

Beaker and Early Bronze Age Tin Exploitation in Cornwall: Cassiterite Processing Identified through Microwear and pXRF Analyses

CHRIS CAREY¹ , CHRISTINA TSORAKI² , ANDY M. JONES³ ,
OLIVER J.T. HARRIS², RACHEL J. CRELLIN²  AND PETER LYONS¹

¹*School of Applied Sciences, University of Brighton, UK*

²*School of Archaeology and Ancient History, University of Leicester, UK*

³*Cornwall Archaeological Unit, Truro, UK*

The appearance of Beaker pottery in Britain and Ireland during the twenty-fifth century BC marks a significant archaeological horizon, being synchronous with the first metal artefacts. The adoption of arsenical copper, mostly from Ireland, was followed by that of tin-bronze around 2200 BC. However, whilst the copper mine of Ross Island in Ireland is securely dated to the Early Bronze Age, and further such mines in the UK have been dated to the Early and Middle Bronze Age, the evidence for the exploitation of tin ores, the other key ingredient to make bronze, has remained circumstantial. This article contains the detailed analyses of seven stone artefacts from securely dated contexts, using a combination of surface pXRF and microwear analysis. The results provide strong evidence that the tools were used in cassiterite processing. The combined analysis of these artefacts documents in detail the exploitation of Cornish tin during this early phase of metal use in Britain and Ireland.

Keywords: Beaker, Cornwall, cassiterite, microwear, metallurgy, ore processing

INTRODUCTION

The arrival of Beaker material culture into Britain and Ireland during the twenty-fifth century BC is a significant moment, coinciding with the appearance of the first metal artefacts from around 2450 cal BC (Allen et al., 2012). The first metal implements in Britain were made of copper, later followed by tin-bronzes around 2200–2100 cal BC. Whilst some of these objects were placed in graves, for example with the Amesbury Archer (Fitzpatrick, 2011) or with the Racton burial in West Sussex (Needham et al., 2017), the

majority of the period's metalwork, in the form of axes, was deposited as single finds or in small hoards (Needham, 2017). Early copper alloys within Britain and Ireland were largely derived from arsenical copper ore mined from Ross Island in south-western Ireland (O'Brien, 2004), which was the source of most of the copper in Britain from c. 2400 cal BC (Bray, 2012). Although copper mines dating to the Early Bronze Age (EBA hereafter) have been discovered in recent decades, such as Copa Hill, Cwmystwyth, in Wales, Ecton Hill and Alderley Edge in the English Peak District (Timberlake, 2003, 2014, 2017; Timberlake

& Pragg, 2005), and the largely Middle Bronze Age mine at Great Orme in Wales (Williams & Le Carlier de Veslud, 2019), Ross Island is currently the earliest mining site known in Britain and Ireland (Carey et al., 2019), although some of the earliest deposits at Copa Hill could date to a similar period (Timberlake & Craddock, 2013).

Bronze is an alloy of copper and tin; though it has been postulated that tin was obtained from the rich metalliferous deposits of south-western England (Budd & Gale, 1997; Haustein et al., 2010), the evidence for its exploitation in the Bronze Age remains largely elusive. The numerous Middle Bronze Age artefacts recovered from tin streamworks in Cornwall provide evidence for prehistoric exploitation (Penhallurick, 1986: 173–224), and this has recently been confirmed by a date of 1620–1497 cal BC (3269 ± 27 BP, OxA-36336 at 93.9% confidence) obtained for an antler pick from the Carnon valley near Truro (Timberlake & Hartgroves, 2018). Furthermore, two EBA pits recently excavated in Cornwall contained several kilos of cassiterite pebbles, granules, and ore, demonstrating the collection of alluvial cassiterite for processing (see below Truro TEDC; Taylor, 2022).

Evidence for EBA metalworking in the south-western English peninsula, such as furnaces or ‘smithies’, has not been identified and potential data are again restricted to indirect clues including stone moulds and hammerstones (Craddock & Craddock, 1997; Timberlake & Craddock, 2013; Brüggemann et al., 2017). Significantly, fragments of tin slag were recovered from an EBA barrow at Caerloggas in Cornwall (Miles, 1975); however, smelting took place off-site, the slag having been deposited in a secondary context. Currently, the earliest *in situ* evidence for metalworking in southern Britain dates to the Middle Bronze Age, at Tremough (Cornwall), where moulds and a hearth indicate that bronze was cast inside a

roundhouse dated to *c.* 1500–1300 cal BC (Jones et al., 2015; Webley et al., 2020: 84).

This sparse evidence for the exploitation of metalliferous resources in south-western Britain and indeed western Europe (Gandois et al., 2020) during the EBA presents a paradox, as the Cornish peninsula is rich in copper, gold, and especially tin (Penhallurick, 1986; Timberlake, 2017; Radivojević et al., 2018). Recent advances in analytical techniques, including isotopic analysis of artefacts and identification of potential ore sources, have revealed that traces of these metals from south-western England were probably present in Bronze Age artefacts (Rohl & Needham, 1998; Haustein et al., 2010; Bray & Pollard, 2012). Cornish gold may have been circulated before *c.* 2000 cal BC to make lunulae, which are found in Ireland and Atlantic Europe (Standish et al., 2015), and gold from the river Carnon, along with tin from the Redruth area, may have been used in the Nebra Sky Disc (Esher et al., 2011; Borg & Pernicka, 2017). We have good reason, and increasingly good secondary evidence, to believe that sources of tin and gold in south-western Britain were being exploited, but no direct indications of how or where this was happening. Understanding metalworking in this region has implications for our knowledge of this period across north-western Europe: evidence for tin exploitation is a critical missing piece of the puzzle.

NEWLY DISCOVERED SITES IN CORNWALL

It is within the context of a lack of evidence of EBA exploitation of metalliferous resources within south-western Britain that three excavated sites in Cornwall are significant: two, Sennen and Lelant, are associated with Beaker pottery, and a third, in Truro, dates to the EBA (Figure 1). These have the capacity, as we



Figure 1. Location of the two Beaker-period and one Early Bronze Age archaeological sites at national (A), regional (B), and sub-regional (C) scales.

will demonstrate, to provide new evidence for tin ore extraction and processing, increasing our understanding of the development of these traditions in Britain and their role further afield. Here we describe the new sites before outlining the analytical tools employed to document the exploitation of tin (for site descriptions contexts given as (XXX) are a deposit or fill, and those given as [XXX] are cut features).

SENNEN PS07: STRUCTURE 108

The excavation of an EBA site at Sennen identified Structure 108, an irregular oval feature measuring 4.2×3 m aligned on a north-east to south-west axis (Jones et al., 2012; Figure 2). The interior was deliberately sunken (by 0.25 m) and around the perimeter were at least eight small postholes, potentially supporting a superstructure.

