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New investigations and new ideas on Prehistoric-Roman metal mining and smelting in Wales

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Abstract: At least ten Bronze Age, three probable Iron Age, and up to half a dozen Roman mines and smelting sites have now been identified (and in some cases archaeologically excavated) within Wales and on the Welsh Borders. Amongst the most recent investigations carried out has been the statistical modelling of many of the radiocarbon dates obtained from the Welsh Bronze Age mines. This has provided us with a better idea of the probable sequence of exploitation, as well as some of the earliest reliable dating evidence for metal mining within mainland Britain. In the absence of much evidence for Bronze Age copper smelting, experimental archaeology has also afforded us a glimpse of how the earliest metal might have been created. The work of the Early Mines Research Group continues to push forward the boundaries of our knowledge in this rather specialist subject.

Introduction

The 25th anniversary of the founding of the Early Mines Research Group (EMRG) has provided us with an opportunity to take stock of the archaeological work carried out to date, this being a good occasion also to present some of the latest ideas in publication. Amongst these are the results of recent work, such as the modelling a large number of radiocarbon dates from the UK's prehistoric mines, the re-examination of the character of prehistoric ores, an examination of the palaeoenvironmental evidence for mining, and finally, the provision of new theories on contemporary smelting and metalworking through the undertaking of experimental archaeology and furnace reconstructions.

One of the surprising facets of this subject is that the vast majority of archaeological and palaeoenvironmental investigations have taken place within a 25 km radius of Aberystwyth, a reflection perhaps on the geographical incidence of Bronze Age copper mining in the Cambrian Mountains of mid-Wales, and more specifically the area around Plynlimon. The reason behind this anomaly, even to this day, isn't clear; a fact which is all the more perplexing given the very wide distribution of copper deposits across Great Britain, many of which would have been suitable for exploitation in prehistory.

Wales seems also to have played an important role in the acquisition of metal following the Roman Conquest in AD 49, and there are a number of newly discovered sites of lead, gold and copper mining which have been identified, several of which have been investigated by the EMRG.

The current paper only presents a summary of the known archaeology, thus for more specific site details the reader should refer to the paper written for the 2007 Welsh Mines Society Conference publication (Timberlake, 2009a), alongside a number of rather more technical reports submitted to the journal *Archaeology in Wales* between 1992 and 2010.

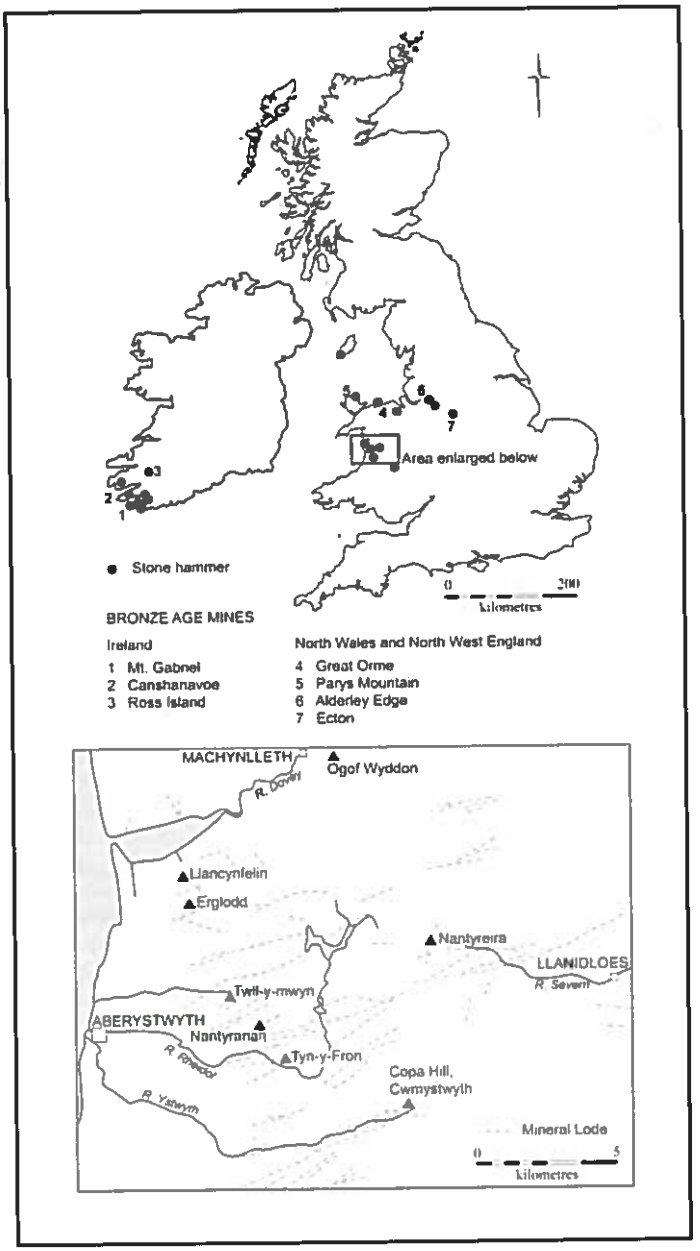


Figure 1a: Map of the British Isles showing Bronze Age copper mines and the distribution of cobble stone mining tools. The highest concentration of sites within Central Wales is shown in detail in Figure 1b.

Figure 1b: The Central Wales Orefield showing mineral veins as well as excavated and dated Early Bronze Age mines (drawing B. Craddock (EMRG))

Bronze Age Mines in Britain

Over the last twenty-five years the discovery and excavation of some twelve Bronze Age metal mines or prospection sites, and the probable identification of at least eight others within England and Wales, have provided a suitable timeframe for the first exploitation of metal within these islands (Timberlake, 2009b). This consisted of a widespread phase of early prospection, most of which took place between 2000 and 1650 BC, followed by production at a very limited number of sites (such as the Great Orme in North Wales) which continued right up until the Late Bronze Age (Timberlake & Marshall, 2013). All of these investigations, except for that on the Great Orme, form part of a long term programme of study currently being undertaken by the author and the EMRG.

