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BRONZE AGE MINES OF THE GREAT ORME: INTERIM REPORT

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Abstract: Six years research have established the Great Orme as a major prehistoric technological centre. A summary of the techniques and methods adopted in the understanding of the site are presented. Comment is made on the present state of research and on future proposals for investigations of the site.

INTRODUCTION

The purpose of this account is to update all previous reports that have described and discussed the unique early mine workings located at the Great Orme on the north Wales coast (Fig. 1). This will include detail of all present and proposed research at the site, and will attempt to discuss some of the questions currently being presented on aspects of processing, smelting and distribution of worked ore.

Documentary evidence indicates that copper ores had been mined intermittently on the headland between 1692 and the 1880s, with the main period of activity occurring from 1820 to the 1850s. Mineral was exploited to depths of 700ft (213m) below surface at three sites, the "Old", "New" and Ty-Gwyn mines (William's 1979).

In 1831 and 1849 prospecting miners at the Old mine broke into workings of some considerable age, reputed at the time to have originated during the Roman period. Some accounts of the day were particularly descriptive of the 1849 discovery and report a chamber 60ft below surface containing stone hammers, antler picks, quantities of bone, remains of fires, a fragment of bronze and impressive formations of calcite (stalactite) that hung like tree branches from the cavern ceiling (Hicklen 1863).

These accounts give the first indication of earlier mining, and even at this time certain authors postulated an origin before the Roman period. They followed the argument that Roman workers are unlikely to have used such simple tools as stone and antler when iron implements were available to them, so attributing the mines to the "old Welsh" or Celtic people. Unfortunately the 1849 cavern was destroyed by miners in their search for ore; the 1831 working is also thought to have met the same fate. The locations of both of these are lost, although recent researches place them towards the area of Bryniau Poethion.

During the 1940s the celebrated archaeologist Oliver Davies, who was commissioned by the Committee of the British Association, visited the site, he also ascribed a Roman date, based largely on pottery fragments and coins located at a possible settlement site 1km away on the southern slopes of the Great Orme (Davies 1948).

More recently during the late 1970s, underground explorations of mainly 19th century workings beneath an area known as Bryniau Poethion, lead to the chance discovery of clearly older workings containing similar artefacts to those of the 1849 event (James 1990). Collected charcoal was dated at 2940 ±80BP (HAR-4845) 1410-920cal BC, providing an impetus that lead to the now extensive evidence for Bronze Age mining at the site.

The most recent investigations have centred around the Pyllau valley to the south of the raised ground of Bryniau Poethion. Here studies by Great Orme Mines Ltd., Gwynedd Archaeological Trust and the Great Orme Exploration Society have indicated a complex array of both surface (Lewis 1990; Jenkins and Lewis 1990; Lewis 1993), and underground workings (Dutton *et al* forthcoming) originating during the Bronze Age period

The importance of the site can not be overestimated, having prompted research from a number of organisations, some completing individual analyses on collected material, others conducting more detailed programs of research. In order to evaluate the current state of research it became necessary to form an archaeological steering committee from interested parties, with an aim to appraise all previous work and to advise on future research requirements.

GEOLOGY AND MINERALISATION

The two main factors that are likely to have governed early mining on the Great Orme rely on the geological and mineralogical conditions of the ore deposit. Firstly the actual visual outcrop of the ore must have been obvious, with vivid green and blue colourations due to copper carbonates in the oxidised zone. It is considered that the hollowed nature of the Pyllau valley would have provided some protection against complete removal of the weathered gossan from glacial action. This differs to the situation at other early mine sites which tend to have more exposed settings, and so the likelihood of complete removal of the gossan is increased.