An area of burning indicated a possible internal hearth (103), 1.1×0.85 m, located in a slight hollow in the floor in the structure's south-western half. A single, deliberate, backfill (89) sealed the structure and contained many artefacts, including Beaker pottery, twenty-one flints (six waste pieces, one split pebble and fourteen tools, including an engraver that was probably hafted), and thirteen stone tools, including SF2, SF3, and SF5, discussed below. Context (89) dated to 2337–2059 cal BC (SUERC-21077, 3785 ± 30 BP, 95%).

A row of postholes was found outside the north-western side of Structure 108, on the same north-east/south-west alignment, and to the north-east and east of Structure 108 there was an alignment of pits and postholes set at right angles to the posthole row. Several pits were also identified, some of which contained flint, Beaker pottery, and worked stones. To the

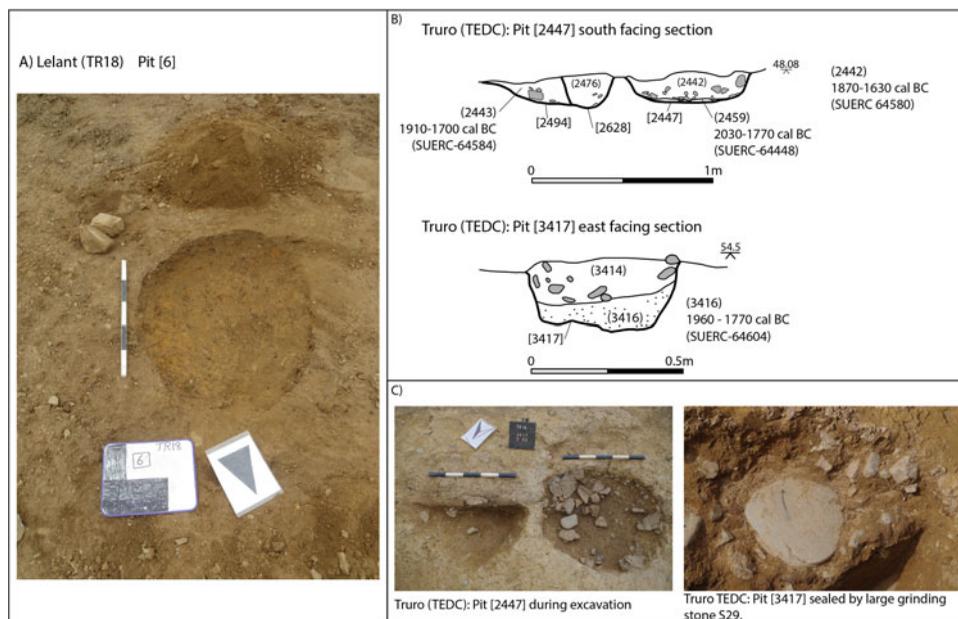


Figure 3. A) Lelant (TR18) pit [6] post excavation working shot; B) Truro: simplified sections of pits [2447] and [3417]; C) pit [2447] during excavation (left) and pit [3417] covered by artefact S29 (right).

The arrangement of the artefacts in pit [6] indicates more than the routine discard of occupation material. The assemblage represents both a deliberate clustering and a separation of different types of artefacts into distinct groups. There was deliberation in the choice of stone-processing tools which were selected and sourced from different geologies and used for separate tasks. The deposit thus contains a set of visually distinctive tools, which are likely to have been associated with particular people, activities, and places. The pit's location close to the Hayle Estuary may be significant as this was an important waterway linking people and places in the Bronze Age (Brück, 2019: 220–23; Johnston, 2020: 140–45).

Truro TEDC: Pit [3417]

The Truro Eastern District Centre (TEDC) site on the eastern side of Truro comprised numerous pit groups spanning the Neolithic and EBA, many of which

had been deliberately infilled (Taylor, 2022). Two of these pits, securely dated to the EBA, contained cassiterite (Figure 3b and 3c). The bowl-shaped pit [3417], 0.5 m in diameter and 0.24 m deep, was found in isolation and contained two fills. The lower, dated to 2010–1964 cal BC (SUERC-64604, 3543 ± 30 BP, 95%), contained cassiterite-rich cobbles weighing *c.* 1.25 kg and the environmental sampling residue contained a further 9.1 kg of crushed cassiterite. The upper fill contained 2.6 kg of cassiterite ore and pebbles, and the top of the pit was sealed by a large grinding tool (S29). The deposition of a significant quantity of crushed cassiterite, which was a valued material, coupled with the placing of the grinding tool across the top of the pit strongly suggests that it was a structured deposit. A second pit [2447] was also associated with cassiterite and abraded Collared Urn sherds; five waste flints and small rounded cassiterite granules were found at its base. The upper fill contained a large quantity

of Trevisker pottery (a style particular to EBA south-western Britain), flints, and nearly 0.6 kg of cassiterite pebbles. Two radiocarbon determinations were obtained from the lower and upper fills, respectively: 2027–1774 cal BC (SUERC-64448, 3567 ± 7 BP, 95%) and 1870–1622 cal BC (SUERC-64580-3414 ± 28 BP, 95%). The dates for [2447] straddle a long timeframe, allowing for the possibility that infilling was slow, although the pit was shallow and there was no sign of silting between the layers. The abraded Collared Urn sherds in the primary fill also contrast with the Trevisker sherds in the upper fill. This suggests that the pit received two distinct artefact-rich caches in succession.

MATERIALS AND METHODS

Sequence of analysis

Initially, the stone tool assemblages from Sennen (PS07, fifteen artefacts), plus selected artefacts from Lelant (TR18, one artefact), and Truro (TEDC, one artefact) were analysed by portable X-Ray Fluorescence (pXRF hereafter) scanning to detect elements associated with metalliferous ores. When elements such as tin (Sn) were detected, the stone tools were subjected to a more detailed pXRF analysis. This used an Innov-X Alpha Series instrument, using a five-minute count time per reading, obtaining indicative readings for Al, Si, P, K, Ti, V, Cr, Mn, Fe, Ni, Cu, Zn, As, Rb, Sr, Sn, W, Zr, and Pb. Given the calibration limitations of the pXRF technique, a bespoke set of Sn calibration standards were used to quantify the Sn data values. Principal Component Analysis was used to define geochemical signatures within the data. A selection of artefacts were subsequently subjected to microwear analysis, including those that displayed elevated levels of Sn, as well as some

artefacts chosen for their morphological and technological features (e.g. SF2).

