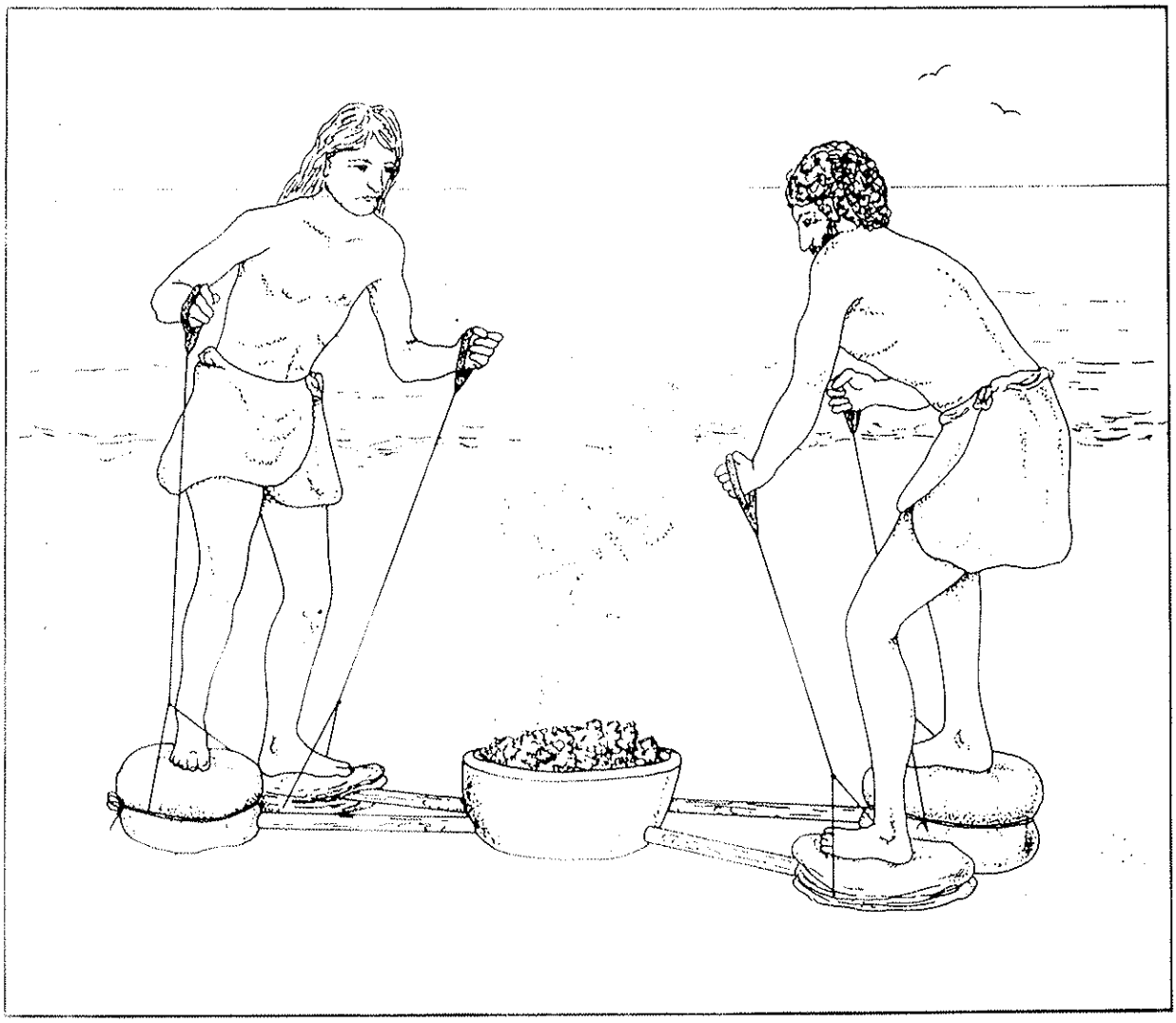
JOURNAL OF THE GREAT ORME EXPLORATION SOCIETY



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Front Cover: An impression of an early copper smelting furnace, circa 3000 BC, by Alison Walton (adapted from Man and Machines, in Joy of Knowledge by Mitchell Beasley)

EDITORIAL

HAS THE SMELTING DEBATE BEEN BEACHED?

Members who have followed the Bronze Age smelting debate over the years will be aware that because no smelting slag had been found on or around the Great Orme it had been proposed that a non-slagging process, involving carbonate ores exclusively, had been used to reduce the ore to metal. This may indeed be the case, however, in recent months substantial quantities of copper slag have come to light and aroused considerable interest at the British Museum, Plas Tan y Bwlch, UCNW and Liverpool University.

At the Council for Independent Archaeology meeting held in Llandudno in May this year the smelting issue was debated; were only carbonate ores smelted, where are the smelting site(s) and from where did the fuel come? Nigel Bannerman's smelting-site hypothesis was discussed with interest and accompanied by an abstract included in the supplement of the Journal we had prepared for the meeting. Since then, Nigel has refined his hypothesis which has been strengthened by the finding of abundant copper smelting slag on many beaches where, to our knowledge, there has been no smelting at least since the revival of British mining in Elizabethan times, i.e. 1560s onwards.

The absence of historical data does not prove an ancient origin for these smelting slags. Ships returning to Llandudno, Dulas, Moelfre and Llanddulas from Swansea, Runcorn, Amlwch or elsewhere during the 18th and 19th centuries may have sailed in ballast and then discharged it prior to loading. Discharge outside the harbour or beaching area is one thing but, because of the risk of hull damage, discharge within these confines would not be a very seaman-like practice. Nevertheless, might this have happened at Llandudno? Until similar slag is found ashore, and in quantity, ballast must remain on the list of suspects.

