Heavy Metal – lead in Bronze Age Scandinavia

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Solid lead occurs in Bronze Age Scandinavia from Per. II onwards. In the Early Bronze Age lead is exclusively found on sword tangs. In the Late Bronze Age, use of the metal is more diverse: lead is found in several different shapes and there are also some indications of bronze being leaded in Scandinavia during this period. The widespread leading in Western and Southern Europe in the Late Bronze Age and Early Iron Age also seems to have influenced the composition of metal in Scandinavia.

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Although lead played a significant part in metal circulation in Western and Southern Europe during the Bronze Age, the material is absent in Scandinavian Bronze Age research. For instance, although lead occurs in various forms from Montelius' Period II on, the metal is not mentioned in syntheses of the period (Brøndsted 1958; Burenhult 1999; Jensen 2002; Kristiansen & Larsson 2005; see however Oldeberg 1942, p. 80; 1976, p. 64). The lead content of the Scandinavian Bronze Age bronzes is thought to derive either from natural impurities in the copper ore, or from imported leaded bronze recycled in Scandinavia (Liversage 2000, p. 66; Ling et al. 2013; 2014). Thus lead has been given only scant consideration in recent studies of the period's metallurgy and metal trade. This paper aims to bring lead into the discussion of metalwork in Bronze Age Scandinavia.

There are several examples of early experimentation with lead in the Old World, but the metal was not widely used before the centuries about 3000 cal BC, when it became common in the Mediterranean and Near East as a by-product of silver production (Gale & Stos-Gale 1981, p. 178; Glumac & Todd 1987). Lead was used for simple beads and pendants in south-east France during the 3rd millennium BC (Arnal et al. 1979, p. 49), while the earliest lead objects from Northern Europe are dated to the earliest Bronze Age (Hunther & Davis 1994, p. 824). Lead objects are generally rare in North-West European Bronze Age contexts: very few are known from Northern Germany (Olshausen 1883, p. 330; Uenze 1953); none have been found in the Netherlands (Butler & Fokkens 2005, p. 380) and only a handful in Britain (Needham & Hook 1988; Guilbert 1996). The small number of lead finds is however unlikely to reflect the actual circulation of the metal, but may rather be due to lead, during the Bronze Age, mostly being used for the alloying of copper.

There may have been several reasons to add lead to copper. Lead lowers the alloy's viscosity, making it well suited for the casting of long narrow objects and for the making of elaborate ornamentation. Lead also lowers the melting point of bronze and may thereby substitute for tin. However, as lead forms globules in the bronze, a high lead content makes it brittle and vulnerable to corrosion (Staniaszek & Northover 1983, p. 262; Huth 2000, p. 25). In Wales, copper was alloyed with lead as early as in the Acton Park phase 1500–1300 cal BC (Northover & Gale 1983, p. 284). Large-scale lead alloying began around

1000 cal BC and lasted into the Early Iron Age, when huge quantities of highly leaded bronze circulated in Western and Southern Europe (Craddock 1980, p. 55; Northover 1980, p. 235; Huth 2000, p. 25; Montero et al. 2003; Giumlia-Mair et al. 2010). In other parts of Bronze Age Europe, leaded bronze was rare, but nevertheless influenced the metal composition. An example is Late Bronze Age Switzerland: here, leaded bronze was never common. The lead content of the Swiss Late Bronze Age bronzes, however, increases gradually from east to west, likely because small amounts of extraneous lead entered metal circulation through the recycling of leaded bronze from the west (Rychner & Kläntschi 1995, pp. 62).

Early Bronze Age lead finds from Scandinavia

In Scandinavia, lead objects are as mentioned found from Per. II of the Montelian system onwards. In Per. II and III, i.e. the Early Bronze Age, the lead is exclusively found on sword tangs (fig. 1). The catalogues of Scandinavian Early Bronze Age finds reveal a total of 30 swords with a lead-covered tang (Aner & Kersten 1973 ff; Oldeberg 1974). 25 are from Denmark, four from Schleswig-Holstein, and one from Östergötland in Sweden. Most of these swords have been found in graves, and a few in hoards. The majority are of Sprockhoff's type Ia (tab. 1). Sophus Müller suggested that swords of this type were made in Italy (1909, p. 45 ff). It cannot indeed be excluded that some of them were imported from Central or Southern Europe. More recent studies however suggest that type Ia swords were likely produced in Northern Europe. A few other swords with lead-covered tangs are of types Ib and IIa, which are also of North European origin (Sprockhoff 1931, p. 7; Schauer 1971, p. 125). Consequently, some Scandinavian bronze casters must have been familiar with the use of lead in the Early Bronze Age.