The second and more important factor is the weathered nature of the dolomitised limestone host rock that results in a greatly softened and rotted gangue material. Initial studies did not contemplate such an explanation, but research now indicates that some dolomitised limestones adjacent to veins of copper mineralisation have altered to produce a rotted deposit that could have been worked with minimum effort using simple tools (Lewis 1993). In brief, a mechanism involving the oxidation of primary chalcopyrite to carbonate ores

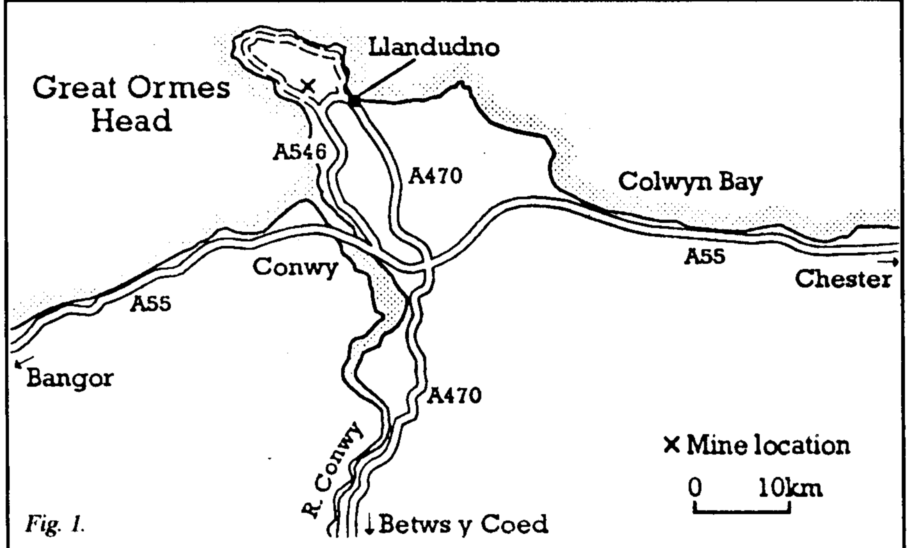

Fig. 1.

