A palaeoecological assessment of the blanket peat surrounding the Source of the Severn, Plynlimon

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INTRODUCTION

This report fulfils part of one of the principal objectives of the Metal Links Project, namely to undertake a palaeobotanical and geochemical study of a peat bog to reconstruct the vegetation history in an area formerly affected by metal mining.

Site details

The chosen sampling site is located near Pumlumon Cwmbiga (SN82794 89889), close to the source of the River Severn (Figure 1). It is within a kilometre of the Bronze Age and 19th Century mine of Nantyreira (SN 826875), approximately 2 km from the 19th Century Eisteddfa Gurig mine (SN 796857), 2 km from the 19-20th century Nantiago Mine (SN 826864), 2.5-3 km from the 17-19th Century Siglenlas mine (SN 840864), 4 km from the Nantmelin Mine (SN 862878), 5 km from the Bronze Age working at Nantyricketts (SN 864867), and approximately 7 km from the 17-19th Century copper mine of Guefron (SN 886857) (Figure 2). Two of these sites, Nantyreira and Nantyricketts, have been already been investigated by Timberlake (1988, 1990, 1995).

The locality is ideal to meet aims of the project: 1. It is close to mines spanning several archaeological periods; 2. It has upland location; 3. There are suitable peat deposits; 4. The record preserved in the bogs extend back three millennia and allow us to identify both local and regional records of vegetation change and palaeo-pollution (prehistoric, Roman, medieval and post medieval). 5; It will complement the findings of a pollen-analytical studies undertaken by Moore (1969) and Taylor (1973) in the area (site P1, Figure 2).

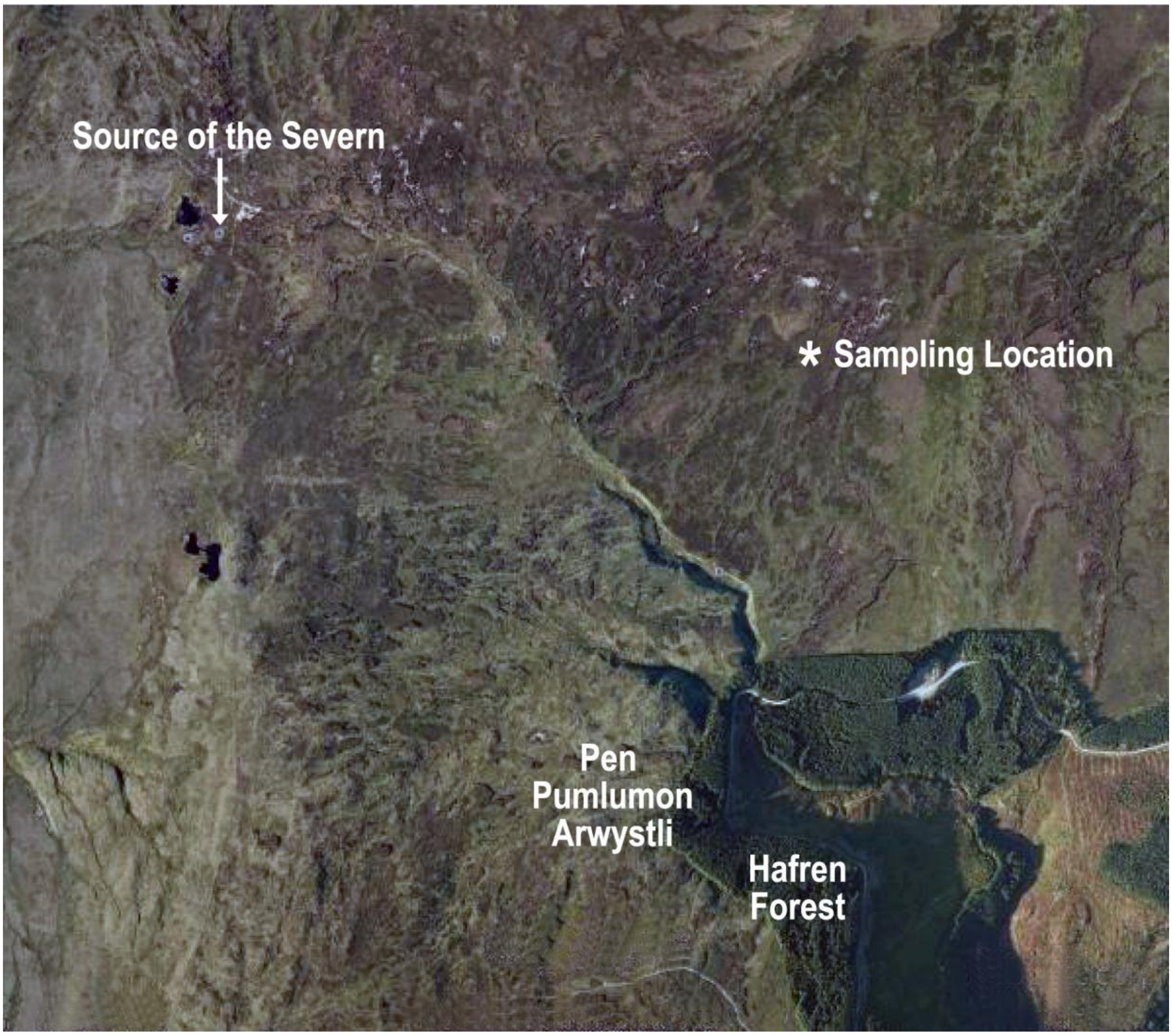


Figure 1: The Study Area. The yellow pin marks the approximate site of the core: Source: Google Earth. The sampling location (referred to as SOS) for this study is marked on the map.

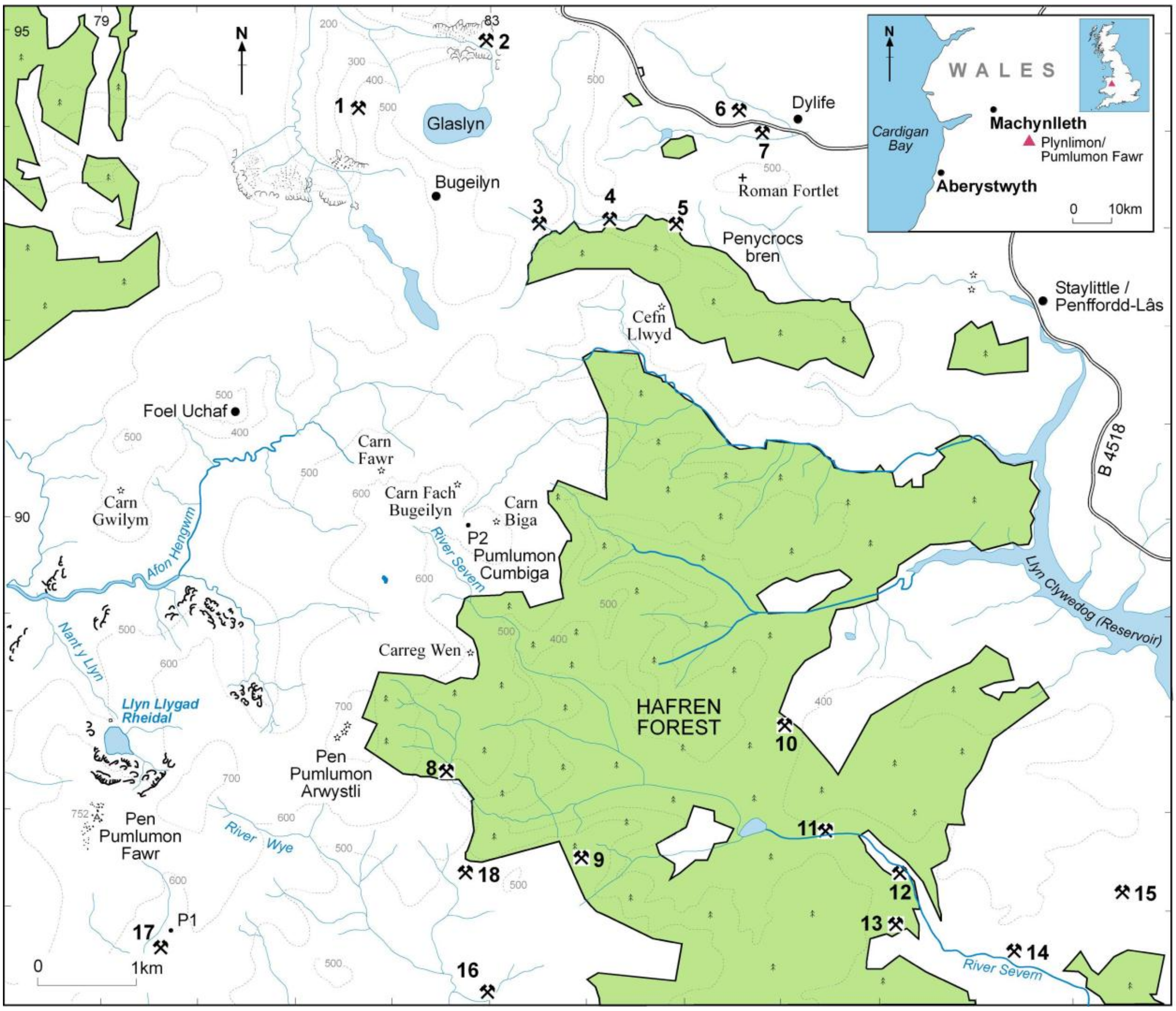


Figure 2: The location of the study area. Numbered sites are: P1 – Pollen site from Moore & Chater (1969); Moore (1968). P2- SOS; the sampling location for this study. Mining and related sites include: 1 - Glaslyn ("ancient workings"); 2 - Moel Fadian; 3 - Cafartha; 4 - Castle Rock (pretty old); 5- Dyfmgwm; 6 - Esgairgaled; 7 - Dylife (possible Roman site at Pen Dylife); 8 - Nantyreira (Bronze Age opencast mine + 19thC); 9 - Siglenlas (17thC at least); 10 - Nantmelin (17thC); 11 - Nantyrickets (Bronze Age prospection 'Loches Ladron'); 12 - Rhydyronnen ('ancient workings'); 13 - Hafod Feddger; 14 - Guefron (17th-19thC copper mine); 15 - Gwestyn (17-19thC copper mine); 16 – Wye valley mine(s); 17 – Eisteddfa Gung mine (19th C); 18 – Nantiago mine (19-20thC)

ARCHAEOLOGY

The archaeology of this upland landscape within the watersheds of the Rivers Severn, Wye and Rheidol is largely dominated by prehistoric (Bronze Age) funerary monuments (cairns and barrows), with rarer standing stones, stone rows, flint arrowhead findspots, probable Iron Age enclosures and hut circles, Roman roads and marching forts and Medieval/Post-Medieval house platforms. The vast majority of these sites are to be found above the 450m-500m contour, with most of the summit cairns being above 560m AOD. The archaeological distribution of such monuments below 500m is perhaps skewed slightly by the current forest cover (Hafren Forest) on the eastern side of Plynlimon, but Bronze Age cairns are generally rarer on the lowland-upland margins except for a distinct concentration in the Upper Clywedog valley near Staylittle, just to the east of the study area. Most of the archaeological sites have been identified through the Clwyd-Powys (CPAT) Sites and Monuments Record, although the county boundary between Powys and Ceredigion lies only 0.5km from the core site. Both peaks of Plynlimon (Pumlumon Fawr (752m) and Pen Pumlumon Arwystli (741m)) lie within a salient of Ceredigion, alongside a number of cairns and other sites, all of which are referred to within the Ceredigion County History (Davies 1994) and National Monuments Record.