Fig. 1. Part of a sword of Sprockhoff's type Ia found at Jørlunde on Zealand (Aner & Kersten 1973, #175). Remains of lead are preserved on the tang. Photo: author.

Lead was first identified on Scandinavian Bronze Age sword tangs by Otto Olshausen (1883, pp. 86 ff). The phenomenon was further investigated and discussed by Müller (1909, p. 46), who identified ten swords with lead-covered tang in the Danish National Museum. Müller (p. 47) suggested that the function of the lead was to fill out the cavity between the bronze tang and the organic hilt, thereby fixing the hilt in position. Lead is likely well suited for filling the gaps behind a hilt made of antler or horn that may end up uneven or warped over time. This however seems to be a complicated solution, given that lead is not naturally available in Scandinavia and therefore was likely both rare and expensive. While Müller's interpretation cannot be dismissed, it has also

Place	Type. Context. Date.	Reference
Birkedal, Jørlunde psh, Zealand*	Ia. Grave. PII.	AK 1973, #175. NM 8979
Tjørnhøj, Kregme psh, Zealand*	Ia. Grave. PII.	AK 1973, #228F. B 6141. Sb. #26
Gerdrup, Kirkerup psh, Zealand	Ia. Grave. PII.	AK 1973, #475B. B 12787. Sb. #20
Lejre, Allerslev psh, Zealand	IIa. Unknown. PIII.	AK 1973, #559I. B 15512
Åstofte, Asnæs psh, Zealand	Ia. Hoard. PII.	AK 1976, #771. B 11297. Sb. #75
Ris, Fårevejle psh, Zealand	IIa. Grave. PIII.	AK 1976, #801. NM B 9179. Sb. #98
Hønsinge, Vig psh, Zealand*	Ia. Grave. PII.	AK 1976, #895. B 7425. Sb. 44
Klarskov, Tårnborg psh, Zealand*	Ib. Grave. PII.	AK 1976, #1158. B 308
Voldtofte, Flemløse psh, Funen	Ia. Unknown. PII.	AK 1977, #1755. NM 25913
Lumby psh, Funen*	Ia. Grave. PII.	AK 1977, #1802. NM 13522
Palles Høj, Odense psh, Funen*	Ia. Grave. PII.	AK 1977, #1856. NM 13521. Sb. #20
Griesgaard, Kr. Schleswig-Flensburg. Schleswig-Holstein	Ia. Hoard. PII.	AK 1978, #2184I. K.S. 2227
Skærbæk psh, Jutland	Ia. Grave. PII.	AK 1981, #2889, F.S. 4952
Rumohrsgård, Notmark psh, Jutland	Ia. Grave. PII.	AK 1981, #3247. K.S. 4645
Store-Stabel, Ullerup psh, Jutland	Ia. Grave. PII.	AK 1981, #3333. SØM 3563
Ribe or Vejle Amt, Jutland	Ia. Grave? PII.	AK 1986, #4232. Mus. Grindsted 1026
Metteshøj, Gårslev psh, Jutland	Ia. Grave. PII.	AK 1990, #4351. Sb. #21. Mus. Vejle 446x1
Trappendal, Hejls psh, Jutland	Ia. Grave. PII.	AK 1990, #4395B. Sb. #42
Dørken, Thyregod psh, Jutland	Ia. Grave. PII.	AK 1990, #4472. Sb. #221. B 13 800
Albersdorf, Ditmarschen. Schleswig-Holstein	Ia. Grave. PII.	AK 1991, #9013. K.S. 8743
Albersdorf, Ditmarschen. Schleswig-Holstein	Two Ia. Graves. PII.	AK 1991, #9022. K.S. 8801b
Süderhastedt, Ditmarschen, Schleswig-Holstein	IIa. Grave. PIII.	AK 1991, #9241. Mus. Heide
Hagebrogård, Haderup psh, Jutland	Ia. Grave. PII.	AK 1995, #4648. Sb. #42. (B 9353)
Struer psh, Jutland*	Ia. Grave. PII.	AK 1995, #4821. NM B 5497
Ullerup, Mors, Galtrup psh, Jutland*	Ia. Grave. PII.	AK 2001, #5287. B 7287
Sillerslev, Øster Assel psh, Jutland*	Ia. Grave. PII.	AK 2001, #5432. NM 17037
Randrup, Vinkel psh, Jutland*	Ia. Grave. PII.	AK 2008, #6081. NM 13978
Hulbæk, Ørum psh, Jutland	Ia. Grave. PII.	AK 2008, #6412. VSM 5982
Resebro bog, Borg psh, Östergötland	Ia. Bog. PII.	Oldeberg 1974, #2288. SHM 20053

