Janne Ikäheimo

# NEOLITHIC NATIVE COPPER FINDS FROM FINLAND AND NORTH-WEST RUSSIA: A MULTI-METHOD APPROACH

Abstract

Archaeological native copper finds pertaining to Neolithic sites in Finland and Russian Karelia were analysed using a multi-method approach comprising portable X-ray fluorescence spectrometry (pXRF), electron-probe microanalysis (EPMA), metallography and the Vickers hardness test of microhardness. The results indicate how the processing of this exotic raw material took place in several ways. Native copper nuggets show evidence of annealing. Small copper sheets and strips have been produced by both cold hammering and hot working, while the making of some artefacts has involved smelting and casting. Some finds previously interpreted as possible Neolithic native copper objects are shown to be made of copper alloys or other metals and dated to later periods. The use of float copper of local or regional origin, or even the utilization of copper ore, instead of or alongside native copper are also briefly discussed.

Keywords: Finland, metallurgy, Neolithic, native copper, Russian Karelia, scientific analyses

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Received: 21 April 2019; Revised: 30 August 2019; Accepted: 19 September 2019.

## INTRODUCTION

Copper was among the first metallic substances actively used and manipulated by humanity. Yet, the use of copper was not intensive in all areas where the material was available in quantities and forms that would have allowed its more extensive exploitation. Judging by the number of archaeological finds known to date, the present-day eastern Fennoscandia and north-west Russia, the latter of which will henceforth be referred to as Russian Karelia, was one of these marginal areas. The earliest copper finds there date to circa 3900 calBC (Nordqvist & Herva 2013), which stands in local relative chronology for the Middle Neolithic period. This is followed by two millennia of seemingly sporadic utilization of native copper, while the beginning of the proper Bronze Age circa 1900 calBC heralded the somewhat intensified use of metal. At present, the copper finds from the period spanning two millennia total slightly over 170 objects. However, approximately 90% of them have been recovered from 10 dwelling sites located by the northern shores of Lake Onega in Russian Karelia (Nordqvist et al. 2012; Fig. 1, Table 1).

Previously, most scholars have focused on the distribution and dating of these copper finds, which is the reason why these topics are largely omitted from the present study. In particular, two recent research projects entitled *Copper, Material Culture and the Making of the World in Late Stone Age Finland and Russian Karelia* and *The Use of Materials and the Neolithization of North-East Europe (c 6000–1000 BC)*, have managed to identify and discuss various archaeological, social and cognitive aspects related to the early use of copper (Herva et al. 2012; 2014). In general, native copper studies have covered many interesting research questions related to immaterial aspects such as animism and agency (see e.g. Cooper 2011; cf. Chernykh 1992: 5) or proper-

| Location | Site | Site ID | Find | Find ID(s) | Analyses |
|---|---|---|---|---|---|
| Oulu | Hangaskangas E | 1000006785 | Bead | KM 39158:1313 | pXRF |
| | Kierikki Eteläharju | 972010043 | Knife | KM 30775:1 | EPMA, SEM-EDS |
| | Kierikki Sorakuoppa | 972010027 | Knife (fragment) | KM 23431:57 | pXRF |
| | Purkajasuo Korvala | 972010038 | Ribbon | KM 32134:1387 | SEM-EDS, pXRF |
| Polvijärvi | Suovaara | 607010001 | Ring | KM 14982:1 | EPMA, NAA |
| Puumala | Hiekkaniemi | 623010007 | Whirl | KM 39115:40 | pXRF |
| Rääkkylä | Vihi 1 | 707010045 | Plate, piece etc. | KM 30460:11958–66 | EPMA, pXRF |
| Saarijärvi | Rusavierto | 729010032 | Plate | KM 32195:1 | SEM-EDS, pXRF |
| Suomussalmi | Kukkosaari | 777010114 | Adze | KM 20850:1 | AES, EPMA, NAA |

*Table 1. Neolithic native copper finds from Finland: an update.*

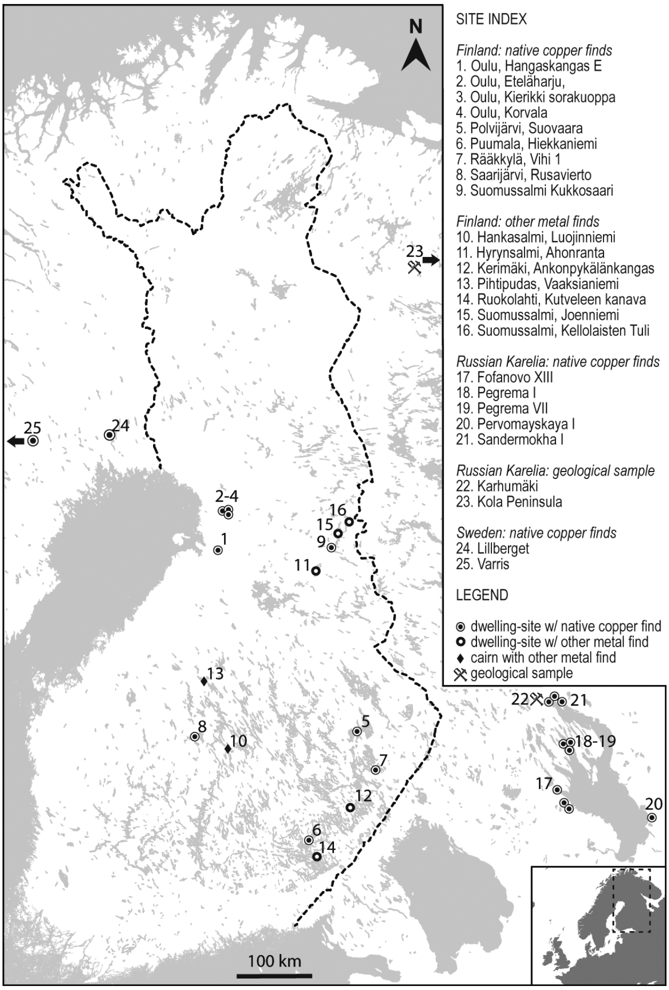
ties such as the colour and luminosity of native copper (Keates 2002), and it is sincerely hoped that these topics continue to draw attention. The main aim of this paper, however, is to focus on certain technological aspects of the early metal utilization in the research area, which is a topic that has recently received much less attention.

In this study, this vast topic has been narrowed down to two interrelated themes. The first concerns the composition of metal, which was also a frequently discussed theme in publications on Neolithic copper finds from the research area in the 1980s (e.g. Huurre 1981; Kinnunen 1982). The interpretative scheme regarding this question was often built on either the geographic distribution of copper finds or the results of elemental analyses. The latter were carried out using a great variety of methods (see Table 1) and nearly always without reference materials from geological deposits (see e.g. Levine 2007: 577, 585). Another common feature of the previous analyses performed on Neolithic copper finds has been their limited scope; they have usually focused on a single copper object 'found' by the author while directing archaeological excavations on a Neolithic dwelling site.

In such contributions, the presence or absence of (a) certain chemical element(s) thought to be indicative of a certain provenance has been usually emphasized. An elevated arsenic content, for instance, has been taken as a positive proof of the Uralic provenance (Halén 1994: 156–7, 159), while in the British Isles the same chemical element has been connected with the exploitation of Irish copper deposits (Budd et al. 1992: 678). Yet, the elemental composition of metal deposits and metal ores may be altered due to enrichment or depletion in complex chemical processes. Particularly the studies focusing on inter-deposit variability (e.g. Allert et al. 1991; Budd et al. 1992: 678; Kuleff & Pernicka 1995; Mauk & Hancock 1998) have shown show that the keenness to focus on the presence or concentration of one chemical element does not stand closer scrutiny. The intra-site element variability has been shown occasionally to exceed the inter-site variability, and the degree of variation is also dependent on element specific properties (Allert et al. 1991: 350). This inherent variation in native copper deposits has not prevented researchers from examining, comparing and interpreting the composition of archaeological copper finds, even though the analyses themselves have been made using different methods and analytical equipment (Table 1).

The picture concerning the utilization of native copper in the research area during the Neolithic was static and straightforward for a very long time. The metallurgical knowledge of the era was assumed to have been somewhat limited, as native copper – a substance usually containing no less than 99.9% of metallic copper (e.g. Wayman 1985b: 75) – was the only suitable raw material for the procurement of metal objects. Conclusive archaeological evidence on the extraction of copper from oxide or sulphide ores during the Neolithic is yet unknown, although various scholars have proposed this from time to time (e.g. Salo 1984: 107). In addition to the scarce occurrence of suitable raw materials, the technologies for the transformation and refinery in the Neolithic are both topics of great interest. Based on common reasoning, but rarely on empirical evidence, cold hammering and anneal-

*Fig. 1. A map of Finland and Russian Karelia showing the dwelling sites with Neolithic copper finds as well as other locations discussed in the article. Map: J. Ikäheimo.*




ing have been identified as the main processing techniques for processing native copper in the Neolithic. Conversely, more advanced techniques such as forge welding, melting, casting and the extraction of copper metal from ore by smelting were for long thought to have been unknown in north-eastern Europe.