The mines (most of which were worked for lead but some such as Guefron, Gwestyn and Siglenlas predominantly for copper) occur in two principle groups; a northerly one in the Upper Clywedog Valley, at Dylife and Glaslyn, and a southerly one in the Hafren Forest either side of the Severn and its tributaries (Nantyreira in the west to Guefron/ Gwestyn in the east). There are also a few mines (Plynlimon (Eisteddfa Gurig) and Nantiago) located just to the south of this within the catchment of the River Wye. Primitive (stone hammer) mining sites dating from the Bronze Age are restricted to the upper reaches of the River Severn at Nantyreira and Nantyricketts, whilst there remains the potential for Roman mining activity at Pen Dylife. During the 17th - early 18th century (1700s) copper mining was undertaken by the Company of Mine Adventurers at Siglenlas, Hafodfeddgar, Guefron, Gwestyn and Dylife, whilst in the 19th century lead mining was carried out at all the sites with major production at Dylife (35,505 tons of lead ore and 1,342 tons of copper ore), as well as at Esgairgaled, Dyfyngwm and Plynlimon in the south. The last lead mining took place at Nantiago in the 1920s and at Dyfyngwm in 1935. The important Van Mine which lay some 4-5 km to the east of here towards Llanidloes would have been an important local source of lead pollution during the latter half of the 19th century, alongside other important mines such as East Van, Penyclun and Bryntail on the edge of the Clywedog Reservoir which will have contributed to this. References to these mines can be found in Part 4 of Old Metal Mines of Mid-Wales (Bick 1977), The Mines of Montgomeryshire by J.R. Foster Smith (1978), and within O.T.Jones' Geological Survey Memoir of 1921.

Archaeological monuments and occupation within the central Plynlimon uplands

Bronze Age

Less than half a kilometre north of the coring site lie the two (north and south) roughly circular 16-17.5m diameter and 1.9-2.1m high gritstone *Carn Biga burial cairns* [SN 83048994 and 83028991]. Both these cairns show faint indications of the presence of a kerb, perhaps also of a capping of white quartz, yet there are also signs of modern disturbance in the form of construction of drystone-walled shelters. Meanwhile, less than a kilometre to the NNE is *Carn Fach Bugeilyn* [SN 82649038]. This 12.5m diameter and 0.6m high stone burial cairn lies on a local summit, and is surmounted by a modern cairn; the original shape of this being lenticular and convex. The site affords significant views of Cadair Idris and Aran Fawddwy. On the north-west facing side of this northern spur of the Plynlimon ridge, above the Severn source peat basin and perhaps more than a kilometre from the core site lies *Carn Fawr* [SN818906]. More distant (at about 2 km) are the group of two stone-built burial cairns plus a probable modern-built cairn on *Pen Pumlumon Arwystli* [SN 81538777]. Another important group of four barrows and a standing stone are to be found along the top of an east-west ridge at *Cefn Lwyd* [SN 848922] (454m AOD), east of Llyn Bugeilyn and 2.5m from the coring site. Just west of Plynlimon on the north side of the Afon Hengwm valley lie the two rounded cairns of *Carn Gwilym* [SN 79249084], one of them (Carn Gwilym II) consisting of a cairn and turf-covered ring bank, whilst further to the west of this lie more barrows at *Hyddgen* [SN 779906] and also cairns on *Banc Llechwedd-mawr* [SN 775899]. There are the remains of kerb cairns lower down in the Hengwm valley either side of the Hengwm River (e.g. at SN 773882); thus now on the edge of, or else buried beneath the Nant y Moch Reservoir.

On the opposite side of the peat-filled valley basin near to the source of the Severn, and perhaps just over a kilometre south the coring site, is to be found the 1.75m high by 0.75m x 1.25m wide quartz standing stone of *Carreg Wen* [SN 82938853], originally the larger of a pair known as “y fuwch wen a’r llo” (‘the white cow and calf’). In some ways this paired grouping resembles the stone pairs found on the *Afon Hyddgen* some 4km to the west. The latter is part of a north-south stone row which runs along the base of the western flank of Plynlimon Fawr.

The find of a Bronze Age rapier is purported to have come from *Carn Hyddgen* [SN 788904] just to the south of the Carn Gwilym cairns, but perhaps the most significant finds are the 40+ barb and tanged flint arrowheads found as loose finds along with scrapers and blades at *Banc Bugeilyn* [SN 82589260] on the hillside a half kilometre to the east of Bugeilyn lake (Peate 1925a+b; 1928), thus 3 km due north of the coring site over the peat-covered moorland. Further barb and tanged arrowheads were found on the north shore of *Llyn Glaslyn*, some 4.5 km north of the coring site [SN 826943]. It seems possible these arrowheads reflect losses incurred from the hunting of game, possibly red deer, groups of which may have congregated near these upland lakes during the Early Bronze Age. Tree clearance in these areas may thus have been intentional for the purposes of hunting, as well as for transhumance grazing, and for this reason the significance of these activities should be considered in any future environmental interpretation of this archaeological landscape. These abundantly distributed flint arrowheads were thought by Iorwerth Peate to show affinities with Irish forms, although they appear to be classically

Beaker in style, and some of them of particularly fine workmanship. Some 5km to the north-east at *Dylife* was found an *in situ* flint flaking floor [SN 860941] – but this was thought to be of Neolithic rather than Early Bronze Age in date. The nearest evidence for Mesolithic occupation comes from Llanidloes (a flint production site), and this was outside the upland zone.

Good palaeo-environmental deposits over 1m deep are also located just 100m to the NE of Carn Gwilym cairn I (CPAT Prehistoric Ritual and Funerary Monuments 2002), whilst another environmental site was examined by Caseldine (1990) and is also referred to by Taylor (1973) on the peat-covered moorland blanket bog to the south of Glaslyn lake. A sediment core was recovered by Sean Cronin (UCW Aberystwyth) from the centre of Glaslyn lake in the early 1990s. This consisted of some 3-4m of sediment providing an intact Post-Glacial to Holocene record with evidence for agriculture and local burning/disturbance from the Neolithic into the Early Bronze Age. This core was subsequently re-examined for any associated metal content by Jenkins & Timberlake (1997). A very minor rise in copper was detected at the beginning of the Bronze Age, though this was not considered significant enough above background to postulate a link with any sort of local metal mining/ metalworking activity.

Bronze Age – Iron Age

One and a half kilometres to the south-east of Bugeilyn on *Foel Uchaf* [SN 808911] have been found the remains of one and possibly two hut circles (of around 9m diameter), a small 'D-shaped' enclosure earthwork, and a 40m length of curving rubble stone wall. These have been referred to simply as 'prehistoric', yet an Iron Age date seems most likely. These features lie above the Afon Hengwm valley and 2.5 km to the north-west of the coring site, just to the west of the watershed divide.

Roman

The evidence for Roman settlement or occupation within this upland area is slight, the nearest 'permanent' presence here represented by the Flavian-period (140 – 180 AD) marching fort at *Penycrocbren* on Pen Dylife [SN 855934] which lies on the line of a minor Roman road which follows the ridge westwards, a route which crosses the Cambrian Mountains linking Caersws with the coast either heading south-west to Erglodd fort near Talybont, or north-west along the Dulas valley to Machynlleth, then west to the Roman fort at Pennal, the latter guarding the pass across the Dovey Estuary. In 1856 the nearby Dylife Mines were visited by David Davies of the Cambrian Archaeological Society who was shown the purported remains of a lead smelting furnace on the north side of Penycrocbren hill 'with Roman style bricks in abundance'(Davies 1857). Other than this statement and the location of the fort there is no evidence of Roman involvement in mining here. However, six miles east of Penycrocbren, in 1835, the remains of a smelting furnace was found in association with coins, none of which were dated after 180 AD (Hughes 1981). Penycrocbren is about 4.5 km to the north-east of the coring site.

Some 7.5 kilometres due south of the coring site, on the south slopes of the Wye valley, and guarding the narrowest point of this east-west pass through the mountains, lies the Roman fort of *Cae Gaer* [SN 823819]; a rather small turf-built rampart 'fortlet' of around 1 hectare in area. It has been suggested that the garrison presence (of cohors peditata size) may thus have been split between Cae Gaer and the Penycrocbren fort (www.roman-britain.org/places/caegaer.htm); something which implies a link and communication across Plynlimon between these two sites. The presence of a crushed quartz floor found during excavations here in 1913 (Pryce 1914) was interpreted as evidence of mineral working, perhaps linked to the mines of Cwmystwyth to the south. There are however no immediately local mining remains, therefore this association seems most unlikely.

Medieval and Early Post-medieval

Some of the upland hafod setlements, for instance in the Afon Hore, at *Bugeilyn* [SN 823930], *Hengwm* [SN 796894] and *Hyddgen* [SN 780909] may have Medieval origins, but actual evidence for occupation within this upland tract is sparse. It seems likely that transhumance agriculture involving the occupation of summer dwellings and grazing of cattle (*lluestai*) and sheep (*haffottai*) was prevalent on these eastern and western flanks of Plynlimon, but probably less intensively than on the edges of the valleys of the Wye and the Ystwyth to the south. The latter up until the mid-16th century was part of the wool-producing area associated with the Cistercian Strata Florida Abbey. However, it is very unlikely that mining played any part of the rural economic life of upland Plynlimon area until at least the beginning of the 17th century. Peat cutting for domestic fuel use may have been carried out on a small scale throughout this period, but not above the 500m contour, and probably not within 2 km of the source of the Severn. It seems probable that by the end of the Medieval period blanket bog was well-developed on the Plynlimon plateau, and that the tops of the valleys draining off this were largely clear of trees.