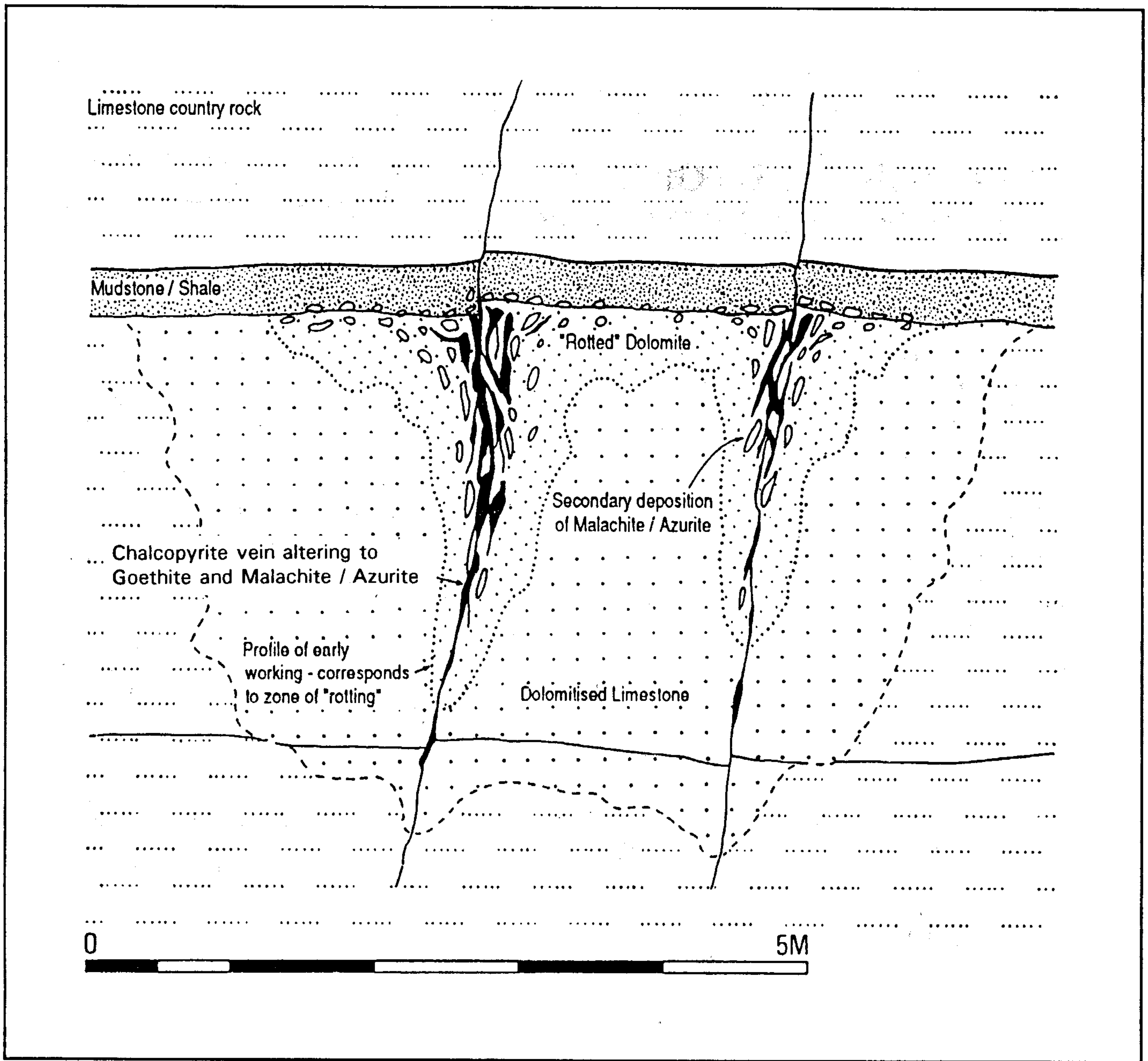

Fig. 2. Section through mineralised fractures, indicating oxidised ores and relationship between "rotted" dolomite and morphology of the early workings.

(malachite and azurite) has resulted in acidification of ground and pore water in the adjacent dolomite, causing solution of bonding cements and at grain boundaries. These effects produce a zone of apparent rotting surrounding the ore vein or body. When removed the junction between the deteriorated and unaltered dolomite is defined by a smooth curved surface, often giving irregular profiles to the mined passage, sometimes resembling the shape of cave passage. These features are a characteristic of the early workings (Plate 1, Fig. 2).

Rotting of the dolomite is more pronounced at surface and decreases in extent with depth, though not totally, as softened pockets of material can be found at depths of 120m (in workings of the 19th century). Rotted dolomite containing malachite and some azurite could have easily been removed with bone tools, indicating that the high incidence of these implements suggests they were more than suitable for the task.

The presence of mudstones interbedded with the limestones may also have governed the extent of early mining. These deposits also have a tendency to soften in the vicinity of mineralised fractures and laterally extending ore bodies, and so could be worked along the thickness of the horizon (Plate 2). A number of examples of this type of working have been recognised, one of these accessible from Owens shaft is on average 1m in height and covers an area of about 700 sq m.

Such simple geological factors as alteration of the vein-host rock are not always taken into consideration at other early mine sites. It is often assumed that many dated workings are the result of firesetting with the combined use of stone hammers. Care in observation of any mineral alteration is a prerequisite to explaining the true reasons for the extent of some workings. The presence of bone and antler tools may also assist in this reasoning, and where absent because of acidic ground water conditions, then evidence for tool marks must be investigated.

A number of mineral studies are presently underway, including reflected light microscopy (Birmingham University) and electron microprobe analysis (Bangor University). Several new minerals to the site have been identified including erythrite, olivinite, cerussite, covelline, digenite, blaubleibender covelline, djurleite, marcasite and chalcocite.

With regard to the age of the mineralisation it is generally assumed to be Variscan, based on data from the lead-zinc ore fields of the Conwy valley that have similarly trending mineralised fractures to those of the Great Orme (Ineson and Mitchell 1975). It is hoped a number of ore samples presently submitted for geomagnetic dating (Liverpool University) may provide an indication whether this is the case.

Throughout the past twenty years a number of studies have attempted to relate trace element compositions of ores from various mines to those of Bronze Age artefacts to determine source locations of the included copper (Jenkins 1986, Tylecote 1986). Unfortunately no conclusive associations were proved and limited work continues. Another technique that might have more promising results is through stable lead isotopes. Already this method has provided favourable comparisons between ores and metal artefacts analyses for Turkey. Research conducted by Sayre et al (1992) has helped to advance these techniques. It is hoped that similar work to be completed at Oxford (Rohl - pers com) and Liverpool (Taylor - pers com) will assist in answering some of the longstanding questions for artefacts from Britain and Ireland. However analyses of Great Orme samples do present their own set of problems, because of the presence of radioactive minerals concentrated in hydrocarbons associated with the mineralisation. As a result lead isotope ratios vary between low and high values so it is very difficult to ascribe any individual signature to the ore deposit (Rohl, pers comm).