During the 19th century, flats and ships about to load slate at Port Penrhyn discharged ballast outside the harbour onto the Bangor sands, where they have formed a bank recorded by the Admiralty in their sailing directions[1]. What they discharged is as yet unknown but is clearly highly relevant to the research project. In contrast, one of the first specimens of slag was found at Port Penrhyn in the foundations of a quay laid down in 1790: this deposit must therefore be at least this old.

In the frothy slag, found on the upper surface, can be found remnants of unburnt fuel which in one section appears to be coke. Whether the fuel was coke or coal which became coked during the smelt is not known, but this finding does suggest a modern origin. The size of the slags is thought to be too big for an ancient origin and the appearances suggest blast furnace technology. At present they are impossible to date and may have been smelted at any date from medieval times onwards. Another opinion recognises the presence of free silica within the slag. Since this characteristic may be found in slags from antiquity onwards the potential age range is large.

The project is still in its early stages. The fact that slag has been recorded in so many places is new, indisputable and exciting but we must wait for a consensus on the age of the material found so far. The paper was conceived and written as a discussion document and in that respect it has been highly successful. It has been well received by leading national and international authorities in the field who have recommended further work in this area, particularly in surveying beaches. Since all beaches change with each tide, subtly in good weather and dramatically in bad, it will be essential to re-examine beaches to plot the distribution, as sand and gravel shift, in order to estimate the tonnage of the slag deposits. Nigel would be very grateful for any assistance that members can give; you need not be one of the Society gladiators or extraordinarily fit, any or all would be most welcome.

Don Smith, October 1992

1 West Coast of England Pilot. Hydrographic Office, 6th Edition 1910 p 357

The Editor will welcome correspondence on this or other matters for publication in the next issue of the Journal of the Great Orme Exploration Society.

NEWS ROUNDUP

HUW TUDNO WILLIAMS: Huw Tudno, as he was known to so many, died aged 64 on August 21st, 1992. Born of an old, established Llandudno family, he was a keen sportsman who, as a boy, developed a lasting interest in all aspects of the Great Orme and the history of Llandudno. At first this interest, being practical and investigative, got him into trouble at home on several occasions, but over the course of many years the depth and breadth of his knowledge grew and was respected by all who knew him. He wrote many articles on the Great Orme mines, contributed to, advised on, and assisted with others and wrote a thesis (unpublished) on the history of the Mostyn family. He was a strong advocate when defence of things worthy and historical was necessary, was a founder member of the Llandudno Historical Society, the Great Orme Exploration Society and its predecessor, the Great Orme Cave and Mine Exploration Society. He will be sadly missed.

THE CONSTITUTION: The working party have completed their task, having allowed it to mature in the drawer during the summer before submitting it to the final review, fresh. The suggestions made by the Society at the EGM have been acted upon and I believe this constitution, if voted in, will assist us to apply for trust or charitable status in the future, if such an option becomes appropriate. It was proposed at the EGM, and agreed by the members present, we would have a postal vote to accept or reject the constitution. **A VOTING SLIP HAS BEEN CIRCULATED WHICH I URGE YOU TO COMPLETE, SIGN AND RETURN TO THE SECRETARY BEFORE DECEMBER 31ST, 1992.**

NAMHO: Earlier this year, eight members of the Society attended the NAMHO

Field-meeting held at Telford; the weather held and a grand time was had by all. Tony attended the underground video-recording sessions, while Frank, Steve and Don attended the survey course at Clive copper mine. Back at base, Jeannie, Ros, Ian and Erik practised SRT on the climbing wall, following which, Ian and Erik went on one of the underground trips. They shot through the trip in very short order, they say, because it was easy but perhaps the pubs were open!

In April 1993, the NAMHO meeting will be held in the Isle of Man. Tony has the booking form if you want to book at' place. Having spent two months in Douglas in the summer of 1987 I can recommend the beer, if nothing else. There is a wealth of mining remains above ground, such as engine houses, waterwheel casings, Lady Isabella and much more, all of which would be of interest. With our interest in Bronze Age mining a trip to Bradda Head would be a must and, I think, a trip to an iron mine south of Ramsey (Kirk Maughold). The exact itinerary has not been published yet.

When asked if we would like to present data at the meeting I offered a choice of four subjects, Bronze Age smelting sites in North Wales, the Tom and Jerry water-engine, the Ty Gwyn beach adit dig and a biography of Captain William Vivian. The organisers have chosen the Tom and Jerry water-engine which will appropriate as the Wanlochead Museum Trust are presenting data regarding their water engines. There will also be a strong Llandudno flavour to the meeting as Chris Williams, author of 'The Llandudno Copper Mines' due to be re-published in 1993, will be presenting data on mining at Llandudno from 1692 to 1881. Registration will be on Friday, April 23rd at the Groudel(?) Hotel and the lectures will be in the Manx Museum Saturday and Sunday. Field trips of various types, from surface walkabouts to serious grovelling, will be laid on at the Laxey Mine and information sheets, with map references, will be available for independent field trips.

CIA: A quotation from the current CIA Newsletter shows our efforts were appreciated: "... Tom Parry then outlined the activities of the Great Orme Exploration Society which was formed in 1985 by local cavers, geologists, archaeologists and historians, mainly to investigate the mines, but also other aspects of the area. The society had produced for us a special supplement to their newsletter to welcome us to Llandudno, reprinting 6 articles which proved an invaluable guide to our visit and demonstrated just what an active local society can do..." Well done (Ed). In Current Archaeology, a good account was given of the development of the Bronze Age mine centre.

PENMORFA: During the summer, the mountings of the Penmorfa adit gate were destroyed by person or persons unknown, making repair impracticable. A new, substantial, gate has been fabricated by Tony and fastened to a disproportionately substantial anchor post. The padlock has been secured inside the gate and is accessible by finger-tip, but only if you are long of limb. As a 'height-challenged' individual I feel discriminated against, however, if a gynaecologist can paint his hall through the letterbox I am sure I can use a similar technique to unlock this chastity belt for a Society expedition.