For the reasons outlined above, the second theme of the present study is the state of metallurgical knowledge in eastern Fennoscandia and Russian Karelia during the Neolithic period. Due to this material-oriented approach and the scarcity of respective archaeological evidence, attention will be paid to the materiality of the finds rather than to circumstantial evidence. In other words, a substantial amount of evidence has accumulated over time, such as artefacts, preforms and (seemingly) unmodified pieces of native copper, some of which are identifiable as copper nuggets. The scientific analysis methods applied here include the examination of polished specimens with electron-probe microanalysis (EPMA) and metallographic microscopy, the re-examination of etched specimens with a metallographic microscope and the determination of the specimen hardness with the Vickers test of microhardness. In addition, thoroughly oxidized archaeological finds not permitting specimen extraction were examined using portable x-ray fluorescence spectrometry (pXRF).

## SAMPLING AND SPECIMEN PREPARATION

Over 170 native copper objects dating to the Neolithic period are known from the research area with nearly three fourths of the material pertaining to the excavations of the Pegrema I, Fofanovo XIII and Voynavolok XVII dwelling sites located in Russian Karelia (Fig. 1; Nordqvist et al. 2012: Table 1). Totalling 17 objects, the number of Neolithic copper finds in Finland is quite low (Table 1), but constantly growing thanks to the adoption of more refined excavation techniques – including the use of trowels and sieves – since the 1960s. At present, all but one of these nine Neolithic dwelling sites have yielded only one native copper object. The only exception is the Rääkkylä Vihi 1 dwelling site with nine copper objects ranging from a piece of sheet metal to indeterminate or dendritic lumps of native copper. Otherwise, the assemblage consists of objects showing various degrees of human agency ranging from a whirl and a ribbon to artefacts such as the Suojärvi copper ring, the Kierikki copper knife and the Kukkosaari copper adze.

The permission for obtaining the specimens of Neolithic copper artefacts found in Finland was granted by the Finnish National Board of Antiquities (NBA, today the Finnish Heritage Agency) after the author and the now retired Keeper of the Antiquities, Leena Söyrinki-Harmo from the Archaeological Collections had examined the material together. From the beginning it was clear that the metal in many archaeological finds the author had identified as potential targets for specimens was thoroughly oxidized. While there was no point to attempt to include such artefacts in a specimen-based analysis, they were later screened with a portable X-ray fluorescence spectrometer (pXRF) to verify their identification. Therefore, a formal request asking for permission to sample just eight archaeological finds was filed in, and this was granted by the NBA.

However, the number of specimens was drastically reduced when the pre-screened objects were subjected to X-ray photography in the conservation laboratory of the National Museum of Finland before the sampling (Fig. 2a–b). The X-ray photographs revealed that only four finds had been preserved in a condition that would permit the extraction of a specimen containing unaltered metal. The specimens were taken by conservator Leena Tomanterä with the assistance of Kerkko Nordqvist, then the junior researcher of *Copper, Material Culture and the Making of the World in Late Stone Age Finland and Russian Karelia* research project (Fig. 3). A polished specimen of the Kierikki copper knife cast in epoxy resin was also available as the fifth Finnish specimen due to previous sampling of the artefact (Ikäheimo & Pääkkönen 2009). The description of these objects can be found in Appendix 1.

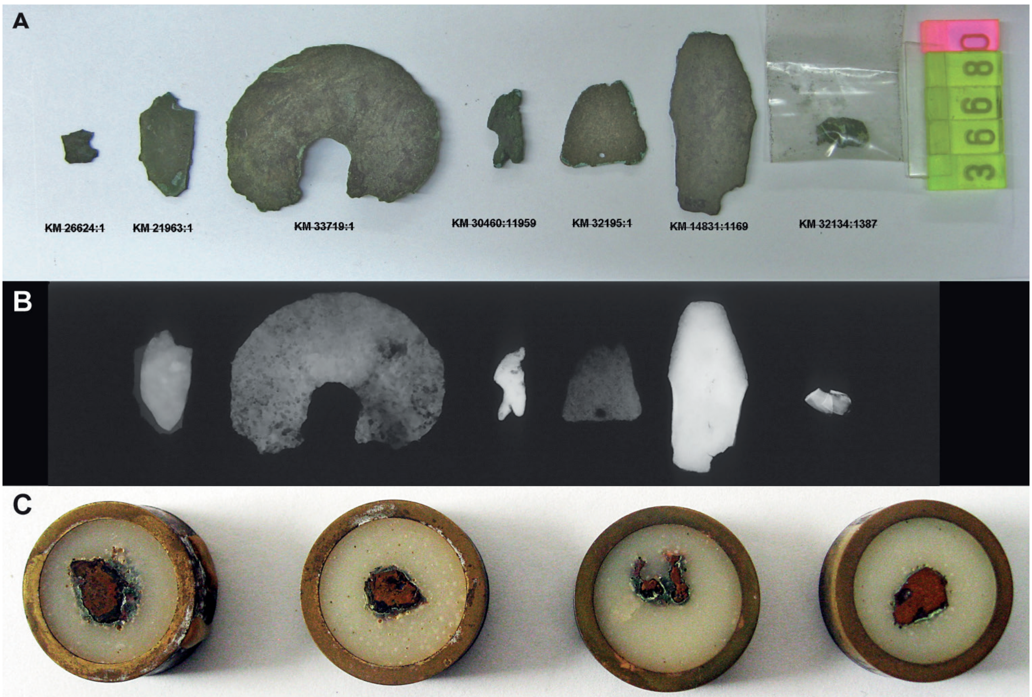



*Fig. 2. The process of sample selection and preparation; a) a collection of presumed native copper finds at the National Board of Antiquities, from left: Kerimäki Ankonpykälänkangas, Hankasalmi Luojinniemi, Pihtipudas Vaaksianiemi, Rääkkylä 1 Vihi, Saarijärvi Rusavierto, Suomussalmi Kellolaisten Tuli and Oulu Purkajasuo Korvala; b) the same finds in an X-ray photograph showing different degrees of oxidization; c) native copper specimens cast in epoxy resin from Russian Karelia, from left: Pegrema I samples 5a, 4b, 2_5 and II). Photos: K. Nordqvist (a & c), L. Tomanterä (b).*

| Country | Site | Sample ID | Object | As | Sb | Cu | S | Sn | Ni | Bi | Ag | VHM |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Finland | Oulu Kierikki Eteläharju | 30775:1 | Knife | + | 0.11 | 99.27 | 0.08 | - | - | - | 0.24 | 82.2 |
| | Polvijärvi Suovaara | 14982:1 | Ring | - | - | 99.73 | 0.16 | - | - | - | - | * |
| | Rääkkylä Vihi | 30460:11959 | Nugget | - | - | 99.52 | 0.33 | - | - | - | - | 114.0 |
| | Suomussalmi Kellolaisten Tuli | 14831:1169 | Adze** | 0.37 | 1.01 | 94.51 | 0.11 | 3.00 | 0.42 | + | 0.37 | 248.0 |
| | Suomussalmi Kukkosaari | 20850:1 | Adze | - | - | 99.68 | 0.20 | - | - | - | + | 98.6 |
| Russia | Fofanovo XIII | 213 | Nugget | + | - | 99.74 | 0.05 | - | - | - | - | 120.0 |
| | | 214 | Spit | - | - | 99.86 | 0.04 | - | - | - | - | 95.1 |
| | | 522 | Nugget | - | - | 99.9 | 0.04 | - | - | - | - | 125.0 |
| | Karhumäki | - | Geological | - | - | 99.76 | - | - | - | - | - | 91.9 |
| | Kola | - | Geological | 0.18 | - | 99.65 | 0.04 | - | - | - | 0.05 | 98.6 |
| | Pegrema I | 5a | ? | - | - | 99.78 | - | - | - | - | - | 65.5 |
| | | 2b | Plate | - | - | 99.83 | - | - | - | - | - | 103.0 |
| | | 2v | Plate | - | - | 99.81 | 0.03 | - | - | - | - | 88.8 |
| | | 2d | Plate | - | - | 99.75 | 0.04 | - | - | - | - | 88.8 |
| | | $2^e$ | Plate | - | - | 99.75 | - | - | - | - | - | 87.8 |
| | | 4b | Plate | - | - | 99.82 | + | - | - | - | - | 127.0 |
| | | 2_5 | Plate | - | - | 99.80 | 0.03 | - | - | - | - | 83.1 |
| | | II | ? | - | - | 99.75 | - | - | - | - | - | 129.0 |
| | Pegrema VII | III | ? | - | - | * | - | - | - | - | - | 99.7 |
| | | V | ? | - | - | 99.77 | + | - | - | - | - | 91.9 |
| | | 792/5358 | Knife | - | - | 99.82 | - | - | - | - | - | 71.0 |
| | Pervomayskaya I | 2410/710 | Nugget ? | + | - | 99.66 | 0.06 | - | - | - | - | 99.7 |
| | Sandermokha I | - | Nugget ? | - | - | 99.87 | - | - | - | - | - | 60.2 |
| | | - | Nugget ? | - | - | 99.83 | - | - | - | - | - | 63.1 |