Most of the Early Bronze Age mines are located along the western seaboard of Britain, with a concentration in North and mid-Wales, but particularly in mid-Wales where they are associated with lead and copper veins (Figure 1b); these being worked at points where enriched pockets of copper mineralisation lay closest to surface (Francis, 1874; Timberlake, 2002a). Many of the sites were originally identified on the basis of finds of cobble stone tools, the majority of these tools collected as beach pebbles along the coast. Only at distances greater than 20 kilometres from the coast, do we find the regular use of river pebbles and glacial erratics (Timberlake & Craddock, 2013).

Somewhat bizarrely, those areas of Britain richest in copper mineralisation and copper mines (such as South-West England (Devon and Cornwall), the Lake District and Snowdonia) seem not to have any Bronze Age mines … or rather no evidence for such activity has been found to date (Timberlake, 2009b).

However, what we do know is that copper mining in south-west Ireland began around 2400 BC (O'Brien, 2004), and it would seem reasonable to suppose therefore that the current spread of sites represents an eastward migration in copper prospecting following the decline of production at Ross Island in Co. Kerry, yet in reality this pattern is far from simple.

Nevertheless, we shouldn't be surprised to find evidence of Bronze Age mining on the Isle of Man, close to one of the shortest sea-crossings between Ireland and Great Britain. Traces of this activity are to be found at the southern tip of the island, close to the copper-veined cliffs of Bradda Head, where stone hammers have been picked up (Pickin & Worthington, 1989), whilst similar finds have also been found on the Langness Peninsula, a short distance to the east (Doonan & Eley, 2000)

Bronze Age Mines in Wales

Just off the North Welsh coast, on the north-eastern tip of the island of Anglesey, lies Parys Mountain, where traces of Early Bronze Age copper mining has been found at surface (Timberlake, 1990), as well as at another 4-5 locations underground, where David Jenkins has been working since the early 1990s (Jenkins, 1995). Whilst there may be different interpretations of the form of these workings, in the model that I suggest, the first miners may have been working this opencast by means of inclined drifts from the surface down to depths of over 20m, following small shoots of oxidised and supergene minerals along the faults, at all times working close to the junction with the sulphide zone (Timberlake, 2010). At the end of the eighteenth century AD when the deposit was rediscovered, lumps of native copper weighing up to 15 kilos were found within parts of this gossan/ supergene zone at spots not worked in prehistory (Lentin, 1800).

Some 20 km to the south-east of Parys Mountain along the North Welsh coast lies an important group of Bronze Age mines located on the Carboniferous Limestone headland of the Great Orme. Here within the Pyllau Valley Bronze Age miners were opencasting a stockwork of parallel copper veins, whilst beneath that a complex of very narrow galleries and larger stopes within these dolomitised and karstic limestones total several kilometres in length, the lowered water table here permitting mining to a depth of at least 30m below surface (Lewis, 1996). Here copper carbonate ores were being worked with stone as well as with bone tools, the latter where the softness of the weathered dolomite and shale allowed it. Estimates of Bronze Age copper production range from 30 to nearly 1800 tons of metal (Timberlake, 2009b, p116).

Copa Hill, Cwmystwyth

The best known of the mid-Wales group of mines is the Comet Lode Opencast on Copa Hill, Cwmystwyth, located at 426m AOD on the western edge of the Cambrian Mountains. This is a good example of a small-medium sized Bronze Age mine; one which is also unique in terms of its near complete survival, and lack of later disturbance (Timberlake, 2009b). The pristine state of this made it an ideal choice for archaeological investigation. Up to 5000 tons of prehistoric mine spoil cover the hillside below the top of the 10m+ deep opencast (Timberlake, 2003).

Within the opencast a short fireset gallery or 'rock overhang' working, with the marks of stone tools in its roof, was found when the opencast was first excavated by the Early Mines Research Group in the early 1990s (Timberlake, 1990b). From inside the mine thousands of stone tools were recovered and recorded which show a range of utilitarian uses. However, with the exception of just one or two examples, none of these were grooved tools, and only 9% showed some evidence of modification for the purposes of hafting. However, more than 41% had been re-used, some of them up to three or four times, and all for different tool functions (Timberlake & Craddock, 2013). The toolsets included mining hammers, chisels, wedges, crushing stones and ore anvils – and a rare example of a double-sided 'saddlequern-type' grinding stone.

The waterlogged condition of the mine sediments overlying the rock floor of the entrance cutting has permitted the survival of many of the objects and tools of daily working life. This includes the twisted handles made of hazel ('withies') which once held hammerstones used as mining tools, the fragments of kreel-type baskets used to carry or to wash ore, of ropes for lifting bags or for carrying wood, and the remains of antler picks also used as mallets with wedges and stone chisels. When these wooden objects were discarded, some were also thrown as fuel onto the fires used to break up the rocks (Timberlake, 2005).

However, the most sensational find from these excavations was the discovery of this hollowed-out 5m-long log launder, perhaps one of the earliest examples of mine drainage known (Figure 2a). This was one of three such launders excavated, this particular one being found *in situ*. in its last functional position in the entrance cutting to the mine. The sides of this launder reveal the marks of the metal axes used to carve it out. The function of this launder may have been to tap the water coming in at a spring on the edge of the working (Timberlake, 2003). Flooding seems to have been a problem here, water contributing to the eventual demise of the mine at or around 1500 BC. This channelled water may also have been used for washing and separating the crushed ore (Figure 2b). This would have been separated from the gangue minerals, the lead minerals from the copper, and perhaps even the malachite from the chalcopyrite.

Micro-excavation of some of the lenses of crushed mineral present within the Bronze Age spoil has revealed considerable amounts of relict chalcopyrite (part of this oxidised to goethite), most of it apparently discarded during the hand-picking and concentration of ore (Jenkins & Timberlake, 1996). The discovery of this supports the idea that secondary copper minerals such as malachite (but perhaps also native copper and copper oxide) might have been sought, and thoroughly collected; the end result being that little or no visible traces of these minerals survive today (Timberlake, 2010).

