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Research Article

From Land's End to the Levant: did Britain's tin sources transform the Bronze Age in Europe and the Mediterranean?

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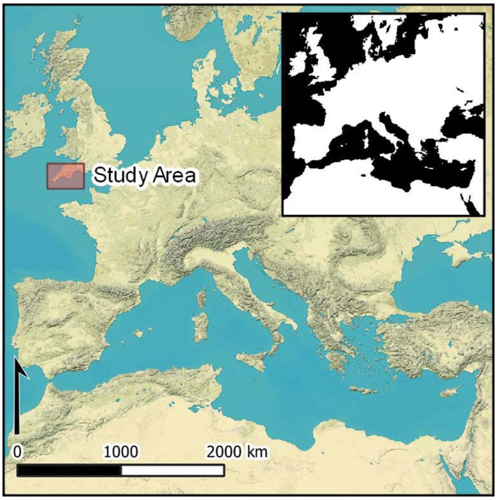

Bronze Age–Early Iron Age tin ingots recovered from four Mediterranean shipwrecks off the coasts of Israel and southern France can now be provenanced to tin ores in south-west Britain. These exceptionally rich and accessible ores played a fundamental role in the transition from copper to full tin-bronze metallurgy across Europe and the Mediterranean during the second millennium BC. The authors' application of a novel combination of three independent analyses (trace element, lead and tin isotopes) to tin ores and artefacts from Western and Central Europe also provides the foundation for future analyses of the pan-continental tin trade in later periods.

Keywords: Western Europe, Bronze Age, lead and tin isotopes, ore and artefact analysis, Mediterranean trade, tin provenance, ingots and shipwrecks

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Introduction

One of the defining debates in Bronze Age European and Mediterranean scholarship is the 'tin problem' (Franklin *et al.* 1978; Muhly 1985; Penhallurick 1986; Giumlia-Mair & Lo Schiavo 2003). Bronze is composed of copper alloyed with around 10 per cent tin, to produce a harder, easier to cast and more golden-coloured metal. Tin is, however, a globally scarce metal, much scarcer than copper. The only major deposits that could feasibly have supplied the large bronze-consuming societies in Europe and the Mediterranean in the second millennium BC are in Western and Central Europe and Central Asia. Minor deposits elsewhere would have been sufficient only for local needs (Figure 1). In Europe, there are four major regions with tin deposits, and the Cornwall and Devon tin province in south-west Britain is one of the largest in the world with an estimated historical tin-metal production totalling 2.5 million tonnes (Mt). This greatly exceeds the other tin provinces of the Erzgebirge, German-Czech border (0.3 Mt), Iberia (0.15 Mt) and Brittany and the Massif Central, France (0.01 Mt) (Lehmann 1990; Robb 2020; Éric Marcoux *pers. comm.*).

In recent years, there has been a lively debate in the academic literature as to whether tin arrived in the Mediterranean from Western and Central Europe or from Anatolia and Central Asia, drawing evidence from tin artefacts associated with fourteenth–thirteenth-centuries BC shipwrecks and Assyrian texts from the nineteenth century BC (Berger *et al.* 2019, 2023a; Powell *et al.* 2021, 2022). Yet, previous studies did not measure the trace elements and lead isotopes in tin ores from Western or Central European sources, only tin isotope compositions, which have proved inconclusive (Berger *et al.* 2019). Hence, it was not possible to clearly provenance tin artefacts to a particular European tin ore source. Project Ancient Tin (https://projectancienttin.wordpress.com/) undertook the first major analytical programme to investigate both tin ores and tin artefacts from south-west Britain and Europe. In combination with evaluating new archaeological and geological evidence, it explored which tin ore source(s) supplied Bronze Age Europe and the Mediterranean with the aim of ending centuries of speculation (e.g. Borlase 1758).

Early tin-bronze in the east and full adoption from the west

The innovation of alloying tin with copper to produce tin-bronze was neither instant nor inevitable, with the process following very different trajectories throughout the world (Pare 2000; Roberts & Thornton 2014). Thus, it is important to distinguish between four different phases of tin-bronze use: rare occurrences; use only in selected artefact types; widespread use alongside arsenical copper; and full adoption. The latter has been influentially termed 'bronzization' by Vandkilde (2016) to highlight how this major technological change across Eurasia fundamentally required the trans-regional trade of one crucial but scarce resource—tin—creating overlapping networks that are analogous to modern globalisation.

The earliest evidence of tin-bronze consists of rare occurrences in the Balkans, *c.* 4650 BC, possibly from the smelting of a naturally mixed copper-tin ore (Radivojević *et al.* 2021). The first sustained appearance in selected object types is seen across West Asia around 3000 BC, despite the region lacking major tin deposits (Pigott 2011). The earliest known tin mines date from the third millennium BC in Anatolia where small, low-grade deposits were worked at Kestel and possibly at

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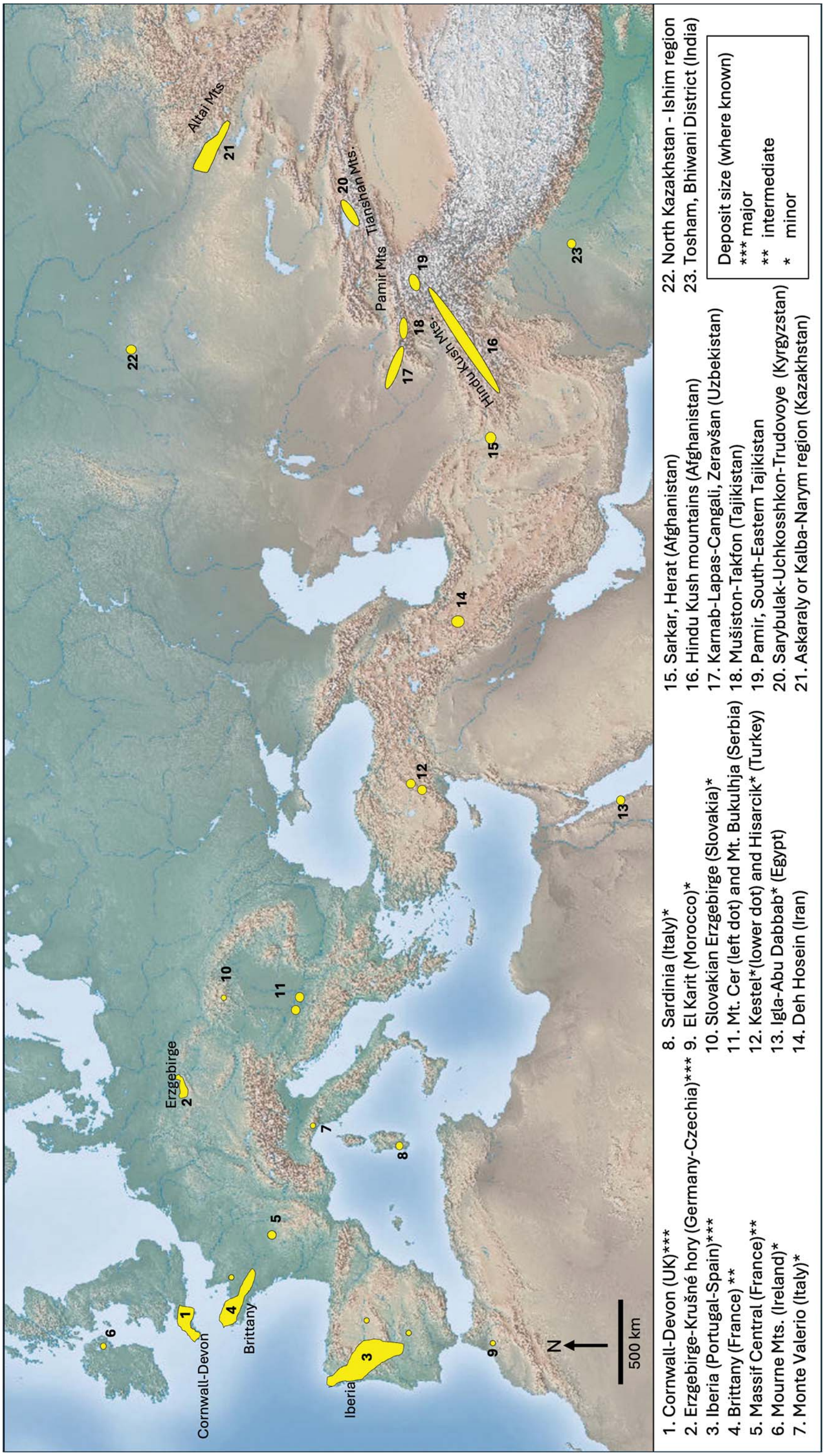