Table 1. Swords with lead-covered tangs found in Sweden, Denmark and Schleswig-Holstein. Types refer to Sprockhoff 1931. The lead on the swords marked with * has been identified by metal analysis, carried out by conservator Georg Rosenberg as part of Sophus Müller's sword study (1909). The find protocols of the Danish National Museum include notes of which swords Rosenberg analysed. The lead on the remaining swords has only been identified by eye as a white, metallic covering of the hilt. AK = Aner & Kersten.

been suggested that the function of the lead was to shift the sword's point of balance from the blade towards the hilt, balancing the sword for thrusting (Schauer 1971, p. 123). If approximately 10 cm3 of lead originally covered the tang, the total weight of the lead would have been 110 g. Swords of type Ia normally weigh about 500 g, and adding 110 g of lead would certainly affect the balance, making Schauer's interpretation of the lead on the hilts the most credible in my opinion.

Late Bronze Age lead finds from Scandinavia

The use of lead seems to have been more diverse in the Late Bronze Age, although finds are fewer. The only certain lead find from Per. IV comes from the destroyed barrow *Kellerbjerg* in Vejby, northern Zealand. The barrow contained several graves, including a stone cist with a pair of tweezers and a large, well-preserved single-edged knife, on which a cavity in the hilt-end contains lead. The knife is likely imported from Germany (Broholm 1946, p. 11; Thrane 1973, p. 167).

Another possible Bronze Age Per. IV lead find has been found in the barrow *Borum Eshøj* near Aarhus, eastern Jutland. The barrow is well known for its oak coffins with well preserved Early Bronze Age textiles. Less famous is a stone cist in the eastern part of the barrow, which among other things included three miniature swords of Per. IV (Boye 1986 [1896], p. 49 ff; Broholm 1946, p. 68). The largest of these has two holes in the blade, which have been filled out with a lead/tin alloy (Madsen 1971, p. 30). It seems odd, however, that these repairs remained undiscovered until 100 years after the miniature sword was found. A possible explanation is that the holes were filled with the lead/tin alloy when the sword was used as a model for museum copies, in order to make the copies look better (pers. comm. Helge Brinch Madsen, 2014-02-12).

A hoard from *Gislinge* near Holbæk on Zealand includes a crescent-shaped lump of solid lead. The lump is 94 mm long and 31 mm wide and is, at 253 g, the largest Bronze Age lead object found in Scandinavia. The lead was found in a pot along with 490 small bronze rings and four arm rings of gilded bronze, which date the hoard to Per. V (Broholm 1946, p. 211; Liversage 2000, #768).

While the vast majority of Bronze Age lead objects have been found in graves or hoards, a single lead object derives from a Late Bronze Age settlement. This is a tiny egg-shaped lead bead weighing 1 g (fig. 2). The bead was found in a large Late Bronze Age waste pit at *Blodhøj* just north of Slangerup on Zealand (Johannsen 2014; Jouttijärvi 2015). The waste pit, which is a feature typical of Late Bronze Age settlements, also contained large amounts of charcoal, fire-cracked stones, potsherds and coarsely worked flint. Metalworking waste was also found, including three fragments of crucibles and two fragments of moulds. A flat red whetstone also possibly relates to metalworking. The pottery and a flint-blade sickle from the pit are characteristic of the Late Bronze Age Per. V and VI.

Fig. 2. Lead bead from Blodhøj on Zealand. Photo: author.

