EXCAVATIONS AT CORS FOCHNO, CEREDIGION 2004 - 2005

INTRODUCTION

This report brings together the results of two seasons of excavation of part of a medieval timber trackway and late Iron Age and Roman industrial deposits on the fringe of Cors Fochno, Ceredigion (Fig. 1), between the villages of Talybont and Llangynfelin (NGR SN64929064) in 2004 (Page 2005) and 2005 (Page 2006a, 2006b). The excavations followed on from an evaluation of the timber trackway in early 2004 (Jones 2004).

Archaeological background

In 2002 the landowner, Mr Dilwyn Jenkins, uncovered part of a well-constructed timber structure during the excavation of a new land drain. Rapid salvage recording revealed the structure to be a planked timber box or trough and two radiocarbon dates were obtained (Table 1), which indicated a Middle Bronze Age date for the timber used in the structure.

Lab No	Sample No -Timber ID	Result (BP)	Calibrated range at 1 sigma	Calibrated range at 2 sigma
Beta-189526	BT02-1	3210 ± 60	BC 3475-3370	BC 1620-1390
Beta-189527	BT02-2	3280 ± 60	BC 1625-1500	BC 1695-1425

Table 1: radiocarbon dates from the 'box' timbers recovered in 2002.

During the course of the fieldwork a linear earthwork was noted in the adjacent field, so an application was made to Cadw for a small grant to investigate its character and to try to recover material suitable to provide a date for it. Cadw agreed to fund the evaluation and a trial trench was opened across the earthwork in March 2004 (Jones 2004) and a substantial stone and timber structure was uncovered. The exposed structure consisted of a layer of flat stones and gravel laid on the surface of the underlying peat and two parallel rows of roundwood stakes driven through the stone layer into the peat. Overlying the stones was a timber structure comprising parallel side rails and transverse planking. This was covered by two layers of gravel giving a track with a distinctive high centre line, with sloping sides. Radiocarbon samples from two of the timbers retuned virtually identical dates from the 10th or early 11th century (Table 2).

Lab No	Sample No - Timber ID	Result (BP)	Calibrated range at 1 sigma	Calibrated range at 2 sigma
Beta - 191064	BTH04-W178	1070 +/- 30	AD 970 - 1000	AD900-1020
Beta - 191065	BTH04-W158	1060 +/- 40	AD 970 - 1010	AD900-1030

Table 2: radiocarbon dates from timbers recovered in March 2004.

The March investigation also highlighted the fact that the timber was deteriorating at a fairly rapid rate due to the dewatering of the site through agricultural improvements carried out over the last couple of centuries and, more importantly, within the last few years. Therefore, it was decided, given the undoubted importance and potential of the site, the deteriorating condition of the timbers and the wish of the landowner to bring the field into cultivation, to approach Cadw to grant-aid a rescue excavation to record as much information about the track, particularly the timber element, as possible before it was lost and to aid the long-term management of the whole track. The excavation was carried out in July 2004.

The 2004 excavation succeeded in its objectives and much new and valuable information about the construction of the trackway was recovered. The results were also surprising, in that an extensive spread of industrial material was recorded underlying the southern terminal of the trackway. Because of the unexpected discovery and extent of the industrial deposits a further request was made to Cadw for a second season of excavation to investigate and characterise the industrial deposits. This second season was carried out in July 2005.

Both seasons of excavation were staffed by Cambria Archaeology and students from the Institute of Archaeology and Antiquity, University of Birmingham.

THE SITE

The excavation site lies on the southeast edge of Cors Fochno. To the south and east the land rises gently to the narrow terrace that carries the A487 Aberystwyth to Machynlleth road before rising more steeply to two high points at Allt y Crib and Cefn Erglodd. These are part of a broken northeast-southwest ridge on the western edge of the Ceredigion uplands. The site sits below a point where the ridge is broken between Allt y Crib and Cefn Erglodd, which gives it a slightly open aspect to the southeast and provides access to the interior along the valleys of the Afon Ceulan and Afon Leri (Fig. 1).

Cors Fochno is an important ecological resource designated (1976) as a British Bio-sphere Reserve. Land reclamation within the area '*has continued since 1820, with the last major phase dating from 1945 to 1970 … These have produced major change over the once extensive area of raised mire, with transitions to a range of tidal and freshwater marshes, reducing the wetland expanse by two-thirds, obliterating the natural habitat transitions, and leaving the remaining mire with damaged margins*.' (http://www.ukmab.org/BRReport/dyfi.htm)

The site consisted of two elements, a Roman lead working site and a medieval trackway. The industrial deposits occupied a strip of at least 120m along the fringe of Cors Fochno and the trackway was built to cross a narrow point of the bog in order to link Llangynfelyn and the dry ground to the southeast. Llangynfelyn occupies the southwest end of a small and narrow southwest-facing promontory, which if approached from the south has the appearance of an island in the bog. To access Llangynfelin on dry ground, by skirting the bog to the north, required a journey of *c*.4km (*c*.2.5 miles) as opposed to *c*.750m across the trackway.

The area surrounding the site contains archaeological evidence dating from the Bronze Age, Roman (Erglodd Roman Fort, PRN 6203) and medieval (a settlement at Goythenes, PRN 10902 and possible place-name evidence at Ynysycapel, PRN 6095) periods. In addition there is evidence for Medieval/Post medieval mining at Coed Erglodd lead mining complex (PRN 25965). To the north of the site there is evidence for mining in the Roman period at Llangynfelin copper mine (PRN 19500).

METHODOLOGY

The excavation strategies differed between 2004 and 2005 as a response to the changes in the site and discovery of the industrial material below the trackway. In 2004 the excavation was concentrated on two sections of the trackway (Trenches

4 and 5) to record its structure and condition and to inform the long-term management of the monument.

The discovery of the industrial material under the southern terminal of the trackway in 2004 led to a different approach in 2005, when one of the key elements of the project was to try to define the extent of the industrial activity. Therefore, as well open area excavations (trenches 6 and 7) a series of test pits (Trenches 8 – 23) were sunk across the site as a rapid way of assessing the extent and character of the buried deposits over a wide area (Fig. 2; Plate 1). Sixteen test pits were excavated, the results from which defined the north and south limits of the industrial deposits and located the remains of a furnace.

THE EXCAVATION RESULTS

The pre-industrial landscape

This section will provide a summary of the various strands of environmental research that were carried out during the excavation to describe the pre-industrial environment and how the industry impacted on the local landscape.

The recovery of a wooden trough dated to the Middle Bronze Age may show earlier activity on the site, although as has been pointed out (Briggs ****) the possibility of the use of bog aok canot be entirely ruled out. Bronze Age activity in the area is also been well attested from other sites within Borth Bog (Moore 1968; Mighall and Timberlake *in prep*), which has revealed human impacts on the vegetation and geochemical evidence suggests mining activity (Caseldine *et al*, see below).

The earliest deposits investigated here were recovered from T20 and date from the early- to mid-Iron Age, *c*.790-410BC (BETA-222224) where the pollen record revealed alder carr along the bog edge and oak woodland on the dry slopes to the south. Low-level pastoral agriculture is hinted at by the presence of fungal spores indicative of dung. Microscopic charcoal within the sequence indicates small fires locally, or perhaps industrial activity somewhere in the region. There was a decline in alder and slightly later in oak from around 420-200 Cal BC (BETA-211077) and a more open environment with increased agriculture is indicated at that time (Caseldine *et al*, see below).

Pollen from nearer the dry land margin (T11 and T17) confirms the constitution of the woodland communities and may indicate a possible clearance episode around 400-340 Cal BC and 330-200 Cal BC (BETA-241084), when high microscopic charcoal values coincide with a decline in alder and later slight reductions in hazel and oak (Caseldine *et al*, see below). Pollen from T17 shows that willow was also part of the carr woodland, at least in that part of the site. Charred alder and hazel from this period shows that some activity was taking place along the bog edge.

By around 80 Cal BC – 120 Cal AD (BETA-211076) there was a marked decline in the local woodland, which was associated with small peaks in microscopic charcoal and an increase in agricultural indicators, including cereal type pollen and weed species (Caseldine *et al*, see below). This occurred just before the onset of lead smelting.

A slightly later episode of clearance is indicated at around 1885-1870 C14 years BP (interpolated date) in the pollen record from T5a, which is about 100m to the north of the bog edge, and is, therefore, less affected by the alder carr, which was prevalent along the bog edge. This second episode is particularly marked in the decline of oak and a rise in lead values suggesting the start of, or an increase in lead smelting.

It is tempting to suggest that the earlier episode of tree clearance may have been associated with the establishemtn of the Roman fort at Erglodd, 500m to the south of the site. DATES AND DETAILS OF ERGLODD FORT.

The lead smelting site

The industrial deposits occupied a strip of at least 120m along the southern edge of the bog, although their full extent is presently unknown. For the most part the deposits consisted of horizontal bands of charcoal, charcoal-rich ash, smelting waste and residue from post-smelting processing (Figs. **** and ****; Plate ****). All the deposits were gritty and many contained fragments of varying sizes of what appeared to be crucible or furnace lining. Possible furnace lining material was recovered from most of the trenches and test pits indicating a widespread disposal of the remains of the furnaces. The horizontal banding of the deposits was consistent across the site, even though the deposits were often of mixed material.

The nature of the deposits changed across the site, with significantly more lead smelting waste present in the area around T4, T6, T12 and T21, suggesting that this area was the main focus of the operations (Fig. ****). The deposits were also substantially thicker in that area, up at least 0.75m thick, in T4 and T6. Not only did the deposits thin out of towards the east, although even on the edge of the excavation area (T17) they were still *c*.0.3-0.4m thick, their character also changed significantly. A sample from T17 contained charcoal and unburnt fragments of wood, possibly oak, but no slag and very few fragments of burnt stone. This confirms that the smelting was taking place further to the west and suggests that other operations, possibly charcoal burning, were taking place on the eastern edge of the site, possibly between T7 and T17.

The smelting hearth

A small smelting hearth (*1118*) was located in Test Pit 21 (Figs **** and ****; Plates **** and ****). The excavated section consisted of a sub-circular patch of orange and grey highly heat affected clay surrounded by a stony charcoal-rich layer. The furnace base measured *c*.0.65m diameter and was sat in a slight hollow, *c*.0.1m deep. Part of a low furnace wall survived in poor condition on its west side (Plate ****). The wall was constructed from clay and stones, some of which were heat affected and some had slag adhering, indicating that they had lined the hearth interior. The surviving section stood to 0.2m in height. The east wall had collapsed or been demolished and was spread over the northeast quadrant of the test pit.

The furnace had been cut into waste material (*1091*) from earlier smelting (Fig. ****; Plate ****) and sealed by a thick deposit of 'crushings' from later operations (*1085*). The furnace was filled with two deposits (**** and *1093*). Deposit *1093*, the upper fill, was charcoal rich and included black glassy vesicular slag containing traces of oxidised lead, suggesting that it might be charcoal from a furnace and smelting waste. It is possible that it came from another hearth a short distance to the north.

The material (*1091*) cut by the hearth (*1118*), was made up from charcoal and waste material from previous smeltings. The waste material included heat-altered rock and black glassy 'conglomerate slag'. The nature of the material suggests that it had been re-deposited, and may have been derived from the raking out an earlier hearth and the subsequent mixing of this material with other deposits in the area.

Underlying *1091* was a deposit of slag, charcoal and crushings (*1109*). The amount and the fresh condition of the slag suggest the close proximity of a smelting hearth, which must be earlier than hearth **** and the nearby hearth indicated by deposit *1091*.

The nature of the deposits encountered in T21 indicated several phases of smelting on or close to the site of the hearth. This is reinforced by the volume of material in this part of the site, with at least 0.75m of deposits present.

Plate ****: Remnants of the furnace wall.

Plate ****: The base of the smelting hearth during excavation.

Galena bearing ore rocks were recovered from T21.

Trench 12

A second, possible smelting hearth was thought to be present in T12. However, here the evidence was much less conclusive and more varied than that in T21 and it has been concluded that no furnace was present in the trench (Fig. ****: Plates **** and ****). It consisted of the west side of an irregular north - south cut feature (*1066*). The feature was cut through a layer of black/brown silty clay and charcoal that contained a fragment of hearth lining and crushed slag fragments (*1058*). There was no evidence for the east side of the feature and, therefore, it seems likely that cut *1066* was a later reworking of the industrial deposits, possibly related to providing material for the construction of the trackway (see below), rather than being a part of the smelting operation.

A discontinuous layer of grey gravel (*1059*) was present across the northeast end of the trench. The layer was made of small rounded stones and crushed industrial material and it was compacted enough to suggest that it had formed a rough surface. A similar gravel layer was visible in the base of a small pit (*1067*) at the west end of the trench close to cut *1066*. There was no evidence to suggest a former function for pit *1067*, although a small alder stake (W304) was recovered from just inside its north edge. Although the stake was badly preserved, it was possible to identify that it had a pencil point. A second possible stake (W303) was present a short distance to the south of W304, although it is thought more likely that it was a fragment of root.

The base of the trench was uneven as there was a number of shallow cuts or hollows running roughly north – south across the trench. These appeared to have been the result of reworking of the deposits, and were probably caused during the construction of the trackway.

A small assemblage of timbers was recovered from the base of the trench consisting of 2 pieces of oak, 2 ash, 2 hazel and one each of alder and willow or poplar. The piece of ash had been charred at one end. The assemblage as a whole reflects the local woodland communities and is in concordance with the pollen record from the site. The assemblage is also similar in composition to the charcoal record from T12, which, although small, was dominated by oak, with lesser values for alder and hazel. Birch and Maloideae type charcoal was also present, although in small quantities (see below for a discussion on fuel and timber resources).

Several large stones were also present in T12, which were similar to those used beneath the trackway to fill hollows in the peat surface. The stones did not appear to have been structural, and it is possible that they were brought to the site along with the ore for crushing.

Plate ****: T12, showing the west edge of cut feature (*1066*) on left of photograph.

The nature of the industrial deposits

The mixed nature of the industrial deposits makes it difficult to talk about layers or individual deposits and this discussion will, therefore, be more wide ranging and discuss the deposits across the whole site and will not necessarily be in trench order. The analysis of the material from a number of the trenches and test pits is presented below in Appendix ****.

Geochemical and slag analysis carried out on samples taken during 2005 indicated that the deposits that made up the bulk of this site were clearly derived from lead smelting. It has also shown that they were for the most part material from the smelting and subsequent reworking of the residues rather than waste from pre-smelting processes.

The deposits were present in varying depths across the site, with Trenches 6, 12 and 21 containing the most abundant quantities of material, with at least 0.75m present, although the true depths were never established and, therefore, the deposits may be significantly thicker. The depth of deposits reduced to the east of the site, with only 20cm of deposits in T17 and between 20cm and 30cm of deposits in T10 and T11 towards the centre of the site.

As well as the reduced depths towards the east of the site (T7, T11 and T17) the make up of the deposits also changed significantly to material containing little or no smelting waste and more charcoal and unburnt fragments of wood, suggesting that other processes were taking place in this part of the site. It has been suggested that the deposits in T17, the easternmost trench, are characteristic of charcoal production, possibly indicating charcoal clamps in this part of the site (Timberlake, see below). Charcoal clamps are usually located by water in case the clamp catches fire and the pollen record from T17 suggests that there was standing water nearby (Caseldine *et al*, see below).

Initial assessment and analysis of the samples has shown that the deposits contain very similar proportions of the same types of material, crushed slags, hearth linings, charcoal and local soil and rock fragments. The indication is that they were all derived from the same range of processes, in this case lead ore smelting, with subsequent re-crushing of slag – possibly to retrieve trapped lead. This has resulted in the significant depths of material that were across the west half of the site. It seems likely that substantial amounts of slag were moved around the site to presumably clear the area and also to level some areas, possibly for the construction of later hearths.

The split between the deposits across the two halves of the site, with the more charcoal rich material on the east half, particularly in T7 and T17, raises the possibility that charcoal production was taking place in a dedicated area of the site.

Resources

The Llangynfelin site has all the requirements needed to smelt lead ore using wind-blown bole furnaces. There was an abundance of local resources within a very short distance and the slight rise at the edge of the flat open bog meant that the virtually ever-present wind was channelled up the slope and into the furnaces.

The different metals present within the slags suggests the use of a mixed and complex ore for smelting, although, the ore is predominantly galena (PbS) associated with quartz in the gangue (Anguilano, see below). An assessment of a few galena bearing rocks recovered from T21 (the only place on the site from which they were recovered) indicates a probable origin in the Allt y Crib or Tan yr Allt mines, which are located 1km to the south and overlook the site (John Mason *pers*. *comm*.). This means that transport of the bulky loads of ore was could be achieved quickily and easily.

Likewise the wood used in the furnaces, either as charcoal or wood, was readily available on the bog, or the nearby local slopes. Oak was the most abundant charcoal represented, although there were also fairly high levels of alder and birch. That oak was clearly the fuel of choice is not surprising because when burnt either as wood or charcoal it provides high heat for longer than most other wood types. The pollen records also show a decline in oak pollen at the same time as a rise in lead values, between *c*.1885 C14 years BP and *c*.1870 C14 years BP (interpolated dates), indicating that the increase in smelting was impacting on the local oak woodland (Caseldine *et al*, see below).

The stones and clay that were used to construct the walls of the furnace were also easily available. It is probable that the stones would have been from the preparation of the ore and the clay would have been readily available along the bog edge.

Processes

The deposits examined indicate a reasonably efficient smelting operation, with a subsequent crushing of the resulting slag, possibly to extract any remaining trapped lead metal.

Analysis of the composition of the slags from three deposits close to the hearth in T21 has shown that it is not homogeneous, but the temperature suggested by the compositions is fairly similar, and indicates a furnace temperature of between 720-780°C. This sort of temperature is easily reached within a wind blown bole furnace. The presence of metal, oxide, sulphate and sulphide indicates very variable red-ox conditions and is another indication of a wind blown furnace (Anguilano, see below).

Dating the industrial activity

All of the deposits contained significant amounts of charcoal suitable for radiocarbon dating. Radiocarbon dates from two samples collected from T4a in 2004 returned calibrated dates of 60BC-90AD and 20AD-220AD (cal 2 sigma: Beta-204040 and Beta-204041), although the dates are inverted. These dates, from charcoal samples taken from within the industrial deposits, overlap with dates obtained from *in situ* peat deposits taken from T5a, which sandwiched a significant ‘spike’ in charcoal levels that appears to relate directly to the period of industrial activity. The peat from below the ‘spike’ returned a calibrated date at 2 sigma of 80BC-150AD (Beta-222223) and the calibrated date at 2 sigma from above the 'spike' was 220AD-440AD (Beta-222222). The concord between the two sets of radiocarbon dates shows that the dates from the charcoal reflect contemporary activity and that the charcoal was from contemporary woodland and not from older bog timbers (Astrid Caseldine *pers*. *comm*.). Further dates from just below and within the industrial deposits in T17 returned calibrated dates of 80 BC – 120 AD (BETA-211076) and 50 BC – 120 AD (BETA-238737), which are also in good accordance with the date from below the deposits in T5a

A peak in lead values recorded soon after 220 – 440 AD (BETA-222222), may indicate another, short-lived, episode of mining or smelting in the area, or it may have been the result of the erosion of earlier deposits (Caseldine *et al*, see below).

An AMS date from the peat directly above the industrial material in Trench 6 (see below) returned a calibrated date of 350-540 AD (BETA-235895), which is also in good agreement with the other dates. Dates from charcoal taken from within the industrial deposits in T20 returned calibrated dates of AD50 – 230 AD (BETA-238739) and 30 BC – 130 AD, which like the dates from T4a were inverted, although they are within two standard deviations and could, therefore, be contemporary. However, the inversion of these two sets of dates seems to indicate a reworking of some of the deposits.

Several of the dates suggest that some industrial activity was taking place in the Late Iron Age, with a marked increase in the Roman period, with production ceasing at the site by the 3rd or 4th century.

The pre- trackway landscape

The hollow (****)

The hollow below the west side of the trackway first encountered in 2004 in T4b was investigated in Trench 6. The hollow was fairly shallow and extended beyond the northwest corner of T6. It had a gently sloping east side and a rounded base, which stepped up on the west side. The hollow was completely filled with peat (*1123*), which was sampled to provide a fairly detailed picture of the environment in this part of the site between the end of the industrial activity and construction of the trackway.

An AMS date from the base of the hollow and the interface with the underlying industrial deposits suggested that industrial activity had ceased by 250-540 AD (BETA-235895), although, it may have ended earlier, with a hiatus between the cessation of the smelting and development of the peat.

The pollen record shows very high poaceae values, suggesting a grassy environment following the abandonment of the industrial activity and a lowering in weed species indicates reduced levels of human activity and disturbed ground habitats. A rise in birch pollen suggests an expansion in birch woodland either on the wet bog, or on the nearby dry land. An increase in oak and alder at the same time indicates that the area may have been all but abandoned as woodland was regenerating across the slopes of the bog edge.

This increase was followed by a reduction of the birch and alder woodland and a rise in hazel or bog myrtle communities around 680-890 Cal AD. An increase in weed species during this period suggests increased human activity in the area, which is thought to have been largely pastoral, although cereal type pollen was also present. Oak woodland continued to expand until sometime after 810-1010

Cal AD, when it declined to low levels. Alongside this was a further increase in weed species, particularly *Plantago lanceolata*, and dung beetles indicating an increase in grazing in the area. It is not certain if the grazing was on the bog itself, or along the dry margin.

Cattle can feed in wet, boggy conditions and current grazing regime on the bog, which has some wet areas grazed by cattle – sometimes up to their flanks in water, may mirror the medieval practice. Dung beetles were also recorded in the upper deposits below the trackway in T5a (see **** below), which is *c*.100m from the bog edge. However, dung beetles can fly reasonable distances and so they could easily have been from the dry ground to either side of the bog. What it does show is that prior to the trackway construction the area along the bog edge at least was grazed and there were some stands of oak woodland on the slopes to the south, and presumably on Llangynfelin to the north, with alder carr on the bog edge.

The trackway

Two areas of the track were machine stripped, cleaned and hand excavated in 2004 (Fig. 2, T4 and T5). Trench 4, which measured 25m x 10m, was partially reopened in 2005 (T6). Trench 4 was located to investigate the junction of the track with the dry ground on the southern edge of the bog. Trench 5 was positioned towards the northern end of the field across an area of the track that been disturbed by drainage works and other agricultural operations. Trench 6 was opened to reinvestigate the trackway and the underlying industrial deposits that were encountered in Trench 4, but not fully examined in 2004.

Trench 4

The principal objective of Trench 4 was to define the nature of the track at the junction of the bog and the dry ground and to investigate the possibility of a terminal of some kind. Prior to excavation the visible earthwork narrowed towards its southern end and appeared to come to a rounded terminal. However, aerial photographs seemed to show it continuing through the excavation area into the base of the ridge some 20m south of the site.

Removal of the thin layer of topsoil and turf revealed the surface of a pronounced agger, comprising a gravel and stone surface with a clay shoulder along its west side (010). It was originally intended to fully hand excavate the track and any underlying deposits. However, this was not practical due to the extent of its survival and the sheer volume of material. Instead, it was decided to excavate a more limited area at the southern end of the area (T4a) and two 1m wide cross sections (T4b and T4c).

T4a - this area was positioned towards the southern end of Trench 4 to investigate the possible terminal of the track and its structure at the point it met the dry ground of the bog edge. It measured 4.5m x 3m and was excavated to a general depth of between 20cm and 40cm.

There was very little of the timber structure left in this area; what did survive consisted of a line of six stakes (039). The stakes, one of which was a sizeable post were arranged along the west side of the trackway and were simply modified roundwood stakes with pencil points driven through the industrial deposits.

The trackway was constructed from layers of gravel, stone and waste material from the Roman lead smelting. The lower layer consisted of blue-grey fairly fine industrial waste, 0.07m thick (020), which was overlain by a thin deposit of humic, organic material that appeared to be degraded timber (019), which may have been part of the timber structure recorded throughout the rest of the trackway. The upper surface of the trackway was 0.16m thick and consisted of buff gravel and larger stones (006) forming a pronounced cambered agger (Plate 4). A clay shoulder had been added to the west side, probably as a result of slumping of part of the track into a peat-filled hollow encountered in T4b and Trench 6 (see below). There was no evidence here for the stone layer below the trackway recorded in all the other excavated areas, suggesting that the firmer nature of the ground at this point precluded the need for any support.

Sometime after the track had been constructed a narrow slot (022) was excavated along at least part of its eastern edge. The slot, which was also recorded in T4b (016), contained bundles of small roundwood rods along its base. Some of the wood had been burnt, possibly prior to deposition in the trench, but this was not certain. The wood did not appear to form a structure (although during the excavation it was thought that they may have been part of a collapsed wattle hurdle) and it seems likely that they were inserted as bundles of roundwood into the base of the open trench, possibly to act as a drain.

T4b – this 1m wide cross section was located approximately midway along Trench 4 to investigate an area where the track survived in good condition. Excavation revealed that the trackway comprised the two upper gravel layers noted in T4a, the timber structure and the clay shoulder along the west edge also noted in T4c and Trench 6.

The timber structure (014) consisted of side rails on the west side and transverse timbers with a number of stakes along the east side. The stakes were small, simply modified roundwood stakes with pencil points and appeared to have been driven from the level of the timber structure, although, it is possible that the tops had been lost. The stakes were presumably intended to prevent the lateral movement of the peat surface and the timber structure.

The cross timbers were predominately oak and ash. One of the oak timbers was suitable for dendrochronology and it indicated a likely felling of ****. This accords well with other dates obtained from timbers in other sections of the track in T5 at the northern end of the site (see below).

The timber structure sloped steeply to the west (Plate ****) and was seen to be slumping into a peat filled hollow below the west edge of the trackway (see Trench 6 below for a discussion of this).

The timber structure was overlain by a layer of blue-grey gravel and industrial waste material, 0.15m thick (011/058), which was overlain by the upper gravel layer (006). A horseshoe of probable post-medieval date recovered from 006 indicates fairly late repairs and long continuity of use.

T4c, was hand excavated through the track to the top of an underlying layer of peat (054) at the northern end of T4 in order to obtain a profile through the track that also included the deposits below and on either side. This peat deposit filled the hollow (****) that was also recorded in T4b (see Trench 6 for discussion).

The trackway had a foundation layer of large stones (009) supporting a timber structure, consisting of side rails, cross timbers and driven stakes (008), which was overlain by two gravel layers (007 and 006). The foundation layer (009) comprised large irregular stones laid onto the surface of the underlying peat (054). Similar layers of stones were noted in other areas along the trackway and it likely that they were dumped to fill wet hollows in the peat surface.