Figure 1. Major and minor tin-ore deposits in Europe, North Africa and Western and Central Asia (figure by Williams).

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Hisarcik (Yener 2021). From the late third millennium BC onwards, there is evidence for the mining of some tin deposits in Central Asia (Garner 2013; Berger *et al.* 2023b). By *c.* 2200 BC, tin-bronze represents a significant proportion of excavated metalwork (up to 50%) alongside arsenical copper across several, but not all, regions of West Asia (Pernicka 1998).

By contrast, in Europe at around 2200 BC, very few metal artefacts are composed of tin-bronze (typically with low tin levels <5%), and they become even scarcer moving westwards (Rahmstorf 2017), with arsenical copper alloys continuing to be widely used across Europe, North Africa and Western and Central Asia (Roberts & Thornton 2014). However, a remarkable change occurred in the period *c.* 2200–2100 BC when Britain was the first region in Europe to completely switch all metalwork from (arsenical) copper to full tin-bronze (typically 10% tin). This full adoption or 'bronzization' subsequently occurred across Scandinavia and Central Europe by around 1800 BC and finally in southern Iberia, the Aegean and Egypt by around 1500/1300 BC (Pare 2000) (Figure 2).

Tin deposits in south-west Britain and Bronze Age exploitation

Bronze Age tin production in south-west Britain was dominated by easier-to-work alluvial tin deposits rather than by the mining of tin veins in hard rock (an option rarely practised in the

Figure 2. Dating the transition to full tin-bronze use in Europe and the Mediterranean (adapted from Pare 2000 with additions).

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region until the thirteenth century AD). Alluvial tin derives from the erosion of tin ore (cassiterite SnO_2, a tin oxide) veins that occur in and around the main granite outcrops in the region (Figure 3). The heavy, resistant cassiterite enters streams where typically gravel- to sand-sized pieces over geological time form heavy mineral-rich layers (placers), sometimes also containing gold, that are later buried under barren alluvium (Camm 1985).

Cornwall and Devon have a widespread tin-rich landscape, probably the richest in Europe, with virtually every valley that drained tin veins containing buried alluvial tin (Figure 3b). The depth of the buried 'tin bed' can vary from only a couple of metres upstream to up to tens of metres downstream. The basic technology that was used to work these alluvial deposits changed little from the Bronze Age onwards, requiring digging, water washing, crushing and smelting, although the methods and scale developed over time. By the medieval period, Cornwall and Devon had a virtual European tin monopoly (Hatcher 1973).

Artefacts unearthed in the nineteenth century during the reworking of alluvial tin beds (e.g. flat axes/palstaves/socketed axeheads, rapiers, spearheads and cauldrons; Penhallurick 1986) provided early evidence for substantial Bronze Age tin extraction, and more recent finds strengthen the case for Cornwall and Devon as a major tin source during this period (Figure 4). A structure at Sennen dating to *c*. 2400–2100 BC contained Beaker pottery and analysis of stone tools highlighted patches of high tin concentration and microwear consistent with their use in tin ore crushing (Carey *et al*. 2023). The aDNA and archaeological evidence demonstrates the large-scale movement of a population from continental Europe to Britain and Ireland around 2400 BC who not only brought Beaker pottery but also introduced copper and gold metallurgy (O'Brien 2015; Vander Linden 2024). The Sennen finds provide the earliest evidence of tin ore exploitation in Europe, essential for tin-bronze metallurgy. Tin ore has been found at several Bronze Age settlement sites, including over 10kg at Tregurra (dating to *c*. 2030–1770 BC; Taylor 2022), Trevisker, Tolgarrick, Tremough and Dean Moor (Jones *et al*. 2015). Tin slag in the Caerloggas I barrow was associated with a Camerton-Snowshill type dagger, dated to *c*. 1900–1750 BC (Jones & Quinnell 2013). The excavation of a cist burial dated to *c*. 1750–1600 BC on Whitehorse Hill, Dartmoor, revealed tin studs and tin beads (Jones 2016). Radiocarbon dating of an antler mining pick and a wooden shovel found in the nineteenth century at the Carnon Valley alluvial tin workings provide estimates for tin mining at 1620–1497 BC and 1266–1108 BC, respectively (Timberlake & Hartgroves 2018 and Project Ancient Tin). Meanwhile, 40 tin ingots were found at a probable Bronze Age shipwreck site off Salcombe, Devon, dating either to *c*. 1300–1150 BC or *c*. 1000–800 BC, and another probable Bronze/Iron Age shipwreck site at the mouth of the River Erme, Bigbury Bay also in Devon, contained 44 tin ingots (Wang *et al*. 2016; Berger *et al*. 2022).

Bronze Age dating evidence from the other main European tin deposits is limited but provides estimates for activity from around 1900 BC in the Erzgebirge (Tolksdorf *et al*. 2019; Schubert *et al*. 2023), 1300 BC in Brittany and Massif Central (Domergue *et al*. 2006; Le Carlier de Veslud *et al*. 2017) and 800 BC in Iberia (Comendador Rey *et al*. 2017; Figueiredo *et al*. 2018).