STONE ARTEFACTS

Stone hammers are often considered to be the main indicator for early mining activity, primarily because they are the most obvious feature to be encountered. Varieties of stone tools from the many provenanced early mines are numerous, with differing attempts to catalogue them (Picken 1990; Gale 1990). More detailed studies also exist and those by Gale (forthcoming) provide the most comprehensive catalogue of finds to date.

At the Great Orme the ratio of stone hammers in proportion to the scale of the workings, is markedly smaller in comparison to similar tools at other known sites. This observation agrees with the view that a significant volume of the ore bearing dolomite was rotted enough to allow removal by bone tools, so excluding the use of stone tools for certain extraction operations. Because of the difference in required use, many hammers display wear patterns indicating use for crushing and pounding rather for than direct hammering of worked faces. The low degree of modification for hafting also lends to this argument.

Typically stone hammers vary between 0.5 - 29kg in weight, are of hard fine grained igneous rocks derived from local beaches and number about one thousand. Other tool types are recognised, such as mortars and pestles for grinding, and dressing stones or anvils for crushing purposes.

BONE TOOLS

Several thousand fragmented pieces and occasional complete components of bone are recorded. A high proportion display a fine state of preservation, provided as a result of the neutral-alkaline conditions generated from the dolomite-limestone host rock and through surface impregnation by copper-iron minerals that impart a characteristic blue-green colouration.

Originally, as was the case last century, all items of bone were considered to have been the remains of food consumed by the early miners within the workings. Studies now indicate this is only partly true, the remainder exhibit wear and fracturing consistent with use as primitive chisels, scrapers, gouges and levers to remove the loose and rotted parts of the ore bearing material. The presence of tool marks consistent with these types of implement are now recognised as being fairly common-place throughout many of the workings (Plate 3).

A comprehensive study by Hunt (1993) has supplemented previous findings and helped to confirm some of the initial ideas. Identified species for derived bone include cattle, sheep, goat, red/roe deer, pig, horse and dog, with cattle representing the predominant type. Proportions of bone per species are comparable to other Bronze Age sites

Plate 1. Bronze Age working with a stone hammer. Note the smooth curved profile of the tunnel, in contrast to the lighter, fresh exposure of rock resulting from 19th Century blasting.