Overlying the foundation stones were very fragmentary remains of the timber structure, consisting of side rails laid longitudinally to support transverse cross beams (008). Three/four parallel rows (050, 051, 052 and 053) of pointed driven stakes were noted within and under the stone foundation layer. The stake rows were aligned north-south, along the track, and had presumably been intended to stabilise the peat surface and to stop lateral movement as the foundation stones were laid. The timber in this trench was very fragmented, desiccated and decayed and most of what survived had been squashed virtually flat, so provided little opportunity for analysis. Above the timber were two layers of gravel (007 and 006), which formed a pronounced flattened, domed agger, c.4-5m wide x 0.4m high. The lower layer (007) was a grey blue gravel and industrial waste material virtually identical to that seen in T4a and T4b. The upper gravel layer (006) contained a number of large stones, rounded and angular, which protruded through the track surface.

The clay shoulder recorded along the west side of the track in T4a and T4b (010) was also present.

Trench 5

This trench was intended to investigate the condition and survival of the timber element of the trackway and to provide, if possible, further material for dating. It was positioned towards the northern end of the field and across an area of the track that been disturbed by drainage works and other agricultural operations. This had resulted in the trackway being less pronounced and the decision was taken to machine off the remainder of the gravel layers in order to expose the timber structure and foundation layer. Trench 5 was sub-divided into four areas separated by 1m wide baulks (areas T5a – T5d).

The timber structure displayed variation among its surviving sections, with some of the typical side rails and cross-timbers being substituted by longitudinal timbers. A number of driven stakes were recorded throughout Trench 5, although they were fairly randomly placed and there were no identifiable rows similar to those recorded in the evaluation trench (Trench 2) and the southern area (Trench 4 and Trench 6). Timber was recovered from all four areas of T5, although very few structural elements (a few stakes and one fragmentary cross timber) survived in T5c, the northernmost area, as it was located closest to the main drain and had subsequently suffered the most from dewatering. Trench 5c had also been heavily disturbed by agricultural activities and the agger had been almost levelled in places. Therefore, the following discussion concentrates on the sections recorded in T5a, T5b and T5d where the preservation of the timber was better and the trackway survived in a reasonable condition.

T5a was **** x **** and aligned north south along the line of trackway. Removal of the **** thick gravel surface exposed a fairly well preserved section of the timber structure (043), which consisted of a ****m length with side rails and transverse cross timbers, which gave way to longitudinal timbers for ****m. Underlying the timbers were patches of large rounded and sub-angular stones (****), which appeared to have been dumped to fill wet hollows in the peat surface. Industrial material was also present below the timbers, but it seems likely that this material was originally used to form the surface and had subsequently dropped though to the peat surface below.

The section of the timber structure that had been constructed using longitudinal timbers had been virtually lost through decay and desiccation of the timbers: only three lengths of timber of any size and a few small fragments survived. Two of the surviving timbers (wood numbers W70 and W71) were Alder roundwood and the third was an oak tangential split plank (W73). Other small fragments of oak were also evident in this part of the structure (W74 and W77). Some of the small fragments were too degraded to be samples for identification.

The side rail and transverse cross timbers section of the structure survived in fairly good condition. At this point the structure was 2.1m across. The west side rail was made up of three, possibly four lengths of radially split oak (W59, W60, W80 and W81). Dendrochronology has suggested felling date ranges of 1085-1121 AD (W59) and 1020-1056 AD (W80) for two of the three timbers.

Of the 26 recorded transverse cross timbers, 19 were alder, 5 were oak and 2 were hazel. Dendrochronology on two of the oak timbers indicated felling date ranges of after 1000 AD (W56) and after 1056 AD (W57). Both these timbers had been radially split, but were in fairly poor condition. Both these timbers, along with W47 and W129 from T5b and W202 from Trench 6 are thought to have been from the same parent tree.

The alder and hazel timbers were all roundwood, except for one alder timber that may have been half split. A few of the roundwood timbers had had side branches removed.

There was little evidence of any major woodworking, and for the most part the structure was constructed using simply converted alder and hazel roundwood. The oak had been worked more, presumably to get the most from it, although, it the conversion into radially and tangentially split timbers was still straightforward.

The dating of the timbers from this section of the structure is slightly ambiguous as one of the side rails has a suggested felling date of between 1020 and 1056 AD, which appears to be significantly earlier than the other dated timbers in this area. However, problems with the preservation of the timbers and the possibility of the loss of some of the heartwood during the conversion of the timbers for construction makes these dates tentative (see below ****).

Plate 2: The construction sequence of the trackway revealed in T5a showing the stones below the timber and the overlying gravel surface.

T5b – This area measured ****m x ****m and was aligned along the trackway. The gravel surface in this section was *c*.0.2m thick and was removed by machine. The timber structure (043) survived in fairly poor condition in this area and the surviving elements consisted of side rails and fragmentary and poorly degraded cross timbers. The stone spreads noted in T4 c and T5a below the structure were also present in this area and, as with elsewhere on the site, appeared to have been dumped to fill hollows in the peat surface. A spread of gravel and industrial waste material was also present on the surface of the peat, but this is assumed to have fallen though from the surface above as the timber structure degraded.

The surviving timber structure consisted of three side rails and a few fragmentary transverse cross timbers (fig. ****). Only eight timbers were in a condition to be examined and lifted. Of these five were oak, two were alder and one was hazel. The oak timbers were lifted for possible dendrochronology and only these will be discussed here.

Three of the oak timbers had been used as the side rails (W129, W130 and W135) and the other two were transverse cross timbers (W131 and W132). The surviving length of the west side rail contained two radially split timbers W129 and W130, while the east side had one surviving timber (W135), which had been tangentially split. The two cross timbers had been radially split.

Only three of the timbers were dateable for dendrochronology: the two side rails from the west side (W129 and W130) and one of the cross timbers (W131). These were too degraded to produce and absolute felling date, but all were able to provide a felling date range; W129 was felled after 1026 AD, W130 was felled after 1038 AD and W131 was felled after 1098 AD. The problems of dating of the degraded timbers and the potential loss of heartwood will be discussed elsewhere (see below), but there are some observations that may be made here. The similarity in the suggested felling date range of two timbers in the west side rail are close enough to the felling date range of one of the side rail timbers in T5a (W80) of between 1020 and 1056 AD and two cross timbers from T5a (W56 and W57), after 1000 AD and after 1056 AD, respectively, may indicate a single building episode. The later date range of the cross timber, after 1098 AD (W131), may reflect a later repair, which may also be supported by the suggested later dates of one of the side rail timbers from T5a (W59) of between 1085 and 1138 AD.

T5d was excavated to the south of T5a to further investigate the timber structure as it was thought that the survival of the timbers would improve further from the drain that flanked the site and had affected T5c. As with the other sections in Trench 5, the *c*.0.2m of gravel was removed by machine to expose the timber structure (043). The southern end of the timber structure rested on a spread of large angular and sub-angular stones (047), similar to those recorded along the length of the trackway. Gravel and industrial waste material recorded below the timber structure has again been interpreted as having fallen through the degrading timber structure.

The timber structure was similar to that recorded in T5a, having a short length of side rails and transverse cross timbers giving way to longitudinal timbers (Fig. ****: Plate ****). A total of 36 timbers were in a condition to allow lifting and identification. Of these the vast majority (30) were alder, with 5 oak timbers and 1 hazel timber also present. Two stakes were recorded below and alongside the structure, which suggests that the stakes recorded in other areas were not present in numbers along the whole of the trackway.

The section of side rails and cross timbers survived in fairly good condition, although only one east side rail (W101) survived: no west rails survived. The surviving side rail was a length of alder roundwood that had been simply modified by the removal of numerous side branches. Most of the cross timbers were alder roundwood, suggesting that branch wood had been used with little or no modification, although all of the timbers were badly compressed and degraded, so it is possible that some detail of conversion was obscured. One of the oak cross timbers (W90) had a through mortice at its east end, which was originally thought to have been a stake hole to anchor the timber in lace, but there was no accompanying stake and it may have been a piece of reused structural timber.

The longitudinal timbers, included a massive tangentially split oak plank (W88), which was over 3m in length and almost 0.5m wide. The other longitudinal timbers were all alder roundwood. The southern end of W88 overlay cross timber W90 and another oak cross timber (W87). The longitudinal timbers appeared to bridge a *c*.3m gap in the structure between two areas of side rails and cross timbers, one of which extended into T5a.

Four of the oak timbers (W87, W88, W98 and W90) in this section were sampled for possible dendrochronology, although, only three were able to provide any dates and even these were not absolute, resulting in either felling date ranges and 'felling after' dates. Of these timbers one (W87) was a small fragment of oak that appeared to have been displaced and was recovered from above the southern end of W88, which adds to the uncertainty of this sample, especially when the concerns over all of the dates from Trench 5 are considered. The two suggested dates from cross timbers W89 and W90 of between 1076 AD and 1112 AD and after 1067 AD, respectively, appear to be in fairly close agreement. There was a recognisable and correlation between the ring sequence of W80 and W90 to suggest that they may have derived from the same parent tree. The suggested felling date of after 1065 AD of W87 is also in tantalisingly close concord, although, as discussed elsewhere, all of these dates must be treated with caution.

Plate ****: the substantial oak timber and other longitudinal timbers in section T5d.

Trench 5 discussion

The timber structure recorded in Trench 5 showed some significant differences in its construction, with the side rails and cross timbers replaced in some sections by longitudinal timbers. There was no evidence in either of the sections of longitudinal timbers that had replaced earlier cross timbers, so they appear to have been part of the original design and not later repairs.

The stone spreads below the timber structure were not present along the whole length of the trackway, suggesting that they were dumped in hollows in the peat surface and were not an earlier stone causeway.

The timber was predominantly alder, with good representations of oak and less presence of hazel, all of which were available in the local region, either on the edge of the bog or on the dry slopes just to the south. A number of the timbers from T5a (W56 and W57) and T5b (W47 and W129) were thought to have derived from the same parent tree. A timber exposed at the south end of the trackway (W202, in Trench 6), was also thought to have been from this tree. Timbers W89 and W90 in T5d were also thought to have come from a single tree.

Problems with dating the timbers and the trackway construction will be discussed in more detail below, but it is worth mentioning that many of the dates are similar and may suggest an initial construction during the mid 11^{th} century with some later repairs around the end of the 11^{th} century or the early 12^{th} century.

Trench 6

Trench 6 measured ****m x ****m and was positioned at the southern end of the trackway to reinvestigate the central part of Trench 4 to further investigate the trackway and its relationship to the underlying industrial deposits.

Mechanical removal of the upper layers of gravel revealed a ****m long stretch of the timber structure overlying the extensive spreads of industrial waste material identified in 2004. The structure consisted for the most part of close-packed transverse cross-timbers, including half-round timbers and split planks. Four parallel rows of stake uprights ran along the line of the trackway and were for the most part below the cross-timbers. A single willow or poplar roundwood branch (W290) had been laid to act as the west side rail for some of the cross-timbers. There did not appear to have been a side rail on the east side.

A total of **** timbers were recorded, of which 85 were identified to species: these were 35 alder, 32 hazel, 12 oak, 3 willow, 2 ash and 1 Maloideae type.

The stakes were all alder or hazel roundwood simply modified with either pencil or chisel points. The cross timbers, which were identifiable to species were a mix of alder and oak, but the timbers were in poor condition, heavily compressed and degraded, so that only approximately 40% of the timbers were identified. Several timbers survived as compressed bark only. The cross timbers that were in a condition to be examined were a combination of tangential and radially split timbers. Most of the timbers appeared to have been laid with the split face downwards, so the bark (where present) and the round sides were uppermost.

A short length of at the extreme south end of the trackway appeared to have been truncated on its eastern edge, but the timbers (W200 – W209) were so degraded that no evidence of any saw or cut marks was visible. This area seemed to have been filled with compacted gravel and industrial waste as a form of simple repair. The central section of the trackway in Trench 6 also appeared to be slightly truncated on its east edge and it is possible that the truncation was the result of differential drying and degradation from the east edge of the timbers on the dryer ground towards the bog edge.

The timbers at the northern end of the trench were sloping to the west, and as with the timbers from T4a (see above) it was apparent that they were slumping into the peat filled hollow (****).

Only five timbers were in a condition to allow dendrochronology. These, in common with all the timbers dated, did not provide absolute felling dates, but rather two were undateable timber and of the other three, two gave felling date ranges or 'felling after' dates. These were W202, which was felled after 1069 AD and W243, which had a suggested felling date between 1094 and 1130 AD. The third timber, W242, gave the closest reliable felling date of soon after 1136 AD, and it is suggested that this is perhaps taken as the best indicator of the date for the trackway, based on the preservation of the timbers and the accuracy of the resulting dates.

It seems likely that W242 and W243 were from the same parent tree and W202 is probably from the same parent tree as timbers W47, W56, W57 and W129 that were recorded in T5a and T5b.

Sometime after the track had been constructed a narrow slot (*1016*) was excavated along at least part of its eastern edge. This slot was also recorded in 2004 when it was seen in T4a to contain bundles of small roundwood rods along its base. Some of the wood had been burnt, possibly prior to deposition in the trench, but this was not certain. The wood did not appear to form a structure (although during the excavation it was thought that they may have been part of a collapsed wattle hurdle) In 2005 the slot was investigated at several points within T6 and wood was recovered lying along the base of the slot in all these areas. It seems likely that the wood was inserted as bundles of roundwood and loose timbers into the base of the open trench, possibly to act as a drain.

Discussion Trench 6

The length of surviving timbers in Trench 6 revealed an important aspect of the structure in that the timbers were laid round side up, so that it seems clear that at the southern end of the trackway at least that the timbers were never intended to be the surface. The original design appears to have been for the timbers to act as a base for a surface constructed out of the compacted industrial waste and gravel.

Much of this end of the timber structure was constructed straight onto the surface of the industrial deposits, which has led to it becoming compressed and badly degraded. The uprights and stakes extend along all of this section of the trackway, which is perhaps a bit surprising as it is assumed that where they are present in other parts of the trackway they were to stop lateral movement of the underlying peat and stabilise the structure. That said, the peat-filled hollow (****) may have been more of an inlet-type feature and may in fact have been the start of the peat proper, which in this area would have developed to cover the abandoned industrial deposits, and so the stakes may have been more necessary than perhaps they first appeared.

The trackway discussion

Resources

Resources used for the construction of the trackway were all available from the bog margins and the dry ground on the surrounding slopes, so presented no particular problems of acquisition or transportation. The majority of the timbers were, unsurprisingly, alder, with a high percentage of oak also used. Other species present were ash, willow, and hazel in varying amounts.

The timbers were, for the most part, in too poor a condition to reveal details of any woodworking technology, although, it was possible to establish the method of conversion of some of the cross timbers. The bottoms of the stakes survived in reasonably good condition, so it was possible to at least record the point type. They were a mix of pencil, wedge and chisel points, none of which required any specialist woodworking knowledge, in fact there was no evidence to suggest that any great level of skill was required to construct the trackway.

One timber (W90) in T5d had a mortice at its eastern end and it may have been reused from an earlier structure. Unfortunately, its condition was too poor to allow survival of any evidence of woodworking technology of the mortice or the rest of the timber.

The stone used to fill the hollows in the surface of the peat was probably collected from close to site and may have been from the industrial deposits.

The surface of the track was constructed from the smelting waste, which at the time may have still been visible as vegetation free mounds along the southern edge of the bog. There were two distinct layers, or surfaces, the later one contained a post-medieval horseshoe showing that the trackway was resurfaced, or at least repaired, late and continued in use for some time.

Dating the trackway

The biggest problem of dating was the loss, or uncertainty of the identification of the boundary between the sapwood and heartwood, which is crucial for dendrochronological analysis. The degradation of the timbers was such that in most cases the sapwood was missing and it was thought that there may have also been the loss of some outer heartwood. Where such a boundary was suspected in the field the timbers were radial splits and it is possible that sapwood was removed from these timbers (along with some outer heartwood rings) by secondary splitting by the builders during construction. Therefore, the apparent heartwood sapwood boundaries may be a result of the construction and have no chronological implications.

Where dates were possible, they were in the form of felling date ranges, or felled after dates, which whilst informative and suggestive do not provide the absolute dates that were hope for. In the one sample where the heartwood sapwood boundary had been definitely identified (W242), and despite the possible loss of a couple of outer rings to degradation, a felling date of soon after 1136 AD is indicated (Nayling ****). The other dates seems to suggest several phases of construction and repair, with perhaps the initial construction in the mid- to late-11th century, with a later repair phase in the early- to mid- 12th century.

Radiocarbon dates from two stakes recovered during the initial evaluation in 2004 returned calibrated dates of 900-1020 AD (BETA191064) and 900-1030 AD (BETA191065). Further radiocarbon dates were obtained from the peat deposits below the trackway in Trenches 5a and from the peat filled hollow in Trench 6. These were calibrated to 660-890 AD (BETA-235891) and 810-1010 AD (BETA-235893) respectively. Both dates were from peat a few centimetres below the top of the peat as the deposition of the industrial waste along the trackway would give erroneous dates. The date from Trench 6 seems to be a reasonable fit with the suggested mid- to late-11th century construction date for the trackway.

Medieval parallels for the Llangynfelyn trackway are not easy to find. However, the method of construction is part of a wide-ranging tradition from Neolithic Ireland (Raftery 1996) to Roman Yorkshire (Kennedy 1984).

The trackway destination

The village of Llangynfelyn occupies the southwest end of a small and narrow southwest-facing promontory, which if approached from the south has the appearance of an island in the bog. To access Llangynfelyn on dry ground, by skirting the bog to the north, requires a journey of *c*.4km (*c*.2.5 miles). The trackway provided a much shorter route, approximately 750m, a saving that was clearly considered more important than the time and investment that would have been needed to construction the trackway.

What was happening on Llangynfelin in the mid to late 11th century? Did the trackway continue beyond? If so where was its final destination? What was being carried along it?

APPENDIX 1: PALAEOENVIRONMENTAL INVESTIGATIONS AT LLANGYNFELIN

Astrid E. Caseldine, Catherine J. Griffiths and John Crowther
University of Wales, Lampeter

The archaeological sites excavated at Llangynfelin lie on the eastern, landward side of the extensive coastal raised bog of Cors Fochno (Borth Bog). There is a long history of palaeoenvironmental work in the area beginning with the work in the late 1930s by Godwin (Godwin and Newton 1938, Godwin 1943, 1981) and others (Williams-Parry and Parker 1939, Slater 1972). Since then the raised bog, the submerged forests on the foreshore at Borth and Ynyslas, and the Dovey Estuary have been the subject of a number of palaeoenvironmental investigations (Moore 1963, 1966, 1968, Taylor 1973, Wilks 1979, Heyworth 1985, Shi and Lamb 1991, Hughes 1997, 2000, Hughes and Schulz 2001, Schulz 2002, Tetlow *et al* 2007, Mighall in prep.).

Much of the work on Cors Fochno has been to do with the development of the bog itself, or to do with its relationship with the submerged forest, but Moore's (1966, 1968) work was particularly concerned with the evidence for anthropogenic activity in the area. This current investigation again focuses on the palaeoenvironmental evidence for human activity, but specifically on the time period from the Iron Age, prior to the industrial activity at Llangynfelin, through to the construction of the medieval trackway.

In recent years, it has been increasingly realised that peats provide an archive of palaeopollution as well as vegetation change in the past (Mighall *et al* 2006). Chambers (2003) has described metal mining landscapes as a palimpsest of human activities in which there have been complex interactions between agriculture and industry. Hence one of the main aims of the palaeoenvironmental investigations at Llangynfelin was to see if it was possible to identify the impact of industrial activity, especially that associated with the lead smelting site, on the surrounding environment as well as evidence for changes brought about by agriculture. A second aim was to determine the environmental conditions and impact of human activity around the time of trackway construction. With these aims in mind an extensive palaeoenvironmental sampling programme was undertaken which included sampling for pollen, plant macrofossils, insects, wood, charcoal and geochemical analyses. The geochemical analyses directly related to the pollen study are considered here, whilst the other analyses are considered separately.

Pollen
Sampling
Samples were taken using monolith tins from a number of locations from which samples were then selected for analysis. The samples examined include pollen columns (LT11, LT17, LT20) at the dry land/wetland interface, which included the record shortly before deposition of the industrial deposits and the industrial deposits themselves; a pollen column (LT6) through deposits between the industrial deposits and the trackway terminal deposits; a pollen column (LT15) post dating the industrial deposits and not sealed by the trackway; and a pollen column (LT5A) from beneath the trackway in Trench 5, the excavation furthest into the wetland. The location of the pollen columns is shown in Fig. xx .

The pollen column stratigraphies are as follows:
LT5A

0-15 cm Stony silty humified peat with less humified peat with monocot. remains *c*. 11-13cm. Charred *Calluna* and *Erica* remains and uncharred *Erica* remains present
15-24 cm Humified peat with monocot. remains. *Erica* seeds and leaf.
24-27cm *Eriophorum* peat.
27-41 cm Less humified herbaceous peat with monocot. remains. *Carex* and *Juncus* seeds and occasional *Betula* and *Erica* seeds. *Calluna* stems present.
41-48 cm More humified herbaceous peat with monocot. remains and wood fragments including *Betula* bark.
48-50.5 cm Humified peat with wood fragments. *Betula* seeds.
50.5- 100 cm Fibrous herbaceous peat with wood fragments. *Eriophorum*, *Calluna* remains and *Erica* remains present throughout. Occasional *Carex* seeds. *Myrica gale* present *c* 65-68 cm and 80cm. *Alnus c* 100cm.
100-120 cm Herbaceous peat with monocot. remains and wood fragments. *Myrica gale* present c 103 cm and 112 cm. *Calluna*, *Erica, Eriophorum* and *Sphagnum* remains present. Occasional *Betula, Carex* and Poaceae seeds.

LT6
0-3 cm Gritty organic clay with sand, gravel and small stones.
3-9 cm Gritty humified silty peaty clay. *Juncus* seeds. Charred *Calluna* flower and leaf and moss stems.
9-18 cm Gritty humified silty peat clay with wood present *c*. 11-14cm. *Juncus* seeds.
18-21 cm Humified silty peat with some monocot. remains and minerogenic material visible. Charred *Erica* leaves.
21-27 cm Humified silty peat with some gritty minerogenic material visible. Charred *Erica* leaf.
27-30 cm Humified silty peat.
30-38 cm Less humified silty peat with monocot. remains. *Carex* seeds *c* 32 cm.
38-47 cm Silty peat with fresh, unhumified small monocot. stems and rhizomes. Poaceae seed, *Calluna* flower and stem fragment *c*. 40cm.
47-50 cm Grey gritty clay with sand and gravel.

LT11
0-2 cm Silty clay with abundant charcoal.
2-25 cm Dark brown organic silty clay with gravel becoming stonier with depth. *Juncus* seeds present.
25- 31 cm. Very stony silty clay with sand and gravel.

LT15
0-30 cm Dark brown silty clay peat with fine monocot. rootlets. *Juncus* seeds present.
30-50 cm Dark brown silty clay peat with gritty material including gravel and charcoal. *Juncus* and Poaceae seeds and occasional wood fragment present.

LT17
0-3 cm Topsoil
3-6 cm Silty clay
8-11 cm Organic silty clay.
11-14 cm Peaty silty clay
14-16 cm Silty clay with charcoal.
16- 20 cm Gritty clay with abundant charcoal.
29- 37cm Clay with charcoal interspersed through it.
37-39.5 cm Peat clay with wood fragments.
39.5-50 cm Silty wood peat with large fragment of *Salix*. *Juncus* seeds present.

LT20

0-3 cm Silty clay. Juncus seeds.
3-6 cm Gritty silty clay with wood fragments including *Alnus*. *Rubu*s and *Juncus* seeds.
6-21 cm Gritty silty clay with sand, gravel and charcoal. *Juncus* and *Carex* seeds.
21-24 cm Silty clay with gritty material.
24-30 cm Monocot. remains interleaved with silty clay. Abundant monocot. remains at 28cm. *Juncus*, *Carex* and *Plantago* major seeds.
30-43 cm Organic clay becoming increasingly peaty with depth, particularly from 41 cm. Wood fragments and monocot. remains. 30-32cm *Carex* and *Rubus* seeds and thorns.
43-50.5 cm Woody peat. *Alnus* and *Carex* seeds and *Calluna* flower.
50.5-86 cm Woody peat with large wood fragments. *Alnus*, *Betula*, *Carex* and *Callitriche* seeds present.
86-93 cm Woody peat with monocot. remains and minerogenic material. *Betula* seeds.
93-100 cm Woody peat. *Alnus*, Betula, Poaceae and *Ranunculus* seeds.

Methods

Pollen

Sub-samples were taken from the pollen columns and prepared following standard procedures (Moore *et al* 1991). These included acetolysis to remove cellulose as well as treatment with hydrofluoric acid and fine sieving to remove minerogenic material. *Lycopodium* spores were added to enable concentrations to be calculated. Pollen and spores were identified using the keys in Moore *et a*l (1991) and Andrew (1984) as well as a modern reference collection. A minimum sum of 300 land pollen grains was counted. Results are shown as percentage total land pollen (TLP) for land pollen types and aquatics and spores are shown as percentage TLP plus the respective group. In addition, selected fungal spores and testate amoebae were recorded and are expressed as percentage TLP. Charcoal was counted and is expressed as concentration data. In addition charcoal in the pollen sievings was counted and is included in the pollen diagrams. The pollen sievings were also examined for plant macrofossil remains and this information is included in the stratigraphic descriptions and text. Pollen nomenclature is modified from Moore *et al* (1991) using Bennett (1994, Bennett *et al* 1994). The diagrams were prepared using TILIA and TILIAVIEW. The results are given in Figs. 1-5.

Loss-on-ignition

The organic content of the samples was assessed using loss on ignition. Samples were dried at 40ºC then ground up and oven-dried at 105ºC for 12 hours. The samples were ignited at 550ºC for 12 hours. The results are included in the pollen and sediment chemistry diagrams (Figs. 1-7) and discussed in the main text.

Sediment Chemistry

Atomic absorption spectrophotometry was used to determine metal concentrations from two sediment columns, LT5A and LT20. Sub-samples of 1 cm thickness were taken from the columns and oven dried at 40ºC**.** Analysis was undertaken on the fine earth fraction (i.e. < 2mm) of the samples. Extraction was by boiling with aqua regia (a 1:3 mixture of concentrated HNO_3 and HCl). Concentrations of lead (Pb), zinc (Zn), copper (Cu) and silver (Ag) were measured using a Philips PU9100X atomic absorption spectrophotometer. The results are presented in Figs. 6-7.

