A short review of the evidence for Bronze Age mining in the British Isles

By Paul T. Craddock

1. Introduction

The recognition that remains of prehistoric metalliferous mining activity survive at many sites in the British Isles has only been realised during the last ten years. From the 18th century on miners and antiquarians had speculated on the age of some of the old mines which bore evidence of firesetting and were littered with stone tools. These were discovered when mining began again in earnest during the Industrial Revolution (Fig. 1). Some realised they were potentially of great age, thus Lewis Morris could write in the 1740's that the use of stone tools at Twll y Mwyn and other copper mines in central Wales surely meant they were worked before men had the knowledge of iron (Morris 1747), itself an interesting and unconscious anticipation of the three age system of classifying prehistory, almost one hundred years before Thomsen.

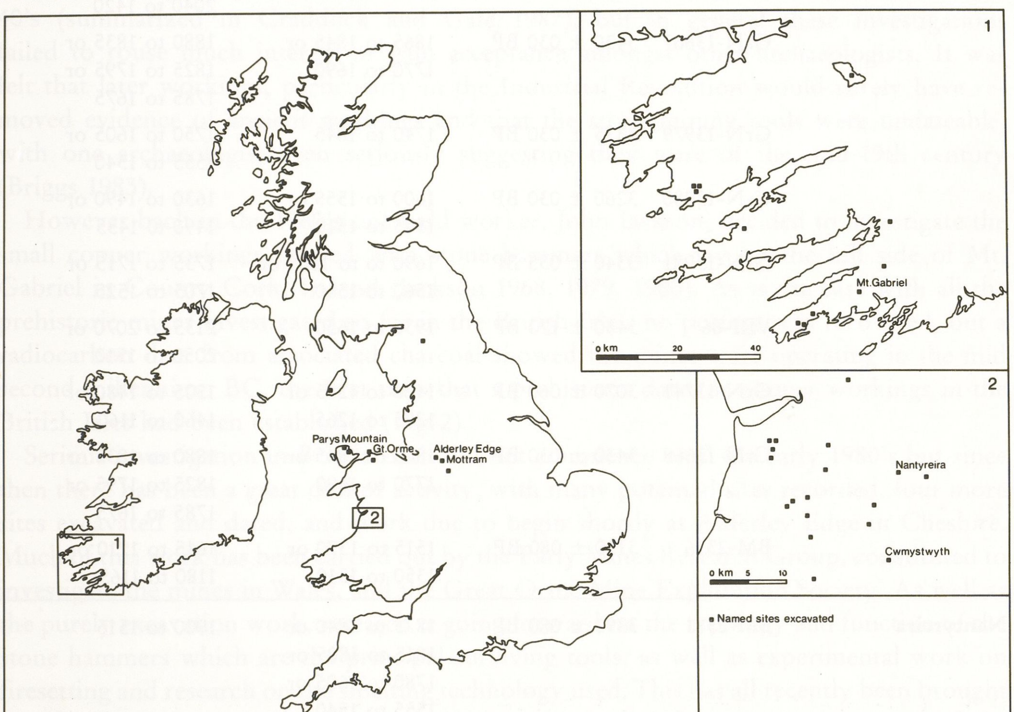

Fig. 1 Mine sites in the British Isles from which stone hammers have been reported, taken from Pickin 1990 and Jackson 1980 with emendations.

			Possible calibrated age range(s) from Pearson and Stuiver, 1986, by probability method* rounded outwards to 5 years Calender BC	
			1δ error term 68 % confidence	2δ error term 95 % confidence
Cwmystwyth	Q-3078	3210 ± 050 BP	1525 to 1430	1620 to 1410
	Q-3076	3220 ± 070 BP	1605 to 1555 or 1535 to 1425	1680 to 1385 or 1335 to 1325
	Q-3077	2990 ± 190 BP	1440 to 990 or 955 to 945	1675 to 810
	BM-2732	3500 ± 050 BP	1890 to 1755	1965 to 1690
	BM-2733	3070 ± 050 BP	1415 to 1300 or 1275 to 1270	1450 to 1210 or 1180 to 1165
Great Ormes's Head	CAR-1184	3370 ± 080 BP	1760 to 1590 or 1570 to 1525	1890 to 1505 or 1475 to 1465
	Har-4845	2940 ± 080 BP	1295 to 1285 or 1270 to 1030	1395 to 975 or 965 to 935
	BM-2641	3000 ± 050 BP	1380 to 1340 or 1230 to 1200 or 1185 to 1160	1405 to 1095
	BM 2645	3290 ± 060 BP	1675 to 1660 or 1630 to 1515	1735 to 1715 or 1700 to 1440
Mt. Gabriel	BM-2271R	3410 ± 140 BP	1890 to 1570	2130 to 2075 or 2040 to 1420
	GrN-13667	3430 ± 030 BP	1865 to 1845 or 1770 to 1690	1880 to 1835 or 1825 to 1795 or 1785 to 1675
	GrN-13979	3375 ± 030 BP	1740 to 1645	1750 to 1605 or 1555 to 1540
	GrN-13980	3260 ± 030 BP	1600 to 1555 or 1545 to 1510	1630 to 1490 or 1490 t0 1455
	GrN-13981	3340 ± 035 BP	1690 to to 1605 or 1560 to 1540	1735 to 1715 or 1705 to 1525
	VRI-66	3450 ± 120 BP	1930 to 1630	2135 to 2070 or 2050 to 1510
	GrN-13741	3070 ± 060 BP	1420 to 1295 or 1285 to 1265	1505 to 1480 or 1460 to 1160
	GrN-13668	3430 ± 030 BP	1865 to 1845 or 1770 to 1690	1880 to 1835 or 1825 to 1795 or 1785 to 1675
	BM-2336	3130 ± 080 BP	1515 to 1370 or 1350 to 1310	1615 to 1210 or 1180 to 1165
Nantyreira	BM-2581	3390 ± 080 BP	1875 to 1840 or 1815 to 1805 or 1780 to 1605 or 1555 to 1540	1900 to 1515

			Possible calibrated age range(s) from Pearson and Stuiver, 1986, by probability method* rounded outwards to 5 years Calender BC	
			1δ error term 68 % confidence	2δ error term 95 % confidence
	BM-2583	3410 ± 050 BP	1875 to 1840 or 1815 to 1805 or 1775 to 1670 or 1655 to 1650	1885 to 1610 or 1555 to 1545
Pary's Mountain	BM-2584	3550 ± 050 BP	2015 to 2005 or 1975 to 1870 or 1840 to 1815 or 1805 to 1780	2035 to 1750
	BM-2585	3490 ± 050 BP	1885 to 1755	1945 to 1685
	BM-2586	3500 ± 050 BP	1890 to 1755	1965 to 1690

* Calibrated ranges previously published for these results were generated using an intercept method of calibration. We now consider this preferable.