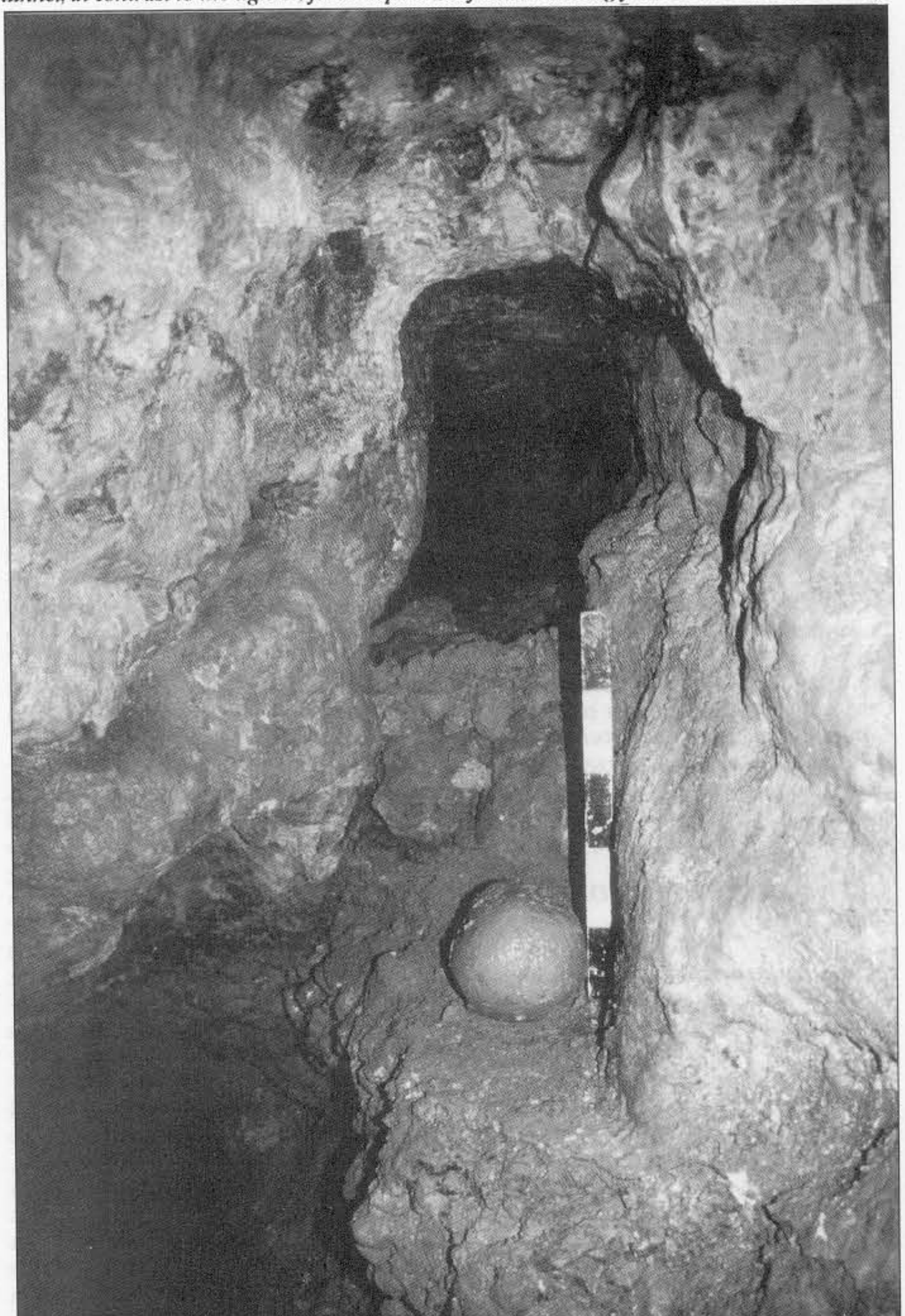

Plate 2. View of an early working along one of the mudstone horizons. Complete stalactites and stalagmites show 18th and 19th Century miners did not penetrate this area.

(Brean Down - Levitan 1990), although there does appear to be a higher incidence of cattle bone, reflecting the increased requirement of this particular species as providing the most suitable material for tool use. Butchery marks on some components further confirm this, as features relate more to tool fabrication rather than marrow extraction or trampling.

Certain bone components have been found to be more suitable than others for tool fabrication, typically tibia, ulna, radius and rib, while other carcass elements such as scapula, humerus, pelvis and femur relate to food use, although equally after consumption they also could become useful for fabrication.

It may even be possible that some bone components located underground may have had some ritualistic significance, comparable to the offerings in historical mining to the "Knockers" or mine spirits. Similarities might also be entertained with a Bronze Age site at Irlingworth, where cattle skulls, mandibles, scapula and pelvises were stacked above a human burial (Parker-Pearson 1993).

DATING METHODS AND SAMPLING

At least ten radiocarbon dates have been obtained from surface and underground workings, spanning a calibrated range of 1880- 600BC, covering the Early to Late Bronze Age period. A grouping around 1300-1400BC is becoming more obvious as additional dates are acquired. Could this reflect an increase in activity during this period or does it simply represent inadequacies in the sampling programme?

Initially many C14 dates were obtained on charcoal, the products of firesetting operations or perhaps the remnant from some form of lighting. The shape of the fragmented charcoal could relate to either case, where the fairly blocky pieces of identified species such as oak, ash, hazel, holly, elm and alder (Dutton *et al* forthcoming) relate to firesetting products, and the rarer elongate fragments (unidentified) situated on rock ledges are more suggestive of a means of lighting.

Some charcoals display evenly spaced growth rings suggestive of coppicing (Jenkins/Lewis 1990), others do not and so could be part of a larger timber section. Therefore depending on where the charcoal originated in the trunk , it could give dates that are not contemporary with the firesetting, instead only the age of that particular part of the tree. This time span could widen if stored timber was utilised, with noticeable increase occurring if the material had been derived from a peat bog, as has been suggested by Briggs (1990) at Copa Hill in mid Wales and at the Great Orme.