Glyndwr's Way passes within 4 km to the east of the coring site, whilst *Glyndwr's Covenant Stones* [SN 783896], traditionally known as the site of Glyndwr's parley, lie 4.5 km to the west of this.

Post-medieval – modern

A more intensive transhumance regime will have operated in this part of the uplands during the 18th-19th centuries; during the 19th century upland grazing was dominated by sheep production, and as with the Upper Ystwyth valley, squatter's settlements may also have been a feature of the more important lead mining area around Dylife. It is unlikely that the scattered group of mines within the Upper Severn valley and tributary valleys to the east of Plynlimon contributed much to an increase in the permanent occupation of this area. With the exception of Dylife Mine to the north, the workforce involved in the operation of a small number of mines and trials working intermittently between 1850 and 1920 would probably have amounted to just tens, rather than hundreds of people. However, the changes in hydrology linked to the collection of water in reservoirs designed to operate waterwheels at the mines via a system of leats may have been more significant in terms of environmental impact. Steam engines were, for a short while, used at a number of the mines, but these never replaced waterwheels as the main source of motive power and pumping.

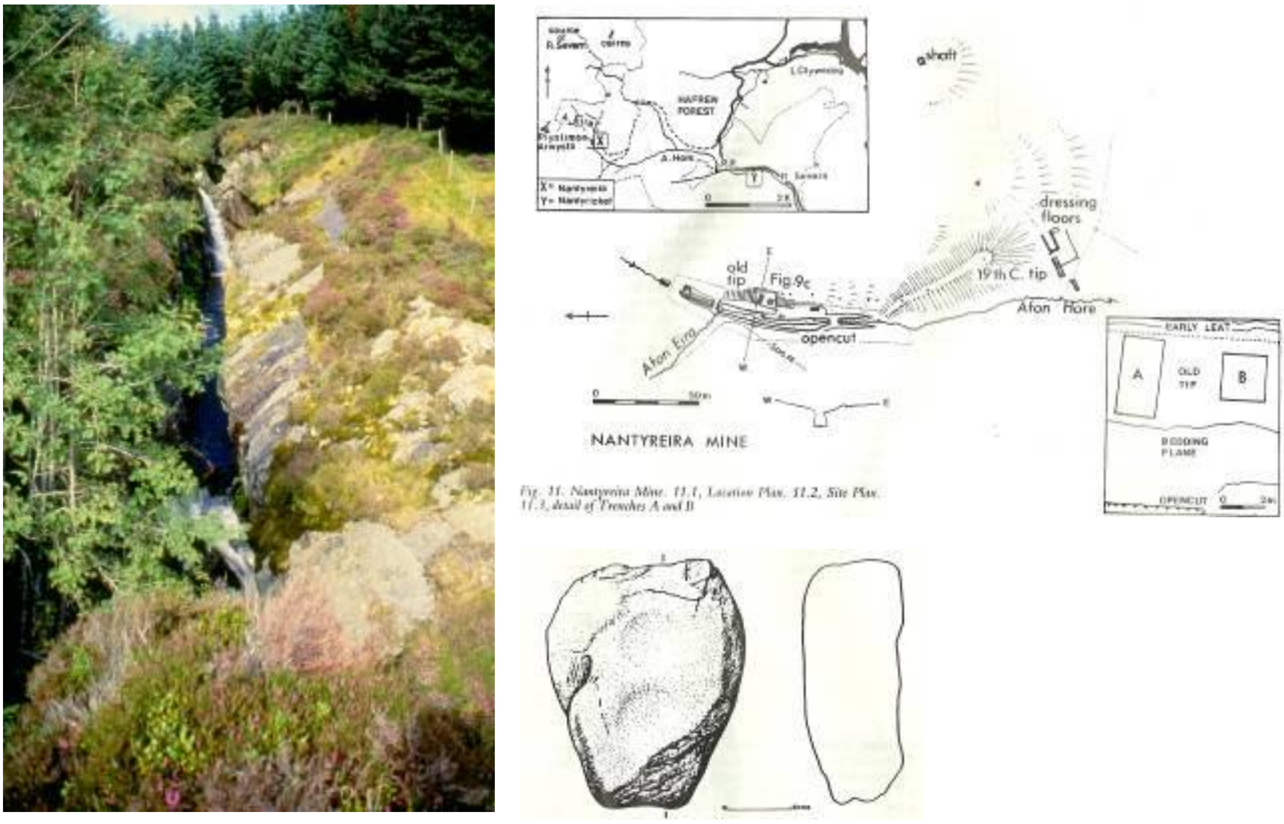
There was very little planting of deciduous woodland or conifer plantations till after the war, much of the planting taking place from the 1960s onwards. The major engineering works associated with the flooding of the upper reaches of the Rheidol valley and Afon Hengwm tributary to create the Nant y Moch reservoir and dam also belong to the post-war period. Meanwhile, de-population of the upland Plynlimon zone has increased since the first half of the 20th century, whilst forest now occupies some 30% of this land area.

Lead and copper mines

As referred to above, the earliest mineral workings are to be found at *Nantyreira Mine* [SN 827874] located at around 500m AOD within the upper reached of the Eira valley (a tributary of the Afon Hore and River Severn) on the lower easternmost slopes of Pen Pumlumon Arwystli. This is the closest mine to the coring site and lies just 2 km due south of the source of the Severn. At the time of its re-discovery in 1858 by Captain Reynolds of Llanidloes the old openworks were found to be ‘6-9 feet wide, 200-300 yards long and of unknown depth’ (Bick 1977). A waterwheel and crusher were erected and the old workings cleared out, resulting in the recovery of 33 tons of lead ore and also a number of examples of primitive mining tools. From a depth of 50 feet inside of the old workings came a ‘stag’s horn fashioned so as to be suited for the handle of some implement’, a stone ball for ‘crushing or pounding ore, and from 60 feet deep an iron pickaxe (*Archaeological Journal* 1860). The Duke of Northumberland was presented with these artefacts by Sir Hugh Williams, Bt., for his museum at Alnwick Castle. At the time, this early mining was presumed to be of Roman date, perhaps continuing into Medieval times (RCAHMW 1911). Later in 1937 Oliver Davies re-examined this site as part of the British Association for the Advancement of Science’s investigation of ancient mining in Wales, identifying one of the early tips upon the side of the opencut which contained abundant evidence of charcoal and some cobble stone tools (Davies 1937 & 1938). The Early Mines Research Group then re-excavated one of these shallow tips in 1988 as one of its first projects; recovering two charcoal samples from firesetting activities which were radiocarbon dated to 3390+/-80 yrs (1865-1845 or 1770-1610 Cal BC) and 3410 +/-50 yrs (1855-1845 or 1765-1675 Cal BC) (Timberlake 1990 & 2009). The clear presence of copper (as chalcopyrite) within the veins, plus the discarding of the lead minerals by the earliest miners, suggests this was the metal being sought here. Meanwhile, the size of the working (with an estimated 4500 cubic metres of rock removed during the earliest phase) places this in the league of the largest Bronze Age workings of its kind in Britain (with the exception of the Great Orme). In fact, this early working appears to be of rather similar size to the Comet

Lode Opencast on Copa Hill, Cwmystwyth (at 5,000 cubic metres (see Timberlake 2003)), and as such could have produced > 50 tons of extractable copper ore. Rather than sulphides (chalcopyrite), the ore recovered here may just have been the oxidised fraction of the vein, which includes malachite (Timberlake 2010); numerous examples of which can be found on the tips. Apart from the potential scale of prehistoric extraction, and the localised metal impact within this valley, the extremely hard rocks (sandstones and grits of the Van Formation) ensured that a very high ratio of wood fuel to rock removed (perhaps 1.5:1 or even 1:1) was necessary during firesetting operations; perhaps an indication that localised demand for wood during the Early Bronze Age would have been significant (perhaps > 3000 tons of wood over a 100 – 200 year period).

Figure 3: Photo of the Nantyreira prehistoric opencast mine with location map and site plan.



Just to the south of Nantyreira (some 3.5 km from the coring site) lies the *Nantiago Mine* [SN 826863] where work began in the 1840s and then continued with very few interruptions right up to the end of the 1st World War, with a total production of 1,709 tons of lead ore and 1,929 tons of zinc blende. Today the remains of rusting machinery can be seen at this isolated site making it one of the industrial archaeological jewels of the mid-Wales mining field (see survey in Jones, Walters & Frost 2004). A kilometre south of Nantiago, and within the same tributary valley, lie the several *Wye Valley Mines* [SN 826850]. These had a short but rich history of working which lasted from about 1865 to 1880. The mine produced some 3,000 tons of lead ore and more than 500 tons of zinc blende. A similar short history of working (intermittently between 1866 and 1891) is characteristic of the *Plynlimon Mine* [SN 795856] located on the southern slopes of Plynlimon Fawr just north of Esisteddfa Gurig (and just over 5 km from the coring site). This mine only produced galena, with a total output of 3,270 tons of lead ore.

The small mine of *Nantyricket* [SN 865867] described by O.T. Jones in his 1922 Geological Survey Memoir lies some 2km downstream of Nantyreira within the same watershed of the River Severn (this lies 4.5 km to the south-east of the coring site). Jones noted a lode of chalcopyrite and calcite crossing the floor of the river which may also have been exploited from an ancient opencut on the slopes above, a site referred to locally as Loches y Lladron ('Thieve's Den'). He also describes an ancient spoil tip down by the river with numerous hammer stones. This site was visited by Davies, but not investigated on account of its 'denuded nature' (Davies 1937). The cobble tools used here were river pebbles, quite different from the beach cobbles which predominate within the prehistoric mines west of the Cambrian Mountain divide. During the late 19th and early 20thcenturies the Nantyricket set of veins produced 209 tons of copper ore, yet the ancient workings (probably only prospections and now lost once again beneath clear-felled forestry plantation) would have produced a tiny fraction of this amount. Downstream from here at *Rhyd yr onnen* [SN 873866] Hamer referred to 'abundant platforms and trenches, believed to be Roman workings' (Hamer 1873-1876), although no discernible trace of these remain today.