Fig. 2 Radiocarbon dates obtained from mining sites in the British Isles (updated from AMBERS 1990).

Other investigations were made by antiquarians in the late 19th century notably at Alderley Edge (Fig. 1) (Carlon 1979) and in central and North Wales in the 1930's and 40's (summarized in Craddock and Gale 1987), but in general these investigations failed to rouse much interest or gain acceptance amongst other archaeologists. It was felt that later workings, particularly in the Industrial Revolution would surely have removed evidence of ancient workings and that the stone mining tools were undateable, with one archaeologist even seriously suggesting they were of the mid-19th century (Briggs 1983).

However back in the 1960's one field worker, John Jackson, decided to investigate the small copper workings littered with stone hammers which lay on the hill side of Mt. Gabriel in County Cork, Ireland (Jackson 1968, 1979, 1980). As is the case with all the prehistoric mines investigated so far in the British Isles, no pottery was recovered, but a radiocarbon date from associated charcoal showed the mines were operating in the mid second millennium BC, the first time that a prehistoric date for copper workings in the British Isles had been established (Fig. 2).

Serious investigation in Britain itself did not commence until the early 1980's but since then there has been a great deal of activity, with many potential sites recorded, four more sites excavated and dated, and work due to begin shortly at Alderley Edge in Cheshire. Much of this work has been carried out by the Early Mines Research Group, constituted to investigate the mines in Wales, and the Great Orme Mine Exploration Society. As well as the purely excavation work, research is going forward on the typology and function of the stone hammers which are the principal surviving tools, as well as experimental work on firesetting and research on the smelting technology used. This has all recently been brought together in Crew and Crew (1990), and this paper attempts to summarize some of the work, and provide an update in what is now a very fast moving area of research in British prehistory.

2. The Mines

About thirty sites are currently known from which stone mining hammers have been reported (Pickin 1990). Some areas of Britain are notably blank, such as Scotland and the southwest of England, and doubtless other sites will be located; equally the reports of hammerstones from some of the sites on Fig. 1 are uncertain and may prove mistaken.

As Fig. 1 demonstrates there are concentrations of sites in the south-west of Ireland and in central Wales. All of the mines so far reported are on a small scale with the exception of Great Orme's Head, Llandudno, and possibly also of Pary's Mountain on Angelsey.

Britain, in common with much of temperate Europe, was extensively glaciated in the Pleistocene and thus the distinctive weathered horizons of the ore bodies, notably the red gossans are largely missing. However research on the mines now suggests that oxidised secondary ores especially malachite, and to a lesser extent azurite were the principal ores sought. This is the conclusion at Mt. Gabriel (O'Brien et al. 1990), Gt. Orme's Head (Lewis 1990), and Alderley Edge (Carlon 1979), although the primary sulphidic ores, chalcolite and chalcopyrite still seem the most likely ores to have been used at other mines such as Cwmystwyth. The early miners cleared the mined areas very thoroughly of all copper ores. Thus the ancient workings and mine tips contain virtually no copper mineral at all, although lead mineral was discarded as useless.

The mines follow the ore from where it outcroped at the surface. In most cases the workings are little better than small pits, as at Mt. Gabriel (Fig. 8) or Alderley Edge or open quarries as at Cwmystwyth (Timberlake 1990a), (Fig. 9 and 10). Usually the workings stopped after a few metres depth when drainage or ventilation became a problem, if the vein had not already been lost. The exception to this are the mines on Great Orme's Head (Fig. 3 and 11) (James 1990, Lewis 1990), where it seems that mining through the second half of the 2nd millennium BC created a complex series of galleries penetrating the hillside for over one hundred metres, following the ore into the hillside from where it outcroped at surface, reaching a depth of over forty metres. The mineralisation is in a very weathered dolomitized limestone that contains many natural fissures and caves and thus much of the mining activity may simply have been enlarging and emptying existing natural cavities and mining the soft malachite ore infilling them. A natural system of passages, some of which may well have penetrated through to the surface would have very much helped ventilate the workings, and the soft rock would not have required firesetting. Even so the mines represent one of the major surviving mine systems from prehistoric Europe.

3. Dating

The prehistoric mines characterised by firesetting and stone hammers investigated so far fall into the second millennium BC (Fig. 2).

In south west Ireland O'Brien (1987, 1990, Brindley and Lanting 1990) believes that the first miners and metalsmiths in the late third millennium BC utilised the primary quartz-pyrites vein deposits containing the sulphide and fahl ores which are the source of the trace elements that characterise the first copper artifacts. However, so far no evidence has been found of the ancient exploitation of the vein deposits. By contrast Mt. Gabriel and the other ancient mines of that type are in primary bedded sedimentary deposits which contain relatively pure oxide and hydrated carbonate ores. These ores produce copper which is typical of that found in the later Early Bronze Age of Ireland.