Later textual evidence may reflect a tin trade dating to the Bronze Age. Herodotus in *c*. 420 BC mentions, but does not locate, the distant *Cassiterides* or tin islands as the source for Mediterranean tin (Penhallurick 1986). Later Roman summaries of a now lost text

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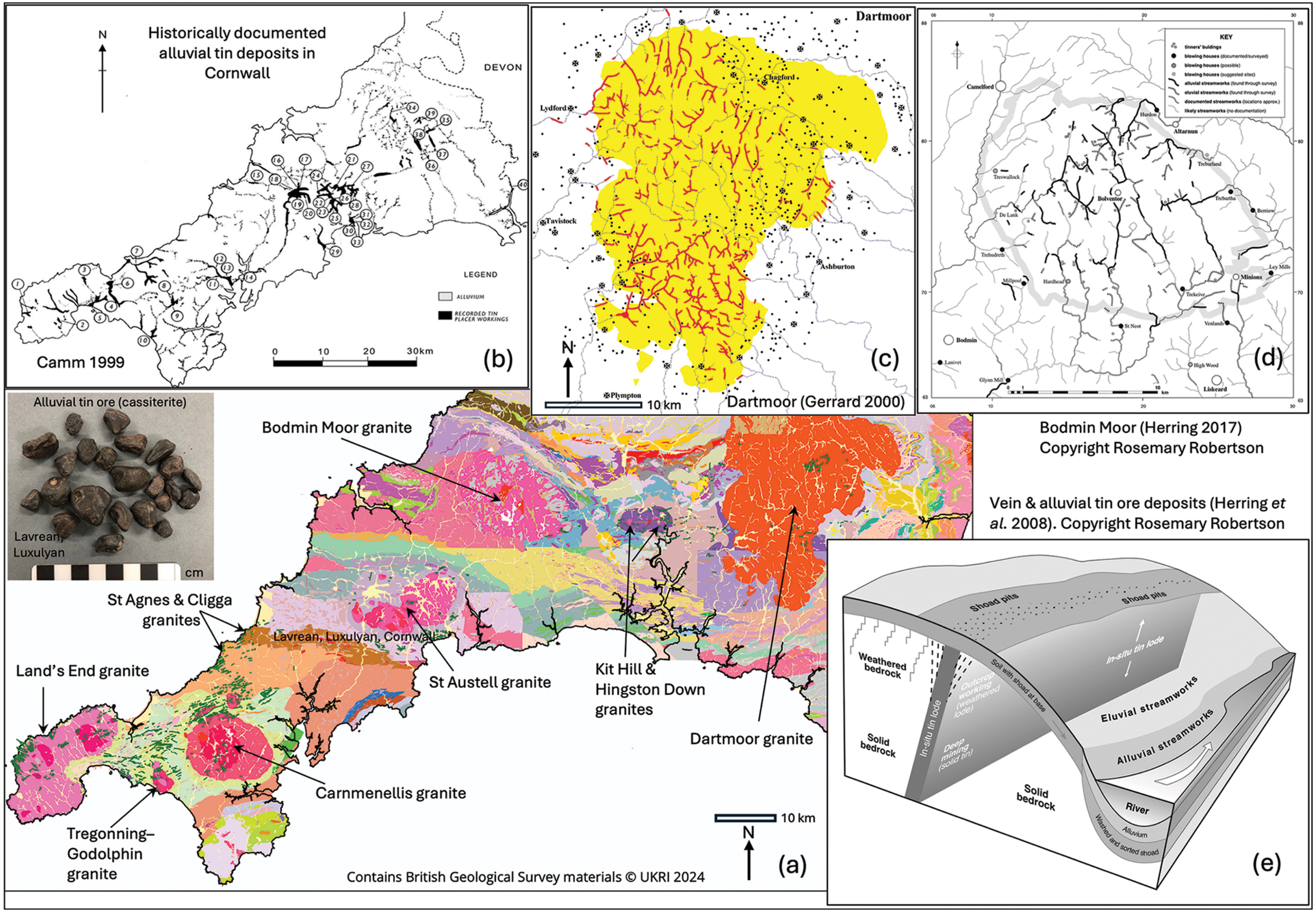

Figure 3. (a) Geological map of Cornwall and Devon showing the tin veins (green) associated with the granite outcrops (red); (b, c & d) inset maps of worked alluvial tin deposits; (e) alluvial tin-ore deposits originate from the erosion of tin veins (see OSM1 for references) (figure by authors except where indicated).

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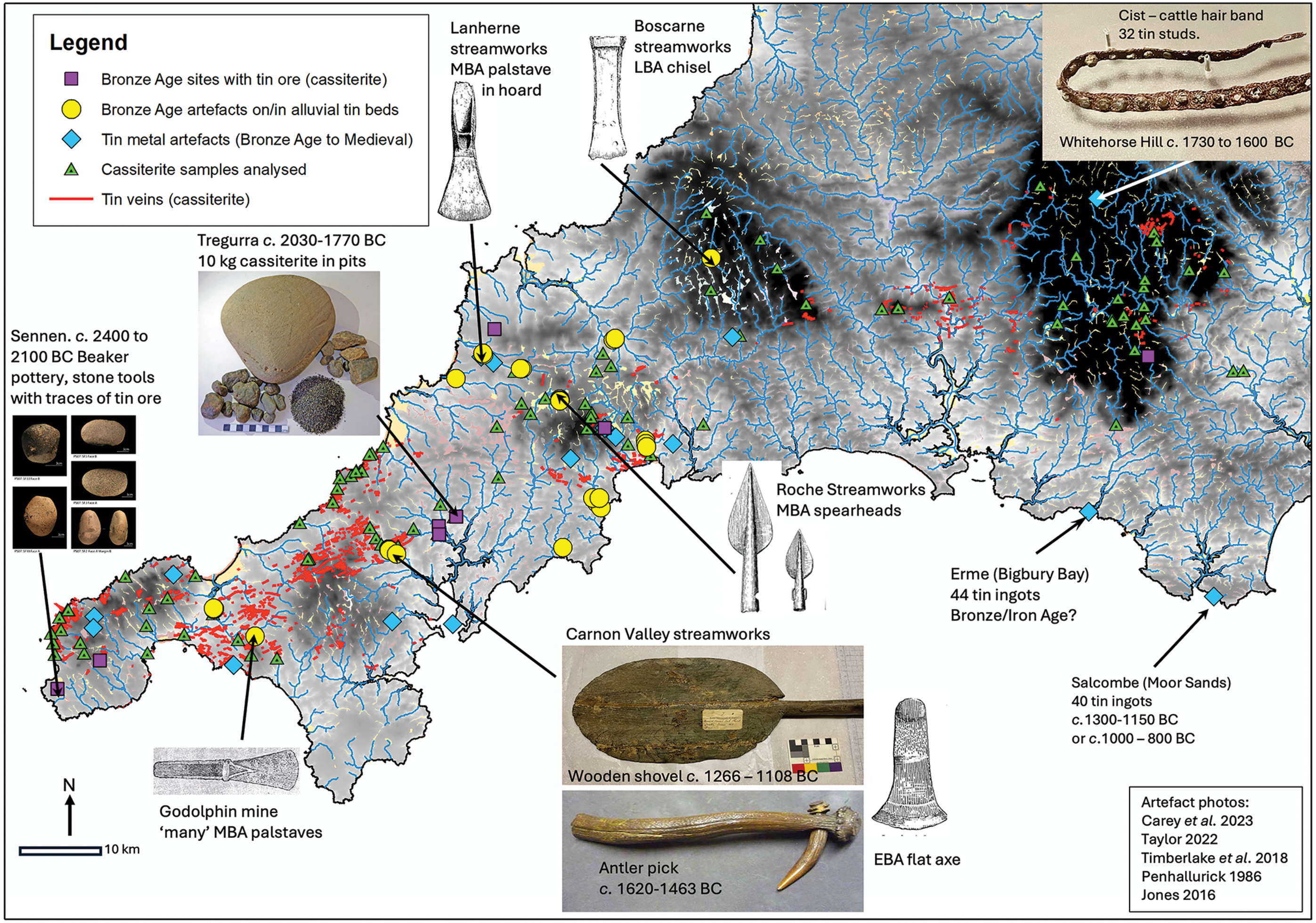