Microwear analysis is a technique that identifies microscopic wear traces that develop on the surface of objects during manufacture, use, handling, but also post-depositionally (van Gijn, 2010, 2014). Microscopic observations were conducted at low (<100×) and high magnifications (100× and 200×) utilizing a stereomicroscope (Leica M80) with an external, oblique light source and a coaxial illumination unit (Leica M80 LED5000 CXI; magnifications up to 230×), and an incident light (metallographic) microscope (Leica DM1750M) with a Leica MC120 HD digital camera. Previous functional studies of stone tools used in mining activities in Britain have focused on macroscopic inspection (e.g. Gale, 1995; Jenkins 2021), and other examinations of metalworking tools have used somewhat different techniques (e.g. Cowell & Middleton, 2011). This article presents the first application of an integrated approach that combines high-resolution microwear and pXRF analyses of stone metalworking assemblages in Britain and Ireland. For further details of the methods used and the artefacts analysed, see the online [Supplementary Material](#).

RESULTS

Microwear traces and tin concentrations

To establish the use of the selected tools, we combine the results from the two techniques in a cautious approach that looks for agreement between competing lines of evidence. [Table 1](#) summarizes the tools that show evidence of use against a hard mineral material (see also [Figure 4](#)). [Table 2](#) combines evidence from the pXRF and microwear analyses to interpret tool use and its relationship with metal production.

Table 1. *The tools analysed: lithology, size, and associated pottery (see also Figure 4).*

| Artefact | Lithology | Weight (g) | Dimensions: max. length, width, thickness (mm) | Object type and key features | Excavated context | Associated pottery |
|----------------|---|------------|--|---|---|------------------------------------|
| Sennen SF33 | Greenstone cobble; polish around girth | 390 | 69.39 × 65.43 × 54.94 | Pestle/pounder, abrading and pounding wear on two opposite ends | Context (101) upper fill of hearth [105] in pit [127] | Beaker |
| Sennen SF18 | Beach cobble; fine grained granite with quartz and tourmaline | 533 | 94.74 × 76.78 × 56.49 | Grinding/pounding tool, abrasive and pounding wear traces on one broad surface and on both narrow ends | Context (89) upper fill of Structure 108 | Beaker |
| Sennen SF5 | Greenstone beach cobble | 500 | 111.09 × 66.56 × 36.21 | Grinding/pounding tool with finger grips on margins, abrasive and pounding wear on both broad surfaces, pounding wear on both narrow ends | Context (89) upper fill of Structure 108 | Beaker |
| Sennen SF3 | Greenstone beach cobble | 658 | 126.31 × 78.12 × 37.26 | Grinding/pounding tool with finger grip on one margin, abrasive and pounding wear on the broad surfaces, percussive wear on narrow ends | Context (89) upper fill of Structure 108 | Beaker |
| Sennen SF2 | Quartzite cobble | 743 | 116.50 × 77.41 × 60.80 | Percussive tool with hafting hollows on margins and body, percussive wear on both narrow ends | Context (89) upper fill of Structure 108 | Beaker |
| Lelant TR18 S1 | Greenstone cobble | 647 | 104.13 × 76.65 × 40.48 | Grinding/percussive tool, grinding and pounding wear on broad faces, intentionally polished surface | Pit [6] | Curated Beaker pottery vessel |
| Truro TEDC S29 | Gramscatho sandstone | 2684 | 186.00 × 165.00 × 56.00 | Lower (stable) grinding tool, abrasive wear on broad surface | Pit [3414] | Trevisker and Collared Urn pottery |

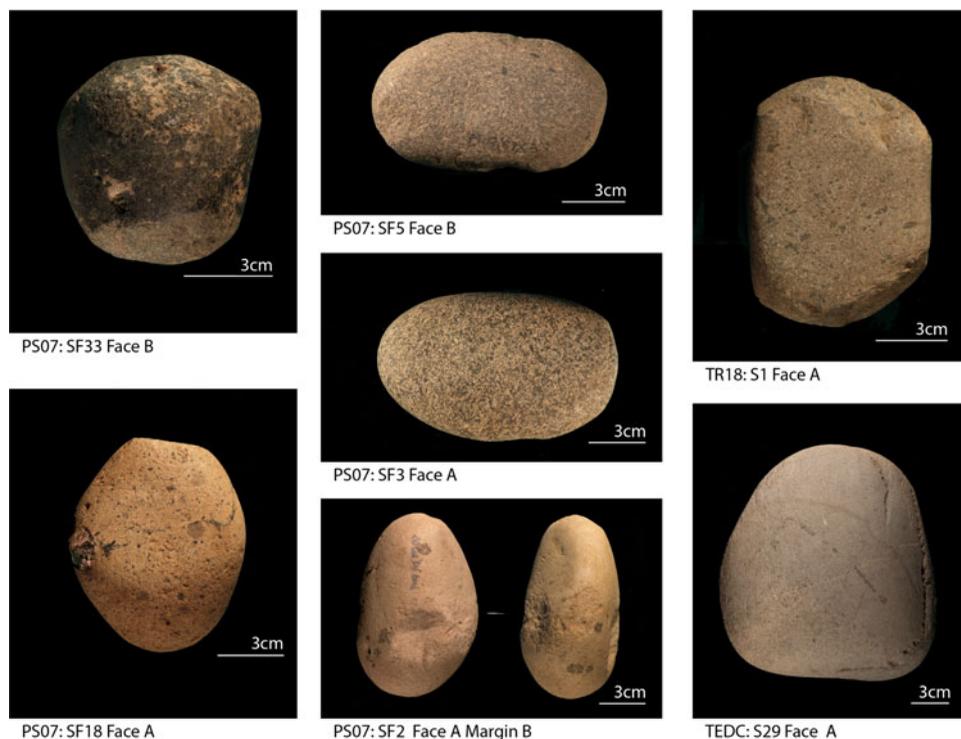


Figure 4. Stone tools presented in this analysis (shown at different scales, all scale bars 3 cm).

The analysis of the complete pXRF dataset revealed a clear geochemical signature related to cassiterite tin ore (Sn, Pb, As, and W) (Wang et al., 2016), defined by Principal Components 4 and 5. The pXRF data detected the presence of some high, but also variable, tin levels on the artefact surfaces, which are interpreted as partly derived from surface residues (based on higher levels on working surfaces) and partly from the artefacts' natural lithologies. The microwear analysis defined a restricted range of actions, namely crushing and grinding, traces of which were found occasionally on the same surfaces. The microscopic wear traces suggest the processing of a semi-hard material of mineral origin; based on observed wear traces, including micropolish features, and on experimental data (e.g. Hayes et al., 2018), we can exclude the possibility that

these traces derived from the processing of materials such as plants or grains, bone, wood, or clay. In places the observed wear traces include a micropolish of highly reflective appearance and in this case mineral micro-residues were incorporated within the micropolish during its formation (Figure 5). This agrees with previous findings that proposed that the presence of copper micro-residues within micropolishes on stone tools was due to metallurgical activities (Hamon et al., 2020: 12–13).