GAT: The Gwynedd Archaeological Trust held a meeting in Bangor recently at which the Society was well represented. Their annual review reported their activities on the Great Orme this year on the engine house. The dig, not yet complete, has been abandoned for the winter and will be resumed next season.

PEN Y BRYN: Having heard Kathy Gibbons at the CIA meeting the Society visited Pen y Bryn during the summer. They were shown around and thoroughly enjoyed the trip, particularly the prospect of re-opening a long abandoned underground passage. Dowsing techniques were brought into use and when the site was re-visited in mid-October members went well armed. Perhaps I should say that during the summer evenings Ramon had introduced members of the Society to dowsing, so much so that scarcely a coat hanger can be found in the wardrobe nor a welding rod had for love nor money.

This site has recently been under threat of repossession but I am glad to say the family Gibbons have had a stay of execution, which may allow appropriate excavation and study of the site in the future, if sponsorship or purchase can be arranged.

NEW BOOKS: The Trevithick Society, as part of their Levant appeal, have published a book on the Levant Mine, 'Levant - A Champion Cornish Mine' by John Corin. It is available at £4.50 plus 50p p&p from their publications secretary Eric Edmunds, Newlands, Tarrandean Lane, Perranwell Station, Truro, Cornwall. TR3 7NW. Dr Roger Burt, Peter Waite and Ray Burnley have produced another book in their Mineral Statistic series entitled 'The Mines of Cardiganshire', ISBN 0 9507624 5 8. It covers mineral output between 1845 and 1913, and is published by the Department of Economic History at Exeter University in association with the Northern Mines Research Society, ISBN 0 9507624 5 8.

TY GWYN BEACH ADIT: Having started the excavation during the summer work has continued on alternate Sunday mornings, regardless of tide which has never quite lapped into the adit while we have been there. The adit is driven through a fissure inclined to the right a few degrees off the vertical. At the entrance over a dozen stemple holes can be seen in the (left) hanging wall, no doubt providing overhead cover from loose fractured limestone which since has been washed away by the sea. At the entrance there are also some larger holes which may have been part of a sea defence system.

Work began at the entrance clearing all the debris which had fallen in, been washed in by the sea and what had been thrown out by previous groups. From the entrance we have followed the 19th century floor as much as possible though we do have a slight uphill gradient to provide a run off when required. We are at present working on a six foot face of sand and gravel capped with glutinous clay and large rocks which the clay is reluctant to release from its grasp. Hard work indeed but a goal is in sight and we hope to have reached 'the heap' by the end of this year. Once through the heap we will have a good run off for using a fire hose on the clay further on. Encouraging news comes from Ramon who suggests the adit penetrates further than the clay fall; we shall have to wait and see.

BLACK DAMP: In an editorial a few years ago, Dave Smith featured radon as a respirable hazard from underground. Another rather unusual hazard from underground was described recently in the British Medical Journal, namely black damp, seeping through the foundations of a new house causing adverse, but not fatal, effects on the occupants. The house (in fact several estates on Tyneside) was built over a colliery abandoned in the early 1940s. In the meantime black damp had been accumulating due to the decomposition of pitprops, and other organic matter, producing excess carbon dioxide and depleting the oxygen concentration.

The rock overlying the worked-out coal measures was fissured sandstone through which the gas could filter under the appropriate conditions, both of which were fulfilled. First, a deep low-pressure weather system reduced the pressure in the mine and allowed the gas to expand and force its way upward and second, the surface layer of clay, already thin in places, was breached during the digging of the foundations allowing the gas into the house. Compared to fresh air this gas contained 8-9% O_2 (N = 21%) and 7% CO_2 (N = 0.03%) which caused dizziness, nausea and headaches in this case.

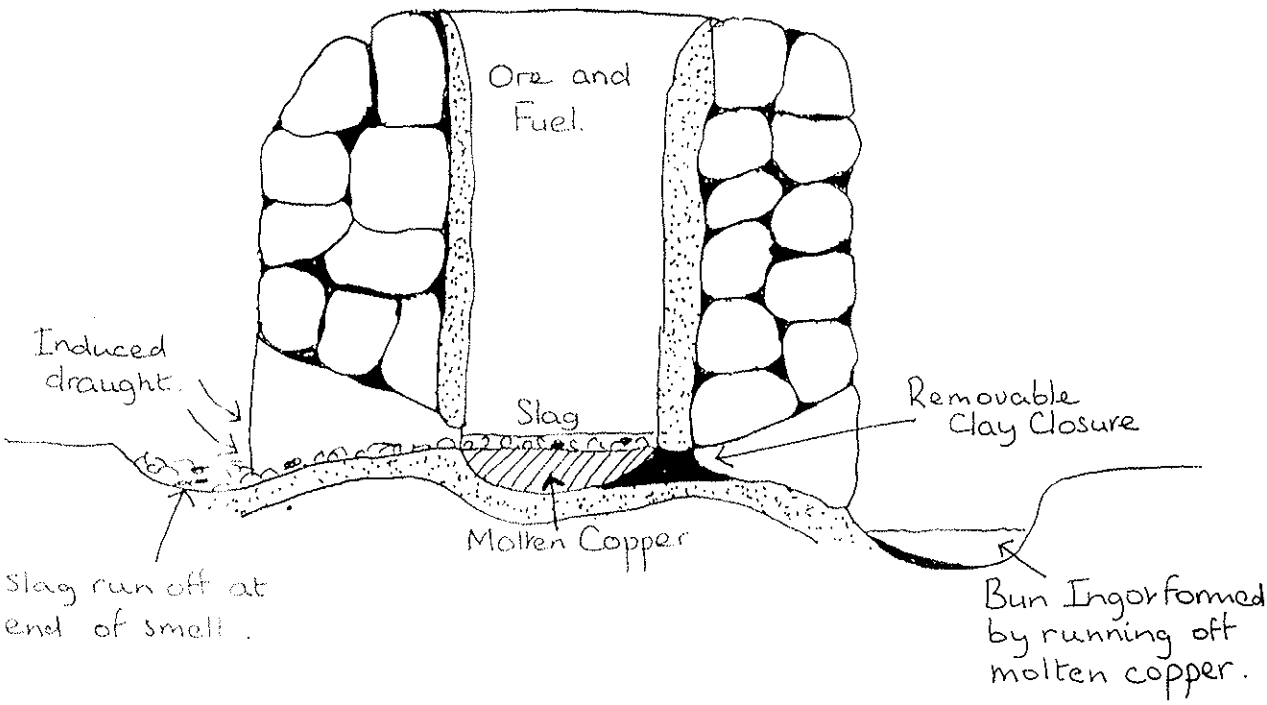
Although we don't have abandoned coal mines to worry about, we should be aware of bad air within the mines we frequent which would accumulate in exactly the same way. It would be expected that it would accumulate in sumps since CO_2 is heavy, but don't count on it. And don't count on getting adequate warning symptoms such as breathlessness, headaches, dizziness and nausea, the first and only effect might be lapse into unconsciousness!