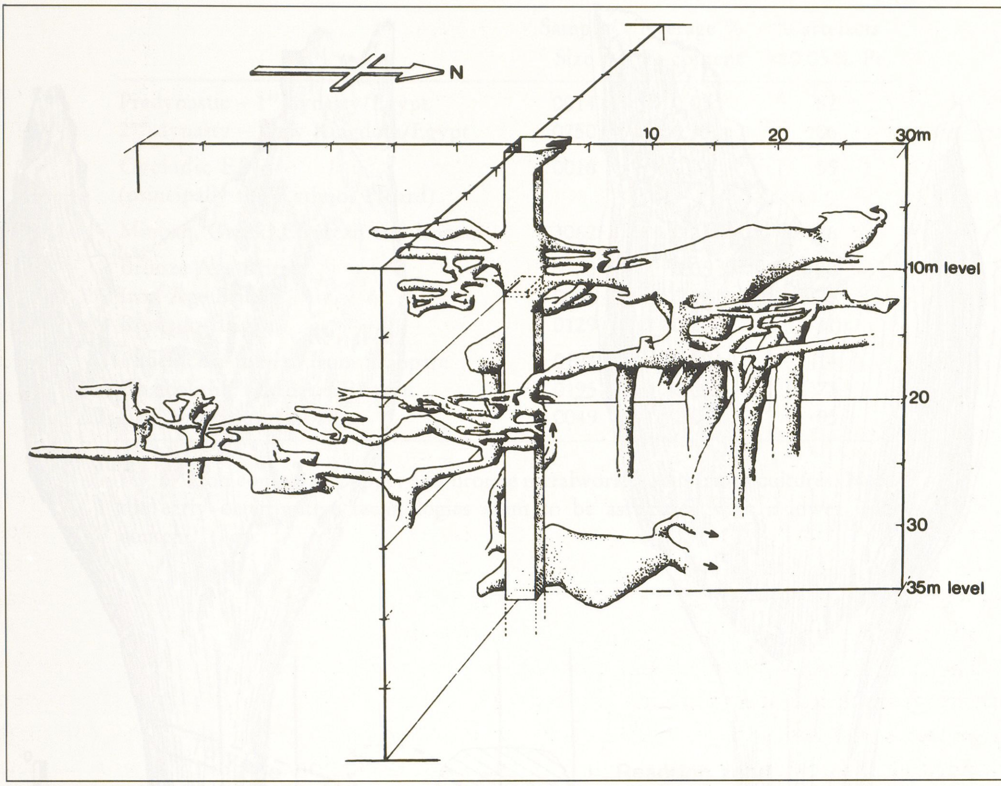

Fig. 3 Small part of extensive Bronze Age gallery system, cut by 19th century shafts at Gt. Orme's Head mine (from LEWIS 1990).

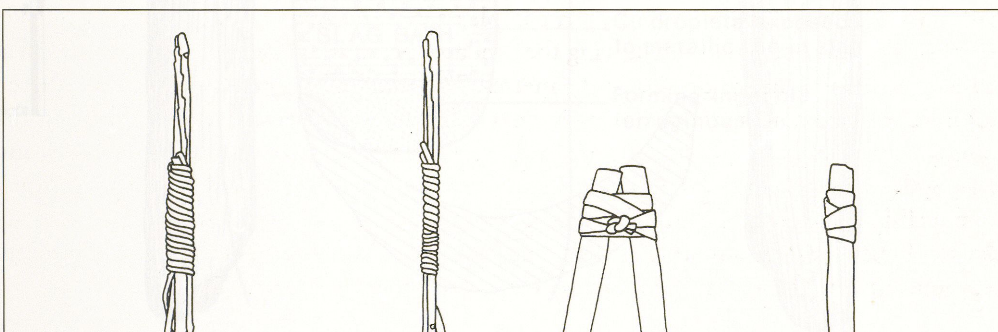

Fig. 4 Stone mining hammers with handles of hazel held with twisted witheys (left) or strips of rawhide (right), made for mining experiments by B.R. CRADDOCK.

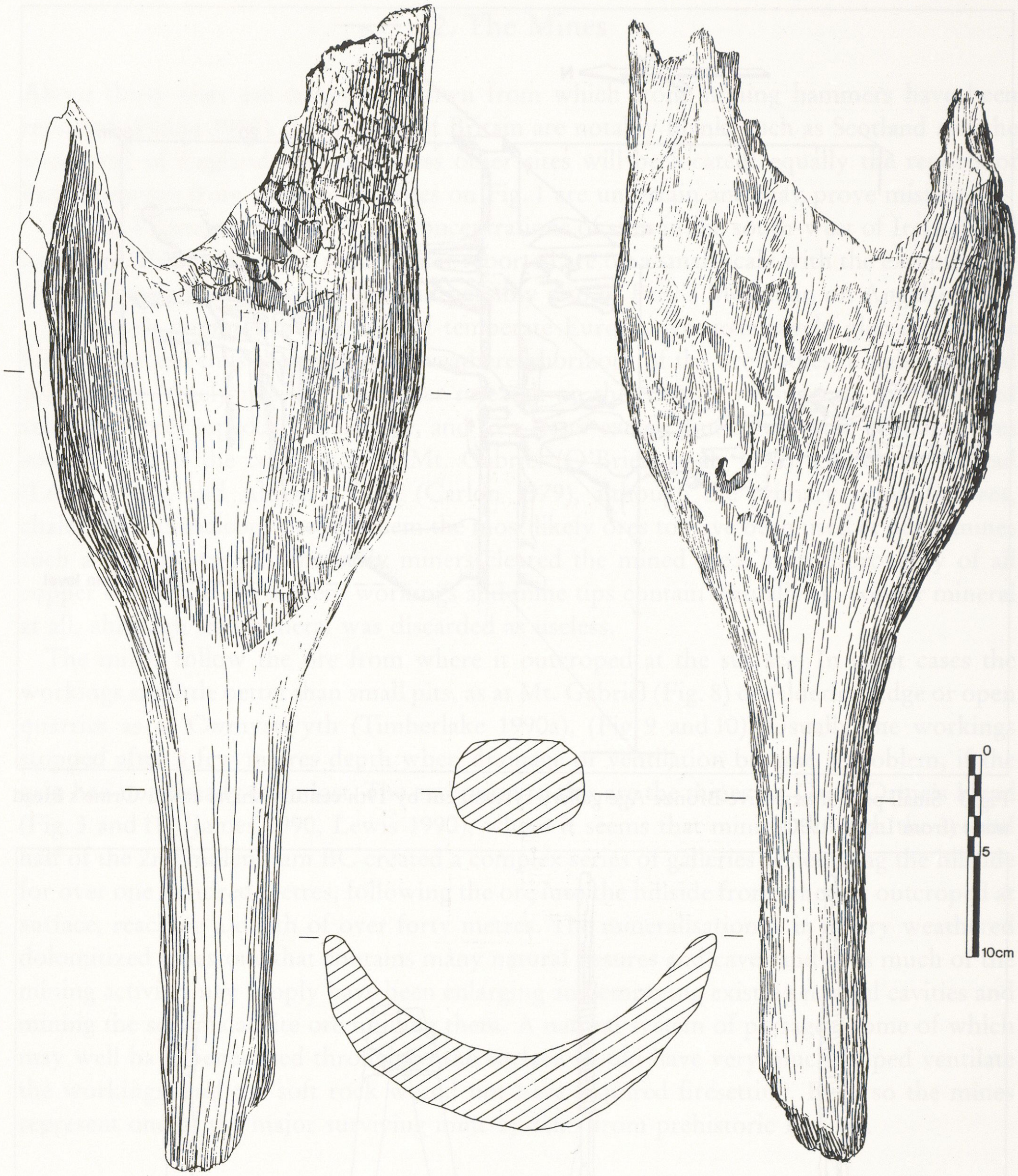

Fig. 5 Short-handled shovel of alder wood, Mt. Gabriel (from O'Brien 1990).