Radiocarbon Dating

Samples were submitted to Beta Analytic Inc. in Florida for radiocarbon dating. Five conventional radiometric dates were obtained for peat samples from pollen columns LT5A, LT 17 and LT20, whilst AMS dates were obtained for peat samples from pollen columns LT6, LT11, and LT15. Three charcoal samples from LT17 and LT20 were also dated using AMS. The dates were calibrated using CALIB 4.1 radiocarbon calibration program (Stuiver and Reimer 1993) and IntCal98 (Stuiver *et al* 1998) and IntCal04 (Reimer *et al* 2004). The results are summarised in Table 1.

Results

Pollen

The pollen zone characteristics are summarised in Tables 2-7. Where possible an estimated calibrated age for the zones is included in the tables. The ages should only be considered as an approximation given possible variations in sedimentation and wiggles in the calibration curve (cf. Telford *et al*. 2004). The estimated age for pollen zones in LT5a and LT6 is based on the mid point of the 2 sigma age range of the calibrated dates and the dendrochronological date for the trackway. The age of zones in LT15 is based on one radiocarbon date and correlation of the zones with pollen zones in LT5A and LT6. Inverted dates are recorded for the charcoal dated from the industrial deposits in LT20, although statistically the dates are indistinguishable at 2 sigma. The dates are also similar to that from charcoal from LT17. The age of the industrial deposits in LT11, LT17 and LT20 is therefore given as a range based on the mid points of the calibrated dates.

Sediment chemistry

The samples analysed from LT5A were from peat deposits whereas those from LT20 included both industrial minerogenic deposits, organic clays and peat deposits. The upper levels from LT5A were not analysed as the upper deposits included earlier industrial material which had been used to make the trackway.

As might be expected in view of the different nature of the deposits examined and the distance of LT5A from the industrial site, the metal concentrations are generally lower in LT5A than in Trench 20. Indeed, at LT5A there is no evidence of Cu enrichment (maximum, 9 µg g^{-1}) and Ag concentrations are below detection level (< 2 µg g^{-1}). However, both the Pb and Zn data do show clear signs of enrichment. The geometric mean for Pb concentrations for soils in England and Wales is 30 µg g^{-1} (Reaves and Bern 1984), whilst the concentration in soils in a nearby valley was found to be 42 µg g^{-1} (Alloway and Davies 1971). The average continental crust concentration for Pb is 14.8 µg g^{-1} and for Zn is 65.5 µg g^{-1} (Wedepohl 1995). Clear peaks in Pb occur at 64-74 cm (maximum values 70-72 cm), although a gradual increase begins earlier, and 48-52 cm, although Pb values a gradual increase from 84 cm. Zn peaks at a number of levels with major peaks at 74-78 cm and 48-52 cm.

Extremely high Pb concentrations (27,600-37,200 µg g^{-1}) and relatively high concentrations of Cu (749-3,760 µg g^{-1}) from the minerogenic deposits at LT20 confirm metal-processing activity. The average concentration in the earth’s crust for Cu is 25.9 µg g^{-1} (Wedepohl 1995). Ag is also present in appreciable concentrations (49-168 µg g^{-1}). The typical concentration of Ag in the earth’s crust is 70 ng g^{-1} (Wedepohl 1995).

Very high concentrations of Pb are also evident in the organic clays and upper peats, especially in the samples from 32-52 cm (range 15,800-28,700 µg g^{-1}), but extending down to 64 cm. However, the difference in the nature of the deposits means that these values are exaggerated because of the much lower density of peat compared with the industrial deposits. Nevertheless, these values are high compared with those from LT5A. A small peak in Pb values occurs at 80cm (786 µg g^{-1}). Some degree of Cu enrichment is also evident in the upper peats, along with traces of Ag in some samples. Extremely high Zn concentrations are recorded in the upper peat layers, with a maximum of 22,500 µg g^{-1} at 50 cm. High Zn concentrations also persist through the lower peats.

Interpretation
Ombrotrophic peats have been widely used to reconstruct evidence of past metal mining (Mighall *et al* 2006). Peat bogs are considered to provide an archive of atmospheric metal deposition (Shotyk 1996). It is argued that post-depositional migration of Pb in peat bogs is not supported by recent studies, including the comparison of Pb concentrations in bogs and lake sediments (Shotyk *et al*. 1997a, b). However, the behaviour of Zn in peat is more problematical. The distribution can show great variability (Shotyk 1988) and most sub-surface peaks have not been adequately explained (Mighall *et al* 2004). Zn is considered to be mobile in peat and susceptible to leaching (Livett *et al* 1979, Livett 1988) and hence peaks have been interpreted as the result of downward translocation of Zn (Mighall *et al* 2004, 2008). It has been proposed that Zn may precipitate as a carbonate or sulphide in the water-table zone, be due to ash enrichment, or result from some unknown process (Shotyk 1988, Jones and Hao 1993).

At Llangynfelin analyses included investigation of a range of deposits, including different peat types and industrial deposits, and therefore some of the results must be treated with caution. However, the mining and smelting of lead is likely to have resulted in the release of large amounts of lead into the surrounding environment and probably accounts for peaks in Pb in the peat deposits at LT5A. A distinct peak in Pb with maximum values at 70-72 cm clearly reflects contemporary mining/smelting activity. This coincides with an expansion in raised bog vegetation, notably heather, locally. Interpolated dates place the main activity *c* 1885 – 1820 ^{14}C yrs BP, although there is slight enhancement from shortly after 1960±60 BP (Beta-222223: Cal BC 80-Cal AD 150) with further enhanced values from *c* 1910 ^{14}C yrs BP (interpolated date). This enhancement could, however, simply reflect some movement down the profile. A second distinct Pb peak, *c* 48-52 cm, may indicate a further period of activity, although not as intensive, *c* 1670 – 1590 ^{14}C yrs BP (interpolated dates). The occurrence of minerogenic input at 48 cm, reflected in the LOI values, may indicate an inwash of eroded material from the industrial site or other mining/smelting sites in the area. This also coincides with an expansion in fen woodland locally and change in peat deposits.

The interpretation of Zn values in peat deposits, as already mentioned, is difficult and Zn shows peaks at several levels in LT5A. Comparatively low Zn values coincide with the earlier peak in Pb values but peak just below, while high Zn values coincide with the later peak in Pb. Although Zn was not deliberately exploited at this time large amounts of it may have been released into the environment when galena was crushed (Mighall *et al* 2008). This would then have been leached out or blown in the atmosphere from exposed spoil tips. It has also been suggested that smelting may preferentially concentrate the more volatile metals, including Zn, compared with lead and copper within the atmospheric fallout (Jenkins and Timberlake 1997, Mighall *et al* 2007). Hence, although some downward translocation of Zn might have occurred, it is possible that the peaks in Zn closely related to the Pb peaks might reflect smelting/mining activity in the area.

Very high concentrations of Pb occur in the industrial deposits at LT20, confirming Pb smelting activity at the site. Enhanced Cu and Ag values also occur in the industrial deposits. However, concentrations of Pb and Cu are also high in the underlying minerogenic and upper woody peat deposits (LOI results indicate the peats also contain inwashed minerogenic material). Although these high values could be interpreted as earlier activity at the site, this column was from the wetland/dry land edge and the deposits are likely to have been subject to a fluctuating water-table. It therefore seems likely that the high concentrations of metals in the organic clays and upper peats at LT20 may reflect downward movement of metal pollution from the overlying deposits, rather than earlier activity. The occurrence of higher Zn values in the deposits beneath the industrial deposits rather than in the industrial deposits themselves is also consistent with the leaching of Zn downwards, although other processes may have been operating as well.

While the results from LT20 are certainly indicative of Pb-related activity at the site, the concentrations of Cu and Ag and Zn in the minerogenic sediments could simply reflect the presence of these metals in the Pb-rich ores and rocks that were being used. This is also suggested by the analysis of slag samples by Anguilano (this paper/p) who concluded that the main ore used at the site was galena (PbS) and that this was associated with other minor sulphides and the arsenides of Sb (antimony), Cu, Fe (iron), Ni (nickel) and Zn. Equally, the Ag concentrations at LT20 are consistent with the Ag-rich phase found in one of the slag samples which suggests that possibly some of the veins exploited were argentiferous.

Palaeoenvironmental Interpretation (Nigel this section is probably for the archive report rather than publication ?)

The environmental record from LT5A

The pollen and peat deposits from LT5A provide a record of environmental change from the Iron Age through to the establishment of the trackway. The location of the site was *c* 100 metres from the dry land edge and it was hoped that the site would be close enough to pick up signals for local anthropogenic activity on the dry land, particularly associated with industrial and agricultural activity.

The environmental record investigated begins *c* 2200±50 BP (Beta-209007: 390-110 Cal BC) and reflects vegetation communities on the margin of the raised bog. Relatively high *Corylus avellana* (including *Myrica gale*) type pollen values during zone LT5A.1 indicate the presence of bog myrtle communities (confirmed by the presence of *Myrica gale* wood) as well as hazel woodland on the dryland. *Betula* and *Alnus* pollen and *Betula* fruits together with occasional pollen grains of *Salix* and *Frangula alnus* indicate carr woodland in the vicinity. This is confirmed by the predominance of *Alnus* wood at a comparable depth in the stratigraphy at Trench 2, approximately midway between LT5A and dry land. An increase in *Alnus* pollen shortly before *c* 1960±60 BP (Beta-222223: 80 Cal BC – Cal AD 150) and the occurrence of *Alnus* wood suggest a brief expansion in alder woodland locally.

However, throughout zone LT5A.1 fluctuations in *Calluna* and Cyperaceae pollen and *Sphagnum* moss spores, and the presence of *Calluna vulgaris*, *Erica tetralix*, *Eriophorum* and *Sphagnum* macrofossils, demonstrate ombrotrophic bog development in the area. *Assulina muscorum* (Type 32A) and *Amphitrema flavum* (Type 31A) testate amoebae are also present. The former is found in a wide range of hydrological conditions but frequently in relatively dry conditions, whereas the latter is often associated with wet conditions, occasionally standing water, but can extend to the tops of hummocks in oceanic areas (Charman *et al* 2000).

An increase in *Quercus* pollen, accompanied by low amounts of herb pollen, suggests a period of oak woodland regeneration on the dry land, before a steady decline in *Quercus* and increase in frequency of herb taxa, notably *Plantago* spp. but including *Rumex* spp., Asteraceae, *Potentilla* and *Ranunculus*, suggests clearance and agriculture, predominantly pastoral activity. An increase in Type 55A *Sordaria* ascospores could indicate the presence of livestock, perhaps even grazing on the wetland, as they can be indicative of dung. *Sordaria* ascospores are produced by fungal species belonging to the Sordariales, many of which are coprophilous, although they are also indicative of mesotrophic conditions and decaying vegetation (Van Geel 1978, Van Geel *et al* 1981, 2003, Buurman *et a*l 1995). The dispersal and transport of coprophilous fungal spores is less efficient than, for example, tree pollen and is therefore likely to indicate the presence of animals close to the sample site (Van Geel *et al* 2003). At the same time relatively high *Plantago maritima* and *P. coronopus* values could reflect a brief increased marine influence in the region, although there is no other evidence to support this. Alternatively, these pollen types could perhaps represent the remains of dung from animals that had previously been grazing on the saltmarshes in the area. As well as Type 55 Sordariaceae spores at this level, there is a peak in Type 368 *Podospora* spores and Type 113 *Sporormiella* spores are present. These fungal spores are similarly indicative of dung and grazing by herbivores (Van Geel *et al* 1981, 2003, Davis 1987). Microscopic charcoal values are low which suggests limited fire activity associated with settlements or agriculture, or any industrial activity. There is an apparent minor recovery in oak woodland before it again declines at the same time as a peak in microscopic charcoal *c* 1980 ^{14}C years BP (interpolated date). Herb pollen continues to be present in low amounts, suggesting a relatively low level of agricultural activity.

An increase in *Calluna* representation during zone LT5A.2, followed later by an increase in *Erica* type pollen, together with macrofossil remains suggest an expansion in heather and heath communities locally, whilst *Eriophorum vaginatum* macrofossils indicate the growth of cotton grass. The presence of *Myrica gale* wood confirms that some of the *Corylus avellana* type pollen is attributable to local bog myrtle communities and an expansion in Poaceae pollen may be partially due to an increase in grasses such as *Molinia*. A decline in *Betula* and *Alnus* suggests a reduction in carr woodland, some of which might be a result of clearance activity as well as changes in vegetation succession. However, *Alnus* wood continues to dominate the stratigraphy in Trench 2.

Two episodes of clearance activity, separated by a short phase of woodland regeneration, are evident during zone LT5A.2. This period also includes the period of industrial activity at Llangynfelin. At the beginning of zone LT5A.2 *Quercus* values fall to a minimum and agricultural indicator species, including cereal type pollen, *Plantago lanceolata* and other herbs, suggest an expansion in farming activity. During the following brief regeneration episode, although cereal type pollen is absent for a short period, *Plantago lanceolata* pollen increases. This suggests that farming activity continued or possibly increased in the local area, even if there was some abandonment of land allowing woodland to regenerate. Alternatively, the increase in *Quercus* pollen could perhaps indicate a deliberate woodland management strategy, possibly involving coppicing of oak woodland to produce more wood for construction or industrial purposes. However, there are no fluctuations, which would indicate harvesting using a rotational coppice cycle, in the oak pollen curve.

An increase in *Pteridium* is also consistent with an increase in oak woodland and the abandonment of land for agriculture. Another possibility is that there was a change in emphasis in the livestock that was being grazed in the area, possibly a reduction in cattle. The latter can help to impede bracken growth by trampling. However fungal spores also indicate grazing activity at this time, including *Podospora* spores which are frequently associated with cattle dung (Lundqvist 1972), although the spores may reflect local livestock grazing on the wetland rather than on the dry land. There is a slight increase in Pb values during this period but they remain relatively low, as do microscopic charcoal values, suggesting any mining or smelting activity, if any, was on a small-scale.

A clear reduction in oak woodland marks the second episode of woodland clearance and declines in *Betula* and *Alnus* pollen suggest that birch and alder woodlands were also being exploited. A slight increase in weed taxa and the presence of cereal type pollen indicate a continuation of a mixed agricultural economy. Pb values show a distinct increase from *c* 1885 ^{14}C yrs BP (interpolated date), immediately before the sharp decline in *Quercus* which coincides with the beginning of maximum lead values *c* 1870 ^{14}C years BP (interpolated date). Maximum Pb values are maintained even though there appears to be a minor recovery in oak woodland after the intial impact. The latter again might indicate some attempt at woodland management. A further decline in *Quercus* and fluctuations in *Alnus* and *Betula* suggest continued exploitation of woodland, although Pb values decline. High microscopic charcoal concentrations occur during this period and may be attributable to industrial activity. However, occasional charred *Calluna* and *Erica* macrofossils and the occurrence of Type 1 *Gelasinospora* fungal spores, which can be indicative of burning but also local dryness (Van Geel 1978), indicate that there was some deliberate, accidental or 'natural' burning of the bog surface. Deliberate burning could have been undertaken to increase browse. Burning and grazing would have helped prevent woodland regeneration.

Because of its close proximity, it seems most likely that the vegetation changes and high Pb and charcoal values largely reflect activity at the Pb smelting site rather than mining activity in the wider area. The maximum period of lead production might have lasted a comparatively short period of time, perhaps as little as around 20 years although a reduced level of activity could have continued until *c* 1800 ^{14}C yrs BP or later.

Oak woodland remains at a reduced level during the latter part of zone LT5A.2 but increases in *Alnus* and *Betula* suggest a slight recovery or expansion in fen woodland. Agricultural activity persists throughout the zone, although the absence of cereal type pollen later in the zone suggests a decline in cereal production. A decrease in fungal spores indicative of dung could suggest a reduction in grazing animals on the bog, coinciding with a reduction in activity at the industrial site. The decline in *Erica* pollen towards the end of the zone is consistent with a reduction in grazing and burning, allowing the progression from an *Erica tetralix* community to woodland (Rodwell 1991) at the beginning of the following zone. This phase ends *c* 1710±60 BP (Cal AD 220-440).

The following phase, zone LT5A.3, is dominated by the development of birch and alder woodland in the local area (confirmed by the presence of bark and wood in the stratigraphy). This lasts until *c* 1390±70 BP (Cal AD 550-770). There is also a slight recovery in oak woodland and the virtual absence of herb taxa indicative of anthropogenic activity could signify a reduced level of agriculture activity in the area. Alternatively the filtering effect of the local woodland might, at least partially, have contributed to the lack of anthropogenic indicator species. A peak in lead values, although not as high as previously, could also indicate renewed smelting activity at the site or mining activity in the area *c* 1670 - 1590 ^{14}C yrs BP (interpolated dates). LOI values indicate an input of minerogenic material, perhaps eroded material from the industrial site *c* 1590 ^{14}C yrs BP.

An increase in monocotyledonous macrofossil remains, including *Eriophorum*, *Molinia*, *Carex*, *Rhynchospora alba* and *Juncus*, and increase in Poaceae and Cyperaceae pollen in zone LT5A.4 follow the decline in local birch woodland. An expansion of *Sphagnum* moss also occurs. The reappearance of agricultural indicator species, notably *Plantago lanceolata*, with the decline in local woodland suggests the latter may have influenced pollen representation. However, *Quercus* values increase which suggests some regeneration of oak woodland in the area. A steady decline in *Quercus* from *c* 1320 ^{14}C years BP (interpolated date) indicates renewed impact on the oak woodland in the area, which continues until after 1250±50 BP (Cal AD 660-890). The decline could represent deliberate clearance or a combination of clearance and grazing pressure, the latter preventing regeneration from taking place. A decline in alder woodland also occurs at this time, which may at least partly be due to anthropogenic activity, whilst an increase in *Fraxinus* may reflect increased flowering because of opening up of woodland.

Finally, a stony humified silty peat with monocotyledonous remains reflects the deposition of minerogenic material onto the peat surface to provide ballast for the trackway. High charcoal values during zone LT5A.5 could indicate increased fire activity in the surrounding region related to settlement, agricultural or mining activity or simply the redeposition of charcoal along with minerogenic material. An increase in Ericaceous species suggests an expansion of raised bog in the area. Mixed farming is indicated by the continued presence of *Plantago lanceolata*, *Rumex* spp, *Artemisia* type and cereal type pollen. Construction of the trackway is dated to shortly after AD 1136 by dendrochronology.

The environmental record from LT6

The pollen profile from LT6 covers the period from when peaty deposits accumulated after the end of the industrial phase through to construction of the trackway. At the beginning of zone LT6.1 high values for weed pollen taxa such as *Plantago lanceolata*, *Rumex* spp. and Lactuceae, and the presence of other species such as *Urtica dioica,* reflect vegetation habitats associated with anthropogenic activity, including pastoralism and waste ground, and represent conditions at the end of the period when the site was in use for industrial activity. Fungal spores indicative of dung also suggest animals grazing in the area, whilst abundant microscopic charcoal probably largely derives from the industrial activity.

An AMS date from a peaty deposit containing abundant unhumified grassy remains at the interface with the industrial deposits suggests the industrial activity had ended by 1620±40 BP (Beta-235895: Cal AD 350-540). The industrial activity might, however, have ceased much earlier as there could be a hiatus between the industrial and peat deposits. Very high Poaceae pollen values reflect the abundant monocotyledonous remains and grassy vegetation. A marked fall in weed species possibly demonstrates a reduction in human activity in the area of the site and fewer disturbed ground habitats, but values might be artificially depressed because of the abundance of Poaceae pollen. However, fungal spores associated with grazing activity are also absent and charcoal values show a marked fall, confirming the end of industrial activity at the site.

Following this, in zone LT6.2, an increase in *Betula* pollen indicates an expansion in birch woodland in the area, either in the wetland or on the dry land. At the same time *Quercus* and *Alnus* begin to increase, suggesting a recovery in oak and alder woodland as well. Pollen indicative of agricultural activity continues to be largely absent, which suggests that during this renewed expansion in woodland there was reduced activity. *Calluna* values indicate the presence of raised bog in the area, as do occasional *Calluna* plant macrofossil remains.

A decrease in birch and, to a lesser extent, alder woodland occurs around 1230±40 BP (Beta-235894: Cal AD 680-890), at the beginning of zone LT6.3. In contrast frequent *Corylus avellana* type pollen suggests an expansion in hazel and/or bog myrtle vegetation communities, whilst low *Calluna* values and occasional charred *Erica* leaves reflect raised bog in the area. An increase in weed taxa, largely *Plantago lanceolata*, suggests renewed activity in the area, mainly associated with pastoralism, although cereal type pollen is present. Initially oak woodland continues to increase, before a gradual decline to low levels in the area slightly after 1120±40 BP (Beta-23583: Cal AD 810-1010) at the beginning of zone LT6.4a.

Fungal spores indicative of dung and a further increase in *Plantago* during zone LT6.4a suggest increased grazing activity in the vicinity. Evidence for activity possibly associated with the construction of the trackway is an increase in microscopic charcoal and minerogenic sediment, probably inwashed from the adjacent industrial deposits. Radiocarbon dates of 1073±30 BP (Beta-191064: Cal AD 900-1020) and 1060±40 BP (Beta-191065: Cal AD 900-1030) from wood from the trackway and a dendrochronological date of AD 1136 date the construction of the trackway. A minor fall in *Alnus* values could reflect felling of alder to make the trackway.

A small increase in *Quercus* pollen during LT6.4b could indicate a slight expansion in oak woodland contemporary with the trackway or might be due partly to the incorporation of older pollen from the earlier industrial deposits. Weed taxa are less frequent, possibly suggesting reduced agricultural activity. The presence of Type 143 *Diporotheca rhizophila* ascospores might indicate local nitrogen-rich environments (Van Geel 2003), perhaps associated with humans or animals using the trackway. Other fungal spores also suggest the presence of livestock. High microscopic charcoal values coinciding with increasingly minerogenic deposits reflect the incorporation of earlier industrial deposits to make the terminal of the trackway.

The environmental record from LT11
The pollen sequence from LT11 reflects the environmental conditions at the wetland/dryland interface in the period immediately preceding deposition of the industrial deposits. Initially, during zone LT11.1a, alder carr dominates but there is some limited evidence for activity on the dry land, including cereal cultivation and pastoralism. At the beginning of zone LT11.1b an AMS date of 2260±40 BP (Beta-241084: 400-340 Cal BC and 330-200 Cal BC) dates the change from a stony clay to an organic silty clay, reflected in the LOI values by an increase in organic matter. The occurrence of *Callitriche* and *Sparganium* pollen, both aquatic taxa, indicates the presence of standing water, whilst *Juncus* seeds confirm a wet and muddy environment at the wetland/dry land edge. The continued presence of alder carr woodland is indicated by frequent *Alnus* pollen while low amounts of *Betula* pollen suggest the woodland contained some birch as well. Pollen of *Salix*, *Hedera*, *Ilex*, *Fraxinus* and *Sorbus* type indicate the presence of these taxa as minor components of the carr woodland although, apart from *Salix,* they could equally have occurred in nearby oak woodland**.** Increased representation of *Quercus* pollen coincides with the sediment change and suggests the presence of oak woodland towards the drier margins of the wetland or on the dry land. At the same time there is some evidence to suggest activity affecting the local woodland. An increase in microscopic charcoal coincides with a brief decline in *Alnus* followed by a minor fluctuation in *Corylus avellana* type and *Quercus* pollen. This might relate to fire activity associated with settlement, agriculture or industrial activity in the wider area but the presence of charred alder and hazel wood in Trench 11 indicates it is local in origin.

Herb taxa indicative of carr woodland include *Chrysosplenium oppositifolium*, *Lythrum salicaria*, *Filipendula* and *Hypericum perforatum* type, whilst taxa such as *Urtica*, *Ranunculus* sp., *Potentilla* type and *Rumex* spp. could owe their presence to 'natural' habitats or agricultural activity taking place in the area. Along with other weed taxa that indicate agriculture, including *Plantago* *lanceolata* and Chenopodiaceae, occasional pollen grains of cereal type pollen suggest mixed farming. The sporadic occurrence of Type 55 Sordariaceae fungal spores provide further possible evidence for stock grazing in the area.

A decline in arboreal pollen and increase in Poaceae pollen during zone LT11.1c, commencing shortly before industrial activity, suggests woodland clearance. However, weed species continue to be relatively scarce with only a slight increase in the final level, which includes industrial deposits and high levels of charcoal. This suggests a low level of agricultural activity in the area of the site prior to the industrial activity but representation of the former might have been reduced by local alder woodland filtering out the herb pollen.

The environmental record from LT15

The pollen record from LT15 is from peat deposits post dating the industrial deposits. An AMS date suggests the record ends shortly after 310±40 BP (Beta-241085: Cal AD 1460-1660). *Alnus* and *Betula* dominate the arboreal assemblage in LT15.1, indicating local wet woodland in the area although the birch could represent birch scrub on the dry land. Relatively high *Salix* values suggest the wet woodland also included stands of willow carr. Low amounts of *Quercus* pollen indicate the continued presence of oak woodland in the region. Relatively high Poaceae values could reflect local wetland vegetation or grassland communities on the dry land. Frequent weed pollen suggests agricultural activity nearby, mainly pastoral, but the presence of cereal type pollen indicates some arable cultivation. Fungal spores indicative of dung provide further possible evidence for grazing activity. *Pteridium* values are higher during this period than later and could suggest the colonisation of abandoned ground, perhaps at the industrial site. LOI values suggest an input of minerogenic material, possibly washed in from the area of the site as a result of later agricultural activity. High microscopic charcoal values also tend to support this.

