 no. 22; Klassen, 2000: 81, 115, pl. 12.48, 183–84). Another instance of these

contacts might be represented by the unique clavicle-shaped ditches surrounding the Starup Langelandsvej enclosure, which are similar to the ditches found at the Sandomierz enclosure in southern Poland (Klassen, 2014a: 255). The Starup Langelandsvej enclosure and the find of the Lønt crucible are situated only a few hundred metres apart and both phenomena are coeval. We can hypothesize that the introduction of early metallurgy and the tradition of enclosure building were the first steps in creating a ceremonial centre at Lønt.

CONCLUSION

Traces of arsenical copper in the crucible were confirmed by several independent analyses and indicate that metallurgy was indeed practised during the Early Neolithic in the northern Funnel Beaker culture. In addition, a funnel-shaped socket may have served as a tuyère for a blow pipe. The two objects were found together in a secure context dating to the mid-fourth millennium and sealed beneath a megalithic tomb dated to 3300–3100 BC. This example of metallurgy in the north is coeval with evidence of metallurgy in the southern Funnel Beaker group and the peak of the production centres in the Alpine area. The transmission of metallurgy followed in the wake of the introduction of other phenomena, such as long barrows and causewayed enclosures, that led to the establishment of fully Neolithic societies in the northern Funnel Beaker group between 3800 and 3500 BC. The two pieces of technical ceramics provide evidence of metallurgy in Scandinavian more than 1500 years earlier than previously thought.

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REFERENCES

- Andersen, N.H. 1998. *The Sarup Pladsen* (Sarup vol. 1). Århus: Århus University Press.
- Andersen, N.H. 1999. *The Sarup Pladsen* (Sarup vol. 2). Århus: Århus University Press.
- Andersen, N.H. 2000. Kult og Ritualer i den ældre bondestenalder. *Kuml*: 13–57.
- Andersen, N.H. 2015. Frydenlund: Early Neolithic Settlement and 'barkaer' Structures in the Sarup Area. In: K. Brink, S. Hydén, K. Jennbert, L. Larsson & D. Olausson, eds. *Neolithic Diversities: Perspectives from a Conference in Lund, Sweden* (Acta Archaeologica Lundensia Series in 8°, 65). Lund: Department of Archaeology and Ancient History, Lund University: pp. 117–27.
- Andersen, N.H. & Madsen, T. 1978. Skåle og bægre med storvinkelbånd fra Yngre Stenalder. *Kuml*, 26: 131–60.
- Bakker, J.A. 1979. *The TRB West Group: Studies in the Chronology and Geography of the Makers of Hunebeds and Tiefstich Pottery*. Amsterdam: University of Amsterdam.
- Bartelheim, M. & Pearce, M. 2015. Early Metallurgy in Iberia and the Eastern Mediterranean. In: C. Fowler, J. Harding & D. Hofmann, eds. *The Oxford Handbook of Neolithic Europe*. Oxford: Oxford University Press, pp. 693–709.
- Bogucki, P.I. 1988. *Forest Farmers and Stockherders: Early Agriculture and its Consequences in North-Central Europe*. Cambridge: Cambridge University Press.
- Bourgarit, D. 2007. Chalcolithic Copper Smelting. *Metals and Mines: Studies in Archaeometallurgy*. London: Archetype Publications in association with the British Museum, pp. 3–14.
- Bradley, R. 2005. *Ritual and Domestic Life in Prehistoric Europe*. London & New York: Routledge.
- Bray, P.J. 2012. Before ²⁹Cu Became Copper: Tracing the Recognition and Invention of Metalleity in Britain and Ireland during the Third Millennium BC. In: M.J. Allen, J. Gardiner & J.A. Sheridan, eds. *Is there a British Chalcolithic? People, Place and Polity in the Later 3rd Millennium* (Prehistoric Society Research Paper 4). Oakville (CT): The Prehistoric Society, pp. 56–70.
- Dehn, T. & Hansen, S.I. 2006. Birch Bark in Danish Passage Graves. *Journal of Danish Archaeology*, 14: 7–22.
- Dolfini, A. 2013. The Emergence of Metallurgy in the Central Mediterranean Region: A New Model. *European Journal of Archaeology*, 16, 21–62.
- Ebbesen, K. 2011. *Danmarks Megalitgrave* (vols 1.1 & 1.2). København: Attika.
- Eriksen, P., Andersen, N.H. & Scarre, C. 2014. *Stendysser. Arkitektur og funktion*. (Jysk Arkæologisk Selskab Skrifter 85). Højbjerg: Jysk Arkæologisk Selskab.
- Frank, C. & Pernicka, E. 2012. 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*. Leiden: Sidestone Press, pp. 113–38.
- Furholt, M. 2011. A Virtual and a Practiced Neolithic? Material Culture Symbolism, Monumentality and Identities in the Western Baltic Region. In: M. Furholt, F. Lüth & J. Müller, eds. *Megaliths and Identities: Early Monuments and Neolithic Societies from the Atlantic to the Baltic*. Bonn: Habelt, pp. 1–16.
- Gebauer, A.B. 2014. Meanings of Monumentalism at Lønt, Denmark. In: M. Furholt, M. Hinz, D. Mischka, G. Nobel & D. Olausson, eds. *Landscapes, Histories and Societies in Northern European Neolithic* (Frühe Monumentalität und soziale Differenzierung, 4). Bonn: Habelt, pp. 101–12.
- Gebauer, A.B. 2016. Lønt: Two Types of Megaliths and One Unusual Dolmen. In: C. Scarre & L. Laporte, eds. *The*