	Sample Size	Average % Fe content	% artefacts < 0.05 % Fe
Predynastic – 1st dynasty/Egypt	0014	0.03	82
2nd dynasty – New Kingdom/Egypt	0250	0.33	06
Cycladic EBII (principally the Kythnos Hoard)	0016	0.04	55
Minoan, Greek, Etruscan and Roman	3062	0.23	26
Bronze Age Britain	0773	0.05	79
Iron Age Britain	0056	0.18	29
Romano-British	0129	0.27	11
Phoenician-Iberian from SE Spain	0104	0.27	14
Chalcolithic – MBA, SE Spain	0195	0.05	73
Late Bronze Age Spain	0049	0.04	95

Fig. 6 Iron content of copper and bronze metalwork from various cultures. Note the early or primitive technologies seem to be associated with a lower iron content.

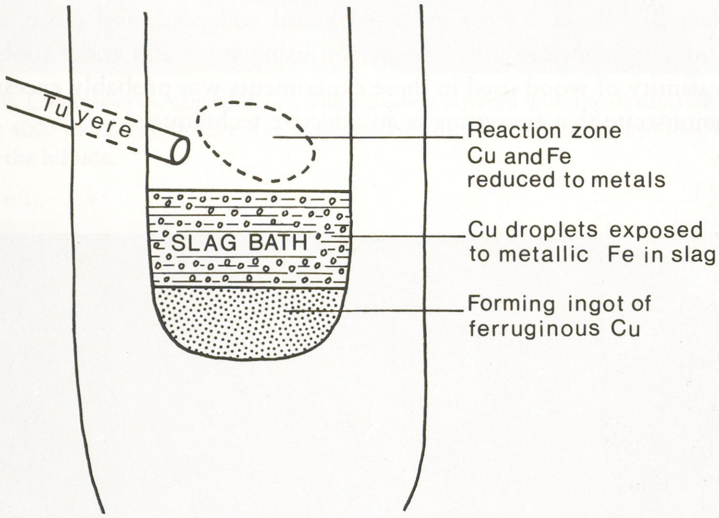

Fig. 7 Schematic representation of copper smelting, showing copper droplets draining through the iron-rich slag (B. R. CRADDOCK).

In Britain the dates are spread through the Early and Middle Bronze Age with only Gt. Orme's Head apparently continuing in use until the beginning of the Late Bronze Age. The absence of any workings dateable to the Late Bronze Age is striking, and reflects the dependence of Britain on continental metal in the 1st millennium BC, as evidenced by the high proportion of imported scrap in bronze hoards of the Late Bronze Age.

4. Mining technology

When the country rock and vein material was very hard it was invariably weakened by firesetting (Craddock 1992). This leaves very distinctive evidence. Fireset walls have smooth continuous contours with no sharp angles. Fireset rock tends to peel away in plates giving smooth surfaces with little evidence of tool marks (Fig. 12). Little is recorded of firesetting as a mining technique although its use was universal until the introduction of gunpowder in the 16th and 17th centuries, and it continued in use in Europe until the 19th century, being especially effective against very hard rocks. From the few old accounts that were written (Agricola 1912, p. 118–120, Timberlake 1990b) and experiments that have been carried out by Holman (1927) and recently by the Early Mines Research Group (Timberlake 1990c) it seems that the most satisfactory arrangement is to establish a good well-stocked fire burning against the rock face and then leave it to burn out, preferably overnight. The heat is able to slowly penetrate deep and weaken the rock for up to 50 cm behind the face; dousing the fire and hot rock with water would have little further weakening effect as the exposed face in front already is weak. In practice fires burning deep underground would be completely unapproachable along confined galleries. Dousing the hot rock after the fire had gone out could have been necessary simply to cool it sufficiently to be able to commence mining. In a recent experiment about 0,75 tonnes of wood were burnt, and next day about 0,3 tonnes of rock had collapsed, and more, assessed at 1,4 tonnes was brought down easily by one person using stone and antler tools (Timberlake 1990b). The quantity of wood used in these experiments was probably excessive, but even so it does demonstrate that firesetting is an effective technique.

Fig. 8 Small workings on the side of Mt. Gabriel, County Cork, Ireland.

Fig. 9 Copa Hill, Cwmystwyth, central Wales. The hillside is covered with the remains of mining activity spanning almost 4000 years. The Bronze Age workings are at the top of the worked lode running almost vertically down the hillside.