A reduction in *Quercus*, *Betula* and *Alnus* pollen indicates a decline in woodland communities on both the dryland and the wetland at the beginning of zone LT15.2a. At the same time, grassland communities expand and agricultural indicators continue to be frequent. Locally wet grassland, reed and sedge communities would have dominated. LOI values indicate a decrease in minerogenic material and charcoal values are lower, suggesting a decline in eroded material from the dry land. After this, only minor changes in the woodland are suggested. A slight recovery in oak woodland (zone LT15.2b) occurs along with a small increase in birch woodland, followed later by a slight increase in hazel and/or bog myrtle communities and alder carr (zone LT15.3c) *c* 310±40 BP (Beta-241085: Cal AD 1460-1660). Agricultural indicators suggest a reduction in activity after this time, but prior to this occasional cereal type pollen and weed taxa indicate a mixed agricultural economy, although mainly pastoral. Activity associated with the trackway probably dates to LT15.2a and the beginning of LT15.2b

The environmental record from LT17

The deposits from LT17 include peaty deposits immediately preceding the industrial deposits, the industrial deposits themselves and organic deposits immediately post dating them. High *Alnus* and *Salix* pollen values during zone LT17.1, together with *Salix* wood, indicate alder and willow carr at the wetland edge. A decrease in *Alnus* and *Salix* and increase in Cyperaceae suggest a decline in carr woodland and an expansion in sedge communities. This could represent a natural succession but a marked increase in anthropogenic indicator species, notably *Rumex* spp. and *Plantago lanceolata*, could indicate the changes were directly or indirectly related to clearance activity. A steady decline in oak woodland, as well as an increase in microscopic charcoal, followed by a change to an increasingly minerogenic sediment, also suggests increased activity and possible erosion because of woodland clearance and agriculture. These changes date to *c* 1980±50 BP (Beta-238737: 80 Cal BC - Cal AD 120. Prior to this, registration of agricultural indicators is slight but this might be an under-representation because of the effect of local carr woodland. The evidence, however, does indicate increased activity immediately preceding industrial activity at the site.

The occurrence of *Potamogeton*, *Nuphar* and other aquatic taxa, including Zygnemataceae algal spores, suggests the presence of standing water nearby at this time, and this might have influenced the location of activities at the industrial site. Shallow open water and a sufficiently high water temperature during the spring and summer is required for the production of zygospores. An optimum temperature of between 14-22º C for Zygnemataceae has been mentioned (Van Geel *et a*l. 1981) Charcoal clamps were located near water in case they caught fire and Timberlake (see p) has suggested that this area of the industrial site might have been used for charcoal production.

A change to a silty clay with charcoal fragments at the beginning of zone LT17.2 marks the change to industrial deposits. This coincides with an increase in Poaceae, minima in *Quercus*, *Alnus* and *Corylus avellana* type and continued high weed values, suggesting woodland clearance associated with farming or industrial activity. An increase in *Quercus* and *Corylus avellana* type pollen and more gradual rise in *Alnus* pollen in the industrial deposits could reflect a renewed expansion in woodland, possibly involving deliberate attempts at management. Alternatively, it could mean that some of the pollen was derived from wood brought onto the site for fuel, or was older re-worked pollen incorporated within the deposits**.** High levels of indeterminable pollen and *Pteridium* spores provide some support for the latter view. Not surprisingly microscopic charcoal values are high throughout the industrial deposits. Charcoal from the silty clay associated with industrial activity dates the activity to 1970±40 BP (Beta-238737: 50 Cal BC - Cal AD 120) and is almost identical to the radiocarbon date from peat just below the industrial deposits. This suggests that the industrial deposits accumulated within a relatively short period and that industrial activity followed soon after clearance at the site. However, it **is possible that the charcoal could be reworked and derive from earlier clearance of woodland at the site rather than contemporary industrial activity – Nigel any thoughts?.**

Throughout the period of industrial activity, there is evidence of mixed farming in the area, although some of the weed pollen could be from waste and disturbed ground at the site. Frequent *Pteridium* spores could similarly reflect the invasion of bracken on rough ground at the edge of the site. A decline in *Quercus* and *Corylus avellana* type pollen in zone LT17.3 in deposits post dating the industrial deposits suggests either renewed clearance of oak and hazel woodland or that, as previously proposed, the higher values for these taxa during zone LT17.2 resulted from large quantities of woody material brought onto the site or re-deposited older pollen from former woodland soils at the site. *Alnus* values do, however, remain high suggesting the continued presence of alder carr.

The environmental record from LT20

The sediment sequence from LT20 includes wood peats underlying industrial deposits and covers a period from the earlier Iron Age until shortly after industrial activity ceased at the site. The period investigated commences around 2490±50 BP (Beta-222224: 790-410 Cal BC) at which time pollen and plant macrofossils indicate alder carr predominated. Other trees, shrubs and woody climbers within the carr woodland, apart from *Alnus,* probably included *Betula*, *Salix*, *Ilex*, *Frangula alnus*, *Viburnum opulus*, *Hedera, Lonicera* and various Rosaceae species.

A brief increase in *Quercus* pollen possibly reflects a short-lived expansion of oak at the dryland edge, whilst a gradual increase in *Corylus avellana* type could indicate an increase in hazel or bog myrtle.

Occasional aquatic pollen taxa and *Callitriche* seeds suggest shallow pools amongst the sedge understorey represented by Cyperaceae pollen and *Carex* nutlets. Other herbs within the carr woodland could have included *Filipendula*, *Chrysosplenium oppositifolium*, *Valeriana officinalis*, *Viola* sp. and *Urtica*, whilst Pteropsida monolete spores provide evidence of ferns growing in the woodland understorey. Low amounts of *Calluna* pollen and the sporadic occurrence of ericaceous macrofossils indicate raised bog in the wider area.

Taxa indicative of farming, mainly pastoralism but with some cereal cultivation, are present at a low level but might be under-represented because of the abundance of *Alnus* pollen and filtering effect of the carr woodland. The presence of fungal spores frequently found with dung also suggests livestock in the area. Small amounts of microscopic charcoal might reflect fires associated with settlements or agriculture in the area, whilst a small peak might relate to a more extensive or nearer fire event that was the result of either anthropogenic activity or natural fires. Increases in Pb and Cu values seem more likely to be due to movement of metals down the profile because of fluctuations in the water table at the wetland edge rather than contemporary industrial processing or mining activity in the area, although this cannot be totally ruled out.

From around 2290±60 BP (Beta-211077: Cal BC 420-200) a steady decline in *Alnus*, *Quercus* and *Corylus avellana* type pollen indicates a reduction in woodland communities. At the same time, an increase in Poaceae and Cyperaceae pollen indicates an expansion in grass and sedge communities. *Plantago lanceolata* is also slightly more frequent and this might represent increased pastoral activity or increased representation because of more open conditions. A decrease in organic matter suggests an inwash of minerogenic sediment because of clearance and disturbance of the soils.

Coinciding with a change to grey silty clays with thin layers of monocotyledonous remains in zone LT20.2, there is evidence for a marked reduction in oak and alder woodland as well as a decline in birch, while very high Poaceae values and the macrofossil remains indicate an increase in grassland and reed communities locally. Arboreal pollen then increases and, as discussed previously in relation to LT17, could represent a recovery in woodland in the area, pollen from wood brought onto the site to be used as fuel or re-deposited pollen from earlier woodland soils. Certainly frequent indeterminate pollen also suggests the presence of re-worked pollen and sediments. At the beginning of the zone the presence of monocotyledonous remains indicates brief stabilisation periods before further deposition of sediment at the dry land edge. A rise in *Polypodium* fern spores may signify oak woodland, contemporary or older, as it commonly occurs in the understorey or can be epiphytic on tree-trunks. Charcoal fragments from the industrial deposits have been dated to 1880±40 BP (Beta-238739: Cal AD 50 - 230) and 1940±40 (Beta-238738: 30 Cal BC - Cal AD 130), but the dates are inverted which again could suggest re-working and redeposition had taken place. The dates are, however, within two standard deviations and therefore could be considered to date the same event.

Very high charcoal concentrations and high values for Pb, Cu and Ag during zone LT20.2, along with the minerogenic sediments, reflect the erosion and dumping of industrial waste at the site. At the same time, increases in weed taxa and *Pteridium* spores suggest agricultural activity and disturbed/waste ground habitats near the site. Taxa such as *Plantago lanceolata*, *Rumex acetosa*, *R.*

acetosella, Lactuceae and Chenopodiaceae are well represented while a range of other taxa, including *Polygonum aviculare*, *Centaurea nigra*, Brassicaceae and *Urtica,* are also present and together with cereal type pollen suggest mixed farming. Type 55 Sordariaceae spores again suggest the presence of grazing animals, especially at the beginning of the industrial period.

A decline in *Quercus*, *Alnus* and *Corylus avellana* type at the beginning of zone LT20.3, and end of the main industrial period, could reflect renewed clearance, a decline in pollen brought in with wood to the site or a reduction in older, reworked pollen. A decline in *Pteridium* spores, indeterminate pollen and microscopic charcoal also marks the end of industrial activity at the site. However, weed species remain frequent indicating continued agricultural activity nearby, although a brief increase *in Betula,* followed by an increase in *Alnus* and *Corylus avellana* type, suggests some regeneration and a renewed expansion in woodland in the area.

The environmental impact of human activity at Llangynfelin: Synthesis

The main focus of the pollen sites investigated in this study is the effect of human activity on the environment from the Iron Age through to the Medieval period, and especially that associated with ?**late Iron Age**/ Roman industrial activity. However, the recovery of a wooden trough dating to the Middle Bronze Age demonstrates earlier activity in the area of the site. This is consistent with the pollen evidence from other sites on Borth Bog (Moore 1968, Mighall and Timberlake in prep.) which indicate the impact of human activity on the surrounding vegetation during the Bronze Age. There is also geochemical evidence which suggests mining activity during the Bronze Age, pre dating that at Llangynfelin (Mighall pers. comm.).

Iron Age and Roman activity

The earliest evidence from this investigation commences during the early Iron Age *c* 2490±50 BP (Beta-222224: 790-410 Cal BC) at LT20 and demonstrates the presence of alder carr growing along the wetland margin with oak woodland towards the dry land. Ribwort plantain and other herbs, as well as fungal spores indicative of dung (Van Geel 1978, Van Geel *et al* 1981, 2003, Buurman *et a*l 1995), indicate a low level of agricultural activity, largely pastoral, although this might be underrepresented because of the abundance of alder. Microscopic charcoal suggests fire events that might relate to domestic fires at settlement sites or fires associated with clearance and agriculture or, possibly, industrial activity in the wider region, albeit the possibility of natural fires cannot be totally ruled out. From around 2290±60 BP (Beta-211077: 420-200 Cal BC) alder declines, accompanied slightly later by a decline in oak, and an increasingly open environment is evident at LT20. There is also some limited pollen evidence for increased agricultural activity as well as evidence for increased soil erosion, probably related to this activity.

The pollen records from two other sites, LT11 and LT17, at the dry land/wetland interface, provide further evidence for the composition of woodland around this time and possible clearance activity. At LT11, a site nearer to the dry land edge than LT20, a decline in alder *c* 2260±40 (Beta-241084: 400-340 Cal BC and 330-200 Cal BC) is accompanied by an increase in oak, suggesting an expansion in oak woodland or increased representation. High microscopic charcoal values coincide with the decline in alder and, slightly later, minor falls in hazel and oak. Charred alder and hazel wood were found at this level at the site and suggest Iron Age activity at the wetland edge. Further to the northeast along the wetland edge, at LT17, there is evidence that willow, as well as alder, was a significant component of the carr woodland.

By *c* 1980±50 BP (Beta-211076: 80 Cal BC - Cal AD120) there is evidence for a marked impact on oak and alder woodland at all three sites (LT11, LT 17, LT 20). This clearance activity immediately precedes and is contemporary with the beginning of industrial activity at the site. Small peaks in microscopic charcoal and an increase in agricultural indicators, most noticeably at LT17, immediately prior to the industrial phase suggest Late Iron Age activity in the local area. Cereal type pollen and weed taxa suggest mixed farming, although with pastoralism predominating.

A slightly more detailed and regional picture of the vegetation changes taking place from *c* 2200±50 BP (Beta-209007: 390-110 Cal BC) is evident at LT5A, about 100 metres from dry land, where the pollen record is less influenced by local alder carr than at the wetland fringe. Alder carr dominated at Trench 2, approximately midway between LT5A and dry land. Initially evidence for agricultural activity in the area is also comparatively limited. There appears to be a period of oak regeneration, probably the same event as recorded at LT11, before a decline in oak woodland *c* 2120 ^{14}C years BP (interpolated date), after which there is a more consistent record for agricultural activity, mainly pastoralism. Towards the end of this phase the charcoal record indicates fires in the area and by *c* 1960±60 BP (Beta-222223: 80 Cal BC-Cal AD 150) oak woodland appears to have been significantly reduced. There follows a brief period of oak regeneration but whether this represents recolonisation following total clearance or whether the regeneration represents oak that had regrown from oak that had been deliberately coppiced or had coppiced naturally is unclear. There is, however, no evidence of a coppice cycle. An increase in bracken accompanies the regeneration. Microscopic charcoal is largely absent which suggests a period of reduced fire activity but the presence of cereal type pollen and an increase in weed taxa suggests an expansion in agricultural activity. From the radiocarbon evidence, this activity occurred during the Late Iron Age or Roman period. Although the decline in woodland may be a result of clearance for agriculture, it is also possible that it could relate to clearance associated with Roman activity in the area.

A slight increase in Pb values occurs during this period and might indicate a very low level of mining or smelting activity at this time, although some movement of Pb down the profile is possibly more likely. Zn levels are high and probably represents leaching of zinc down the profile rather than contemporary activity**.**

From *c* 1885 ^{14}C yrs BP (interpolated date) there is clear evidence for renewed human impact on oak woodland in the area with a fall in oak values to a minimum by *c* 1870 ^{14}C yrs BP (interpolated date). This coincides with maximum Pb values and suggests that the decline in oak is directly related to activity at the industrial site, although the high Pb values and decline in oak could also reflect activity associated with mining in the wider area. However, the former seems likely given the close proximity of the pollen site to the smelting site. During this period charcoal values also increase and decreasing alder and birch values indicate the exploitation of local carr woodland as well as oak woodland. This is borne out by charcoal identifications from the smelting site (Caseldine and Griffiths p). Although there is a slight recovery in oak and birch woodland *c* 1855 ^{14}C yrs BP (interpolated date), maximum Pb values are maintained. After this Pb values fall and small declines in oak and birch and fluctuations in alder suggest impact on the local woodland was at a reduced level as industrial activity declined. Although the main phase of industrial activity could have lasted as short a period as 20 years, it is possible that industrial activity continued until *c* 1800 ^{14}C yrs BP, or later.

Throughout this phase there is evidence for continued agricultural activity, including cereal cultivation as well as pastoralism. This is especially noticeable immediately prior to and during the industrial period. The industrial activity may have stimulated the agricultural economy. A small peak in cereal cultivation is recorded *c* 1885 ^{14}C years BP (interpolated date) and weed taxa are well represented, suggesting an intensification of farming. Albeit some of the weed pollen could derive from disturbed ground habitats associated with the lead smelting site or similar sites in the area, as could frequent bracken spores. Vegetation would have been sparse on the most toxic areas of the site but common sorrel and certain grasses have strains that are tolerant of heavy metals (Rodwell 2000). On less contaminated ground species such as ribwort plantain and bird's-foot-trefoil would have occurred and were probably more influenced by grazing.

It is possible that some grazing was also taking place on the wetland at this time. Whilst alder carr fringed the dry land, further out into the wetland the woodland gave way to more open bog conditions with less alder and birch. As well as bog myrtle, the vegetation would have included grasses, sedges, heather, cross-leaved heath and cotton grass. The presence of charred heather remains, coinciding with high charcoal values, suggests that some of the charcoal was from local burning of the bog. This could have occurred accidentally, perhaps because of the nearby industrial activity, or could reflect a deliberate attempt to increase browse. There is some insect evidence (Smith *et al* xx) which could indicate grazing animals as well as fungal spores frequently associated with dung. Burning and grazing would have helped prevent or limited woodland regeneration.

The palaeoenvironmental record from the industrial site itself complements the evidence from LT5A. The pollen records (LT17, LT20) from the wetland edge also indicate the exploitation of oak, alder, birch and hazel for use at the lead smelting site. This is confirmed by charcoal identifications from the industrial deposits (Caseldine and Griffiths xx) which indicate that these were the main species, especially oak, used as fuel at the site. Charcoal production may have taken place at Trench 17 (see Timberlake xx) and the environmental evidence suggests this area of the site was possibly chosen for this purpose because of the close proximity of standing water, a necessary requirement in case the charcoal accidentally caught fire.

Following a decline in woodland, dated to *c* 1980±50 BP (Beta-211076: 80 Cal BC - Cal AD120) at LT 17, arboreal pollen increases at both LT17 and LT20. This is similar to the record from LT5A and suggests that, following an initial decline, there was some woodland regeneration in the area. It is possible that there was some attempt at woodland management in the area to ensure there was a supply of wood at the smelting site but neither the pollen nor the charcoal records (see Caseldine and Griffiths xx) confirm this. Also, the increased arboreal pollen values at the industrial site might be at least partly attributable to the presence of older, redeposited pollen from woodland soils in the minerogenic sediments. High levels of indeterminate pollen and a poorer state of preservation tend to support this. Another possibility is that some of the pollen incorporated within the deposits was brought onto the site along with wood used for fuel. The date of 1880±40 BP (Beta-238739: Cal AD 50 - 230) from industrial deposits in LT20 agrees well with the interpolated dates, 1885-1870 ^{14}C yrs BP, at LT5A for maximum industrial activity, although an earlier date of 1940±40 (Beta-238738: 30 Cal BC - Cal AD 130) was also recovered from industrial deposits at LT20. The two dates from LT20 are inverted, possibly providing further evidence for reworking and redeposition of pollen and sediments at the site. Inverted dates were also recovered from deposits in Trench 4.

The range of radiocarbon dates from the industrial site suggests that industrial activity was taking place at the same time as either the clearance episode dated to *c*1960±60 BP (Beta-222223: 80 Cal BC-Cal AD 150) or the later clearance episode estimated *c* 1885-1870 ^{14}C yrs BP at LT5A, or both. However, the geochemical evidence associated with the earlier clearance is slight, suggesting either that the industrial pollution was at too low a level to register significantly or that this episode pre dates the industrial activity. The geochemical evidence associated with the second clearance episode suggests that this episode relates to the industrial activity. Given the range of dates from the industrial site and the limitations of radiocarbon dating, it is possible that the minor intervening regeneration episode at LT5A was short lived and is possibly represented in the reworked industrial deposits. As discussed above, the first clearance episode could represent clearance associated with late Iron Age activity and/or the arrival of a Roman military presence in the area and the construction of the Roman road and the fort at Erglodd. The second clearance episode could represent either Roman military activity and/or industrial activity, depending on how rapidly mining and smelting occurred after establishment of the fort. **Nigel what are your thoughts?**

The very high Pb values from industrial deposits at LT20 are consistent with the other evidence from the site for lead smelting and the presence of Ag in the deposits indicates the presence of silver within the ore. An expansion in the agricultural economy, along with the industrial activity, is borne out by frequent weed taxa and the presence of cereal type pollen, indicating mixed farming, in the records (LT17, LT20) from the wetland edge as well as LT5A. Fungal spores indicative of dung support the pollen evidence for livestock grazing in the area, as does the beetle evidence at LT5A (see Smith *et al* xx). Plant macrofossils from the industrial deposits, including glume bases of spelt wheat as well as seeds such as fat hen, oraches, sheep's sorrel, docks, common nettle, buttercup and grasses and bracken and bramble remains, confirm cereal cultivation in the vicinity of the site as well as grassland and waste and disturbed ground habitats (see Caseldine and Griffiths xx).

The Pb pollution evidence from LT5A suggests that at least the main period of industrial activity occurred over a relatively short period. The lack of evidence for woodland management from the charcoal record (Caseldine and Griffiths xx) might also support this. From *c* 1840 ^{14}C yrs BP (interpolated date), as industrial activity declined, cereal production also appears to have declined and pastoral activity, especially on the wetland, may have reduced.

Post Roman activity

A date of 1620±40 BP (Beta-235895: Cal AD 350-540) from immediately above industrial deposits at LT6 at the smelting site suggests that activity had ceased by that date, if not earlier. Oak woodland was scarce in the area but there is some evidence for an increase in alder carr. A reduction in weed taxa at LT6 at this time could reflect a decrease in disturbed ground with abandonment of the site, a reduction in agriculture or simply the effect of local grass communities masking weed pollen representation. The latter is most likely given that weed taxa remain frequent at LT20. Shortly after this, both at wetland edge sites (LT6, LT15, LT20) and at LT5A, there is, however, some evidence for an increase in birch woodland in the area. Although this could indicate regeneration of birch on the dry land, it is most strongly represented at LT5A where a phase of local birch and alder woodland occurred between *c* 1710±60 BP (Beta-222222: Cal AD220-440) and *c* 1390±70 BP (Beta-235892: Cal AD 550-770). The expansion in woodland might be at least partly due to a reduction in grazing on the wetland, allowing trees to regenerate. Weed taxa are largely absent, which again suggests a reduction in agriculture in the area, but their absence could at least be partly due to the filtering effects of local woodland. The stronger representation of weed taxa at the wetland edge sites compared with at LT5A may signify the closer proximity of these sites to more localised farming activity.

A peak in lead values occurs soon after 1710±60 BP (Beta- 222222: Cal AD220-440), *c* 1670- 1590 ^{14}C yrs BP (interpolated dates), at LT5A which may represent a further episode of mining or smelting activity in the area, although an increase in minerogenic sediment *c* 1590 ^{14}C yrs BP could indicate eroded, older material from the smelting site or elsewhere. The date of 1620±40 BP (Beta-235895: Cal AD 350-540) from LT6 at the smelting site suggests that activity had ceased and there are no other dates that indicate a continuation or renewal of activity. Hence, if the activity is contemporary, it was taking place elsewhere in the area.

Although the timing varies, *c* 1390±70 BP (Beta-235892: Cal AD 550-770) at LT5A and slightly later, *c* 1230±40 BP (Beta-235894: Cal AD 680-890), at LT6, perhaps because of the persistence of local birch near the industrial site influencing pollen representation, there appears to be an increase in oak woodland in the area. This again suggests some land may have gone out of agricultural production, although agricultural indicators demonstrate mixed farming continued in the area. A date of 1250±50 BP (Beta-235891: Cal AD 660-890) at LT5A suggests a renewed impact on the oak woodland in the wider area, whilst it remained in the area of the industrial site (LT6, LT15). However, even here by *c* 1120±40 BP (Beta-235893: Cal AD 810-1010) clearance of oak and possibly birch was taking place, but alder woodland seems little affected throughout this period. The reduction in woodland was possibly the result of deliberate clearance, or sustained grazing activity in the area might have prevented regeneration.

The trackway period

Following the reduction in woodland, especially of oak, a largely open agricultural landscape prevailed in the local area. Pastoralism dominated but there was some cereal cultivation. During this phase, the trackway was constructed. Radiocarbon dates from trackway timbers give a date of 1070±30 BP (Cal AD 900-1020) and 1060±40 BP (Cal AD 900-1030) for its construction, whilst a more precise dendrochronological date suggests that wood for the track was felled soon after AD 1136. The impact of trackway construction on the woodland communities is, however, difficult to detect clearly. (**Nigel any thoughts on trackway phase?/ phases?).**

Oak was one of the principal species used, although not to the same extent as alder, which was the main wood employed (see Caseldine and Griffiths xx). Hazel was more widely used for stakes and posts nearer the dry land, where it was more likely to be growing. Other species such as ash, holly, willow/poplar, cherry and hawthorn type were present in low amounts and also largely occurred towards the dry land. All these taxa occur in the pollen records (LT5A.5, LT6.4a/LT6.4b, LT15.2a/LT15.2b) around the time of trackway construction and initial use, demonstrating their presence in the surrounding woodland communities.

It is possible that a decline in alder towards the end of LT6.4a could relate to felling of alder to make the trackway. Otherwise, there is little evidence to indicate impact on the surrounding woodland. Indeed there appears to be a small recovery in oak, birch and hazel woodland at the beginning of zones LT6.4b and LT15.2b, although there is a slight decline in alder. The limited evidence for human impact on the woodland in the area might be because the amount of wood used in making the trackway had little affect on the overall woodland communities in the pollen catchment, because the woodland exploited was some distance from the trackway or because the clearance episode was extremely brief. Equally, older pollen from industrial deposits used in making the trackway may have masked changes in the contemporary woodland.

The pollen, plant macrofossil (Caseldine and Griffiths xx) and insect (Smith *et al* xx) evidence suggests that the trackway was constructed over a varied wetland landscape encompassing wetland grasses, reed, sedges, heather and cotton grass with wetter pools containing pond weed. Bog myrtle, birch fenwood and alder carr would also have been growing in the area.

Apart from a limited increase in woodland, the local landscape seems to have altered little up to *c* 310±40 BP (Beta-241085: Cal AD 1460-1660). Shortly after this there was slight expansion in hazel and/or bog myrtle communities and alder carr. Agricultural activity also appears to have diminished. After this, the record ceases as a result of recent farming activity.

Discussion

The local Late Iron Age/Roman landscape and archaeology

The pollen and palaeopollution evidence from Llangynfelin demonstrates that both agriculture and lead processing/mining activity had a significant impact on the environment during the late Iron Age/Roman period. The pollen records clearly indicate a marked impact on the local woodland, notably oak. A first phase of activity is dated to *c* 1980±50 BP (Beta-211076: 80 Cal BC - Cal AD120) and 1960±60 BP (Beta-222223: 80 Cal BC-Cal AD 150). At the same time there is an expansion in agriculture. This activity could be related to the presence of a defended enclosure close to the dry land edge at Ynyscapel, about 650m, from the industrial site. The construction of this settlement, as well as clearance for agriculture, would have contributed to a reduction in the local woodland. Equally, the construction of the nearby Roman road, including clear ways on either side, would have resulted in woodland clearance, whilst the construction of the Roman fortlet at Erglodd, around 500m, from Llangynfelin would also have required timber. Recent geophysical survey has suggested the presence of an early phase of timber buildings followed by at least one stone building (Hopewell 2006). Wood would also have been required for fuel at the settlements. It is possible that clearance took place at the smelting site at this time and that the area was initially used for agriculture.

As already discussed, the arrival of a Roman military presence in the area could, alternatively, be represented by the second phase of clearance activity identified at LT5A. This second phase coincides with evidence for palaeopollution at LT5A. The close proximity of LT5A to the smelting site at Llangynfelin suggests that this site was largely responsible for the palaeopollution recorded, although there is a possibility that the peak in Pb could represent other mining or smelting activity in the region, for example at Llangynfelen mine to the north. Equally, some of the pollution may derive from the mining activity, which provided the ore used at the site rather than the smelting activity. There are several mines within the immediate area. **A likely contender is Erglodd mine, located slightly more than 500m from the Roman fort, (Timberlake 2006).** (**Is this likely?**) **Although Erglodd mine is only just over 500m from the Roman fort, analyses (???????) suggest that the ore was not from this mine.** (**Nigel – please comment**). Overall it seems probable that the sharp decline in oak, as well as the decline in other tree species, was directly related to the exploitation of the local woodland for fuel at the smelting site. The use of wood at local mines, as well as for fuel for domestic fires and for other purposes at the nearby settlements, would also have contributed to the reduction in woodland.