- Megalithic Architectures of Europe*. Oxford: Oxbow, pp. 137–44.
- Glob, P.V. 1952. *Danske Oldsager. Vol II. Yngre Stenalder*. København: Gyldendal & Nordisk forlag.
- Gron, K.J. & Sørensen, L. 2018. Cultural and Economic Negotiation: A New Perspective on the Neolithic Transition of Southern Scandinavia. *Antiquity*, 92: 958–74. <https://doi.org/10.15184/aqy.2018.71>
- Hage, F. 2012. Das Trichterbecherzeitliche Gräberfeld von Borgstedt. In: M. Hinz & J. Müller, eds. *Siedlung, Grabenwerk, Grosssteingrab. Studien zur Gesellschaft, Wirtschaft und Umwelt der Trichterbechergruppen im Nördlichen Mitteleuropa* (Frühe Monumentalität und soziale Differenzierung, 2). Bonn: Habelt, pp. 227–45.
- Hage, F. 2016. *Büdelsdorf / Borgstedt. Eine Trichterbecherzeitliche Kleinregion. Teil I – Text und Tafeln* (Frühe Monumentalität und soziale Differenzierung, 11). Bonn: Habelt.
- Hamilton, E.G. 2018. Chaines Opératoires and the Study of Archaeological Metals. In: J.C. White & E.G. Hamilton, eds. *Ban Chiang, Northeast Thailand, Volume 2A: Background to the Study of the Metal Remains* (Pennsylvania University Museum Monograph 149). Philadelphia (PA): University of Pennsylvania Museum of Archaeology and Anthropology, pp. 165–91.
- Hansen, S.I. 2016. *Jættestuebyggerne. Arkitektur i Danmarks stenalder*. Kahrius: Them.
- Hauptmann, A. 2007. *The Archaeometallurgy of Copper: Evidence from Faynan, Jordan*. Berlin: Springer.
- Hodder, I. 1982. *The Present Past: An Introduction to Anthropology for Archaeologists*. London: Batsford.
- Höppner, B., Bartelheim, M., Huijsmans, M., Krauss, R., Martinek, K.-P., Pernicka, E. & Schwap, R. 2005. Prehistoric Copper Production in the Inn Valley (Austria), and the Earliest Copper in Central Europe. *Archaeometry*, 47: 293–315. <https://doi.org/10.1111/j.1475-4754.2005.00203.x>
- Jensen, J. 2002. *Bronzealderen 2000–500 f.Kr. Danmarks Oldtid 2*. København: Gyldendal.
- Jørgensen, E. 1983a. Høje og hegnet næs. *Skalk*, 5: 3–8.
- Jørgensen, E. 1983b. Lønt. En gammelkendt stenalderlokalitet. *Nordslesvigske Museer*, 10: 29–52.
- Jørgensen, E. 1988a. Fire storstensgrave i en højtomt ved Lønt. Om en gammelkendt stenalderlokalitet i ny belysning. *Nationalmuseets Arbejdsmark*, 1988: 195–208.
- Jørgensen, E. 1988b. Stengravens fire trin. *Skalk*, 2: 10–13.
- Jørgensen, E. 2000. Yngre stenalder. In: P. Ethelberg, E. Jørgensen, D. Meyer & D. Robinson, eds. *Det sønderjyske landbrugs historie: Sten- og Bronzealder*. Haderslev: Haderslev Museum og Historisk Samfund for Sønderjylland, pp. 63–134.
- Jouttijärvi, A. 2014. Mulig digel fra Lønt. NM6574/79. Report 14-8, pp. 1–15.
- Kaul, F. 1987. Sandagergård: A Late Bronze Age Cultic Building with Rock Engravings and Menhirs from Northern Zealand. *Acta Archaeologica*, 56: 31–54.
- Kaul, F. 2006. Kulthuset ved Sandagergård og andre kulthuse – betydning og tolkning. In: M. Anglert, M. Artursson & F. Svanberg, eds. *Kulthus og Dödsbus. Det ritualiserede rummets teori och praktik*. Lund: Riksantikvarämbetet, pp. 99–112.
- Kienlin, T.L. & Stöllner, T. 2009. Singen Copper, Alpine Settlement, and Early Bronze Age Mining: Is There a Need for Elites and Strongholds? In: T.L. Kienlin & B. Roberts, eds. *Metals and Society: Studies in Honour of Barbara S. Ottaway* (Universitätsforschungen zur Prähistorischen Archäologie, Bochum, 169). Bonn: Habelt, pp. 67–104.
- Klassen, L. 2000. *Frühes Kupfer im Norden: Untersuchungen zu Chronologie, Herkunft und Bedeutung der Kupferfunde der Nordgruppe der Trichterbecherkultur*. Århus: Moesgård Museum.
- Klassen, L. 2004. *Jade und Kupfer. Untersuchungen zum Neolithisierungsprozess im westlichen Ostseeraum unter besonderer Berücksichtigung der Kulturentwicklung Europas 5500–3500 v.C.* Århus: Jutland Archaeological Society & Moesgård Museum.
- Klassen., L. 2010. Kobberøksen fra Bedegadegård på Bornholm. In: M. Andersen & P.O. Nielsen, eds. *Danefæ. Skatte fra den danske muld*. København: Nationalmuseet, pp. 39–43.
- Klassen, L. 2014a. *Along the Road: Aspects of Causewayed Enclosures in South Scandinavia and Beyond*. Aarhus: Aarhus University Press.
- Klassen, L. 2014b. South Scandinavian Neolithic Green Stone Axes with Perforated

