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Copper ingots from a probable Bronze Age shipwreck off the coast of Salcombe, Devon: Composition and microstructure

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ABSTRACT

The seabed site of a probable Bronze Age shipwreck off the coast of Salcombe in south-west England was explored between 1977 and 1982 and from 2004 onwards. Nearly 400 objects including copper and tin ingots, bronze artefacts/fragments and gold ornaments were found, typologically dating either to c. 1300–1150 BC or 1000–800 BC. The 280 copper and 40 tin plano-convex ingots and ingot fragments represent the largest discovery, measured by total weight as well as by quantity, of plano-convex or bun ingots in northwest Europe. The Salcombe copper ingots provided a wonderful opportunity for the technical study of copper ingots in a probable shipwreck context, as opposed to terrestrial contexts of deliberate deposition. The chemical composition of 25 plano-convex copper ingots was determined using inductively coupled plasma mass spectrometry (ICP-MS) and inductively coupled plasma atomic emission spectroscopy (ICP-AES). Two artefacts from the site were also analysed for comparison with the ingots. Following the compositional analysis, a microstructural study was carried out on ten Salcombe copper ingots selected to cover those with different sizes, shapes and variable impurity levels using metallography and scanning electron microscopy coupled with energy dispersive X-ray spectrometry (SEM-EDS).

All the analysed copper ingots are of unalloyed copper with low levels of impurities. Sulphide inclusions are present in all samples and bulk sulphur contents are of 0.32–0.79% in the ingots but lower in the artefacts. The Salcombe ingots were found to have a quite similar impurity pattern to the Hertford Heath (England) ingots (except for iron content). They are distinctly different from the Uluburun ingots, and, to a lesser degree, from Sardinian ingots. The results are inconclusive as to how the Salcombe ingots were made. On the one hand, the very low concentration of iron and the absence of cuprite inclusions suggest that the ingots were primary smelting products of the primitive smelting process rather than produced from re-melting or refining of primary smelting lumps. On the other hand, the dense metal with very low porosity suggests the product of refining and re-casting operations under reducing conditions. However, the small ingots are not likely to have resulted from breaking of large ingots. The chemical compositions of the Salcombe ingots point to British or Western European sources although the connection with other regions cannot be excluded for some of the ingots. Further studies including lead isotope analysis are needed to address the question of provenance of the copper ingots, which would contribute to the re-emerging debates surrounding the European Bronze Age metal trade.

1. Introduction

The extraction and movement of copper throughout northwest Europe and beyond during the Bronze Age (c. 2200–800 BC) have been investigated and discussed extensively for over a century (Evans, 1881; O'Brien, 2015). The 'metals trade' – whether in copper, tin, bronze or gold – in northwest Europe continues to play a key role in societal narratives and discussions of social change, especially within the context of the Atlantic (Radivojević et al., 2018). The extensive sources of copper ore found throughout parts of Ireland, the Isle of Man and west Britain were exploited from at least c. 2400 BC (O'Brien, 2015; Timberlake, 2017). The earliest evidence comes from the Ross Island mine, southwest Ireland (O'Brien, 2004). Surveys and excavations have established extensive radiocarbon-dated evidence for Early Bronze Age (c. 2200–1600 BC) copper mining in southwest Ireland as at Mount Gabriel (O'Brien, 1994), central and north Wales as at Copa Hill,

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Cwmystwyth (Timberlake, 2003) and the Great Orme (Dutton and Fasham, 1994; Williams, 2014), and northwest and central England as at Alderley Edge (Timberlake and Prag, 2005) and Ecton Hill (Timberlake, 2014). In southwest England, there is only one radiocarbon-dated possible copper mine, at Roman Lode, Exmoor, Devon, which yielded dates of c. 1950–1750 BC (Juleff and Bray, 2007). The copper sources in northwest France and Scotland could well have been exploited during this period, but there are currently no radiocarbon-dated sites. The next closest copper ore sources are found in northern Spain, southern France and the western Alps, hundreds of kilometres away, and were mined throughout the Bronze Age (Huelga-Suarez et al., 2012; Huelga-Suarez et al., 2014a,b; O'Brien, 2015).