*Table 2. The study assemblage with the results of the electron-probe microanalysis (EPMA) and the Vickers test of microhardness. * No data available due to specimen properties/preparation. ** Tin-rich.*

Another and significantly more numerous group, totalling seventeen finds, consisted of native copper specimens from Russian Karelia (Table 2) that were available through mutual collaboration with local archaeologists. The majority of these specimens had already been prepared in the 1980s from nuggets of native copper and copper artefacts found in the excavations of Neolithic dwelling sites located by Lake Onega in Russian Karelia. After the preparation of epoxy resin specimen mounts followed by their subsequent study and publication (Chistyakova 1991; see also Zhuravlev et al. 1991), this material had been stored in Petrozavodsk at the Institute of Linguistics, Literature and History of Karelian Research Centre, Russian Academy of Sciences. Unfortunately, the information regarding the specifics of each sampled find and their exact find context within the dwelling site is rather vague or has been altogether lost, while the actual copper finds were also missing from the storage facility of the institution. Three additional native copper specimens (Fig. 3g–h) were obtained from recent archaeological excavations at the Fofanovo XIII dwelling site located some ten kilometres north-north-west of the city of Petrozavodsk (Fig. 1; see also Tarasov & Stafeev 2014; Tarasov 2015).

Besides archaeological finds, the study assemblage included two reference specimens from geological outcrops. As the specimens are expected to produce reliable information on the composition of a native copper deposit, they naturally form a very weak point of reference. However, as both deposits are located in the territory of the Russian Federation and currently subjected to both administrative and economic interests, to obtain multiple specimens for the study was not really an option. The first specimen comes from a recently abandoned quarry located in Karhumäki near the north-western shore of Lake Onega. The actual specimen was a piece of rock containing abundant grains of native copper, only some millimetres across in size. However, the nuggets found in the area of the mine can be quite big, as the Archaeological Museum of the Karelian Research Centre in Petrozavodsk hosts an example measuring c 50 x 40 x 30 centimetres. The other geological specimen was obtained through the contacts of professor Eero Hanski (geochemistry, University of Oulu) from the Kola Peninsula, where native copper is found associated with c 2.06 Ga old vulcanites of the Imandra/Varzuga Greenstone Belt (Melezhik 2012: 257).

The four archaeological specimens provided by the National Board of Antiquities were small pieces of metal packed in small plastic vials, while the specimens of native copper pertaining to the Fofanovo XIII site in Russian Karelia were sampled in the Archaeological Laboratory at Oulu University. The specimens of native copper from other Neolithic dwelling sites in Russian Karelia had already been embedded in epoxy resin sometime in the 1980s. As their surface had visibly oxidized over the years (Fig. 2c), they were sent along with other specimens to the thin-section laboratory of the Geological Survey of Finland located in Kuopio for repolishing. The new specimens were first cast in epoxy resin and then polished by the same service provider.

## ELECTRON MICROPROBE ANALYSIS

Both archaeological and geological native copper specimens mounted in epoxy resin and polished for further examination were first pre-screened with an electron microprobe micro-analysis (EPMA) to get first-hand information about their microstructure and possible impurities present in the metal. The flexibility and availability of the electron probe micro-analyser was the reason for its preference over more sophisticated methods of elemental analysis. Equipped with several wavelength-dispersive spectrometers, EPMA can be used for semi-quantitative compositional analysis. The point of analysis can be visually defined and focused into a minute area, while in many other methods, a bulk analysis has to


*Fig. 3. Archaeological copper finds sampled for this study and the Oulu Eteläharju copper knife sampled in 1999 (for descriptions, see Appendix 1); a) the Kukkosaari adze, b) the Suovaara ring, c) the Vihi 1 nugget, d) the Kellolaisten Tuli adze, e) the Kierikki Eteläharju knife, f) the Fofanovo XIII nugget/lump (213), g) the Fofanovo XIII spit (214) and h) the Fofanovo XIII nugget (522). Arrows indicate points of sampling. Photos: K. Nordqvist (a–d), J. Ikäheimo (e), J. Heinonen (f–h).*

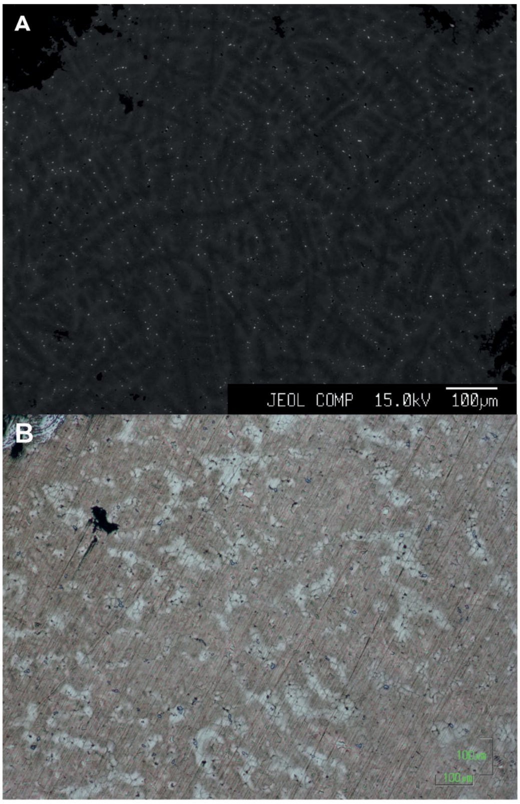



*Fig. 4. The microstructure of a bronze adze from the Kellolaisten Tuli dwelling site in Suomussalmi; a) backscattered electronic image (BEI) showing minute tin inclusions and a dendritic cast structure; b) both the dendritic cast structure and crystal structure become clearly visible when an etched specimen is examined under a metallographic microscope. Photo: J. Ikäheimo.*

be performed on a specimen without knowing about its internal structure. Therefore, the potential existence of structural impurities was an important reason for the use of this method. The possibility to identify, examine and photograph different areas either compositionally or otherwise was the third reason for the selection of this method.

All the specimens were examined with a JEOL JXA-8200 electron probe micro-analyser at the Center of Microscopy and Nanotechnology at the University of Oulu. The work was carried out by the author under the supervision of Dr Olli Taikina-Aho, who was also responsible for preparatory calibrations and the programming of the elemental analysis routine. The fifteen elements analysed (As, Cd, Sb, Cu, S, Sn, Ni, Pb, Zn, Bi, Mn, Ag, Fe, Co, Au) were the same as in a previous study focusing on a copper knife found at the Kierikki Eteläharju site in Yli-Ii (see Ikäheimo & Pääkkönen 2009). The total time for each analysis was approximately 6 minutes and 45 seconds with 10 to 60 seconds allocated for each element. All specimens were analysed four times, each time from a different spot.

Before the actual chemical analysis, a visual inspection of the polished specimen was carried out in BEI-mode (backscattered electron image) aiming at recognizing possible impurities, structural defects such as oxidized areas, major scratches and other factors possibly affecting the analysis (Fig. 4a). At this stage, two photographs were also taken of each specimen: one at the lowest magnification offered by the EPMA (40x) and another (c 650x) showing the surface of metal in detail. Thereafter, four points of analysis were determined for each specimen with the aid of TOPO (topographic) and SEI (secondary electron image) imaging modes providing better control of the specimen geometry. The goal was to find a substantially flat surface area, about 10 x 10 μm in size. This goal was achieved in all but one case. The results of specimen #16 from the Pegrema VII dwelling site in Russian Karelia turned out to be highly unreliable due to its challenging surface geometry.

In the light of the results (Table 2), the number of elements analysed was excessive as altogether seven elements (Cd, Pb, Zn, Mn, Fe, Co, Au) included in the calibration were not detected at sufficient level in any of the specimens. In Table 2 the concentrations in weight percentages are given for specimens in which at least two subanalyses produced a numeric value exceeding the limit of quantification (LOQ). By comparing the relative proportion of each measurement against the LOQ, an additional category was created for observations in which the ratio of the concentration average vs. the LOQ exceeded 50% in at least two measurements. These are marked with a plus-symbol (+). This indicates elements that might have produced a verifiable value, had an analysis method offering higher sensitivity been applied to the research material.