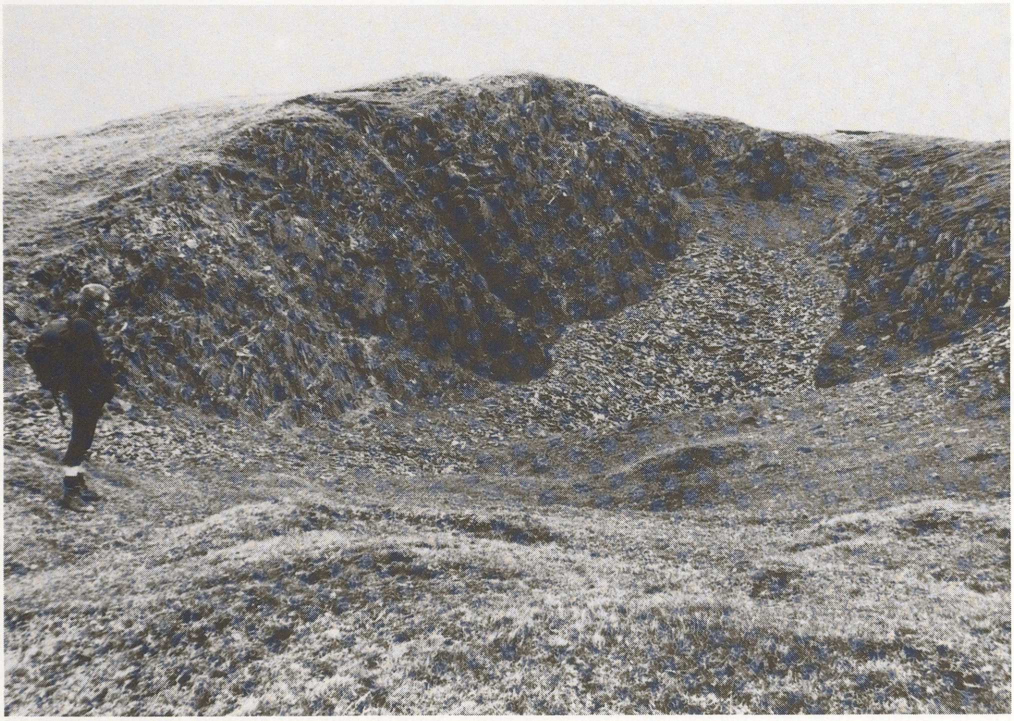

Fig. 10 Bronze Age open cast mine on top of copper lode, at Coppa Hill, Cwmystwyth, central Wales.

Fig. 11 Bronze Age mine workings buried under 19th century mine waste at Gt. Orme's Head, Llandudno. These workings penetrate into the hillside for over 100 metres.

Fig. 12 Bronze Age fire trial on Mt. Gabriel, Ireland, showing smooth sinuous outline typical of firesetting.

Fig. 13 Massive stone hammer from the mines at Great Orme's Head. Such stones have battered ends showing they were used as hammers but are far too heavy to have been hafted in the conventional way. They must have been held in a sling, and swung against the rock face.

The stone hammers litter all the mine sites in profusion. They are river or beach cobbles of whatever hard rock was locally available. Their weights typically lie between about one and five kilograms, but there are smaller pebbles, and reused flakes of rock weighing only a few hundred grams, which could have been useful in the very confined spaces of natural cavities. There are also much larger stones, especially from Gt. Orme weighing up to 30 kilograms which must have been suspended in a sling and swung against the rock face as a battering ram (Fig. 13). Such arrangements are known from later mines but this is the first Bronze Age evidence.

It seems that originally the hammers would have been hafted in some manner and experiments have shown it is difficult and very tiring to use them just held in the hand. Few hammers have ever been found still with their hafts attached. The best example must be those found with the 'copper man' from Chuquicamata, northern Chile (Bird 1979). He was the victim of a mining accident in the 6th century AD and was crushed and mummified together with baskets of cuprite copper ore and interestingly, not one, but a selection of mining hammers of different sizes still hafted in wooden handles (Fig. 14). The Early Mines Research Group took these as models in making reconstructions for the mining experiments (Fig. 4). The handles of hazel (corylus avellana) sticks were lashed to the stone with raw hide (Fig. 15). The surviving stones often have niches pecked onto the edges of the midriffs of the cobbles to hold the handles and small roughened areas on the adjacent flat surfaces which acted as friction pads to hold the wooden wedge used to adjust and tension the raw hide (B.R. Craddock 1990). This is the usual hafting arrangement for hammer stones from the British Isles, however, hammers from Alderley Edge have a pronounced continuous groove pecked all around the middle. This feature is of course common on many of the hammers from mining sites outside Britain, but why it should be prevalent at

Fig. 14 Selection of stone mining hammers still with their wooden handles, found with the 'copper man' from Chuquicamata, Chile (from Bird 1979).

only this one site in the British Isles is a mystery that hopefully the forthcoming excavations will solve. These continuous grooves would seem more suited to a more flexible hafting material such as rope or twisted withey and just such a handle of twisted willow withey has been found at Mt. Gabriel, although unfortunately without its hammer stone and in fact grooved hammer stones are almost unknown in southwest Ireland.

As noted above the hammer stones are very common on the mine sites in the ancient workings, and on the tips, and clearly they had only a short life. Most of them are badly split, but many others were discarded apparently whilst still whole. This is extremely puzzling as at Cwmystwyth, for example, many of the hundreds of discarded hammers are beach pebbles and must have been brought at least 20 km. to the site only to be discarded after minimal use. Possibly blunting of the ends was also a factor in their use.

Against soft or fire weakened rocks the stone hammers proved extremely effective mining tools (Fig. 16). They worked loose in their hafts quite quickly, and it was found most convenient to have someone with the miners just repairing the hammers. Although this was in part no doubt due to our inexperience in hafting them, it does recall the mines at Rudna Glava (Jovanovic 1980) where unused hammerstones found on platforms within the mines suggested repair depots were maintained underground. Antler tools have been found at Cwmystwyth and in quantity from Great Orme's Head. Experiments using antler picks showed they were surprisingly effective to pick and lever out the cracked and weakened rock (Fig. 17). Antler is dense but has considerable strength and spring which adsorbed shock and made the picks easy to use. During a day's work in which over a tonne of material was mined the one antler pick used in conjunction with stone hammers showed little damage, and clearly had several days more use left in it.

These tools have been found elsewhere in Europe, notably at Rudna Glava, where the