Two lead beads, similar in shape and size, have been found at *Jämjöslätt* in Blekinge. They were found in a cremation urn along with burned bones and metal objects, including eight fragments of bronze tubes which may have belonged to a cord skirt (Lönnberg 1936, p. 34; Oldeberg 1942, pp. 82 ff). Since the beads were found in an urn grave, along with the possible remains of a cord skirt, they were likely the personal belongings of a woman and may in some way have been part of her dress. The find dates to Per. V or VI.

Another Swedish Late Bronze Age lead object is from *Hjärpetan* in Grava parish, Värmland. This is a 4 mm wide and 130 mm long bent rod, which consists of 93% lead and 7% silver. The lead rod is part of a hoard containing bronze objects from both Per. IV and V (Oldeberg 1928, p. 326; Ling 2013, p. 119).

Lead was reportedly also used for fitting the hilt to the sword blade on a sword found at *Kråknäs* in Södermanland. The sword belongs to Per. V (Oldeberg 1942, p. 82).

Finally, a stray find of a miniature lead axe from *Gammelgarn parish* on Gotland must be mentioned. Because of its small size (c. 35 mm long and 30 mm wide) it has been suggested that the axe may have been part of a cult object, like the Trundholm sun horse or the Grevensvænge figurines (Nerman 1953, pp. 315; Oldeberg 1974, #2109). The shape of the axe is reminiscent of the so-called Skogstorp axes from Eskilstuna in Södermanland and it has consequently been dated to Per. II. Bearing in mind the find circumstances and the lack of obvious parallels, it cannot however be excluded that the axe is of more recent date.

One might wonder at the fact that in Scandinavia, solid lead is most common in the Early Bronze Age, considering the metal's widespread use in Late Bronze Age Europe. This may partly reflect differences in metalwork deposition between the two periods, as more metal was deposited in graves in the Early Bronze Age than in the Late Bronze Age. However, the disparity may also have something to do with differences in the ways lead was used in the two periods: while the Early Bronze Age lead seems to have reached its final form on the sword tangs, some of the lead objects from the Late Bronze Age (notably the Gislinge lump and the Hjärpetan rod) look more like raw material, intended for the production of lead objects or for alloying.

Lead alloying in Bronze Age Scandinavia

Some West European hoards of the Late Bronze Age contain bronzes with a lead content of 4–7% or even significantly higher (Northover 1982). This makes the recognition of the presence of extraneous lead easy. For lower levels, identification may be more problematic, as a low lead content may derive from natural impurities in the copper ore (Liversage 2000, p. 65). This is usually the case in Scandinavia where the lead content of Bronze Age bronzes is usually below 1%. A minimum lead content of 1–2% is required to give the alloy properties observable to the Bronze Age metalworker (Liversage 2000, p. 65; Northover 2008, p. 4). Consequently, Liversage regards bronze with a content of 1% lead or more as containing extraneous lead (2000, p. 66). This approach creates interesting chronological perspectives and has also been adopted here. In a recent study of lead isotope analyses made on Scandinavian Bronze Age bronzes, the limit was however set to 2% (Ling et al. 2014, p. 117). In order to exclude that lead contents above the set limit may derive from natural impurities in the copper, the 2% limit is also used here.

Out of 592 published analyses of well-dated Scandinavian Bronze Age bronzes, a total of 32 bronzes reveal a lead content above 2% (Liversage 2000; Kresten 2005; Northover 2008; Jouttijärvi 2012; Ling et al. 2013; 2014). Only one belongs to the Early Bronze Age, while the rest belong to the Late Bronze Age.

31 of the bronzes with a lead content above 2% are Danish, while one is Swedish (Ling et al. 2014, #54), and none Norwegian. This does not necessarily reflect differences between Bronze Age Denmark, Sweden and Norway. Rather, the explanation may be that metal analyses of Swedish and Norwegian bronzes are still scarce compared to the number of Danish metal analyses: 79% of the analyses cited are of bronzes from Denmark, 16% from Sweden and 5% from Norway.