The industrial activity is estimated *c* 1885 ^{14}C years BP-1870 ^{14}C years BP at LT5A, which is in close agreement with a date of 1880±40 BP (Beta-238739: Cal AD 50 - 230) from the industrial site. Also, the estimated calibrated date at LT5A is *c*. Cal AD 140 which is equivalent to the mean of the calibrated age range of the date from the industrial site. However, other dates from the smelting site range between 1990-1910 ^{14}C years BP and span Cal BC 60-AD220 and all the dates from both phases are statistically indistinguishable at two sigma. Hence it is difficult to be certain about the date of events, although the smelting activity appears to relate to the second clearance episode recorded at LT5A and therefore must post date the earlier episode. It therefore seems probable that the first clearance episode occurred during the first century AD, shortly before or contemporary with the arrival of the Romans, and the industrial activity occurred at the end of the first century AD and/or during the second century AD. The problem of correlating events registered in calibrated radiocarbon-dated pollen diagrams with calendar-dated Roman occupation has also been encountered in northern Britain (Dumayne *et al* 1995).
(**Any dates from furnace? Nigel any comments?**).

The fortlet at Ergodd is considered to date to the Flavian period and was probably established sometime around 74 AD, with occupation continuing into the 2nd century AD. This is in agreement with the proposed period of main activity at the lead smelting site. The pollen and palaeopollution records support the suggestion that the fortlet was not only involved in the supervision of traffic along the road between the auxiliary forts at Pennal and Pen Llwyn but was also involved in the exploitation of local lead and, possibly, silver deposits.

A mixed farming economy appears to have prevailed throughout the period of smelting/mining activity. Cereal cultivation included the growth of spelt wheat and some grazing of stock may have occurred on the wetlands as well as on the dry land. By the end of the Roman period farming activity appears to have declined and there seems to be a renewed expansion in woodland during the early medieval period. Although agricultural activity may have been reduced, the palaeopollution record does indicate that there may have been some late Roman/early medieval industrial activity in the area.

Comparison with the wider environmental record during the Late Iron Age/Roman period
The results from Llangynfelin are consistent with other evidence from Cors Fochno. Moore (1968, Moore and Chater 1967) also attributed evidence for increased clearance and agricultural activity at Borth to the Iron Age/Roman period, noting that Borth was close to the Roman fording point of the River Dovey (Moore and Chater 1967). In addition he assigned a period of woodland regeneration to the early medieval period, although the changes were undated. Recent work by Mighall and Timberlake (Mighall pers comm.) has identified similar vegetation changes and palaeopollution in a core from the central dome of Borth Bog. Radiocarbon evidence suggests that Pb enrichment, coinciding with a woodland clearance episode, dates to the Roman period and reflects mining/smelting in the area. A recovery in woodland occurs during the early medieval period followed by a clearance episode. These vegetation changes may be comparable to those identified at Llangynfelin.

There is some evidence for the impact of Pb mining during the Roman period from other sites in Wales. The nearest evidence is from the Ystwyth valley where a period of sustained woodland clearance is recorded during the Iron Age in the blanket peats at Copa Hill, Cwmystwyth (Mighall *et al* 2006). This is attributed to an expansion in agriculture because of the absence of metal enrichment in the peat at this time. However, following a slight recovery, a subsequent decline in woodland, accompanied by an increase in Pb concentrations, is considered to reflect Roman mining and smelting in the Ystwyth valley. As at Llangynfelin farming continued throughout the Roman period with evidence both for cereal cultivation and pastoralism and, following cessation of mining, there was a recovery in woodland.

A rise in Pb and Zn values dated to 1720±40 BP in a core from a blanket peat close to the former lead mine at Craig y Mwyn Mine, Llanrhaeadr-ym-Mochnant, Powys, suggests that mining may have commenced in the Roman period (Mighall *et al* BM forthcoming). The evidence for Roman mining activity from a blanket peat at the head of the Nant y Bai valley close to the mines at Rhandirmwyn (Pen Cerrig y Mwn and Nantymywyn Mine(s)), Carmarthenshire (Mighall *et al* 2007) is less certain. A phase of small-scale activity might represent a phase of prospecting activity for gold rather than for lead (Timberlake 2003) during the Roman period, but alternatively might represent small scale mining during the Dark Ages (Mighall *et al* 2008). Either way mining activity had a limited impact. There is also some evidence for agriculture but not on a major scale

As well as evidence from Wales for Roman lead mining activity, there is evidence from peats from south west England (West *et al* 1997). However, evidence from the North Pennine Pb orefield is circumstantial (Mighall *et al* 2006). Pollution records from peats in the area suggest that either local lead ores were not exploited or exploitation was on a scale that was insufficient to generate a pollution signal (Mighall *et al* 2004). There are also metal pollution records from Europe which indicate Pb mining during the Roman period (Görres and Frenzel 1997, Martinez Cortizas et al 1997).

The expansion in clearance and agricultural activity at Llangynfelin during the late IronAge/Roman period has been identified at other sites in Wales, for example Whitland (Caseldine *et al*, 20), Cefn Gwernffrwd (Chambers 1982), Black Mountains (Price and Moore 1984), and Llangorse Lake (Jones *et al* 1985, Chambers 1999). In the uplands of mid-Wales, although undated, it has been suggested that clearance evident in several diagrams, Plynlimon, UTV5 and Llyn Gynon, was related to Roman activity (Moore 1966, Moore and Chater 1969). Plynlimon is close to the Roman fort of Cae Gaer and UTV5 and Llyn Gynon not far from the Sarn Helen road. More recently radiocarbon dated diagrams from Craig y Dullfan, near Nant y Moch reservoir, confirm the evidence for Roman activity in the Plynlimon area (Caseldine and Griffiths 2008). At Bryniau Pica a short-lived decline in hazel has been dated to 1965±65 BP (AA-27632) (Buckley 2000, Buckley and Walker 2001), whilst at Carneddau an extensive period of deforestation occurred between *c* 1960 ^{14}C years BP and 1790 ^{14}C years BP (Walker 1993).

A recent detailed study at the lowland raised bog Cors Caron (Tregaron Bog) charts the vegetation changes during the later Iron Age through to the medieval period (Morriss 2001, Lomas-Clarke and Barber 2007). The events relating to the Roman period are similar to those found at Llangynfelin. From c 100 cal BC there was a period of substantial hazel scrub clearance, accompanied by an increase in mixed farming. This was followed by a further phase of increased agricultural activity dated to *c* cal AD 75 and cal AD 375. It is suggested that this agricultural activity may be related to the construction of the Roman fort at Bremia. A decline in pastoral and arable activity and regeneration of woodland/scrub *c* cal AD 375 is considered to be linked to the withdrawal of the Romans.

The early Medieval - Medieval period

The regeneration of woodland observable at Llangynfelin during the early medieval period is also recorded in other diagrams from Borth (Moore 1968, Moore and Chater 1969, Mighall pers comm), as is the continued presence of agricultural activity. A regeneration phase is observable at a number of pollen sites during this period, for example, Talley (Butler 1984), the Black Mountains (Moore *et al* 1984), Waun Fignen Felen (Smith and Cloutman 1988), the Berwyns (Bostock 1980) and Preselis (Seymour 1985).

By *c* 1120±40 BP (Beta-235893: Cal AD 810-1010) at Llangynfelin, apart from alder, most of the woodland had disappeared from the local area as a result of clearance for agriculture, the use of wood for construction, fuel or other purposes and/or as a result of grazing preventing regeneration. An episode during which oak, alder and birch decline but hazel increases in the pollen diagram from the central dome (Mighall pers comm.) may be comparable with this phase at Llangynfelin but is undated. The evidence from the central dome suggests that woodland was more abundant in the wider region compared with the area around the smelting site.

The trackway at Llangynfelin was constructed shortly after AD 1136. Around the time of trackway construction, or soon after, the pollen records suggest that there was a slight recovery in woodland in the local area or, alternatively, they could be registering an increase in woodland in the wider region. There is some limited documentary evidence for woodland during the 12th century. Giraldus Cambrensis during his tour of Wales in 1188 described the country as having extensive woods. Glanville Jones (1965) suggested that during the later part of the reign of Gruffyd ap Cynan (*obit* 1137) ' the men of Gwynedd began to plant the old woods, to make orchards and gardens surrounded with walls and ditches, and to construct walled buildings' (Musson *et al* 1989). The slight increase in woodland broadly contemporary with the trackway at Llangynfelin may indicate similar activity in the local area.

Figures.

Table 1 Llangynfelin radiocarbon dates from pollen columns.

Laboratory Code Analysis	Sample Depth (cm)	Material	Radiocarbon Age (yrs BP)	2 Sigma Calibrated Age Range (mean)	2 Sigma Calibrated Age Range (mean)
Trench 5					
Beta-235891 Radiometric	17.5-18.5	peat	1250±50	1290-1060 Cal BP (*c.* 1175 Cal BP)	Cal AD 660-890 (*c.* Cal AD 775)
Beta-235892 Radiometric	37.5-38.5	peat	1390±70	1400-1180 Cal BP (*c.* 1290 Cal BP)	Cal AD 550-770 (*c.* Cal AD 660)
Beta-222222 Radiometric	53.5-54.5	peat	1710±60	1740-1510 Cal BP (*c.* 1625 Cal BP)	Cal AD 220-440 (*c.* Cal AD 330)
Beta-222223 Radiometric	84.5-85.5	peat	1960±60	2030-1800 Cal BP (*c.* 1915 Cal BP)	80 Cal BC-Cal AD 150 (*c.* Cal AD 35)
Beta-209007 Radiometric	118.5-119.5	peat	2200±50	2340-2060 Cal BP (*c.* 2200 Cal BP)	390-110 Cal BC (*c.* 250 Cal BC)
Trench 6					
Beta-235893 AMS	21.5-22.5	peat	1120±40	1140-940 Cal BP (*c.* 1040 Cal BP)	Cal AD 810-1010 (*c.* Cal AD 910)
Beta-235894 AMS	33.5-34.5	peat	1230±40	1270-1060 Cal BP (*c.* 1165 Cal BP)	Cal AD 680-890 (*c.* Cal AD 785)
Beta-235895 AMS	46-46.5	peat	1620±40	1600-1410 Cal BP (*c.* 1505 Cal BP)	Cal AD 350-540 (*c.* Cal AD 445)
Trench 11					
Beta-241084 AMS	23.5-24.5	organic clay	2260±40	2350-2290 Cal BP and 2280-2150 Cal BP (*c.* 2320 Cal BP and *c.* 2215 Cal BP)	400-340 Cal BC and 330-200 Cal BC (*c.* 370 Cal BC and *c.* 265 Cal BC)
Trench 15					
Beta-241085 AMS	5.5-6.5	peat	310±40	490-290 Cal BP (*c.* 390 Cal BP)	Cal AD 1460-1660 (*c.* Cal AD 1560)
Trench 17					

Beta-238737 AMS	30	charcoal	1970±40	2000-1830 Cal BP (*c.* 1915 Cal BP)	50 Cal BC-Cal AD 120 (*c.* Cal AD 35)
Beta-211076 Radiometric	39.5-40.5	peat	1980±50	2030-1830 Cal BP (*c.* 1930 Cal BP)	80 Cal BC- Cal AD 120 (*c.* Cal AD 20)
Trench 20					
Beta-238738 AMS	8	charcoal	1940±40	1980-1820 Cal BP (*c.* 1900 Cal BP)	30 Cal BC-Cal AD 130 (*c.* Cal AD 50)
Beta-238739 AMS	20	charcoal	1880±40	1900-1720 Cal BP (*c.* 1810 Cal BP)	Cal AD 50-230 (*c.* Cal AD 140)
Beta-211077 Radiometric	43.5-44.5	peat	2290±60	2370-2150 Cal BP (*c.* 2260 Cal BP)	420-200 Cal BC (*c.* Cal AD 310)
Beta-222224 Radiometric	97.5-98.5	peat	2490±50	2740-2360 Cal BP (*c.* 2250 Cal BP)	790-410 Cal BC (*c.* 600 Cal BC)

Table 2. Zone characteristics for pollen column LT5A.

Zone	Depth (cm)	Estimated Age (*c.* cal BC/AD)	Characteristics
LT5A.1	120-83	*c*. 260 BC-AD 55	*Corylus avellana* type and other arboreal pollen types dominate. *Calluna* pollen is quite frequent. Poaceae and Cyperaceae occur in low amounts. *Plantago lanceolata* and other herbs occur throughout the zone. *Plantago* spp. peak mid-zone. *Sphagnum* spores are relatively frequent. Microscopic charcoal is scarce until the end of the zone.
LT5A.2	83-53	*c*. AD 55-350	Arboreal pollen values are lower but *Salix* increases slightly. Ericaceae and Poaceae values are higher. *Plantago lanceolata* is more abundant than previously and other herb taxa, notably *Rumex* spp. and Lactuceae, are more frequent. Cereal type pollen is present in noticeable amounts. *Lotus* pollen peaks towards the end of the zone. *Pteridium* spores increase. Microscopic charcoal values rise with a marked increase mid-zone.
LT5A.3	53-38	*c.* AD 350-660	*Betula* and *Alnus* dominate. *Calluna* pollen is scarce. Poaceae values are low then increase. Herb pollen is rare. Pteropsida monolete spores are relatively frequent. Microscopic charcoal is present.
LT5A.4a	38-14	*c*. AD 660-850	*Betula* values fall. *Corylus avellana* type pollen increase, whilst. *Quercus* and *Alnus* increase then decline. Ericaceae pollen gradually increases. Poaceae values decrease. Cyperaceae pollen increases. *Plantago lanceolata* pollen is consistently present. Herb pollen is more plentiful. *Sphagnum* spores are abundant.
LT5A.4b	14-0	*c.* AD 850-?1136	*Quercus, Alnus* and *Corylus avellana* type values are lower than previously. *Calluna* and Cyperaceae values are consistently higher. Poaceae values remain constant. *Plantago lanceolata* representation is similar to previously. Herb pollen is relatively frequent. Cerealia type pollen is present. Microscopic charcoal increases.

Table 3. Zone characteristics for pollen column LT6.

Zone	Depth (cm)	Estimated Age (*c.* cal BC/AD)	Characteristics
LT6.1	50-42	*c*. ?AD 335-555	Poaceae pollen dominates. Herb taxa decrease, notably *Plantago lanceolata*, *Rumex* spp. and Lactuceae values. Arboreal values are low. Microscopic charcoal declines from high values.
LT6.2	42-34	*c*. AD 555-	Arboreal values increase, particularly *Betula* and *Alnus*. Poaceae pollen declines but remains

		785	frequent. Herb pollen is rare. *Calluna* pollen increases. Microscopic charcoal is scarce.
LT6.3	34-22	*c*. AD 785-910	*Betula* decreases whilst *Corylus avellana* type and *Quercus* increase. Poaceae pollen is relatively frequent but fluctuates and Cyperaceae pollen increases. *Calluna* pollen is scarce. Herb taxa increase, especially *Plantago lanceolat*a and *Potentilla* type pollen. *Pteridium* spores increase.
LT6.4a	22-6	*c.* AD 910-?1136	*Quercus* and *Corylus avellana* type, followed by *Betula*, decline and Poaceae increases. Herb pollen continues to be frequent. Microscopic charcoal increases.
LT6.4b	6-0	*?c.* AD 1136-?	*Quercus*, *Betula* and *Corylus avellana* type increase very slightly, whilst Poaceae and herb taxa decrease. Microscopic charcoal is frequent.

Table 4. Zone characteristics for pollen column LT11.

Zone	**Depth (cm)**	**Estimated Age (*c.* cal BC/AD**	**Characteristics**
LT11.1 a	30–26	< ? 370 BC or ?265 BC	The assemblage is dominated by arboreal pollen, principally *Alnus. Corylus avellana* type pollen values are around 15% TLP. Poaceae values are low. Herb taxa are scarce but include Plantago lanceolata and Chenopodiaceae. Microscopic charcoal is present
LT11.1 b	26-6	*c*. 370 BC or *c*. 265 BC - < *c*. AD 35-140	*Alnus* declines and *Quercus* increases. Corylus avellana type values remain fairly constant. Herb taxa include *Plantago* spp, *Rumex* spp. and *Succisa*. Microscopic charcoal peaks initially.
LT11.1 b	6-0	< *c*. AD 35-140 – *c*. AD 35-140	Poaceae pollen increases from around 10% TLP to around 30% TLP. Herb taxa increase in frequency. *Quercus* declines followed by *Alnus*. *Pteridium* spores are more abundant. Microscopic charcoal shows a sharp increase

Table 5. Zone characteristics for pollen column LT15.

Zone	**Depth (cm)**	**Estimated Age (*c.* cal BC/AD**	**Characteristics**
LT15.1	50-30	*c.?*AD 600-900	*Alnus* and *Betula* dominate the arboreal assemblage. *Quercus* and *Corylus avellana* type occur in relatively low amounts. *Salix* is present at more than1% TLP. Poaceae pollen values are relatively high and herb pollen is plentiful. Microscopic charcoal is abundant.
LT15.2	30-18	*c*.AD 900-	Poaceae pollen dominates. *Betula* pollen shows a noticeable decrease whilst *Quercus*, *Alnus* and

a		1100	*Corylus avella*na type values also fall slightly. Herb pollen continues to be quite well represented. Microscopic charcoal values decline
LT15.2 b	18-6	*c*. AD 1100-1560	Poaceae values are marginally lower. Herb taxa remain relatively frequent. *Betula* and *Quercus* show a minor recovery
LT15.2c	6-0	*c*. AD 1560-?	Poaceae pollen declines slightly and herb taxa are scarcer. *Corylus avellana* type and *Alnus* increase. Microscopic charcoal increases.

Table 6. Zone characteristics for pollen column LT17.

Zone	**Depth (cm)**	**Estimated Age (c. cal BC/AD)**	**Characteristics**
LT17.1	50-38	< c. AD 20- > *c*. AD 20	Arboreal pollen values are high, notably *Alnus* and *Quercus,* but decline. *Salix* is well represented. Poaceae, Cyperaceae and herb taxa such as *Rumex acetosa*, *R. acetosella* and *Potentilla* type increase towards the end of the zone. *Potamogeton* peaks at the end of the zone. Microscopic charcoal values rise towards the end of the zone.
LT17.2	38-14	> *c*. AD 20- > *c*. AD 35-140	After an initial decline, arboreal pollen increases. Poaceae pollen is frequent and herb taxa are relatively well represented, especially *Plantago lanceolata*, Lactuceae and *Rumex* spp.. *Pteridium* spores are abundant. Indeterminate pollen is frequent. Microscopic charcoal values are high.
LT17.3	14-10	> *c*. AD 35-140-?	Poaceae pollen increases further. *Quercus* and *Corylus avellana* type decline but *Alnus* values remain high. Herb pollen continues to be quite frequent. *Pteridium* spores decrease. Microscopic charcoal values fall.

Table 7. Zone characteristics for pollen column LT20.

Zone	**Depth (cm)**	**Estimated Age (*c*. cal BC/AD)**	**Characteristics**
LT20.1	100-30	*c*. 610- > *c*. 310 BC	AP values are high, with *Alnus* dominating, before a decline at the end of the zone. *Quercus* values fluctuate. *Corylus avellana* type values are relatively constant and *Betula* values are low. A wide range of shrub taxa is present. *Calluna* pollen is scarce. Herb pollen is consistently present in low quantities. Pteropsida monolete and *Pteridium* spores occur in noticeable amounts as does microscopic charcoal.
LT20.2	30-10	> *c*. 310	Poaceae values increase markedly to c 60% TLP before falling back to c 25-35% TLP. *Alnus* and

		BC- *c*. AD 35-140	*Quercus* increase from minima at the opening of the zone. *Corylus avellana* type also increases. Representation of herb pollen is stronger, especially *Plantago lanceolata*, *Rumex acetosella*, *R. acetosa*, Lactuceae and Chenopodiaceae. *Pteridium* spores increase in abundance, as do *Polypodium* spores. Indeterminate pollen values are high. Microscopic charcoal values are high.
LT20.3	10-0	*c*. AD 35-140-?	AP values fall before an increase in *Betula*, *Aln*us, *Salix* and then *Corylus avellana* type. Poaceae pollen is more frequent and herb taxa continue to be well represented. *Pteridium* and *Polypodium* spores decline. Microscopic charcoal, although still frequent, decreases.

APPENDIX 2: THE CHARACTERISATION OF THE INDUSTRIAL SEDIMENTS ASSOCIATED WITH LLANCYNFELIN ROMAN LEAD SMELTING SITE: A MINERALOGICAL AND TEXTURAL ANALYTICAL ASSESSMENT

SIMON TIMBERLAKE

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Summary

A small selection of bulk soil samples from the second season of excavations undertaken at this site by Cambria Archaeology in June/July 2005 were sub-sampled as part of this initial rapid assessment of the potential of these deposits for more detailed analysis in 2007/8.

Seven samples were examined, representing a range of different types of potential processing or waste sediments across the site. These included four samples from the Test Pit 21 (Trench 21), where the only lead hearth (so far identified) was located, plus single samples from Trench 12, a short distance to the west along the same slope, at a site where possible cut features and wooden stake holes which could have been associated with other furnace(s) was located, Trench 6, the largest excavated area where dumped industrial sediments and charcoal layers underlying the medieval trackway had previously been radiocarbon dated to around 60BC-90AD and 20AD-220AD, and Trench 17 furthest away from the core area of the site, a location it was believed might provide information on the disposal of waste material. Samples from these particular trenches had been identified as being a priority for analysis, with Trench 21 clearly forming the main part of this investigation.

Either the same, or else a similar set of sub-samples from these same bulk-sampled Trench contexts were taken for the purposes of carrying out two parallel investigations; the chemical analyses (XRF/ AAS) of the lead contents of these sediments (at Aberdeen University undertaken by Dr.Tim Mighall), and metallographic work on the slag and furnace fragments (by Lorna Anguilano, Institute of Archaeology, London), the latter undertaken with a view to interpreting the type of smelting process employed.

This post-excavation assessment of these samples was addressing one of the main objectives of the 2005 season of work, namely 'to assess the extent, character, date and significance of the industrial deposits and any associated processing complex'.

Methodology

Sub-sample aliquots of between 150 – 200 ml were taken from each of the bulk sample bags, were weighed, then washed using tap water through a stack of four Endecotts sediment sieves, six fractions being collected. This included one hand-picked fraction (>10 mm clast grain size) from the upper sieve, a <10 mm >2mm gravel-grit fraction, a <2mm >1mm grit fraction, a <1mm >0.5 mm (30#) coarse sand fraction, a <0.5mm (30#) >0.25mm (40#) medium-fine sand fraction, and a <0.25mm (40#) sandy-silt fraction, plus an assessment of the still finer residues (such as the clay and/or peat suspension. These fractions were then air dried and weighed, then spread out and scanned by eye using a hand-lens magnifier and a low-power binocular microscope where this was advantageous. A written mineralogical and textural assessment was produced, with estimates of the percentage proportions of different mineral, slag, lithic and organic components within each of the 5-6 sample fractions.

Results

Trench 21 SAMPLE 22 layer (1091): 1 bag of charcoal taken from around the stones (furnace?); interpreted as an industrial residue from the smelting process.

>10 mm fraction = 34 g

x 6 charcoal pieces (10mm approx)
x3 broken pieces of glassy black slag (largest 20mm diameter)
x2 pieces of heat altered mineral vein (probably from a lead vein; includes lead oxide staining, some adhering glass, plus heat-affected quartz and rotted carbonate (largest is 15 mm across)
x2 pieces of quartz rock gangue from vein (both >30mm)
x2 waterworn natural shale clasts from soil/fluvioglacial (unburnt) approx 10 mm
x1 burnt piece waterworn shale clast from soil

slag characterisation: broken, lightweight, empty gas vesicles, no visible inclusions of galena or of lead eutectoid, but small red inclusions within glassy groundmass may be of lead oxide? Slag has a conglomeratic nature; it contains grit-sized inclusions from soil or country rock such as calcined feldspar and small rounded quartz grit grains – could be crushed grit (silica) which has been added as a flux, clearly only partly absorbed into the groundmass of the glass

<10mm >2mm fraction = 6g

x 223 pieces of charcoal
x14 pieces of broken well developed vesicular back glassy slag with quartz and feldspar inclusions (but no lead) NB same type as above
x8 pieces of 'slaggy' and part-fused mineral, in this case mineral vein gangue such as quartz
x20 pieces of roughly broken shale and quartz vein (not heat altered)
x7 pieces of well fired (heat reddened) rock, mostly of waterworn clasts originally from the soil or a stream (possibly part of the disaggregated grit/clay hearth lining daub for the simple furnaces?)
x3 pieces of unfired waterworn shale

<2mm >1mm fraction = 1g approx

70% of it is charcoal flecks and ash
some shale flakes (perhaps from heat decrepitation of shale rocks?)
some grains of burnt (reddened) grit
2-3 pieces only of small broken grit size pieces of glassy black slag

<1mm >0.25 mm =35g: a dirty dark grey/brown sand with charcoal

approx 20% charcoal
remaining 80% a fine gritty sand made large of shale flecks and quartz grains:
approx. 15% of this is made up of small and mostly waterworn fakes/grains of shale which has been distinctly reddened as a result of heating
nothing is really visible in the way of slag particles

no ore grains (galena, blende etc.)