PEN Y DINAS: This well known hill fort or refuge is thought, by some authorities, to date from the Iron Age, and by others, to date from the Roman occupation as a Romano-British settlement. Since the site has never been studied we don't know for sure. However, thanks to initiatives by Tom Parry, its origins and use may soon be brought to light. Funding has been found to survey the site as a preliminary step before clearing the overgrowth and starting a community archaeology project under the guidance of GAT and CADW. This is clearly related to our work in the mines and investigating smelting sites; I hope members of the Society will wish to contribute to this project.

CHRISTMAS DINNER: The 1992 Christmas Dinner was held at the King's Head on Friday 27th November, at which 35 members of the Society attended. Prior to grace, said by Ramon, the assembled dinners paused for a few moments silence to remember absent friends, Huw Tudno Williams, Kristian and Justin Mills, who died recently. The fare was good, the wine plentiful and the company good. Following the meal, Tom Stone gave an illustrated lecture on Indian Cave Temples he had visited while serving in the Indian Army in 1945 which was enjoyed by all.

FIELD TRIP: I am hoping to be able to arrange a field trip to visit the Wet Earth Colliery Group at Clifton, North Manchester, during December. I think this would be of interest to the Society and highly relevant to our dig in the Beach adit as they regularly use firehoses to do the job.

CALL TO AUTHORS: I shall be looking for contributions for issues of the Journal next year, original practical or archive research, accounts of club activities, reviews, artwork, photographs and letters to the editor. Work is taking me away to Plymouth in January 1993 for a couple of years but I shall be in contact and will visit regularly. Until I have a forwarding address, please deposit your submissions with Tony Davies.



A Roman bun-ingot furnace by Eve Parry
(adapted from, Mining and Metallurgy in the Greek & Roman World, JF Healy)

BRONZE AGE SMELTING IN NORTH WALES

A discussion paper examining possible Bronze Age copper smelting sites

FOREWORD

As early as 1849 evidence of pre-Roman mining on the Great Orme was recognised[1&2] and in the Archaeological Journal[3] of 1850 W.O. Stanley FSA MP made quite decisive comments linking stone and bone tools to pre-Roman times.

In 1986 a paper presented by Duncan James[4] to the Ancient Mining and Metallurgy Conference at Bangor proved a most significant development in the study of Bronze Age Mining on the Great Orme. Radiocarbon dating proved conclusively that Bronze Age mining had taken place. The findings gave impetus to much exploration and research. The Great Orme Exploration Society were, and still are, deeply involved in this work.

Further radiocarbon dates have by now been obtained which strengthen the evidence of Bronze Age mining. A commercial venture, Great Orme Mines Ltd., has opened a few of the workings to the public.

It is hoped that this paper will be instrumental in the search for Bronze Age smelting sites used to process copper ore from the Great Orme. The search impinges upon many disciplines, and seeks advice and information from many sources and from such diverse authorities as master mariners and veterinary surgeons. For this reason it is felt that basic explanations of mining techniques and other processes may prove helpful.

INTRODUCTION

Late in 1990 I realised that current thinking on the location of Bronze Age smelting sites, for Great Orme ore, was at variance with my own views. My experience and knowledge of the lead mining and smelting industry, gained working in and around the Derbyshire mines, and my active membership of the Peak District Mines Historical Society, and the Eldon Potholing Club led me to consider the following fact:-.

> In Derbyshire, the demand made on local timber supplies by smelting processes denuded the Peak District of trees. By 1650 lead ore was being transported many miles over the difficult terrain of the Pennines to be smelted near fuel supplies.

I felt that an analogous situation could have arisen on the Great Orme during the Bronze Age. Four main questions presented themselves. Arriving at the answers to them could suggest a reasonable research exercise, aimed at locating the sites of Bronze Age smelters.

1. Quantity of Extracted Ore:

If the quantity of ore mined on the Great Orme over the period indicated by radiocarbon dating could be estimated and reduced to an average weekly amount it would facilitate an understanding of the scale of the industry.

2. Fuel:

If the amount of fuel, i.e. charcoal, required to process this amount of ore was also expressed as a weekly average, it would be possible to envisage the area and type of woodland required for its production.

3. Conditions:

What conditions were necessary to establish smelting sites?

4. Transport:

What methods were available to transport fuel and ore?

In addressing these questions it was necessary to avoid the temptation of exploring the many fascinating avenues suggested by them. It was imperative to concentrate on an attempt to perceive the industrial and social framework into which the mines of the Great Orme fitted.