As mentioned, the lead alloying technique was known in Western Europe in the first half of the Middle Bronze Age (Northover & Gale 1983, pp. 284 ff), roughly corresponding to Per. II and III, when the earliest lead objects occur in Scandinavia. It cannot be excluded that lead was occasionally used for alloying in Scandinavia in this period, as indicated by a single metal analysis revealing a lead content above 2% (Liversage 2000 sample #597). However, taking the very low lead levels of bronzes of this period into consideration (fig. 3), there is reason to believe that lead alloying did not occur, or occurred only very rarely, in the workshops of Early Bronze Age Scandinavia, and that lead-alloyed bronze was rarely if ever imported.

The next question is whether the lead content above 2% found in the 31 Scandinavian Late

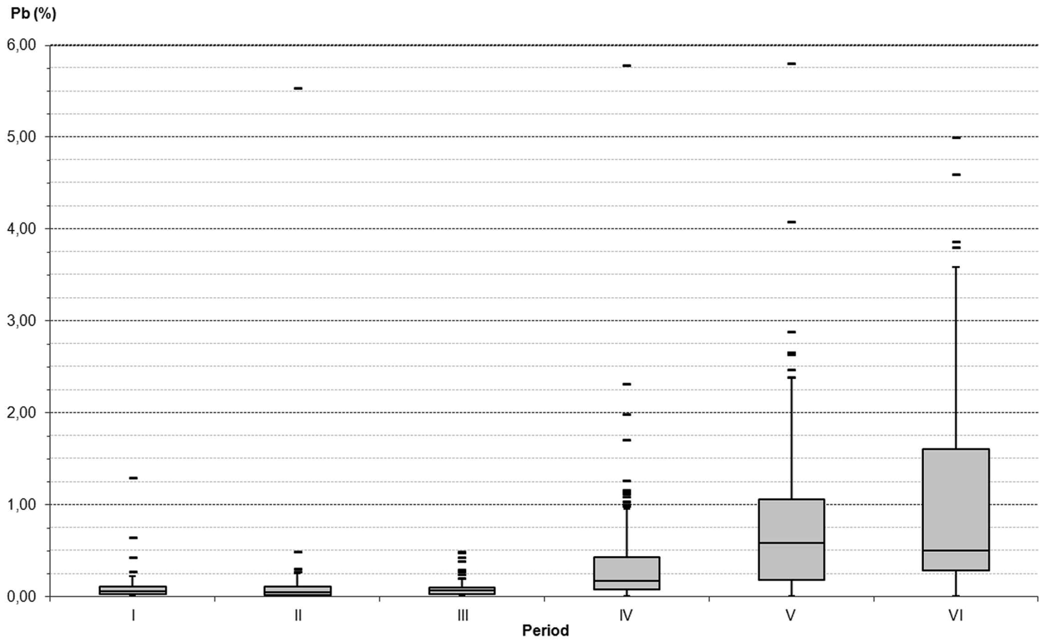

Fig. 3. Box plot of the lead values from metal analyses made on 592 well dated Scandinavian Bronze Age bronzes. The plot is based on analyses taken from Liversage 2000; Kresten 2005; Northover 2008; Jouttijärvi 2012; Ling et al. 2013; 2014. Diagram by Anders Pihl.

Bronze Age objects is an expression of deliberate alloying, or reflects recycling of imported metal. The latter is generally thought to be the case (Liversage 2000, p. 66; Melheim 2012, p. 104). There are however a few strong indications that leaded bronze was at least occasionally used deliberately in Scandinavia. These are two samples with a lead content of about 5%, which derive from a so-called run-on-repair to a fibula and a cast-on sleeve to join together two segments of a lure, both objects being strictly Scandinavian artefact types (Liversage 2000, #224 & 238). Interestingly, samples from other parts of the two objects do not have the same high lead content (Liversage 2000, #222–223, 237, 239–241). Leaded bronze is especially well suited for these types of castings (Northover 1982, p. 92), which suggests that the high lead content here reflects deliberate use (Liversage 2000, p. 66). This makes it likely that at least some of the other bronzes with a lead content above 2% also reflect intentional leading in the Late Bronze Age.

As leaded bronze was present in Late Bronze Age Scandinavia, there is reason to believe that lead entered the period's metal pool on a wider scale through recycling. One way to investigate this is to examine the chronology of lead levels in bronzes. I have plotted all available metal analyses of well-dated Scandinavian bronzes in fig. 3, grouping them according to period. Although the figure shows that the lead content is generally low, it is clearly significantly higher in the Late Bronze Age than in the Early Bronze Age. There are several possible reasons for this:

1. The higher lead content may be due to a general change to exploitation of lead-rich copper ores.
2. The lead may derive from leaded bronze becoming mixed with non-leaded bronze by recycling.
3. The higher lead content may derive from alloying with lead rich tin.