A means of overcoming anomalies introduced by sampling is important, and for this reason, when available, bone collagen has been sampled for dating purposes. Fortunately at the Great Orme the neutral-alkaline groundwater conditions have favoured the preservation of bone, although this is not the case at most other early mine sites where any possible bone has long since been destroyed by more acidic groundwaters.

As yet no comparable dates from charcoal and bone from the same context are available. This presents its own problems, for each material may represent a different mining technique (Lewis forthcoming) that in turn relates to the nature of the ore deposit. For example firesetting is likely to have been used on the harder ore bearing rock formations, while bone, by virtue of its comparative weakness, relates to the removal of the softer rotted dolomite host rock. So bone and charcoal do not necessarily occur together in the same context underground, although they do in surface and some underground spoils that are considered to be in a redeposited context.

One possible means to obtain comparative dates is through other dating techniques. A programme following these lines is presently being investigated via uranium series dating (courtesy Liverpool University). Six samples were collected from calcite speleothems at a number of assumed Bronze Age workings down to depths of 50m below surface. Only a single date is presently available around 2600 BP, this is similar to a ^{14}C date of 2940 ± 80BP sampled at a location some 20m away.

Other dating techniques may also prove worthwhile in those situations lacking in suitable material for radiocarbon methods One candidate is palaeomagnetism: already calcite flowstone with appreciable content of iron oxide has been located and awaits sampling. Another possibility may be laser luminescence. Research in this field of dating calcite speleothems has been completed by Shopov et al (1990). As yet though, no direct contacts to research proposals in this area are forthcoming.

SPOIL DEPOSITS AND ASSOCIATED MATERIALS

At least eight varieties of spoil are recognised from the surface and underground of both prehistoric and recent workings (Dutton *et al* forthcoming). These reflect the source rock type and the mining technique employed for its removal. Differences are often subtle and care is needed in distinguishing similar types especially where the context appears the same. The main distinctions are based on degrees of angularity/rounding, sorting and size.

Typically Bronze Age waste-material tends to be fairly evenly sorted having average sizes of 50-125mm. Fragments are sub-angular to rounded in shape, with a matrix of a sandy component derived from the rotted dolomite. Occasionally more angular fragments mixed with charcoal are found; these deposits are considered to be the product of firesetting and occasionally show reddening through oxidation. Complete or spalled stone hammers occur throughout these spoil types, while bone has a tendency to occur to a greater extent in the sandier rounded material than that presumed to be produced by firesetting.

In contrast the 18-19th century spoils have a greater degree of angularity, also reflected in the mined passageways, indicating extraction by blasting and/or pick and chisel work. Sorting is poor with varying size components of dolomite, as well as limestones that indicate non-productive mining through barren rock. Complete or fragmentary iron tools sometimes occur, helping to further distinguish the spoil character. Clayey deposits are found in both ages of spoil; they are the product of rotted mudstones/shales and also superficially derived material from glacial drift.

Spoil deposits can easily be overlooked as an indicator for early mining as they are often conveniently taken to be all of the one type. This is not so, as demonstrated at the Great Orme. There does exist, therefore, the opportunity to investigate these seemingly uninteresting materials, to perhaps record quantitatively, identify and interpret many more varieties. These may not only categorise prehistoric and recently derived material, but also subdivide Bronze Age material on the basis of mining technique as related to the controlling geology, and in turn lead to deducing the relative ages of those locations.

Microscopic examination of spoil may also prove worthwhile for palaeo-environmental material. Samples of a possible soil horizon were submitted for pollen analysis (Sheffield University); unfortunately preservation was not ideal due to the alkaline conditions. Nevertheless at least ten species were identified.

Spoil is also being subjected to other investigative techniques, including detection for metal fragments, of which nearly eighty pieces are known. All of these were obtained from one location about 20m below surface in a narrow working dated to around 1300BC (Lewis 1990). The majority of the fragments are bronze and, on analysis, the metal gave a very similar composition to bronze artefacts discovered last century (Craddock, pers comm.; Budd 1992), which might also suggest a common source. These compositions fall into Northover's M2 MBA group (Tylecote 1986). The remaining fragments were identified as oxidised chalcopyrite.