In addition to copper (Cu), the most consistent element is sulphur (S), which is present on a per mille level in archaeological copper objects found in Finland, but only on a hundred ppm level in specimens from Russian Karelia. As sulphur is a rarely reported minor element in native copper, its presence in these specimens can be explained in several alternative ways. While sulphur may reflect local or regional native copper deposits associated with reduced environmental and sulphide copper ores, its presence could also result from post-depositional contamination or from substances used in the conservation of the artefact. The last but not very likely explanation is that the preparation of the specimens or instrument calibration could have introduced a systematic bias to these analyses.

Regarding the individual specimens, the presumed native copper or bronze adze from the multi-periodic Kellolaisten Tuli dwelling site in Suomussalmi (Fig. 3d) turned out to be bronze, and this would have justified its exclusion from further studies. The compositional analysis reveals that the metal contains c 3% of tin together with some minor elements (As, Sb, Ni, Ag), thus identifying it as a tin-poor bronze. The Kellolaisten Tuli bronze adze is therefore either somewhat or significantly younger than the native copper objects which are the focus of this paper. Still, it was decided to process this specimen further as reference material to gain information on the metallurgical properties of the early bronzes in the research area and to illustrate the difference in the properties of native copper and bronze objects.

It was hoped that the inspection of the specimens with the electron probe micro-analyser's COMP, SEI and TOPO visualisation modes would yield data for dividing the research material into smaller groups according to differences in their composition as well as the presence, size and shape of impurities or defects observed in the crystal structure. While impurities show up as abrupt differences in brightness in the SEI-images, twinning and other crystal defects are usually visible only as delicate changes in otherwise featureless images reflecting the homogeneous chemistry of a native copper specimen. The results were rather disappointing, because all but two specimens were homogeneous in composition and therefore rather featureless in their appearance.

The visual examination of a small post-Neolithic bronze adze from the Kellolaisten Tuli dwelling site in Suomussalmi revealed two details: one related to the structure of the metal and the other to its composition (Fig. 4). Numerous bright minute spots visible in the microphotograph are lead inclusions, which are evenly dis-

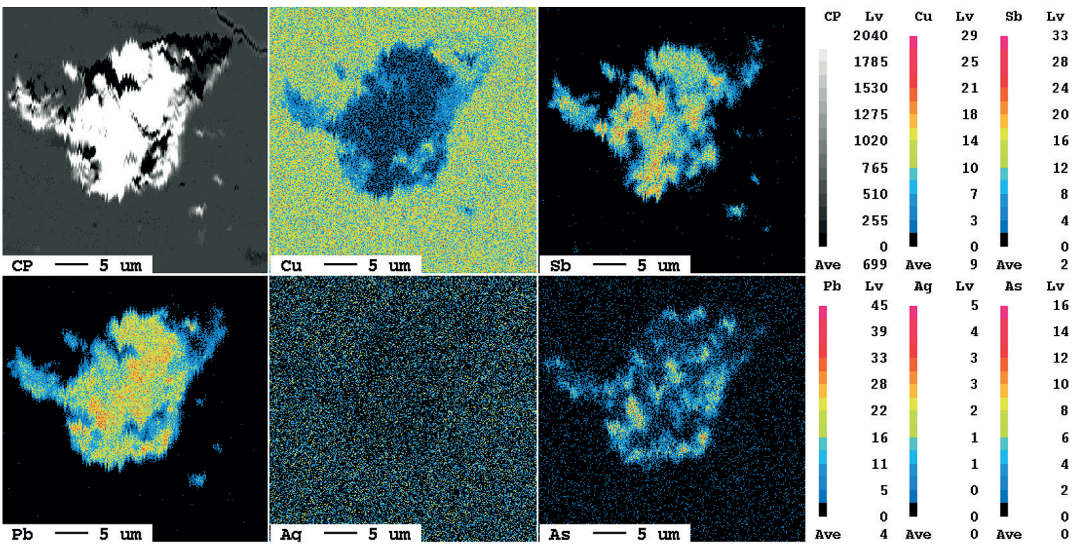



*Fig. 5. Element distribution map of the Kierikki Eteläharju copper knife. Silver is dispersed evenly in the body metal, while antimony, arsenic and lead are concentrated in inclusions. Photo: J. Ikäheimo.*

tributed throughout the copper matrix. Another notable feature is the dendritic structure which is characteristic of cast metal objects. Therefore, the object can be identified as low-grade cast bronze item dated, at the earliest, as Early Bronze Age (from c 1900 calBC). Besides the improved identification of the metal, however, the results do not add much to the original discussion presented by Huurre (1981: 21–2).

Another specimen with variations exceeding the limit of what normally might be expected from the structure of unaltered native copper was the copper knife found at the Kierikki Eteläharju site in Oulu (Fig. 3e). In the backscattered electron image it shows sparse (c 5%) multi-element inclusions in the 5–60 μm size range. The main constituents of these inclusions were identified with element mapping as antimony, arsenic and lead (Fig. 5). On the other hand, silver shows up as the main impurity in an elemental analysis and is evenly dispersed throughout both the matrix and the inclusions. While this kind of variability fits within the definition of native copper, it most certainly merits further attention when introducing the results of metallographic analyses.

## METALLOGRAPHIC ANALYSIS

A metallographic analysis examines the microstructure of metallic objects with a reflected light microscope. As cast, cold-worked or otherwise treated metal can be identified with this method, it has belonged for long to the repertoire of archaeometallurgists (archaeologists specialized in the study of ancient metals). Advances in archaeometallurgy have been quite rapid, thanks to the scholarly interest in the history of metals and the ever-expanding range of their modern application. For this reason, also the properties of native copper captured scholarly attention quite early on. Previously, metallographic analyses of archaeological native copper have been carried out especially with finds from the Western Arctic and Subarctic North America (Franklin et al. 1981). In addition, the importance of the pioneering work by Chistyakova (1991; see also Zhuravlev et al. 1991) with native copper objects from Neolithic archaeological sites in Russian Karelia must be stressed. Archaeological metallography was also generally well advanced in the former Soviet Union (Chernykh 1992: 31).

In Finland, on the other hand, metallographic studies on Neolithic native copper objects were for long non-existent (but see Ikäheimo & Pääkkönen 2009), mainly due to prevailing approaches excluding more advanced knowledge of pyrometallurgy than annealing. However, already during the first examination of archaeological native copper finds from Russian Karelia, Chistyakova (1991: 196–200) found corroborating evidence from the sites of Orovnavolok XVI, Chelmuzhkaya kosa XXI and Zalavruga IV of smelting and casting. This showed that rather than categorically excluding the possibility of finding examples of advanced pyrometallurgy as a chronological-chorological impossibility, it ought to be taken seriously. If annealing complemented by cold working and possibly also hot working were the only production methods, this would have seriously limited the production of artefacts.

Firstly, annealing and cold working are techniques that do not allow the amalgamation of raw materials as other techniques such as forge welding or smelting do. The reason lies in an oxide film formed at high temperatures on the surface of copper (Coghlan 1975: 120). This undesired property limits the size of native copper objects. While it is theoretically possible to combine several copper sheets together mechanically hammered from individual nuggets, the size of a copper nugget normally regulates the size of the object it can be used for. While the size of native copper grains or nuggets may range from a few micrometres to several hundred tons, the most abundant examples are naturally the ones belonging to the lower end of the size-range. For this reason, Neolithic copper finds tend to be normally small hammered sheets, as the production of more complex forms was very difficult without the knowledge of more advanced pyrometallurgy.

The issue can be illustrated well with the largest native copper artefact found in Finland, the Kukkosaari copper adze (Fig. 3a), that weighs approximately 309 grams. This object has reportedly been formed by hammering the piece of native copper first into a substantially flat sheet which has, in turn, been folded over from the edges to form an adze-like object that measures 82 millimetres in length, 28–45 millimetres in width and 13–18 millimetres in thickness (Huurre 1981: 20). For the making of such object, a substantially large piece of native copper exceeding by 3 millimetres in height the size of an ordinary Finnish matchbox (52 x 35 x 16 mm) would have been needed. While this might not sound an excessive demand at first, copper nuggets of that size were very unlikely to have been commonplace items of exchange or trade during the Neolithic. Thus, the larger a presumed native copper artefact is, the more cautious one should be when deciphering its production technique with the aid of metallography.

All native copper specimens were examined with a Nikon Eclipse MA100 metallographic microscope mounted with a Nikon Digital Sight-2Mv High Speed Colour Camera Head. The Materials Engineering Laboratory of the Department of Mechanical Engineering at Oulu University provided this equipment. Each specimen was examined twice, both before and after etching. Magnifications from 50x to 500x with both plain and polarized light were used to detect features other than copper crystal structure that could have been masked by etching.