A recent study of the small crushed mineral fraction present within the Bronze Age mine spoil has revealed the presence of some of these minerals which ore replacement textures

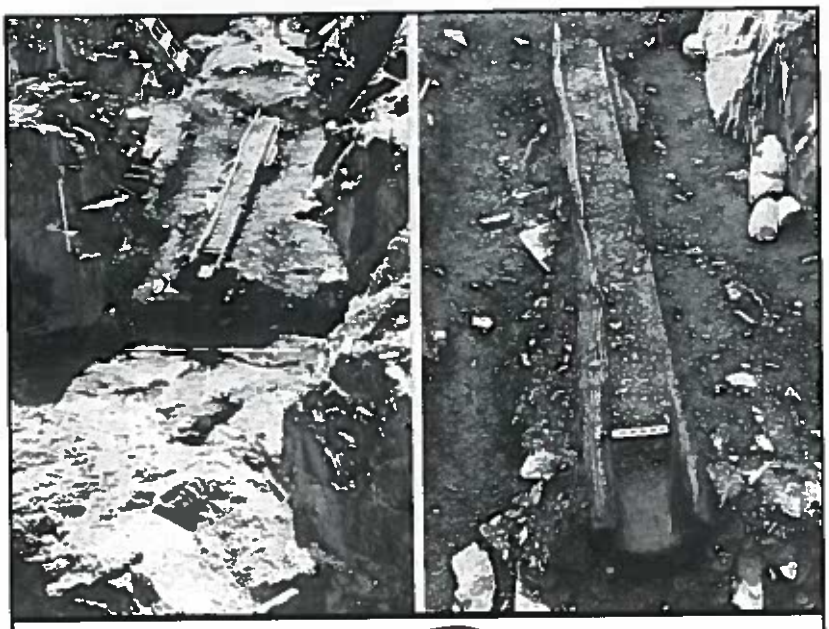
suggest were part of the original constituent of the veins, rather than just the product of post-mining alteration. Shown here (Figure 3a-c) are some beautiful thin-sections of small surviving samples of the original ore which have been photographed by Alan Williams. These reveal cores of native copper and cuprite surrounded by malachite and azurite that is replacing chalcopyrite. In the bottom right hand side (under plane polarised light) we can see native copper. A good example of a visible ore the prehistoric miners may have encountered when they first mined these deposits is the banded malachite that can still be found at the Guefron Mine, in the upper reaches of the Severn valley to the east of Plynlimon. The oxidized vein outcrop at Guefron does not appear to have been discovered during the Bronze Age, thus both the malachite and native copper were available to the miners who first exploited this in the 17th century.

To try to prove the nature of the 'prehistoric ore' at Cwmystwyth we took several drill core samples from the sides of the emptied Bronze Age working. These showed that the prehistoric miners worked the relatively oxidized carbonate-quartz vein right up to the edge of the solid un-altered sulphide ... then abruptly stopped.

Similarly interesting is the evidence which suggests their interest (or lack of interest) in the accompanying lead minerals. For example, at Cwmystwyth the Bronze Age miners started to investigate a small lead vein within the rock-cut entrance to the prehistoric mine, as suggested by the stone chisel found embedded in it. From this vein large lumps of galena were removed and left, presumably discarded, either side of the work. One explanation is that they knew both copper and lead occurred together, and that if they followed one, they might encounter the other. It is also possible that they recovered some of the lead, and attempted to smelt it. During excavation we noted some discrete layers of finely crushed lead (galena) in between layers of copper-rich mine sediment. Although finds of lead metal artefacts in Britain are extremely rare before the Late Bronze Age, there could have been hundreds of years of experimentation in metals before their use becomes commonplace within the archaeological record (Mighall *et al.*, 2000).

The latest model for the sequence of exploitation of the Bronze Age opencast has taken into account the new radiocarbon dates obtained from the base of the earliest spoil tip (Lateral Tip) which lies adjacent to the mine trench (Timberlake, 2004). In this the first exploitation of oxidized minerals took place at the now disappeared cliff-side vein outcrop between 2200 and 2000 BC. This was followed by opencasting down into the vein(s), then by working horizontally in a northerly direction from lower down the slope in order to mine the (slightly poorer) mixed sulphide-oxide mineral assemblage, the miners reaching the water table and sulphide zone at or around 1900-1850 BC. Following this they retreated upwards as the water level rose, picking the walls clean of ore, finally abandoning the site sometime around 1600-1550 BC.

During the final stages of working the bottom of this opencast was left flooded. Moss started to accumulate here, but was buried beneath some of the debris raining in from above, including pit props and charred timber from firesetting, although by 1400-1300 BC the site had returned to nature,