The bronze pieces vary in size from 3-15mm across, and all have irregular profiles with sharp edges reminiscent of brittle fracturing. No evidence of any slagging residues were observed, although corrosion products are noted on certain fragments. The pieces of metal appear to be evenly distributed through the excavated horizons. Originally they were thought to be part of some damaged tool, though this now seems unlikely, due to their number. As yet sufficient evidence just does not exist to confirm to what extent metal tools may have been employed in the mine. But it seems conceivable that metal tools had increasing use as harder ore bearing formations were encountered, corresponding with increasing depth of working or the need to exploit the sulphide ores that were overlooked during earlier stages of mining.

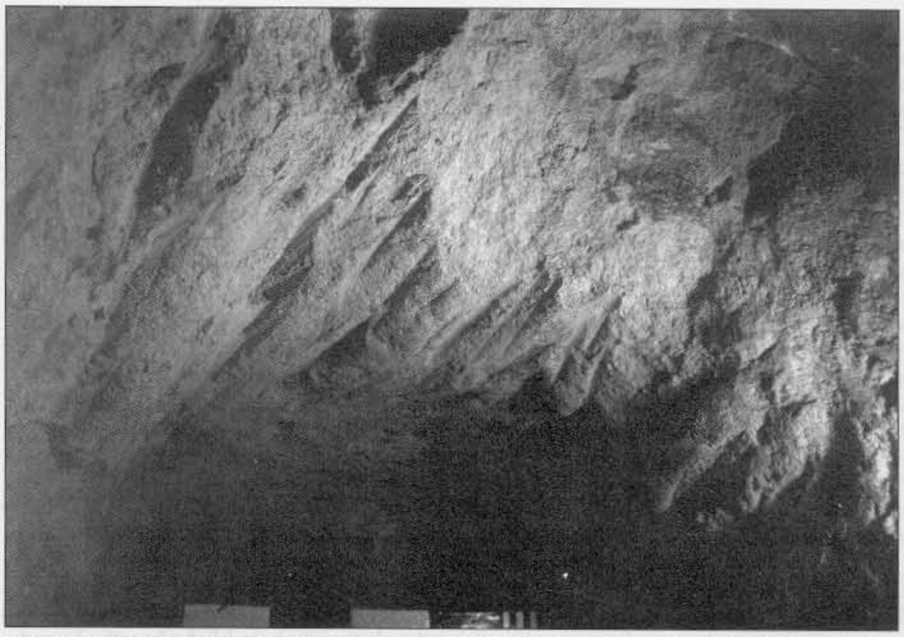

Plate 3. Bone tool-marks preserved in a rotted dolomitic formation, about 7m below surface.

Small mollusc shells are occasionally found in areas of undisturbed spoil, predominantly where entrance passages have collapsed allowing surface derived material to be washed in and accumulate. The morphology of these shells can be a useful indicator of former climatic conditions at the time of the animals death, so helping to provide additional ways of deducing relative ages of material.

SURVEYING AND EXTENT OF THE WORKINGS

The differentiation and positioning of mined areas at the site is very complex:. This is due primarily to the interconnecting nature of the workings that are a product of the multiple veins and lateral ore bodies, and secondly to the superimposition of various ages of activity. Only by understanding these factors can the true extent, size and orientation of the workings be realised. At first this was achieved by the production of basic tape and compass survey plans, often of individual locations unrelated to one another or to any surface features, such as the 19th century shafts.

Although many surveys existed, it was still difficult to appreciate the complexity of the mining and relationships to geological conditions of the mineral deposit. This remained the case until autumn 1992 when CADW commissioned Great Orme Mines Ltd to conduct a comprehensive plan and section survey of all the main routes below surface, including detail on all locations where Bronze Age activity was evident (Lewis 1993a). The completed drawings provided a base outline onto which additional information could be added including detail on mineralisation, rock lithology, location of early artefacts and features, sampling positions and also evidence for recent mining. The drawings might then be used as a predictive tool to locate sealed and backfilled areas of workings, which are common-place in both the Bronze Age and recent passages.