Given that neither technique provides data that unequivocally defines tin ore processing, several lines of reasoning can be used to support our interpretation. The Cornish Gramscatho sandstone of the large grinding tool (TEDC S29) found with the cassiterite ore acts as a comparator for the other stone tools; it has some

Table 2. *Analysed stone tools: key evidence and confidence of the interpretation (see also highlights on Figure 5 and online Supplementary Material).*

| Artefact | pXRF evidence | Microwear analysis | Key interpretations | Confidence in interpretation and relationship to metalworking |
|-------------|---|--|--|---|
| Sennen SF33 | Very high Sn and Arsenic (As) measurements on both working ends of the tool. Sn mineralization also visible on the interior of drilled core. Object recorded as a greenstone, but contains an anomalous geochemical signature | Step fractures and edge rounding on crystal grains, patches of reflective micropolish on higher elevations of crystal grains. Wear development including the creation of facets on the opposite ends suggests use with a rotational motion | Tool used for grinding/crushing small-sized particles of a medium hard mineral. Some elevation of Sn and As on the working ends, although elevated Sn and As is also a natural component of the tool lithology | High |
| Sennen SF18 | Sn measurements slightly elevated on the working ends | Levelling of crystal grains associated with striations and grain extraction, patches of reflective micropolish, impact fractures with a pointed morphology and crushing on the higher elevation of the grains, occasionally edge rounding and micropolish | Tool used for grinding and pounding/pulverizing semi-hard material of mineral origin, interpreted as cassiterite | Medium-high |
| Sennen SF5 | Slight Sn elevations recorded on use faces and ends | Levelling of grains, associated with striations and grain extraction, patches of highly reflective, striated micropolish. Both ends exhibit grain extraction and occasional grain edge rounding consistent with pounding actions | Tool used to reduce and pulverize larger fragments of semi-hard mineral material into smaller, finer particles, interpreted as cassiterite | Medium-high |
| Sennen SF3 | Moderate elevations of Sn | Levelling of grains associated with striations and grain extraction, patches of highly reflective, striated micropolish, grains with step fractures or pointed morphology, grain extraction and occasional grain edge rounding | Tool used to reduce and pulverize larger fragments of semi-hard mineral matter into smaller, finer particles interpreted as cassiterite | High |
| Sennen SF2 | No Sn or As detected on tool surface | Wear traces include grain extraction and grain fractures with a pointed morphology and step fractures on the highest elevation of the crystal grains, patches of flat micropolish. The location and microwear signatures indicate pounding against a hard mineral material | Possible tool use to break up larger nodules of cassiterite into smaller fragments, however the use on another mineral material also possible. No detectable Sn | Medium |

Table 2. (Cont.)

| Artefact | pXRF evidence | Microwear analysis | Key interpretations | Confidence in interpretation and relationship to metalworking |
|----------------|---|--|---|---|
| Lelant TR18 S1 | Sn and As elevated on the working surfaces | Levelling of the topography accompanied by striations, grain removal and fractures, patches of highly reflective, striated micropolish, well-developed micropolish of flat topography and smooth texture and multi-directional striations resulting from the intentional polishing of the surface of the stone tool. Both ends show grain edge rounding, occasional microfractures of pointed morphology and micropolish | Tool used for grinding and pounding cassiterite and possibly for smoothing and shaping metallic (tin?) objects. No Cu was detected by the pXRF, therefore no direct evidence for smoothing/shaping Bronze | High |
| Truro TEDC S29 | Extremely high, and high measurements of Sn | Levelling of the topography accompanied by striations, and limited grain removal and fractures, small patches of reflective micropolish on the higher elevations of the microtopography | Tool used as a lower (stable) grinding tool for processing cassiterite ore prior to smelting. Tool was found with cassiterite pebbles and angular fragments of processed cassiterite | Extremely high |

very high tin levels recorded, but it also has some tin elevations that are directly comparable to some readings on the other tools. Likewise, microwear on TEDC S29 includes traces (e.g. reflective micropolish, grain removal) that are consistently observed on the other stone tools. Moreover, the micropolish and other wear patterns identifiable on the stone tools are consistent with mineral processing. There is a close association between higher tin elevations and tool surfaces with developed micropolishes; this strongly suggests that some of the Sn readings relate to the function of the tools. Finally, it is possible that the tools were used on another hard mineral material that was not cassiterite, e.g. haematite (for use as a dye) or chalcocopyrite (copper ore); there are, however, no distinctive staining or pigment particles on the artefacts (see Hayes et al., 2018) to support this, or any corroborating geochemical evidence. For each stone tool, we therefore indicate how confident we are that the stone tools were used within metalworking (Table 2).

DISCUSSION

The stone tools

The microwear patterns and residues observed indicate that the tools were used to process a semi-hard mineral material. The pXRF analysis detected the presence of tin, associated with lower values of arsenic and tungsten, on six implements. Both arsenic and tungsten have been recorded as trace impurities within Cornish cassiterite ore and tailings (Yim, 1981; Camm et al., 2004), in prehistoric and historic Cornish tin slags (Tylecote et al., 2010), and within the probable Bronze Age tin ingots from the Salcombe shipwreck in Devon (Wang et al., 2016).