- Butt. In: R.-M. Arbogast & A. Geffier-Richard, eds. *Entre archéologie et écologie, une préhistoire de tous les milieux. Mélanges offerts à Pierre Pétrequin*. Besançon: Presses universitaires de Franche-Comté, pp. 199–212.
- Klassen, L. & Stürup, S. 2001. Decoding the Riesebusch-Copper: Lead-Isotope Analysis Applied to Early Neolithic Copper Finds from South Scandinavia. *Præhistorische Zeitschrift*, 76: 55–73.
- Klatt, S. 2009. Die neolithischen Einhegungen im westlichen Ostseeraum. Forschungsstand und Forschungsperspektiven. In: T. Terberger, ed. *Neue Forschungen zum Neolithikum im Ostseeraum*. Rahden: Marie Leidorf, pp. 7–134.
- Knöll, H. 1981. *Kragenflaschen. Ihre Verbreitung und ihre Zeitstellung im europäischen Neolithikum*. Neumünster: Wachholtz.
- Krismer, M., Töchterle, U., Goldenberg, G., Tropper, P. & Vavtar, F. 2013. Mineralogical and Petrological Investigations of Early Bronze Age Copper-Smelting Remains from the Kiechlberg (Tyrol, Austria). *Archaeometry*, 55: 923–45. <https://doi.org/10.1111/j.1475-4754.2012.00709.x>
- Liversage, D. 1992. *Barkær: Long Barrows and Settlements* (Arkæologiske Studier, 9). København: Akademisk Forlag.
- Madsen, T. 1978. Et yngre stenalder kobbermykke fra en dysse ved Soed. *Nordslesvigske Museer*, 5: 15–20.
- Madsen, T. 1994. Die Gruppenbildung im frühesten Neolithikum Dänemarks und ihre Bedeutung. In: J. Hoika, ed. *Beiträge zur frühneolithischen Trichterbecherkultur im westlichen Ostseegebiet. 1. Internationales Trichterbeckersymposium in Schleswig vom 4. bis 7. März 1985* (Untersuchungen und Materialien zur Steinzeit in Schleswig-Holstein, 1). Neumünster: Wachholtz, pp. 227–37.
- Mainberger, M. 1998. *Das Moordorf von Reute. Archäologische Untersuchungen in der jungneolithischen Siedlung Reute-Schorrenried*. Staufeu i.Br.: Teraqua.
- Martinon-Torres, M. & Rehren, Th. 2014. Technical Ceramics. In: B.W. Roberts & C.P. Thornton, eds. *Archaeometallurgy in Global Perspectives: Methods and Synthesis*. New York: Springer, pp. 107–31.
- Melheim, L. 2015. *Recycling Ideas: Bronze Age Metal Production in Southern Norway* (British Archaeological Reports International Series 271). Oxford: Archaeopress.
- Melheim, L., Prescott, C. & Anfinset, N. 2016. Bronze Casting and Cultural Connections: Bronze Age Workshops at Hunn, Norway. *Præhistorische Zeitschrift*, 91: 42–67.
- Meurers-Balke, J. 1983. *Siggeneben-Süd. Ein Fundplatz der frühen Trichterbecherkultur an der holsteinischen Ostseeküste*. Neumünster: Wachholtz.
- Midgley, M.S. 1992. *TRB Culture: The First Farmers of the North European Plain*. Edinburgh: Edinburgh University Press.
- Midgley, M.S. 2008. *The Megaliths of Northern Europe*. London: Routledge.
- Müller, J. 2011. Early Pottery in the North: A Southern Perspective. *Berichte der Römisch-Germanischen Kommission*, 89: 287–99.
- Müller, S. 1906. Bopladsfundene, den romerske tid. *Aarbøger for Nordisk Oldkyndighed og Historie*, 21: 93–224.
- Nielsen, P.O. 2009. Den tidligneneolithiske bosættelse på Bornholm. In: A. Schülke, ed. *Plads og rum i Tragtbægerkulturen*. København: Det Kongelige Nordiske Oldskriftselskab, pp. 9–24.
- Nielsen, P.O. & Sørensen, L. 2018. The Formation of Social Rank in the Early Neolithic of Northern Europe. *Acta Archaeologica*, 89: 15–29.
- Nordqvist, K., Herva, V.-P., Ikäheimo, J. & Lahelma, A. 2012. Early Copper Use in Neolithic North-Eastern Europe: An Overview. *Estonian Journal of Archaeology*, 16: 3–25.
- Nordqvist, K., Ikäheimo, J., Herva, M. & Lahelma, A. 2011. Lillberget Reloaded: Re-examining an Anomalous Comb Ware Site in Överkalix, North Sweden. *Fennoscandia Archaeologica*, 28: 71–78.
- O'Brien, W. 2015. *Prehistoric Copper Mining in Europe, 5500–500 BC*. Oxford: Oxford University Press.
- Papiernik, P. 2012. Sprawozdanie z Badania wykopaliskowych na stanowisku 20 w Redczu Krukowym, Pow. Włocławski, Woj. Kujawsko-Pomorskie. *Prace i Materiały Muzeum Archeologicznego i Etnograficznego w Łodzi. Seria Archeologiczna*, 45: 195–238.
- Pedersen, S.L. 2008. Skår af en helhed... Et teoretisk og metodisk bidrag til en mere aktiv udnyttelse af keramikens potentiale i fortolkningen af Tragtbægerkulturens systemgravs-indrammede pladser (unpublished dissertation, Saxo Institute, Copenhagen University).

