Copper mining in the Bronze Age at Mynydd Parys, Anglesey, Wales

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Summary
The Bronze Age is defined by the first extensive use of the metal copper. Prehistoric mining for this metal has been identified in surface and underground workings in Parys Mine, Mynydd Parys, Anglesey, although almost all of the surface workings are now obscured by the extensive deep spoil from more recent mining in the industrial period. These copper-bearing ores are in bedded lodes, together with some intruded vein deposits. The Bronze Age workings have been exposed underground where they have been intersected by the early 19th century industrial workings on the 16 fm (fathom) level in the Parys Mine. Spoil exposures contain stone hammers ("mauls"), wood fragments and charcoal; samples of the latter have been radiocarbon dated with chronological modelling suggesting activity taking place in the first half of the second millennium cal BC. Although relatively limited in extent these important prehistoric mining sites are among the earliest found in the UK. They have survived due to their protection from surface erosion and limited accessibility.

Keywords: copper mining, Bronze Age, Mynydd Parys, radiocarbon dating

INTRODUCTION

In Britain the Early Bronze Age is dated to the period *c*. 2300–1600 cal BC, and by *c*. 2100 cal BC copper was being regularly alloyed with up to 10% tin to produce bronze (Timberlake & Marshall 2013). Accompanying the increase in metal use was a search to find more local sources of copper ore to supply this rapidly expanding industry. The discovery of major Bronze Age copper mining sites in Britain languished well behind the typological and technological study of metal artefacts, at least until the end of the 1980s, when extensive underground workings dating to the Bronze Age were first reported from the Great Orme Head, near Llandudno in North Wales (James 1988; 1990; Jenkins & Lewis 1991; Dutton & Fasham 1994) and from an opencast mine at Cwmystwyth in West Wales (Timberlake 1987; Timberlake and James 2018). The surface exploitation of copper ores across Western Britain has now been shown to have been more widespread than this, with up to 16 Early Bronze

Age mines and prospecting sites identified from the Plynlimon (Plumlumon) district (mid-Wales), the North Wales coast and the Southern Pennines of England (Alderley Edge and Ecton); most of this activity dates to the period *c*. 1950–1650 cal BC (Timberlake 2009; 2014; 2016). Mynydd Parys in Anglesey is unusual — and fortunate — in having associated evidence for underground mining.

The present paper describes the underground workings that have been identified, investigated, surveyed and dated in the Parys Mine. This became possible following the renewal of access to the mines in 1995, their access having been capped in 1980 for insurance reasons (Jenkins 1995). Following a brief outline of the site's location, geological context, and more recent mining history, these underground archaeological mine deposits form the subject of this paper.

THE BACKGROUND TO PREHISTORIC MINING ON MYNYDD PARYS

Mynydd Parys (Parys Mountain) is a low (146 m O.D.) but prominent mountain comprising a band of hard rocks (rhyolites, silicified shales) within the region's softer rocks (shales). It is located a few kilometres inland to the south of the town of Amlwch on the coast of Anglesey (Ynys Môn) in north-west Wales (Fig. 1). The nature of mining on Mynydd Parys in recent times, and indeed in prehistory, relate to the origin, nature, and spatial distribution of various ores. These arise from geological factors described in more detail elsewhere (Jenkins 2015, 77). The copper mined is mainly in the form of lodes along bedding planes and was formed by volcanic activity some 390 million years ago, but was also deposited in later veins along fault zones. These lodes consist of the mineral chalcopyrite ($CuFeS_2$) accompanied by quartz (SiO_2), often as a fine-grained mixture (known as "Bluestone", or in Welsh as "*Carreg Las*"), together with zinc sulphide (ZnS - sphalerite) and minor lead sulphide (PbS – galena).

Early references to the mineral deposits here date back to 1607 when Sir John Wynn of Gwydir recorded the presence of copperas (iron or copper sulphate) and brimstone (sulphur) on the mountain; he also noted the existence of 'a great mineral work' in 1579 from which Mr Hedley obtained a 'mineral water' that made 'alome and copperas and transmuted iron into copper' (NLW 1926, 75–77; Harris 1964, 19; North 1962, 60). There is also mention of a mine at 'Trysclwyn' in 1698 (Dodd 1926, 92), whilst Lewis Morris (1748, 3–4) refers to the presence of 'okery earths' suitable for use as a paint. Rutty (1761, 470) draws attention to the medicinal value of the iron-rich waters. However, the first discovery of copper ores on the mountain was by the landowner Sir Nicholas Bayly and Charles Roe & Co. of Macclesfield at a place called Golden Venture, recorded (and subsequently celebrated) as being March 2nd

(St. Chad's Day) 1768 (Harris 1964, 22). The excavated ore from these works was carted down to the small harbour at Porth Amlwch that developed concurrently with the mines, and from there it was shipped to Swansea or across to Ravenshead in Lancashire for smelting and sale (Hope 1994). In the early Industrial Revolution Mynydd Parys became a major site of mining which briefly dominated world copper production for around a decade at the end of the 18th century (Rowlands 2002). Production reached 44,000 tons of copper ore *per annum*, surpassing that of Falun in Sweden, which had previously dominated world copper trade. A very useful account of the underground operation and working conditions at the mines at this time is provided by Michael Faraday who visited the Parys Mine during his tour of Wales in 1819 (Tomas 1972, 78–89). By the 1880s, the workforce at Mynydd Parys had shrunk from over a thousand to a few hundred and, in common with other metal mines in Britain; the mines had effectively ceased production (Harris 1964).

The ores were extracted initially from numerous shallow shafts (approximately 30–40 m deep) that later merged into the two separately owned impressive opencasts seen today (Fig. 1). Mona Mine on the east side was owned by Nicholas Bayly, and Parys Mine on the west jointly by Bayly and Reverend Edward Hughes (Rowlands 2002). From 1778 the latter was successfully worked for more than a decade by the Parys Mine Company under the management of Thomas Williams of Llanidan, known locally as 'The Copper King' (Harris 1964). Later shafts were developed to extract ore at greater depths up to a maximum of 330 m deep at the northern edge of the ore field. The resulting Parys and adjacent Mona Mines comprise many kilometres of passages, and extend to a depth of 156 fm at Gwen's Shaft, but they are now flooded and inaccessible below the 45 fm level. In the early twentieth century, another later minor phase of mine development and ore production took place by John Taylor & Co. Ltd, whilst more recently the mines have been under evaluation by Anglesey Mining plc., through a programme of borehole drilling for possible renewed production of zinc, copper, and minor lead (AMC 2005).

All access to the underground workings was closed for insurance reasons in 1980 by the sealing of more than 100 shafts and adits with concrete caps. However, it was appreciated that there might be evidence for prehistoric mining within the underground workings, particularly since a hammer stone (then unrecognised as such) had been recovered in the 1970s from an underground site before access was closed. It was used as a convenient door-stop before its significance was recognised, ten years later, as a stone hammer or "maul" which is now considered as a likely indicator of prehistoric mining. Indeed, it was by then appreciated that these underground workings could provide the best opportunity for locating

such mining in view of the extensive deep surface cover of later 18th–19th century spoil. In 1995 the Marquess of Anglesey kindly granted permission for the footway to Parys mine to be reopened to allow renewed access to the underground workings for survey and research purposes (Jenkins 1995, 35).

THE BRONZE AGE WORKINGS AT PARYS MINES

Background

Indications of an 'earlier' phase of mining on Mynydd Parys were suggested by Thomas Pennant in 1770 and by Christopher Sykes in 1796 (Sykes 1796, 59; Briggs 1976). Sykes was the first to recognise the form of these fireset excavations and associated spoil dumps containing the characteristic stone tools described later in this paper. Locations of four such sites are recorded on an estate map of 1764 (Hawarden Record Office D/KK/534) and are shown in Fig. 2. The prehistoric sites on the mountain so far recorded correspond to three of those identified on the 1764 map (sites 1, 3 and 4). Site 2, at Henwaith to the east (SH 4506 9075), is located in what is now a private garden although early 18th century workings have recently been investigated and recorded nearby.

The observations by Sykes and others prompted a visit by Oliver Davies during his national survey of ancient mines, under the auspices of a committee set up by the British Association for the Advancement of Science in 1935 to investigate the remains of early mining in Wales (Davies 1939, 40). His excavation of spoil at Site 1, at Oxen Quarry in the area of Mona Mine just to the north of the summit (SH443906), revealed charcoal-rich sediments containing stone hammers (Davies 1939). In 1988 Oliver Davies's site was located and his original trench re-excavated by the Early Mines Research Group (EMRG) leading to the recovery of more than 30 stone tools together with charcoal fragments (Timberlake 1988).

The charcoal subsequently produced three statistically consistent radiocarbon determinations at the 5% level (T'= 0.8; T'(5%)= 6.0; ν= 2; Ward & Wilson 1978) suggesting activity in the first quarter of the second millennium cal BC; the Early Bronze Age (Timberlake 1989). These have now been supplemented by a further nine dates, from workings underground (Table 1). The three other sites recorded on the 1764 map are now buried beneath considerable depths (up to 10 m) of later 19th century industrial spoil (Fig. 2). The location and nature of the original ore deposits mined in the Bronze Age is not evident. No shallow deposits of ore, nor records of such, have been found in the present study and none have been observed immediately underground. Evidence of small surface excavations that might have provided Bronze Age spoil could be submerged under present-day ponded

surface water, and although shallow old workings (Drift Mawr), to the north of the Mona Opencast (Fig. 2), are recorded, these have not yet been located underground since entry was apparently by shafts that are now capped and inaccessible.

The underground prehistoric workings, which are the focus of this report, were discovered when permission to re-open the Parys footway was kindly given by Lord Anglesey (Jenkins 1995), which led to the subsequent exploration and survey of passages and chambers located on the 16 fm and 20 fm levels in Parys Mine, about 29 m and 36 m underground.

The prehistoric miners recognised outcrops of at least two of the major ore bodies in this area of the mountain, namely the Carreg-y-doll and North Discovery lodes. Two specific underground sites have been identified. The first is an impressive inclined open passage on the Carreg-y-doll lode (S3), the second is a cluster of linked workings on the North Discovery lode at the 16 fm level (S1, S2, and S4) together with associated deposits also containing mauls at the 20 fm level (S5 and S6). Additional prehistoric material has been identified elsewhere on the 20 fm level (S7), but this appears to have derived from collapse from the 16 fm workings above rather than being *in situ* (Figs 2 and 3).

The morphology of the underground excavations

The distribution and morphology of the underground workings have been established by continuing exploration and survey over the last fifteen years and it is apparent they were originally exposed when intersected by mining ‘stopes’ (work chambers) driven up-dip from the 16 fm and 20 fm levels by 19th century miners (Fig. 3). The workings are not extensive in nature, with a limited passage length of a few hundred metres as compared to those, for example, in the Great Orme mines where kilometres of passages have been identified (Jenkins & Lewis 1991; Lewis 1996). They do, however, indicate that the prehistoric miners were able to mine through hard and resilient rock types (argillites and silicified stockwork respectively), and to depths of many metres, although actual values are difficult to measure because of the unknown contemporary ground surface level and thickness of later overlying spoil. Furthermore, they provide a valuable insight into prehistoric mining technique in this distinctive and unusual ore field.

The North Discovery Lode sites

Sites S1, 2, 4, and 5 are clustered around what is described on the 1764 survey (Hawarden Record Office D-KK-534-03) as “Old Roman Works” on the North Discovery lode. This is

now indicated by a 5 m deep conical depression in thick surface spoil, but from underground observations it appears to have been a chasm some 20 m by 10 m in size, now filled in by loose recent spoil. Sites S2 to S5 take the form of 'windows' intersected by the 18th-19th century workings whilst at S1 a sizeable work chamber was broken into and re-excavated in the early 19th century, some 10 m from the 'chasm', and this provides the principle section through the prehistoric spoil, which is described in detail below. Site S2 is a small inaccessible cavity in the roof of a passage nearby, whilst S4 is a small roof chamber at the edge of the "Roman shaft" and blocked by its spoil. The 'window' located high up in the 20 fm workings (S5) is limited to an infilling of spoil of approximately 2 m by 1 m in extent and, from the survey, appears to be at the same level as sites S1 to S4 and only a few metres to the north.

The Carreg-y-doll lode site.

Site S3 on the Carreg-y-doll lode differs from those on the North Discovery lode; here the 18th-century workings intersected the bottom of a sloping open passage extending up-dip some 15 m before becoming choked with spoil (Fig. 3). Draughts observed under strong surface wind conditions suggests its choked end must be close to the surface, which survey again locates in an area under surface spoil. A possible model for the working of this type of inclined opencast-drift exploitation is shown in Fig. 4.

The deposits

As is common on such sites, the main artefactual evidence is represented by angular rock spoil, the waste product of mining, back-filling or infilling (through slumping) the excavated workings.

Ore is evident on the roof of the 18th–19th-century work chamber below S1 as sinuous quartz veins carrying chalcopyrite, weathering to a green stain of brochantite. However, a 5 kg sample of spoil examined from S3 was notably devoid of copper ore, suggesting either the efficiency of its recovery or that the site was excavated for access not production. Surprisingly, the only ore found was a sample of bluestone (the mixed lead/zinc/copper ore) supporting the former suggestion and implying this ore was rejected by the early copper miners.

Spoil may provide evidence of the method of mining and also of any subsequent treatment. Such methods may be recorded in the particle size and shape in relation to the rock type involved, particle size being plotted and shape being categorized by standard criteria.

Particle size may be restricted in range and shape by the properties of the rock and by the mining procedures involved in 'development' work to access the ores; alternatively, where spoil is subsequently redistributed and perhaps mixed, it may lose such characteristics. It may also be modified by *in situ* 'weathering' leading to disaggregation and accumulation of finer grades at the expense of the initial material, and this is particularly true in the very acidic environment of the Mynydd Parys mines: fine products of weathering (ie clay size, <2 μm) may be redistributed to lower horizons. Even the angular coarser spoil is variously enriched in interstitial fine-grained material (hydrous-mica/quartz/jarosite) and iron ochre by weathering or by downwash ("illuviation"), and this should be taken into account in the interpretation of the results.

The nature of the spoil is illustrated in a series of analyses of samples from the main section S1.1 (Fig. 5). Coarse angular spoil of varying grades is common and mixed/weathered spoil can also be distinguished. In particular, a sample from the base of section S1.1 comprising banded, well-sorted quartz sand (context 107) suggested the residue from some sort of crushing and washing process from which copper ore was removed. Whether this came from work carried out underground, or from sediments washed down into the workings in successive phases from above, is an interesting question. There is clearly useful information available from such data on the spoil, but unfortunately such a 'sedimentological' approach does not appear to have been employed in the study of prehistoric mining elsewhere, so comparative data remains unavailable.

In addition to the sand layer (context 107) in section S1.1, there was also a layer of finely banded clay-silt material (Fig. 5, S1.1 (context 104)) which is indicative of ponding during a quiescent spell between two phases of back-filling or natural infilling of the working with a sandier spoil. Various organic remains were identified in this horizon, including acorns, oak leaves, bracken, charcoal and an, as yet unidentified, fibrous material.

Associated artefacts – stone hammers/mauls

The stone mauls/hammers

The distinctive artefact of prehistoric mining at Mynydd Parys, as elsewhere, is the stone hammer or "maul" (Fig 6). The extreme acidity of the mine environment (pH ≤3) would preclude survival of any bone tools, such as those found at the Great Orme. However, it is probable that bone or antler implements were used whose original presence might still be detectable as localised phosphate anomalies retained within the abundant secondary ferric

hydrous oxide deposits in the spoil; this is likely due to the low mobility of soluble phosphate anions under the prevailing conditions, a possibility to be tested in a future project.

A sample of 136 "mauls" (or hammer stones) has been collected and examined from the mines, 42 from surface sites and 94 from underground workings: their properties are summarised in Table 2. A dozen examples have been left *in situ* on the surface and some 50 underground. The surface collection is clustered at particular sites (Fig. 2), recorded as "old workings" on the 1764 map of the mountain, as referred to by Sykes (1796). These sites have been re-examined and resampled by the EMRG (Timberlake 1988) and in the present study, and comprise:

(a) 'old spoil' within the Oxen Quarry excavated by Oliver Davies (1939) and by the EMRG in 1988 (Site 1 on Fig. 2).