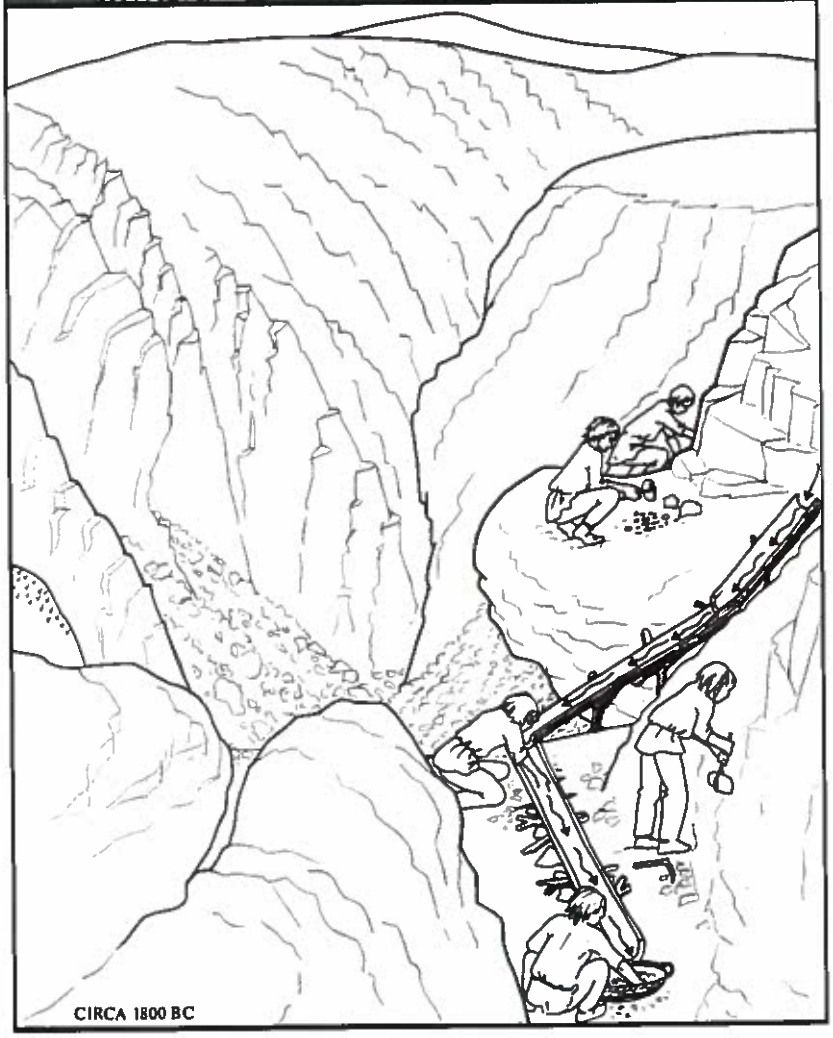
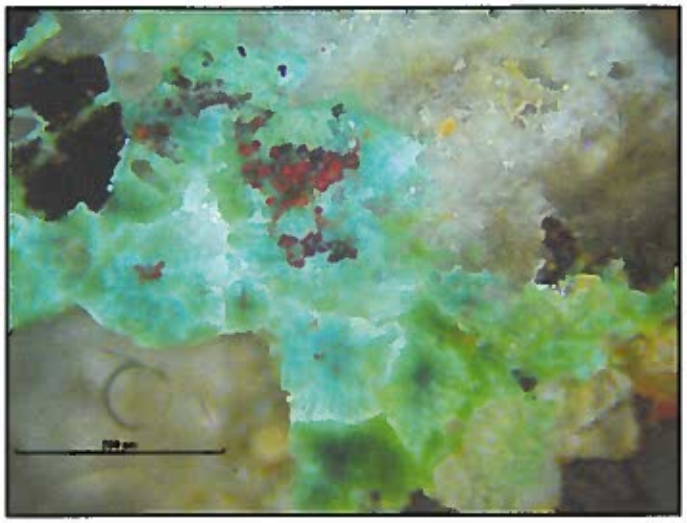
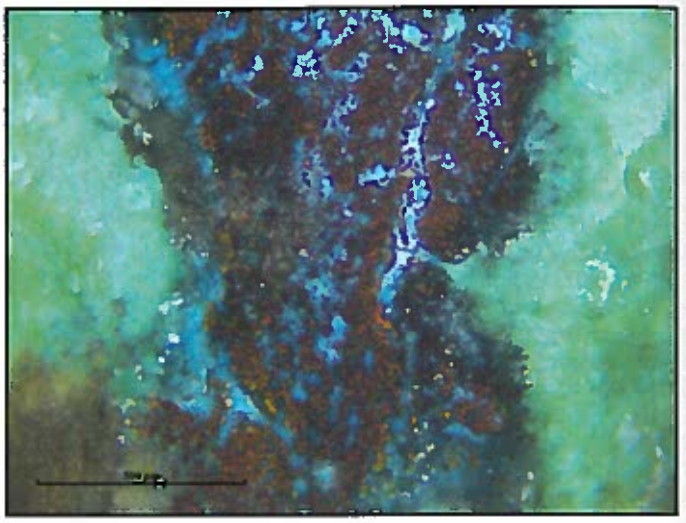


Figure 2a: One section of the 4000-year old 5m-long alder wood launder lying in situ. within the entrance cutting of the Comet Lode Opencast, Copa Hill, Cwmystwyth.

Figure 2b: Detail of the launder with its axe-worked sides and accompanying stone tools (photos S. Timberlake (EMRG))

Figure 2c: Reconstruction of the interior of the Comet Lode Opencast showing possible arrangement of launders to tap water coming in at a spring, and the dual use of this for washing and separating ore (drawn B. Craddock (EMRG))





Polarising microscope images of secondary copper minerals from the prehistoric tips on Copa Hill (photographs courtesy of Alan Williams (University of Liverpool))

(Top left) Figure 3a: Malachite in quartz (X-polars; 500um (0.5 mm) scale)
(Top right) Figure 3b: Azurite with cuprite (X-polars; 500um scale)
(Lower left) Figure 3c: Malachite with cuprite (X-polars; 500um scale)
(Lower right) Figure 3d: Malachite and cuprite with cores of native copper (plane polarised light; 100um scale)