- Pedersen, S.L. & Witte, F. 2012. Langelandsvej i Starup – en ceremoniel samlingsplads fra bondestenalderen. In: S.Å. Karup, L.S. Madsen & B.V. Rønne, eds. *Langs Fjord og Dam. Lokalhistorie omkring Haderslev*. Haderslev: Gammelting & Museum Sønderjylland, Arkæologi i Haderslev og Historisk Arkiv for Haderslev Kommune, pp. 77–88.
- Price, T.D. & Gebauer, A.B. 2017. The Emergence of Social Inequality in the Context of Early Neolithic Northern Europe. In: S. Hansen & J. Müller, eds. *Rebellion and Inequality in Archaeology: Proceedings of Kiel Workshops 'Archaeology of Rebellion' (2014) and 'Social Inequality as a Topic in Archaeology' (2015)*. Bonn: Habelt, pp. 135–53.
- Radivojevic, M., Rehren, Th., Pernicka, E., Slijvar, D. & Brauns, M. 2010. On the Origins of Extractive Metallurgy: New Evidence from Europe. *Journal of Archaeological Science*, 37: 2775–87. <https://doi.org/10.1016/j.jas.2010.06.012>
- Ravn, M. 2011. The Early Neolithic Volling Site of Kildevang: Its Chronology and Intra-spatial Organisation. In: S. Hartz, F. Lüth & T. Terberger, eds. *Early Pottery in the Baltic: Dating, Origin, and Social Context*. Frankfurt: Römisch-Germanische Kommission, pp. 135–63.
- Rice, P. 1987. *Pottery Analysis: A Sourcebook*. Chicago (IL) & London: University of Chicago Press.
- Roberts, B.W. & Frieman, C.J. 2015. Early Metallurgy in Western and Northern Europe. In: C. Fowler, J. Harding & D. Hofmann, eds. *The Oxford Handbook of Neolithic Europe*. Oxford: Oxford University Press, pp. 712–27.
- Roberts, B.W., Thornton, C. & Pigott, V.C. 2009. Development of Metallurgy in Eurasia. *Antiquity*, 83: 1012–2.
- Roden, C. 1988. Blasordüsen. *Der Anschnitt*, 6: 60–82.
- Schirren, C.M. 1997. *Studien zur Trichterbecherkultur in Südostholstein* (Universitätsforschungen zur Prähistorischen Archäologie, 42). Bonn: Habelt.
- Schlicht, E. 1973. *Kupferschmuck aus Megalithgräbern Nordwestdeutschlands* (Nachrichten aus Niedersachsens Urgeschichte 42). Neumünster: Karl Wachholtz Verlag, pp. 13–52.
- Schlicht, E. 1979. Handels- und Kulturbeziehungen auf Grund von Importfunden von niedersächsischen Großsteingräber. In: H. Schirning, ed. *Großsteingräber in Niedersachsen*. Hildesheim: August Lax, pp. 169–78.
- Schlichterle, H. & Rottländer, R. 1982. Gusstiegel der Pfynur Kultur in Südwestdeutschland. *Fundberichte aus Baden-Württemberg*, 7: 59–71.
- Skaarup, J. 1975. *Stengade. Ein Langeländischer Wohnplatz mit Hausresten aus der frühneolithischen Zeit* (Meddelelser fra Langelands Museum). Rudkøbing: Langelands Museum.
- Sørensen, L. 2014. *From Hunter to Farmer in Northern Europe: Migration and Adaptation during the Neolithic and Bronze Age* (Acta Archaeologica Supplementa, 85). Oxford: Wiley-Blackwell.
- Strahm, C. 1994. Die Anfänge der Metallurgie im Mitteleuropa. *Helvetica Archaeologica*, 25: 2–39.
- Strahm, C. 2010. Catalogue. In: C. Lichter & K. Weber, eds. *Jungsteinzeit in Umbruch. Die 'Michelsberger Kultur' und Mitteleuropa vor 6000 Jahren*, Karlsruhe: Badisches Landesmuseum. Darmstadt: Primus.
- Strahm, C., Wiermann, R. & Müller-Scheessel, N. 2013. Salzmünde – Kupfer: erst Prestige, dann Technologie. In: H. Meller, ed. *3300 BC Mysteriöse Steinzeitote und ihre Welt*. Mainz am Rhein: Nünnerich-Asmus & Halle: Landesamt für Denkmalpflege und Archäologie Sachsen-Anhalt, Landesmuseum für Vorgeschichte, pp. 71–77.
- Thrane, H. 2006. 'Figurinen' fra Prysgården – et alternativt tolkningsforslag. *Fornvännen*, 101: 268–73.
- Vandkilde, H. 1996. *From Stone to Bronze: The Metalwork of the Late Neolithic and Earliest Bronze Age in Denmark*. Aarhus: Aarhus University Press.
- Vernon, W.W., White, J.C. & Hamilton, E. G. 2019. Metal Product Manufacturing Evidence: Crucibles, Molds, and Slag. In: J.C. White & E.G. Hamilton, eds. *Ban Chiang, Northeast Thailand, Volume 2B: Metals and Related Evidence* (Pennsylvania University Museum Monograph 150). Philadelphia (PA): University of Pennsylvania Museum of Archaeology and Anthropology, pp. 103–24.