The question of manpower in its various aspects, and the different specialist skills required, was addressed. In this way it was hoped to produce a theoretical model of the Bronze Age Society involved in the process of extracting ore and producing finished metal. It was to be centred on ore production from the area of the Great Orme close to Vivian's Shaft, bounded to the north by Bryniau Poethion and to the south by Maes y Facrell and Pyllau.

It is recognised that there are in North Wales many other sites which might have been mined during the Bronze Age. The activities, quantities and aspects discussed here in reference to the Great Orme could well have been applicable to other sites. Smelters might well have processed ore from many different mining areas such as Parys Mountain and Snowdonia.

ORE PRODUCTION

Much physical and academic effort has been expended on the area around Vivian's shaft. However, as a volumetric survey of the workings had not been conducted it was difficult to estimate the amount of ore extracted during the Bronze Age.

Such a survey would have been useful, but of necessity, would have been of questionable accuracy as in some places 19th century miners, using explosives and steel tools, cut through and destroyed old Bronze Age workings. However, in many areas Bronze Age workings have been preserved by backfilling during this later, modern, mining.

As no unworked ore bodies have survived it was impossible to calculate the ratio of copper ore to 'gangue' or unwanted minerals. Bronze Age workings are still being discovered and it will be some time before it can be confidently claimed that all the Bronze Age workings are known.

Despite these problems it was possible to make a conservative estimate of the ore extracted from the Bronze Age workings. After discussions with members of the Great Orme Exploration Society, and the staff of Great Orme Mines Ltd. a figure of 50,000 tonnes was considered feasible. Calculated over a 1,500 year period this represents 0.5 tonnes per week.

Initial mining operations would probably have extracted ore outcropping on the surface. This opencast mining would have been relatively easy compared to the difficulties and dangers inherent in pursuing the mineral veins as they dipped deeper underground. Virgin unbroken mineral deposits are not easily worked. Malachite [$Cu_2(CO_3)(OH)_2$] has a hardness of 3.5 to 4 on the Moh's scale, as does dolomite [$CaMg(CO_3)_2$] and chalcopyrite [$CuFeS_2$]. These substances can only just be scratched with a brass pin.

Firesetting is a tried and tested mining practice and certainly appears to have been used extensively during the Bronze Age. It also provided charcoal samples from which radiocarbon dates were obtained (bone collagen provided further radiocarbon dates). Many examples of ore extraction from very narrow fissures are evident, fissures too small for even a child to gain access. Perhaps they were worked with 'maul stones' lashed onto long sticks. Whatever the method, these worked out fissures bear witness to the determination of the early miners to extract every particle of ore.

Conveying the ore to the surface would have been a task as arduous and difficult as mining. The workings wind tortuously, 'dog legging' both vertically and horizontally every few feet. Water, mud, fumes from firesetting, and the subterranean darkness would all have combined to create a difficult and dangerous working environment.

Possibly some of the initial sorting of ore was carried out underground, but the absence of light and the importance of winning even the smallest amounts of vein material, would have made it more practical to carry the work out on the surface. This was the case at Amlwch[6], Llandudno[7], and other metalliferous mines during the 19th century. 'Copa Ledis', and boys using spalling hammers, buckers, (flat hammers) and knock stones were employed to break up and sort the ore.

After the breaking up and sorting of ore, 'buddling' took place. This process of washing the ore, as described by Agricola[8] in 1556, not only washes out clay, but can in some instances, facilitate the separation of substances of differing specific gravities. Dolomite at 2.8-2.9, malachite at 3.7-4.0, chalcopyrite at 4.1-4.3. The process can be compared with 'panning' for gold or the 'streaming' process employed by the Cornish tin miners referred to by Diodorus Siculus[9] in the first century BC. The buddling process requires copious amounts of clean fresh water

and leaves a residue of, 'tailings', clay, and 'gangue' minerals.

The operation might have been carried out at the smelting site. Members of the Great Orme Exploration Society have, in recent years, spent much time engaged in digging and clearing old passages and workings, and hauling equipment through them. After extensive discussions, and drawing on my own experience of the commercial working of small mineral veins by independent miners, it was felt that the extraction of 0.5 tonnes of ore per week, would require the full time efforts of between six and ten men.

FUEL PRODUCTION

Consideration was given to the specialised knowledge required to produce charcoal. By-products of the process, wood pitch and pyroligneous acids formed mankind's earliest chemical industry. The high temperatures attained over various sands and earths could well have pioneered the production of glass and the art of enamelling.

Figures for copper smelting in Amlwch using coal quote a ratio of three to one fuel to ore. The use of coal would be more efficient than the use of charcoal and the ratio of charcoal to ore considerable higher. Exactly how much higher is still being researched but 10 to 1 including fuel for firesetting would not seem untoward. That sufficient fuel would have been available in quantities consistent with the apparent volume of excavated ore on the Great Orme seems highly improbable. The area would have been denuded of trees in a short space of time.

This point, above all others, gave rise to the original premise that ore was taken elsewhere for smelting. The production of 5 tonnes of charcoal per week would require some 30 tonnes of wood. With early methods of production the volume of wood cut from the tree would be reduced by 25% but the weight reduction was in the region of 85%, hence 30 tonnes of wood becomes 5 tonnes of charcoal.

This quantity of wood and the small diameter of the annual growth rings in recovered charcoal samples, suggests the existence of well husbanded coppices of oak and alder.

Wood needs to be prepared well in advance to allow it to dry properly and needs to be cut into relatively short lengths of small diameter. This, even with modern tempered steel saws would be hard work, but with perhaps only stone axes it would mean a huge amount of effort. It is possible that a method known as 'ringing' was used to ease wood collection. When saplings have reached a diameter of 90 to 150 mm (3.5-6.0") the bark is removed to a height of 500 mm (20.0"), the tree then dies and within a year or so will become easier to break than green wood.