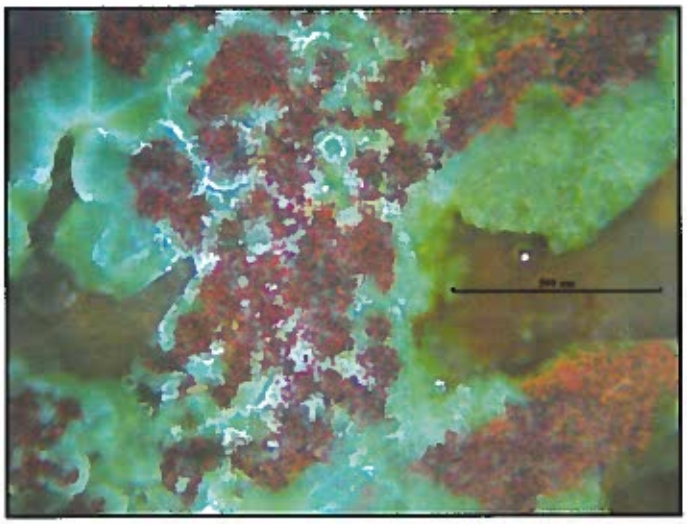
the hole now being half-filled with slumped-in mine spoil overlain by accumulating peat. Some 4m of peat was deposited before being capped by more peat during the Late Bronze Age, subsequently by scree and organic silts during the Roman period, then by a buried soil (turf horizon) during Early Medieval times, then finally more scree and a small layer of mining debris which relates to a late 18th century prospection (shaft). This dated sequence has provided us with a superb environmental record for the surrounding landscape (Mighall *et al.*, 2002a).

Palaeoenvironmental investigations on Copa Hill

Over the last 20 years a considerable body of palaeoenvironmental evidence for mining and smelting during the prehistoric – Roman – Medieval period(s) has been gathered from the mine and blanket peat (raised bog or ombrotrophic mire) at Cwmystwyth; this on-going programme of work on the pollen and peat geochemistry being led by Dr Tim Mighall of Aberdeen University (see Mighall & Chambers, 1993; Mighall *et al.*, 2002b; Mighall *et al.*, 2002c). Analysis of the wood from the Bronze Age mine suggests that the miners used scrub oak branchwood from the surrounding hillsides for firesetting, oak for pit props and stemples, alder and oak for the drainage gutters, and hazel for basketry, rope and the withy handles for the hammerstones. We see exploitation of these same species within the pollen record, but no serious declines, suggesting that mining here was relatively small scale and presumably discontinuous/ seasonal, but perhaps carried out over a long period of time (up to 500 years). Equally significant was a small copper pollution peak found towards the base of the radiocarbon-dated peat which was recorded within several of the cores and monoliths sampled across the blanket peat bog at distances of 300-500m north of the prehistoric mine. This geochemical anomaly (of up to 100ppm Cu) corresponds to a probable pollution event resulting from mining or smelting activity which took place on this hillside sometime between 2000 and 1600 BC. Deposited either by wind-borne dust from the top of the exposed tips, or else by smoke from firesetting, this record of ancient metal contamination provides corroborative evidence for former local mining and smelting. It's not for nothing that we refer to these rain-fed upland blanket bogs as an 'environmental archive' encapsulating the story of man's impact in the landscape.

Further Bronze Age mines in the Central Wales Orefield

This map of the orefield (Figure 1b) shows the location of eight confirmed, and at least four possible Bronze Age mines. These correspond to some, but by no means all of the surface outcrops of copper ore associated with what are predominantly Pb-Zn-Ag veins. What we can see of their distribution, however,



shows some sort of grouping or nucleation within five distinct prospection areas. The common element to all of these locations is an association with east-west river valleys and in particular with veins outcropping on the steep valley sides or hilltop ridges, and sometimes on the edges of peat bogs. One additional factor to consider regarding the discovery and exploitation of these sites might be the extent of de-afforestation and clearance associated with early agriculture. Rapid surface run-off on slopes recently cleared of trees will contribute to erosion and loss of soil cover, and perhaps therefore to the exposure and subsequent discovery of mineral veins.

As these veins become exposed, there are certain accompanying diagnostic features which might be considered to be prospection indicators for copper. One of these might be the streaked green colouration on the rocks, particularly where issuing springs along the line of these veins have led to the deposition of mineral. Yet another might be the incidence of the rusty brown weathered vein mineral ankerite - in mid-Wales a sure harbinger of copper (chalcopyrite) ore (Bick, 1976, p48) – a mineral commonly associated with what is now referred to as A1 Type mineralization (Mason, 1997).

One of the first small mines we looked at was Llancynfelin near Tre'r-ddol. This mine is located upon a rocky isthmus partly surrounded by the large peat basin of Borth Bog. Here several small workings consisting of shallow opencuts and pits exploited a stockwork of minor veins containing surface pockets of copper ore. One of these sites close to the bog edge was partially excavated in 1992, and may have been a trial or prospection site where they tried to mine sometime between 1750 and 1650 BC (Timberlake, 1992 & 1995). It seems likely this site was discovered when the prehistoric miners followed the outcrop of a strong quartz vein across the island, mining it in three different places, all of which have been identified based on finds of stone tools. The lowest working we examined appears to have been buried by peat as water levels rose during the Medieval period.

Just to the north of Banc y Darren hillfort, on the opposite side of the Ervin Valley, is to be found the little known ancient mine known as Twll y mwyn. It was here in 1742 that Lewis Morris' miners opened-up an abandoned mine and found much evidence of burning and numerous stone tools, one of which he drew in the margin of his manuscript '*Mines within the Manor of Cwmmd y Perveth*' (Bick & Davies, 1994). He correctly recognized these as mining implements fashioned from beach pebbles, and he was also the first to make the logical link that the Darren Lode "had been mined before Man knew the use of iron". In 2005 we re-visited this site to undertake preliminary excavations at the copper-rich end of this vein. The opencast here is now partly filled with pools of cattle slurry, but on the marginally more comfortable edge of it we found the prehistoric mine spoil, where we uncovered many hammerstones and obtained Bronze Age radiocarbon dates associated with the early firesetting (Timberlake, 2006).