Figure 4. Archaeological discoveries related to Bronze Age tin in south-west Britain and the locations of analysed tin ore samples and tin artefacts (figure by Williams & Montesanto).

describe the voyage of Pytheas the Greek to Belerion (Cornwall) around 320 BC (Cunliffe 2001), mentioning the tin workings, friendly inhabitants and the tin trade from a tidal island, *Ictis*, probably St Michael's Mount, Cornwall. Tin was taken by boat to France and apparently reached the Mediterranean in 30 days. Possible river-land routes include the Gironde Valley and through the Loire or Seine to the Rhône Valley (Mairecolas & Paillier 2010).

Unlocking tin provenance: methods and samples

To provenance tin artefacts to tin ores, Project Ancient Tin developed a major ICP-MS (inductively-coupled plasma mass spectrometry) analytical programme using three independent analyses: trace elements, lead isotopes and tin isotopes. Tin ores contain trace levels of lead from associated ore minerals and from the radioactive decay of uranium within the tin ore (cassiterite). Solutions were preferred over laser ablation for greater sensitivity and larger, more representative samples (typically 30mg/analysis). While straightforward for tin artefacts, the exceptional insolubility of cassiterite has led to its exclusion from recent studies of lead isotopes or trace element analyses. Tin isotope data were obtained by first smelting the ore to tin metal (Berger *et al.* 2019; see online supplementary material (OSM1)), a technique unsuitable for the other types of analysis due to trace element contamination/loss. The current project resolved the tin ore dissolution problem by developing lithium tetraborate fluxing for trace element analysis and by adapting a recently developed multi-acid, multistage pressure-vessel technique for lead isotope and trace element analysis (detailed in OSM1).

An extensive tin ore sampling programme was undertaken across Cornwall and Devon from museum and private collections and from stream-panning fieldwork. Tin ore samples from the other main Western and Central European tin deposits were also obtained, mainly from the Curt-Engelhorn-Zentrum Archäometrie (CEZA) in Mannheim, Germany. In total, 142 ores were selected for trace element analysis, 98 for lead isotope analysis and 23 for tin isotope analysis, to supplement existing CEZA data on tin isotopes for 72 samples. Typically, aliquots were taken after several grams of sample were crushed to average out the composition of tens of thousands of grains (in addition to natural mixing from the eroded veins that form alluvial deposits). These are more representative of the bulk ore composition smelted than micro-analysis of individual cassiterite grains. Bronze Age tin ores excavated from the Tregurra and Tolgarrick sites were included in the analytical programme along with the tin produced from laboratory and field smelting experiments (see OSM2 data) and will be discussed in more detail in a future publication.

More than 200 tin artefacts were sampled by drilling—the largest collection of prehistoric and historic tin metal samples ever assembled. These were predominantly terrestrial and shipwreck tin ingots (Figure 5)—including samples from Bronze–Iron Age shipwrecks from near Salcombe (*c.* 1300–800 BC) and Erme/Bigbury Bay (prehistoric, undated), both in Devon, and from Rochelongue in the Mediterranean (*c.* 600 BC)—plus a few small tin artefacts and slags, mainly from Cornwall and Devon but also from elsewhere in Europe (see OSM2). Erzgebirge tin samples came from stamped ingots aboard the Aanloop Molengat, a Dutch shipwreck from AD 1635. In total, 71 tin metal samples were selected for trace element analysis, 50 for lead isotopes and 23 for tin isotopes. The results were compared with existing tin ingot data from shipwrecks near Israel (Hishuley Carmel, Kfar Samir South & near Haifa; *c.*