Although the lead content of the bronze increases in the Late Bronze Age, the vast majority of the bronzes of this period still have a lead content too low to have had any effect observable to the bronze caster. This may be an argument for the first explanation. It is however hardly a coincidence that the lead content of the Scandinavian bronzes reached its highest levels when lead alloying culminated in Western and Southern Europe. There is, as presented above, evidence of leaded bronze being circulated in Scandinavia in the Late Bronze Age, and even some indication of bronze being deliberately leaded in Scandinavia. This makes it likely that the generally raised lead levels of the Scandinavian bronzes in the Late Bronze Age must be explained by the presence of leaded bronze. The leaded bronze may through recycling have entered the pool of Scandinavian bronze and thereby have influenced the composition of the bronze on a wide scale, no matter that the lead content was in most cases too low to have any effects on the properties of the metal.

Given lead's relative rarity in the Scandinavian Bronze Age context, the scant attention paid to it is understandable in some respects. However, its presence has some consequences for the use of lead isotope analysis, which is seen as a key to one of the core questions of the Scandinavian Bronze Age: what were the origins of the large quantities of copper used in Bronze Age Scandinavia? In short, the method relies on the identification of ore deposits that were used for prehistoric production of metals via comparisons of available lead isotope data for minerals from different mines and the data obtained from samples of ancient artefact (Ling et al. 2014, p. 116). However, even a small amount of extraneous lead will bias the isotopic signature, as lead isotopy may provenance the added lead instead of the copper (Northover et al. 2001, pp. 30). This problem has been played down in recent studies. There, deliberate alloying with lead is assumed only if the lead content is higher than 2%, while a lead content below this level is assumed to derive from the copper ore. The low lead content of most Swedish bronzes is consequently seen as indicating that no lead was added to the bronze, making the material suitable for lead isotopy studies (Ling et al. 2014, p. 117). Yet, as argued above, there is reason to believe that a large share of Late Bronze Age bronzes do contain extraneous lead, even though their lead content is below 2%. Thus, it is questionable whether lead isotopy can provenance Late Scandinavian Bronze Age copper. At least, a more critical approach to the method is needed.

Concluding remarks

Lead is just one of several metals that circulated in Bronze Age Scandinavia. Copper, tin and gold are often mentioned, but silver and iron also occur (Oldeberg 1942, pp. 89, 138; Nørbach 1998, p. 53; Högberg et al. 2011, p. 64). Furthermore, the occasional addition of lead and the variation in the amount of tin added to the copper show that Bronze Age bronze cannot be seen as one homogeneous type of metal, but includes numerous different alloys. This shows that at least some Scandinavian Bronze Age metalworkers were familiar with several types of metal, which different properties that they knew and controlled. That leaded bronze was apparently only rarely used intentionally in Scandinavia, suggests that only a small group of people knew about it. These were perhaps the ones who produced the most complex artefacts, the lures being significant examples. The use of various alloys in the Bronze Age may thus be an important point in the ongoing discussion of the specialisation of metal craft.

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Summary

Among finds from Early Bronze Age Scandinavia, lead is exclusively found on the tangs of swords of Sprockhoff's types Ia, Ib and IIa. Its function was either to balance the sword or to fit an organic hilt to the tang. In the Late Bronze Age, the use of lead was more diverse. At this time it occurs in several different shapes, at least some of which are likely to be ingots. This may be because lead in the Late Bronze Age was mainly used for alloying bronze. A few metal analyses of Scandinavian Late Bronze Age artefacts suggest that bronze was occasionally alloyed with lead in Scandinavia. However, the lead content of the Scandinavian bronzes is generally below the level where it would be of any use to a metalworker. Nevertheless, the lead content of the Scandinavian bronzes clearly increases from the Early to the Late Bronze Age. This is likely because leaded bronze was recycled in Scandinavia. It is thus questionable whether lead isotope analyses of Late Scandinavian bronzes can be used for provenancing the copper these artefacts were made of.