Meanwhile, high up (at 500m AOD) on the eastern slopes of Plynlimon lies the isolated mine of Nantyreira (or Snowbrook). This mine was 're-discovered' in 1858 when Capt. Reynolds came across a 200 yd long ancient openwork which had been anciently cut through the hard sandstones of the Van Formation using only fire and cobble stone tools (Jones, 1922). Most of the mineral in this vein (which we know must have included copper) was long gone, and a number of relics reminiscent of both prehistoric and Medieval mining were found. In fact this was one of the first mines we looked at in 1988. Plagued by midges and horseflies and deluged by rain we surveyed this site and excavated tips first sampled by Oliver Davies in the 1930s (Davies, 1938), from which we obtained the first prehistoric radiocarbon dates (Timberlake, 1990). It seems that the Bronze Age miners followed the river bed upwards along the upper reaches of the River Severn looking for copper. They mined both here and at Nantyricket, a few miles downstream in the Hafren Forest.

Radiocarbon dating

More than 91 radiocarbon dates recovered from excavations of Bronze Age mines in England and Wales have recently been subjected to Bayesian statistical analysis by Peter Marshall, English Heritage's Scientific Dating Officer. This includes a series of site-based Bayesian models constructed for interpreting the chronology of the following sites: Alderley Edge (Timberlake & Prag, 2005), Copa Hill, Ecton (Timberlake, 2013), Parys Mt and the Great Orme (Timberlake & Marshall, 2013).

When we examine the Bayesian distribution model of dates for the exploitation of Copa Hill, the posterior density estimates for the start and end dates of mining suggest a likely date range from around 2200 to 1500 BC.

By way of contrast to this the recent re-analysis of the Great Orme C14 dates suggests that mining began there around 1700 BC, but then had its most active period around 1500-1300 BC, when most of the copper was being produced. Some of the latest Middle Bronze Age-Late Bronze Age dates come from the deepest levels in the mine.

When all of these dates are looked at together (i.e. for the whole of the UK), it would appear that British mines fall into three spatially distinct groups: (1) mid-Wales (the Plynlimon area); (2) the north Wales coast; and (3) north-west central England. By estimating the first dated mining activity within each of these areas (i.e. *First mid_Wales*;), an evaluation of the temporal spread of mining activity can be determined. It would seem therefore, that the earliest dated mining activity in Britain probably took place in the mid-Wales group of mines (i.e. there is an 80% probability that this is the case). In fact the most likely order for the start of mining within each of these three areas, is as follows: Mid-Wales>north Wales coast> north-west central England (there is a 43.3% probability of this).

The smelting of ores

It has been an on-going challenge of the last 25 years of investigation to try and locate the evidence for smelting, or otherwise explain the lack of it within those areas where copper seems to have been mined during the Bronze Age (Timberlake, 2007). At present we have partial evidence from only one such site in Wales; Pentrwyn, a cliff-edge site located on the north shore of the Great Orme. Most of the deposit on this ledge was lost to the construction of the Marine Drive, whilst much of the remaining evidence has been removed by erosion. However, there is another equally enigmatic site where 'smelting' evidence was recovered at Ross Island, Killarney; here a number of Early Bronze Age (Beaker) 'furnace pits' were found, but with no trace of slag, and also very little clear evidence for the smelting method used (O'Brien, 2004).

At Pentrwyn just a few hundred grams of slags and copper prills smelting residues (mostly <10mm diameter) were recovered from excavations that were carried out in 1998 and 2011 (Chapman, 1997; George Smith. *pers. comm.*, 2012).The analysis of this these has provided strong evidence for the simple smelting of high-grade secondary copper ores without added fluxes, and which were never fully molten (Alan Williams, *forthcoming).* The residual textures and mineralogy in these are consistent with the smelting of oxidized malachite-goethite ores that sometimes had traces of unconverted primary copper sulphides (chalcopyrite). The less-weathered slag samples of these suggest that the goethite converts to magnetite or wustite, depending on the redox conditions, and that the malachite eventually forms copper prills, with later weathering to cuprite and atacamite. As the ores are generally low in silica, only a small amount of glassy slag phase was formed, but possibly enough to allow some aggregation of the copper prills which helped in the recovery of the copper metal when the smelt was crushed. The current analysis of the slag, metal and ores being carried out by Alan Williams (University of Liverpool) has also

The smelting of copper and tin and bronze casting on Copa Hill during the 2013 NAMHO Conference (photographs courtesy of Alan Williams)
(Above) Figure 4a: Pouring bronze
(Below) Figure 4b:The recently cast Early Bronze Age-type knife blank alongside a finished dagger

revealed a scenario of copper prills with both high and very low iron (<0.03%), possibly suggesting some remelting and refining.

A programme of experimental work might be useful here in order to try and reproduce some of the slag and prill compositions/textures resulting from the smelting of some of the Great Orme ores. This has been demonstrated once before in the reconstruction and operation of a furnace to smelt a malachite-rich ore from mid-Wales based upon the Ross Island 'pit' model (Timberlake, 2007). The latter produced something similar in terms of copper prills, and just small amounts of slag, such as was not dissimilar to that found at Pentrwyn (Timberlake, 2005).

From this we can reconstruct the whole process of smelting, the re-melting of copper prills to produce copper, the alloying of this with tin to produce bronze, and following that, the simple casting of an artefact such as Early Bronze Age dagger. Indeed, this *chaine operatoire* of simple production was demonstrated to some of the delegates by the author at the Cwmystwyth Mine meet during the NAMHO 2013 conference (Figure 4). We should remember though that experimental archaeometallurgy is just one avenue of investigation to follow. Analysis of original materials such as metal artefacts, ingots and ores provides an additional perspective on the subject.

Laboratory analysis of the isotopic composition of lead impurities present within Bronze Age ores and metalwork can be used to try and determine the provenance of the metal used. For example, when we plot the compositions of Bronze Age ores from mines such as Cwmystwyth, Parys Mt, Great Orme and Ross Island we can see that there is some correlation with the spread of isotopic and chemical data from the metalwork (Rohl & Needham, 1998). This is particularly the case with metal emanating from Ross Island source during the Copper and Early Bronze Ages, but to some extent also with metal from the Great Orme (which has a much wider spread of Pb isotope compositions due to its radiogenic nature) which is exploited later on. However, there is almost certainly an added complexity to the circulation of metal, for even during the Early Bronze Age a significant proportion of this metal was probably re-melted and recycled, leading to a loss of volatile impurities such as arsenic (Bray & Pollard, 2012), whilst other indigenously mined and smelted metal may have been mixed with scrap, some of it perhaps of imported metal. In fact, from the Middle Bronze Age onwards we may well be looking at the large scale import of metal from continental sources following the gradual decline in copper production on the Great Orme (Timberlake & Marshall, 2013, p65).