- White, J.C. & Hamilton, E.G. 2018. Metals in Economic Context. In: J.C. White & E. G. Hamilton, eds. *Ban Chiang, Northeast Thailand, Volume 2A: Background to the Study of Metal Remains* (Pennsylvania University Museum Monograph 149). Philadelphia (PA): University of Pennsylvania Museum of Archaeology and Anthropology, pp. 117–36.
- Winiger, J. 1971. *Das Fundmaterial von Thayngen-Weier im Rahmen der Pfynner Kultur*. Basel: Birkenhäuser.
- Wisłanski, T. 1979. Kształtowanie się miejscowych kultur rolniczo-hodowlanych. Pleminona kultury pucharów lejkowatych. In: W. Hensel & T. Wisłanski, eds. *Prabistoria Ziemi Polskiej. Tom 2: Neolit*. Wrocław: Ossolineum, pp. 165–260.
- Wunderlich, M. 2012. Ein unscheinbares Flachgrab der Trichterbecherkultur in Brekendorf, Kr. Rendsburg-Eckernförde. In: M. Hinz & J. Müller, eds. *Siedlung, Grabenwerk, Großsteingrab. Studien zu Gesellschaft, Wirtschaft und Umwelt der Trichterbechergruppen im nördlichen Mitteleuropa* (Frühe Monumentalität und soziale Differenzierung, 2). Bonn: Habelt, pp. 259–70.
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La première métallurgie en Europe du Nord : un creuset et une tuyère probable provenant du site de Lønt au Danemark