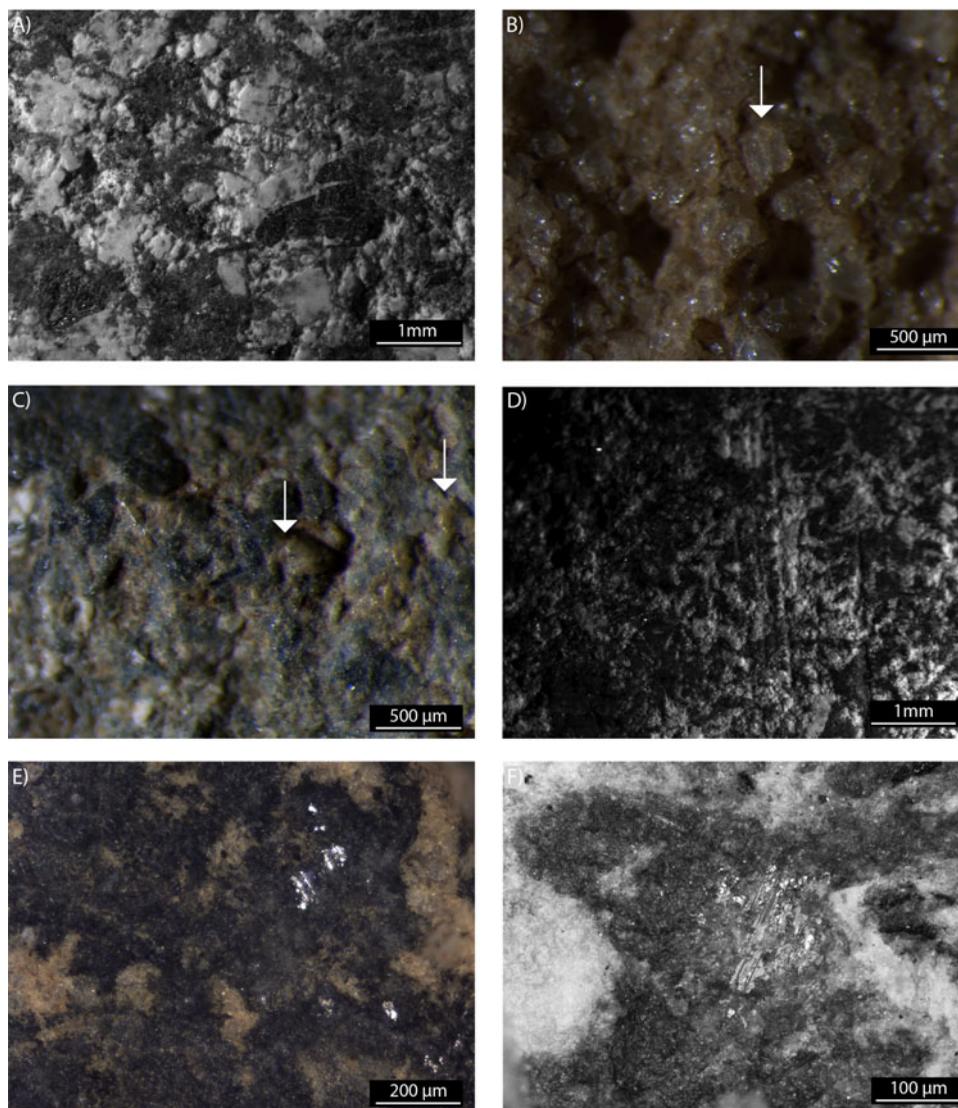


Figure 5. Key examples of macro- and microwear traces observed on the analysed tools: *A*) levelling of the surface topography (PS07-SF3); *B*) microfractures of grain crystals (indicated by arrow) (PS07-SF2); *C*) grain edge rounding (indicated by arrows) (TS18-S1); *D*) linear traces in the form of parallel, closely distributed striations (PS07-SF5); *E*) patches of highly reflective micropolish (taken at $\times 100$) (PS07-SF5); *F*) patch of flat, reflective, striated micropolish (taken at $\times 200$) (TS18-S1) (see [Supplementary Material](#) for full analyses).

The presence of this elemental grouping indicates that cassiterite ore is the signature's source. The stone tools analysed are made from granite, greenstone, quartzite, or sandstone and define a sub-group of artefacts that are geochemically different

(due to elevated Sn levels) from the other predominantly local beach cobbles (although TEDC S29 is a sandstone cobble probably collected from a river bed) characterizing the sites' wider stone assemblages. Significant variations in the relative

tin concentrations between artefacts and across the surfaces of individual tools are interpreted in terms of tool function, lithology (especially for the granitic stone tools), and post-recovery artefact cleaning procedures with water, which is likely to have removed or reduced some tools' residues. Our interpretation has prioritized the information gained from microwear analysis where the pXRF data are weaker. This is because we have a better understanding of the effects of post-depositional processes on microwear traces (see Marreiros et al., 2015; Hayes et al., 2018) than we have on the presence of residues detectable through pXRF analysis.

All tools survive complete, and they retain the cobbles' original morphology. The tools show consistency in raw material use, with an emphasis on cohesive and dense materials that could effectively withstand impact. This is also suggested by the consistency in the percussive tools' size and weight (see Table 1). The microwear analysis indicates that they were used for crushing, grinding, and pounding. The cobbles were modified, mainly through use, and they exhibit moderate degrees of wear (see Adams, 2014). The creation of hafting hollows or finger grips ('comfort features': Adams, 2014: 103) on SF2, SF3, and SF5 allowed for easier handling, suggesting that intensive use was intended. This is supported by the employment of multiple surfaces on each tool, possibly indicating an attempt to maximize the potential of each implement. However, with the exception of SF33, none of the recorded implements were used for an extensive period.

The weight of the five Beaker tools (SF2, SF3, SF5, SF18, and TR18 S1) ranges from 500 g to 743 g. Percussive traces on SF2, the heaviest implement (743 g), are consistent with its use for breaking up larger nodules. This tool could be associated with an early phase of

a multi-stage ore processing sequence (see O'Brien, 2015: 224). In this case, the addition of a haft would have increased the tool's downward impact force. Following this stage, grinding or pounding tools weighing less than 700 g (e.g. SF3, SF5, and SF18) were used for crushing and pulverizing the larger fragments into finer particles to produce a fine concentrate for smelting (O'Brien, 2015: 225). Likewise, Lelant S1 was used for crushing and fine grinding of mineral material, and its intentionally polished surface may have also been used for the smoothing and shaping of metal, thereby providing associations with the final stages of metal production. Tools weighing between 100 g and 500 g (SF33 and SF5) were also potentially used for crushing and pulverizing; in the case of SF33 this may have involved a rotational motion executed in a basin or hollowed surface. Based on their weight and the macro- and microwear traces, the Cornish tools are consistent with processing smaller ore fragments rather than direct mining. Cassiterite pebbles eroded out of tin lodes would have been easily visible and collectable from the gravel bedload in Cornish streams and rivers. The exception is S29 from TEDC18. This tool's lithology differs from that of the other tools and it was used differently as a stable lower grinding surface. At Copa Hill, one larger anvil stone was located amongst generally smaller hammerstones (Timberlake & Craddock, 2013) and thus the size of S29 might relate to its function in processing alluvial tin. However, EBA stone assemblages, as opposed to those associated with Beaker material, tend to be more diverse (Watts, 2014: 98-101). The larger size of S29 could thus be related to functional aspects of tool use (as a lower grinding tool), reflect changing styles of artefacts morphologies and/or structured deposition in the EBA.

The tools in their wider context

An important aspect of the stone tool assemblages from Sennen and Lelant are their early date. Needham et al. (2017) estimate the earliest tin-bronzes to be in circulation within Britain around 2200–2100 cal BC. Given the relatively quick adoption of bronze at this time (in comparison to continental Europe where copper has a more extensive history), the evidence of processing cassiterite ore in Cornwall between 2300 and 2100 cal BC is highly significant.