The tin question is also an interesting one. Britain emerges into a fully-fledged tin Bronze Age around 2100-1900 BC; a date which is surprisingly early in the evolutionary sequence of development of metal-using technologies, given that use of copper here only begins around 2600-2500 BC. Furthermore, when bronze first appears in these islands, the tin level is high, with between 5-12% tin content being typical of flat axes during the Early Bronze Age (Northover, 1999, p223), rising to 10-12% by the Middle Bronze Age. Most likely this reflects the easy availability of alluvial-

sourced tin from SW England (W. Devon and Cornwall), and the existence of trade exchange pathways between the tin and copper-producing areas.

The social and environmental context of Bronze Age mining

It may be useful at this point to say something about the origins and organization of prehistoric copper mining.

At Cwmystwyth the beginnings of mining may be linked to the circumstances surrounding the deposition of a Bell Beaker-type gold foil disc found within a grave dug close to the foot of Copa Hill (Timberlake, 2004). The suggested date of this disc seems consistent with the very earliest dates for mining at this site, yet the complete absence of other Beaker-type finds here (such as were found at Ross Island) suggests that it might just have been the ideas and interests of visiting metal prospectors that encouraged local peoples to mine (Timberlake, 2009).

Both here and at some of other upland sites the first miners may have been transhumant pastoralists who regularly brought their animals from the coast to the uplands during the summer months. Mining may thus have been periodic and seasonal work carried out during the slack time of year. The type of work undertaken, for the most part, would have been low skilled, most likely with cross-community involvement. Fresh stone tool material would have been brought up from the coast each mining campaign, whilst requirements for fuel and timber would have been met locally in the clearance of new grazing pasture. Perhaps ore concentrate rather than the smelted metal was traded as a means to enter the exchange economy. Somewhat ironically, the ore may have been indirectly or even directly exchanged for metal artefacts.

The situation might have been a little different for the Great Orme, particularly when this site became the main source of British copper sometime between 1600-1400 BC. Here miners may have chosen to live in or close by to the mine – they could have been supplied with meat and tool material, and the working may have been continuous (Timberlake & Marshall, 2013). The deepest workings here suggest mining continued well into the Late Bronze Age – perhaps reaching water and the sulphide zone. Metal was now coming from other sources.

Iron Age mining

The absolute dating evidence for Iron Age non-ferrous metal mining in Wales is limited.

What we can say is that a couple of Late Bronze Age – Early Iron Age radiocarbon dates from underground workings on the Great Orme suggest that the last mining to take place continued into the Iron Age (Lewis, 1996), but by this time the mine must have been a shadow of its former self.

Meanwhile in Ceredigion, at the Darren Iron Age hillfort we recently uncovered some slightly enigmatic dating evidence implying that the large mining trench that cuts the edge of the hillfort earthworks (and which seems to have resulted in some later change to the ramparts to accommodate this) originates in the Middle-Late Iron Age, when excavation for the inner ditch of the hillfort intersected the top of the vein (Timberlake & Driver, 2005). An archaeological investigation of the ancient mine tip to one side of this ditch revealed evidence for two phases of mining; the earliest one defined by a mine spoil devoid of stone hammers (or other tools) overlying a Late Bronze Age ground surface, and an upper one overlying a Medieval buried soil (i.e. Late Medieval – Postmedieval in date). There is yet other evidence from hillforts in the mineral-rich areas of Wales which implies that the populations of these may have controlled or even initiated the exploitation of metals such as iron (Bryn y Castell in Snowdonia (Crew, 1984)), lead (Dinorben in Clwyd (Lewis, 1967)), copper (Braich y dinas (Hughes, 1922), or even silver-rich ores - Darren being a good example of this.

One of the most interesting early mining sites, however, must be that of Llanymynech Ogof, an ancient copper mine on Llanymynech Hill located on the border between Wales and England. Sometimes referred to as a 'Roman mine', the burial of Roman coins here actually suggests the presence of a much earlier abandoned mine (Timberlake, 1994, pp137-138). Several Late Bronze Age - Early Iron Age metalworking hearths were found nearby (Musson & Northover, 1989), whilst a palaeoenvironmental investigation of the hilltop peat basin also appears to confirm the evidence for contemporary metalworking/ mining activity within the hillfort enclosure (Moore, 1992). The local importance of this mine is suggested by the recent discovery of a copper smelting site nearby at Domgay Lane near Four Crosses. Dating from the Middle Iron Age, 'Llanymynech type' Cu-Zn ores have been identified here, along with the very first evidence for the use of clay tuyeres for copper smelting within the British Isles (Young, 2010).

Roman mining

Fieldwork undertaken by the EMRG and other archaeologists between 1993 and 2005 has revealed new evidence for Roman lead mining and smelting within the orefields of South-West, Central and North-East Wales.

At Cwmystwyth on Copa Hill the ancient leat which brings water from the head of the Nant yr onnen for a later phase of hushing on the Comet Lode was archaeologically sectioned in a number of different places (Timberlake, 2004c). From one of the peat layers infilling this an Early Medieval radiocarbon date was recovered; the context of this suggesting that the feature was probably already long abandoned and infilled by this time. A possible interpretation therefore is that this late feature is Roman, something which is supported by the evidence for a local lead pollution peak of this date preserved within the ombrotrophic blanket peat sampled on the top of Copa Hill (Mighall *et al.*, 2000c). More importantly, there is the archaeological evidence nearby of Roman lead smelting.