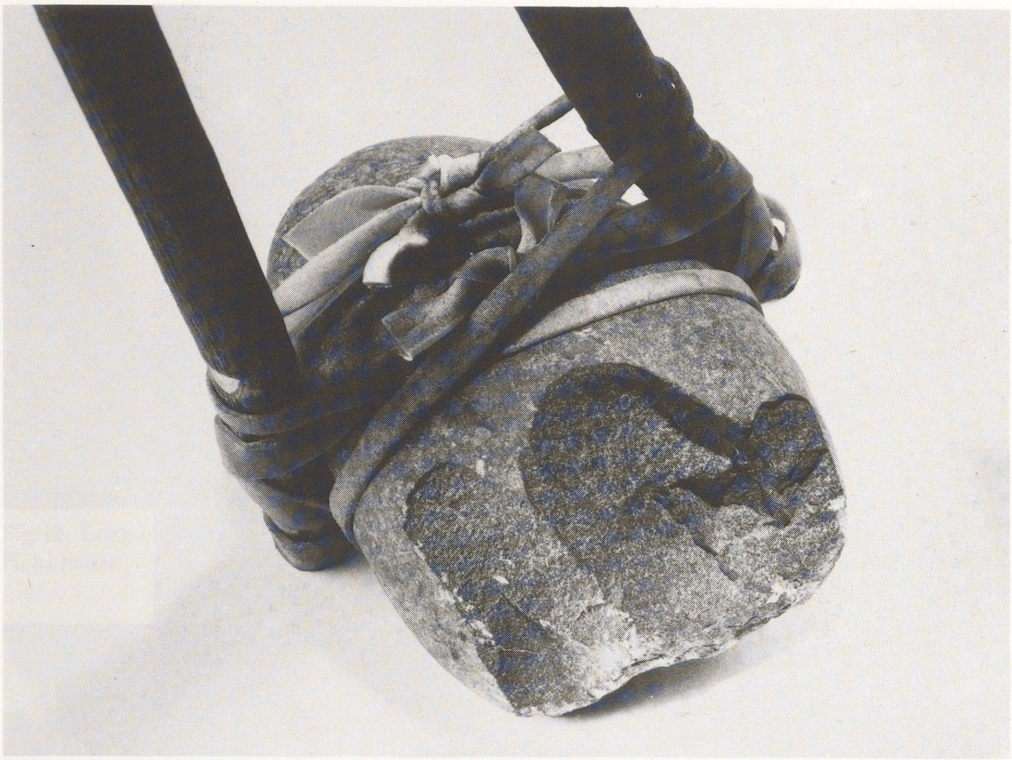

Fig. 15 Mining hammer after several hours use in mining experiments against fireset rock. The notched hammerstone is lashed to the handle with rawhide.

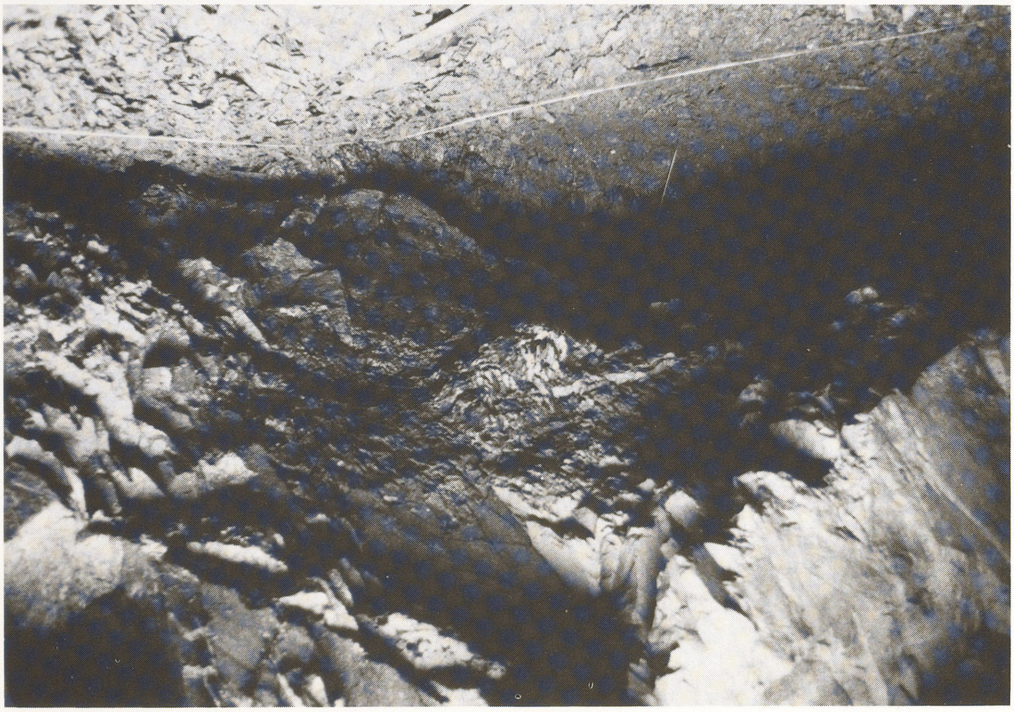

Fig. 16 Distinctive marks made by battering with stone hammers. Bronze Age work at Cwmystwyth.