Only slightly nearer (3.5 km SSE of the coring site) lies the mine of *Siglenlas* [SN 866840] first worked for copper during the late 17th to early 18th centuries (1690s - 1700s) by William Waller and the Company of Mine Adventurers, and then again for copper and lead during the late 19th century (1850s - 1870s). Here ancient (but undated) outcrop workings show abundant evidence of secondary copper mineralisation, a good indication of potentially early-exploited veins (O.T.Jones 1921; Bick 1977).

Nantmelin Mine [SN 860878] (also 3.5 km ESE from the coring site) was worked for copper and lead by the Company of Mine Adventurers in around 1708, then again at the beginning of the 19th century, and finally between 1851 and 1853. This was a relatively small mine with abundant chalcopyrite associated with a calcite vein (Jones 1921).

Hafod Feddgar [SN 874858] (6 km SE of the coring site) is another copper and lead mine which was worked from four different levels on this hillside around 1855 (Foster Smith 1978). Copper carbonates are associated with lead ore, iron oxides and barytes, and at the surface a gossan (an intensely oxidised, weathered or decomposed rock, usually the upper and exposed part of an ore deposit or mineral vein.) was noted. Once again this was the sort of outcrop exposure which could have been worked in prehistory.

Still within this same area of copper production, and a little downstream of Hafod Feddgar on the Severn, lies the *Guefron Mine* [SN 885857]. Whilst nearly 7 km to the south-east of the coring site, this mine is worth mentioning in the context of its producing an ore consisting largely of malachite with, in places, native copper, during the first recorded working period in 1708. These near-surface ores continued to be mined in the 18th century, although by 1852 the much deeper ores, consisting largely of chalcopyrite, were being worked. Somewhat surprisingly, no evidence for prehistoric mining has been found at this site, and we can only conclude that this area was once forested or otherwise concealed, and thus remained undiscovered up to the time of the clearances and more intensive land use/ prospection during the late 17th century. During the most recent phase of mining, between 1855 and 1874, Guefron was worked together with another former 18th-century copper mine *Gwestyn* [SN 894481], which lies half a kilometre to the north-east; producing more than 500 tons of copper ore.

Three and a half kilometres to the north of the core site lies *Cafartha Mine* [SN 833932]; a mine worked between 1842 and 1880 with an output of several hundred tons of lead and copper ores. Eastwards from Cafarthfa, the Clywedog gorge follows the line of weakness of the main lode to reach a pinnacle formed from an upstanding mineral vein at *Castle Rock* [SN 843931]; an outcrop referred to by O.T.Jones as 'the finest natural exposure of a lode to be seen in the country' (Bick 1977). East of here lies the *Dyfngwm Mine* [SN 849931] which was mined from 1842 to 1935 with a recorded output of 4,930 tons of lead ores and 134 tons of copper, and with large amounts of zinc blende left on the tips. The *Dylife Mines* [SN 855940] worked the junction of the Esgairgaled and Llechwedd Ddu veins at a valley site located 5 km to the north-east of the source of the Severn. Dylife was one of the major metal producers of mid-Wales, with a final output of 36,684 tons of lead ore, 1,540 tons of copper ore and 391 tons of zinc blende mined between c. 1770 and 1891. The mine was certainly operating in 1691, and perhaps before that in Roman times, yet the height of its production was reached in 1863 with an annual output of 2,571 tons of lead ore. Around this time this mine must have been one of the most significant polluting sources, alongside the Van group of mines located some 9-12 km east of the core site.

Some idea of the scale of importance of the *Van Mine* [SN 942878] as a lead producer can be gauged by its total recorded output between discovery in 1852 and closure in 1921 of some 96,739 tons lead ore and 28,424 tons of zinc blende. Nevertheless, when considered together, this group of mines (Van, East Van, Glyn, Penyclun and Bryntail) would actually have produced in excess of 100,000 tons of lead ore. As well as lead and zinc, some of these West Montgomeryshire mines (for example *Bryntail Mine* [SN 915869]) produced barium minerals (milled barite and witherite).

METHODS

Field Sampling

Ideally, ombrotrophic (rain-fed only) peats, raised above the mineralised water table, are preferred to reconstruct past metal deposition histories as this environment only receives metal pollutants from the atmosphere and it minimises the risk of such post-depositional mobility (Shotyk, 1996). Therefore a 2 m deep core, named SOS, was taken from the ombrotrophic blanket peat on the upland plateau close to Pumlumon Cwmbiga. The core was collected on the 10th February 2012 using a 1 m long, 5 cm wide Russian corer from the middle of an eroded peat hag (SN82794 BNG 89889). The cores were then wrapped in plastic, sealed and stored in a cold store.

Laboratory work

Geochemistry: The Aberystwyth XRF core scanner was used to analyse the core for multi element geochemistry at the Institute of Geography and Earth Sciences in the University of Aberystwyth. The scanner provides very high-resolution, non-destructive elemental analysis of the peat core. Density and colour information is provided through X-radiography and digital RGB optical imagery. Scan resolution was set at 200 µm intervals, providing element concentrations in the range Al - U within 10-18 hours for a 1 m sediment core. The effective XRF spot size is 0.2 x 4mm. Data evaluation, analysis and plotting is carried out with dedicated software, or can be output in spreadsheet formats (http://www.aber.ac.uk/en/iges/facilities/xrf-core-scanner/).

Microfossils: Samples of c. 2g wet weight and 0.5 cm thickness were prepared for pollen, non-pollen palynomorphs (NPPs) and microscopic charcoal analyses using the procedure described by Barber (1976). At least 500 land pollen grains were counted for each sub-sample, except for levels 100 and 74 where the pollen content was sparse and the count was restricted to 300. Pollen identification was made using the identification keys from Fægri *et al*. (1989), Moore *et al*. (1991) and a pollen type slide collection housed in the University of Aberdeen. When possible, cereal-type pollen was differentiated from wild grass pollen based on grain size, pore and annulus diameter and surface sculpturing (Andersen, 1979). Pollen preservation was recorded following Cushing (1967) and each pollen grain was classified as broken, corroded, crushed or degraded. Pollen grains that had no remaining distinguishing features were categorised as unidentified. NPPs were recorded during routine pollen counting and they were identified using the descriptions and photomicrographs of van Geel (1978), van Geel *et al.*, (1989; 2003) and van Geel and Aptroot (2006).

RESULTS

Stratigraphy: the stratigraphy of the SOS core is described below using the classification system devised by Troels Smith (1955).

0-6 cm: surface vegetation

6-38 cm: dark brown humified herbaceous peat (Th$^{2.5}$4 nig 3, sicc 2.5, strf 0)

38-48 cm: orange brown *Sphagnum* peat (Tb Sphagni$^{1.5}$4, nig 2, sicc 2.5, strf 0)

48-61 cm: dark brown humified herbaceous peat with *Calluna* rootlets (Th$^{2.5}$4 Callunae +, nig 2.5, sicc 2.5, strf 0)

61-83 cm: brown *Eriophorum*-rich peat (Th$^{1.5}$4 nig 2.25, sicc 2.5, strf 0)

83-190 cm: dark brown humified herbaceous peat (Th$^{2.5}$4 nig 3, sicc 2.5, strf 1)

190cm – base: dark black well humified organic soil (Sh$^{3.5}$4 nig 3.5, sicc 2.5, strf 0)

Radiocarbon dating: Two bulk peat samples from the core have been radiocarbon dated using AMS at the Poznań Radiocarbon Laboratory, Poland. The results are shown in Table 1 including the calibrated ages (using CALIB 6.0 radiocarbon calibration program and IntCal04 after Reimer *et al*., 2009) and 2 sigma age ranges. Best estimated ages or calibrated radiocarbon ages (to the nearest five years) are cited in brackets in the text (AD/BC = calendar years). An age-depth curve was constructed using the Clam software (Blaauw, 2010) (Figure 4).

Microfossils: the pollen and non-pollen palynomorph diagrams are shown in figures 5 and 6. Plant nomenclature follows Stace (1997) and takes into account the problems of categorising plant species on the basis of their pollen morphology (Bennett *et al*., 1994).

Table 1: Radiocarbon dates from the SOS site.

Sample depth (cm)	Lab no.	Age ^{14}C BP	Calibrated Age
90-92	Poz-45839	770±30	calAD 1217-1281
200-202	Poz-45840	3360±35	cal BC 1740-1603; 1588-1534

Summary curves for trees, shrubs (constituting arboreal pollen, AP), dwarf shrubs and herbs (non-arboreal pollen, NAP) are shown. NPP terminology follows the type system devised by van Geel (1978) and uses the laboratory code as prefix (HdV), followed by the type number. The pollen and microscopic charcoal data are expressed as percentages of total land pollen (TLP). NPPs are expressed as percentages of total land pollen plus NPPs. Microscopic charcoal pieces were also counted during routine pollen analysis and are expressed as a percentage of total land pollen. The key changes are described in Table 2.

Geochemistry: determinations were done at 200 micron intervals with reasonably long count times of 15 seconds. This yielded data for iron (Fe), sulphur (S), bromine (Br), silicon (Si), calcium (Ca), copper (Cu), nickel (Ni), titanium (Ti) and lead (Pb) (Figure 7a-c). Note the validity column – where it shows 1 (or the green line at left on the plots) the data are valid. Invalid data (=0) occur where there is a hole or irregularity in the core surface. Peat is not ideal for XRF because of the high organic and water contents, expressed as inc (incoherent scatter).

INTERPRETATION

Microfossils

Bronze Age: Mixed deciduous woodland characterises the Bronze Age with *Quercus* (oak), *Alnus* (alder) and *Corylus avellana*-type (hazel) with *Betula* (birch) and *Ulmus* (elm). *Pinus* (pine), *Tilia* (lime) and *Fraxinus* (ash) are present in trace amounts and were either present in relatively low numbers locally or their pollen is derived from long distance transport (Figure 5). *Alnus* and *Salix* (willow) probably occupied the damp margins of lakes, stream and river banks, on wet substrates in valley bottoms and basin mires (Chambers and Price, 1985; Bennett 1986) with the other trees colonising drier and/or fertile soils on floodplains and valley sides (Birks, 1989). Oak and alder woodland most likely covered the foothills and valleys with a hazel understorey (Moore and Chater (1969). A slight decrease in *Quercus* and *Corylus avellana* type pollen occurs at 195 cm, *c*. 1490 Cal BC, and possibly represents a short-lived phase of forest disturbance. Initially high percentages of Poaceae, along with *Plantago lanceolata* (ribwort plantain), *Potentilla* type (tormentil) and *Pteridium* (bracken) suggest that open areas of grassland existed and may have been disturbed and/or grazed. Coprophilous fungi, including *Sporormiella* type, *Cercophora* type and possibly *Sordaria* type are also recorded (Figure 6). A permanent phase of woodland clearance occurs at the end of the Bronze Age, commencing at 172 cm, *c*. 885 Cal BC, and continuing into the early Iron Age. *Quercus*, *Alnus*, *Corylus avellana*-type, *Betula* and *Ulmus* are all adversely affected. A suite of non pollen palynomorphs indicative of dry conditionson the bog surface are regularly recorded, including *Gelasinospora*, HdV3, HdV5, HdV6, HdV10 and *Meliola cf niessleana*. *Anthostomella fuegiana* and *Microthyrium* spec. are associated with *Eriophorum vaginatum* (cotton grass) remains (Yeloff *et al*., 2007) and coincide with relatively high percentages of Cyperaceae (sedges).