At the non-etched stage, at least two microphotographs were taken: one at a magnification of 50x to preserve a general impression of the specimen and another at a magnification of 500x to show the general features of the metal matrix. If the matrix turned out to be heterogeneous, features considered to be significant were documented with additional photographs. Such features included but were not limited to possible impurities and inclusions detected within the proper copper metal, as well as various forms of copper corrosion observed near the edges of some specimens. The second stage of the metallographic research comprised the examination of the specimens after etching. The second microscopic examination followed the same principles as the first.

The metallographic examination of the native copper specimens confirmed the previous observations by Chistyakova (1991) about the large variation of techniques used to manipulate this novel material in the Neolithic. The assemblage includes objects characterized as 'nuggets or bits' that show no evidence of human interaction and are thus similar to geological samples in which the twinning observed in large well-formed crystals (Fig. 6a) is likely to be the product of recrystallization resulting from a strain-inducing geologic event (Cooper 2007: 19). The specimens of Sandermokha I (see also Chistyakova 1991: 188 Fig. 7.6, 192), Pervomayskaya I and Fofanovo XIII from Russian Karelia belong to this group and so does the copper nugget from the Rääkkylä Vihi 1 dwelling site (Figs. 3c & 6b) in Finland, despite of its external appearance and high HV-value. These examples seem to indicate that native copper was valued *per se* as a substance and for this very reason, it did not always require further procurement. However, the possibility that some of these finds represent a reserve of raw material that was lost before further procurement or that some objects were exposed to extreme temperatures due to post-depositional disturbance, for example forest fires (Cooper 2007: 124), cannot be excluded either.

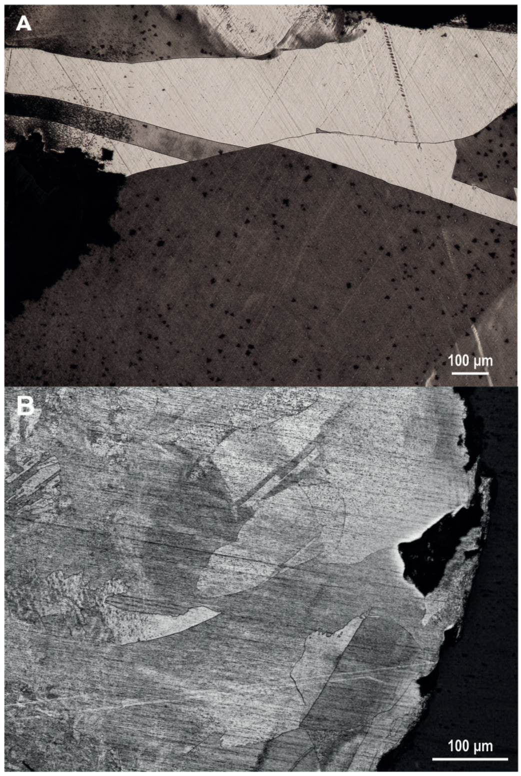



*Fig. 6. Metallographic microphotographs of native copper showing a relatively unaltered crystal structure; a) geological sample from the Kola Peninsula; b) nugget from the Rääkkylä Vihi 1 dwelling site. Photo: J. Ikäheimo.*

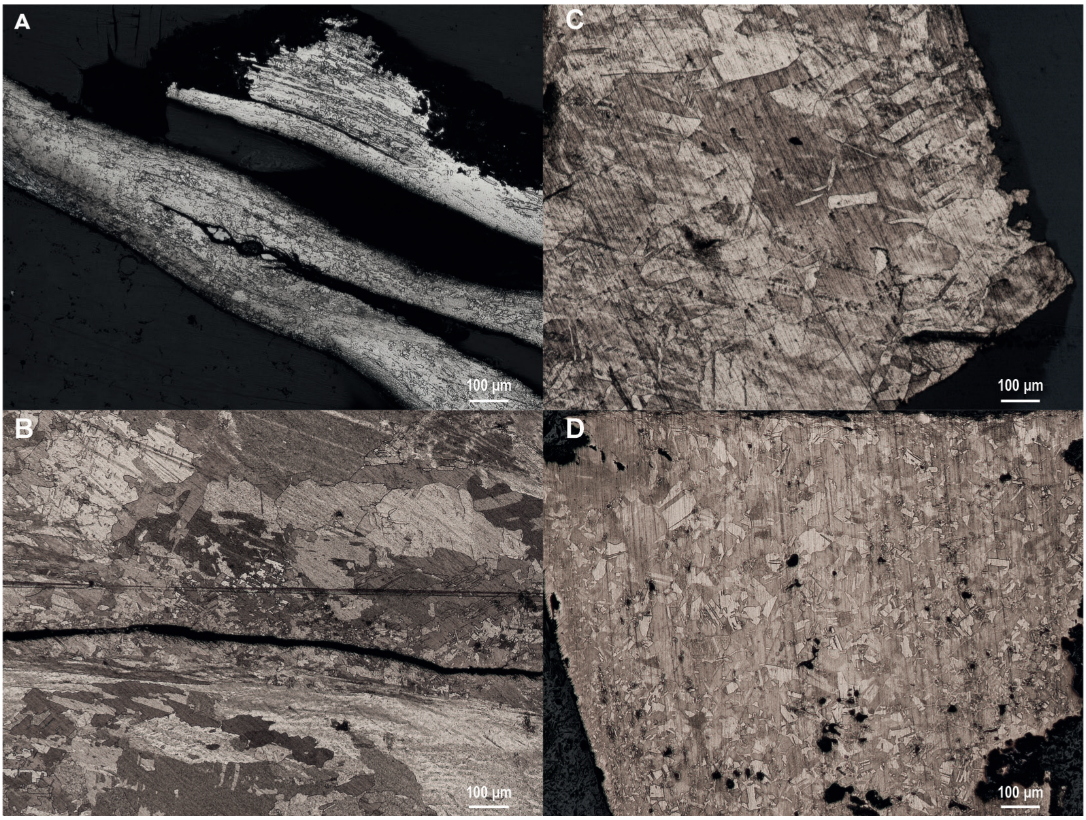



*Fig. 7. Metallographic microphotographs of native copper objects with microstructures resulting from different production techniques; a) results of extensive cold hammering on a copper sheet from Pegrema VII; b) a knife from Pegrema VII has been annealed and hammered; c) the Kukkosaari copper adze has been annealed and hammered after casting; d) the section of the Eteläharju copper knife indicates how the object was worked more along the edges resulting in a smaller crystal-size. Photo: J. Ikäheimo.*

The main body of the research material is composed of flat objects, mainly pieces of sheet metal, the forming of which has evidently required human input. The microstructure of these objects shows evidence both of cold hammering and annealing (Fig. 7a–b). For example, the shaping of the copper ring from the Suovaara dwelling site in Polvijärvi (Fig. 3b) with its substantially large crystal structure with bent twin-interfaces has required annealing and hot working. Copper sheet V from the Pegrema VII dwelling site in Russian Karelia with its macroscopically visible evidence of folding as well as its layered microstructure characterized by elongated crystals (Fig. 7a), exemplifies the outcome of prolonged cold hammering (see also Chistyakova 1991: 190). Only two objects, both purportedly functional artefacts, show advanced complexity that merits further attention.

The first object is the Kukkosaari copper adze (Fig. 3a), which was for long considered the outcome of a painstaking forming process based on the hammering of a substantially large native copper nugget (Huurre 1981: 20). However, the microstructure of the adze (Fig. 7c) incorporates light blue, regularly distributed blebs of cuprite ($Cu_2O$), which indicate casting was its principal method of manufacture. The blebs result from the reaction between molten copper and oxygen found in the air (e.g. Tylecote 1987: 93; Wayman & Duke 1999: 59). When etched, the specimen displays heterogeneous copper crystals in the c 130–300 μm size range that show both internal strain marks and twinning with curved twin boundaries. These features are indicators of annealing and cold working (Tylecote 1987: 91; Scott 1991: 6–10). These observations mark a pronounced departure from the long-cherished paradigm that strongly stressed the haphazard nature of the human–copper relationship during the Neolithic, because the era heralding the proper manipulation and use of metal(s) had been reserved in the narrative for the Bronze Age (see Ikäheimo & Nordqvist 2017: 58–60).