(b) an area on the outcrop of the Carreg y Doll lode near Quarry shaft (see Fig. 2)

(c) at the Mona Footway and within the area of the adjacent EMRG surface find clusters (sites 'Z', 'X' and 'Y' (Timberlake 1988, fig.1)) (Site 4 on Fig. 2)

(d) a site in a private garden at Henwaith which was not sampled (Site 2 on Fig. 2).

Other examples have been found scattered across the northern slopes of the mountain and, rarely, in the Great [Parys] Opencast. Those recovered from underground have been revealed where 18th–19th century mining on the 16 fm and 20 fm levels broke upwards into shallower Bronze Age workings that exploited both the Carreg-y-Doll and North Discovery Lodes. Underground mauls are generally encrusted with hard iron ochre which has required removal by chemical treatment (dithionite/citrate buffer) before washing to allow detailed examination. The weight, dimensions and morphology of the samples have been recorded and their petrology examined by stereo-zoom microscopy at x15–x75 magnification. However, for the mostly (65%) fine-grained (<1 mm grain size) rock types involved, the petrology is difficult to identify in hand specimen and full confirmation will require thin-section microscopy.

The mauls take the form of very well-rounded cobbles and are mostly of high sphericity, and thus conspicuous underground amongst the angular mining spoil (Fig. 6). These were presumably readily available from till as cobbles eroded by the sea and deposited on beaches. This has been investigated along the north coast of Anglesey and two possible sources so far identified. One is at Porth Helygen (SH 491 908) providing a variety of rock types including porphyries, andesites, and granites and other unidentified igneous rocks in the Irish Sea till; the other is at Porth Llanlleiana (SH 388 951) providing local Gwna meta-quartzites. Two mauls of distinctive local basal Carboniferous sandstones could be from Llanbedrgoch, some

10 km to the south east. However, a source for a distinctive pale-buff orthoquartzite used in 16% of the mauls has not yet been identified.

Cobbles would have been selected for their appropriate properties as hammers or "mauls", such as microstructural strength and absence of weaknesses (close jointing, bedding, cleavage, etc.). This is evident in the prevalence of fine-grained homogenous rock types, often showing sub-conchoidal fractures. The samples have been divided into:
(a) nearly whole cobbles,
(b) large portions of original fractured cobbles,
(c) flakes (one face usually conchoidal),
(d) smaller fragments.

The cobbles initially chosen seem to have been dominated by those of small weight showing sub-conchoidal fractures. The sample size includes cobbles up to 2 kg in weight and 150 mm in diameter, but this may be biased toward smaller sizes as a result of the preferential collection of lighter samples from underground sites.

The original use of these cobbles is evident from the flaking and battering of ends, edges, and even faces (when used as mortars or anvils), whilst over 30% show evidence for re-use in the form of secondary battering upon already fractured faces/edges. Some samples (10%) show evidence of pecking ("rills") (Groups 2a–c Pickin 1990; Type 2A, Timberlake & Craddock 2013) or notches (Groups 3a and b) indicative of attachment to hafts (or possibly ease of use by hand); these results are summarised in appendix Table 2. The groups present within this relatively small sample of 130 are comparable to the somewhat larger examples from Mount Gabriel and Ross Island (O'Brien 1994; 2004) and Cwmystwyth (Timberlake 2003; Timberlake & Craddock 2013). The still larger collection of cobble stone tools (approximately 3,500) found at the Great Orme mines appear to be dominated geologically by beach pebbles derived from chilled margins of the 'micro-diorite' outcrop at nearby Penmaenmawr to the west of Llandudno, though this assemblage has yet to be studied in petrological detail (Dutton & Fasham 1994).

Dating of the deposit

Sites S1, S2, S4, S5 and S6 (see Fig. 4) all provided suitable material for nine radiocarbon dates, together with three dates deriving from samples from the surface deposits excavated by the EMRG (Timberlake 1989) (Table 1). The section locations that the samples were recovered from in S1 are shown in Fig. 5.

The radiocarbon dates on charcoal from underground spoil within the mine and from surface spoil at Oxen Quarry clearly fall into a coherent group concentrated in the first half of the second millennium cal BC. The measurements are though, not statistically consistent at the 5% level (T'= 22.8; T'(5%)= 19.7; ν= 11; Ward & Wilson 1978), and so they represent more than one episode of mining activity.

Simple visual inspection of the calibrated radiocarbon dates does not allow us to assess the date of mining activity at Mynydd Parys accurately, since the calibration process does not allow for the fact that this group of radiocarbon dates are related – they all come from the same site. Bayesian statistical modelling is required to account for this dependence (Buck *et al.* 1992; Bayliss *et al.* 2007), which we have undertaken using OxCal v.4.3 (Bronk Ramsey 2009) and the atmospheric calibration curve for the northern hemisphere published by Reimer *et al.* (2013).

The model (Fig. 7) shows good agreement (Amodel: 89) between the radiocarbon dates and assumption the mining activity took place at a uniform rate over a period of time (Buck *et al.* 1992). The model estimates that mining activity first took place in *2245–1785 cal BC*(*95% probability*; *start_mynydd_parys*; Fig. 10), probably *2085–1890 cal BC* (*68% probability*) and finished in *1815–1300 cal BC* (*95% probability*; *end_mynydd_parys*; Fig. 10), probably *1735–1485 cal BC* (*68% probability*). The dated mining activity is estimated to have taken place over a period of *40–550 years* (*95% probability*; Fig. 8) probably 175–440 years (*68% probability).*

The beginning of dated mining activity on Mynydd Parys is clearly earlier than at the Great Orme (*94% probability*; Fig. 9), where the ores being mined were probably more recognisable (green and blue copper carbonates), and perhaps more easily extractable and reducible.

Palaeoenvironmental evidence

Palaeoenvironmental data was collected from sections S1.1 and S3 and processed. The conclusions are presented here, and the full report is given in Appendix II at the end of this paper.

The pollen results confirm that the Bronze Age landscape at Mynydd Parys surrounding the mine was largely open with areas of heathland and wet grassland with some pools of water (Fig. 10 and 11). Deciduous woodland was present, mainly comprising oak and hazel. A permanent decline in woodland was recorded at Site 3 with oak being most affected (Fig.

11). Otherwise, the tree and shrub pollen record is characterised by small-scale fluctuations of oak, hazel, birch, and alder, all known to have been used in prehistoric mines.

Both pollen diagrams, drawn using Tilia and Tilia.graph version 2.0.b4 (Grimm 1991-1993), are presented as percentages of total land pollen (TLP), excluding spores and aquatics. Spore and aquatics are also expressed as a percentage of total land pollen. A cross denotes one pollen grain. Plant nomenclature follows that of Stace (2010) and takes into account the problems of categorising plant species on the basis of their pollen morphology (see Bennett *et al*. 1994). Summary curves for trees, shrubs (constituting arboreal pollen, AP), dwarf shrubs and herbs (non-arboreal pollen, NAP) are shown.

Notwithstanding taphonomic and dating issues, trends in both pollen diagrams are similar to those recorded in other pollen diagrams close to prehistoric mining and metalworking sites, in particular small-scale fluctuations of *Quercus*, *Corylus*, *Alnus* and *Betula* (Mighall & Chambers 1993; Mighall *et al*. 2017). It is possible that these fluctuations are the result of exploitation of local woodland for timber and charcoal. The permanent decline in tree and shrub pollen at Site 3 contrasts with evidence from other Bronze Age mines in Wales and Ireland which suggests woodland was not severely cleared (Mighall & Chambers 1993; Mighall *et al*. 2017). However, all these mines, including Mynydd Parys, did not operate in isolation and agricultural activities, in particular grazing, occurred as part of a dual economy.

DISCUSSION

The recognition of copper ores in the Bronze Age would have been determined by the nature of the landscape and its ecology, and by the distribution and nature of ore exposures. The mineralisation on the mountain is of an unusual nature for Britain, the so-called "Kuroko" type of ore deposit, leading to inter-bedded seams and scattered pods of rich ore. The host rocks comprise an Ordovician/Silurian inlier of hard fine-grained volcanic rocks (rhyolitic extrusives, intrusives and pyroclastics) often also intensely silicified in a later phase. These relatively hard rocks within the softer shales were more resistant to glacial erosion, with the result that they produced a low, but prominent, feature, Mynydd Parys, standing at 147 m OD above the generally planated surface of Anglesey at 70 m OD. As a result Mynydd Parys would have been a prominent hill or landmark within the Bronze Age landscape on Anglesey.

The appearance of exposed ores would again have been a notable feature in an otherwise 'normal' environment. Copper deposits can be recognised by the secondary copper minerals produced by weathering, but the distinctive carbonates malachite (green) and azurite (blue)

are not stable in the acidic environment of Mynydd Parys, whilst the various sulphates are relatively soluble and would only be preserved within protected cavities and overhangs at the surface and in 'weathered' underground workings. In environmental terms, the weathering of the predominant sulphide mineral, iron pyrite (FeS_2), results in the production of a very acidic environment (*p*H ≤3) and of a distinctive sparse vegetation comprised mainly heather and specialised lichens. The release of iron and its subsequent oxidation and deposition as a distinctive orange-brown stain upon exposed rocks would again be a distinctive feature in an otherwise 'normal' environment. Bronze Age metal miners would therefore have needed to locate the sulphide-rich rocks and to recognise the presence of copper within these sulphide and oxidised sulphide ores.

Yet another means of recognising and possibly also extracting copper during the Early Bronze Age could have been through the burning of the superficial peats accumulated within a number of poorly drained valley sites scattered across the mountain. Such deposits were in fact noted on the 1764 map where the peat was exploited in "turbaries". The chemistry of copper, released into solution by weathering of its sulphide ores in the acidic, anoxic, conditions, is such that it can form a stable metallic precipitate, visibly sheathing plants. This form of deposit was readily exploited in the 18th–19th century at mines such as Dolfrwynog in Coed y Brenin, mid Wales (Price & Abrahams 1994, 27). Such distinctive precipitates in any early peats on Mynydd Parys would themselves have attracted attention in the Early Bronze Age and, even more so, any metallic residues left after the burning of such peat.

The intriguing question arises as to which particular ore was extracted during the Early Bronze Age. Various possibilities exist – either it was the primary copper sulphide itself (chalcopyrite), the secondary enriched copper sulphides (chalcocite and covellite), native metallic copper, or the secondary oxides, carbonates, or sulphates. Of these by far the most usable would have been native copper, although both the carbonates and oxides are relatively easily smelted to metal (Chapman & Chapman 2013). By contrast, the recovery of copper from chalcopyrite involves a much more complex smelting process which includes preliminary roasting (oxidation to remove the sulphur) followed by reduction and slagging (for removal of iron) in order to obtain the metal. Of the secondary minerals, the brightly coloured carbonates are absent here due to the highly acidic environment, whilst the ephemeral nature of copper sulphates has already been discussed. However, secondary deposits of metallic copper are generally predictable in peaty anaerobic sites (Krauskopf & Bird 1994), and significant occurrences of native copper were reported by Lentin in 1800 (Rothwell 2007, 10–12) and before that by Pennant (1778, 255–6) from the near-surface zone

of the Parys orebody, whilst Greenly (1919, 837) noted the presence of leaf-like or moss-like aggregates of native copper present within the gossan of the Great Lode, as well as from the nearby mine at Rhosmynach; specimens of which are held within the National Museum of Wales collections (Bevins 1994).

As noted above chalcopyrite, the main copper ore at Mynydd Parys, is notably sparse within the Bronze Age spoil examined from site S1, suggesting that either it was not encountered in any great amount within the areas they were working in, or that it had been extracted selectively from these same areas with remarkable efficiency. A sample of *Carreglas* (bluestone) was, however, recovered from section S1, possibly after having been discarded by the Bronze Age miners, suggesting that chalcopyrite or perhaps rotten chalcopyrite (here consisting of a mixture of oxidised or enriched secondary copper minerals) was the most likely ore sought. Both the Carreg y Doll and North Discovery lodes were exploited in the Bronze Age, whilst no evidence has survived for lodes in the opencast, possibly due to the scale and intensity of later historical operations. The ores currently exposed in the opencast are now mostly dominated by zinc/lead with minor copper, presumably those rich in copper having been selectively extracted during the historic/ prehistoric period.

The provenance of the copper used to make bronze has variously been suggested on the basis of distinctive trace metal patterns in metal as discussed by Northover (1980) with respect to Wales. Northover proposed a number of Early Bronze Age metal-types, one of which he considered had its origin in north-west Wales (Group B3), which he identified by its trace metal composition As<0.75%, Ni>0.06% and its prevalence alongside other metal types (ie Groups B1, C and A (as Irish metal)) in the period *c*. 2200–1600 cal BC. The actual source of this B3 copper was not ever stated, although the implication was that it might include Mynydd Parys. Analysis of such assemblages is complicated by several factors such as probable separate sources of the minor alloying elements involved (eg tin), the mixing of coppers, and the progressive dilution of any signature metal assemblage as bronzes were merged during metal recycling. However, the copper ore (chalcopyrite – $CuFeS_2$) at Mynydd Parys is lacking in distinctive levels of trace metals and no derived artefacts have yet been identified which would allow comparisons of composition. Rohl & Needham (1998) used a combination of stable lead isotope analysis of the lead compositions within artefacts and ores and the trace element patterns present in metalwork to define a set of Bronze Age implement metal (IMP-LI) groups which could then be compared with ore sources as defined for the English and Welsh ore fields (EWLIO). Once again, no clear match could be established

between any metal type and Mynydd Parys, although chalcopyrite from here was analysed, the 'best fit' perhaps being with ores from north-west Wales and Shropshire and IMP-LI 6 (Willerby metalwork (1900–1700 cal BC) (Needham 1996)). A specific Mynydd Parys source of Early Bronze Age metal was likewise not defined by Peter Bray in his re-evaluation of evolving metal types in use in the Bronze Age, although he does refer to specific metal types appearing in Wales during the Early Bronze Age (such as DC2 (As) and DC 11 (As +Ni)) which he considers to be a signal for local exploitation (Bray & Pollard 2012). The answer here may be to try and identify the exact (mineralogical/ chemical) composition(s) of the ore(s) the Bronze Age miners were removing at Mynydd Parys, by following the same (or a similar) mine-based metal type model Alan Williams has developed in his investigations of the Great Orme (Williams 2019). This approach proved remarkably effective on the Orme, but will be more difficult to attempt at Mynydd Parys on account of the very considerable alteration of the mined ore body and its wholesale removal.

Chronological modelling of the 12 radiocarbon dates taken from surface and underground samples of burnt wood associated with firesetting and from un-burnt wood associated with slumped-in/ washed-in mine sediments suggest that Early Bronze Age mining took place in the first half of the second millennium cal BC. The estimated dates obtained so far indicate that mining began in *2085–1890 cal BC* (*68% probability*) and ended in *1735–1485 cal BC* (*68% probability*), over a period of *175–440 years* (*68% probability)*, though more dates would be necessary to demonstrate whether this covers the full duration of mining across the site. The most likely scenario is that we are looking at (probably intermittent) underground mining, centred upon the earlier part of this widespread phase of prospection taking place within Western Britain at the beginning of the Bronze Age, but with dates a little later than in Central Wales.

Fig. 12 is a schematic diagram summarising the estimate dates when mining activity at sites with three or more radiocarbon dates occurred. The horizontal bars represent the probability that a particular site was in use in a 100-year-period (light shading is less probable, darker shading more probable). Distributions have been taken from the model shown in Timberlake & Marshall (2014, fig 4). Mining activity at Mynydd Parys is broadly contemporary with that at Copa Hill, Alderley Edge and Ecton (The Lumb and Stone Quarry mine) suggesting the main flourit of early Bronze Age mine took place in the centuries either side of 2000 cal BC.

At Mynydd Parys more dates would be needed to confirm whether the surface workings at the Oxen Quarry were later than the underground ones on the North Discovery and Carreg-

y-ddol lodes, though this may be difficult to demonstrate as some of the underground material appears to have been transported from the surface. The current chronology therefore provides a fairly robust estimate of the date of Bronze Age mining on the site. We see this same phenomenon of surface material being deposited below ground within the Comet Lode Opencast at Cwmystwyth, but in the latter case these infill sediments were only slightly (or not at all) mobilised, therefore the stratigraphical and chronological sequence appears correct, with the earliest mining debris on the bottom (Timberlake 2003, fig. 41).