Survey data were converted to a format in x,y and z coordinates for future processing. Eventually these data will be submitted for three dimensional modelling, so allowing a more powerful means of the display, prediction and geological/archaeological interpretation of the various ages of mining activity, from which a chronology of mining development could be deduced. Already a progression of mining activity from surface trenching, to opencast working, to shallow then to deep underground workings is contemplated, with the possibility of also a degree of reworking (Lewis forthcoming). A superimposition of detailed surface surveys would also assist with these interpretations.

Accurate drawings and representations may also be useful for determining the scale of the ore deposits in early times. However, because so little ore remains at the site, any attempt to calculate possible ore reserves to produced metal are difficult and fraught with dangers of over estimation, as has been the case at Mount Gabriel, S.W. Ireland (Jackson 1980, O'Brien 1990).

Some 6km of Bronze Age passages are now recorded within an area of almost 24000 sq m, they vary in width between 300 mm and 3 mand occasionally they are of great size as observed in the large stope just north of Vivians shaft off the tourist route. Considered at first to be 19th century, this chamber proved through excavation and radiocarbon dating to be the result of activity around

1300-1400 BC. In contrast other workings are extremely narrow and could only have been effectively mined by people of small stature or by children. Overall the volume of ore bearing material removed from just the known workings underground must amount to thousands of tonnes. When combined with production from surface trenches and opencast workings apparent tonnages could be doubled. Even if a recovery rate of 0.5% is considered the amount of produced metal could be nearly one hundred tonnes or so (Lewis 1993). Obviously this constitutes a major contribution from the Great Orme to metal production throughout the Bronze Age, and therefore has important implications as a site of technological significance during this period.

ORE PRODUCTION, PROCESSING, SMELTING AND DISTRIBUTION

A few locations for potential mineral processing exist on the Great Orme, and these were referred to last century as Roman ore washing sites. They are reported to have been investigated in the early to mid 19th century, when considerable quantities of copper bearing material were excavated. Contained mineral was of a sufficient concentration to justify their almost complete removal. Only a small amount of the material remains today. Excavation of one site at Ffynnon Galchog, some 0.8km distant, yielded fragments of bone and stone tools similar to those at the mine. Further excavation is planned at this and two other locations where similar deposits are reported. If successful they may then provide some of the first links to understanding the movement of the excavated ore, and its destination through processing, washing and smelting.

To date no evidence for smelting from the early period is known at the mine. The present view is that there is little likelihood of finding any major remains of this process at the site, primarily due to the non-availability of charcoal fuel. Ratios of this fuel to ore are generally assumed to be in the region of 10:1, and might be reasonably even higher depending on the smelting technique. Obviously this means a requirement for large quantities of timber, which is unlikely to have been obtained from the Great Orme, partly because of its limited size, but more so since such timber would have also been sought for domestic and possible firesetting uses (Lewis 1993). Economically, therefore, taking the ore to the fuel source would be a more viable proposition than transporting quantities of timber or charcoal up the steep slopes that surround the headland. Recent studies (Bannerman and Chapman pers com) propose a number of possible sites in the local region where ore could be taken by boat to locations having suitable access to timber for charcoal and water for ore washing.

In addition to what already has been commented on above, unique opportunity exists for examination of the socio-economic aspects of a Bronze Age presence here and in the surrounding region. A remarkable number of field monuments and artefacts from the prehistoric period are known from the local area. Unfortunately few of these have been investigated, but those that have been (Bibby 1979) indicate an occupation during the Bronze Age within a kilometre or so of the mine.

CONCLUSIONS

Bronze Age mining at the Great Orme is now firmly established. This has been achieved through a number of investigative techniques, often involving a development of established methods and extending them to encompass changing fields of research. Gradually these lines of study have been built on to give a more realistic picture of the real scale and understanding of mining at the site. What is needed now is to apply all the present knowledge and reasoning to the questions of mineral distribution, processing and smelting. In addition to this, studies outside the normal association of mining are required, ideally through limited excavation of particular occupational sites assumed to be of Bronze Age origin.

There now exists an opportunity to develop fields of interest to encompass those detailed above. By doing this it will possible to consider the Great Orme on a holistic level within the realms of landscape archaeology rather than a collection of individual unrelated components.

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