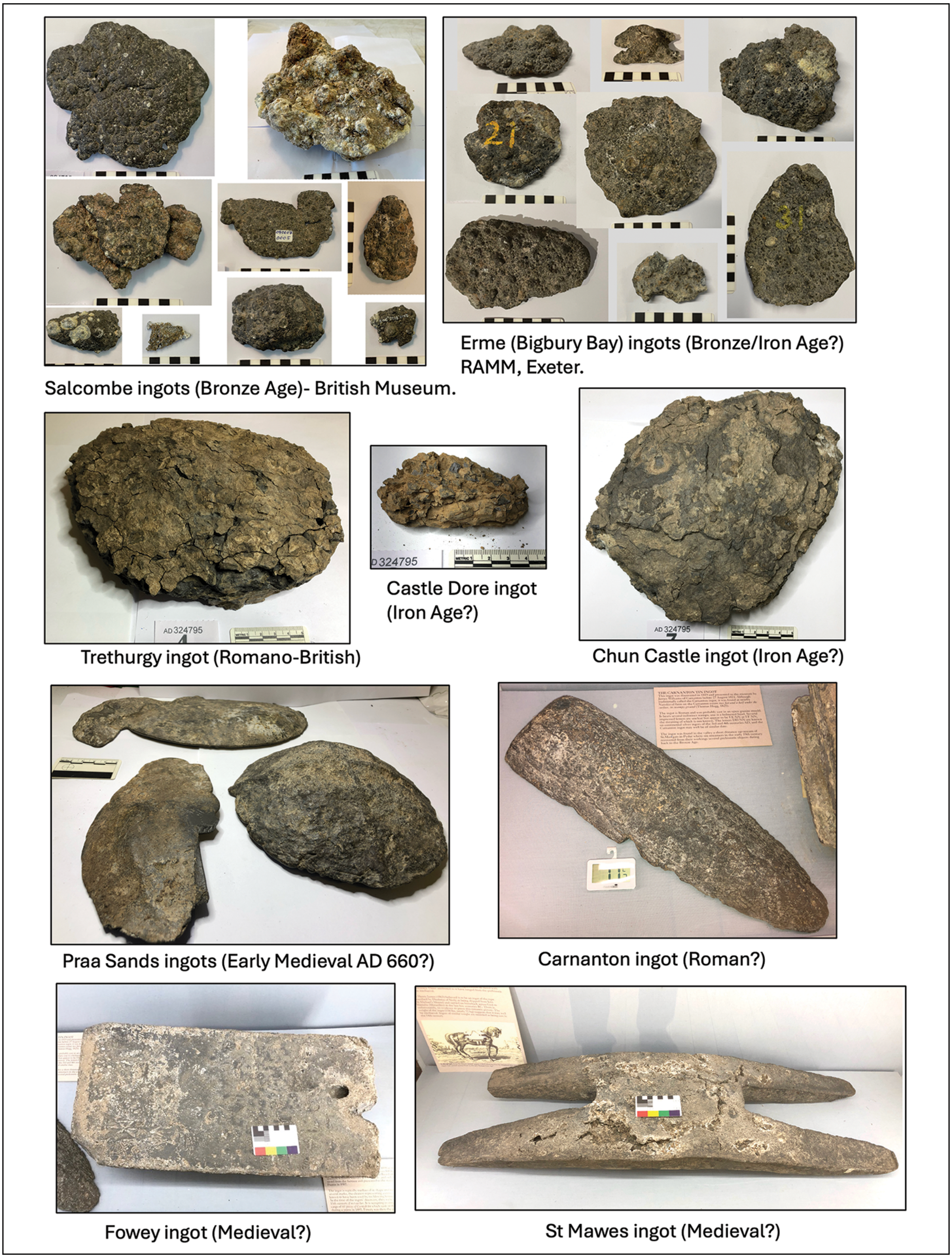

Figure 5. Examples of the tin artefacts sampled (where not otherwise indicated, artefacts are from the Royal Cornwall Museum) (photographs by Williams).

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1400–1300 BC) and from the Uluburun shipwreck, Türkiye (*c*. 1300 BC) (Wang *et al.* 2016; Berger *et al.* 2019; Powell *et al.* 2021).

Tin-provenancing results

More than 60 elements were measured in the ore and tin metal samples to maximise the chances of identifying elements that distinguish between major European sources both before and after smelting. The element that produces the strongest indication of provenance is indium (cf. Berger *et al.* 2019; OSM1). Figure 6 shows that most of the Cornwall and Devon cassiterites contain substantial amounts of indium (up to 176ppm or mg/kg), whereas the Iberian and Brittany and Massif Central ores all contain less than 10ppm. Erzgebirge ores have indium levels closer to those from Cornwall and Devon.

Tin artefacts from Cornwall and Devon have similar indium levels to the ores from that region indicating high levels of indium retention during smelting (Figure 6), which is also evidenced in our smelting experiments. All Bronze Age to Early Iron Age tin ingots from the Mediterranean shipwrecks analysed to date have indium levels consistent with Cornwall and Devon ores or, to a lesser extent, with Erzgebirge ores but not with ores from Iberia and France. Further evidence to exclude Iberian ores comes from their low levels of bismuth and antimony relative to the Israel and Rochelongue ingots (see OSM2 G1 & G2).

Geological age provides a means to distinguish between the two remaining potential European sources. Both sources are broadly linked to the Variscan orogeny, but the formation ages

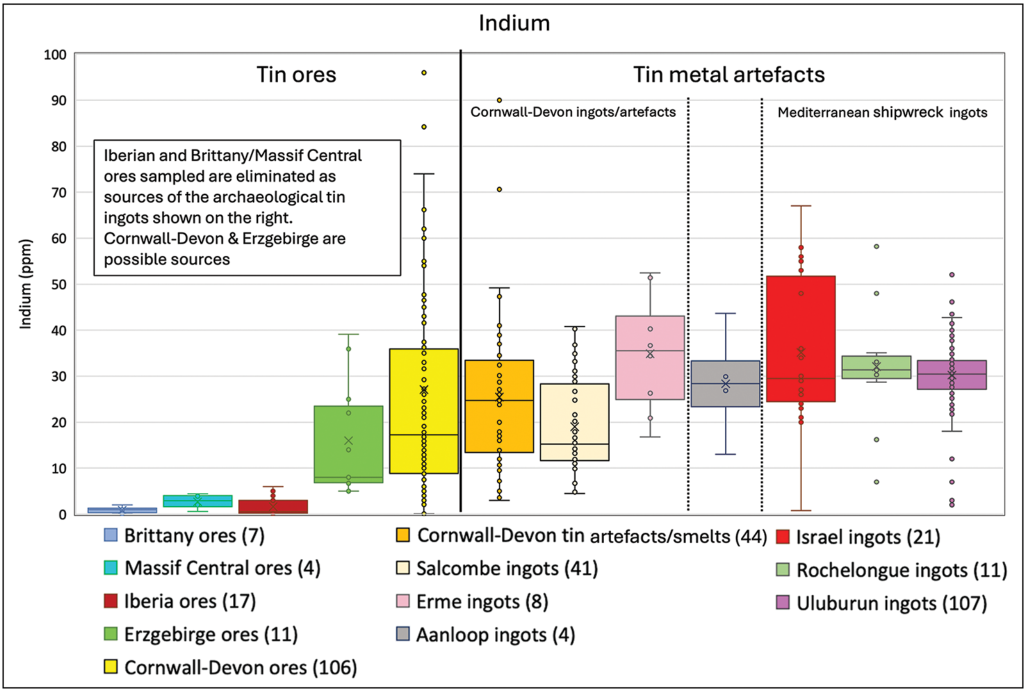

Figure 6. Indium levels in European tin ores and tin-artefact assemblages (figure by authors).

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of the granites and associated ores of Cornwall and Devon (274–293 million years (Myr)) are substantially younger than those of the Erzgebirge (318–323 Myr) (Romer *et al.* 2007; Andersen *et al.* 2016). The lead isotope technique used to detect this difference was developed by Molofsky and colleagues (2014) on African tin and uses the slope of the straight line (isochron) defined by the ratio plots ($^{206}Pb/^{204}Pb$ versus $^{207}Pb/^{204}Pb$) to calculate the geological formation age of the tin ores used to make an assemblage of tin artefacts. A basic understanding of both the technique and the sources of lead involved is important to ensure the technique is applied correctly (Figure 7) and is discussed in more detail in OSM1 (Lead isotope dating) (Berger *et al.* 2019; Powell *et al.* 2024; see also OSM2 G3 & G5).

Combining new and existing data on tin artefacts and using the IsoplotR geochronology software, we can calculate the mean predicted geological formation age of the ores from which the tin artefacts were produced (Vermeesch 2018). The data points produced for each assemblage were all filtered to remove clear deviations from the linear trend caused by lead pick-up, often at the lower end of the $^{206}Pb/^{204}Pb$ and $^{207}Pb/^{204}Pb$ ratios, typical of contaminant lead. Some assemblages did not show a regular linear trend, probably due to variable 'foreign' lead pick-up during smelting (e.g. Salcombe) or had very variable data caused by samples from active streams containing modern lead contamination (e.g. some Cornwall and Devon ores).

Six tin-artefact assemblages and an ore dataset with reasonably consistent slopes gave clear mean predicted formation ages despite the inevitable noise within this type of data. The Erzgebirge ores (319 Myr) and the Aanloop tin ingots with Erzgebirge stamps (322 Myr) lay within the published formation age range of the Erzgebirge granite (323–318 Myr). Similarly, the Cornwall and Devon tin artefacts (289 Myr) and Erme ingots (293 Myr) from the mouth of the river draining Dartmoor in Devon lay within the published formation age range of the Cornwall and Devon granites (274–293 Myr). Importantly, the results from ingots found at Hishuley Carmel, Kfar Samir South and near Haifa (290 Myr) and Rochelongue (278 Myr) clearly indicate for the first time a source consistent with Cornwall and Devon rather than the Erzgebirge (see OSM2).