At the foot of Copa Hill lies the field of Banc Tynddol. Here traces of lead smelting were noted during fieldwalking in 1992, whilst the presence of several smelting hearths was suggested by geochemical soils analysis using PXRF and by a geophysical (magnetic susceptibility) survey (Jenkins & Timberlake, 1997, pp29-30). One of the strongest of these magnetic anomalies was investigated in 2002. This turned out to be a well-preserved, yet atypical, type of lead bole (wind-blown) furnace comprising a shallow scoop into the top of the ridge, a clay and stone-lined interior, and a channel running some 8m downslope through the buried soil (Timberlake, 2002b). From this channel a sample of lead sealing charcoal dating to the Roman period (1st-2nd century AD) was recovered. We have only located one Roman furnace to date, the rest of these hearths being Medieval and of different construction. We might therefore be witnessing a small scale operation here for the purposes of assaying the lead/silver content of the surrounding veins rather than production.

However, a considerably larger Roman lead smelting site has recently been found by Cambria Archaeology on the edge of Borth Bog at Erglodd, near Talybont (Page, 2005). This site appears to be of industrial proportions with layers of charcoal and many tons of crushed lead slag overlain by a Medieval wooden trackway which crosses Borth Bog. At a deeper level upslope were found the traces of several buried lead smelting hearths. Radiocarbon dates associated with these were both Late Pre-Roman Iron Age and Early Roman, yet the association of this site with the Flavian (1st century) Erglodd Roman fort nearby suggests that there could have been some Roman military involvement in the mining and smelting of lead (Page *et al., forthcoming*).

The story of Roman gold mining at Dolaucothi in Carmarthenshire is really the subject of another paper, but suffice it to say that there is enough artefactual and dating evidence already to suggest mining here from the 1st–3rd century

AD, whilst recent radiocarbon dates recovered from the gold ore milling site indicates earlier activity from the Late Iron Age/ Late Pre-Roman Iron Age to the Roman period (Burnham, 1997). Late Iron Age exploitation of this mine was also been suggested by Beatrice Cauuet who undertook work on similarly-dated mines near Limousin in Central France (Cauuet, *pers. comm.* & Cauuet, 2004). A short distance from the mine lies the Flavian-period Roman fort and later civilian settlement/bath house at Pumpsaint (Lewis & Jones, 1969).

Relevant to the study of the Dolaucothi hinterland was our fieldwork carried out between 1996 and 2003 at Nantymwyn, a short distance to the east of on the other side of the Mallaen Mountain (Timberlake, 2004c). At this site we were looking for evidence of Roman leat systems designed for the purposes of prospection, particularly by means of hushing. One such site, flagged up by Peter Lewis, included several leat feeder and hush channels perched on top of the massive quartz vein outcrop at Pen Cerrig y Mwyn (see Manning, 1986). From one of these leat channels we obtained a late 4th-5th century AD radiocarbon date from the peat infill of the abandoned leat, which suggests that up to several centuries earlier they may have been looking here for gold, yet found lead; the date of this prospection perhaps contemporary with the last period of activity at Dolaucothi.

My final example is another recently re-evaluated site, this time in the Berwyn Mountains of NE Wales. Craig y Mwyn is a large partly opencast-mined site 'anciently rent by water' in the search for lead (Davies, 1810). In air photographs this mine resembles some of the classic sites of Roman hushing for gold which are located within the mountains of Asturias and Leon in NW Spain (Lewis & Jones, 1970). In a rather similar fashion we see low level leats surpassed by higher level leats bringing in water to small square hushing tanks located above the edge of a large 'hushed-out' opencast. Very little archaeology has been done here, yet in 2003 we obtained a radiocarbon date from the peat infill of the sequentially latest leat feeder channel on site which seemed to suggest that the whole site had been abandoned by the 15th century AD (Timberlake, 2004c). More revealing still were the early lead peaks which could be seen in the geochemical record we obtained from the blanket peat above the site (Mighall *et al.*, 2007). This record showed a distinctive Roman lead peak as well as two possible Medieval ones. We are left therefore with the tantalizing suggestion of both Roman and Medieval large-scale lead extraction at a little-known site within the otherwise empty uplands of North-East Wales.

Summary Conclusions

The following key points provide a summary of what is now known from archaeology, investigations of ores and metalwork, and the most recent radiocarbon dating programme. However, it should be remembered though that the narrative presented here is just an interpretation of the facts combined with theories developed from years of discussion and writing on this subject. Yet the gaps in our knowledge are still plugged with the stuff of hunches, and like all good archaeological stories the thread of this will change with time, if not be made quite obsolete in another 25 – 50 years from now.

However, these are the salient conclusions, in a nut shell:

Bronze Age mining

- Copper mining began at Ross Island, Killarney in Ireland around 2400 BC.
- Prospecting for new copper sources in Britain begins *before* the decline of Ross Island, and Central Wales appears to have been one of the earliest areas of interest. There may well have been Beaker 'association' with the initiation of mining at these sites.
- Prospectors or perhaps just the ideas then spread rapidly east into North Wales, and following that into Central-NW England.
- Bronze Age copper miners were working the oxidised or supergene zone minerals of these deposits.
- By 1600-1500 BC most of these mines were flooded and already abandoned.
- The Great Orme was probably the main source of British copper between 1600 and 1400 BC
- bronze from continental and probably Alpine sources reaches the UK as recycled scrap from 1400 BC onwards.

Iron Age mining

- Local mining for a variety of metal ores persisted on a small scale during the Early-Middle Iron Age, most probably under tribal control, and often centred upon hillforts

Roman mining

- Wales was probably a significant place for lead, copper and gold mining, and there is a good chance that some of this evidence survives. Indeed, the Central Wales Orefield has provided us with some of the best evidence for lead smelting in the UK
- Mines may have been operational within 10-20 years of the Roman Conquest, and perhaps worked by or under the control of the military. It seems increasingly likely that many of these were in fact Iron Age mines re-worked.

The opinions and interpretations presented in this paper are those of the author and the EMRG.

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