Despite the evidence for Bronze Age mining from both surface and underground contexts, little in the way of further investigation of the mountain for evidence of contemporary settlement or processing sites has ever been attempted, in part due to the extreme level of disturbance encountered, and in part due to the paucity of mapping evidence prior to 1764. However, one possible prehistoric site has been identified on the south-western side of the mountain at Penyfynwent, near the hamlet of Rhosybol, a little distance from the most intensively mined area. The pentagonal earthwork is of unknown date, although it is adjacent to a small, nearly ploughed out, barrow, both perhaps being Bronze Age features. The site was examined by Simon Timberlake as a possible one for further investigation, using either geophysics or geochemistry to detect structures or the evidence for mineral processing or smelting (the latter by means of a geochemical survey of the soil similar to the one carried out on the Great Orme (Jenkins *et al.* 2001)), but to date none of this has been pursued. Nevertheless, a palaeoenvironmental study of the hinterland area of the mountain did include a pollen and geochemical record for a 2 m+ core taken from the bog at Rhosybol (Fig. 13; Jenkins & Timberlake 1997 unpubl., 87–89). This and a subsequent core revealed the Holocene history of the site from at least 8330–7580 cal BC (8870±150 BP; Beta-169435); the upper part of it showing the loss of woodland and pollution resulting from historic mining and smelting, the lower part (from 70 cm) showing elevated concentrations of copper, zinc, and lead as minor releases of heavy metals probably generated by mining from the prehistoric period onwards (Mighall & Timberlake 2006 unpubl.). The pollen data suggests that woodland cover is already quite limited between 80 cm and 54 cm but there is a small decline in tree and shrub pollen at 70 cm. Tree and shrub percentages increase from 54 cm suggesting increased woodland in the local vicinity indicating that any early mining activity or agricultural activities did not have a significant impact on woodlands. A more detailed chronology of the core is needed to fully assess this evidence. Similar geochemical evidence pointing to possible prehistoric-Roman mining was recovered in 1996 from a 2.75 m core

drilled through sediments at Traeth Dulas near the mouth of the Afon Goch (Timberlake & Jenkins 2001).

The possibility of Roman mining on Mynydd Parys has been suggested on a number of different occasions by various different authors (Rowlands 2002, 20). This raises a number of questions since the evidence from here is in part impressive, and in part circumstantial and indirect. This takes the form of copper cake ingots weighing on average around 20 kg (15–45 kg), some of them 30 cm in diameter and 5 cm thick (RCAHMW 1961). Added to those recorded by the RCAHMW, a total of 18 ingots have now been found at various sites across Anglesey, two of them on the flanks of Mynydd Parys itself, and one recently recovered from the Menai Strait. Three, possibly five, of these ingots bear a stamp in Roman script on an embossed dab of copper. However, despite efforts to identify and date possible underground workings in the Parys mines to the Roman period, none has yet been identified, and the current chronology does not extend beyond the Early Bronze Age. Perhaps such workings were located upon other lodes since worked out, for example within the opencasts. None of these though are indicated on the 1764 map and it would be expected that at least some traces would have been detected underground in the Carreg-y-doll and North Discovery lodes, both of which were worked during the Early Bronze Age. It is relevant that small lead ingots were apparently found in a hearth within the Great Opencast (Pennant 1778) and, although these have since been lost, scraps of highly oxidised folded lead sheeting have been found in spoil near the summit of Mynydd Parys, which are currently under investigation for their nature and age. For the present, however, any mining activity during the Iron Age and Roman times has yet to be identified.

CONCLUSIONS

The programme of exploration work undertaken at Mynydd Parys has identified evidence for surface and underground extraction of copper within the first half of the second millennium cal BC, during the Early Bronze Age. The sites are located both on the surface and underground, although at least some of the latter appear to have been reached through the excavation of opencast drifts up to 20 m deep. The excavations would have been undertaken using stone mauls and fire-setting techniques. Animal bone has not survived in the acidic environment, so its use, as at the Great Orme mines, can only be extrapolated from evidence elsewhere.

The chronology indicates a period of exploitation preceding that at the Great Orme, but contemporary with Irish mining and that within mid-Wales. A chronological development of

exploitation westwards, from Ireland to central and North Wales and into north-west England, has been suggested (Timberlake & Marshall 2014).

More work needs to be undertaken to understand the full extent of prehistoric mining at Mynydd Parys, both above and below ground. This needs to be linked to a wider review of the Beaker and Early Bronze Age landscape of north Anglesey. Other avenues of future research might include chemical analysis as developed by Williams at the Great Orme (Williams 2019) despite the inherent difficulties caused by the different chemical composition. Evidence for later exploitation of the mines during the Roman period is still lacking, despite the numerous finds of 'Roman-style' copper ingots on Anglesey.

The painstaking work to identify the Early Bronze Age workings has provided evidence for the development of copper mining at Mynydd Parys. This makes a major contribution to the relatively small number of extraction sites known, and fits in well with the chronological model currently being developed. There is considerable potential for future work at this site to further our knowledge of Early Bronze Age mining and to search for the evidence of processing sites and the earliest smelting hearths.

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APPENDIX I: TABLES

Table 1: Mynydd Parys radiocarbon results

Dates calibrated using OxCal 4.3.2 (Bronk Ramsey 2009) with Intcal13 calibration curve (Reimer *et al.* 2013), rounded out to nearest 10 years.

Lab No.	**Radiocarbon Age (BP)**	**$\delta^{13}C$ (‰)**	**Context**	**Material**	**95.4% probability (cal BC)**
Surface spoil (Oxen Quarry, Timberlake 1988)					
BM-2584	3550±50	−23.9	Site 3/20	Charcoal - mature oak	2030–1750
BM-2585	3490±50	−25.2	Site 3/13	Charcoal - mature oak	1940–1680
BM-2586	3500±50	−25.2	Site 3A	Charcoal - mature oak	1950–1690
Underground spoil (Parys Mine)					
BM-3114	3540±40	16 fm (Main Chamber) S1.1/105-002		charcoal *Quercus ssp.*	2010–1750
BM-3115	3240±70	16 fm (North link) S2		Coppiced wood	1690–1320
BM-3116	3600±70	16 fm (W of Quarry Shaft) S4		Branch wood birch	2150–1750
Wk-14001	3524±68	S5 *via* 20 fm (Grand Stope)		Coppiced wood	2040–1680
Wk-14186	3576±46	16 fm (Main Chamber) S1.1/103-016		Branch wood Hazel	2120–1770
Wk-14187	3499±43	S1.1/104-005		Branch wood Oak	1940–1690
Wk-14188	3552±102	S1.1/107-003		Branch wood Oak	2200–1630
Wk-14189	3595±42	S1.3/307-014		Charcoal *Quercus ssp*.	2130–1780
Wk-14190	3514±44	S1.3/308-015		Branch wood Hazel	1960–1690

Table 2: Some characteristics of Early Bronze Age mauls from Mynydd Parys

(a) Properties		**Intact cobbles**	**Fractured cobbles**	**Flakes**	**Fragments**
Number		66	17	35	12
Weight (g)	Max-min	7800–460	4080–210	1630–60	1560–190
	Average	2050	1740	750	750
	Mode	1880	1500	660	620
Dimensions (mm)	Maximum	270–40	205–105	190–70	175–80
	Mode	140	150	120	
	Minimum	140–40	105–20	80–10	80–25
	Mode	70	70	35	50
(b) Petrology					
	Silicified siltstone	2	-	1	1
	Sandstones	10	2	5	1
	Orthoquartzite (pale buff)	13	4	2	2
	Orthoquartzite (Carb.)	2	2	-	-
	Metaquartzite (Gwna?)	8	-	-	1
	Quartz breccia	-	1	-	-
	Rhyolite/tuff	4	1	9	3
	Porphyry	5	1	3	1
	Microgranite	3	3	6	1
	Microgranodiorite	2	2	4	1
	Microdiorite	2	-	1	-
	Andesite	3	-	-	-
	Basalt	1	-	-	1
	Granite	1	-	1	-
	Granite gneiss	1	-	-	-
	Granodiorite	2	-	-	-

	Dolerite	2	1	2	-
	Meta-tuff	1	-	-	-
(c) Modifications			Intact & fractured cobbles	Flakes	(Average)
Numbers			83	35	
By use	Flaked		24	12	
	Battered one end		39	15	
	Battered both ends		20 (71%)	1 (46%)	64%
	Battered edge		15	1	
	Battered face (mortar?)		4	-	
Re-use	battered one end		18	5	
	Battered both ends		14 (35%)	1 (16%)	30%
Adaptation	pecking/rill/notch		10 (12%)	3 (9%)	11%

Table 3: Site S1.1, unit 104 stratigraphy

Stratigraphic layers	**Depth (cm)**	**Characteristics**
12	0–3.2	Brown/green clay with charcoal.
11	3.2–5	Sand yellow coloured clay.
10	5-7	Light brown clay with small pieces of quartz and charcoal.
9	7–10	Light brown/cream clay with quartz.
8	10–15	Grey clay, possibly with some organics characterised by lighter brown bands. Lenses of charcoal are visible.
7	1515.5	Dark brown irregular band. Possibly peat.
6	15.5–17.5	Dark brown organic substance with clay, charcoal and quartz.
5	17.5–22	Light grey clay with thin organic? Lens at 20–20.5 cm.
4	2226	Dark grey clay.
3	26–27	Very dark grey clay with possible charcoal or decayed wood. Charcoal at 26.5 cm.
2	2729	Light brown/cream clay with quartz.
1	29–33	Light brown, grey, irregularly laminated clay

Table 4: Site S3 stratigraphy.

Stratigraphic layers	**Depth (cm)**	**Characteristics**
15	08	Mid-dark grey silt with small charcoal fleck inclusions and small flecks white-yellow spots of clay/shale flakes (sub 2mm diameter).
14	8–18	Mid-dark grey slightly clayey silt, with charcoal inclusions
11	18–26	Mid-dark grey clayey silt with small charcoal fleck inclusions, rotted shale and light clay pieces and larger shale pieces (5-10mm diameter)
9B	26–30	Light grey-brown silt with light grey/white clay laminae
9A	30–37	Dark grey to mid grey silt with micro laminae (dark)
7	37–38	Light grey clay-rich silt speckled with black charcoal with small shale inclusions
5	38–43	Light brown clay with yellowish jarosite inclusion
3	43–44	Dark grey laminated, slightly organic silt
3	44–46	Dark grey laminated, slightly organic silt
2	46–47	Dark grey organic silt with small twigs and organic matter
1	47-50	Grey clay-rich silt

Tables 5 and 6

The nomenclature for Coleoptera (beetles) follows that of Lucht (1987). The right hand Column in Table 5 lists the host plants for the phytophage species of beetle that were recovered and are predominantly derived from Koch (1989; 1992). The plant taxonomy follows that of Stace (2010). The affiliation of each beetle species to a particular ecological grouping is indicated in the third column of Table 5. The meaning of each ecological code is explained in the key at the base of Table 5. The occurrence of each of the ecological groupings is expressed as a percentage in Table 6 and is illustrated in Fig. 14. The pasture/ grassland, dung and woodland ecological groupings are calculated as percentages of the number of terrestrial species only, as opposed to the whole fauna. An individual taxon can occur in more than one ecological grouping and, therefore, the proportions presented in Table 6 and Fig. 15 can exceed 100%. The second column also includes the Red Data Book (rarity) status of the insects recovered. This information, and the codes used are derived from Hyman and Parsons (1992; 1994). The RDB classifications are outlined at the base of the table.

Table 5. The insects recovered from the material from Mynydd Parys

(Nomenclature follows Lucht, 1987)

Taxa	Red data book status	ecological code	Site S1	Site S3							Phytophage host plants (based on Koch 1999)
			0 – 30cm	50 - 46cm (Sub-units 1-2	46 - 38cm (Sub-Units 5-3)	38 – 30cm (Sub-Units 9A-6)	30 – 26cm (Sub-Unit 9B)	26 – 18cm (Sub-Unit 11)	18 – 8cm (sub-Unit 14)	8 – 0cm (Sub-Unit 15)	
CARABIDAE											
Carabus violaceus L.	-	-	-	-	-	-	-	-	1	1	
Carabus problematicus Hbst.	-	-	-	-	-	-	-	-	1	-	
Notiophilus hypocrita Curt.	-	-	-	-	-	1	-	-	-	-	
Notiophilus spp.	-	-	-	-	-	-	-	-	3	1	
Trechus quadristriatus (Schrk.)	-	-	-	-	1	-	-	-	-	1	
Trechus quadristriatus (Schrk.) /T. *obtusus* Er.	-	ws	3	-	-	-	-	-			
Trechus spp.	-	-	7	-	-	3	-	1	3	-	
Bembidion spp.	-	-	-	-	-	-	-	5	-	11	
Trichocellus placidus (Gyll.)	-	ws	-	-	-	-	-	-	-	8	
Acupalpus flavicollis (Sturm.)	Nb	ws	-	-	-	-	-	-	6	-	
Acupalpus spp.	-	-	-	-	-	-	1	2	8	-	
Pterostichus. diligens (Sturm.)	-	ws	-	-	-	-	-	-	-	4	
Pterostichus niger (Schall.)	-	-	-	-	-	-	-	1	-	-	
Pterostichus madidus (F.)	-	-	2	-	-	-	-	-	-	-	
Pterostichus spp.	-	-	3	-	-	-	-	4	9	-	
Calathus melanocephalus (L.)	-	-	-	-	-	-	-	-	-	4	
Calathus spp.	-	-	5	-	-	2	-	4	-	7	
Agonum spp.	-	-	1	-	-	-	-	-	7	4	
Amara tibialis (Payk.)	-	-	-	-	-	-	-	-	8	-	
Amara bifrons (Gyll.)	-	-	-	-	-	1	-	-	-	-	
Amara equestris (Duft.)	Nb	-	1	-	-	-	-	-	6	-	
Amara spp.	-	-	3	-	-	-	1	2	4	-	
DYTISCIDAE											
Hydroporus spp.	-	a	4	-	-	-	-	1	-	6	
Agabus bipustulatus (L.)	-	a	-	-	-	-	-	-	1	-	
HYDRAENIDAE											
Limnebius spp.	-	a	-	-	-	1	-	1	8	-	
HYDROPHILIDAE											
Cercyon analis (Payk.)	-	df	-	-	-	-	-	-	-	2	
Cercyon spp.	-	df	-	-	-	-	-	2	-	1	
Megasternum boletophagum (Marsh.)	-	df	2	-	-	-	-	-	-	-	
Megasternum sp.	-	-	-	-	-	-	-	-	-	1	
Hydrobius fuscipes (L.)	-	a	-	-	-	-	-	-	1	-	
Laccobius spp.	-	a	-	-	-	-	-	-	2	-	
Chaetarthria seminulum (Hbst.)	-	a	-	-	-	-	-	-	3	-	
			-	-	-	-	-	-	-	-	
SILPHIDAE											