More broadly, the Variscan age of the Mediterranean ingots excludes many Central Asian sources apart from the most distant (around 4000km from the Mediterranean) in the Tianshan and Altai mountains (Figure 8). Although we have no comparable trace element or lead isotope data on these ores and artefacts, there is currently no contemporary archaeological evidence for an overland tin trade to the Mediterranean from these distant areas. The earlier textual evidence (dating mainly to 1895–1865 BC) of tin being traded long distances from the east by Assyrians to Anatolia does not specify the sources involved (Powell *et al.* 2021; Berger *et al.* 2023a).

Furthermore, the trace element and isotope results from tin ingots from shipwreck sites off the coast of Israel are nearly identical to those of the Salcombe and other ingots found in south-west Britain (Berger *et al.* 2019, 2022). The Uluburun shipwreck tin ingots are also within the ranges of Cornwall and Devon ores and tin artefacts both for key trace elements (this study) and for tin isotopes (Berger *et al.* 2023a). However, tin provenancing using Uluburun lead isotopes is problematic because of variable lead contamination (22ppm to 11.5%, median 231ppm) probably from Anatolian lead sources, often swamping the trace lead levels from the tin source (see OSM2 graphs G3 & G5). Pieces of a lead bar found in one tin ingot further suggests remelting, probably into larger ingots, somewhere along the trade route (Powell *et al.* 2022; Berger *et al.* 2023a).

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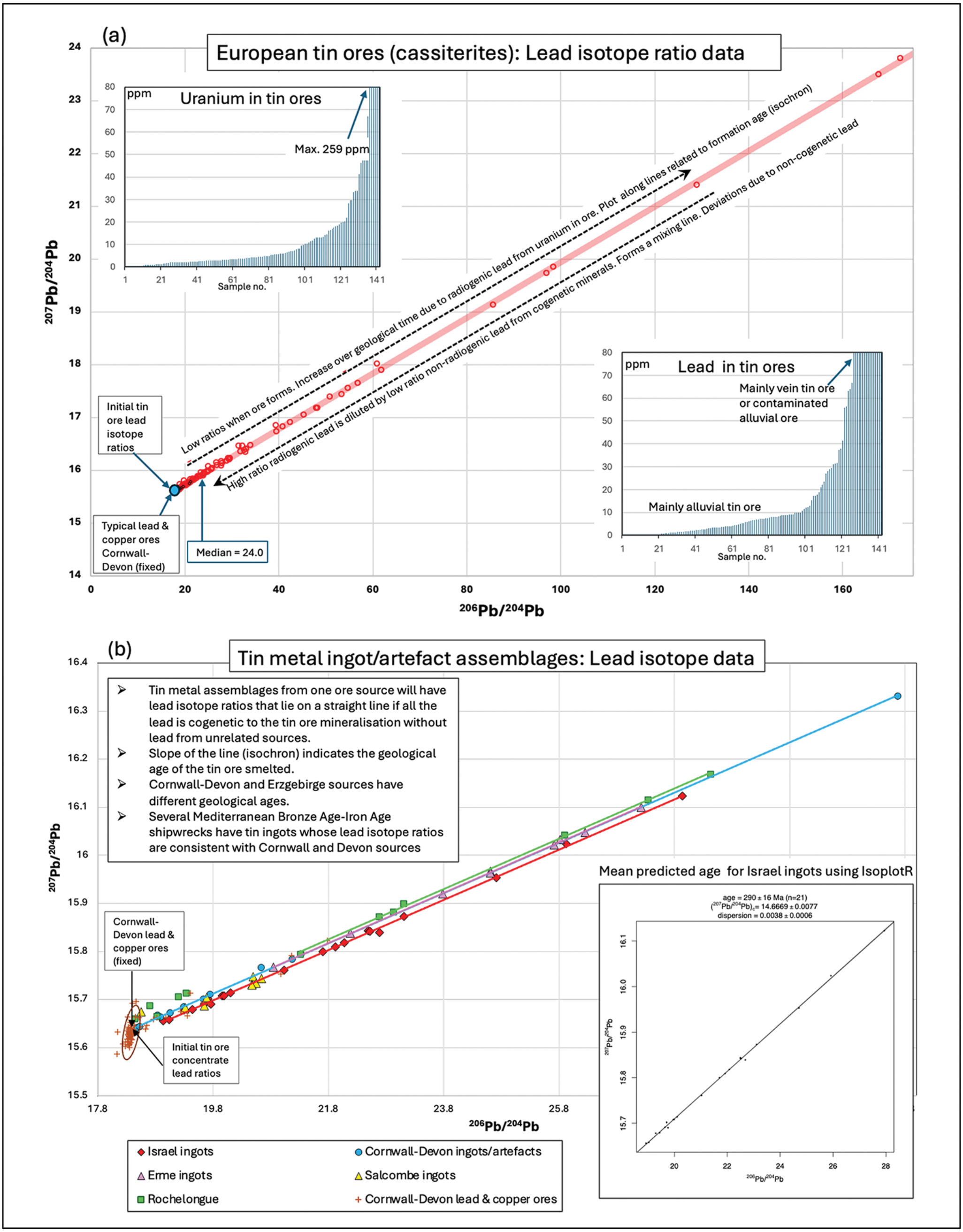

Figure 7. Lead isotope ratio plots for: a) European tin ores and the range of their lead and uranium contents; b) tin metal ingot/artefact assemblages showing the similarity of Cornwall-Devon data (Erme, Salcombe & terrestrial) to Mediterranean shipwrecks (Rochelongue & Israel coast), plus an example of predicted geological age using IsoplotR. (see OSM1 for details) (figure by Williams).

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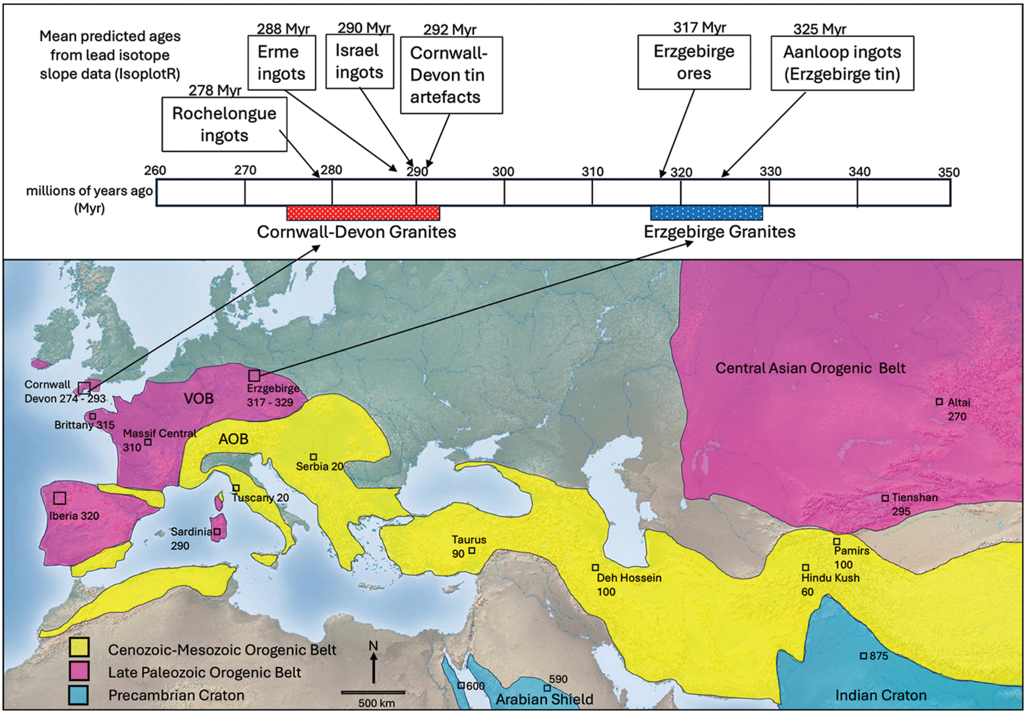