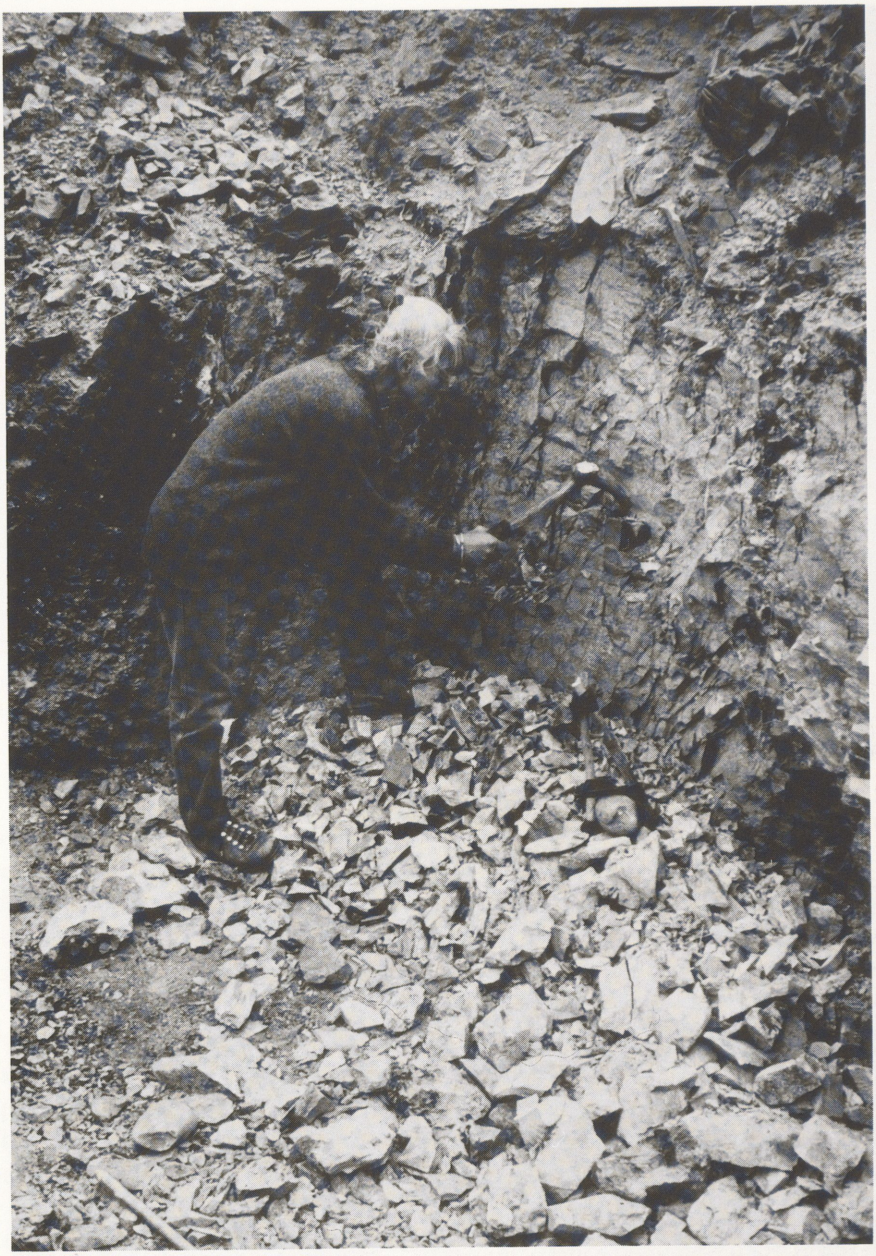

Fig. 17 Antler pick in use on fireset rock, Cwmystwyth 1989.

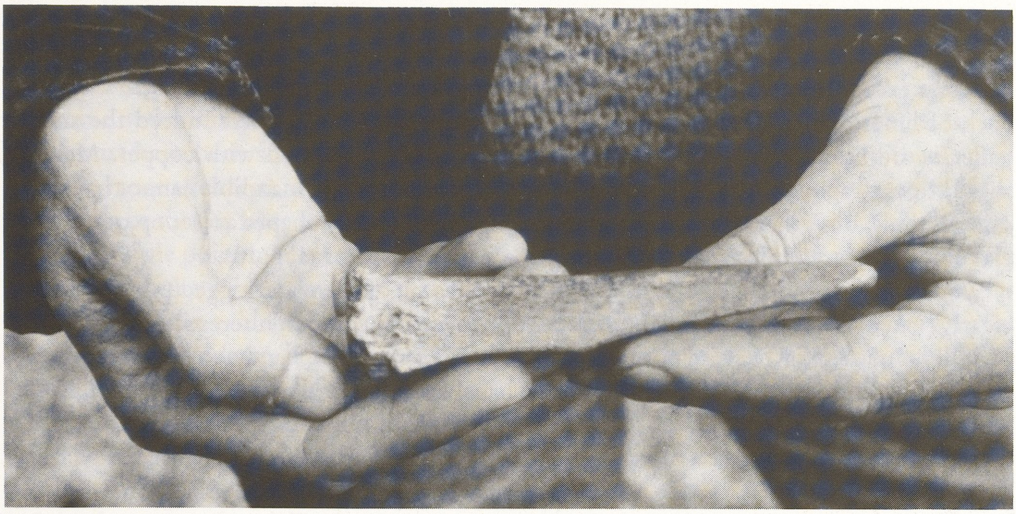

Fig. 18 Long bone fragment used as a scoop, one of many bone tools recovered from the Great Orme's Head mines.

Fig. 19 Crushing and hand-sorting galena and sphalerite at Ishiagu, Nigeria, December 1989.

All photographs by author unless otherwise stated.

alkaline conditions favoured their preservation. Most of the mines in the British Isles are in very wet acidic conditions where antler or bone could not really be expected to survive. The one exception investigated so far are the mines of Gt. Orme's Head set in a country rock of limestone and here antler and bone tools survive in quantity. Indeed the ancient galleries are littered with enormous numbers of bone, all stained with copper. Many of these bones, fragments of skull or vertebrae, including a human mandible cannot have been mining tools, but other pieces of long bone or rib were clearly shaped to scoop out the soft clayey copper ore which had collected in the natural fissures (Fig. 18).

Wood survives quite well and in quantity from some of the waterlogged mines, and was clearly extensively used. Mt. Gabriel has produced the most interesting finds so far including 'pry sticks' to prise out the split rock, and a complete hand shovel of alder wood (Fig. 5) in addition to the handle of twisted hazel mentioned above (O'Brien 1990).

5. Beneficiation

Much of the ore would have been processed on site by crushing and hand-picking the richest mineral as was the common practice over much of the world until recently (Fig. 19). Marks on some of the larger hammer stones show they were reused as anvils. Washing the ores in the fast flowing mountain streams that are so abundant in the west of Britain would surely have suggested itself.

6. Smelting

To anyone with experience of early mines and production sites the most noticeable feature of the mines in the British Isles is the total absence of slag. So far not a single piece of prehistoric copper smelting slag is known from the British Isles, although here is a minute amount of tin slag from some sites in Cornwall. The consequences of this absence are far reaching, and thus all possible explanations for the absence must be carefully considered.

These are:
(1) Originally there was slag in the immediate vicinity of the mines but it has now gone.
(2) The ore was smelted away from the mines at sites still to be located.
(3) The smelting process was essentially non-slagging.

The first of these scenarios is most easily dealt with. The British mines tend to be in remote areas, and thus the tips are largely undisturbed by later settlement or agriculture. Later mining was very destructive but the debris that it generated is very distinctive and can be easily recognised from the earlier debris. As the ores from the later operations were taken away for processing there is generally no later slag to contaminate the site, beyond the small amount produced by the mine forges and clinker from the engine house boilers which can sometimes bear a striking resemblance to metallurgical slag.

True fayaltic smelting slag is almost indestructible, especially in the wet acidic environments found in the west of Britain, thus for example identical iron smelting slags survive in pristine conditions from Iron Age sites in the same environments. The slags are worthless and thus there would be no point in removing them, and anyway the total absence of even small fragments from the undisturbed ancient mine tips does suggest slag was never present.

The second possibility is more difficult to answer as there is a general absence of excavated Bronze Age settlements in western Britain, and of course smelting might have taken place on sites isolated from both mines and known settlements. It must be admitted that some of the mines located in the mountains have very inhospitable micro-climates, and some must have been so regularly wet as to make smelting noticeably more difficult than down in more sheltered areas. However it was the general prehistoric practice to smelt at least some of the ore near to the mine, as evidenced by the Mitterberg production sites etc. There was little point in moving heavy ore when only the metal was required, thus smelting took place at the mine providing that fuel was available. At the sites investigated so far there is abundant evidence of woodland in the immediate vicinity, as indicated by leaves preserved in the contemporary peats. Thus at least some evidence of smelting should be expected at the mines themselves.