The site of the kiln must be carefully chosen, i.e. well drained, but not too dry, and after digging a pit the stacking of wood can commence. The actual amount of wood and size of pit varies in the parts of the world where this method is still

used, but a maximum of a ton of wood should be considered for a woodland 'Pitstead'. Proper arrangement and selection of the wood is needed to ensure an efficient burn, which is initiated after covering the wood over with bracken or straw, and earth.

The burn time varies but it is vital that the kiln is watched day and night during this process as a break in the earth cover would let in excess air and quickly reduce the results of several weeks labour to ashes rather than charcoal.

Part of the charcoal burner's skill is knowing when all the wood has been converted into charcoal. This can be judged from, among other things, the colour of the smoke. The fire is then extinguished and the kiln allowed to cool.

As the kiln described here would only produce around 0.3 tonnes and the whole process could take some two man-weeks. Five tonnes per week would require a workforce of 30 men employed full time on charcoal production alone.

The activities described here to provide fuel must have taken place somewhere other than the Great Orme. It is just not big enough for the necessary woodlands needed to sustain this industry. Moving 0.5 tonne of ore to 5 tonnes of fuel also makes sense.

TRANSPORT

As yet,little is known of Bronze Age roads in North Wales, or the draught animals of that time. As 0.25 tonne can be transported in a very small boat with ease and safety I determined to examine local natural inlets which could have provided a suitable smelting site and landing place. Winds, currents and runs of tide have to be taken into account as does the possibility that the Bronze Age coastline could have been different from today's as a result of different sea levels, earth movements and erosion or deposition. However due to the steep littoral gradients of the area a five metre higher or lower sea level would not have a significant effect on the coastline. At the higher level the Great Orme would have been a tidal island, and the Mochdre valley inundated, forming what could be known as Ynys Creuddyn. The Conwy valley would also be flooded as would the lower part of the Vale of Clwyd. At the lower level the Great Orme isthmus would have been wider and parts of Traeth Lavan dry land as well as the Red Wharf Bay area.

The actual type of boat that could have been used to carry ore could be discussed and debated upon endlessly, but for the present the Irish curragh, which could carry three tonnes load and a craft similar to a 6 metre Canadian canoe with a 0.25 tonne load capability were considered. The boat design question could for the moment be left at that point. Both these vessels can be propelled with oars, paddles or sails. It would seem at the outset that such relatively frail vessels as these would be easily damaged landing on beaches, however there is a common practice among boatman the world over to appoint 'Beach Masters' or 'Beach Bosuns' to guard against this[10]. The main duty was to ensure that the landing beaches were kept clear of stones, large pebbles, driftwood or any object that

could damage boats coming onto the shore. Another method of dealing with a rough beach is to hold the boat in waist deep water as close to the shore as possible, while the cargo is carried to dry land. After the vessel has been emptied it too can be brought ashore in a similar manner if necessary.

Any sailor or boatman soon learns the basic laws of stability science. Failure to do so being attended by possibly fatal results. The relevance of stability is seen in figures 1 & 2. In fig. 1 a cross section of a boat loaded with ore is shown. Copper ore being dense forms a small heap in the bottom of the boat, with the vessel's centre of gravity in this case being below the water line making for a very stable situation. Fig. 2 is a cross-section of the same vessel with the same weight of charcoal which has a greater volume to weight ratio with the resulting centre of gravity being dangerously high, and liable to capsize at any time.

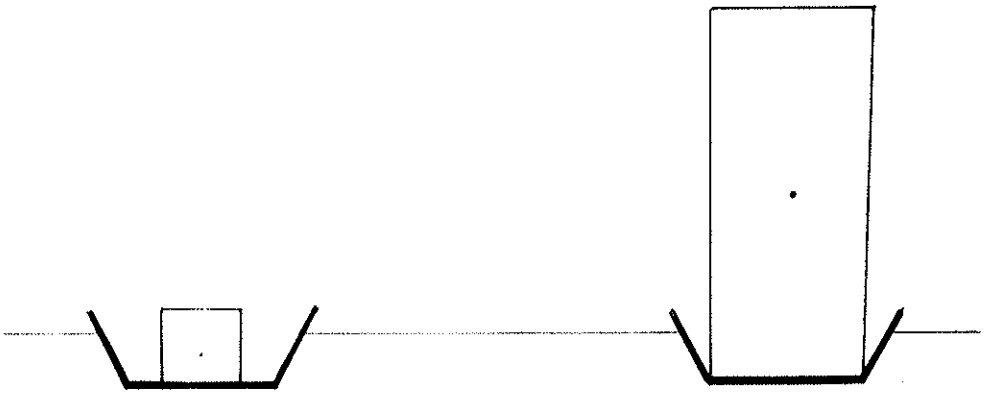


Fig 1
Cargo: Cu ore

Fig 2
Cargo: Charcoal

The cargoes have equal mass, though different density (1:10), and displacement is identical. Fig 2 has a high centre of buoyancy (dot) and is therefore unstable.

This, however, is not to say that charcoal was not carried in boats but that moving large quantities would present problems. It would of course make sense to take some charcoal as a return cargo as it would be needed in the mines for firesetting and for cooking etc.

It should be kept in mind that in the figures the same weights of ore and charcoal are represented, and that for smelting purposes ten times the weight of charcoal would be needed.

SMELTING SITES

At the start of the search for a smelting site, Aber Cegin with its good natural harbour suggested a very suitable site for investigation. This proved to be so, as

large quantities of what could be ancient slags have since been found in this area.

The ease of ore transport compared to that of charcoal, points to the possibility that smelting, or at least the initial stages of the process would have taken place wherever there were, and in many cases still are, suitable conditions.

These would be:-

i) Suitable landing place.
ii) Fresh water for washing ore.
iii) Fuel supplies.
iv) A clean area for smelting.
v) Good natural draught to assist combustion.