<0.25 mm fraction =13 g

consists of a fine charcoal (sludge) sediment, almost all of this floated or in suspension in water, no mineral component

Trench 21 layer (1085): a grey gravel layer 0.22 m (average) deep, interpreted as 'layering to cover charcoal, perhaps to create a flat surface

Dry weight = 305 g (dry sieved)

> 10 mm fraction = 58 g

x1 large piece (> 20 mm): drip slag, perhaps coating rock – black vesicular glass with rock inclusions (= 'conglomeratic slag' type on stone hearth lining)
x9 smaller pieces of crushed black 'conglomeratic slag', some with litharge stains (red), but no free metal. Inclusions of shale rock and fired quartz up to 5 mm long
x1 mineral vein fragment (1.5 mm) with quartz vugh and tiny bit of galena
x3 pieces of vein quartz
x25 slightly rounded/ sub-angular shale fragments derived from soil
x5 rounded pebble shale fragments (gravel size)

< 10 mm >2mm fraction = 131 g

pieces of charcoal approx 5%
crushed black vesicular glassy ('conglomeratic') slag; some with litharge stains, stony inclusions, but with no visible metal 25-30 %
fired or burnt (reddened) rock < 0.5%
mineral vein (unslagged); mostly gangue, but no galena <2%
sub-angular shale fragments 50%+
rounded shale gravel from out of soil approx. 10%

<2 mm > 1 mm fraction = 40 g

charcoal 15%
crushed slag 15-20%
burnt/calcined rock fragments <2%
mineral vein/quartz vein fragments 5% +
angular/ sub-angular slate fragments (mostly crushings) 50-60%

<1 mm > 0.5 mm (30#) fraction = 22 g

charcoal 25%
crushed glassy slag shards 10%
burnt (reddened) rock <5%
sub-angular shale and quartz grit 60%
rootlets

< 0.5 mm (30#) > 0.25 mm (40#) fraction = 13 g

Same constituents and proportions as previous fraction

<0.25 mm (40#) or silt fraction

charcoal 10%+
?powdered slag dust >40 %
earth and silt 40%
organics

Trench 21 layer (1109) SAMPLE 013: reddish-brown gravel from the NW quadrant of Tr. 21 = the area of ‘heavy burning’ (hearth base or surround)

Weight = 268 g.

>10 mm fraction = 91 g

x1 piece of charcoal
x1 burnt (reddened) slate
x1 larger piece of furnace lining (reddened sandstone rock) up to 30 mm diameter, has a fused glassy surface (both black and red glassy phases), with accreted inclusions of charcoal, plus ‘conglomeratic slag’ phase in part, with inclusions of quartz and felspathic grit
x24 pieces of crushed conglomeratic slag with part smelted/fused mineral inclusions within glass: appears as a conglomerate with gas bubbles and many clasts of unaltered quartz grit , also crushed rock inclusions. Some are more glassy slag pieces with flow lines in, and very rarely, minute patches of anglesite, suggesting possible rotted galena inclusions. Otherwise little macroscopic evidence for lead or un-smelted ore..
x3 fragments from mine spoil/ore vein (mostly quartz and a little lead mineral: iron staining and cerussite growing on surface)
x4 rounded pebbles of slate from fluvioglacial/ river gravels
x7 pieces rough slate (largest 40 mm)

<10 mm > 5 mm fraction = 35 g

x 55 pieces of crushed, coarse conglomeratic glassy slag with many unaltered inclusions of quartz grit etc
x6 pieces of rolled shale/quartz gravel pebbles incorporated within (or adhering to) glassy slag
x5 fragments of mineral vein incorporated in slag
x1 piece of part-fired clay lining
x7 fragments of mineral vein and quartz
x9 pieces of angular (crushed or freshly broken) rock
x7 small pebbles of shale and sandstone (derived from soil)

< 5 mm > 2 mm fraction = 61 g

consists of approx.500 fragments:

crushed conglomeratic glassy slag (includes some glassy shard fragments) 60%
charcoal 2%
un-slagged/ fired vein fragments 5%
angular shale and quartz fragments (some crushed) 20%
rounded waterworn clasts of shale/slate + sandstone + quartz <15%

< 2 mm > 1 mm fraction = 9 g

tiny shards of slag, some glass-like splinters 15-20%
charcoal 35%
some burnt coarse sand/grit grains <5%
grit/sand grains 35%
small waterworn rock fragments (derived from soil) 5%

< 1 mm > 0.5 mm (30#) fraction = 6 g

charcoal approximately 50%
glass shards of slag 10%
crushed rock/sand including some slightly burnt 30%
naturally weathered sand from soil 10%

<0.5 mm (30#) > 0.25 mm (40#) fraction = 7 g

charcoal 30-40%
tiny glass shards of slag 5-10%
burnt rock flakes/sand 15-20%
crushed rock and sand 30%

< 0.25 mm (40#) fraction silt fraction = 25 g

a charcoal-rich silt with ?40% + charcoal dust and up to 60% mineral silt, some from crushing activity

Trench 21 layer (1093) SAMPLE 3: bag of industrial residues

> 10 mm fraction = 68 g

x10 large pieces of charcoal
x1 large piece of slag (>20 mm): black, glassy and vesicular, but generally with a greater abundance of quartz grit inclusions, also iron stain and deposits of anglesite/cerussite indicate slightly higher lead content; probably oxidised metal or unsmelted galena residues
x9 other smaller pieces of slag, including at least two with similar oxidised traces of lead in
x5 very angular pieces of slate
x4 rounded clasts of slate derived from soil

<10 mm > 2 mm fraction = 32 g

charcoal 30-40%
coarse conglomeratic glassy slag, but with greater abundance of lithic/ quartz inclusions in it (also more lead) 15-20%
burnt (reddened) rock < 5%
probable mineral vein (gangue) rock 10%
angular shale plus rounded shale clasts 25%

< 2 mm > 1 mm fraction = 6 g

charcoal 50%
burnt rock fragments (reddened) 5-10 %
visible crushed slag < 10%
quartz and shale grit 30%

< 1 mm > 0.5 g (30#) fraction = 7 g

charcoal > 50%
burnt rock sand grains 5-10%
visible crushed slag shards < 5%
quartz and shale grit 40%

< 0.5 mm (30#) > 0.25 mm (40 #) fraction = 5 g

charcoal 50%
burnt rock flecks with slag shards amongst sand 5-10%
quartz and shale sand 50%

< 0.25 mm (40#) silt fraction = 8 g

very charcoal-rich silt

Trench 12 layer (1119) SAMPLE 033: ‘gravel’ layer within industrial residues

Weight = 242 g

> 10 mm fraction = 83 g

x1 piece of mineralised material attached to shale, possibly used as lining to a hearth, or else part of a slag base on to rock – has glassy (but weathered) surface, and with drop of decayed lead, now probably anglesite. Not a conglomeratic slag.
x1 large weathered fragment of dull black/red glassy slag with gas bubbles and blobs of now oxidised lead mineral (once metal drops?). Also contains inclusions of un-reacted crushed quartz (conglomeratic slag)
x13 small fragments of above conglomeratic slag, but with no visible lead, yet some cerussite/ anglesite stain in places. All clearly crushed slag material
x2 burnt pieces of (reddened) shale rock (derived from soil layer)
x2 pieces of mineral vein gangue
x12 pieces of rough shale (derived from soil)
x1 rolled fragment of quartz
x3 rather more waterworn pebble clasts

< 10 mm > 2mm fraction = 65 g

charcoal 5%+
crushed black conglomeratic slag which includes rock + quartz inclusions 25%
small fragments of burnt rock (<3-4 mm) 1% or less
mineral vein fragments 10% +
rough shale and quartz 40%
small rounded shale pebbles (derived from soil) 15-20%

< 2mm >1 mm fraction = 25 g

charcoal 20%
crushed black slag 15%+
small fragments of burnt (reddened) rock 5-10%
grit-sized rock (includes crushed quartz sand) 30%
shale flecks and fragments 25%

< 1mm > 0.5 mm (30#) = 15 g

charcoal 15%+
crushed black slag shards 5-10%
small fragments of burnt (reddened) rock 5-10%
grit-sized rock (crushed quartz) 30-40%
small shale flecks 30%

< 0.5mm (30#) > 0.25 mm (40#) = 14 g

charcoal <10%
crushed back slag <5%
fragments of burnt (reddened) rock 5-10%
fine sand (crushed quartz?) 50%
shale flecks 30-40%

< 0.25 mm (40#) silt fraction = 28 g

charcoal in finest fraction
spots of burnt rock (?) <5%
slag sand ?
quartz sand/silt 50-60%
clay and undefined silt 30-40%

Trench 6 layer (1129) SAMPLE 031: coarse and silty industrial residue

Weight = 175 g

> 10 mm fraction = 9 g

x1 15 cm fragment burnt rock (with accretion of lead oxidised minerals)
x6 angular- sub-angular fragments of shale and quartz
x2 'pebbles' of shale (derived from soil)

< 10 mm > 2 mm fraction = 69 g

charcoal 2%
burnt rock 1%
crushed coarse conglomeratic slag with enclosed lithic/quartz fragments, also traces of oxidised lead minerals. Not fresh-looking, possibly re-deposited and weathered, typical size for this is < 4mm 30%
angular shale and quartz fragments (< 4mm) 30%
rounded pebbles of shale and country rock (soil derived); 2mm>10mm 30-40%

< 2 mm > 1 mm fraction = 22g

charcoal 3-5%
burnt (reddened) rock fragments 3-5%
crushed glassy/ sub-glassy slag fragments 5-10%
'crushed' quartz grit 20%
rounded grains of shale and quartz derived from soil (natural grit) 50%
grains of woody/peaty material 5%

< 1 mm > 0.5 mm (30#) fraction = 11 g

charcoal <2%
crushed glassy slag sand 5%
burnt rock sand 3-5%
crushed quartz and mineral 15-20%
rounded/flattened natural grains of shale and quartz (soil derived) 60%

< 0.5 mm (30#) >0.25 mm (40#) fraction = 3 g

charcoal up to 5%
glassy slag sand 5%
burnt rock sand 5%
crushed quartz grains 10-15%
shale flecks 20-30%
natural fine quartz sand (soil derived) up to 40%
peaty/woody organics 5%

< 0.25 mm (40#) silt fraction = 10 g

contains a large amount of paler quartz-rich fine sandy silt-sized grains with up to 5% charcoal and some 'burnt' material, plus lighter fraction of organic clay sediment

Trench 17 layer (1115) SAMPLE 18: a charcoal clay-rich layer with soft grey clay "possibly result of preparing ore"

Weight = 155 g

> 10 mm fraction = 34 g

all charcoal (probably mostly oak/); the largest pieces are 25 mm in diameter, most are fresh looking, whilst 10-15% are more rounded (perhaps re-deposited lumps) surrounded by clay nodules in part

<10 mm > 2mm fraction = 28 g

charcoal fragments 98%
un-burnt wood chips 1.5%
rock (several grains only of quartz and partly calcined rock) 0.5%

<2 mm > 1 mm fraction = 26 g

charcoal 85-90%
un-burnt wood 2-3%
sand/ grit grains (mostly quartz) 5%
clay 5-10%

< 1 mm> 0.5mm (30#) fraction = 19 g

charcoal 70%
un-bunt wood 5%
fine sand grains (quartz and lithics) 15%
clay lumps 10%

< 0.5 mm (30#) > 0.25 mm (40 #) fraction = 5 g

charcoal 40-50%
un-burnt wood/ organics 5-10%
burnt sand 5%
fine sand grains and shale flecks 40%

< 0.25 mm (40#) silt fraction

charcoal 'sludge' with gritty fraction, probably;
charcoal and organics 70%
silt fraction 10%
clay 20%
Interpretation

Trench 21 : layer 1109

Clearly out of all the samples looked at, this was the sediment richest in the evidence for nearby metallurgical activity. It appears that this context lay just to the side of the furnace hearth.

Proximity, however, was not suggested by the presence of any part-smelted ore (galena) or even droplets of lead metal, a factor which suggests a fairly efficient and thorough process (considering the primitiveness of the bole hearth). It was suggested instead by the profusion of slag, and slag fragmentation material, from coarser through to the finer sediment fractions, and by the overall freshness of the slag; all of these being good in situ indicators. Crushing of this slag therefore is clearly indicated, perhaps on the spot or close by, much of it being crushed quite finely, perhaps by hand querns (?), but certainly not intentionally much finer than the 5-2 mm size. Whilst crushing may have been undertaken to release prills of metal, such an inefficient labour-consuming process does not seem likely, given that the slag itself seems to be lead-poor, something which also implies effective smelting conditions. The reasons for this therefore, are not entirely clear. However fragmentation of the slag may have been achieved by dousing it in water, this might explain the presence of very fine glass shards from the slags, as well as greater amounts of burnt rock fragments, or dusts, within the smaller fractions. Some of the crushed/fragmented slag could have been re-used as a grog in pottery, or else as a flux. These conglomeratic slags are very typical of this smelting site; they contained large inclusions of often un-reacted quartz and rock, suggesting perhaps that excess amounts of silica were intentionally being added as a flux in order to aide slag separation. The incidence of slag-coated fragmented rock surfaces amongst the coarser fractions (eg. > 10 mm) provides the best evidence yet for the fragmentation or breaking up of a stone hearth surround nearby. In addition, the incorporation of some soil-derived shale clasts within the sediment suggests the scraping up of material from the underlying ground surface along with the slag, perhaps when incorporating this into a shallow waste mound.

Trench 21 : layer 1091

The layer immediately overlying and either side of the hearth. Much of this consists of charcoal, at least within the fractions > 1mm (70%), although the very largest fractions include a mixture of broken and mixed up waste material, including fewer pieces of heat-altered rock and mineral and the same crushed or pounded black glassy 'conglomeratic slag' as found in profusion within layer 1109 (although any indications of oxidised lead metal droplets or un-reacted ore within this are rare). The smaller proportion of broken (but heat unaffected) shale plus waterworn clasts present within this (alongside the slag) suggests re-deposition. This probably took the form of 'raking out' the unburnt wood and charcoal, and following that, the inadvertent mixing of this with the soil, before the dumping of the charcoal fines around the furnace site. The increased % of grains of what may be heat-decrepitated rock within the sub-2mm fractions is a good indication of the existence of a partly open hearth (or bole furnace), yet there are many different ways of interpreting this sort of evidence. The presence of charcoal 'rake outs' around one of the hearths was also observed at Penguelan, Cwmystwyth, although here, much of this lighter material had since been washed away, and altogether this was on a much smaller scale.

Trench 21: layer 1085

There existed several different kinds of slag within this dry gravel layer of 'crushings', for instance the 'drip slag' coating the rock hearth surround, plus the 'conglomeratic slag', the latter once perhaps a molten layer which formed above the metal in the furnace, which was then tapped or ladled off. The presence of these gravel 'crushings' suggests a layer or lens formed from the mechanical re-processing of this material, perhaps milling carried out to extract previously formed lead, or incompletely smelted ore. The much smaller percentage of burnt or fired country rock supports this, as does the suggested presence of powdered 'slag dust' (from crushing) within the finest fractions, along with the smaller amount of charcoal. The suggestion from the excavation notes that this had been lain down in order to create a level flat surface or base for something (perhaps another hearth), has at least some validity, given the thickness of poorly consolidated charcoal sediment

Trench 21: layer 1093

This layer, evidently richer in charcoal, and also fresher-looking black glassy vesicular slag containing small traces of oxidised lead within it, might perhaps be part of a lobe of dumped furnace charcoal and the remnants of smelting waste. Such a sediment lens could be interpreted as 'spilling over' from a deposit up-slope of this site, perhaps one associated with another smelting hearth. This also makes sense with the higher incidence of burnt rock fragments and grains formed from the rapid weathering/ disintegration of these rocks. However, without analysing all of the sediment layers, and without sampling sufficient volumes of material from each, it is difficult to make any really useful, and even barely accurate comparisons between them.

Trench 12: layer 1119

A small fragment of slag-adhered stone (shale) hearth lining with traces of oxidised lead on it, alongside what are very clearly large (> 10mm) crushed pieces of dull-black/red glassy slag, evidently slightly more weathered and devitrified, implies the presence of other, possibly earlier furnaces in this direction. The changing ratios of charcoal, burnt rock fragments, mineral vein and slags, suggest that these furnaces are unlikely to be that close by. It is difficult to deduce from all this exactly what processes are going on here at this site.

Trench 6: layer 1129

The absence of crushed slag within the largest (>10 mm) fraction, and also its presence as sub-4mm size pieces of slightly devitrified, non-fresh looking material , implies an increasing distance from source. The very similar percentage equivalent amongst the larger size fractions between crushed slag, soil-derived rock clasts, and the angular shale rock (@ 30% each), and the rising % of natural components amongst the smaller (sub-2mm) fractions, suggests that some of the re-deposition processes involved at the bog margin may be partly natural.

Trench 17: layer 1115

Referred to as a 'charcoal clay layer', this is quite a distinctive and contrasting sediment, consisting largely of fresh lumps of oak (?) charcoal, some up to 25 mm in diameter, with no evidence for slag, and very little evidence for burnt rock. Some small fragments of completely unburnt wood chips survive, whilst the increasing amount of burnt shale flecks and sand, silt and clay, suggest the presence of at least one hearth (though not a mineral/smelting hearth) nearby. In the absence of any other sampling, this evidence might be taken to imply the existence of another related activity producing charcoal within this corner of the site, perhaps even charcoal clamps to produce charcoal fuel for smelting. However, it remains uncertain as to how representative this sample is of the deposit. Further sampling may yield a different interpretation altogether

Conclusion

Whilst a basic visual identification of sediment lithic/mineral/slag/organic components and size fraction analysis for each of the representative samples has been achieved, the interpretations of these deposits and the industrial processes which produced them are at the moment merely suggestive, since the archaeological detail and comprehensive sediment sampling data required to properly evaluate this site is currently lacking.

These initial observations need to be compared to the results of the chronological chemical archive obtained from monoliths taken through the peats, to the chemical analyses of these industrial sediments, the analyses of the slags themselves, and finally, to a comprehensive sequential sampling of the deposits in a similar fashion to that carried out above. All of the sediments looked at contain only slightly different proportions of the same types of material. In that sense, all these sediments are not that distinctive from one another.

So far, sediment analysis does seem to support the following scenarios, although other interpretations may equally be valid:

- Lead ore (galena) was smelted at a number of different locations along the base, and possibly a little further up the slope above the bog margin

- The ore was probably smelted in small open hearth ephemeral bole furnaces. These may have been cut into the ground surface or into existing charcoal/slag deposits and were lined with stone (shale or sandstone) and possibly cemented in place using clay and gravel

- The smelting process was efficient. Crushed quartz and rock may have been added as a flux, this formed a lead-poor slag of typical black glassy 'conglomeratic' appearance

- The slag seems to have been broken up more or less in situ. then crushed or shattered to a minimum of <5mm >2mm, possibly to remove entrapped lead metal. This may have been undertaken by hand using querns, or possibly there was a mill on site. Small shards of glassy slag and slag dust report to the finest sediment fractions.

- Layers of crushed slag may have been re-used as level layers for the construction of new hearths. Large amounts of it were moved, along with the charcoal sediments, and dumped along the bog margin. However, a certain amount of re-deposition seems to be due to natural processes.

- The slag weathers and devitrifies, and this can be used as a measure of proximity to a hearth or its residuality

- Vast amounts of charcoal were raked out from the hearths. This became mixed with the slag, soil and sub-soil in varying proportions

- The decrepitation of the hearth surrounds releases small amounts of burnt rock into the sediments

- Charcoal burning may have taken place on-site

Future work

A limited programme of further sediment analysis would be desirable. In particular a full characterisation of the remaining sediments associated with the Trench 21 hearth, whilst larger sample amounts should be processed. The sequential sampling of a monolith of the industrial layers sectioned by Trench 6 would also be useful in objectively charting sediment change and changing chemistry.

Beyond this, time and money might better be spent concentrating on a comprehensive programme of slag analysis and a more thorough programme of chemical work instead. The latter work might include the sampling of both proximal and distal sediments associated with the site, whilst work on those sediments further away (>100m from the epicentre of the area of hearths) will be necessary in order to pick up a more general chronological and spatial signal of activity for the site which will give a much better idea of phases of production and pollution events. Sampling within the areas of industrial waste may give results which prove rather more difficult to interpret; local signals from individual piles of crushed residues, slags and buried hearths which geophysics has so far failed to distinguish and excavation has proved difficult to find.

APPENDIX 3: ANALYSIS OF SLAG SAMPLES AND FURNACE LINING (METALLOGARPHIC AND SEM PROBE OF METAL, GLASS AND UNALTERED MATERIAL (INCLUDING RESIDUES ON FURNACE LINING) IN ORDER TO DETERMINE CHARACTER OF SMELTING PROCESS), BORTH INDUSTRIAL SITE, LLANCYNFELIN

Lorna Anguilano
Institute of Archaeology, University College London

METHODOLOGY

Ten samples have been selected from the excavation in Borth. These ten samples are the ones that mostly looked like a slag. This choice of slags is because the debris gives lots of information on the parameters of the smelting such as temperature, homogeneity of the process, oxygen pressure etc. From these parameters is possible to reconstruct the process and the type of furnace.

The heterogeneity of the samples (most rich in residual quartz) dictated the decision of analysing them by SEM instead of XRF, because the SEM permitted area analyses, thus avoiding the residual crystals. It was important to analyse only the area without residual crystals because the latter were not part of the process, they were in excess (unreacted), so they would give a false indication of the temperature of the process. The area analysed without the residual crystals was the one that was liquid during the process, thus indicating exactly the temperature reached in the furnace.

The SEM analyses has been done in two steps:

The first step was area analyses, ten per sample, avoiding the residual crystal, and the average of those ten analyses was used to calculate their bulk composition.

The second step was the analysis of ten sulphides in order to understand the composition of the ore used for the charge.

RESULTS

The ten samples have been chosen from three different contexts, and referred to with the name of that context plus one identification letter (e.g. a,b,c etc.). Therefore

- Borth 1 = Trench 21, furnace site context [1085];
- Borth 2 = Trench 21, context [1093];
- Borth 3 = Trench 21, context [1109] sample 13.

The bulk compositions so measured are the composition of the liquid produced during the process, and, as said earlier, this gives us the idea of the temperature of the process itself (compositions in wt%)

	BORTH 1 A	**BORTH 1 B**	**BORTH 1 C**	**BORTH 1 D**	**BORTH 1 E**	**BORTH 1 F**	**BORTH 2 D**	**BORTH 2 E**	**BORTH 3 B**
Na_2O	0.31	0.26	0.17	0.10	0.37	0.96	1.27	0.40	0.33
MgO	0.23	0.13	0.48	1.09	0.96	0.24	1.25	0.42	0.60
Al_2O_3	9.16	7.70	7.88	6.53	7.98	14.71	17.27	6.81	11.22
SiO_2	47.19	42.86	48.18	47.18	44.93	50.96	66.15	51.25	51.72

SO3	0.00	0.00	0.00	0.00	0.00	0.55	0.00	0.00	0.00
K2O	2.23	1.52	1.54	1.80	2.08	2.60	3.16	1.71	2.36
CaO	3.58	1.44	3.68	4.72	7.31	0.38	0.00	5.68	0.94
TiO2	0.00	0.11	0.00	0.00	0.00	0.67	0.49	0.00	0.19
FeO	5.00	4.12	3.09	5.25	4.40	3.07	6.26	2.99	3.77
ZnO	2.03	0.00	0.00	0.00	4.63	0.19	0.00	2.27	0.00
As2O3	0.41	0.15	0.00	0.05	0.32	0.00	0.00	0.14	0.00
PbO	21.58	28.32	25.33	24.92	18.83	4.02	0.00	25.39	14.38

The sample BORTH 3d does not appear in the table because the quartz in this sample is finely disseminated and an area analysis could not be carried out.

When we compare the main compounds with the phase diagrams we obtain a temperature between 720 and 780°C for the smelts (i.e. the range of temperatures reached within both the excavated furnace and other as yet unknown examples).