Figure 8. Bottom) geological ages (Myr) of tin ore provinces (adapted from Powell et al. *2021); top) mean predicted age (IsoplotR) from lead isotope data of tin artefact and ore assemblages against the published Cornwall and Devon and Erzgebirge granite dates (see also OSM2) (figure by authors).*

Tin isotope measurements were pioneered by CEZA, which analysed cassiterite deposits from Eurasia. While the substantial overlap between the major tin provinces prevents them from being clearly distinguished, smaller regions or even individual mines within these provinces can still exhibit statistically significant differences in tin isotope ratios (Berger *et al.* 2019). Cornwall and Devon ore and metal tin isotope data ranges are fully consistent with the Israel and Rochelongue shipwreck tin ingots (Figure 9).

Making the European Bronze Age

The west-to-east adoption of full tin-bronze ('bronzization') spreading from Britain by around 2200/2100 BC to the Eastern Mediterranean by *c.* 1500/1300 BC can be viewed in three phases. The first phase marks the discovery and exploitation of tin ores in Britain prior to 2200 BC, as evidenced at Sennen, Cornwall (Carey *et al.* 2023), and in radiocarbon-dated tin-bronze grave goods across Britain (see OSM1 for references). Tin metallurgy could have arisen from the innovative use of the large volumes of dense tin ore unavoidably produced during the prospecting and exploitation of gold by Beaker metallurgists in south-west Britain (Standish *et al.* 2015). In contrast, there is no earlier evidence for tin ore exploitation in Europe, and tin-bronze metalwork prior to 2200 BC remains exceptionally rare

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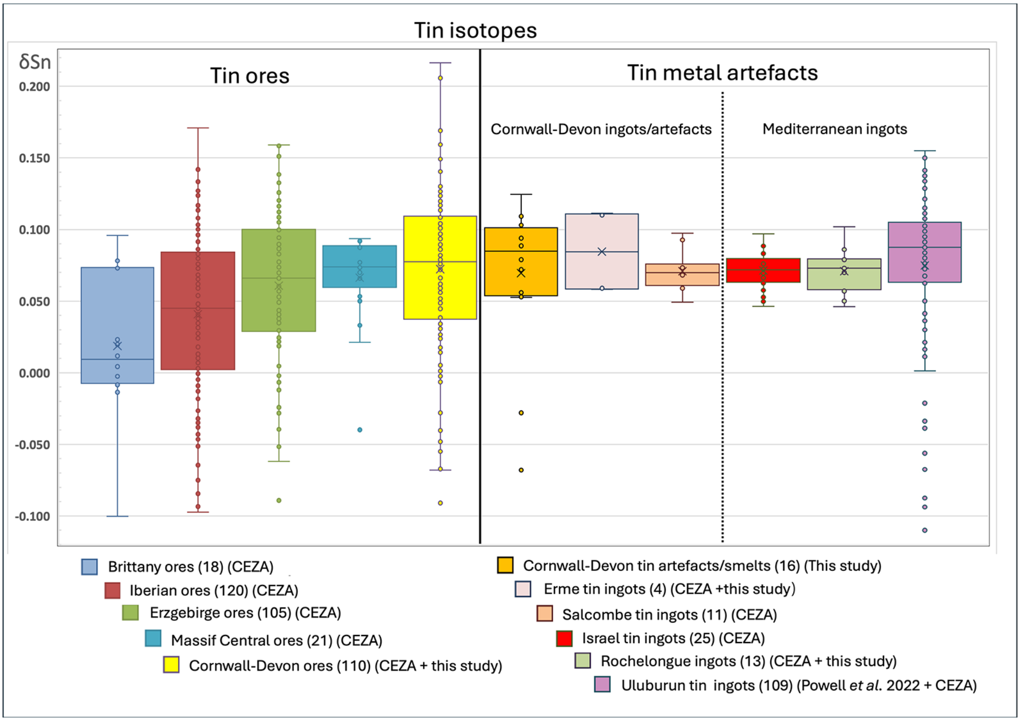

Figure 9. Tin isotope data (in ‰ u^{-1}) from this study and the earlier CEZA Mannheim project without any artefact fractionation correction (see OSM2) (includes CEZA data; figure by authors).

(Rahmstorf 2017). Full tin-bronze adoption then occurred in Britain around 2200/2100 BC, centuries ahead of continental Europe (Pare 2000; OSM1).

The second phase is a more gradual 'bronzization' across continental north-west, Northern and Central Europe *c.* 1900–1700 BC, coinciding with the exploitation of tin deposits not only in Cornwall and Devon but also in the Erzgebirge. This phase would have required a substantial upscaling in tin production and distribution. Contemporary connectivity across large parts of Europe is evidenced in bronze, gold, amber and faience technologies and artefact types found in graves and hoards (see Meller & Bertemes 2010). Gold (and potentially tin) from the Nebra Sky Disc, found in central Germany, has been provenanced to south-west Britain (Borg 2019), and consideration of around 5000 Early Bronze Age burial cairns and barrows in Cornwall and Devon shows that inorganic grave goods demonstrating trade or long-distance connections in type, technology or material are rare but present, including the Rillaton gold cup and the (lost) Hameldown gold studded dagger (Jones 2012; Jones & Quinnell 2013). Far higher concentrations of such exchange goods are found in the Early Bronze Age grave groups of Wessex in south-central Britain (Woodward & Hunter 2015) and especially in the Armorican (Breton) grave groups in north-west France (Nicolas 2016). Tin artefacts from Wessex, Armorica or the Central European Únětice and neighbouring grave groups have not yet been fully analysed (see OSM2), so it remains unclear who was involved in, and who benefited from, the Early Bronze Age tin trade. However,

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access to tin was not the only factor determining 'bronzization'—for example, as demonstrated by the distinct trajectory in Iberia *c.* 1700–1400 BC (Figure 2).