Dans cet article, les auteurs présentent neuf fragments appartenant à un creuset et les restes de ce qu'ils interprètent comme représentant une tuyère, ce qui démontrerait l'existence d'une métallurgie du cuivre précoce en Scandinavie, quelques 1500 ans avant la date généralement acceptée pour son apparition. Les restes de céramique utilisée dans ce processus technique ont été découverts dans une couche culturelle

contenant des tessons de la culture des gobelets en entonnoir (culture TRB) du Néolithique ancien (datant autour de 3800–3500 av. J.-C.) sous un tumulus daté entre 3300 et 3100 av. J.-C. Trois analyses indépendantes par spectrométrie de fluorescence des rayons X confirment la présence d'un alliage de cuivre dans le creuset : par examen de la fluorescence des rayons X par instruments stationnaires et de poche, en appliquant la méthode SEM-EDS, et par un scanner Bruker Tornado de fluorescence des rayons μ -X (μ -XRF). L'arrivée de la métallurgie dans le sud de la Scandinavie coïncide vraisemblablement avec l'émergence des tumulus funéraires, des enceintes à fossés interrompus, des maisons à deux travées et de certains types d'objets. La métallurgie semble donc faire partie des nouveaux réseaux qui ont permis à une société pleinement néolithique de s'enraciner. Translation by Madeleine Hummler

Mots-clés: métallurgie, cuivre, creuset, Néolithique ancien, culture des gobelets en entonnoir (culture TRB), Danemark, spectrométrie de fluorescence des rayons X

Die erste Metallurgie in Nordeuropa: ein frühneolithischer Schmelztiegel und eine mögliche Blasdüse aus Lønt, Dänemark

In diesem Artikel beschreiben die Autoren neun Bruchstücke eines Schmelztiegels und eine mögliche Blasdüse, was darauf schließen lässt, dass die Kupfermetallurgie sehr früh (mindestens 1500 Jahre früher als bisher angenommen) in Skandinavien auftauchte. Die Keramik, die dieses technische Verfahren belegen, ist in einer Kulturschicht mit frühneolithischen Scherben der Trichterbecherkultur (um ca. 3800–3500 v. Chr.) unter einem langen Grabhügel (der zwischen 3300 und 3100 v. Chr. datiert wird) gefunden worden. Die Anwesenheit einer Kupferlegierung im Schmelztiegel wurde durch drei verschiedene und unabhängige Röntgenfluoreszenzanalysen bestätigt: mit einem Handmessgerät sowie einem konventionellen Röntgenfluoreszenzgerät, durch SEM-EDS Analyse, und auch mithilfe eines Bruker Tornado μ -X-Ray-fluorescence (μ -XRF) Scanners. Die Übertragung der Metallurgie nach Südsandinavien fiel wahrscheinlich mit dem Auftreten von langen Grabhügeln, von Grubenwerken, von zweischiffigen Häusern und von bestimmten Typen von Artefakten zusammen. Somit gehört die Metallurgie offenbar zu den neuen Netzwerken, die es ermöglichten, eine völlig neolithische Gesellschaft aufzubauen. Translation by Madeleine Hummler

Stichworte: Metallurgie, Kupfer, Schmelztiegel, Frühneolithikum, Trichterbecherkultur, Dänemark, Röntgenfluoreszenzanalyse