From this updated perspective regarding the knowledge of advanced pyrotechnology, it is reasonable to pay attention to the copper knife found in the Kierikki Eteläharju site (Fig. 3e), as it might also be a cast metal object like the Kukkosaari adze. Firstly, its microstructure (Fig. 7d) differs markedly from the copper knife found in the Pegrema VII dwelling site (Fig. 7b), which is an object formed by cold hammering (Chistyakova 1991: 190–1). The structure of the Kierikki copper knife is far more complex displaying smaller crystals (≥20 μm) near the edges and larger crystals (50–100 μm) in the middle, while the small inclusions composed of multiple elements (Sb, As and Pb) are dispersed throughout the copper matrix. The specimen is comparable both structurally and compositionally to 19th century smelted copper artefacts published by Wayman et al. (1985: 370 Fig. 2, 371 Table 1) in a study focusing on the Copper Inuits of the west-central Canadian Arctic. Thus, the artefact has likely been made by shaping a cast billet further with cold hammering and hot working. If so, the previous interpretation put forward by Ikäheimo & Pääkkönen (2009) represents an unfortunate attempt to fit the seemingly anomalous object into the prevailing paradigm concerning the state of the metallurgical knowledge in the research area.

## VICKERS TEST OF MICROHARDNESS

The Vickers test of microhardness, as indicated by the name of the method, determines the hardness of an object. In the method, a square-based diamond pyramid is pressed with a predetermined force caused by a known weight (e.g. 10 g) against the surface to be studied. The dent thus produced is observable only with a microscope, hence the name 'the test of microhardness'. The Vickers hardness is usually indicated with an abbreviation HV and is calculated using the formula HV= [1.854xF]/d2. The formula takes into account the weight used in the test, hence force (F), and the average of the two diagonal measurements taken from the square dent (d). As copper belongs to the cubic crystal system with isotropic properties, the direction in which the specimen has been cut does not affect the results of the test. Thus, the same epoxy resin embedded specimens previously used for the analyses conducted with the EPMA could be safely tested for microhardness.

The tests were carried out in the Laboratory of Material Technology (University of Oulu), using an M-type mechanical microhardness detector NT-M001 manufactured by Shimadzu Seisakusho Ltd. A force resulting from a 15-gram load was applied to the specimen surface for 15 seconds. The analysis was performed three times for each specimen, each time in a different spot. The analysed points were in areas showing the homogeneous surface of metal with no visible scratches or other structural defects. If one of the three measurements differed significantly from the other two, an additional control measurement was carried out to determine whether the outlier resulted from an analysis point located too close to the edge of the specimen or due to another reason. As the specimen taken from the Polvijärvi Suovaara copper ring did not contain sufficiently healthy metal, it had to be excluded from the analysis.

The Vickers test of microhardness can be used to infer mechanical and heating processes to which the object has been subjected during its manipulation. As with most other metals, annealing increases the malleability of native copper and is a method used to restore the ductility of a native copper object through recrystallization. The effect of the annealing temperature on the HV-value has been studied experimentally with specimens from native copper deposits located in Michigan. Although it does not form a straightforward compositional reference to the present study assemblage, the graph published by Schroeder and Ruhl (1968: 168 Fig. 11) illustrating the changes in the hardness of native copper as a function of the processing temperature can be used as an interpretative starting point.

Moreover, once the data on microhardness is combined with information regarding the average crystal size of a specimen, as determined by the metallographic analysis, the interpretations regarding different ways of working with the copper metal will stand on much firmer ground.

In addition to the annealing temperature, the amount of mechanical stress applied to an object also affects the size and the shape of metal crystals. Normally this type of manipulation is done by hammering an object that has cooled down sufficiently, and it usually proceeds to a stage referred to as cold working, when the piece of metal is completely cooled off. Cold working tends to reduce the malleability of the metal by simultaneously increasing the object's strength and hardness. In prolonged cold working the object may become brittle and prone to break. Malleability can be restored by re-annealing the object, and some objects may undergo several cycles of annealing and cold hammering before they are finished. The microstructure preserves traces of these manufacturing stages. While hot working would be the most natural technique for working with metal from the modern point of view, it probably posed serious difficulties related to the handling of hot objects with somewhat primitive tools, e.g. stone hammers and anvils, available during the Neolithic (Wayman 1985b: 76–7).

Another point to bear in mind when reviewing the results of a Vickers microhardness test and a metallographic analysis is that diverse parts of a copper object might have been subjected to a different amount of annealing and cold hammering. In a copper knife, for instance, the blade edge is the part which receives the most input from the smith, as it needs to be tough. The tang of a knife, on the other hand, might not require as much attention. Specimens for scientific analyses are usually taken from 'less visible' parts of archaeological artefacts, thus being normally from anywhere else than the blade area. The discrepancy may be significant between the hardness of the spot the specimen was taken from and other, functionally more critical parts of the object. On the other hand, a specimen taken from an annealed, but not thoroughly cold worked part of the object may provide more accurate information about temperature maximums reached during smithing.

The results (Table 2) should be reviewed against the hardness of a pure copper, which is commonly reported in SI-units as 369 MPa and converts into a conventional Vickers hardness value of HV 37.63. Still, the results from the analysis of various native copper deposits published by Chistyakova (1991: 173 Table 2) with the main body of values falling between HV 50.8 and HV 64.5 might form a better base line against which to reflect the hardness of native copper specimens in the study assemblage. As indicated in Table 2, the HV-values range from 60.2 to 129 HV, while the small post-Neolithic bronze adze from the Kellolaisten Tuli dwelling site in Suomussalmi scores a very high value (HV 248) which is factually nearly twice as hard as the hardest native copper item in the assemblage. The difference perfectly illustrates why copper alloys, tin bronze in particular, became the preferred technology for metal production during the Bronze Age.

The native copper finds, on the one hand, fall into three distinctive hardness groups: soft (HV 60.2–71.0), medium (HV 82.2–103.0) and hard (HV 114–129). Somewhat surprisingly, nuggets of native copper represent both ends of the hardness spectrum. Unless these finds come from different geological formations that have undergone varying amounts of natural strain, the discrepancy either arises from selective human interaction with the objects or differences in the post-depositional processes. Soft nuggets can be products of a natural, strain free geological environment or represent intentionally annealed, but otherwise untreated pieces. Hard nuggets, on the other hand, have either undergone considerable geological strain or received various amounts of cold hammering. The nugget recovered from the Rääkkylä Vihi 1 dwelling site, which has clearly been hammered down a bit, on one side at least, evidences the latter type of treatment (Fig. 3c). The two recently excavated specimens identified as copper nuggets from the Fofanovo XIII dwelling site might also belong to this group (Fig. 3f, h).

The group with the lowest HV-values contains only four specimens, the two softest of which are 'bits' from the Sandermokha I dwelling site. The remaining two are an unidentified object from Pegrema I and a knife from Pegrema VII. The low HV-value of the knife may come

| Location | Site | Site ID | Find | Find ID | Cu | Sn | Zn | Pb | Fe | As | Ti | Sb | Ni | Ag |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hankasalmi | Luojinniemi | 77010003 | Sheet | KM 21963:1 | 36.65 | 54.55 | - | 0.45 | 3.62 | 1.93 | - | 0.54 | 0.51 | 0.15 |
| Hyrynsalmi | Ahonranta | 105010007 | Arrow | KM 15073:1 | 45.07 | 48.93 | - | - | 1.22 | 1.58 | - | 0.97 | - | - |
| Jomala | Jettböle | - | Plate | KM 4782:180 | 72.57 | 15.53 | 4.34 | 3.72 | 2.54 | - | - | - | - | - |
| Kerimäki | Ankonpykälänkangas | 246010082 | 'Plate' | KM 26624:1 | - | 0.25 | 92.15 | 3.25 | 2.72 | - | 0.19 | - | - | - |
| | | | (reverse) | KM 26624:1 | - | 0.15 | 72.30 | 3.59 | 7.59 | - | 15.10 | - | - | - |
| Oulu | Hangaskangas E | 1000006785 | Bead | KM 39158:1313 | 96.55 | - | - | - | 0.96 | - | - | - | - | - |
| | Kierikki Sorakuoppa | 972010027 | Knife frg. | KM 23431:57 | 98.83 | - | - | - | 0.35 | 0.03 | - | - | - | 0.31 |
| Pihtipudas | Vaaksianiemi | 601010053 | Plate | KM 33719:1 | 65.60 | 20.37 | 1.16 | 8.01 | 3.40 | - | - | - | 0.51 | 0.26 |
| Puumala | Hiekkaniemi | 623010007 | Whirl | KM 39115:40 | 98.20 | - | - | - | 0.81 | - | - | - | - | - |
| Ruokolahti | Kutveleen Kanava | 700010031 | Arrow | KM 32948:1 | 88.10 | - | 9.56 | 0.16 | 1.19 | - | - | - | - | - |
| Suomussalmi | Joenniemi | 777010117 | Arrow | KM 21023:1 | 56.00 | 35.57 | - | 0.70 | 4.78 | 0.44 | 0.02 | 0.15 | 0.20 | 0.12 |

*Table 3. Portable x-ray fluorescence spectrometry (pXRF) analyses of fully oxidized archaeological finds tentatively identified as native copper objects from Finland.*

at first as a surprise, but the forming of an object of such complexity very likely took several rounds of annealing and hammering. As the blade of a knife demands more attention than the tang, the tang is usually softer than the blade, and the HV-values determined by Chistyakova (1991: 190–1) from the very same specimen – HV 92 for the blade and HV 57 for the tang – confirm this observation.