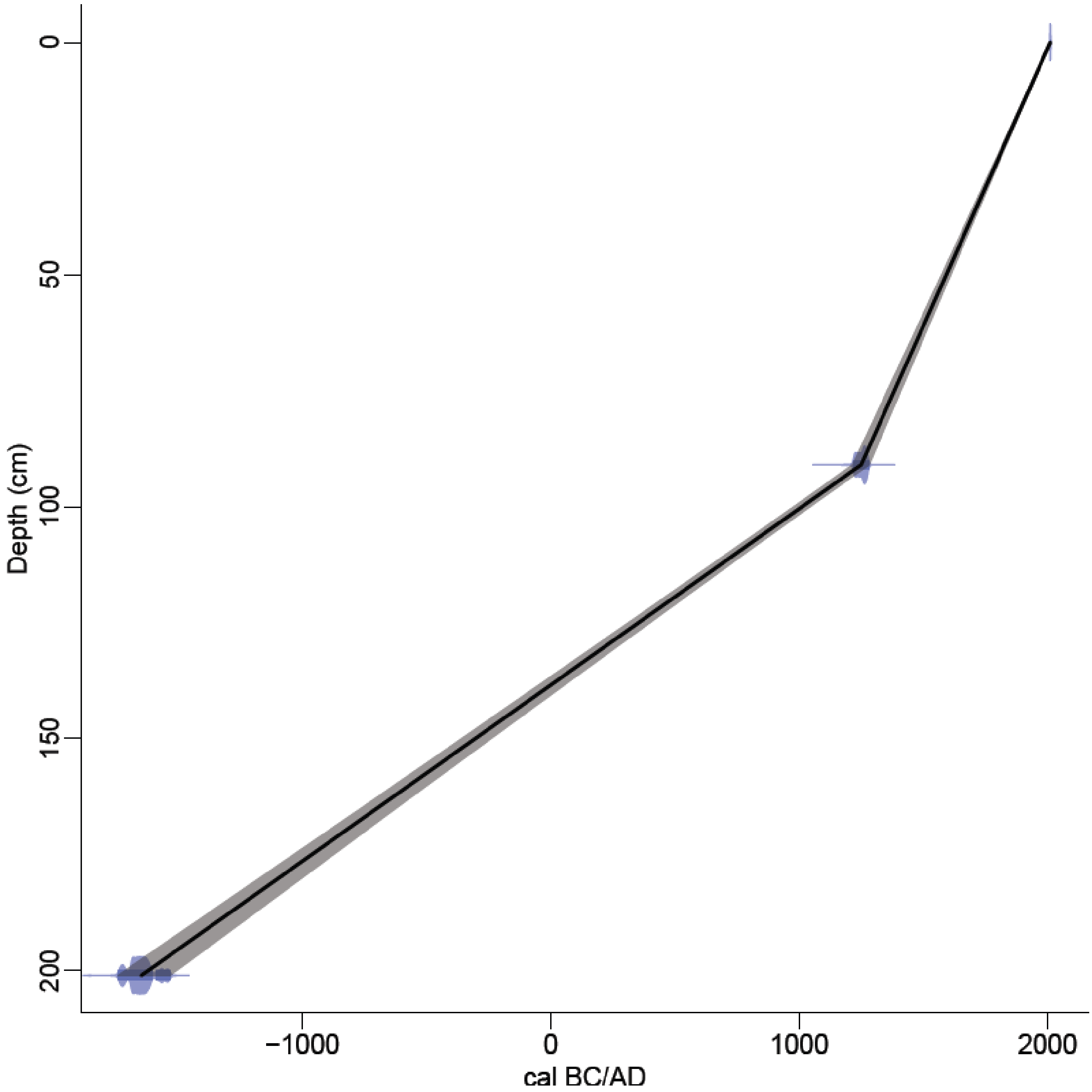


Figure 4: Age-depth curve for SOS.

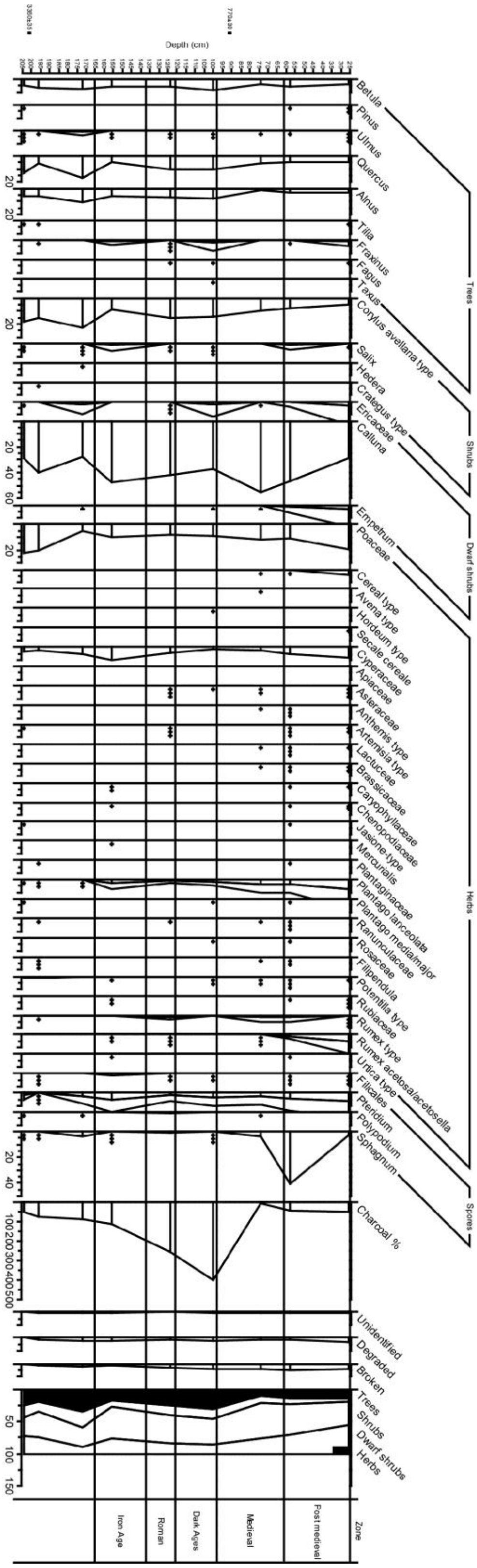


Figure 5: Percentage pollen diagram from site SOS

Iron Age: The phase of woodland clearance described above ended at 156 cm, *c*. 465 Cal BC; thereafter woodland gradually regenerates but total arboreal pollen percentages do not recover to their former values. *Fraxinus*, taking advantage of a more open canopy (Birks, 1989) and *Salix*, a low pollen producer, increase in representation. Local expansion of peat is suggested by the increase in *Calluna* (heather) and Cyperaceae percentages. While Poaceae only increases slightly, other non-arboreal pollen and spore indicators of disturbance and/or pasture including *Plantago lanceolata*, *Rumex acetosa/acetosella* (common, sheep sorrel), Chenopodiaceae (goosefoot family) and Rubiaceae either increase in value or they are present in trace amounts (Moore and Chater, 1969; Brown *et al*., 2007). *Pteridium* increases, possibly taking advantage of newly cleared ground on the valley sides. Fire may well have been used to initiate and maintain open spaces as microscopic charcoal percentages are slightly higher compared to the Bronze Age and they continue to increase during the Roman occupation. The NPPs indicative of drier bog surface conditions fade, as *cf* HdV12 increases in value, suggesting that the bog surface may have become slightly wetter (Yeloff *et al*., 2007).

Roman: Woodland regeneration is suggested by the increase in all the major tree and shrub taxa but *Fraxinus* and *Salix* fade. *Fagus* (beech) is recorded for the first time and possibly took advantage of abandoned, cleared areas on shallow, well drained soils (Birks, 1989). *Calluna* and Cyperaceae pollen percentages decrease, possibly due to the renewed influx of tree and shrub pollen. HdV 10 also increases substantially and it is indicative of drier bog surface conditions and it grows on the rootlets of heather (Yeloff *et al*., 2007). Poaceae is still well represented and other non-arboreal pollen and spore indicators of disturbance and/or pasture are present but percentages of *Plantago lanceolata* and *Pteridium* dip in value while *Rumex acetosa/acetosella*, *Artemisia* type (mugwort), Ranunculaceae (buttercup family) are present in trace amounts. *Sporormiella* type and *Sordaria* type are indicative of grazing and/or the presence of decayed wood (van Geel *et al*., 2003).

Dark Ages/early medieval: Woodland regeneration continues as *Betula*, *Quercus*, *Alnus* and *Fraxinus* all increase in representation but *Corylus avellana* type decreases. *Pinus*, *Fagus*, *Taxus* (yew) and *Salix* occur in trace amounts and represent minor or more regional constituents of woodland. Fire may well have been used to maintain open spaces or there was a period of local burning on the peat bog surface as microscopic charcoal percentages peak. Drier bog surface conditions are also suggested by the presence of HdV5 and HdV6, although surface pools exist as spermatophores of Copepoda are present. *Assulina muscorum* and *Amphitrema flavum* are commonly associated with ombrotrophic conditions (Figure 6). *Calluna*, Ericaceae (heather family) and Cyperaceae represent peatland communities but HdV10 declines. Indicators of disturbance and/or pasture including *Plantago lanceolata* and *Pteridium* both increase as *Potentilla* type, Asteraceae (daisy family), *Plantago media/major* (Hoary, Greater plantain) occur towards the end of the period. Cereal cultivation also took place: *Hordeum* type (barley) pollen is also recorded, *c*. AD1015 (Figure 5).