Silpha tyrolensis Laich.	-	g	1	-	-	-	-	-	-	-	
Silpha sp.	-	-	-	-	-	-	-	-	1	-	
CATOPIDAE											
Choleva spp.	-	-	7	-	-	-	-	4	3	2	
LIODIDAE											
Agathidium atrum (Payk.)	-	t	-	-	-	-	1	4	2	-	
Agathidium sphaerulum Rtt.	-	t	5	-	-	-	-	-	5	-	
Agathidium spp.	-	-	-	-	-	1	-	3	-	2	
SCYMINIDAE Genus and species Indeterminate		-	1	-	-	-	-	1	4	4	
STAPHYLINIDAE											
Micropeplus staphylinoides (Marsh.)	-	df	-	-	-	-	-	1	6	2	
Metopsia gallica (Koch.)	-	-	-	-	-	2	1	-	-	-	
Omalium sp.	-	-	1	-	-	-	-	-	-	-	
Lathrimaeum unicolor (Marsh.)	-	ws	-	-	-	1	7	9	-	7	
Olophrum piceum (Gyll.)	-	ws	-	-	1	1	-	2	5	-	
Olophrum fuscus (Grav.)	-	ws	-	-	-	-	-	-	-	7	
Olophrum spp.	-	ws	6	-	-	-	-	-	-	2	
Acidota crenata (F.)	Mb	df	-	-	-	-	-	1	-	2	
Lesteva longelytrata (Goeze)	-	ws	-	-	-	-	-	-	2	-	
Lesteva sp.	-	ws	-	-	-	-	-	1	-	-	
Stenus spp.	-	-	-	-	-	-	-	2	4	5	
Lathrobium spp.	-	-	-	-	-	-	-	-	1	3	
Xantholinus linearis (Ol.)	-	-	-	-	-	-	-	-	13	-	
Xantholinus spp.	-	-	-	-	1	2	-	4	-	4	
Philonthus spp.	-	-	-	-	-	-	-	-	11	-	
Staphylinus spp.	-	-	-	-	-	-	-	-	3	4	
Quedius sp.	-	-	-	-	-	-	-	1	-	-	
Tachyporus spp.	-	-	-	-	-	-	-	-	14	7	
PSELAPHIDAE										-	
Bryaxis bulbifer (Riechb.)	-	-	-	-	-	1	-	-	5	-	
ELATERIDAE											
Agriotes sp.	-	p	-	-	-	-	-	-	-	1	
HELODIDAE											
Cyphon spp.	-	ws	1	-	-	4	-	1	2	-	
NITIDULIDAE											
Meligethes sp.	-	p	-	-	-	-	-	-	-	1	
LATHRIDIIDAE											
Enicmus minutus (Group)	-	-	-	-	-	-	-	-	1	-	
Corticaria or *Corticarina* spp.	-	-	-	-	-	-	-	-	2	-	
TENEBRIONIDAE											-
Cylindronotus laevioctostriatus (Goeze.)		t	2	-	-	-	-	2	2	3	*Calluna* spp. (heather), under bark and in deadwood of a range of trees
SCARABAEIDAE											
Geotrupes spp.	-	df	5	-	-	-	-	-	-	-	
Aphodius spp.		df	-	-	-	-	-	-	2	-	
CHRYSOMELIDAE											

Phyllotreta spp.	-	p	1	1	-	-	-	-	-	-	
Haltica spp.	-	t	1	-	-	-	-	1	-	-	
Chaetocnema concinna (Marsh.)	-	p	-	-	-	1	-	-	-	-	
SCOLYTIDAE	-										
Dryocoetes villosus (F.)	-	t	-	-	-	2	-	-	-	-	Under bark of a range of deciduous trees
CURCULIONIDAE											
Apion frumentarium (Payk.)	Nb	p	-	1	-	-	-	6	3	1	On *Rumex* spp. (dock)
Apion spp.	-	p	6	-	-	-	1	1	-	5	
Polydrusus sp.	-	p	-	-	-	-	-	-	-	1	
Phyllobius spp.	-	t	-	-	1	-	-	-	5	-	
Trachyphloeus alternans Gyll.	Nb	p	-	-	-	-	1	1	3	7	Often associate with *Helianthemum nummularinum* (L.) Mill. (rock-rose) or *Plantago* spp. (plantains)
Trachyphloeus spp.	-	-	-	-	-	1	-	1	-	-	
Barypeithes spp.	-	-	4	-	-	-	-	3	4	7	
Strophosoma capitatum (Geer.)	-	t	-	-	-	-	-	-	-	1	
Sitona regensteinensis (Hbst.)	-	p	-	-	-	1	-	-	-	-	*Cytisus scoparius* (L.) Link (broom) or *Ulex europaeus* L. (gorse)
Sitona hispidulus (F.)	-	p	1	-	-	1	-	2	8	1	*Trifolium* L. (clover), FABACEAE (Pea Family)
Sitona cylindricollis (Fahrs.)	-	p	3	-	-	-	-	-	-	3	*Melilotus* spp. (melilot)
Sitona spp.	-	-	5	-	-	-	-	3	6	5	
Alophus triguttatus (F.)	Nb	p	-	-	-	-	-	1	-	-	*Plantago lanceolata* L. (ribwort plantain)
Hypera spp.	-	-	-	-	-	-	-	2	1	3	
Ceutorhynchus spp.	-	-	-	-	-	-	-	2	-	-	
Micrelus ericae (Gyll.)	-	m	-	-	1	-	-	-	-	2	*Calluna vulgaris* (L.) Hull (heather), *Erica tetralix* L. (crossed leaved Heather)
Gymnetron spp.	-	p	1	-	-	-	1	3	-	2	*Plantago lanceolata* L. (ribwort plantain), *Plantago* spp. (plantains)

Key to ecological groupings used
a= aquatic water beetles
ws = waterside taxa often associated with emergent vegetation
df = taxa often associated with dung
g = taxa often associated with grassland/pasture
p= taxa associated with grassland and open areas
t = taxa associated with dead wood, fallen timber and tree leaf
m= taxa associated with moorland

Red Data Book status (Hyman and Parsons 1994)
RDB1 = Endangered
RDB2 = Vulnerable
RDB3 = Rare
RDBK = Status not sufficiently known
RDBX = presumed extinct in the British Isles
NA and NB = notable species

Table 6. The proportions of the ecological groups of Coleoptera from Mynydd Parys

	Site S1	**Site S3**						
	0 – 30 cm	**50 – 46 cm (Sub-units 1-2)**	**46 – 38 cm (Sub-units 3-5)**	**38 – 30 cm (Sub-units 6-9A)**	**30 – 26 cm (Sub-unit 9B)**	**26 – 18 cm (Sub-unit 11)**	**18 – 8 cm (Sub-unit 14)**	**8 – 0 cm (Sub-unit 15)**
Minimum Number of Individuals	82	2	5	26	14	85	189	145
Minimum Number of Taxa	26	2	5	16	8	34	41	41
% Aquatic (a)	4.9%	0.0%	0.0%	3.8%	0.0%	2.4%	7.9%	4.1%
% Waterside (ws)	18.3%	0.0%	20.0%	23.1%	57.1%	20.0%	11.6%	19.3%
% Dung/ Foul Matter (df)	11.1%	0.0%	0.0%	0.0%	0.0%	6.1%	5.3%	6.3%
% Grassland (p)	20.6%	100.0%	0.0%	15.8%	50.0%	21.2%	9.2%	19.8%
% Trees/ Woodland (t)	12.7%	0.0%	25.0%	10.5%	16.7%	10.6%	9.2%	3.6%
% Moorland (m)	0.0%	0.0%	25.0%	0.0%	0.0%	0.0%	0.0%	1.8%

Table 7: Plant macrofossils – Site S1.1

Section		**1.1**	**1.1**	**1.1**	**1.1**	**1.1**	**1.1**	**1.1**	**1.1**	**1.1**	**1.1**	**1.1**
Context		**101**	**104**	**104**	**104**	**104**	**104**	**104**	**104**	**104**	**104**	**105**
Unit		**Top**	**12 + 11**	**10+9**	**8**	**6+7**	**5**	**4**	**3**	**2**	**1**	
Volume processed (ml)		100	100	100	100	100	100	100	100	100	100	100
Bud scales		-	(+)	+	-	+	+	(+)	(+)	-	+	(+)
Charcoal		+	-	-	+++	-	-	-	+++	++	+++	+
Insect / beetle		-	(+)	+	(+)	+	+	+	+	(+)	+	-
Waterlogged remains (total count)												
(g) *Leontodon* sp (Hawkbit)	achene	-	-	-	-	-	-	-	1	-	-	-
(q) *Chara* sp (Stoneworts)	oosporangium	-	-	-	-	-	-	-	1	-	-	-
(r) *Cerastium* sp (Mouse-ears)	seed	-	-	1	-	3	1	-	1	-	1	-
(r) *Persicaria lapathifolia* (Pale Persicaria)	nutlet	-	-	-	-	-	1	-	-	-	-	-
(r) *Plantago major* (Greater Plantain)	seed	-	-	-	-	-	1	-	-	-	-	-
(r) *Urtica dioica* (Common Nettle)	achene	-	-	1	3	2	2	2	-	-	1	-
(t) *Betula* sp (Birches)	fruit	-	-	-	1	1	-	-	-	-	-	-
(t) *Rubus* sp (Brambles)	fruitstone	-	-	-	-	1	-	-	-	-	3	-
(t) *Rubus fruticosus* agg. (Bramble)	fruitstone	-	-	-	-	1	-	-	-	-	1	2
(t) *Rubus idaeus* (Wild Raspberry)	fruitstone	-	-	-	-	1	-	-	-	-	-	-
(w) *Carex* sp (Sedges)	trigonous nutlet	-	-	-	-	4	1	-	-	-	2	-
(w) *Juncus* sp (Rushes)	seed	9	36	20	9	9	9	2	3	5	17	21
(w) *Juncus articulatus* type (Jointed Rush type)	seed	-	-	-	-	1	1	-	-	2	4	-
(w) *Juncus effusus* type (Soft-rush type)	seed	-	3	15	43	72	26	12	16	18	15	14
(w) *Rorippa* sp (Yellow-cresses)	seed	-	-	1	2	3	2	-	3	-	10	-
(w) *Schoenoplectus lacustris* (Common Club-rush)	nutlet	-	1	-	-	-	-	-	-	-	-	-
(w) *Sphagnum* sp (Sphagnum moss)	leaf	-	-	1	3	13	7	1	-	-	3	1
(w) *Sphagnum* sect. *Acutifolia* (Sphagnum moss)	leaf	-	66	-	-	1	-	-	-	-	-	-
(w) *Typha* sp (Bulrush)	seed	-	-	-	-	1	-	-	-	-	-	-
(x) Brassicaceae undiff. (Cabbage family)	seed	-	-	-	-	2	-	-	-	-	-	-
(x) Caryophyllaceae undiff. (Pink family)	seed	-	1	-	4	4	2	3	3	2	3	-
(x) *Cenococcum geophilum* (Soil fungus)	sclerotia	10	55	23	30	35	13	8	12	4	12	7
(x) *Chenopodium* sp (Goosefoots)	seed	-	-	1	-	-	-	-	1	-	-	-
(x) *Hypericum* sp (St John's-worts)	seed	-	-	1	-	1	1	1	1	-	-	-
(x) Musci sp (Mosses excluding *Sphagnum*)	branch	-	12	3	52	>200	51	8	12	19	32	-
(x) *Potentilla* sp (Cinquefoils)	achene	-	-	-	1	-	-	-	-	-	-	-
(x) Poaceae undiff. (Grass family)	caryopsis	1	11	3	21	16	11	8	17	6	35	-
(x) *Prunella vulgaris* (Selfheal)	nutlet	-	-	-	-	-	1	-	1	-	-	-
(x) *Pteridium aquilinum* (Bracken)	frond fragment	-	-	11	25	>200	4	3	11	2	5	-
(x) *Pteridium aquilinum* (Bracken)	sporangium (with spores)	-	97	-	248	408	-	-	166	31	-	-
(x) Pteridophyta undiff. (Ferns)	sporangium	-	-	60	-	-	114	90	-	-	63	30
(x) *Ranunculus* subgenus *Ranunculus* (Buttercup)	achene	-	-	-	-	-	1	-	-	-	-	-

[g-grassland; q-aquatic; r-ruderal; t-tree/woodland; w-wet/damp ground; x-wide niche.
(+): trace; +: rare; ++: occasional; +++: common; ++++: abundant]

Table 8: Plant macrofossils – Sections S1.2 and S1.3

Section		**1.2**	**1.2**	**1.2**	**1.2**	**1.3**	**1.3**
Context		**207**	**204**	**204**	**204**	**307**	**308**
Unit		**A**	**B**	**C**	**D**	**A**	**B**
Volume processed (ml)		100	100	100	100	100	100
Bud scales		-	(+)	-	-	-	-
Charcoal		+	+++	++	+++	(+)	+++
Insect / beetle		-	-	-	(+)	-	+
Waterlogged remains (total count)							
(r) *Cerastium* sp (Mouse-ears)	seed	-	-	-	-	-	1
(r) *Plantago major* (Greater Plantain)	seed	-	-	-	-	-	1
(r) *Urtica dioica* (Common Nettle)	achene	1	-	-	-	-	3
(t) *Rubus* sp (Brambles)	fruitstone	-	-	-	1	-	1
(w) *Carex* sp (Sedges)	trigonous nutlet	-	-	-	1	-	-
(w) *Juncus* sp (Rushes)	seed	11	5	8	16	7	10
(w) *Juncus articulatus* type (Jointed Rush type)	seed	-	-	-	1	-	-
(w) *Juncus effusus* type (Soft-rush type)	seed	8	-	-	20	-	59
(w) *Rorippa* sp (Yellow-cresses)	seed	-	-	-	2	-	3
(w) *Sphagnum* sp (Sphagnum moss)	leaf	4	1	-	9	-	2

(w) *Typha* sp (Bulrush)	seed	-	2	-	1	-	1
(x) Brassicaceae undiff. (Cabbage family)	seed	-	-	-	-	-	1
(x) *Cenococcum geophilum* (Soil fungus)	sclerotia	16	12	3	8	3	45
(x) *Chenopodium* sp (Goosefoots)	seed	-	-	-	-	-	1
(x) Musci sp (Mosses excluding *Sphagnum*)	branch	-	4	-	22	-	26
(x) *Potentilla* sp (Cinquefoils)	achene	-	1	-	-	-	1
(x) Poaceae undiff. (Grass family)	caryopsis	1	1	2	2	-	6
(x) *Pteridium aquilinum* (Bracken)	frond fragment	-	3	1	3	-	5
(x) *Pteridium aquilinum* (Bracken)	sporangium (with spores)	7	-	-	168	-	179
(x) Pteridophyta undiff. (Ferns)	sporangium	-	20	-	-	-	-

[r-ruderal; t-tree/woodland; w-wet/damp ground; x-wide niche.
(+): trace; +: rare; ++: occasional; +++: common; ++++: abundant]

Table 9: Plant macrofossils – Section S3

Section		**3**	**3**
Depth (cm) from the top		**0-30**	**30-52**
Volume processed (ml)		200	200
Ericaceae undiff. (Heathers)	leaves	+++	+++
Insect / beetle		+++	(+)
Waterlogged remains (total count)			
(g) *Leontodon* sp (Hawkbit)	achene	3	-
(q) *Callitriche* sp (Water-starwort)	fruit	2591	36
(q) *Lemna* sp (Duckweeds)	fruit	-	1
(r) *Aphanes* sp (Parsley-pierts)	seed	1	-
(t) *Betula* sp (Birches)	fruit	-	3
(t) *Rubus* sp (Brambles)	fruitstone	2	-
(t) *Rubus idaeus* (Wild Raspberry)	fruitstone	1	-
(w) Cyperaceae undiff. (Sedge family)	trigonous nutlet	1	-
(w) *Juncus* sp (Rushes)	seed	>2000	804
(w) *Juncus articulatus* type (Jointed Rush type)	seed	15	5
(w) *Juncus effusus* type (Soft-rush type)	seed	>2000	548
(w) *Rorippa* sp (Yellow-cresses)	seed	259	43
(w) *Sphagnum papillosum* (Sphagnum moss)	branch	1	-
(x) Brassicaceae undiff. (Cabbage family)	seed	-	1
(x) *Cenococcum geophilum* (Soil fungus)	sclerotia	51	82
(x) *Hypericum* sp (St John's-worts)	seed	1	-
(x) Lamiaceae undiff. (Dead-nettle family)	nutlet	-	1
(x) Musci sp (Mosses excluding *Sphagnum*)	branch	20	-
(x) *Potentilla* sp (Cinquefoils)	achene	11	-
(x) Poaceae undiff. (Grass family)	caryopsis	1	-
(x) Pteridophyta undiff. (Ferns)	sporangium	10	9
(x) *Rumex* sp (Docks)	nutlet	1	-
(x) *Saxifraga* sp (Saxifrages)	seed	2	-
(x) *Viola* sp (Violets)	seed	2	-

[g-grassland; q-aquatic; r-ruderal; t-tree/woodland; w-wet/damp ground; x-wide niche.
(+): trace; +: rare; ++: occasional; +++: common; ++++: abundant]

APPENDIX II: PALAEOENVIRONMENTAL DATA

Introduction

Palaeoenvironmental data collected from mine spoil heaps, gallery floors and sediments that accumulate in mines and adits during and after the cessation of activities can all feasibly preserve evidence of human-environment interactions in the mining landscape including resource-based aspects of mining, such as firesetting and the use of wood fuel, and vegetational changes such as the depletion of local woodland, as well as generating a pollution signal (Burnham *et al.* 1992; Mighall & Chambers 1993; Mighall *et al*. 2000; 2002a and b, 2009, 2017).