The group characterized by medium hardness values consists of dozen objects including the majority of flattened pieces of copper that have been recently identified as intentionally produced sheets or plates (Nordqvist et al. 2012: 11–2). Chistyakova (1991: 186–9), on the other hand, sees them as unintentional by-products of making proper native copper artefacts. The artefacts should have undergone further stages of processing and yielded higher values of hardness than their presumed by-products, but this is not the case. Curiously, also the geological specimens from the Kola Peninsula and Karhumäki fall into this group suggesting that they were subjected to post-depositional strain after crystallization. However, the Vickers hardness values obtained for this study are generally somewhat higher than those published by Chistyakova (1991). While she determined the hardness values using an average of ten measured points instead of three or four, the different number of measurements does not explain the difference in hardness very satisfactorily. The care taken by Soviet scientists in the preparation stage of the samples to avoid research-induced bias (Chistyakova 1991: 172) in sample preparation might well be it. As the thin-section laboratory of the Geological Survey of Finland, which prepared the samples for the present study, was not aware of their intended use for the Vickers test of microhardness, they were probably processed with less care as ordinary geological samples.

## X-RAY FLUORESCENCE SPECTROMETRY

The possibility to examine the composition of archaeological finds identified as possible items of native copper by previous scholars but excluded from further analyses due to their poor state of preservation, opened up only after the completion of the studies explained in previous chapters. This was due to advancement of portable x-ray fluorescence spectrometry (pXRF), which has recently opened a fast and efficient means of enquiry for the basic identification of archaeological materials. In this case, thoroughly oxidized metal objects were analysed with a portable Bruker IV-SD X-ray fluorescence spectrometer to distinguish native copper items from ones made of copper alloys. The analyses were carried out using the supplier's general calibration for metals and with the duration of the analysis set to 60 seconds. While other metallic elements than copper, lead and tin in particular (Orfanou & Rehren 2015: 391–5), are prone to enrich on corrosion surfaces, the results obtained with the pXRF are indicative enough to distinguish native copper objects from those made of various copper alloys.

The first group of finds contains objects that the pXRF-analysis confirmed to be made of native copper (Table 3). As many of these objects have been found only recently thanks to improved methods of excavation, the new native copper finds are customarily quite small. A copper bead from the Oulu Hangaskangas E site and a copper whirl from Puumala Hiekkaniemi with their respective dimensions of 5 x 5 x 3 and 6.5 x 3 x 3 millimetres illustrate this point perfectly. In addition, the fragment of a copper knife from the Oulu Kierikin Sorakuoppa dwelling site found originally in 1986, but only recently re-identified as a rare Neolithic metal artefact (Ikäheimo et al. 2015), shows the potential hidden in already existing archaeological collections that just need to be re-examined.

Two finds previously classified as relatively certain objects of native copper, but now shown to be of a different composition, form the second group. The first object is a small piece of sheet metal from the Jomala Jettböle dwelling site located in the Åland Islands. This find has been put forward in general treatises on Finnish prehistory as the earliest example of the use of metal within the sphere of societies that later developed into a conceptual entity referred to as the Western Bronze Culture (Salo 1984: 106–7; Edgren 1992: 70). The other item found at the Ankonpykälänkangas dwelling site at Kerimäki was initially identified and catalogued as a small fragment of a copper sheet. However, the results obtained with the pXRF indicate zinc as the main element instead of copper with a high presence of titanium on one side. Therefore, the find is most likely a flake of zinc-plating worn off from an excavation tool containing traces of titanium paint.

Finally, many of the metal finds from chronologically insecure contexts, but tentatively classified as Neolithic native copper finds, turned out to be made of copper alloy. Some of these finds have been discovered at multi-periodic dwelling sites in the Kainuu region in north-eastern Finland, and the small bronze adze from the Kellolaisten Tuli site in Suomussalmi (Fig. 3d), now identified as a post-Neolithic find, is a good example of this. Other objects worth mentioning here are the two tin-rich bronze sheets found in the excavations of the so-called Lapp cairns at Hankasalmi and Pihtipudas. The inland location of this cairn type and the scarcity of finds or other datable materials they contain, has usually inhibited their direct dating. Still, the earliest Lapp cairns are assumed to have been built during the Neolithic period (Halinen 2015: 104) and consequently any metal finds in them have been considered to be possible native copper objects. The results of this study do not support this kind of reasoning.

## DISCUSSION

While the various properties of native copper objects introduced above might be interesting *per se*, they also provide a viable way to touch upon themes such as the significance and provenance of this rare substance in the Neolithic. The significance is reflected in the first place by the multitude of ways the metal has been treated and processed, and how the processing technologies evolved over time. There is now substantial evidence on smelting and casting of native copper from both Finland and Russian Karelia. The observation implies that while we have no straightforward method to estimate the recycling of copper metal in the Neolithic, it has represented one possible strategy of interaction. This brings us to the question regarding the apparent rarity of Neolithic copper artefacts in the research area: is it real or just a reflection of the exhaustive process by which this raw material was recycled? Of course, the answer is greatly dependent on attitudes and beliefs people had towards this substance during the Neolithic.

The archaeological contexts in which native copper objects have been found offer one valid way to investigate the significance of native copper in the Neolithic. The finds seem to be almost exclusively associated with dwelling sites, particularly with hearths, which is a pattern observed also in Alaska (Cooper 2011: 265). On the other hand, these finds are systematically lacking from burials in the research area, while the nearest examples of native copper objects from such contexts have been unearthed in Zvejnieki, in Latvia (Zagorska 2006: 99–102). Copper may have been considered a living and even conscious substance that should have not been buried 'alive' with the deceased. In the research material, the signs of annealing detected in seemingly unaltered pieces and nuggets seem to back up this conclusion. Furthermore, ethnographic data from this historical period suggests that copper objects and even pieces of copper scrap metal could have been heirlooms that were passed down in the family (Clark & Martin 2005: 120). While the number of excavated Neolithic burial sites in Finland are only a small fraction of the contemporary dwelling sites subjected to invasive archaeological investigations, it is difficult to believe that the picture would be significantly altered by future discoveries.

When it comes to the provenance of raw materials, it is very clear that the methods used in this study are insufficient to provide a definite answer or even a sufficient estimate in answer to this question. If the intra-site element variability of copper deposits exceeds the inter-site variability, as indicated above, it is also doubtful whether the question can be resolved with any method of compositional analysis. As there is now evidence of the use of techniques such as smelting and casting from the Neolithic, a somewhat different research question could be put forward. It concerns the probability that the metal used in the making of a Neolithic copper artefact was native copper or copper refined either from oxide or sulphide ore. One way to answer this question is to use the method developed by Friedman et al. (1966), which is based on concentration range probabilities assigned for the occurrence of six key elements (Ag, As, Fe, Bi, Pb and Sb) in different deposit types. These are used to calculate the relative likelihood that the object is native copper or made of metal refined from oxidized and reduced ores. When the method is applied to well-known Fennoscandian copper artefacts that have been analysed with a method providing sufficient accuracy (Table 4), rather interesting results emerge that are also aligned to a certain extent with previous interpretations.