Research on copper sources, both in terms of their excavation (e.g. Dutton & Fasham, 1994; O'Brien, 1994, 2004, 2013, 2015; Timberlake, 2003, 2014, 2017; Timberlake et al., 2004; Timberlake & Pragg, 2005) and the understanding of their chemical signatures (Ixer & Budd, 1998; Rohl & Needham, 1998; Bray & Pollard, 2012), has been very successful over the last three decades. Yet the discovery of tin mining and processing remains elusive. Copper-containing deposits, such as malachite, azurite, fahlore, bornite, and chalcopyrite, were exploited in Bronze Age Europe generally by open-cast techniques alongside surface pits, surficial deposit exploitation, and underground workings (O'Brien, 2013: 447; 2015). These sources were mined with relatively simple lithic technologies, often in combination with wooden and bone tools (though at Great Orme, between 1600 and 1400 cal BC, bronze tools were potentially used in the mining process: Williams & Le Carlier de Veslud, 2019: 1181). Firesetting was commonly used to break up rock surfaces, allowing lithic tools, likely hafted, to be swung underarm to break up the surface and extract the ore (Timberlake & Craddock, 2013). These technologies and techniques reflect the nature of the copper deposits exploited at this time in Europe, where solid mineral

deposits were being extracted from bedrock lithologies. Tin (and gold) are quite different, in that they often occur as eroded fragments in secondary deposits, such as alluvial gravels and other surficial deposits; therefore, they do not require the same extractive techniques. Timberlake (2017: 719, 722) has argued that prospection for early gold from alluvial sources may have been linked to the discovery of tin in those same environments, thus strengthening our perception of the connection between Ireland and south-western England and suggesting a movement back and forth of gold, tin, and copper. He also noted the lack of evidence for the exploitation of the rich copper deposits of south-western England, suggesting that the exploitation of the two metals may have been mutually exclusive (Timberlake, 2017: 723), at least during the EBA (2450–1600 cal BC).

Many mining sites have been identified as belonging to the Bronze Age on the basis of the hammerstones recovered there. As Timberlake and Craddock (2013: 39) discuss, a wide range of terms are employed for these tools, including stone mining mauls, stone hammers, hammerstones, pounders, crushers, stone picks, and stone anvils; they prefer to use the term 'cobble stone mining tool' because this captures their variability and interchangeable uses. The Ross Island lithic assemblage (containing over 7000 hammerstones) includes percussive tools, derived from well-rounded alluvial water-worn cobbles selected for their rounded shape (often elliptical, oval, or pear shaped) and lithology. The weight of the percussive tools used for processing ore was a significant variable, with a preference for cobbles weighing between 500 g and 1500 g for hammerstones, and lighter cobbles (100–500 g) used as specialized pecking tools; these cobbles were brought to Ross Island specifically for mining and

processing ores and 86 per cent have some kind of modification to allow hafting (O'Brien, 2004: 341–47). The assemblage is comparable to the slightly later material from Mount Gabriel (O'Brien, 2004: 339), though only 47 per cent of the Mount Gabriel hammerstones show signs of hafting (O'Brien, 2004: 347); they are thought to have had a shorter use life.

The analysis of the cobble stone mining tools from Copa Hill revealed that at least 79 per cent were smoothed and rounded, suggesting they came from beaches or rivers; the majority weighed around 2–2.25 kg and were around 15–25 cm long and 8–13 cm wide (Timberlake & Craddock, 2013: 42). Timberlake and Craddock (2013: 42) argue that the cobbles were selected not only for their texture and size but also for their shape, with a clear preference for cylindrical or flat-sided exemplars. They note that there is a slight preference for finer-grained and harder rocks, which may indicate that form and size were generally more important than geology. The probable source of the cobbles used at Copa Hill was at the storm beach shingle bars near the mouth of the river Ystwyth some 25 km away (Timberlake & Craddock, 2013: 42).

There are some key overlaps and differences between the stone tools from these mining sites and the stone tools associated with tin processing presented here. The stone tools we analysed are well-worn and rounded cobbles that appear to have been selected for their shape and their cohesive dense lithology suitable for heavy work. The assemblage discussed here is lighter in weight and smaller in size than the tools from Ross Island, Mount Gabriel, and Copa Hill but this is not unexpected; the latter were used to extract mineral ore associated with solid bedrock, whilst the tools from our sites were primarily used at a later stage in the *chaîne opératoire*, processing alluvial cassiterite that was already

broken down into smaller particles through natural fluvial weathering. There is also an overlap with some of the grinding slabs and anvil stones identified at the settlement site associated with Ross Island (O'Brien, 2004: 356–59) and S29 from TEDC, which was also used as a grinding slab. These Ross Island tools are associated with the processing (rather than mining) of copper ore, being used as a surface for grinding and crushing, and the same processes are suggested for S29, albeit for alluvial tin (Figure 6).

The tools analysed here are not those used for extraction and mining but are those used in processing. In terms of the structures they are associated with, there are also some similarities and differences between Ross Island (particularly Structure C) and Sennen's Structure 108. They are of similar size and shape, although the Ross Island structures were defined by gullies and several of the structures are much larger, whilst Sennen Structure 108 was sunken. There is also more evidence for intensive activity, centred around a mine, on the Ross Island site and its chronological span is longer (*c.* 500 years, but see Carlin, 2018 who questions their association with the site's active period of mining). The site at Sennen is interpreted as shorter lived and more likely to have been associated with the collection of readily available cassiterite from streams, which may have contributed to its temporary nature.

Finding Bronze Age tin

The absence of evidence for tin mining and processing has long been a puzzle in Bronze Age Britain and Europe. At Sennen, the stone tools interpreted as having been associated with cassiterite processing were not randomly scattered across the site; all were found close to areas of burning or in features with other