Sediments from S1.1 and S3 were targeted for analysis. A monolith was cut from context (hereafter referred to as 'unit') 104 (Fig. 5; Table 3), which has been radiocarbon-dated to 3499 ±43 BP (1940-1690 cal BC; Table 1) that appear to confirm that the sediments are of prehistoric age. Additional bulk samples were obtained from units 101, 105, 204, 207 307 and 308 for plant macrofossil analysis. The latter two units have radiocarbon dates of 3595 ±42 (307; 2130-1780 cal BC) and 3514 ±44 (308; 1960-1690 cal BC) placing them into the Bronze Age. A second monolith was taken from S3 (Fig. 5; Table 4).

A stratigraphic description of both monoliths is provided in Tables 3 and 4. Each sedimentary layer was assigned a sub-unit number and a sample from each sub-unit was analysed for pollen using the procedure described by Barber (1976), incorporating a density flotation procedure (Nakagawa *et al*. 1998). Three hundred land pollen grains were counted for each sub-sample. Pollen was identified with the aid of keys (Fægri *et al.* 1989; Moore *et al.* 1991; Andrew 1984), photographs (Reille 1992) and reference to a modern type slide collection. The results of the pollen analysis are shown in Figs 10 and 11. The data are expressed as percentages of total land pollen (TLP).

Insect samples were processed at the Department of Classics, Ancient History and Archaeology (University of Birmingham) using the standard method of paraffin flotation as outlined in Kenward *et al*. (1980). Insect remains were sorted and identified under a low-power binocular microscope at magnifications between x15 – x45. Where achievable, the insect remains were identified to species level by direct comparison to specimens in the Gorham and Girling Insect Collections housed at the University of Birmingham. The majority of the insect fauna recovered were Coleoptera (beetles) with a few Hemiptera (true bugs) and Diptera (flies) present. A list of the insects recovered is presented in Table 5. In order to aid interpretation, where possible, taxa have been assigned to ecological groupings,

following a simplified version of the scheme suggested by Robinson (1981, 1983; Table 5, column 3).

Sub-samples of sediment were disaggregated in cold water and washed through a nest of sieves ranging from 150-500μm to extract plant macrofossils. The 17 sub-samples from Site S1.1 were 100ml in volume, while the two from Site S3 (0-30cm and 30-52cm) were 200ml. The wet residues were scanned for botanical remains at up to x60 magnification using a Leica MZ7.5 stereomicroscope. Fern sporangia were examined at up to x600 magnification to look for diagnostic spores. Identifications were undertaken by comparison with modern reference material. Plant nomenclature follows Stace (2010). Habitat classifications follow Preston *et al.* (2002). Results are presented in Tables 7, 8 and 9.

Sites S1 .1, 1.2, 1.3, Unit 104 (Fig. 10; Table 5, 7, 8 and 9)

Twelve samples were analysed from 11 stratigraphic sub-units for microfossils. Two samples were analysed from sub-unit 8, whilst sub-unit 11 contained no pollen. The pollen diagram is characterised by the regular occurrence of tree and shrub pollen. *Corylus avellana*-type is well represented along with *Quercus, Betula* and *Alnus*. *Pinus, Ulmus, Tilia* and *Fraxinus* are recorded sporadically in trace amounts. Notwithstanding the taphonomic processes that have led to the accumulation of these sediments, these data suggest the presence of a mixed deciduous woodland locally. This woodland contains taxa (such as oak and hazel) commonly used in prehistoric mines, for example, firesetting (Timberlake 2003). The total percentage of tree and shrub pollen suffers a short-lived decline in the lowest sample of sub-unit 5, and selective declines in *Quercus* occur between sub-units 5 and 6 and from sub-unit 7 to 8. *Corylus avellana*-type percentages decrease between sub-units 6 and 7 and sub-units 10 and 11 (along with *Alnus*). These declines may well be the result of demand for timber and wood by the miners. They are typical of the small-scale, temporary decreases in woodland taxa reconstructed in pollen diagrams close to prehistoric mining and metalworking sites (e.g. Mighall and Chambers 1993; Mighall *et al*. 2000).

Evidence for trees and shrubs in the plant macrofossil record from S1.1, S1.2 and S1.3 is limited to a few remains of *Betula* (birch), *Rubus* (brambles and raspberry), indeterminate bud scales, and sclerotia of the soil fungus *Cenococcum geophilum*. The latter is an ectomycorrhizal species commonly found in soils of scrub and woodland and has mutualistic associations with certain trees, particularly members of the Betulaceae (birch, alder and hazel), Fagaceae (oak) and Pinaceae (pine) families (Hudson 1986). Charcoal remains are common in six of the S1 samples, reflecting availability of wood fuel.

The insect fauna from S1.1 is moderately sized, fairly diverse and dominated by a range of beetles (Coleoptera). This includes a limited number of taxa associated with woodland: *Agathidum sphaerulum*, which is associated with rotting wood and timbers, and *Cylindronotus laevioctostriatus*, which is found under the bark or in the rotting wood of oak, beech and in the decayed stumps of heather. The members of the *Haltica* genus are normally associated with willow or heather.

Wet, acidic grasslands were also part of the mosaic of vegetation in and around Mynydd Parys. Poaceae percentages are well represented in each sub-unit, with a suite of herbaceous pollen taxa present in low percentages throughout the S1.1 sedimentary sequence including Cyperaceae, Caryophyllaceae, Apiaceae and *Succisa*, indicative of fen/marsh (Brown *et al*. 2007). This is supported by the plant macrofossil record from S1.1, S1.2 and S1.3 which comprise a broadly similar range of plant remains, largely deriving from open grassland and wetland habitats. Damp ground communities with *Juncus* sp (rushes), *Carex* sp (sedges) and *Rorippa* sp (yellow-cress) are represented, with low occurrences of *Sphagnum* leaves reflecting mire vegetation. A single oosporangium of the submerged aquatic *Chara* sp (stonewort), coupled with rare records of emergents *Typha* sp (bulrush) and *Schoenoplectus lacustris* (common club-rush), and the trace occurrence of *Potamogeton natans*-type pollen, indicates the presence of plant species associated with small pools of standing water.

Damp open grassland, meadow and/or grazed pasture are additional features of the landscape, as reflected by plant macrofossil records of Poaceae (grasses), *Leontodon* sp (hawkbits), *Cerastium* sp (mouse-ears), *Potentilla* sp (cinquefoils), *Prunella vulgaris* (selfheal) and *Ranunculus* sp (buttercups). Ruderals including *Persicaria lapathifolia* (pale persicaria) and *Plantago major* (greater plantain) would have favoured open disturbed habitats, with *Chenopodium* sp (goosefoots) and *Urtica dioica* (common nettle) indicating areas of relatively nutrient-rich soils.

A noticeable peak in Ranunculaceae, *Potentilla*-type and *Plantago lanceolata*, that are indicative of disturbed ground and pasture, is also observed in the lowest sample from sub unit 5 in the S1.1 pollen record, and coincides with the decrease in the percentage of tree and shrub pollen. Changes in the percentages of these taxa and the presence of others, including Lactuceae, *Rumex* sp. and *Polygonum aviculare*-type, and the occurrence of coprophilous dung fungi, *Tripterospora*-type (HdV-169A) and *Podospora*-type (HdV-368) (van Geel *et al*. 2003), suggest that humans were exploiting local grasslands, possibly for grazing. *Calluna* also exceeds 5% (of total land pollen) and this may well be derived from heather that still colonises the spoil deposited on Mynydd Parys today.

Bracken, a fern of moorland and hill pasture, is represented in most of the samples by both sporangia and frond fragments, and would have been well suited to the acidic soil conditions of the site. Notably large numbers of bracken (and moss) remains are present in context 104 (sub-unit 6 & 7; Table 7), the most species diverse sample from Site S1.1. Bracken may have provided a useful resource to former inhabitants of the site, as the dry, brown fronds in autumn make a good fuel and fresh fronds were useful for packing and flooring material (Gale & Cutler 2000).

The beetle fauna also contains a number of taxa that are associated with species of plants from open areas, grassland or disturbed ground (group 'g' in Table 5 and Fig. 14) consistent with the pollen evidence. Typical of these taxa are *Apion* spp., *Sitona hispidulus* (associated with melilots – *Melilotus* spp.), *Sitona cylindricollis* (associated with clover – *Trifolium* spp.) and *Gymnetron* spp. (associated with plantains – *Plantago* spp.). The 'dor beetle' *Geotrupes* spp. is usually associated with animal dung in heathland, rough grassland and sandy areas (Jessop 1986). Most species of *Choleva* and *Barypeithes* are found associated with the roots of grass and mossy areas. Many of the Carabidae 'ground beetle' recovered, such as *Trechus quadristriatus*, *Pterostichus madidus*, and *Calathus* spp., are associated with heathland or chalkland and *Amara equestris* is particularly associated with stony or sandy ground in heathland or chalkland environments (Lindroth 1974; Luff 2007). A small number of water beetles such as *Hydroporus* spp. and *Cyphon* spp. were also recovered.

S3 (Fig. 11)

The upper (0-30 cm) and lower (30-52 cm) plant macrofossil samples from site S3 (Table 9) comprise largely similar vegetation communities, with a greater number and diversity of macrofossils present in the upper sample. A number of herbaceous taxa in the upper plant macrofossil sample are characteristic of areas of open grassland, pasture and disturbed ground. The species are similar to those recorded for Site S1.1, with the additional presence of *Rumex* sp (docks) and *Aphanes* sp (Parsley-pierts) in the plant macrofossil record and taxa such as *Plantago lanceolata*, *Rumex*, *Potentilla*-type, Lactuceae and Brassicaceae consistently found in the pollen record.

Although a number of taphonomic processes may have been involved in the formation of the organic deposits within the mine, it is interesting to note that a significant proportion of the plant remains from both sites are indicator species for the use of grassy moorland turfs from archaeological deposits, as defined by Hall (2003). In particular, bracken, mosses and heather are frequent elements, with *Potentilla*, *Leontodon*, *Prunella vulgaris*, *Ranunculus*,

Rumex, Viola and *Cenococcum geophilum*, listed as characteristic above and below ground species. Turfs were used for a variety of purposes, and it is feasible that locally-cut turfs were brought into the mine as packing material or for retaining water.

Calluna and Ericaceae pollen and macrofossils are abundant, suggesting that ericaceous plants have become well established locally. However, both decline from sub-unit 11 in the pollen record as Poaceae, *Potamogeton natans*-type and *Equisetum* all increase dramatically. The latter two taxa are indicative of open water and/or very wet conditions. Abundant *Callitriche* sp (water-starwort), which occurs with a minor element of *Lemna* sp (duckweed) in the plant macrofossils, indicates shallow pools of temporary or permanent water. Associated damp ground taxa, predominantly comprising species of *Juncus* and *Rorippa*, occur in the plant macrofossil record. Taxa such as *Filipendula*, Apiaceae and Cyperaceae are regular members of wet grassland/rough meadow communities and are present particularly in the upper sub-units of the S3 pollen record.

Beetle species associated with rough grassland and open areas occur in some numbers. Typical of this kind of landscape is the range of ground beetles recovered such as the *Carabus, Trechus, Calathus* and *Amara* species (Table 5). A number of species such as the ground beetle *Trichocellus placidus* and the weevil *Trachyphloeus alternans* are associated with sandy open areas, often within chalkland and heathland, with the latter species sometimes associated with rock rose (*Helianthemum nummularinum* Mill). Other species commonly occur on plants within rough grassland; for example, *Apion frumentarium* is associated with docks, *Alophus triguttatus, Gymnetron* spp. with plantain (*Plantago* spp.) and *Sitona hispidulus* with clover (*Trifolium* spp.). There is also some indication for heather in the area, since this is the food plant of the small weevil *Micrelus ericae*. Very small numbers of *Aphodius* spp. dung beetles were recovered from samples at sub-unit 11 at Site S3, which suggests that grazing animals may have been present.

Cenococcum geophilum, *Betula* and *Rubus* in the plant macrofossil record provide evidence for scattered trees and shrubs and scrub/woodland soils. Initially total tree and shrub pollen percentages are similar to those recorded at S1.1. However, they decline permanently to less than 25% TLP by sub-unit 3 in S3 and remain around that value until they drop slightly once again between sub-units 14 and 15. *Quercus* is most adversely affected. *Corylus avellana*-type is the dominant shrub taxa fluctuating between 5 and 10% TLP. Small fluctuations also affect *Alnus* and *Betula*, but the percentages of both taxa show minor increases between sub-units 7 and 11 (Fig. 11). The permanent loss of *Quercus* may well be related to its use in the mine, especially as herbaceous pollen associated with pasture and/or

disturbed ground also decline. The increased presence of heathland, suggested by higher percentages of *Calluna* and Ericaceae, replaces woodland as the major type of local land use. Given the much lower percentages of arboreal pollen in this section, it is possible that it represents a different and probably later time period than S1.1.

There is also evidence for trees or woodland in the area in the beetle record. Both *Agathidium atrum* and *A. sphaerulum* are associated with decaying wood, leaf litter and moss in woodland. *Cylindronotus laevioctostriatus* was also recovered in some numbers at site S3 and indicates the presence of rotting wood and heather stems. The wood boring scolytid *Dryocoetes villosus* was recovered at 38 – 30 cm (Table 5, sub-units 9A-6) and is associated with a wide range of hard-wood trees and is more likely to occur on live trees than timbers.

Discussion

The S1.1 deposits comprise waste spoil from mining and the back-filling or infilling (through possible slumping) of the excavated workings, as well as possibly residue from the crushing and washing process by which copper ore was removed (Fig. 5 - S1.1). Whether this came from work carried out underground, or from sediments washed down into the workings, is unknown, but the radiocarbon dates clearly place these deposits in the Bronze Age. While not directly radiocarbon-dated, the layers of finely banded clay-silt material (unit 104) sandwiched in-between the dated units are indicative of ponding during a period between two phases of back-filling or natural infilling of the workings.

The macro- and micro-fossil records support the idea that the unit 104 deposits were washed-in from the surface. The pollen, plant macrofossil and insect faunas recovered clearly have an origin outside of the mine. There has been little intensive research into the beetle faunas from cave and mine sites, but a few species have been recorded from both the thresholds and interior of underground systems. It appears that a number of ground beetles such as *Trechoblemus micros* (Hbst.) and *Trechus fulvus* Dej., the staphylinid *Quedius mesomelinus* (Marsh.) and the catopid *Choleva* spp. have been recorded regularly in caves (Cambrian Caving Council 2010), but such taxa are noticeably absent from the Mynydd Parys insect faunas. This suggests that these faunas along with pollen and plant macrofossils have probably been swept into the mine, possibly during floods or more gradually as water percolated from the surface. These insects, pollen and plant macrofossils suggest, therefore, that the area around the mine itself was mainly open grassland and rough ground with some limited woodland.

It is not clear how representative these assemblages are of the surrounding landscape. The beetle faunas are comparatively small (with a minimum number of individuals ranging between two and 145 identifications, representing between two and 41 different taxa) and there are issues over how these insects' remains and the macro- and microfossils may have entered the mine and their resultant taphonomy. Despite these reservations, it does appear that generally there are fewer insect species associated with woodland towards the top of the deposit than lower down. Taken at face value this provides limited evidence to support a progressive clearance of the landscape over this period of time, which broadly confirms the results of the pollen analysis.

Pollen preservation appears to have been largely unaffected by any transportation process(es). Whilst the condition of pollen grains show signs of deterioration, identifiable counts of 300 TLP were achieved throughout the sequence (Delcourt and Delcourt 1980; Jones *et al*. 2007). Pollen grain damage (broken, crushed, corroded and/or degraded) was recorded at both sections S1.1 and S3, with crushing and degradation most likely caused during transportation in water. Some of the corroded, crushing and broken grains will reflect in-wash and possible reworking of pollen contained within eroded material (cf. Tipping 1987; Wilmshurst & McGlone 2005a; 2005b). Degraded grains are commonly crushed or crumpled, which also indicates that they have been transported and are then redeposited (Cushing 1967; Lowe and Walker 1997). Notwithstanding these issues, the proportion of unidentifiable grains is below some of the thresholds suggested for data being unrepresentative from soils (Bunting *et al*. 2001; Tipping *et al*. 1994).