The third phase sees the extension of full tin-bronze adoption into south-east Europe and the Mediterranean from *c.* 1500–1300 BC. Our data show that tin ingots from three fourteenth–thirteenth-century BC shipwrecks off the coast of Israel are fully consistent with tin ores from Cornwall and Devon. There is no evidence for a direct connection between Britain and the East Mediterranean in the second millennium BC, but smaller riverine and maritime routes provide a network along which the tin could have been moved (e.g. Mairecolas & Pailler 2010; Iacono *et al.* 2022; Perra & Lo Schiavo 2023). Overland links between major rivers would have been crucial, creating geographical and cultural 'buffer zones'—exemplified by the Yonne/Seine region where there is a substantial increase in the number of settlements and funerary wealth from *c.* 1300 BC, potentially due to growth in trade (Mordant *et al.* 2021).

The Cornwall-and-Devon provenance of tin ingots from the *c.* 600 BC shipwreck site of Rochelongue, off the south coast of France (Aragón-Núñez 2023), provides the first direct evidence for tin trade across France to the Mediterranean, as described by Pytheas in *c.* 320 BC. From there, the metals trade was probably organised by communities on Sardinia (Perra & Lo Schiavo 2023) which, from *c.* 1500 BC, had trading connections to Sicily and Cyprus (Iacono *et al.* 2022). This would explain both the Cypro-Minoan inscriptions on the tin ingots from Cornwall and Devon found on shipwrecks near Israel (Berger *et al.* 2019) and the presence of lead ingots from Sardinia on the same shipwrecks (Yahalom-Mack *et al.* 2022). The connectivity enabling this pan-European trade in tin around 1500–1300 BC (Figure 10) was facilitated by the emergence of wide-ranging merchants, weight systems and markets trading other metals, textiles, precious stones, foodstuffs and much more across western Eurasia (Radivojević *et al.* 2019; Iacono *et al.* 2022; Knapp *et al.* 2022; Perra & Lo Schiavo 2023).

Estimating the scale of the Bronze Age tin trade is difficult. No continental European tin mines from this period have thus far been identified and surviving, unoxidised and unalloyed tin artefacts are extremely rare. Estimates of Bronze Age copper production at well-studied mining sites, such as the Great Orme in Wales, the Mitterberg in Austria and Kargaly in Russia (O'Brien 2015), may, however, provide approximations. Assuming a tin requirement equal to 10 per cent of total copper extraction for the mid-second millennium BC, when tin-bronze production was favoured over copper or arsenical copper, these three mines alone suggest an output of around 25 tonnes of tin metal per year. Given that more than 100 Bronze Age copper mines survive across Europe and the Mediterranean (Roberts & Thornton 2014; O'Brien 2015), speculative estimations in the order of 100–200 tonnes of tin traded annually during the mid-second millennium BC in the region are feasible. Tin production in south-west Britain more than two and a half millennia later, in AD 1200, used largely the same technology, manufacturing around 400 tonnes per year and employing approximately 6000, mainly part-time, farmers (Hatcher 1973)—a fraction of this production in the Bronze Age is therefore credible.

Conclusions

This study used a novel method for provenancing Bronze Age tin ores and artefacts that can potentially be applied to all periods and regions across Europe and beyond. Tin ores and artefacts from shipwrecks found off southern Britain, southern France and Israel have trace

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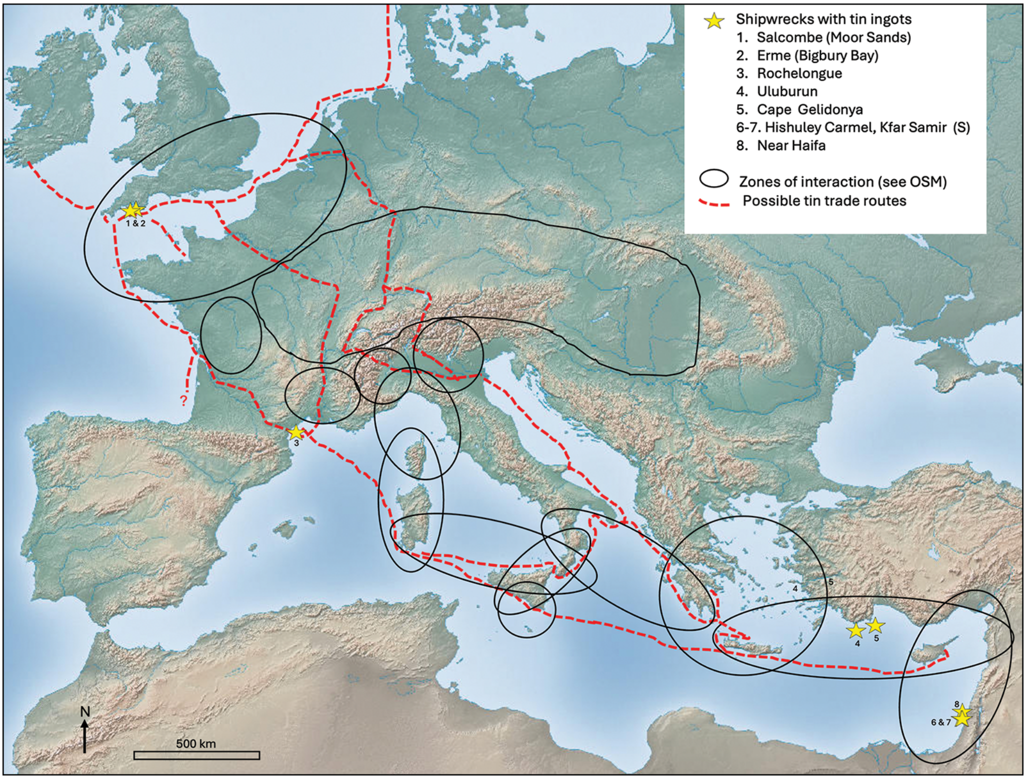

Figure 10. Possible down-the-line trade routes from south-west Britain to the eastern Mediterranean through archaeologically defined areas of intensive interaction c. *1300 BC (adapted from Mordant* et al. *2021; Knapp* et al. *2022; see OSM1 for details) (figure by authors).*

element and isotopic ranges fully consistent with tin ores and artefacts from south-west Britain. Results from the shipwrecks near Israel strongly suggest that the 'bronzization' of the East Mediterranean, occurring 1500–1300 BC, was primarily driven by European tin sources, particularly from south-west Britain, rather than Central Asian sources. Tin ore finds from settlements across Cornwall and Devon suggest a decentralised production model in prehistory, with agriculture still dominant alongside numerous small alluvial tin workings. The tin would have been taken to coastal *Ictis*-type trading places (e.g. potentially St Michael's Mount) before being moved along riverine, overland and maritime routes in continental Europe. To build on this where and when of the 'tin problem', it is necessary now to: survey and excavate the potential coastal trading sites; explore the processes involved in tin-bronze adoption and the scaling up of the tin trade; and evaluate the impacts on societies across Europe and the Mediterranean from the Bronze Age onwards (Figure 10).

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Online supplementary material (OSM1 and OSM2)

To view supplementary material for this article, please visit https://doi.org/10.15184/aqy.2025.41 and select the supplementary materials tab.

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