According to the results, the most likely artefacts made of native copper are the Kukkosaari adze and the Polvijärvi Suovaara ring (Fig.

| | Concentration (ppm) | | | | | | Probability | | |
|---|---|---|---|---|---|---|---|---|---|
| | Ag | As | Bi | Fe | Sb | Pb | native | oxide | sulphide |
| Kukkosaari copper adze[1] | 225 | 3,6 | - | <400 | 10.4 | - | 0.930 | 0.063 | 0.073 |
| Kukkosaari copper adze[2] | 70 | <70 | - | 5 | <10 | 9 | 0.912 | 0.080 | 0.008 |
| Polvijärvi Suovaara copper ring[1] | 35 | 280 | - | - | - | - | 0.844 | 0.148 | 0.007 |
| Varris copper adze[3] | 50 | 4800 | 20 | 10 | 30 | 900 | 0.001 | 0.820 | 0.179 |
| Lillberget copper bead[4] | 810 | 11680 | 390 | 3.6 | 6530 | 1150 | - | 0.002 | 0.998 |

*Table 4. Defining the most likely source of metal for some well-known Neolithic copper artefacts from Fennoscandia with the method developed by Friedman et al. (1966). [1] Neutron Activation Analysis, FiR1 research reactor, VTT, Otaniemi (Espoo); [2] Atomic Emission Spectrometry, Hilger-spectrometer, Outokumpu AB research laboratory, Pori; [3] Atomic Emission Spectrometry, Boliden Mineral AB, Central Laboratory, Skelleftehamn; [4] Secondary Ion Mass-Spectrometry, SIMS-laboratory, Chalmers Technical Highschool, Gothenburg.*

3a–b). The Kukkosaari adze is particularly interesting from this point of view, as it has been subjected to two independent compositional analyses. The metal in the preform of a copper adze from Varris, in northern Sweden (Huggert 1996) comes from copper oxide minerals, while the finds from the Lillberget dwelling site in northern Sweden (Halén 1994: 153–63; see also Nordqvist et al. 2011) would have been processed from metal derived from sulphide copper ore. These results are, of course, both tentative and exploratory in their nature and they are presented here as a motivator for further studies that should be accompanied with some form of out of the box thinking about the state of metallurgy and pyrotechnology during the Neolithic.

A question of an equal importance is, whether there even was anything that could be classified as a source or a deposit by modern standards. It is possible that 'float copper' – in other words native copper transported by glacial erosion or alluvial forces – was exploited during the Neolithic in the research area. At least float copper was the main source of metal for many prehistoric groups in North America (Wayman 1985a: 68). The literature on the early use of metal in Finland includes one, probably unintentional, reference to this possibility. In his treatise on the Kukkosaari copper adze Huurre (1981: 21) mentions in passing a quartz stone containing native copper found in a gravel pit in Suomussalmi. He states that glacial drift could not have transported the stone for a long distance, however, unfortunately, the argument was not developed any further.

At present, no sites containing indisputable evidence of the mining of native copper during the Neolithic can be pointed out (see, however, Zhuravlev 1991: 147; Ikäheimo 2014: 19–22) either in Russian Karelia or Finland. Even the Lake Onega area in Russian Karelia, where the exploitation of this raw material seems to have been most intensive does not form an exception to this rule. Quite to the contrary, the finds from the Fofanovo XIII dwelling site include an example (Fig. 3f; see also Nordqvist & Herva 2013: 14) characterized by rounded and worn shapes that look more like pieces of float copper than raw material extracted through mining (but cf. Chernykh 1992: 188 Pl. 19:11–5). Thus, the first encounters with this novel substance might have taken place by chance instead of determinate efforts carried out by people purposefully surveying for new raw material resources (cf. Huurre 1998: 351).

## CONCLUSIONS

A multi-method approach to archaeological native copper finds from Neolithic dwelling sites in Finland and Russian Karelia confirmed previous observations regarding the state of metallurgical knowledge in the research area. The results indicate how the acquisition and processing of this novel raw material took place in ways that do not always match well with inductive reasoning based on superficial examinations of these finds and their find contexts. Thus, native copper nuggets may show evidence of annealing, and both cold hammering and hot working have been used to produce small copper sheets and strips, while smelting and casting have been essential for the making of some artefacts. Other finds formerly interpreted as potential Neolithic native copper objects have turned out to be made of copper alloys or other metals and dated to later periods. The use of float copper of local or regional origin, or even the utilization of copper ore, instead of or alongside native copper is also a possibility that should be explored in the future with more adapt methods such as lead-isotope analysis.

The most important adjustment, however, concerns the way native copper finds should be comprehended and researched by future scholars. Previously, the Neolithic groups engaging with native copper have been seen as passive recipients of a somewhat useless substance that had hardly anything but a curiosity value. Today, it is quite evident that native copper had meanings and uses that called for active engagement with the material in those places it ended up in, in other words Neolithic dwelling sites. The signs of this engagement, which are probably not readily recognizable signs of metallurgy and pyrotechnology, but traces of a more mundane character witnessing other type(s) of interaction, are there to be discovered for those willing to see this material and its associations with new eyes.

## ACKNOWLEDGEMENTS

The research for this paper was conducted mainly under two research projects: *Copper, Material Culture and the Making of the World in Late Stone Age Finland and Russian Karelia* funded by the University of Helsinki (2010–12; grant #490055) and *The Use of Materials and the Neolithization of North-East Europe (c 6000–1000 BC)* funded by the Academy of Finland and the University of Oulu (2013–17; project #269066). The author, who acted as the nominal principal investigator in both projects, wants to express his sincere gratitude to the generous funders and the hard-working persons involved with these projects: Vesa-Pekka Herva, Antti Lahelma, Teemu Mökkönen, Kerkko Nordqvist and Aleksey Tarasov. Thanks are also owed to the two anonymous reviewers of Fennoscandia archaeologica, as well as to Leena Söyrinki-Harmo and Leena Tomanterä† (National Board of Antiquities of Finland) and to Eero Hanski, Jari Heinonen, Seppo Järvenpää and Olli Taikina-Aho (University of Oulu).

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# APPENDIX 1: SPECIMEN CATALOGUE

1. Suomussalmi Kukkosaari copper adze (National Museum of Finland, KM 20850:1). A trapezoid adze with the blade exceeding the stem in breadth. Relatively flat, slightly convex backside; frontside develops into a substantially wide convex gouge. Blunt, c 3 mm thick edge; uneven stem with rectangular in section. Heavily corroded surfaces. Context: found by a schoolgirl in June 1980 on the Kukkosaari Island 'on a sandy shore between the rocks'. Size: 82 x 28 – 45 x 18 mm; weight 321.865 g. Sample (0.031 g) taken from the stem of the adze. Fig. 3a.

2. Polvijärvi Suovaara copper ring (KM 14982:1). Open ring with roughly a fourth of the circumference missing. Flattened, rectangular cross-section. Deep green corrosion patina. Context: found during the excavations of the Suovaara dwelling site in 1960 at a depth of 35 cm in association with Comb Ware pottery. Maximum diameter 62 mm, minimum diameter 55 mm, width 6 mm, thickness >1 mm; weight: 3.933 g. Sample (0.059 g) taken from the other end of the ring. Fig. 3b.

3. Rääkkylä Vihi 1 copper nugget/dendrite (KM 30460:11959). Irregular lump of metal with three dendritic 'branches' in addition to slightly flattened appearance. Heavily corroded, deep green surfaces. Context: found during the excavations of the Vihi 1 dwelling site in 1997 associated with Early Asbestos Ware and Typical Comb Ware. Size: 20 x 9 x 3 mm; weight 1.512 g. Sample (0.068 g) taken from a 'branch'. Fig. 3c.

4. Suomussalmi Kellolaisten Tuli copper adze (KM 14831:1169). A roughly lozenge-shaped object with a flattened, narrowing stem. Slightly raised, partially broken lateral sides. Oxidized, but substantially clean and well-preserved surfaces. Context: found during the excavations of the Kellolaisten Tuli II dwelling site in 1959 in square K:3 with undecorated pottery, burnt bone and quartz scrapers. Size: 42 x 20 x 2 mm; weight 8.634 g. Sample (0.095 g) taken from the stem of the object. Fig. 3d.

5. Oulu Kierikki Eteläharju copper knife (KM 30775:1). A tanged knife with a pointed, slightly bent tip, even spine substantially straight cutting edge. The spine has been formed by twisting and pressing the copper sheet against itself. Heavy spot corrosion in addition to overall oxidization. Context: found during the excavations of the site in 1997 directly underneath the topsoil in the middle of a Neolithic house depression. Size: 127 x 19 x 1.5 mm; weight: 16.5 g. Sample taken in 1999 from the end of the tang. Fig. 3e.

6. Fofanovo XIII (213) copper nugget. Irregular, but yet somewhat rounded copper nugget or lump. Thoroughly oxidized surfaces. Context: found during the 2010–11 excavations of the Fofanovo XIII within 50–90 cm deep cultural layer together with pottery, amber pendants, unburnt bones and, above all, slate artefact preforms and production debris. Size: 25 x 22 x 6 mm; weight: 6.6 g. Sample taken from a shallow protrusion. Fig. 3f.

7. Fofanovo XIII (214) copper spit. A short spit with pointed ends and a roughly rectangular section. Heavily corroded surfaces. Context: cf. no. 6. Size: 43 x 5 x 4 mm; weight: 3.7 g. Sample taken from the other end of the spit. Fig. 3g.

8. Fofanovo XIII (522) copper nugget. An irregular dendritic lump of copper with one pronounced and two smaller protruding 'branches'. Heavily corroded object with turquoise green oxidized batches. Context: cf. no. 6. Size: 26 x 13 x 5 mm; weight 4.3 g. Sample taken from a short protruding 'branch'. Fig. 3h.