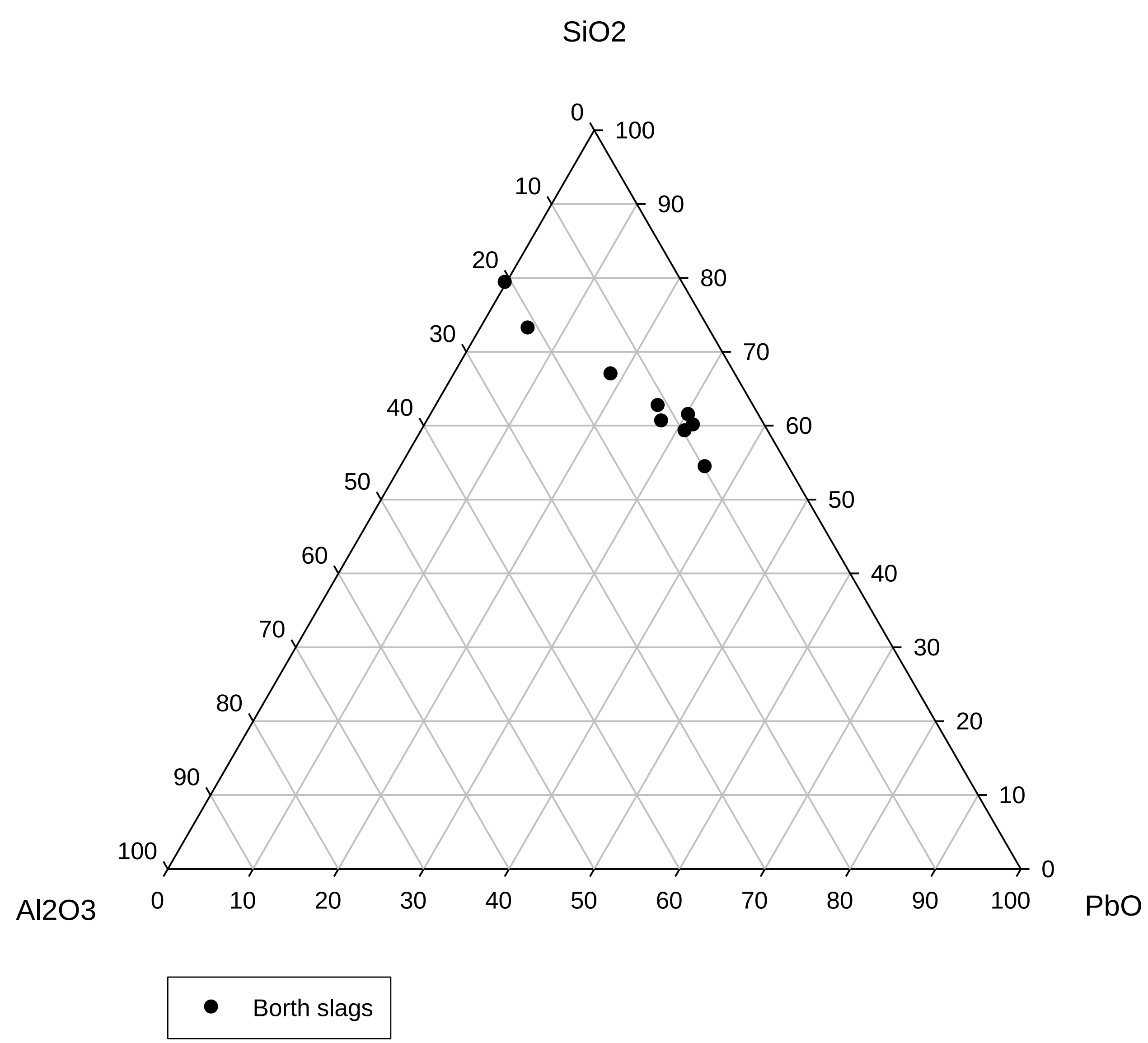


Fig. 1 Diagram of the main compounds in the analysed samples(%)

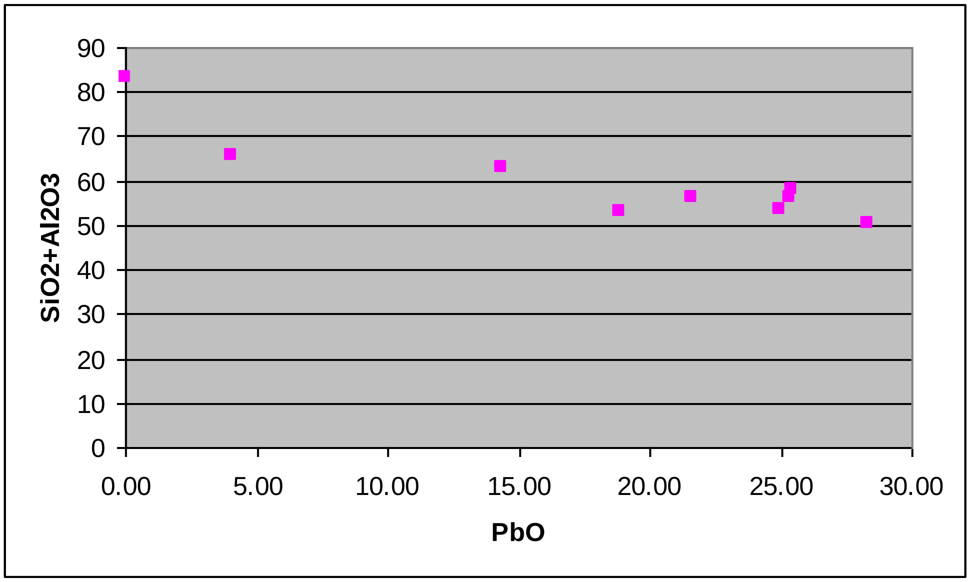


Fig. 2 Diagram of the main compounds in the analysed samples

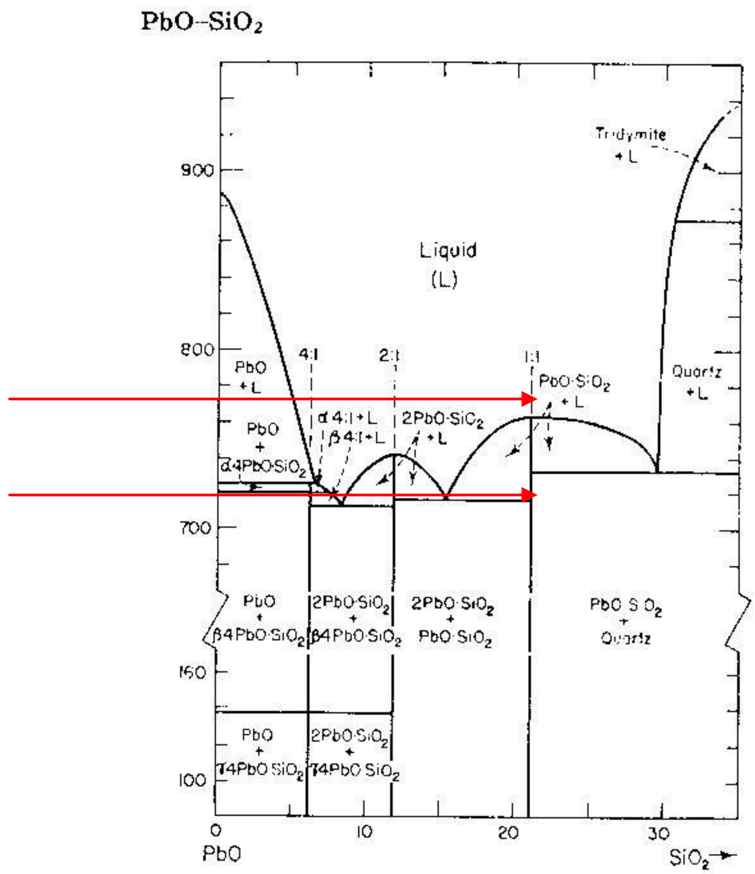


FIG. 284.—System PbO–SiO_2.

R. F. Geller, A. S. Creamer, and E. N. Bunting, *J. Research Natl. Bur. Standards*, 13 [2] 243 (1934); RP 705.

Fig. 3 Phase diagram PbO-SiO_2, the samples from Borth plot between the temperature of 720 and 780°C.

The presence of high alumina in the slags (between 6 and 15%) can be justified by the reaction of the very reactive lead oxide vapour produced during the smelting with the clay lining of the furnace.

The analyses of the sulphidic and metallic phases has been carried out in order to establish the ore exploited and oxidizing-reducing conditions in the furnace. Ten phases per sample were analysed in order to have an exhaustive perspective of the material. Following there is the list of the phases found in the different samples:

- BORTH 1 A:
  - Pb metal;
  - Pb sulphate;
  - Pb sulphide;

    - Pb oxide.
- BORTH 1 B
    - Pb oxide;
    - Pb metal;
    - Pb sulphide;
    - Pb and Sb metal;
    - Pb and Cu sulphide.
- BORTH 1 C
    - Pb and Sb metal;
    - Pb oxide;
    - Pb and Cu oxide;
    - Pb metal;
    - Pb sulphate;
    - Pb sulphide.
- BORTH 1 D
    - Pb, Cu and Fe sulphide;
    - Pb, Cu sulphide;
    - Pb, Cu oxide;
    - Pb oxide;
    - Pb, Cu sulphate;
    - Pb, Cu and Sb sulphate.
- BORTH 1 E
    - Pb oxide, Pb metal, Pb sulphide
- BORTH 1 F
    - Pb, Zn sulphide;
    - Pb sulphide;
    - Pb, Sb, Ni sulphate;
    - Pb, Sb sulphate;
    - Pb, Sb and Ni oxide;
    - Pb oxide;
    - Pb metal.
- BORTH 2 D
    - Pb phosphate;
    - Pb arsenate;
    - Pb and Ag arsenate (Ag=6.62 wt% in this point analysis).
- BORTH 2 E
    - Pb, Cu oxide;
    - Pb sulphate;
    - Pb, Cu sulphate;
    - Pb sulphide;
    - Pb, Zn sulphate;
    - Pb arsenate.
- BORTH 3 B
    - Pb metal;
    - Pb, Cu oxide;
    - Pb oxide;
    - Pb, Sb, Cu metal
- BORTH 3 D
    - Pb phosphate;
    - Pb arsenate.

CONCLUSION

The composition of the slags is not homogeneous, but the temperature suggested by these compositions is fairly homogeneous, and between 720/780°C. This sort of temperature is easily reached within a wind blown bole furnace.

The contemporary presence of metal, oxide, sulphate and sulphide indicates very variable red-ox conditions. Once again this is an indication of a wind blown furnace.

The different metals present within the slags suggests the use of a mixed and complex ore for smelting. However, the ore is predominantly galena (PbS) associated with quartz in the gangue. The quartz may have been left in voluntarily to assist as a flux, thus for the purpose of forming a slag.
The galena was associated with other minor sulphides and also the arsenides of antimony, copper, iron, nickel and zinc. The presence in one sample of a silver rich phase might suggest that some of the veins were argentiferous. These analyses might provide some clue as to the provenance of the ore. Nickel, copper, silver, arsenic and antimony are probably all present in minor amounts within the range of ore samples recovered from the nearby Erglodd Mine.

For the statistic of these ten samples, the suggestion is that the galena rich vein was exploited for lead and not for silver, and that the ores were smelted within a wind blown bole furnace made of stones lined with clay. However, still further analyses are needed on the burnt and vitrified rocks (as well as on the slags) in order to better define the clay lining, and to investigate further the slight possibility of silver production.

APPENDIX 4: HEAVY METALS ANALYSIS OF CORE SAMPLES FROM THE LLANGYNFELIN EXCAVATION

J. Crowther
University of Wales, Lampeter

INTRODUCTION

Determinations of lead (Pb), zinc (Zn), copper (Cu) and silver (Ag) were made on 60 bulk samples from two cores from the Llangynfelin Excavation, near Borth: one from Trench 20 (n = 27), which is adjacent to an area of known industrial/metal-processing activity of Romano-British? age; and the other from Trench 5a (n = 33) which is located about XX? m from the industrial area. The present investigation forms part of a much wider palaeoenvironmental investigation at Llangynfelin, and in due course its findings will need to be integrated with the reports of other specialists.

METHODS

Analysis was undertaken on the fine earth fraction (i.e. <2 mm) of the samples. Concentrations of Pb, Zn, Cu and Ag were determined by atomic absorption spectrophotometry following extraction with boiling *aqua regia* (a 1:3 mixture of concentrated HNO_3 and HCl). This method breaks down much of the organic matter present and therefore extracts the metals released from the organic fraction and those originally present in a mineral form.

RESULTS AND DISCUSSION

The analytical data for Trenches 20 and 5a are presented in Tables 1 and 2, respectively. It should be noted that the samples appear to be broadly of two types, minerogenic and organic-rich, with the majority of the latter being peats of various types and degrees of humification (see descriptions in Tables 1 and 2). Direct comparison of the metal concentrations in these two sample types is likely to be problematic because the peats themselves are likely to contain relatively low concentrations of heavy metals (i.e. the most of the metals in the peat layers are likely to be in the form of particulate mineral deposits, either wind- or water-borne), and have a very low density compared relative to the mineral components, both within the peats and in the minerogenic samples. Interpretation of the data would undoubtedly be facilitated by determination of the relative proportions of mineral and organic matter present, as this would enable better characterisation of the samples identified as being intermediate in character (e.g. the 'organic mud' samples), and might provide a basis for assessing how rich in heavy metals the mineral fraction actually is. One possibility would be to estimate the mineral component through LOI (loss-on-ignition), though issues of accuracy and ash residues from the peats may arise for samples with such high very organic matter contents.

Trench 20

Industrial layers: The uppermost samples analysed (from 8-28 cm) largely comprise grey, minerogenic, silty deposits which are thought to be associated with the Romano-British metal-processing activity. This would appear to be confirmed by the extremely high Pb concentrations (range, 30200-37200 □g/g) and relatively high concentrations of Cu (749-3760 □g/g). Ag is also present in appreciable concentrations (49-168 □g/g). While these results are certainly indicative of Pb-related activity at the site, the concentrations of Cu and Ag and also Zn (range, 244-810 □g/g) in the minerogenic sediments are not especially high, and could simply reflect the presence of these metals in the Pb-rich ores and rocks that were being used.

Upper peats: Interestingly, very high concentrations of Pb are also evident in the upper peats, especially in the samples from 32-52 cm (range, 15800-28700 □g/g). These high values are clearly not simply a reflection of the low density of the peat (see above), since the concentrations fall as low as 29 □g/g in the peats at the base of the section. These results may indicate earlier phases of metal-related activity in the vicinity of the site, since it seems unlikely that such high concentrations in the upper peats are simply the result of leaching or downwashing of sediments from the overlying industrial layers. Equally interesting, and more puzzling, are the extremely high Zn concentrations recorded in the upper peat layers, with a maximum of 22500 □g/g at 50 cm. Concentrations of this magnitude seem unlikely to be natural, and may be indicative of an earlier phase of Zn- and Pb-related activity. It should be noted, however, that Sanders (2005?: dissertation, UWA) identified considerable Zn enrichment further down some peat profiles nearby [not sure of details of this study or of the concentrations that were recorded….]. Some degree of Cu enrichment is also evident in the upper peats, along with traces of Ag in some samples.
Lower peats: The persistence of high Zn concentrations through the lower peats is even more difficult to explain, especially as these layers show no corresponding signs of Pb, Cu or Ag enrichment.

Trench 5a
The core sampled from Trench 5a is comprised entirely of peats, and as would be anticipated in view of the distance of this site from the area of industrial activity, the metal concentrations are generally lower than in Trench 20. Indeed, there is no evidence of Cu enrichment (maximum, 9 □g/g) and the Ag concentrations are all < 2 □g/g. However, both the Pb and Zn data do show clear signs of enrichment, with one clear peak occurring at 48-52 cm depth, and a second peak at 68-78 cm. In due course, it will be interesting to establish whether one or both of these can be related to the activity recorded in the core from Trench 20.

CONCLUSIONS AND RECOMMENDATIONS
The heavy metal analysis has revealed very marked variations in concentrations, both down the individual cores sampled in Trenches 20 and 5a, and between the two cores. These results are very encouraging and indicate the potential value of this type of analysis at Llangynfelin. At present the interpretation must be regarded as both provisional (e.g. estimates of organic matter content through LOI may permit a more rigorous analysis of the data) and partial (the present findings need to be examined in light of the dating of the sequences in the two cores studied and other specialist environmental reports). In light of the findings it is recommended that:

- LOI determinations are made on the samples analysed from Trenches 20 and 5a in order to estimate the proportions of mineral and organic matter present and thereby provide a basis for more rigorous interpretation of the heavy metals data; and
- further metals and LOI analysis is undertaken on specific contexts revealed in excavation to provide further insight into variations in these properties, and also on cores from key locations across the site in order to explore the spatial variability in concentrations within the peat sequences.

Table 1: Analytical data for samples from Trench 20

Depth (cm)	Description (as supplied)	Pb (□g/g)	Zn (□g/g)	Cu (□g/g)	Ag (□g/g)
8	Mineogenic; peat(?) + industrial material	36800	584	749	49
12	Minerogenic; industrial material	31300	244	1250	56
20	Minerogenic; industrial material	31900	239	1910	100
22	Minerogenic (grey silt)	30200	358	1090	168
23	Minerogenic (grey silt)	31900	305	965	138
24	Minerogenic (grey silt)	37200	379	828	147
26	Minerogenic (silt) with org laminations	35700	640	2150	84
28	Minerogenic (grey silt)	31200	810	3760	64
32	Mixed minerogenic/organic	27600	1100	2170	4
36	Organic with higher mineral content	28700	3390	801	2
40	Organic clay with wood fragments	20500	7350	397	2
46	Organic mud	15800	17900	345	<2
48	Organic mud with wood fragments	16300	16600	456	2
50	Woody peat, inc. large wood fragments	17000	22500	658	4
52	Woody peat, inc. large wood fragments	20200	9460	906	5
56	Woody peat, inc. large wood fragments	7080	14200	48	<2
60	Woody peat, inc. large wood fragments	3780	6400	52	<2
64	Woody peat, inc. large wood fragments	2500	11500	42	<2
68	Woody peat, inc. large wood fragments	476	16800	30	<2
72	Woody peat, inc. large wood fragments	460	10900	29	<2
76	Woody peat, inc. large wood fragments	255	4760	19	<2
80	Woody peat, inc. large wood fragments	786	8820	32	<2
84	Woody peat, inc. large wood fragments	383	5540	24	<2
88	Woody peat, inc. large wood fragments	220	3180	19	<2
92	Woody peat, inc. large wood fragments	75	4630	12	<2
96	Woody peat	290	5190	20	<2

100	Woody peat	29	19300*	18	<2

* This sample from the base of the section has an unusually high Zn concentration. Has it possibly been contaminated by Zn from the galvanised monolith tin?

Table 2: Analytical data for samples from Trench 5a

Depth (cm)	Description (as supplied)	Pb (□g/g)	Zn (□g/g)	Cu (□g/g)	Ag (□g/g)
16	Humified peat	403	243	5	<2
20	Humified peat	186	627	5	<2
24	Humified peat	122	1700	2	<2
28	Less humified peat	167	1650	5	<2
32	Less humified peat	155	2630	5	<2
36	Less humified peat	232	2010	7	<2
40	Less humified peat	249	1810	5	<2
44	Less humified peat with small wood frags	448	988	3	<2
48	Quite humified peat with small wood frags	1140	3320	6	<2
52	Fibrous peat with small wood fragments	1100	4740	9	<2
56	Fibrous peat with small wood fragments	578	834	5	<2
58	Fibrous peat with small wood fragments	213	677	3	<2
60	Fibrous peat with small wood fragments	408	152	3	<2
62	Fibrous peat with small wood fragments	356	480	3	<2
64	Fibrous peat with small wood fragments	592	647	4	<2
66	Fibrous peat with small wood fragments	895	412	4	<2
68	Fibrous peat with small wood fragments	1450	970	4	<2
70	Fibrous peat with small wood fragments	2580	612	5	<2
72	Fibrous peat with small wood fragments	2500	378	5	<2
74	Fibrous peat with small wood fragments	930	1100	2	<2
76	Fibrous peat with small wood fragments	285	2330	2	<2
78	Fibrous peat with small wood fragments	214	3950	2	<2
80	Fibrous peat with small wood fragments	137	392	1	<2

82	Fibrous peat with small wood fragments	118	478	2	<2
84	Fibrous peat with small wood fragments	109	701	2	<2
88	Fibrous peat with small wood fragments	65	2080	2	<2
92	Fibrous peat with small wood fragments	32	582	2	<2
96	Fibrous peat with small wood fragments	26	419	2	<2
100	Fibrous peat with small wood fragments	20	1830	1	<2
104	Woody peat with monocot root/stem frags	6	741	2	<2
108	Woody peat with monocot root/stem frags	9	1330	1	<2
112	Woody peat with monocot root/stem frags	6	262	1	<2
116	Woody peat with monocot root/stem frags	7	1050	2	<2

APPENDIX 5: LLANGYNFELIN WOOD IDENTIFICATION

Astrid E. Caseldine and Catherine J. Griffiths
University of Wales, Lampeter

Introduction

The majority of the wood identified from Llangynfelin was from the medieval trackway but a small amount was identified from Trench 11 from below industrial deposits and from contexts associated with a **possible furnace/industrial waste deposits in Trench 12** (**Nigel – comment please**). . The main aim was to determine the types of wood that had been exploited, particularly for the construction of the trackway, whilst the wood from the earlier contexts provided further information about woodland resources in later Iron Age/Roman times. Wood was also identified from the pollen columns and this is included with the pollen evidence. Most of the oak (*Quercus* spp.) was identified in the field by Nigel Nayling and it was largely the non-oak species that were identified in the laboratory.

Methods

Transverse, radial longitudinal and tangential longitudinal thin sections were cut from the wood and examined under a Leica DMR microscope with transmitted light source. The wood was identified by reference to wood identification texts (Schweingruber 1978, Schoch *et a*l 2004) and by comparison with modern type slides. The results are given in Tables 1. Nomenclature follows Stace (1991).

Results

The small late Iron Age/Roman assemblages from Trenches 11 and 12 contained a limited range of species, including alder (*Alnus glutinosa*), hazel (*Corylus avellana*), ash (*Fraxinus excelsior*), oak and willow/poplar (*Salix/Populus*). The main assemblage was from the medieval trackway and most of it consisted of alder. Hazel and oak were also comparatively frequent but other species were rare. They included ash, beech (*Fagus sylvatica*), holly (*Ilex aquifolium*), cherry (*Prunus* sp.), willow/poplar and Maloideae type, which includes Rosaceae species such as hawthorn (*Crataegus* spp.), crab apple (*Malus sylvestris*), rowan (*Sorbus aucuparia*), common whitebeam (*S. aria*) and wild service-tree (*S. torminalis*).

Discussion

Although the assemblages from Trenches 11 and 12 are very small they indicate the exploitation of local woodland comprised of alder, oak, hazel, ash and willow/poplar (probably willow although aspen or black poplar could have been present) and are consistent with the pollen evidence (see Caseldine *et al* xx). The wood from Trench 11 pre dates the industrial deposits and a few pieces, including alder and hazel, showed evidence of charring, suggesting earlier activity in the local area. A peak in charcoal also occurs at this time in the pollen record from LT11. A piece of ash from Trench 12 also showed signs of charring and was probably associated with lead smelting activity. Further evidence of the fuel used in the **?furnaces/waste deposits** in Trench 12 (**Nigel – please comment**) is evident in the charcoal record where alder, oak and hazel charcoal were the main species identified (see Caseldine and Griffiths xx).

The assemblage from the medieval trackway suggests that alder woodland provided the main source of material for its construction and this is consistent with the pollen record which indicates alder in the surrounding area (see Caseldine *et al* xx). In addition, oak made up a significant part of the structure and hazel was also quite widely used. Both taxa are present in the pollen record, although oak pollen occurs only in low amounts. The majority of the hazel was found in Trench 6 at the southern terminal end of the trackway, indicating the exploitation of dry land woodland communities. The greatest range of species, including a single piece of beech, also occurs in the trenches at the southern end of the trackway. This suggests a more diverse woodland on or at the edge of the dry land. Whilst willow is more likely to be found in wet woodland, most of the other taxa, apart from beech, can be found in either alder carr or oak woodland. Although alder, oak and hazel seem to have been preferred, the occasional occurrence of other species suggests that any wood that was readily available was exploited. However, birch is not recorded from the trackway, although the pollen evidence indicates it was present in the area, which could mean it was deliberately avoided.

Although availability was probably the main determining factor in the wood used for construction of the trackway, alder is durable in wet conditions and has been used to make tracks since prehistoric times, notably the Neolithic Abbot's Way in the Somerset Levels (Coles and Orme 1976). Oak and hazel have also been widely used in the construction of trackways and other wooden structures in wetland areas in England and Wales (Coles and Coles 1986, Bell *et al* 2000). In addition, there is some limited evidence from other areas in Wales for the construction of wooden trackways dating to the medieval period. Further north along the Welsh coast, trackway timbers from a Medieval trackway at Llanaber, near Barmouth, were identified as alder, ash and willow (Hibbert in Musson *et al* 1989) and tree roots in the peat as alder. Wood, possibly part of a simple trackway, associated with the discovery of an Early Medieval brooch at Newton Moor, South Glamorgan included oak, hazel and alder (Redknap 1991, 1992).

Table 1 Wood identifications from Llangynfelin.

Trench	2	4A	4B	4C	5A	5B	5C	5D	6	11	12	Total
Fagus sylvatica L. (Beech)	-	-	1	-	-	-	-	-	-	-	-	**1**
Quercus spp. (Oak)	-	1	3	-	12	5	-	5	12	2	2	**42**
Alnus glutinosa (L) Gaertner (Alder)	21	1	21	-	20	2	5	30	35	3	1	**139**
Corylus avellana L. (Hazel)	6	2	-	1	1	1	1	-	32	2	2	**48**
Salix/Populus sp. (Willow/poplar)	1	-	-	-	-	-	-	-	3	-	1	**5**
Prunus spp. (Cherries)	-	-	1	-	-	-	-	-	-	-	-	**1**
Maloideae type (Hawthorn, rowan, crab apple, common whitebeam, wild service-tree)	-	-	-	-	-	-	-	-	1	-	-	**1**
Ilex aquifolium L. (Holly)	-	-	1	-	-	-	-	-	-	-	-	**1**
Fraxinus excelsior L. (Ash)	-	2	-	-	-	-	-	-	2	1	2	**7**
Totals	**28**	**6**	**27**	**1**	**33**	**8**	**6**	**35**	**85**	**8**	**8**	**245**

APPENDIX 6: LLANGYNFELIN CHARCOAL IDENTIFICATION

Astrid E. Caseldine and Catherine J. Griffiths
University of Wales, Lampeter

Introduction

Charcoal from the industrial deposits at Llangynfelin was identified to ascertain the species that were selected for use in the lead smelting process at the site. Most of the samples examined were from contexts that were also characterised by a mineralogical and textural assessment (see Timberlake), analysed geochemically for their lead content (see Mighall) and from which slag and surface lining fragments had been selected for SEM analyses (see Anguilano). The samples were also examined for plant macrofossils (see Caseldine and Griffiths xx).

The samples were from a range of contexts including contexts from Trench 21 where a lead smelting hearth had been found; Trench 12 where there were features possibly associated **with other furnace activity/ waste material (Nigel – please comment)**; Trench 6 where industrial material had been dumped and over which the medieval trackway had later been constructed; Trench 17, the site furthest from the main area, where there were waste deposits associated with another hearth, and **Trench 23 where there was further industrial material (Nigel –please comment).**

Methods

A sub-sample of 20 fragments was selected from the samples for identification, unless the charcoal available for identification was less. The samples were fractured to produce three clean sections (transverse, radial longitudinal, tangential longitudinal) and examined using a Leica DMR microscope with an incident light source. Identification was by comparison with a modern charcoal collection and by reference to Schweingruber (1978) and Schoch *et a*l (2004). The results are presented in Table 1. Nomenclature follows Stace (1991).

Results

Charcoal often fragments on archaeological sites so the number of fragments of a particular species does not necessarily reflect the actual quantity of the species at the site. However, taxa can be considered dominant or frequent at a site when they are present in most of the samples and occur in large quantities compared with taxa which only occur occasionally and/or in low concentrations. The most frequently recorded taxa at the site were oak (*Quercus* spp.), birch *(Betula* spp.), hazel (*Corylus avellana*) and alder (*Alnus glutinosa*), with oak present in the greatest quantities. Taxa that were present occasionally included ash (*Fraxinus excelsior*), cherry (*Prunus* spp.), willow/poplar (*Salix/Populus*.) and Maloideae type, which includes hawthorn (*Crataegus* spp.), rowan (*Sorbus aucuparia*), crab apple (*Malus sylvestris*), common whitebeam (*S. aria*) and wild service-tree (*S. torminalis*).

Discussion

Although the assemblages from individual contexts are relatively small, a few observations can be made. The charcoal assemblages, like the sediments from the deposits (see Timberlake), are similar with little difference between those from contexts directly associated with hearths or furnaces and those from dumps of waste material. In general, oak dominates the assemblages, apart from one of the contexts in Trench 12 where alder and hazel are slightly more frequent than oak, although this could be related to sample size. However, the results suggest that, as well as oak, a wide range of species were used from the surrounding area as fuel.

Oak makes an excellent fuel, either as wood or as charcoal. Similarly, both birch wood and charcoal are good fuels, whilst alder wood, provided it is seasoned, burns well and the charcoal is excellent (Taylor 1981). Hazel, ash and willow are also good fuels. However, certain woods, for example oak and ash, which are denser than woods such as alder, willow and poplar, do provide a longer-lasting source of heat (Porter 1990). Hence larger volumes of light-weight wood would be required to produce comparable heat to that produced by dense heavy wood, especially oak heartwood (Cowgill 2003). In addition, fast-grown oak is denser than slow-grown oak (Gale 2003).