The current evidence in northwest Europe indicates that only two copper mines – the Great Orme in northwest Wales (Williams, 2014; Smith et al., 2015) and Derrycarhoon in southwest Ireland (O'Brien and Hogan, 2012) – were exploited beyond c. 1600–1500 BC. Explanations for this apparent cessation of copper extraction across northwest Europe have tended to emphasise a transition towards the importing of bronze from the continent and the recycling of existing bronze objects (Rohl and Needham, 1998; Timberlake, 2017). Williams (2017) has proposed that in Britain, the mostly small copper mines with low grade ore, and lacking substantial secondary ores were superseded from c. 1600 BC -1400 BC by the large, very rich and easily worked Great Orme mine. However, the lead isotope and trace element data indicate that the Great Orme mine played only a limited role in copper production and consumption in Britain after c. 1400 BC. What is not currently determined, either archaeologically or archaeometallurgically, is where Bronze Age communities in Britain obtained their copper (or indeed tin) from c. 1400 BC onwards. The existence of spatially and chronologically distinctive metal compositions in bronze metalwork assemblages spanning c. 1400–800 BC (Northover, 1982a; Williams, 2017) demonstrates that any explanation must involve the exploitation of new copper ore sources and cannot rely solely on recycling (cf. Radivojević et al., 2018). The destruction of Bronze Age mines by later mining activity, especially for copper and tin mining in southwest England (Craddock and Craddock, 1996), should not be ignored. The existence of only one radiocarbon-dated and archaeometallurgically studied copper smelting site from the entire Bronze Age in Britain, at Pentrwyn, near the Great Orme copper mine, north Wales, which dates to c. 1000–800 BC or the Late Bronze Age (Smith et al., 2015), would appear to support the large-scale importation of copper and/or bronze. Whilst the potentially archaeologically ephemeral nature of Bronze Age copper smelting should not be ignored (Timberlake, 2007; Williams, 2014), this current absence of primary production evidence stands in contrast to the now-extensive evidence for the secondary melting and (re-) casting of bronze, especially during the Middle-Late Bronze Age (c. 1600–800 BC) throughout southern England (Needham, 1980; Medlycott and Brown, 2013; Knight, 2014; Jones et al., 2015; Webley and Adams, 2016; Adams et al., 2017). There is also a vast quantity and range of Middle-Late Bronze Age bronze objects being deliberately deposited, with the highest concentrations in southern and eastern England, frequently far from any copper ore sources (Yates and Bradley, 2010; Roberts et al., 2013; Brandherm and Moskal-del Hoyo, 2014; Knight et al., 2015). Finally, the findspot distribution patterns of Middle-Late Bronze Age metal object types across southern England – whether weapons, tools or ornaments – are frequently also found in northern France, Belgium and beyond (O'Connor, 1980; Needham et al., 2013). Yet the debates on presence or absence of primary copper, tin and thereby tin-bronze production and subsequent trade in Middle-Late Bronze Age Britain are far from being over.

The discovery of 40 plano-convex or bun-shaped tin ingots weighing 18.45 kg in total, typologically dated by association either to c. 1300–1150 BC or 1000–800 BC or the late Middle-Late Bronze Age, off the coast of Salcombe has provided the most extensive, direct evidence for Bronze Age tin production and trade in Europe (Wang et al., 2016a). In addition to the tin ingots, the Salcombe seabed assemblage yielded 280 copper or copper alloy plano-convex ingots and ingot fragments, making it the largest discovery, measured by total weight (62.43 kg) as well as by quantity, of Bronze Age (c. 2200–800 BC) copper or copper alloy plano-convex ingots in northwest Europe.