Medieval: A second permanent episode of woodland clearance takes place during the transition from the Dark Ages/early medieval times into the medieval period, *c*. AD1015-1385. *Betula*, *Quercus*, *Alnus* and *Corylus avellana*-type and *Fraxinus* are all adversely affected. *Calluna* increases, suggesting that a renewed phase of peat growth occurred (Figure 5). Whilst there is no significant change in Poaceae percentages, indicators of disturbance and pasture increase, especially *Plantago lanceolata*, *Rumex* and *Pteridium*. Trace amounts of *Potentilla* type, *Artemisia* type, *Brassicaceae* (cabbage family), Lactuceae (lettuces) and Ranunculaceae are recorded. Cereal type and *Avena* type (oats) pollen are also recorded and provide evidence for cultivation, *c*. AD1395. Fires were less intense as microscopic charcoal percentages are much lower compared to the previous period. The presence of HdV3, *Amphitrema flavum* and *Assulina muscorum* suggest that dry, ombrotrophic conditions continue on the peat surface (Figure 6). *Anthostomella fuegiana* coincides with *Eriphorum vaginatum* remains in the peat stratigraphy.

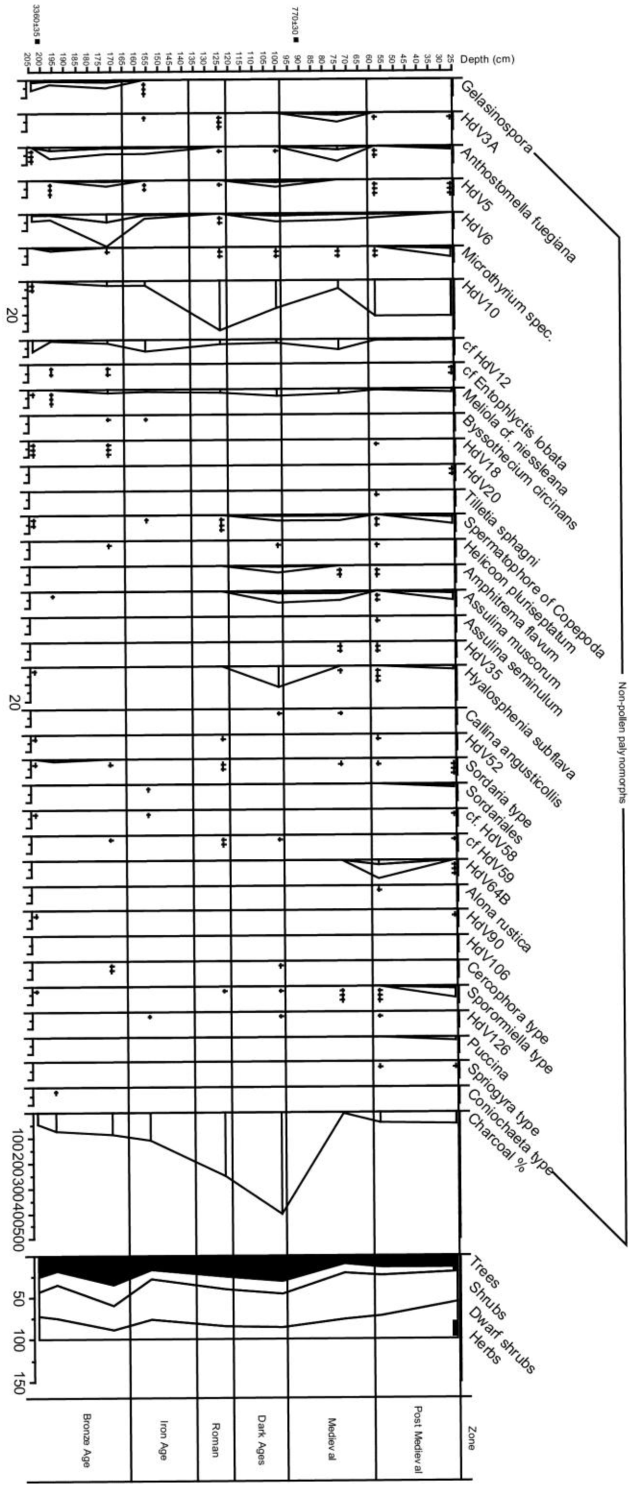


Figure 6: Percentage non-pollen palynomorph data from site SOS.

Post medieval: Woodland cover remains relatively stable as total arboreal pollen percentages do not change substantially during this period, although *Fraxinus* percentages increase as the representation of *Corylus avellana*-type pollen decreases. The bog plant community also changes slightly: *Calluna* percentages decrease as Cyperaceae, *Sphagnum*, Ericaceae and *Empetrum* are all recorded in higher percentages. HdV64B also is present and it is associated with macrofossils remains of *Empetrum nigrum* (crowberry) (van Hoeve & Hendrikse, 1998). The increase in Poaceae might also represent an expansion of grasses on the bog, or the creation of pasture. A suite of non-arboreal pollen indicative of disturbance and pasture are recorded, including *Plantago lanceolata*, *Rumex acetosa/acetosella* and *Pteridium*. Coprophilous dung fungi (*Sordaria* type, Sordariales, *Sporormiella* type) increase in value, implying more intense grazing from *c*. AD1525. An increase in cereal type pollen suggests that a phase of agricultural intensification occurred during this period.

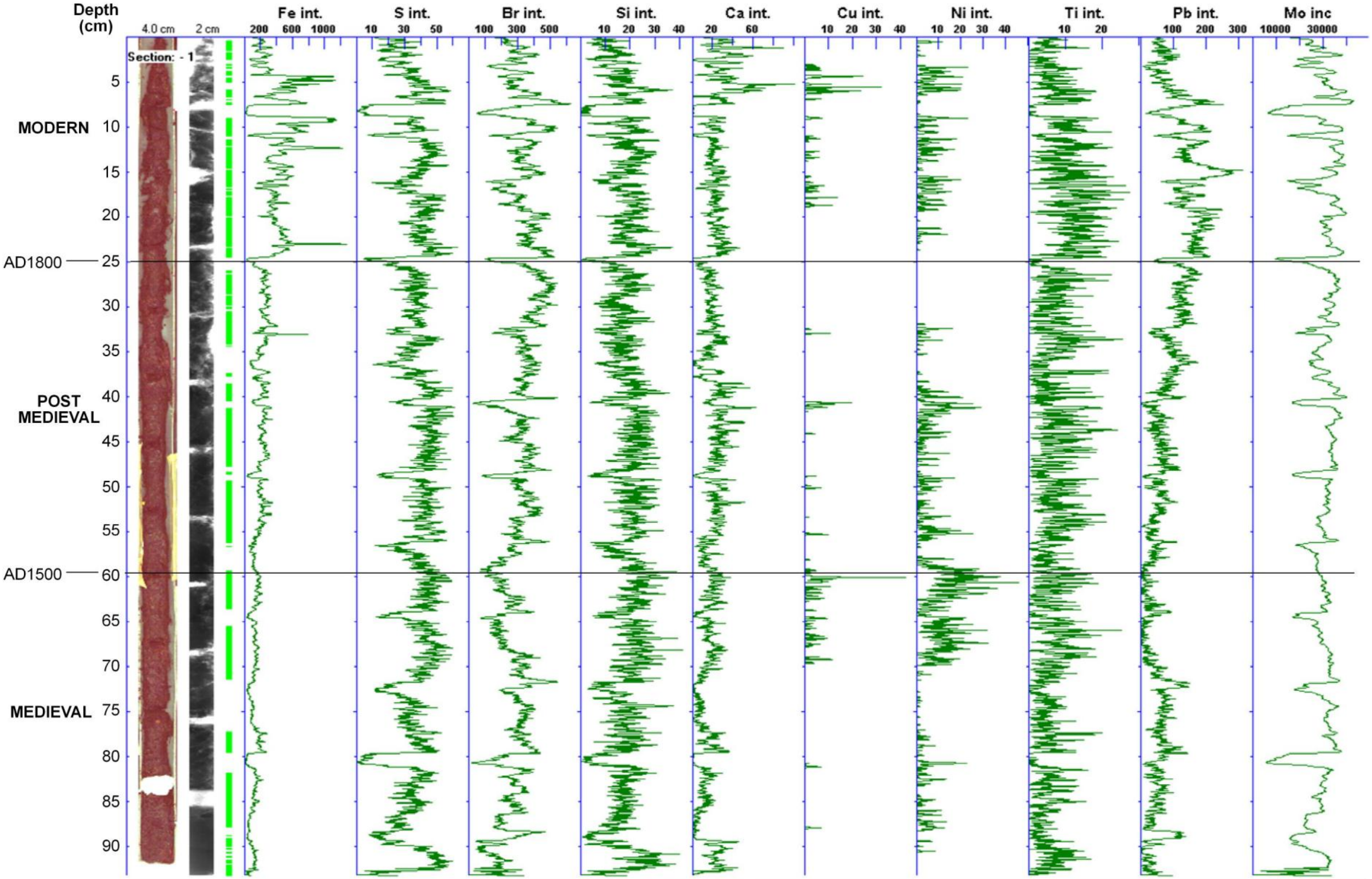
Geochemistry

The geochemical data is provisionally presented in figures 7A-C. The base of the core from 207 to 107 cm is shown in figure 7C and from 90 to 190 cm is replicated in figure 7B. Higher concentrations of Pb occur between 207 and 200 cm, coinciding with lower concentrations of Si, Ti, Br and S. These patterns most likely represent the change in the stratigraphy from a well humified organic soil to peat. Once the herbaceous peat develops, the concentrations reverse as Pb decreases and others increase most notably S, Si and Br, which is mainly derived from the oceans and deposited onto the bog surface by precipitation. Most of the elemental profiles remain fairly constant throughout the reminder of the basal metre of the core. However, Pb concentrations do increase from *c*. 165 cm (*c*. 700 Cal BC), the start of the Iron Age and remain, on average, higher until c 125 cm (AD124) and these elevated concentrations might reflect mining and metallurgical activities. Lead (Pb) concentrations decrease thereafter and there is no definable peak during Roman times, as seen elsewhere in Wales, for example Copa Hill, Cwmystwyth and Borth Bog (Mighall *et al*., 2002a,b, 2009). Figure 7A displays the geochemical data from 100 cm to the bog surface. Pb concentrations remain relatively high throughout the medieval period until *c*. AD1425 which might represent pollution from local/regional mining and metallurgical activities. Lead concentrations start to increase once again at 40 cm, c. AD1660 and they remain at elevated levels until the uppermost 10 cm before declining, c. AD 1928. Another smaller decline in lead in the upper 5cm probably represents the phasing out of leaded petrol. This phase of increased pollution coincides with the main period of historical metal mining described earlier in this report. The increase in calcium at the bog surface is likely to be the result of biological recycling and uptake by living plants (Martínez Cortizas *et al*., 2005). Other elements decrease (e.g. Fe, Si and Ti). The decline of these lithogenic elements suggests the amount of dust deposition from soil erosion has declined (Martínez Cortizas *et al*., 2005). Unfortunately copper (Cu) was only determined sporadically and it is difficult to discern any pattern in the data that can be related to mining and /or smelting.