The seven samples from S3 produced a series of insect faunas that are also essentially similar to that recovered from S1.1 However, it is noticeable that the insect remains were recovered in high numbers and were better preserved moving up the section. This is unexpected and runs counter to the nature of preservation in most archaeological deposits, where preservation usually is best at the base of the material sampled.

Conclusion

The palaeoenvironmental records from Mynydd Parys confirm that the landscape surrounding the mine was largely open with areas of heathland and wet grassland with some pools of water. Deciduous woodland was present, mainly comprising oak and hazel. A permanent decline in woodland was recorded at site S3, with oak being most affected. Otherwise, the tree and shrub pollen record is characterised by small-scale fluctuations of oak, hazel, birch and alder, all known to have been used in prehistoric mines.

Notwithstanding taphonomic and dating issues, trends in both pollen diagrams are similar to those recorded in other pollen diagrams close to prehistoric mining and metalworking sites, in particular small-scale fluctuations of *Quercus*, *Corylus*, *Alnus* and *Betula* (Mighall & Chambers 1993; Mighall *et al*. 2017). It is possible that these fluctuations are the result of exploitation of local woodland for timber and charcoal. The permanent decline in tree and shrub pollen at Site S3 contrasts with evidence from other Bronze Age mines in Wales and Ireland which suggests woodland was not severely cleared (Mighall & Chambers 1993; Mighall *et al*. 2017). However, all these mines including Mynydd Parys, did not operate in isolation and agricultural activities, in particular grazing, occurred as part of a dual economy.

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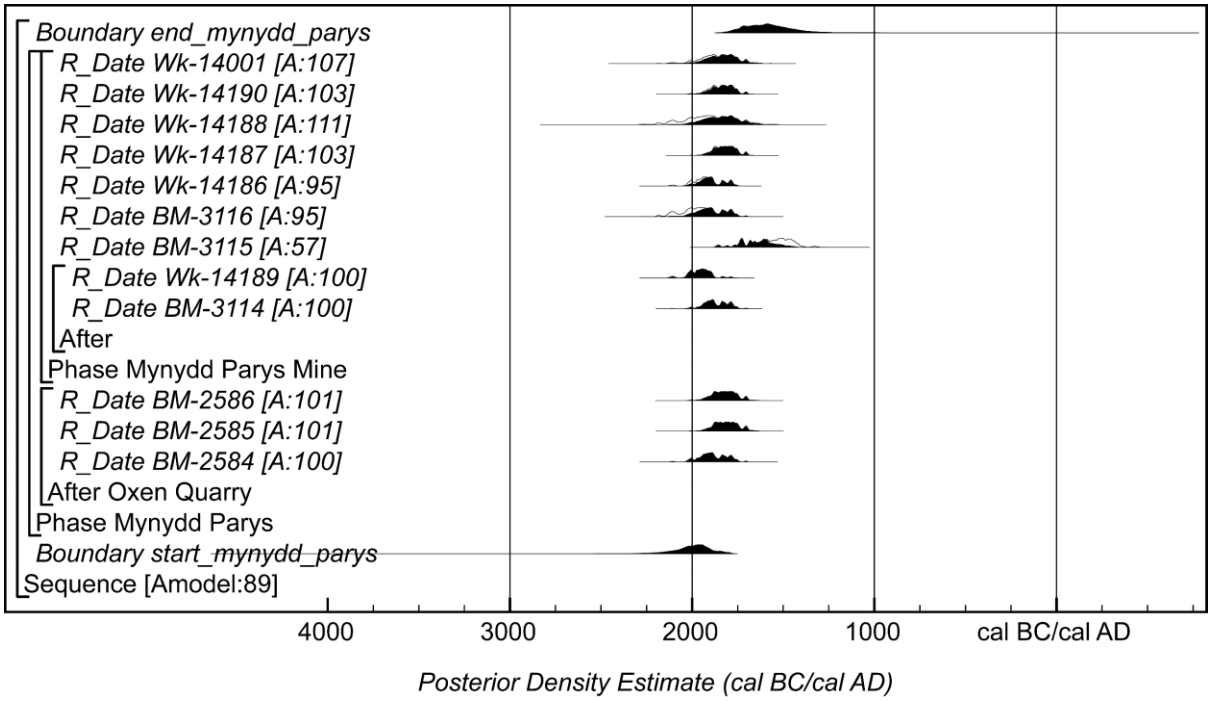
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R_Date BM-3115 [A:57]
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After
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Phase Mynydd Parys
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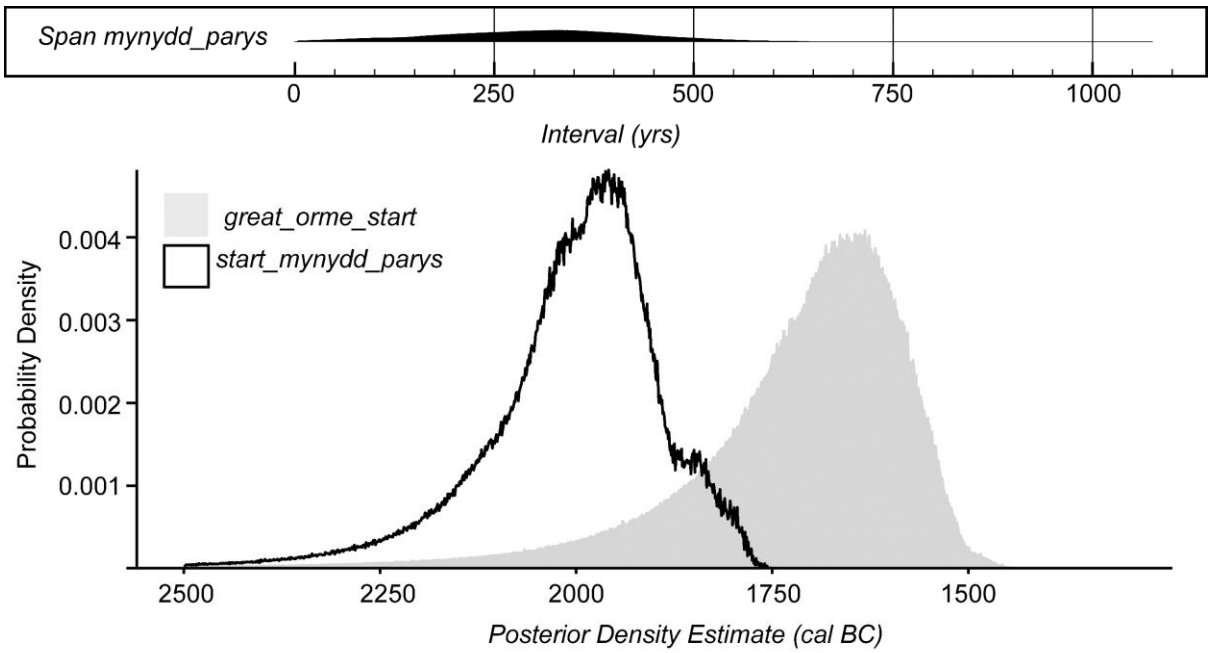
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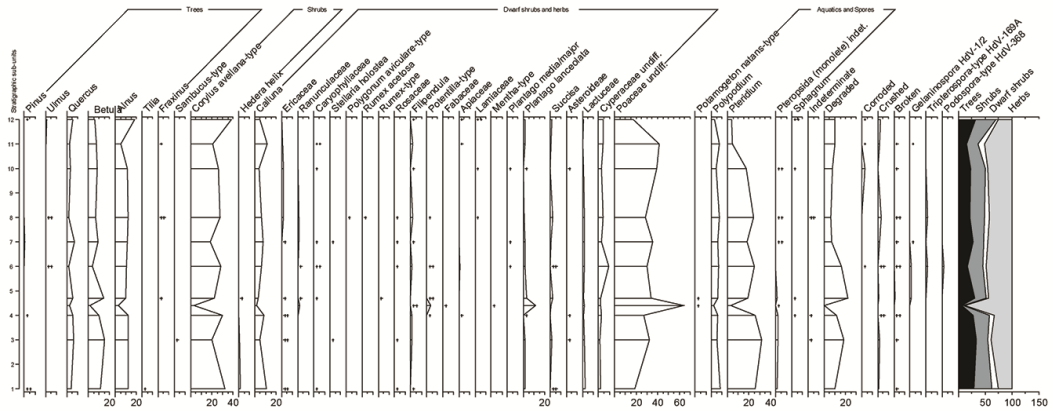
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Shrubs
Dwarf shrubs and herbs
Aquatics and Spores
Stratigraphic subunits
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Alnus
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Sambucus-type
Corylus avellana-type
Hedera helix
Calluna
Ericaceae
Ranunculaceae
Caryophyllaceae
Stellaria holostea
Polygonum aviculare-type
Rumex acetosa
Rumex-type
Rosaceae
Filipendula
Potentilla-type
Fabaceae
Apiaceae
Lamiaceae
Mentha-type
Plantago media/major
Plantago lanceolata
Succisa
Asteroideae
Lactucaceae
Cyperaceae undiff.
Poaceae undiff.
Potamogeton natans-type
Polypodium
Pteridium
Pteropsida (monolete) indet.
Sphagnum
Indeterminate
Degraded
Corroded
Crushed
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Shrubs
Dwarf shrubs
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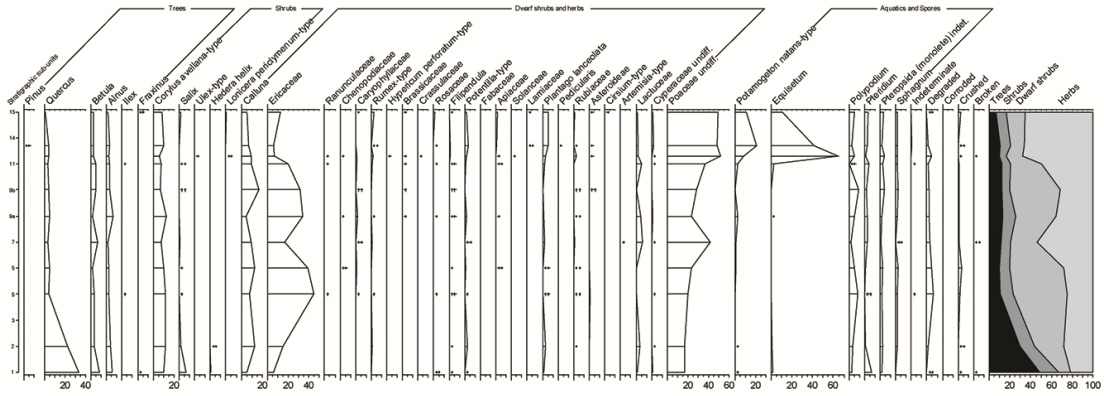
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Shrubs
Dwarf shrubs and herbs
Aquatics and Spores
Stratigraphic subunits
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Salix
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Calluna
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Ranunculaceae
Chenopodiaceae
Caryophyllaceae
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Rosaceae
Filipendula
Potentilla-type
Fabaceae
Apiaceae
Solanaceae
Lamiaceae
Plantago lanceolata
Pedicularis
Rubiaceae
Asteroideae
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Artemisia-type
Lactucaceae
Cyperaceae undiff.
Poaceae undiff.
Potamogeton natans-type
Equisetum
Polypodium
Pteridium
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Sphagnum
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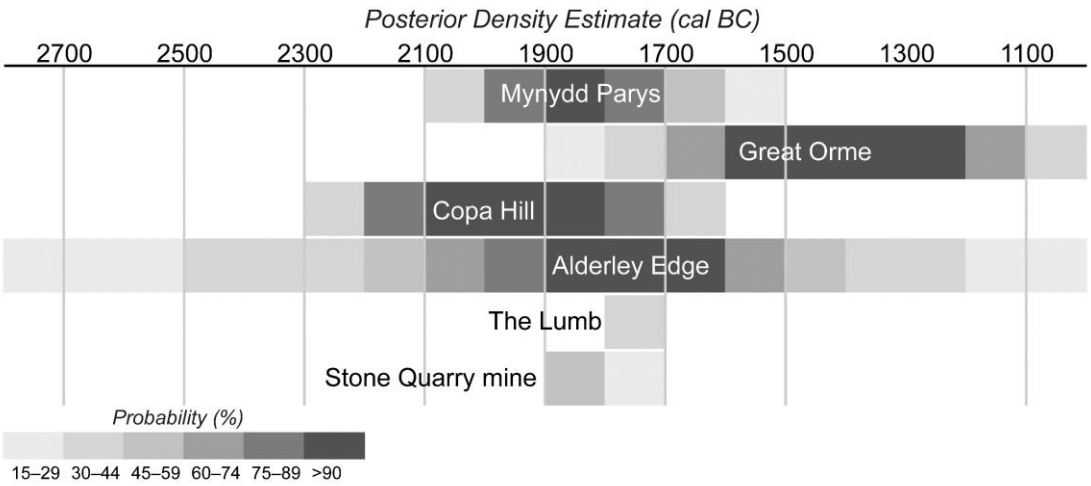
Corroded
Crushed
Broken
Trees
Shrubs
Dwarf shrubs
Herbs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The Lumb
Stone Quarry mine
Probability (%)
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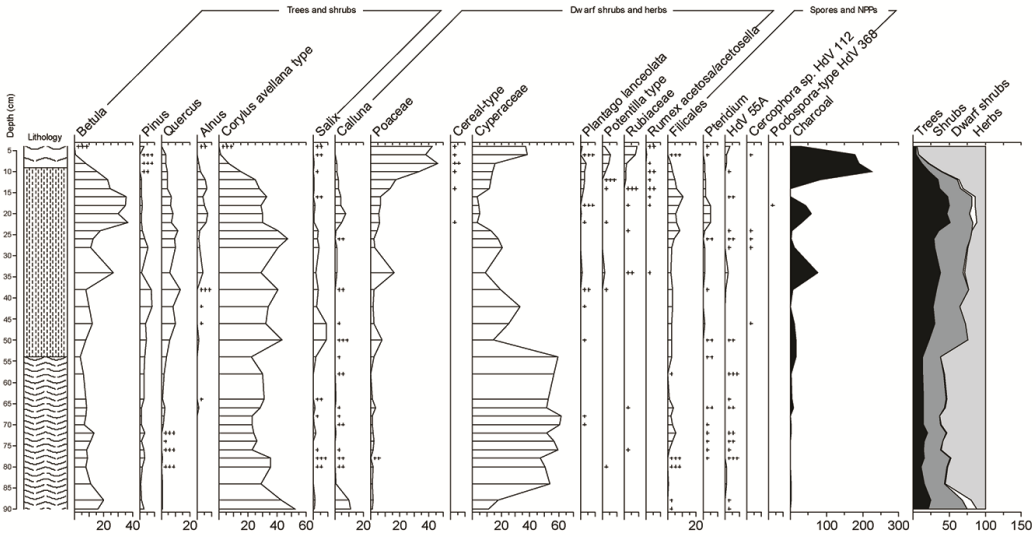
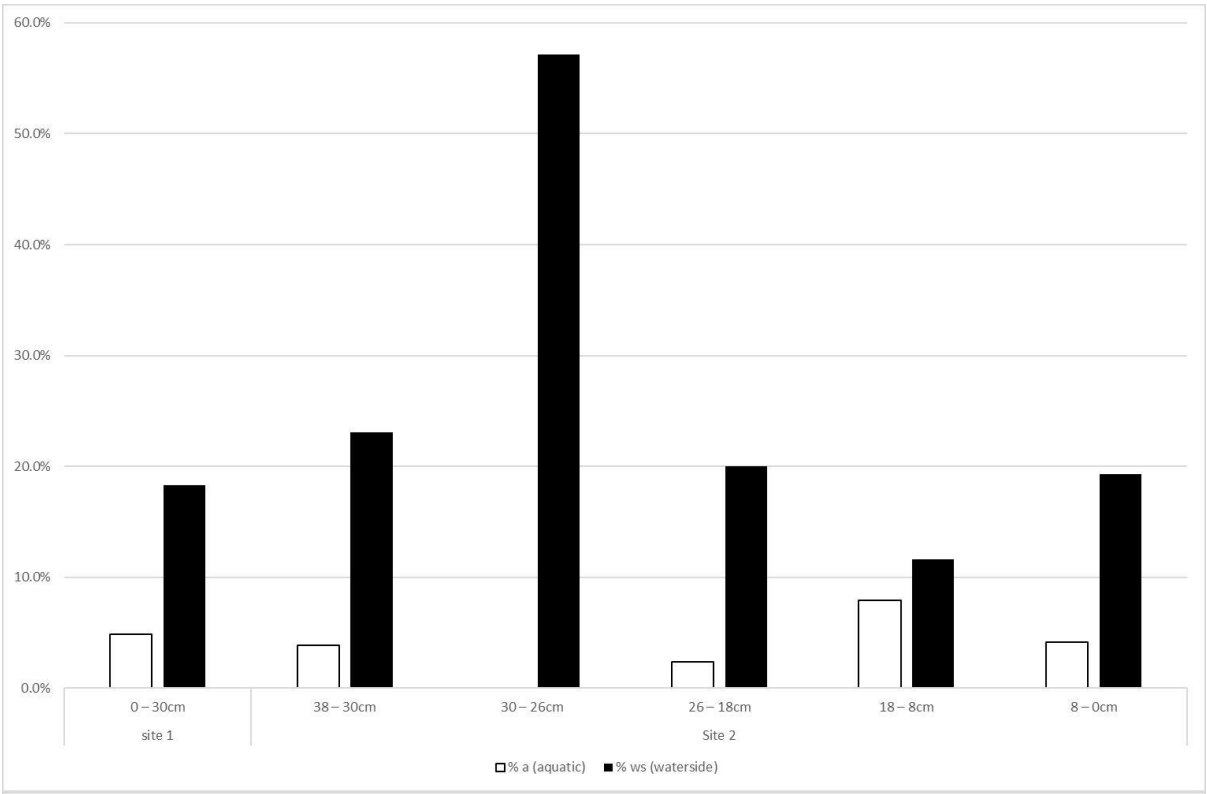
30–44
45–59
60–74
75–89
>90