This leaves the third possibility, namely that the smelting did take place near the mines but the process was non-slagging, and it is now necessary to consider the evidence for the possible smelting process.

It is of course rather difficult to reconstruct processes based largely on negative evidence, but the principal arguments have been sent out detail in Craddock and Meeks (1987), Craddock (1990) and Craddock (1991).

A number of projects have shown that it is possible to reduce both oxidised and sulphidic copper ores to metal in very simple furnaces, and producing little or no slag, or in fact any permanent trace of the smelting operation at all (Craddock 1990; Rostoker et al. 1989; Pollard et al. 1990) managed to smelt arsenic-rich fahl copper ores with no slag at temperatures as low as 700° C, although there is no suggestion that prehistoric smiths used temperatures as low as this. It is quite easy to attain temperatures in excess of 1000° C in a charcoal fire; the problem is maintaining strongly reducing conditions. However, the vitrified surfaces of the furnace and crucible linings from other primitive smelting operations in Europe (Hook et al. 1991) and elsewhere (Hauptmann 1989) have the mineral delafosite ($CuFeO_2$) which forms under relatively mild reducing conditions. It is perhaps significant that Moesta et al. (1984) has estimated that the pO_2 of the Bronze Age smelting process at the Mitterberg was in the range of 10^{-6} to 10^{-9} (based on analysis of the slags by Mossbauer spectroscopy) that is once again rather poor reducing conditions. However in the British Isles, there is a total dearth not only of slag, but also of fragments of furnaces, or of any other smelting refractories. This is not too surprising as early furnaces generally were very slight ephemeral structures and the poorly fired refractories would be most unlikely to survive in the wet acid peats.

However some evidence for the smelting process does survive in the metalwork itself. Early copper and bronze tends to be rich in most trace elements such as arsenic and antimony, but have very little iron, typically of the order of 0,03% (Fig. 6). Later copper alloys tend to have much lower trace element contents but much more iron, typically 0,3% i.e. approximately an order of magnitude higher. The mechanism by which iron enters the copper has been explored in depth by Craddock and Meeks (1987) but may be summarised here. In the more advanced furnaces, typified by those studied in great detail from Timna (Rothenberg 1990) iron minerals were an integral part of the furnace charge. They were added to promote slag formation and the conditions were much more reducing typically with a pO_2 between 10^{-10} to 10^{-14}, such that some of the iron minerals present were reduced to metallic iron. This was held within the molten slag through which the forming droplets of molten copper drained, and could dissolve into the copper (Fig. 7). Thus the copper tapped from the furnace regularly contained several percent of iron, enough in fact to seriously weaken the metal (Craddock 1980). Fortunately the iron content could easily be reduced down to about 0,3% by remelting in an open crucible and skimming off the light, oxidised iron fraction from the surface.

Iron is an excellent deoxidant, and it is noticeable that the swarms of various oxide inclusions regularly found in European Bronze Age metalwork are almost entirely absent in later bronzes where metallic iron was present during the smelting.

Thus the low iron, but high inclusion content of most British Bronze Age metalwork is strongly indicative of a simple non-slagging process for indigenous copper production.

7. Conclusion

At a superficial level the general similarity of composition of the metalwork across Bronze Age Europe suggests a similar process was in use, but this is not supported by evidence from the production sites themselves which are now at last being investigated all over Europe (Crew and Crew 1990, Eluère 1991). Just the three areas with which the author of this paper is familiar, the British Isles, south east Spain, and central Europe show great variation in process. To some degree this was dictated by the very different environments. As noted in the beginning of this paper much of the gossans and secondary deposits favoured by early man in southern Europe would have been removed by glacial action from temperate Europe. Also the very different climate conditions in the various areas may have influenced smelting practise to some extent. The recent experiments of Merkel and also of Bamberger reported in Rothenberg (1990) demonstrated the enormous volumes of air drawn through the furnace during the smelting and the great quantity of water vapour contained within it. They also recorded the very considerable quantities of energy this abstracted from a smelting system that operated only on the edge of viability. In practical terms it was much more difficult to get the furnace up to heat on a cold damp morning in London than in the south of Israel. How much more difficult would it have been the very wet conditions prevalent in the west of Britain. However the variations observed across Europe seem to go beyond those dictated by environment. In the south east of Spain a non-slagging process of smelting in durable crucibles is attested at a number of sites of the Chalcolithic period (Hook et al. 1991, Fernandez-Miranda et al. 1991), whilst in central Europe a variety of processes have been postulated for the smelting of the Mitterberg ore (Eibner 1982, Moesta 1990) but all are agreed the smelting was carried out in a furnace and produced slag. The evidence from Atlantic or western Europe, especially the British Isles is for processes even more simple.

Thus by the late third millennium BC when metallurgy was firmly established in the eastern Mediterranean-Middle East and copper was already smelted in slagging furnaces under highly reducing conditions, a variety of much simpler but very different processes were commencing in temperate-western Europe suggesting indigenous development at a number of centres. To some degree independent discovery was promoted by relative isolation of the non-ferrous ore deposits. It is worth remembering that the copper deposits exploited in the western British Isles lie well over a thousand kilometres from the nearest continental source exploited in the Bronze Age. Unlike agriculture for example, extractive metallurgy could not spread smoothly and continuously.

The mechanism by which metallurgy could have come about are many, but it could have been through the dissemination of metal artefacts westwards and northwards into Neolithic Europe. The appearance of metal artifacts in metalliferous areas could have prompted the exploitation of local resources, especially of the recognition of native metal. It is perhaps significant that whilst the earliest metals in the Middle East are copper and lead, the two metals which introduced metallurgy to Europe are copper and gold. Copper and gold both occur as native metals, but lead has to be smelted and thus would not be recognised as a local resource. The exploitation of tin provides another indicator. Tin bronze was in use in the Near East from the beginning of the 3rd millennium BC (Muhly 1989), long before metallurgy is supposed to have begun in the British Isles. Yet for the first few centuries copper was used in an unalloyed state in Britain and Ireland. If the wandering smiths postulated by the old diffusionist model had come to Britain surely they would have picked up the extensive deposits of tin in south west Britain, and of lead elsewhere, as readily as they located the copper and much more elusive gold deposits. The evidence again suggests a local initiative that was to flourish throughout the Bronze Age.

8. References

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