The Salcombe site actually comprises two named sites 400 m apart within an open bay at the mouth of an estuary – Moor Sand and Salcombe B – where two groups of Bronze Age objects have been found between 50 and 400 m off the coastline (Fig. 1). Archaeological work at Moor Sand occurred between 1977 and 1982, led by Philip Baker and Keith Muckelroy (Muckelroy, 1980, 1981) whilst work on Salcombe site B started later in 2004 by the South West Maritime Archaeology Group (www.swmag.org) and remains ongoing (see Needham et al., 2013, 3–15 for the research history at the site). These excavations (spanning the years 1977–1982 and 2004) at the Salcombe site (Moor Sand and Salcombe site B) have been recently published with extensive environmental, archaeometallurgical and archaeological analyses (Needham et al., 2013). The investigations together recovered 31 objects including bronze objects of 22 weapons/fragments, one palstave-adze, one cauldron handle, one rectangular block/weight, one Sicilian *strumento con immanicatura a cannone*, three gold objects/fragments, an iron awl with a bone handle and a tin lump (Needham et al., 2013). In the absence of surviving organic material suitable for radiocarbon dating, detailed typo-chronological analyses of diagnostic bronze and gold objects, supported by radiocarbon dates from terrestrial sites containing comparable metalwork, placed the Salcombe assemblage in the Middle Bronze Age Penard metalwork phase (c. 1300–1150 BC) with the exception of one Type Nantes bronze sword which typologically dated to the Late Bronze Age Ewart Park metalwork phase (c. 1000–800 BC) (Needham and Giardino, 2008; Needham et al., 2013; Brandherm and Moskal-del Hoyo, 2014). Compositions of the bronzes as well as the high purity of the tin lump are consistent with this dating (Northover, 2013). The analysis of the sea level history and coastal geomorphology demonstrates that coastal retreat cannot explain the distribution of the metalwork and it is therefore argued that the objects were transported to their location before being dispersed on the seabed (Needham et al., 2013). The prevalence of later shipwrecks – Salcombe B was only found in the course of the investigation of a 17th century AD shipwreck site termed Salcombe A – suggests an accidental shipwreck or deliberate/votive shipwreck with objects eventually dispersed across the Moor Sand and Salcombe B sites. However, the presence of Bronze Age metalwork that is conventionally dated two centuries apart also implies two distinct events (Needham et al., 2013).

Further investigations at the Salcombe B site from 2005 to 2013 yielded finds that include 280 copper or copper alloy and 40 tin plano-convex ingots, 15 bronze objects and nine gold ornaments. The tin ingots have been recently published (Wang et al., 2016a), the copper/copper alloy ingots are the subject of this paper, and the gold ornaments and the bronze tools and weapons will be studied in subsequent papers. All finds have been acquired by the British Museum, are registered and have been catalogued on Collections Online (http://www.britishmuseum.org/research/collection_online/search.aspx?searchText=Salcombe).

Due to their morphological simplicity, neither the copper/copper alloy nor the tin ingots are especially typo-chronologically diagnostic (Gomez-Ramos, 1993; Bachmann et al., 2002/3; Le Carlier et al., 2014; Wang et al., 2016a). The bronze rapiers and palstaves as well as the gold twisted torc fragments and twisted wire bracelets all indicate a Middle Bronze Age Penard phase date (c. 1300–1150 BC) (see Collections online). However, the Ewart Park type bronze sword can only be placed in the Late Bronze Age Ewart Park phase (c. 1000–800 BC) and is therefore contemporary with the previously discussed earlier find of the Type Nantes bronze sword from the site. The absence of any terrestrial bronze or copper ingots in Britain during the earlier date range (Needham, 2017), as opposed to their relative ubiquity in the later date range – see (Pearce, 1983; Knight et al., 2015) for a comprehensive Bronze Age metalwork catalogue for southwest England – is not

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