Trees and shrubs
Dwarf shrubs and herbs
Spores and NPPs
Depth (cm)
Lithology
Betula
Pinus
Quercus
Alnus
Corylus avellana type
Salix
Calluna
Poaceae
Cereal-type
Cyperaceae
Plantago lanceolata
Potentilla type
Rubiaceae
Rumex acetosa/acetosella
Filicales
Pteridium
HdV 55A
Cercophora sp. HdV 112
Podospora-type HdV 368
Charcoal
Trees
Shrubs
Dwarf shrubs
Herbs


60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
0 – 30cm
38 – 30cm
30 – 26cm
26 – 18cm
18 – 8cm
8 – 0cm
site 1
Site 2
% a (aquatic)
% ws (waterside)

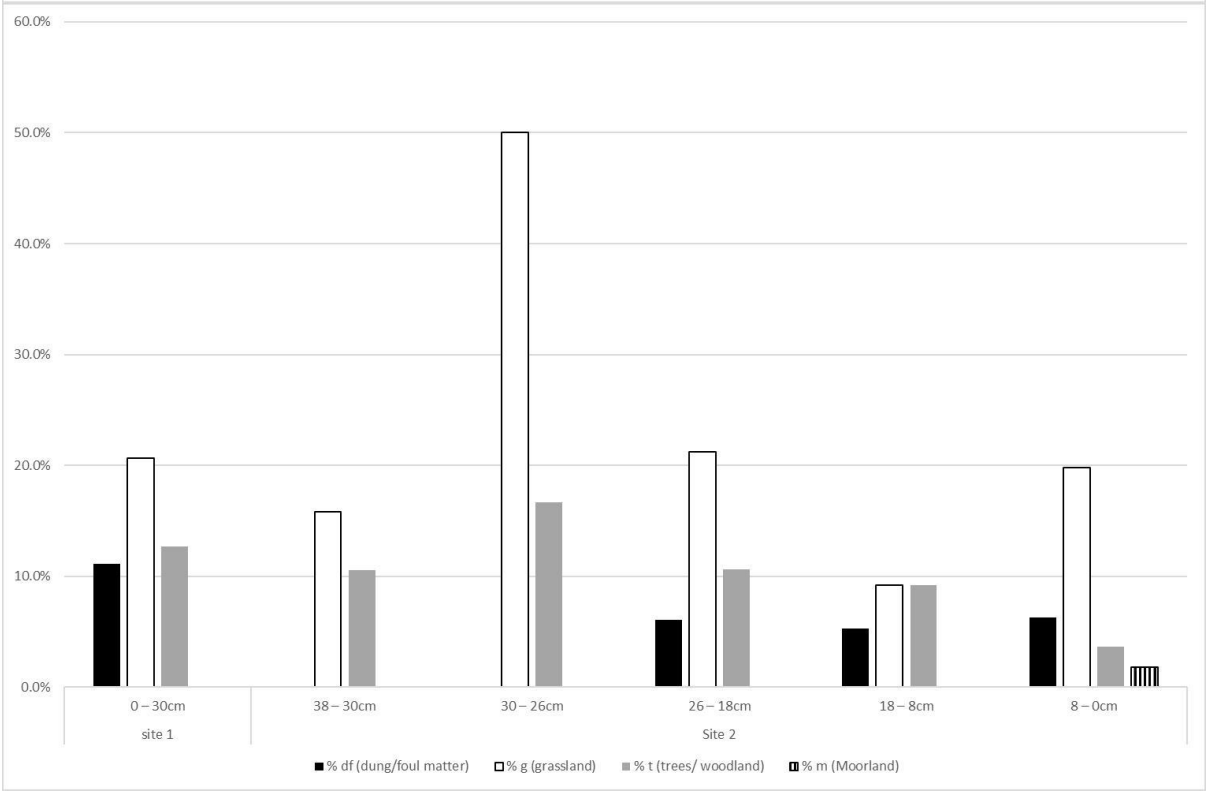

60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
0 – 30cm
38 – 30cm
30 – 26cm
26 – 18cm
18 – 8cm
8 – 0cm
site 1
Site 2
% df (dung/foul matter)
% g (grassland)
% t (trees/ woodland)
% m (Moorland)

Figure captions

Fig. 1. Location map for the mines on Mynydd Parys.

Fig. 2. Map of above ground Bronze Age sites 1 to 4 on Mynydd Parys showing distribution of mauls found on the surface and location of underground sites in relation to surface features (superimposed on the 1924 OS 25 inch map).

Fig. 3. Plan of the 10, 16 and 20fm levels with above a 3D sketch map of the underground Bronze Age sites (S1-7).

Fig. 4. One suggested method of working from the surface using inclined opencasts (hatched) excavated by firesetting. NB most of the mining will have taken place within the oxidised/ supergene zone above the pre-mining water table (drawing S. Timberlake, after Jenkins 1995, 36).

Fig. 5. Sections at underground sites S1 and S3 with lab numbers for dated samples marked.

Fig. 6. Hammerstones recovered in 1988 from surface excavations carried out at the Oxen Quarry – **a** Site 3 Trench D (001); **b** Split and notched hammerstone re-used from Site 2 surface find; **c** Hammer spall surface find; **d** Hammerstone with a faint rill around its middle modified to take a handle Site 3 Trench A (drawn by Brenda Craddock).

Fig. 7. Probability distributions of dates from Mynydd Parys. Each distribution represents the relative probability that an event occurs at a particular time. For each radiocarbon date, two distributions have been plotted: one in outline which is the result of simple radiocarbon calibration, and a solid one based on the chronological model used. The other distributions correspond to aspects of the model. For example, the distribution '*start_mynydd_parys*' is the estimate for when mining activity started. The large square brackets down the left-hand side of the diagram and the OxCal keywords define the overall model exactly.

Figure 8. Probability distribution for the number of years during which mining activity occurred at Mynydd Parys, derived from the model defined in Fig. 10.

Fig. 9. Probability distributions of estimates for the beginning of mining activity at Mynydd Parys (derived from Fig. 10) and the Great Orme (derived from the model described in Timberlake & Marshall (2013, fig 4)).

Fig. 10. Pollen diagram for S1.1, Unit 104.
Both pollen diagrams, drawn using Tilia and Tilia.graph version 2.0.b4 (Grimm, 1991-1993), are presented as percentages of total land pollen (TLP), excluding spores and aquatics. Spore and aquatics are also expressed as a percentage of total land pollen. A cross denotes one pollen grain. Plant nomenclature follows that of Stace (1991) and takes into account the problems of categorising plant species on the basis of their pollen morphology (see Bennett et al., 1994). Summary curves for trees, shrubs (constituting arboreal pollen, AP), dwarf shrubs and herbs (non-arboreal pollen, NAP) are shown.

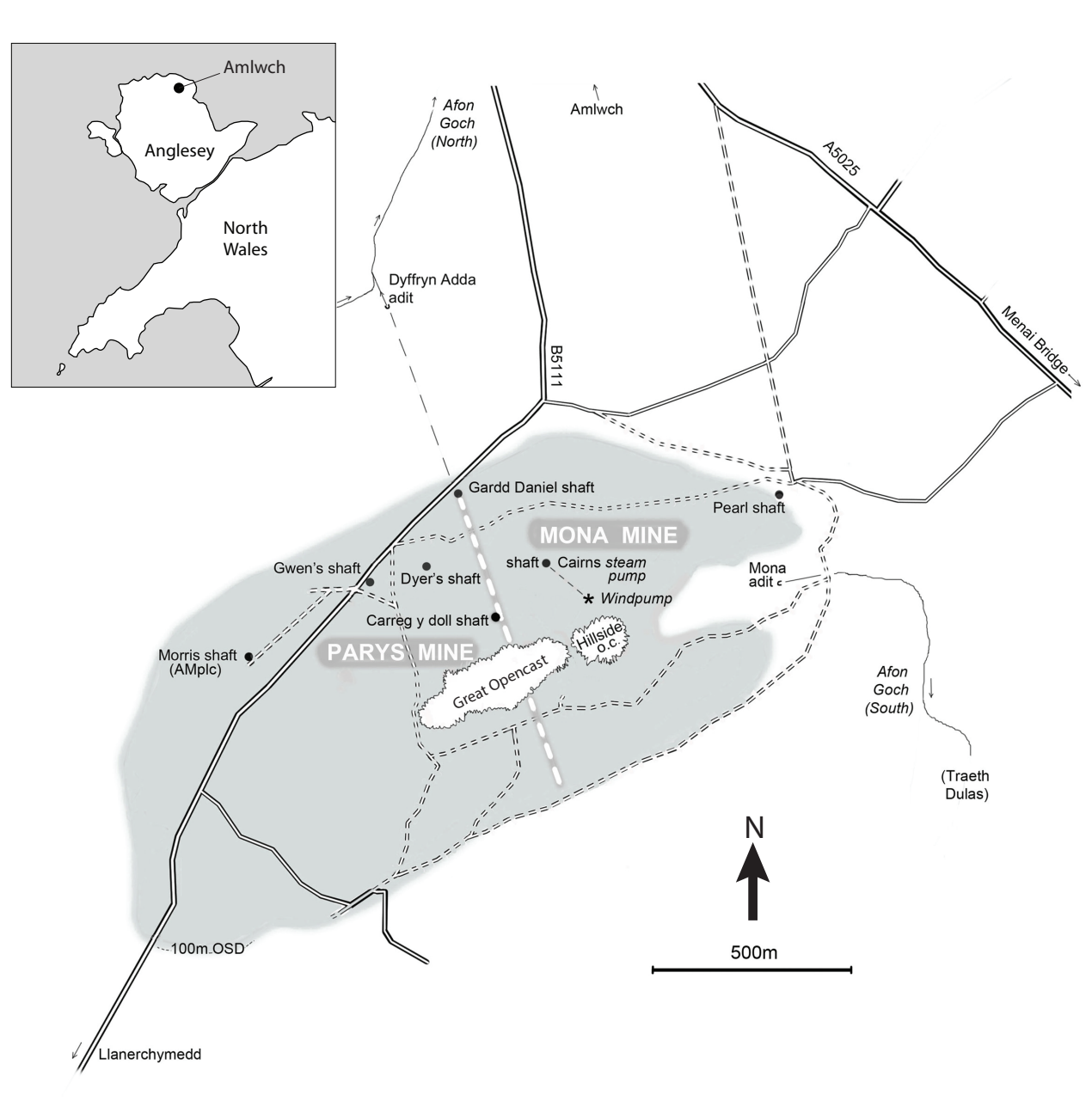
Fig. 11. Pollen diagram for S3.

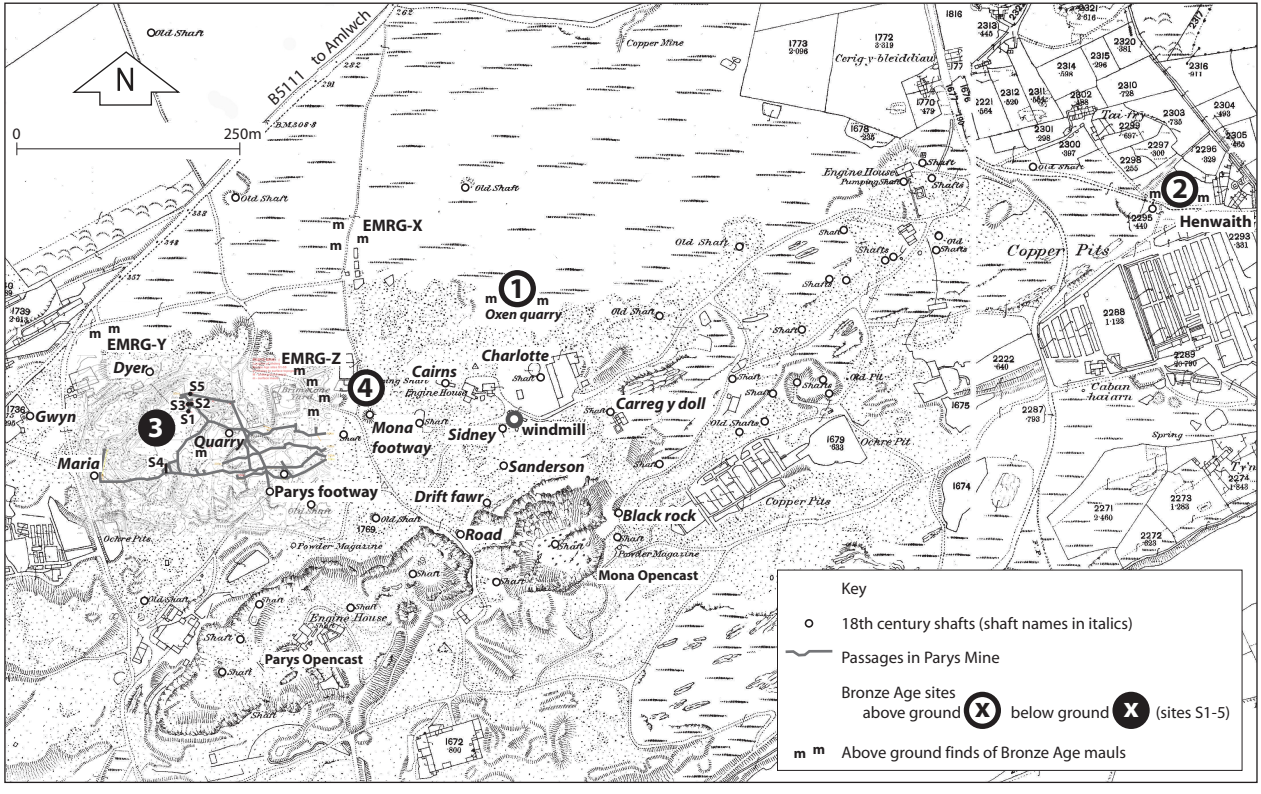
Fig. 12. Schematic diagram showing the periods of use of dated Bronze Age mining sites (Peter Marshall).