DISCUSSION and CONCLUDING COMMENTS

The peat coring site lies within the important Early Bronze Age burial landscape of the Plynlimon plateau. The necessary visibility of these burial cairn monuments would seem to suggest that a good part of this area had already been cleared of woodland by the beginning of the 2nd millennium BC, whilst the significant finds and distribution of arrowheads might suggest hunting within this territory, perhaps for red deer (see Timberlake 2009), in the open areas around natural lakes. Mining the oxidised outcrops of copper-bearing mineral veins would have been a significant enterprise on the eastern margins of this plateau, judging from the considerable amount of potentially Bronze Age exploitation of the veins we see at Nantyreira – also the nearest mine to the sampling site. There would also appear to be some association here between the discovery of these copper sources and the River Severn; perhaps the connection being the exposure of these veins within the river beds and gorges of the tributary streams. The evidence from Nantyreira implies the consumption of considerable amounts of wood fuel in the working of this mine.

Figure 7A: Geochemical data from SOS, 0-100 cm. Order from left to right: Fe, S, Br, Si, Ca, Cu, Ni, Ti, Pb.



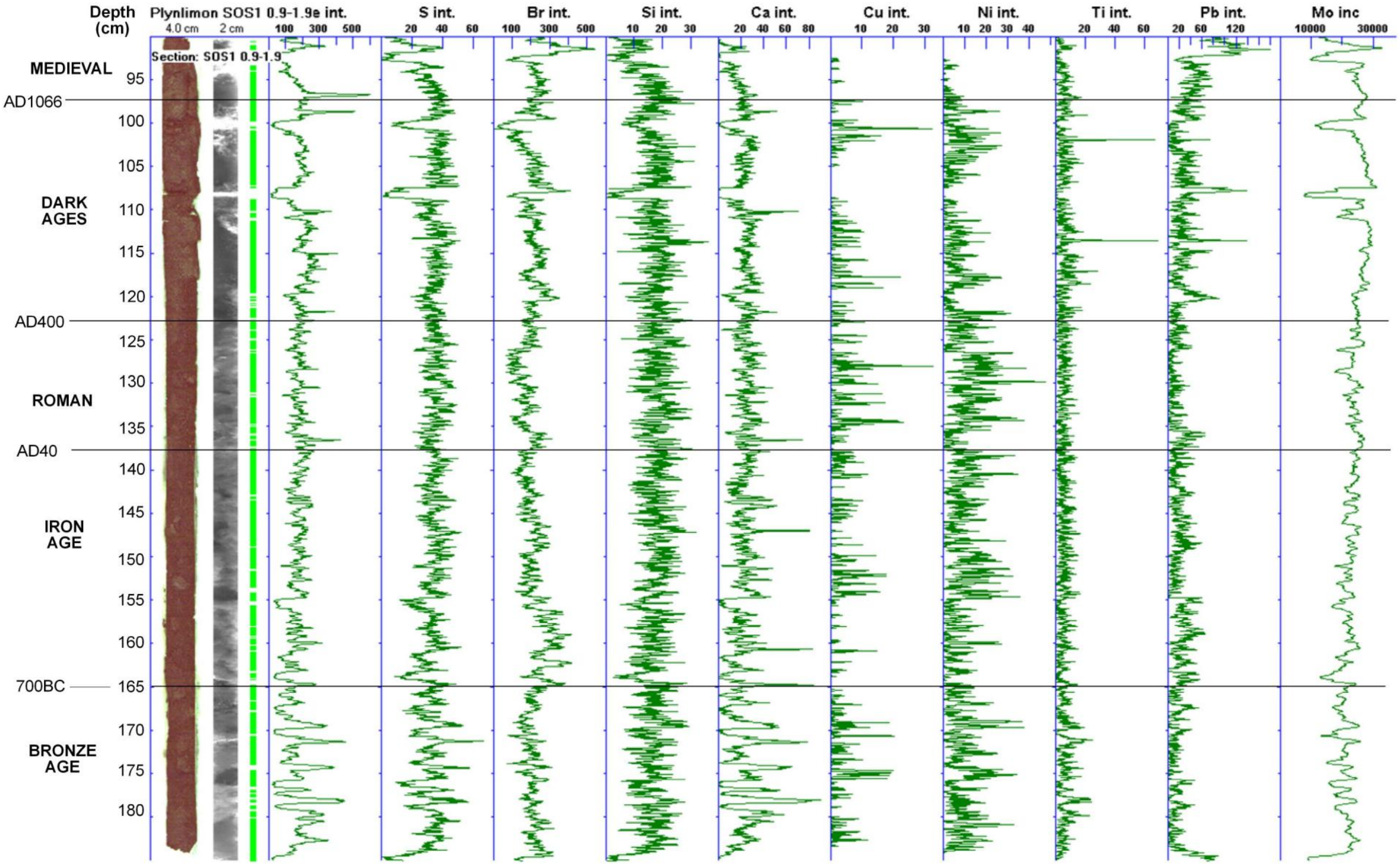
Core:	Section: - 1	User:	Date: 00/00/0
X-Ray tube: target		Filename: 0-1	Data produced by the AIGES Itrax
X-radiograph Conditions	,	Step Size: 200 microns	Dwell time: 0 /increment

Radiocarbon dates from charcoal taken from spoil heaps place the period of prehistoric copper mining at Nantyreira around 1865-1610 Cal BC. This corresponds with the lowermost part of the peat core at SOS, the basal date of which overlaps with the age of the mine. During this time a short-lived phase of woodland clearance takes place, particularly affecting *Quercus* (oak) and *Corylus* (hazel). Despite the possible high demand for wood fuel, the clearance is neither severe nor permanent. Even so, the decline might be in part the result of mining. Both taxa are commonly found in mine spoil and were most likely used for firesetting (Timberlake, 2003, Mighall *et al*., 1993a) and previous studies have suggested that small scale, short-lived disturbances on woodland are more typically associated with mining and/or metallurgical activities in prehistory (Mighall *et al*., 1993b; Mighall and Chambers, 1997; Mighall *et al*., 2010). Mighall and Chambers (1997) suggest that the duration and scale of mining reduced the severity of any impact on woodlands.

However, whilst microscopic charcoal percentages do increase at this time, no definable peak is recorded in the pollen record and microscopic charcoal might not be a reliable proxy for firesetting (Mighall *et al*., in press). The clearance may also be the result of agricultural activities or a combination of agriculture and mining. Non-arboreal pollen normally associated with pasture and/or disturbance was recorded during the Bronze Age, suggesting that people were exploiting the landscape for pasture, which could have been year round or seasonal.

Two major phases of woodland clearance were identified in the pollen record from site SOS. The first occurred during the late Bronze Age and early Iron Age, *c*. 885 to 485 Cal BC. Whilst there is little archaeological evidence for Iron Age or later occupation of this core area of the Plynlimon landscape, the pollen record provides evidence for human activity in the uplands during this period and may relate to the probable Iron Age enclosures and hut circles described earlier. The pollen data supports the contention made by Moore (1968) who suggested that Iron Age cultures were probably responsible for the considerable destruction of forests in the uplands of Wales. This decline also coincides with an intensification of land use, especially grazing as indicated by the renewed presence of pastoral and disturbance indicators in the pollen record during the Late Bronze Age and Early Iron Age despite a possible downturn in climate, *c*. 850 cal BC (Dark, 2006).

Figure 7B: Geochemical data from site SOS, 90-190 cm.



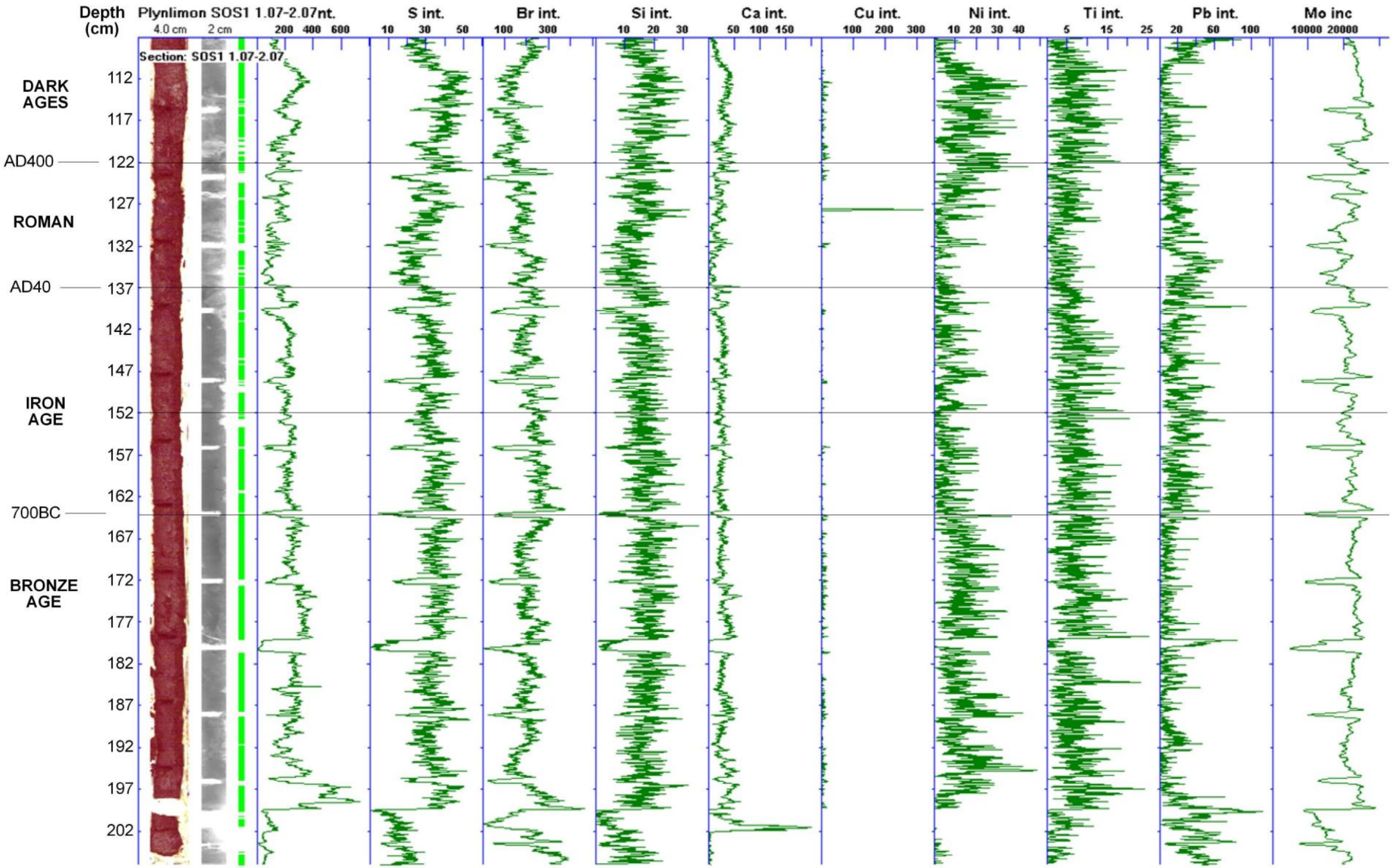
Core: Plynlimon SOS1 0.9-1.9	Section: SOS1 0.9-1.9	User: hfl	Date: 22/03/2012
X-Ray tube: target	Line camera signal 39139 at 25 ms	Filename: SOS1 0.9-1.9	Data produced by the AIGES Itrax
XRF Conditions	30 kV, 30 mA	Step Size: 200 microns	Count-time: 15 seconds/increment
X-radiograph Conditions	40 kV, 25 mA	Step Size: 200 microns	Dwell time: 200 ms/increment