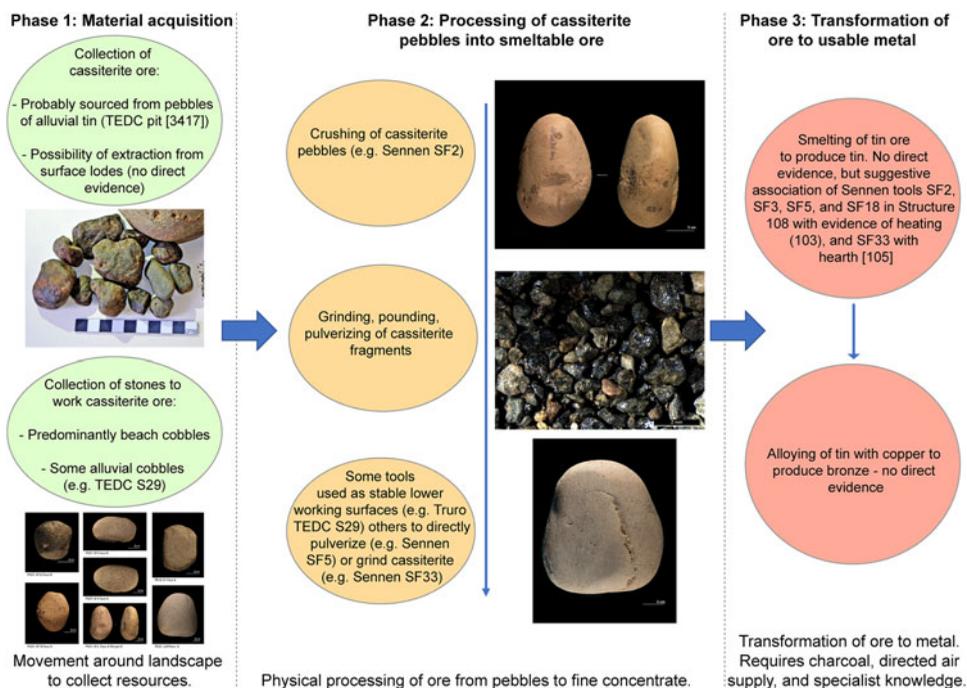


Figure 6: Simplified chaîne opératoire of tin processing. The evidence from our work pertains to Phases 1 and 2. Phase 3 remains necessarily speculative given the evidence presented in this paper, although the association of tools with evidence of heating at Sennen (PS07) is suggestive.

burnt material. Four tools (SF2, SF3, SF5, and SF18) were found above the burnt area within the infill of Structure 108, whilst SF33 was found in the hearth complex outside the structure. The association with fire is suggestive and it is possible that these hearths were used to smelt tin. Such smelting would not require a specialized furnace lining; tin can be smelted in a small ceramic vessel in a hearth with a directed air supply (Ottaway & Roberts, 2009). The excavation at Sennen yielded no moulds or crucibles, which is in line with much of the evidence for metalworking in Britain and Ireland in this period (see Webley et al., 2020). Instead we have an assemblage of stone artefacts more closely associated with processing, involving the primary pulverizing and crushing of cassiterite pebbles and subsequent grinding to produce a fine

concentrate for smelting. Structure C at Sennen, whilst it has a definable relationship to cassiterite processing, is not definably a metal workshop; rather it is a slight, seasonal or temporary structure associated with a range of activities (e.g. SF14 was associated with plant processing identified from microwear analysis), similar to the situation described by Hamon et al. (2020) in Brittany. All three of our sites had evidence of the deliberate deposition of materials and objects. In certain respects, this is comparable with practices of the later Bronze Age (Webley et al., 2020: 184–86), when moulds and crucibles, as well as objects, were increasingly deposited in formal deposits.

Our analysis suggests that the search for evidence for tin exploitation is unlikely to be resolved by following traditional assumptions of what metalworking sites

look like. We have, in effect, been looking for the wrong things. Instead, the primary evidence may lie in the close examination, through geochemical but especially micro-wear analysis, of stone tools. Stone tools in the Bronze Age are often paid less attention than lithics from earlier periods. Our evidence for the extraction of tin differs from that for the extraction of copper. In the case of copper exploitation, which targeted bedrock concentrations, it has long been stone tools that have led us to mining sites. In the case of tin, alluvial and surficial deposits of cassiterite do not require mining, but they do require similar processing, potentially undertaken with a similar toolkit of multifunctional cobbles. It is in these objects, often only briefly summarized or ignored, that the detailed evidence of how early metals were worked may lie. In the case of the tools analysed here, their deposition suggests their critical importance for people at the time, but it is in attending to the microhistories of their wear and the tiny traces lodged in their chemical composition that their role in shaping past histories can more clearly emerge.

CONCLUSION

The small-scale collecting and smelting of tin ores, primarily from cassiterite pebbles, is unlikely to have left direct traces in the archaeological record, and hence we must apply other suites of analyses to detect such activity. The study of artefacts, using geochemistry alongside microwear analysis, can substantively contribute to understanding the processing of metal ores and the finishing of metal artefacts (see Hamon et al., 2020). Our study highlights the value of applying combined microwear and pXRF analyses to stone tools from EBA sites.

In an article summarizing the state of research concerning Bronze Age mining and metal production, Simon Timberlake

(2017: 716) wrote: 'There is good circumstantial evidence and a strong narrative tradition which asserts Cornwall (and Devon) to be the European home(s) of prehistoric tin.' Our results strongly suggest that Cornish tin sources were being processed from as early as *c.* 2300–2200 cal BC, and that ores from these sources were integrated into the circulation of metals, first across Britain and Ireland and subsequently in the wider Atlantic region and beyond (Berger et al., 2022). This ties in with the goldwork evidence, in terms of the Atlantic distribution of the broadly contemporary lunulae found in Ireland, Cornwall, and Brittany (Taylor, 1980; Needham, 2000), and with respect to geochemical analyses which have identified Cornish gold in other artefact types (Esher et al., 2011; Standish et al., 2015; Krause et al., 2021). We can therefore potentially see tin and gold from Cornwall, and copper from Ireland and Wales, as forming part of a wider Atlantic exchange network. The discoveries presented here constitute not only the earliest secure evidence for tin exploitation in Britain, but also they showcase a new methodological approach for identifying tin processing, opening up a critical new perspective on the emergence of bronze.

SUPPLEMENTARY MATERIAL

To view supplementary material for this article, please visit <https://doi.org/10.1017/ea.2022.30>.

ACKNOWLEDGEMENTS

We would like to thank Henrietta Quinnell and Simon Timberlake for reading this article and Sean Taylor for information on the Truro TEDC site. The microwear analysis on the stone tools discussed here was carried out as part of the Leverhulme-funded 'Beyond the Three Age System' project (RPG-2017-375). We

would also like to thank David Dawson for introducing the research teams.

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BIOGRAPHICAL NOTES

Chris Carey is a principal lecturer at the University of Brighton. He specializes in archaeological science and geoarchaeology, researching in areas such as prehistoric landscape dynamics and change, archaeometallurgy and geospatial data modelling. Current research projects include investigating the signatures of landscape use between the Early and Middle Bronze

Age, applying multi/hyperspectral remote sensing technologies to map prehistoric land divisions, and modelling the alluvial sedimentation at Avebury to identify landscape change and transition.