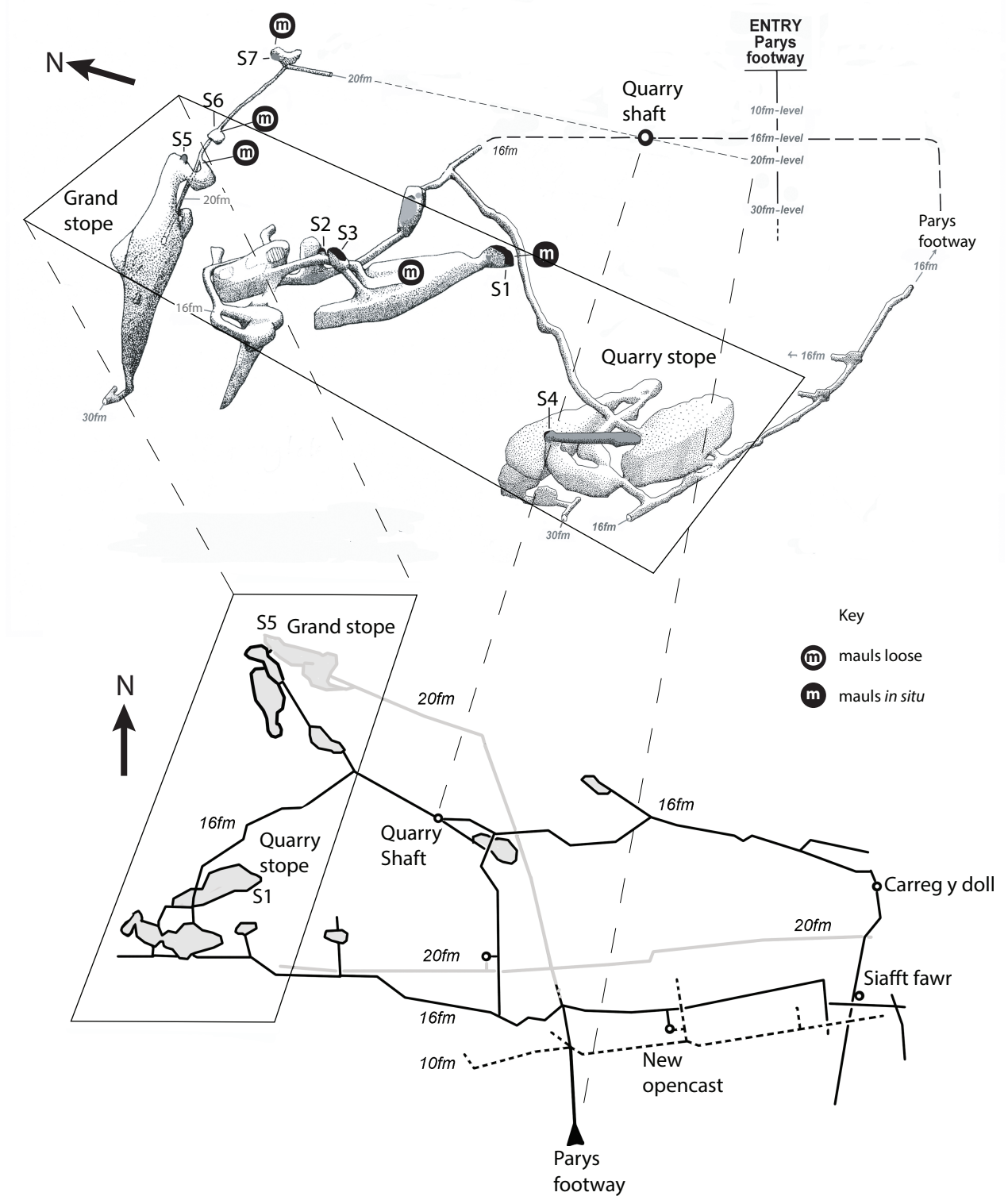
Fig. 13. Pollen diagram from Rhosybol.

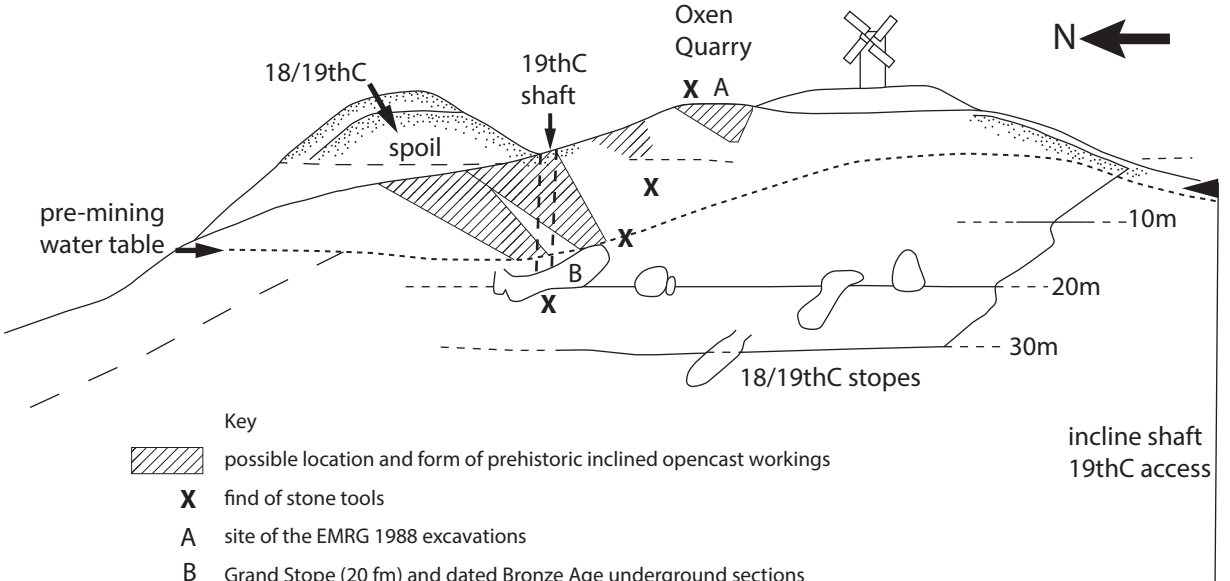
Fig. 14. The proportions of the aquatic ecological groups from Mynydd Parys.

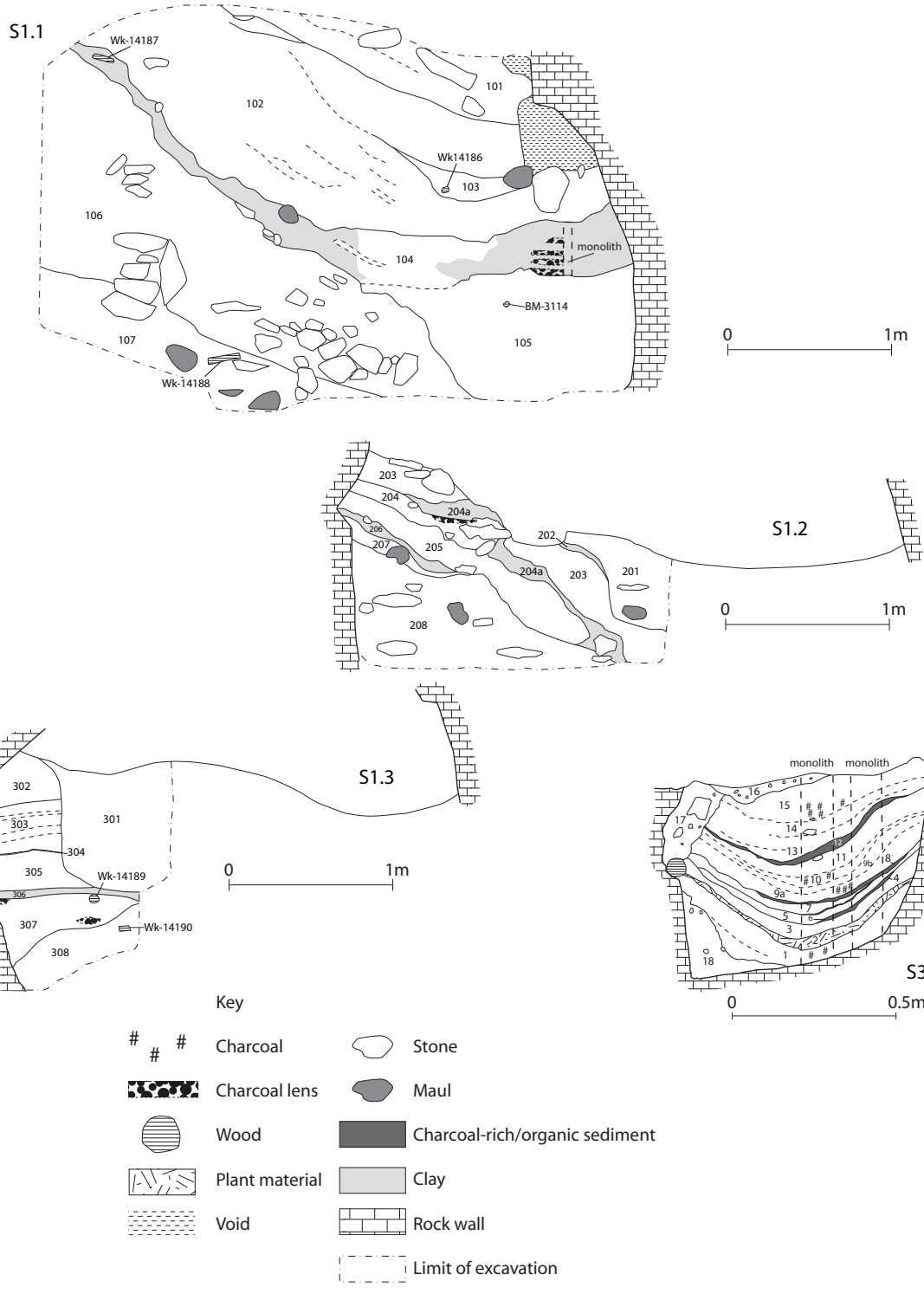
Fig. 15. The relative proportions of the terrestrial ecological groups from Mynydd Parys.

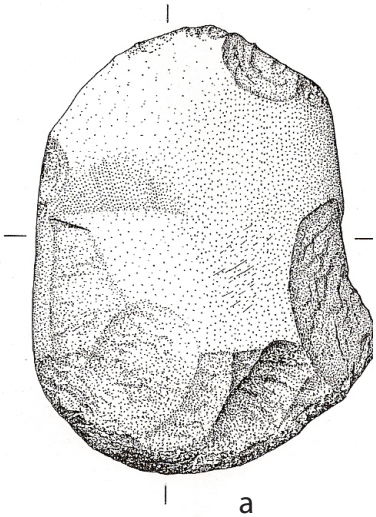

Amlwch
Anglesey
North
Wales
Afon
Goch
(North)
Amlwch
A5025
Menai Bridge
Dyffryn Adda
adit
B5111
Gardd Daniel shaft
Pearl shaft
MONA MINE
Gwen's shaft
Dyer's shaft
shaft
Cairns steam
pump
Windpump
Mona
adit
Carreg y doll shaft
Hillside
o.c.
Morris shaft
(AMplc)
PARYS MINE
Great Opencast
Afon
Goch
(South)
(Traeth
Dulas)
N
100m OSD
500m
Llanerchymedd


N
0
250m
B5111 to Amlwch
Old Shaft
Copper Mine
Cerig-y-bleiddiaw
Tai-fry
Engine House
Pumping Shaft
Shafts
Old Shafts
Copper Pits
Henwaith
EMRG-X
EMRG-Y
EMRG-Z
Oxen quarry
Charlotte
Cairns
Engine House
Carreg y doll
Dyer
Gwyn
Quarry
Maria
Mona footway
Sidney
windmill
Sanderson
Parys footway
Drift fawr
Road
Black rock
Mona Opencast
Parys Opencast
Ochre Pits
Powder Magazine
Caban haiarn
Spring
S1
S2
S3
S4
S5
Key
18th century shafts (shaft names in italics)
Passages in Parys Mine
Bronze Age sites
above ground
below ground
(sites S1-5)
Above ground finds of Bronze Age mauls

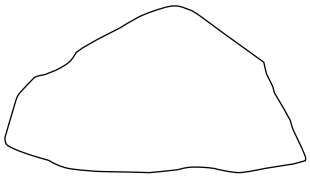

N
S7
S6
S5
S2
S3
S1
S4
m
20fm
16fm
30fm
Grand stope
Quarry shaft
ENTRY
Parys footway
10fm-level
16fm-level
20fm-level
30fm-level
Parys footway
Quarry stope
Key
mauls loose
mauls in situ
Quarry Shaft
Carreg y doll
Siafft fawr
New opencast
Parys footway

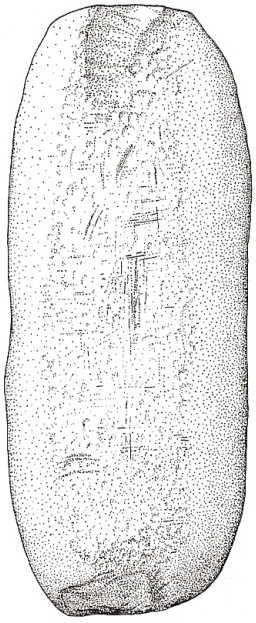

Oxen
Quarry
N
18/19thC
19thC
shaft
X A
spoil
pre-mining
water table
X
X
B
X
10m
20m
30m
18/19thC stopes
incline shaft
19thC access
Key
possible location and form of prehistoric inclined opencast workings
X find of stone tools
A site of the EMRG 1988 excavations
B Grand Stope (20 fm) and dated Bronze Age underground sections

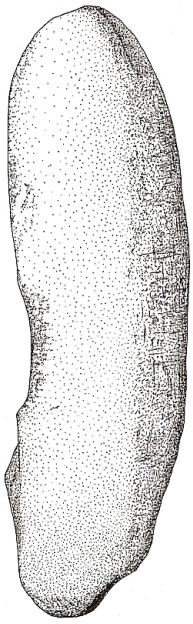

S1.1
Wk-14187
101
102
Wk14186
103
106
monolith
104
BM-3114
107
105
Wk-14188
0
1m
S1.2
203
204
204a
206
207
205
202
204a
203
201
208
0
1m
S1.3
302
303
301
304
305
Wk-14189
306
307
Wk-14190
308
0
1m
monolith
monolith
S3
0
0.5m
Key
Charcoal
Charcoal lens
Wood
Plant material
Void
Stone
Maul
Charcoal-rich/organic sediment
Clay
Rock wall
Limit of excavation



a

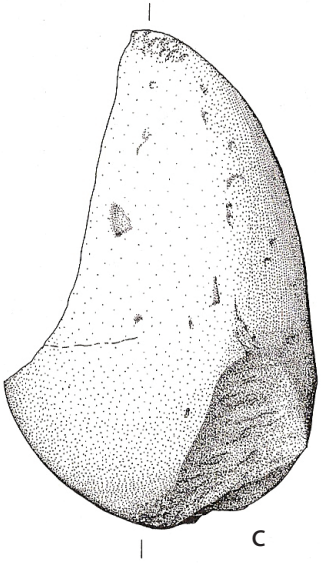




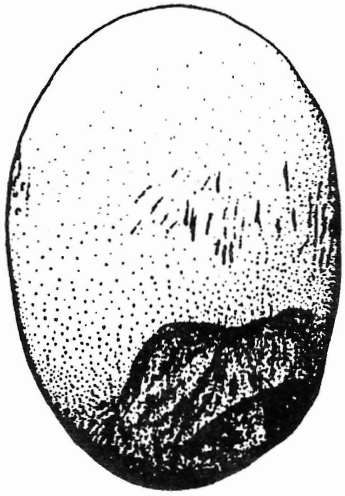
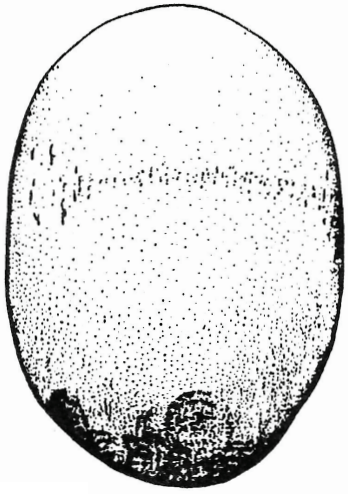


b

0 50mm



c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