The sulphurous ores of Parys Mountain were burnt on the beach at Amlwch in the 19th century, taking advantage of the clean shingle as a base upon which to burn ore, and the katabatic breezes and winds invariably present on beaches. Half a tonne of chalcopyrite ore could be expected to produce from 50 to 100 Kg (i.e. 10-20%) of copper metal.

CASTING

The possibility must be considered that initial roasting and smelting of ore took place at scattered convenient sites. As the resulting material became more refined and of greater value it was transported to a central site or sites.

Discussions took place with David Chapman RCA, a casting expert in which the number of people required to convert 50-100 Kg of metal per week into axes, spearheads, etc. was considered. Although the average weight for axes and spearheads was not confirmed it was felt that 0.5-1.0 Kg would be a reasonable estimate.

This would require the use of somewhere in the region of 100 clay and sand moulds per week, or the same amount of reusable stone moulds. Stone moulds would require regular replacement and would be far more difficult to construct.

Completely dry conditions are required for casting, unless these could be guaranteed the operation would have to be carried out under cover. A drop of rain on a hot mould could cause violent shattering to occur.

The use of an open sided shed with moveable hide or wattle walls to protect the casting floor was considered. It was estimated that the preparation of moulds and crucibles, casting and cleaning off of the finished products would provide continuous employment for ten people.

The smelting of copper produces poisonous fumes, and for this reason it is reasonable to assume that smelting took place some distance from dwellings. This was certainly the case with lead smelting during the mid-seventeenth century.

In fact land which had been poisoned with lead compounds from smelting processes and mining was known as 'Belland Land' and cattle were kept off such areas. Medical and veterinary science, very properly, requires long and well documented studies before making statements on such matters. Laymen, especially those on the receiving end of deadly pollution without understanding the processes involved often gain an understanding of the effects and take precautions. This is basically what happened in the first two centuries of lead smelting. With the scale of copper processing indicated in North Wales during the Bronze Age it would be reasonable to assume that the same conclusions were reached. In the 19th century air pollution caused many disputes in the Parys Mountain area[6].

The end result of all this labour was a considerable amount of what must have been a very much sort after metal to be traded with areas many miles distant. Two more specialists were therefore required, organizers, and, human nature being what it is, security men.

This then is the view of the metal industry of Bronze Age North Wales proposed here. Copper ore mined at the Great Orme and at Parys Mountain and possibly other places, moved by land and sea to suitable sites for smelting and brought together at one or two main sites such as Aber Cegin for finishing, amalgamating, and safe keeping before being traded. This commerce being supported by charcoal burners, farmers, fishermen, etc. to supply the daily needs of all concerned in it.

CONCLUSION

To mine and process 0.5 tonnes of copper ore per week from the area near Vivian's Shaft on Bryniau Poethion would require the following manpower:-

Ore Production	7
Transport	2
Charcoal production	30
Smelting and casting	10
	49

It has been noted that copper ore was mined at other sites on the Great Orme and in other parts of Wales, though no evidence of on-site smelting has been uncovered and this is also the case with the Bronze Age copper mines in Ireland. This is most significant as from the estimated Great Orme production alone slag amounting to tens of thousands of tonnes should have been produced.

Preliminary investigations have resulted in the discovery of slag at Aber Cegin and Moelfre. The recovered samples are mainly dark brown to black with bright green and gold patches and white inclusions. The specimens are heavy and give off a green flame when heated sufficiently.

One sample sent for analysis using the EDAX FL X Ray facility proved to be mainly

iron (90%) with an amount of silicon and traces of calcium, potassium, manganese, copper and magnesium. The conclusions reached stated, "The sample appears to be slag from the separation of iron and copper and suggests the ore was chalcopyrite."

This particular sample came from an area which had been covered with stone pitching in 1790 and exposed in 1991 during renovations to the dock basin at Port Penrhyn.

The aim of this paper is to encourage debate and point out a possible avenue of research into not only the Bronze Age mining and metal industry, but also the society which supported it.

Some sites mentioned are of course on private land and permission to visit should always be obtained. The Aber Cegin/Port Penrhyn area is a working port and visits should be arranged through the author (27 Abbey Road, Llandudno. Tel. 0492 879416).

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N.V.C. Bannerman, September 1992

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ADDENDUM

In the relatively short time since this paper was released there have been many developments and favourable reactions, which has been very heartening and even exciting at time. This discussion paper has already fulfilled some of its purpose, in that it has started people talking about, and looking for, possible smelting sites with the result that copper slag has been found in no less than seven locations. No date has yet been ascribed to any of the deposits nor would I make any claims at this time. Two points are, however, very clear. First, these deposits were pinpointed as a result of deductions made in the paper. Secondly, and more importantly, the discovery of what must be several hundreds of tons of copper slag, in plain view, on a public beach, within half a mile of the most important prehistoric copper mine in these islands shows that the search for smelting sites prior to this paper could perhaps have been more thorough. The internationally held opinion that there was no smelting of chalcopyrite ores in the Bronze Age, based on the absence of primary slag, may, therefore, need to be reviewed.

Another popular view that must be questioned is that the Great Orme ore bodies were composed of carbonate ores even though chalcopyrite can be found at the surface and 19th century records speak of it being mined in some quantity. Perhaps a truer picture would be that mainly carbonate ores were found at the surface and with increasing depth they changed to chalcopyrite in an irregular pattern due to surface water finding its way through fissures etc. in the ore bodies and mother rock. Due to the fact that in the Great Orme workings no unworked veins have as yet been found the actual composition of them can be but speculation, or, at best, an informed guess.

There is one problem with the paper, a few who have read it have taken it as a definitive work; it is not, and was never intended as such. It is a discussion paper that asks a number of questions and makes some deductions with the aim of encouraging debate and research.