The changes identified in the pollen record could relate to land use at lower altitudes, with pollen being transported by wind on to the upland plateau (Price and Moore, 1984). Alternatively if the evidence reflects changes in the uplands, it is inconsistent with the suggestion that this climatic downturn caused the abandonment of upland settlements in parts of Wales (Dark, 2006). In contrast it appears that the uplands surrounding Plynlimon continued to be used for grazing. Notwithstanding the limited sampling resolution, evidence for grazing appears to have been continuous from later prehistoric times onwards. The absence of cereal pollen is not totally precluding arable farming occurring during this time period. Cereals are self pollinated and their pollen is poorly dispersed due to their large grain size. Cereal pollen is not often found in abundance in peat bogs or lakes, even when located close to cultivated areas unless the pathway to transport sediment and cereal pollen from the field to a lake is very efficient (Pittam et al., 2006). For example, Hall (1989) has demonstrated that the representation of cereal-type pollen frequencies falls away very rapidly as distance from source increases (to less than 1% beyond 20m of its release).

Roman influence is limited to the passes of the River Wye (Cae Gaer fort) and River Clywedog at Dylife (Penycrocbren Fort), though at the latter site there is circumstantial evidence of Roman interest in the lead, and unsubstantiated claims of local lead smelting. There was no strong evidence for human activity during the Roman period in the pollen diagram from SOS where total arboreal pollen percentages increased implying woodland regeneration and non-arboreal pollen associated with cultural activities declined in value. The core did not reveal any substantial evidence for lead pollution. Elevated concentrations occurred during the Iron Age but declined during the early part of the Roman occupation between AD48 and AD124. Whilst most Pb pollution records in Britain see an initial increase in lead during the late Iron age (e.g. Le Roux *et al*., 2004), the absence of a more prominent Roman peak was unexpected as lead pollution, especially as it has been identified in peat cores close by in mid-central Wales in upland (Cwmystwyth) and lowland contexts (Borth Bog) during Roman times (Mighall *et al*., 2002a & b, 2009) and has been widely reported elsewhere across Britain and north west Europe (e.g. Martínez Cortizas *et al*., 2002). This discrepancy might be resolved by improving the chronological record of SOS.

The second phase of woodland clearance occurs at the end of the early medieval period *c*. AD1015-1385. Moore and Chater (1969) suggested that oak and alder woodland was probably cleared from valley bottoms and on the foothills during this time. This period of woodland clearance also coincides with the foundation of the Strata Florida Abbey. Moore and Chater (1969) suggest this resulted in intensive sheep grazing of the uplands. This is reflected in the increase of pastoral indicators in non-arboreal pollen record at SOS but there is no increase in the percentages of coprophilous fungi.

Figure 7C: Geochemical data from site SOS, 107-207 cm.



Core: Plynlimon SOS1 1.07-2.07	Section: SOS1 1.07-2.07	User: hfl	Date: 23/03/2012
X-Ray tube: target	Line camera signal 39276 at 25 ms	Filename: SOS1 1.07-2.07	Data produced by the AIGES Itrax
XRF Conditions	30 kV, 30 mA	Step Size: 200 microns	Count-time: 15 seconds/increment
X-radiograph Conditions	40 kV, 25 mA	Step Size: 200 microns	Dwell time: 200 ms/increment

Woodland clearance continues until c. AD 1390 (74 cm) and lower levels of woodland by this time are consistent with the requests by Edward I to clear woodland in order to limit rebellion against the King (Moore and Chater, 1969). However, human presence is also visible in the archaeological record with the existence of upland hafod settlements of possible medieval age in the study area. This is associated with both pasture and cereal cultivation. Because of the relatively coarse resolution of the pollen record, it is not possible to identify whether warmer conditions during the medieval warm period stimulated albeit marginal farming practices (cf. Parry, 1975) or permanent occupation of the uplands, but the grazing indicators in the pollen and NPP records support the idea that transhumance agriculture, including the grazing of cattle and sheep at least occurred during the summer months. The occurrence of both cereal pollen and pastoral indicators also provide evidence for mixed farming since the early Medieval period. More detailed analyses are required to test whether such practices can be extended back into later prehistory (Chambers *et al*., 1989).

There also appears to be little or no interest in mining before the end of the 17th century. At this point the copper and to a lesser extent the lead sources are re-discovered, but the scale of this work is small and probably with little environmental impact. No clear pollution signal for copper or lead was identified at SOS until approximately the 1660s when lead concentrations gradually increase. Whether or not there was another early historic phase of exploitation at Nantyreira remains an interesting, but as yet unanswered question.

Increased settlement within this upland area during the 19th century might relate in some way to the rise and a small boom in lead mining at Dylife which took place between the 1850s and 1880s, with some 300 miners being employed here by 1863, plus numerous others at the mines round about. Around this time Dylife could have been a source of more widespread lead pollution, although around the same time one of the largest lead mining operations in Britain was taking place at Van Mine only 12 kilometres to the east of the Plynlimon sampling site.

Acknowledgements

Thanks are due to the following people and organisations: CCW, especially Karen Heppingstall and Cinzia Sertorio, the landowner for permission to take the core, Henry Lamb for his assistance with the XRF scanner and Emma and friends for logistical assistance. Jenny Johnston helped draw the figures. Tomasz Goslar kindly fast-tracked the radiocarbon analyses.

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RADIOCARBON CALIBRATION PROGRAM*
                                CALIB REV6.0.0
                  Copyright 1986-2010 M Stuiver and PJ Reimer
          *To be used in conjunction with:
          Stuiver, M., and Reimer, P.J., 1993, Radiocarbon, 35, 215-230.
                    Annotated results (text) - -
                    Export file - c14res.csv
```

```
 Sample ID
 Lab Code
 Sample Description (80 chars max)
 Radiocarbon Age BP    770 +/-   30
 Calibration data set: intcal09.14c                # Reimer et al. 2009
   % area enclosed       cal AD age ranges             relative area under
                                                   probability distribution
   68.3 (1 sigma)     cal AD 1227- 1233                    0.151
                             1239- 1248                    0.173
                             1251- 1274                    0.677
   95.4 (2 sigma)     cal AD 1217- 1281                    1.000
```

```
 Sample ID
 Lab Code
 Sample Description (80 chars max)
 Radiocarbon Age BP   3360 +/-   35
 Calibration data set: intcal09.14c                # Reimer et al. 2009
   % area enclosed       cal AD age ranges             relative area under
                                                   probability distribution
   68.3 (1 sigma)     cal BC 1730- 1719                    0.076
                             1692- 1612                    0.924
   95.4 (2 sigma)     cal BC 1740- 1603                    0.856
                             1588- 1534                    0.144
```

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Table 2: Main characteristics of the pollen record from the SOS site.

Archaeological Period	Sample depth (cm)	Calibrated age range	Characteristics
Post medieval	25-58	AD1800-1500	Decreasing *Corylus avellana*-type, *Calluna*, Increasing Ericaceae, *Empetrum*, Poaceae, Cereal-type, *Plantago lanceolata*, *Rumex acetosa/acetosella*, *Pteridium*.
Medieval	61-98	AD1500-1065	Decreasing arboreal pollen (*Betula*, *Alnus*, *Corylus avellana-type*), increasing *Calluna*, *Plantago lanceolata*, *Rumex acetosa/acetosella*, *Pteridium*. Cereal-type present. Decreasing charcoal.
Dark Ages	98-121	AD1065-450	Total arboreal pollen gradually increasing. HdV 10 high but falling. *Plantago lanceolata*, *Rumex acetosa/acetosella*, *Pteridium* all well represented. Increasing HdV5, HdV6, spermatophore of Copepoda, Assulina muscorum, Hyalosphenia subflava. Charcoal peaks
Roman	123-137	AD450-40	Total arboreal pollen gradually increasing but *Salix* declines. High but falling Calluna and Cyperaceae. Poaceae well represented. HdV 10 peaks.
Iron Age	137-165	AD40-700BC	Total arboreal pollen initially decreases and the gradually recovers. *Calluna* increases. Cyperaceae peaks. *Plantago lanceolata*, *Rumex* & *Pteridium* increase. Increasing HdV10. Charcoal gradually

			increasing.
Bronze Age	165-210	700BC-1650BC	Tree and shrub pollen well represented but decline at the end of the period, high *Calluna*, declining Poaceae, increasing *Pteridium*. *Gelasinospora*, *Anthostomella fuegiana*, HdV6 and *Meliola cf niessleana* all present. Charcoal gradually increasing.