Address: School of Applied Sciences, University of Brighton, BN2 4GJ, UK. [email: C.J.Carey@brighton.ac.uk]. ORCID: [0000-0001-7459-9640](https://orcid.org/0000-0001-7459-9640).

Christina Tsoraki is an honorary fellow at the University of Leicester. She was previously a postdoctoral research associate working on the Leverhulme-funded 'Beyond the Three Age System' project. She specializes in prehistoric archaeology focusing on material culture studies, stone technology, and microwear analysis. Her research interests include object histories, cross-craft interactions, depositional practices, and household archaeology. Between 2012 and 2018 she was head of the Ground Stone team for the Çatalhöyük Research Project (Turkey). She is co-editor of *Communities at Work: The Making of Çatalhöyük* with Ian Hodder.

Address: School of Archaeology and Ancient History, University of Leicester, University Road, Leicester, LE1 7RH, UK. [email: ct293@leicester.ac.uk]. ORCID: [0000-0001-9282-0847](https://orcid.org/0000-0001-9282-0847).

Andy M. Jones is the projects manager at Cornwall Archaeological Unit. His research interests include the Neolithic and Bronze Age of western Britain. Major publications include: *Settlement and Metalworking in the Middle Bronze Age and Beyond: New Evidence from Tremough, Cornwall* (2015), *Preserved in the Peat: An Extraordinary Bronze Age Burial on Whitehorse Hill, Dartmoor, and its Wider Context* (2016), and *Later Prehistoric*

Settlement in Cornwall and the Isles of Scilly: Evidence from Five Excavations (2021).

Address: Cornwall Archaeological Unit, Pydar House, Pydar Street, Truro, UK. [email: Andy.Jones@cau.org]. ORCID: [0000-0001-9349-7818](https://orcid.org/0000-0001-9349-7818).

Oliver J.T. Harris is an associate professor of archaeology at the University of Leicester. His research interests focus on the Neolithic and Bronze Age of Europe and archaeological theory, and he directs fieldwork on the Ardnamurchan Peninsula, excavating sites from all periods. He is the author of *Assembling Past Worlds* (Routledge), and a co-author of *Archaeological Theory in Dialogue, Archaeological Theory in the New Millennium* (both Routledge) and *the Body in History* (Cambridge University Press).

Address: School of Archaeology and Ancient History, University of Leicester, University Road, Leicester, LE1 7RH, UK. [email: ojth1@leicester.ac.uk]. ORCID: [0000-0002-2053-9172](https://orcid.org/0000-0002-2053-9172).

Rachel J. Crellin is an associate professor of archaeology at the University of Leicester. Her research interests centre on archaeological theory, Neolithic and Bronze Age Britain and Ireland, and metalwork wear analysis and she directs fieldwork on Neolithic and Bronze Age sites from the Isle of Man. She is the author of *Change and Archaeology* (Routledge) and a co-author of *Archaeological Theory in Dialogue* (Routledge).

Address: School of Archaeology and Ancient History, University of Leicester, University Road, Leicester, LE1 7RH,

UK. [email: rjc65@leicester.ac.uk].
ORCID: [0000-0002-8297-1083](https://orcid.org/0000-0002-8297-1083).

providing analytical services to research projects from across the School of Applied Sciences.

Peter Lyons is technical manager for the Department of Earth and Environment at the University of Brighton. He oversees the Geochemical Laboratories,

Address: School of Applied Sciences, University of Brighton, BN2 4GJ, UK. [email: P.lyons2@brighton.ac.uk]. ORCID: [0000-0002-8003-0845](https://orcid.org/0000-0002-8003-0845).

L'exploitation de l'étain au Campaniforme et au Bronze Ancien en Cornouailles : le traitement de la cassitérite identifié par analyses des microtraces et par fluorescence des rayons X

L'introduction de la céramique campaniforme en Grande-Bretagne et en Irlande durant le vingt-cinquième siècle av. J.-C. marque un horizon archéologique important qui coïncide avec l'arrivée des premiers objets en métal. L'adoption du cuivre arsénié, principalement en Irlande, fut suivie par celle du bronze (alliage de cuivre et d'étain) autour de 2200 av. J.-C. Cependant, alors que la mine de cuivre de Ross Island en Irlande date très certainement du début de l'âge du Bronze et que d'autres mines en Grande-Bretagne ont été attribuées au Bronze Ancien ou Moyen, les données concernant l'exploitation de l'étain, le second ingrédient indispensable à la fabrication du bronze, restent conjecturales. Dans cet article, les auteurs présentent leurs analyses de la fluorescence des rayons X par instrument portable (pXRF) et des microtraces d'usure conduites sur sept objets en pierre provenant de contextes bien datés. Les résultats fournissent de solides indications que ces objets avaient été utilisés dans le traitement de la cassitérite et documentent que l'étain provenant des Cornouailles avait été exploité dans les toutes premières phases de l'utilisation des métaux en Grande-Bretagne et en Irlande. Translation by Madeleine Hummler

Mots-clés: Campaniforme, Cornouailles, cassitérite, microtraces, métallurgie, traitement de minerai

Die Glockenbecherzeitliche und frühbronzezeitliche Ausbeutung von Zinn in Cornwall: Mikroverschleiß- und Röntgenfluoreszenzanalysen identifizieren die Verarbeitung von Kassiterit

Das Vorkommen der Glockenbecherkeramik in Großbritannien und Irland während des fünfundzwanzigsten Jahrhunderts v. Chr. kennzeichnet ein wichtiger archäologischer Horizont, der mit den ersten Metallartfakten übereinstimmt. Die Aufnahme von Arsenkupfer, meist aus Irland, wurde um ca. 2200 v. Chr. durch den Gebrauch von Zinnbronze ersetzt. Jedoch, obwohl das Kupferbergwerk von Ross Island in Irland sicher frühbronzezeitlich ist und andere solche Bergwerke in Großbritannien in die Früh- oder Mittelbronzezeit datiert werden, bleiben die Nachweise, dass Zinn—das zweite Hauptelement in der Herstellung von Bronze—ausbeutet wurde, gering. In diesem Artikel legen die Verfasser die Ergebnisse der Analysen von sieben Steingeräten aus sicher datierten Kontexten vor. Die Kombination von Mikroverschleiß-Untersuchungen und pRFA-Analysen liefern aussagekräftige Hinweise, dass diese Steingeräte zur Verarbeitung von Kassiterit dienten. Die Resultate zeigen, dass Zinn aus Cornwall zu den ersten Stufen der Verwendung von Metall in Großbritannien und Irland gehört. Translation by Madeleine Hummler

Stichworte: Glockenbecher, Cornwall, Kassiterit, Mikroverschleiß, Metallurgie, Erz-Bearbeitung