Nigel Bannerman, 12th November 1993

If you have any comment, criticism or praise, if you think this good work, iconoclastic or incorrect I want to hear from you, Society members, archaeologists and anyone with an interest in this subject. This paper was intended as a discussion document and I hope to published your letters in the next issue of the Journal followed by the author's reply where appropriate. Editor.

COPPER CULTURES IN NORTH AMERICA

The Bronze Age in Europe was associated with mining of copper ores, their cleaning and concentration, smelting, casting and, in the transition from its early Chalcolithic period into the middle Bronze Age, alloying with tin to form bronze, and other bronzes based on allowing with eg. arsenic. In a similar period in the Lake Superior basin of North America another copper culture, the 'Old Copper Culture[1]' (3000 to 1500 BC), was well developed.

In contrast to our experience on the Great Orme this culture was based on native copper rather than carbonates and pyrites of copper. In the Keweenaw Peninsula, on Isle Royale (Michigan) and Brule River (Wisconsin), large surface and superficial deposits of native copper were found and mined in pits by the native population using wood and stone tools. In addition, there were deposits of 'float copper', copper left as a glacial moraine, which is often green when found due to oxidation. Although native copper has been described in the Great Orme[2], it was only as a curiosity in a zone of secondary enrichment and it seems never to have been present in quantities of economic value in history or pre-history.

Not only does the winning of the copper contrast with European experience so does the processing. Although skilful in processing the copper and in producing finished goods, the native artisans appear to have used annealing and cold-hammering alone and did not smelt or alloy. The range of goods produced included spear/arrow points, semilunar blades, awls, knives and axes as well as beads and plates.

Copper goods appear to have been highly valued and were widely distributed over the states (USA) and provinces (Canada) as far south as New Mexico and east as the Atlantic sea-board often being found in caches and as grave goods[1,3]. It should be remembered that the Great Lakes are the largest accumulation of fresh water in the world and are large enough in European terms to be called seas, and the continent itself is vast.

Further north, in fact a lot further north, in the Canadian Arctic can be seen another aspect of the use of copper in a North American native society. The source of copper here being the Coppermine river area of Coronation Gulf and Victoria Island, again as native copper. Copper was used by the pre-history Inuit (Eskimo), who have become known by archaeologists as the Copper Inuit, in an similar manner to further south. It was mined, annealed and cold-hammered to work the copper into goods, a practice which continued well after first contact with Europeans.

Metal, already a valuable commodity, was brought into this Inuit society by trade but also by salvage from abandoned ice-bound ships such as HMS Investigator which, because it had sailed via tropical waters, was copper-bottomed. Thus large amounts of European copper was injected into the society which curated its copper stocks well creating problems for the archaeologist, what was the vintage of the artefact, what was made from native copper and what from European copper?

Wayman et al[4] addressed this issue using microscopy and elemental analysis from neutron activation. Native copper from the Coppermine river and Victoria Island could be distinguished from European smelted copper, acquired from trade and salvage, by the large crystal structure and high purity. European smelted copper, in contrast, contained more non-metal inclusions as well as traces of arsenic, nickel, selenium, antimony, silver and gold. Cobalt, zinc, tin and mercury were found in similar quantities in both native and smelted copper.

Contrasting the copper age in Europe and North America, copper was still being used for the principle tools until almost living memory in the Canadian Arctic. Although the mineralogy and processing was different from European practice there were areas of overlap for models of the two societies, mining, processing and distribution over great distances of land and water. An interesting comparison can also be made between the origin of Inuit copper artifacts and the problem of dating copper slags found recently on North Wales beaches, a problem which I hope can be resolved using appropriate analytical techniques.

Don Smith, October 1992

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CERRIG CANNAN - CANNON STONES

On Saturday May 16th, 1992, the Council for Independent Archaeology held a conference in Llandudno. In the early evening a walk over the Great Orme was arranged by GOES. As befitted such an august occasion, an interesting discovery was made on Pen y Dinas. In a section of limestone pavement near the Rocking Stone were found 16 drilled holes, 1.25" in diameter and varying in depth from 2.25" to 6.5". These were in an irregular formation over four separate patches of limestone. During the ensuing inspection and discussion it was suggested that this was a 'Carreg Cannan', a cannon stone. Subsequent enquiries appear to support this theory.

Although sounding rather like an advanced Neolithic missile launcher, cannon stones were in fact a series of drill holes in which controlled explosions of black powder were set off for celebratory purposes.

A 'phone call to Graeme Catlett of CAIL, the Llandegai and Llanllechid Archaeological Society, produced a copy of a paper she had written on the subject. Nineteen examples have been identified and recorded in the two parishes. The largest had over 300 holes and the smallest only 25 or so. Others are to be found throughout the slate quarrying districts of Gwynedd. She describes them thus:-

"In fact in Dyffryn Ogwen they were made to celebrate the pomp of Penrhyn and Royal occasions. Elsewhere they might celebrate the opening of railways, as at Llanberis, or reservoirs, as at Eigau. The practice continued for over a century and we have examples from 1838 and 1937. ... One is reported to play 'God Save the Queen', and one, with over 120 holes, has a large inscription at its centre and celebrated Victoria's Coronation..."

Several explanations suggest themselves for the existence of a cannon stone on Pen y Dinas.

In 1887 Chwarel y Fach, the Happy Valley Quarry, ceased operations. The quarry was sited directly below Pen y Dinas. This was the 50th year of Queen Victoria's reign. Was the cannon drilled as part the Jubilee celebrations? Could it have been the quarrymens' explosive farewell to their redundant workplace?

In 1890 Queen Carmen Sylva of Roumania visited Llandudno. The Llandudno Advertiser reports a 'pyrotechnic display' on the Orme to mark her departure. Was the cannon stone involved?

Or is there some other explanation for the drill holes?

Tom Parry, November 1992