Timberlake (see xx) suggests that the charcoal deposits (1115) in Trench 17 could indicate charcoal production, perhaps even charcoal clamps, in this area of the site. If possible, charcoal clamps were constructed near streams or pools in case the clamp caught fire, and the pollen evidence from LT 17 (see Caseldine *et al* xx) suggests that there was water nearby. About 6 tons of wood are required to produce 1 ton of charcoal (Armstrong 1978, Horne 1982). Efficient carbonisation produces a smokeless fuel with about twice the calorific value of the uncarbonised wood. At Llangynfelin it is probable that a fire of charcoal or wood and charcoal was used in the lead smelting process, although charcoal reduction was not a necessity for smelting 'black ore', galena, (Homer 1991, Craddock 1995) and wood alone could have been used. Charcoal reduction was necessary for smelting 'white ore' and to rework litharge (residual lead after silver extraction from argentiferous lead). Simple stone lead-smelting hearths where the ore was scattered on top of the fire are recorded from other parts of Roman Britain (Craddock 1995), whilst medieval records indicate that layers of brushwood and crushed ore were piled onto a log base in a large hearth or bole (Homer 1991, Craddock 1995).

As species may have been deliberately selected for use as fuel, charcoal is not necessarily an accurate reflection of the frequency of the species or the range of species in the surrounding woodland communities. However, the taxa present suggest the exploitation of local oak, hazel and carr woodland and the pollen record (see Caseldine *et al* xx) confirms the existence of these communities in the local area. A distinct fall in *Quercus* pollen values as well as reductions in *Betula* and *Alnus* values at LT5A may well reflect the felling of woodland for use at the site. These species are also evident in other pollen profiles at the site. The distance to the woodland exploited may have been a consideration in the location of the site; the closer the woodland then the less time and labour would have been involved in transporting the wood.

Coppicing would have been the most efficient method of ensuring a supply of wood for fuel but there is no conclusive evidence from the charcoal record to confirm this. Coppicing tends to produce rapid growth but most of the charcoal examined displayed a growth ring pattern indicating slow rather than fast growth, suggesting exploitation of 'natural' rather than managed woodland. The presence of both fast and slow grown wood indicates the trees had grown under varying environmental conditions.

Low amounts of species such as ash and willow, which also make reasonable fuels, suggest these species were present less frequently or were largely avoided. Whilst ash may have been scarce, pollen evidence from LT17 indicates willow was clearly growing nearby, confirmed by the presence of *Salix* wood in the stratigraphy. A decline in *Salix* pollen associated with the deposition of industrial deposits suggests the clearance of willow woodland, but generally willow carr may have been more limited than other woodland and, perhaps because of wetter conditions where it was growing, less favoured for exploitation.

Table 1 Charcoal identifications from industrial deposits at Llangynfelin

Trench **Context**	**6** **1128**	**6** **1129**	**12** **1119**	**12** **1120**	**17** **1115**	**21** **1085**	**21** **1091**	**21** **1093**	**21** **1109**	**21** **1116**	**23** **1095**	**Total**
Quercus spp. (Oak)	-	10	11	4	12	11	31	10	16	14	4	**123**
Betula spp. (Birch)	1	3	2	1	2	7	4	5	1	1	-	**27**
Alnus glutinosa (L.) Gaertner (Alder)	-	1	1	9	-	-	2	-	2	2	1	**18**
Corylus avellana L. (Hazel)	-	1	-	5	4	2	-	4	1	3	-	**20**
Salix/Populus sp. (Willow/poplar)	-	-	-	-	-	-	1	-	-	-	-	**1**
Prunus spp. (Cherries)	-	4	-	-	1	-	-	-	-	-	-	**5**
cf. *Prunus* sp.	-	-	-	-	1	-	-	-	-	-	-	**1**
Maloideae type (Hawthorn, rowan, crab apple, common whitebeam, wild service-tree)	-	-	-	1	-	-	-	-	-	-	-	**1**
Fraxinus excelsior L. (Ash)	-	1	-	-	-	-	2	1	-	-	-	**4**
Total	**1**	**20**	**14**	**20**	**20**	**20**	**40**	**20**	**20**	**20**	**5**	**200**

APPENDIX 7: TREE-RING ANALYSIS OF TIMBERS FROM LLANCYNFELIN TRACKWAY, BORTH BOG, CEREDIGION

Nigel Nayling
University of Wales, Lampeter

Summary

Awaiting completion following review meeting with AC and NP on 17/7/8

Introduction

This document is a technical archive report on the tree-ring analysis of samples taken during the excavation of a wood and stone trackway on the northern edge of Borth Bog (Cors Fochno), in Ceredigion, West Wales. Excavations were undertaken by Dyfed Archaeological Trust, directed by Nigel Page. The author visited the site on a number of occasions during excavation of a preliminary evaluation trench in March 2004 and subsequent larger excavations in 2004 and 2005.
Tree-ring samples were taken from timbers deemed appropriate for dendrochronological analysis. With one exception all the timbers sampled were oak and included both transverse and longitudinal elements from the structure.

Methods

Methods employed at the Lampeter Dendrochronology Laboratory in general follow those described in English Heritage guidance documents (EH 1998). The complete sequence of growth rings in each sample was measured to an accuracy of 0.01mm using a micro-computer based travelling stage (Tyers 2004). Cross-correlation algorithms (Baillie and Pilcher 1973; Munro 1984) were employed to search for positions where the ring sequences were highly correlated against each other. The *t*-values reported below are derived from the original CROS algorithm (Baillie and Pilcher 1973). A *t*-value of 3.5 or over is usually indicative of a good match, although this is with the proviso that high *t*-values at the same relative or absolute position must be obtained from a range of independent sequences, and that satisfactory visual matching supports these positions. Correlated positions were checked visually using computerised ring width plots. Highly correlated series (*t*-values>10) with similar growth patterns and absolute ring widths were interpreted as timbers derived from the same parent trees. Two such groups of samples were identified and average ring-width series constructed for each. These along with cross-matched series from individual timbers were used to construct a mean site ring-width sequence which was then compared with a range of reference chronologies from Britain and Northern Europe

Results

Details of individual timbers are given in Table 1. The original wood numbers have been employed as filenames for the ring-width data from each sample. A total of 22 tree-ring samples were taken, mostly from transverse oak timbers. One sample was ash (*Fraxinus excelsior*). Five samples with high computer correlations and very similar growth trends (W47, W56, W57, W129 and W202; see Table 2a and Figure 1a) were interpreted as timbers derived from the same parent tree and their ring-width series were combined to form a single tree sequence entitled BT_T1_t5. Similarly, two closely matching series from samples W89 and W90 were combined to form a single tree series entitled BT_T2_t2 (see Table 2b and Figure 1b). These two tree sequences were cross-matched against eight individual timber ring-width sequences (see Table 3 and Figure 2) with good replication of significant correlation values and visual matching of ring-width patterns. A mean of these synchronised tree-ring sequences was calculated, entitled BT_T15. This was dated against a range of British and Irish regional chronologies and site masters to AD 902 to AD 1136 inclusive (Table 4). The ring width data for this mean are given in

Table 5. The date ranges for individual sequences are shown in a bar diagram (Figure 2) with the implied felling date ranges for the parent trees based on sapwood estimates for oak trees of 10-46 rings.

Discussion

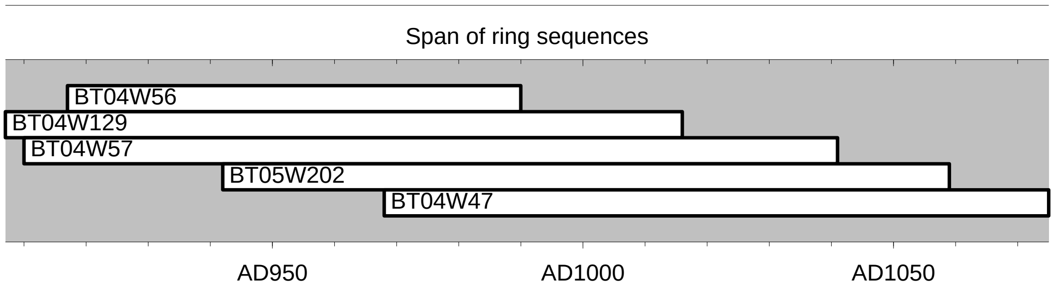
The site master curve has been securely dated against a wide range of sites, of which examples are given in Table 4. There is no reason to suspect that the timber is anything but local on the basis of the correlations identified. Interpretation of the implied felling date ranges for individual timbers provides some challenges and may require re-examination of the structural evidence to address. *If* identifications of the heartwood sapwood boundaries on timbers are correct (particularly with reference to W80, W89 from tree 2, W59 and W243) then the implication is that the trackway has multiple phases of construction and/or repair. It should however be stressed that preservation of many of the timbers was far from perfect and sapwood was rarely observed in the field and present on only one of the 22 samples subjected to dendrochronological analysis. This makes identification of the boundary more difficult. It may be that degradation has led to loss of sapwood alone but loss of outer heartwood may also have occurred. Most of the samples where such a boundary was suspected in the field were radial splits. It is possible that sapwood was removed from these timbers (along with some outer heartwood rings) by secondary splitting by the builders during construction. Hence apparent heartwood sapwood boundaries might be a reflection of woodworking practice and have no chronological implications. In this case, dating the trackway would necessarily focus on the sample from W242 which retained near complete sapwood. Again, preservation was not perfect but there is perhaps only the loss of a couple of outermost rings due to degradation and it would be reasonable to suggest that the parent tree had been felled soon after AD 1136.

Acknowledgements

I am most grateful to Nigel Page of Dyfed Archaeological Trust for providing documentation and site access. Sampling assistance was provided by a number of University of Wales Lampeter students including Pamela Rudge-Pickard and Jenny Arnold. Ian and Cathy Tyers kindly provided assistance with access to unpublished data.

Figure 1 Bar diagram showing the relative dating positions of timbers with high correlations and close visual matching of growth trends, interpreted as deriving from the same parent tree:

a) 'Tree 1' comprising five samples combined to form the raw ring width sequence BT_T1_t5



b) 'Tree 2' comprising two samples combined to form the raw ring width sequence BT_T2_t2

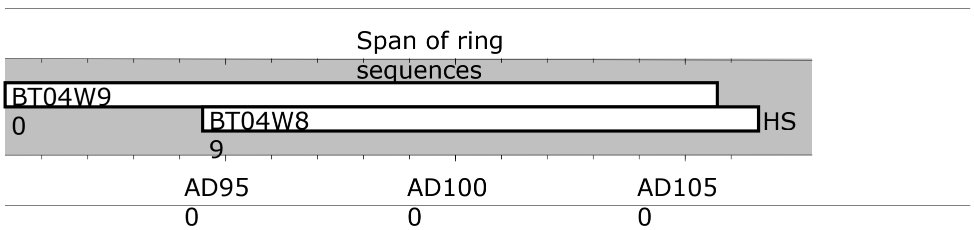
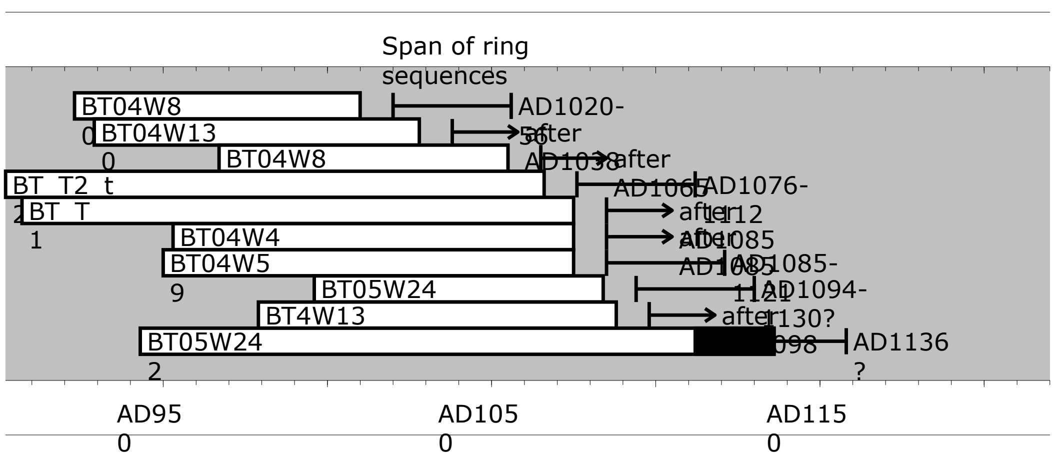


Figure 2 Bar diagram showing the date ranges of absolutely dated tree-ring series and implied dates of felling of the parent trees



<u>Table 1</u>Sample details

Sample Code	Origin of sample	Cross-section	Dimensions	Total rings	Sapwood	ARW mm/year	Date of sequence	Felling Date Range
W46	BT04, Trench 4 Area B. Drawing 7	Tangential	150 x 80	123	-	0.95	AD953-AD1075	after AD1085
W47	BT04, Trench 4 Area B. Drawing 7	Tangential	115 x 85	108	-	1.27	AD968-AD1075	after AD1085
W56	BT04, Trench 5 Area A	Tangential	145 x 36	74	-	1.79	AD917-AD990	after AD1000
W57	BT04, Trench 5 Area A	Radial	205 x 100	132	-	1.57	AD910-AD1041	after AD1051
W59	BT04, Trench 5 Area A	Radial	125 x 55	126	+HS	0.98	AD950-AD1075	AD1085-1121
W73	BT04, Trench 5 Area A.	Tangential	170 x 65	71	-	1.12	Undated	-
W80	BT04, Trench 5 Area A	Radial	165 x 110	88	+HS	1.82	AD923-AD1010	AD1020-56
W86	BT04, Trench 5 Area A	Radial	90 x 25	75	+?HS	1.18	Undated	-
W87	BT04, Trench 5 Area D	Radial	96 x 34	89	-	1.04	AD967-AD1055	after AD1065
W88	BT04, Trench 5 Area D	Radial	130 x 55	100	-	1.06	Undated	
W89	BT04, Trench 5 Area D	Radial	124 x 40	122	+?HS	0.91	AD945-AD1066	AD1076-1112?
W90	BT04, Trench 5 Area D	Radial	163 x 75	156	-	1.14	AD902-AD1057	after AD1067
W129	BT04, Trench 5 Area B	Radial	175 x 80	110	-	1.50	AD907-AD1016	after AD1026
W130	BT04, Trench 5 Area B	Radial	90 x 70	100	-	0.79	AD929-AD1028	after AD1038
W131	BT04, Trench 5 Area B	Radial	195 x 57	110	-	1.70	AD979-AD1088	after AD1098
W132	BT04, Trench 5 Area B. Ash	Radial	92 x 40	75	-	1.12	Undated	-
W135	BT04, Trench 5 Area B	Tangential	156 x 34	134	-	0.99	Undated	-
W202	BT05	Radial	190 x 50	118	-	1.38	AD942-AD1059	after AD1069
W242	BT05. Two measure raw. Just short of bark edge	Radial	254 x 54	194	24	1.23	AD943-AD1136	AD1136?
W243	BT05	Tangential	275 x 70	89	+?HS	0.74	AD996-AD1084	AD1094-1130?
W340	BT05 Trench 12. Cross-matches against W351	Tangential	100 x 67	57	-	1.12	Undated	-
W351	BT05 Trench 12. Cross-matches against W340	Radial	95 x 60	60	-	0.99	Undated	-

Total rings = all measured rings ARW = average ring width of the measured rings. All samples were oak (*Quercus* spp.) with the exception of W132. Timbers from common parent trees are indicated by shading – light grey from tree 1 and dark grey from tree2.

Table 2 High correlations between samples indicating origin from the same parent tree. In addition to high *t*-values, visual matching indicated similar growth trends in the ring-width series. A raw ring-width series was calculated in each case and subsequently used in construction of a site mean

a) BT_T1_t5

Samples	W56	W57	W129	W202
W47	6.31	13.12	6.52	12.31
W56		13.65	13.85	8.37
W57		*	14.11	12.58
W129		*	*	9.13

b) BT_T2_t2

Samples	W90
W89	15.05

Table 3 Correlations between synchronised samples used to calculate the site mean BT_T15.
- = t-values less than 3.00

Filenames	BT_T2_t2	W46	W59	W80	W87	W130	W131	W242	W243
BT_T1_t5	7.33	6.43	6.48	7.11	7.17	5.48	8.74	9.45	6.73
BT_T2_t2		-	3.74	4.72	5.31	5.51	4.85	4.82	4.96
W46			4.54	3.79	4.27	8.24	-	4.86	3.39
W59				4.30	3.71	3.11	3.93	7.52	-
W80					3.15	3.11	-	6.35	6.59
W87						3.08	3.18	5.05	5.89
W130							-	5.08	3.11
W131								6.96	3.62
W242									-

<u>Table 4</u> Correlations between the dated site master BT_T15, dated to AD 902 to AD1136 inclusive, and regional chronologies and site masters for Britain and Ireland

Filenames	Description	*t*-value
Regional Chronologies		
England	East Midlands (Laxton and Litton 1988)	6.60
England	England West Midlands (Tyers pers. comm.)	7.61
England	England North West (Tyers pers. comm.)	6.51
England	England SW Region inc Devon 101 chronology mean made IT 22/03/2001 excl 24 wrong types & WORGRET no ovrlp	6.89
England	England Yorkshire/North Lincolnshire (Tyers pers. comm.)	7.46
Ireland	Dublin (Baillie 1977)	7.26
Scotland	South Central Scotland (Baillie 1977)	6.27
Site Masters		
Cambridgeshire	Peterborough Cathedral roof timbers (Tyers 1999)	7.19
Herefordshire	Pembridge bell tower (Tyers 1999)	5.23
Hampshire	The Brooks, Winchester (Hillam 1992)	6.42
Bristol	Dundas Wharf (Nicholson and Hillam 1987)	9.43
Yorkshire	Beverley Eastgate (Groves 1992)	7.37
Dublin	Wood Quay, Dublin (Tyers pers. comm.)	7.85
Glasgow	Glasgow Cathedral ,Scotland (Tyers pers. comm.)	5.85
Wales	Hen Domen, Montgomery (Tyers pers. comm.)	6.20
Wales	Market Street , Brecon (Nayling 2004)	6.17
Wales	Llyn Peris Log Boat (Nayling 2000)	9.80

<u>Table 5</u> Tree-ring widths for the site master BT_T15, dated to AD902 to AD1136 inclusive

Date	Annual mean ring widths (1/100 mm)									Number of samples									
AD902		159	189	122	162	193	163	170	222	202		1	1	1	1	1	2	2	2	2
-	178	196	149	126	147	144	170	136	136	177	2	2	2	2	2	2	2	2	2	2
-	158	148	170	215	189	222	219	170	131	130	2	2	3	3	3	3	3	3	4	4
-	139	198	94	105	86	116	151	150	101	115	4	4	4	4	4	4	4	4	4	4
-	99	127	121	86	143	147	180	135	88	155	4	4	5	5	5	5	5	5	5	6
AD951	128	99	94	97	147	71	157	113	111	108	6	6	7	7	7	7	7	7	7	7
-	135	85	137	107	81	139	144	160	123	146	7	7	7	7	7	7	8	8	8	8
-	118	148	116	99	148	133	171	97	182	155	8	8	8	8	8	8	8	8	9	9
-	90	126	122	105	125	137	165	118	158	151	9	9	9	9	9	9	9	9	9	9
-	152	167	119	133	126	123	163	120	150	132	9	9	9	9	9	10	10	10	10	10
AD1001	139	118	134	138	131	98	128	145	133	132	10	10	10	10	10	10	10	10	10	10
-	105	127	125	81	96	78	77	93	92	104	9	9	9	9	9	9	9	9	9	9
-	113	132	130	117	118	121	121	103	83	121	9	9	9	9	9	9	9	9	8	8
-	107	97	98	83	70	62	120	117	84	86	8	8	8	8	8	8	8	8	8	8
-	90	104	107	78	87	80	117	118	121	90	8	8	8	8	8	8	8	8	8	8
AD1051	107	104	95	67	81	74	104	102	91	110	8	8	8	8	8	7	7	7	7	7
-	110	105	93	111	62	79	99	105	110	129	7	7	7	7	7	7	6	6	6	6
-	92	112	71	83	95	114	128	144	108	107	6	6	6	6	6	3	3	3	3	3
-	87	106	85	74	167	144	149	196	155	78	3	3	3	3	2	2	2	2	1	1
-	70	60	83	58	80	80	82	125	120	82	1	1	1	1	1	1	1	1	1	1
AD1101	57	69	122	70	125	110	85	56	53	65	1	1	1	1	1	1	1	1	1	1
-	72	90	113	86	132	133	117	114	59	101	1	1	1	1	1	1	1	1	1	1
-	88	90	125	136	129	129	111	81	53	74	1	1	1	1	1	1	1	1	1	1
-	83	154	143	79	161	62					1	1	1	1	1	1				

APPENDIX 8: THE PLANT MACROFOSSIL EVIDENCE FROM LLANGYNFELIN

Astrid E. Caseldine and Catherine J. Griffiths
University of Wales, Lampeter

Introduction

Samples from both the Roman industrial deposits in Trenches 4a, 6, 12, 17 and 21 and from deposits directly beneath the medieval trackway in Trenches 5a and 6 were examined with the aim of gaining information about the local environment and, possibly, agricultural activity.

Methods

In most instances one kilogram sub-samples were taken from the Roman industrial deposits (the remaining material was kept for mineralogical analysis), unless the sample available was less than this in which case all of it was processed. Larger samples were processed from Trench 4. The samples from under the trackway were 0.5 litres. Sample size details of all the samples are included in the tables. All the samples were sieved through a stack of sieves. The finest mesh used was 250μm. The remains were examined using a Wild M5 stereomicroscope and identified with the help of identification texts (e.g. Berggren 1969, 1981, Schoch *et al* 1988, Anderberg 1994) and a seed reference collection. The results are given in Tables 1 and 2. Nomenclature is based on Stace (1991), as is most of the ecological information.

The Roman industrial deposits

The results from Trenches 4a (contexts 27, 69, 70) and 6 (contexts 1129, 1130) are considered together as they are from the same area of the site. The archaeological remains consist of dumps of industrial deposits underlying the southern terminal end of the medieval trackway at the dry land/wetland interface. The plant remains recovered were uncharred, apart from a charred orache (*Atriplex* sp.) seed from context 69 and charcoal. The assemblages from the samples are similar and indicate a variety of habitats in the vicinity of the site at the time the charcoal, ash and other industrial material was deposited.

Wet or damp ground conditions are suggested by the presence of rushes (*Juncus* spp.), sedges (*Carex* spp.), water-pepper (*Persicaria hydropiper*), marsh pennywort (*Hydrocotyle vulgaris*), blinks (*Montia fontan*a ssp. *fontana*), celery-leaved buttercup (*Ranunculus sceleratus*) and crowfoots (*Ranunculus* subgenus *Batrachium*), probably reflecting the marshy conditions at the dry land edge where the deposits were dumped. Pale persicaria (*Persicaria lapathifolia*) is also typical of damp ground as well as waste and cultivated areas. Other weed species such as common nettle (*Urtica dioica*), fat-hen (*Chenopodium album*), parsley piert (*Aphanes arvensis*), slender parsley-piert (*Aphanes inexspectata*) and common hemp-nettle (*Galeopsis tetrahit*) could represent waste or bare ground associated with the site, or nearby cultivation. Local arable activity is confirmed by the presence of glume bases of spelt wheat (*Triticum spelta*) from contexts 27 and 1129. Bramble (*Rubus fruticosus* agg.) seeds and bracken (*Pteridium aquilinum*) leaf fragments provide further evidence for waste or abandoned ground as well as woodland edge habitats, whilst species such as sheep's sorrel (*Rumex acetosella*) could indicate cultivation or grassland. Grasses (Poaceae), selfheal (*Prunella vulgaris*) and creeping buttercup (*Ranunculus repens*) type, the last suggesting wet grassland, also indicate grassland habitats.

The plant remains from Trench 12 were from **contexts associated with possible furnace activity? waste deposits? The deposits were later quarried to make the medieval trackway (Nigel is this info. correct?).** The only charred remains, aside from charcoal, were one charred orache seed and one charred dock seed from an ashy layer (1098) below a layer (1097) containing partly charred wood. The weed seeds probably became charred incidentally along with wood used for fuel. The other seeds from 1098 comprised grass and rush seeds indicating damp grassland.

Plant remains were also recovered from two contexts (1133, 1134) which lay below a layer of ash, charcoal and clay (**1061) that was possibly part of feature 1060 (Nigel – any comments?).** Few remains were recovered from 1133, a silty soil, but they included dock, fat-hen, bramble and a thorn, again reflecting disturbed and rough ground. Rather more seeds were recorded from 1134, a silty soil below 1133, and, as well as species indicative of waste ground, sedge and common club-rush (*Schoenoplectus lacustris*) suggest wetter conditions nearby. Common club-rush is typically found in shallow water in rivers, ponds and lakes. The occurrence of the latter two species, and slightly greater abundance of seeds in 1134 compared with 1133, suggests a wetter depositional environment and conditions more favourable for preservation when 1134 was deposited than 1133.

The only seeds recovered from an industrial deposit (1115) of charcoal, grit and clay in Trench 17 were rush seeds.

Virtually all the plant remains recovered from contexts (1085, 1091, 1092, 1093, 1109, 1116) associated with the lead hearth in Trench 21 were uncharred. The uncharred remains could represent much later intrusive material but the assemblage is similar to that recovered from wetter contexts at the site and the high lead levels may have aided preservation.

An indeterminate charred seed was recovered from each of 1085 and 1093, a charred orache from 1109 and a charred sedge nutlet from 1116. The charred seeds were probably burnt incidentally along with wood or charcoal used for fuel. In general the uncharred remains were scarce but they included a range of weed species such as nettle, fat hen, thistle (*Cirsium* sp.) and docks suggesting disturbed or waste ground habitats at the site or, possibly, arable activity nearby. The presence of grasses, sedges and rushes indicate damp grassland, whilst blackberry remains could derive from disturbed ground or hedges and woodland in the surrounding area.

Discussion
The industrial activity would have had a considerable impact on the vegetation in the immediate area of the site. Large parts of the area would have been highly toxic and sparsely vegetated but certain taxa are tolerant of the extreme environmental conditions presented by soils rich in heavy metals. Fescue type grasses and docks are recorded from the site and sheep's fescue (*Festuca ovina*) and probably common sorrel (*Rumex acetosa*) have strains tolerant of heavy metals (Rodwell 2000, 447). Other species would have colonised around the periphery of the site where toxin levels were lower. Many of the seeds and other plant remains recorded probably reflect plants that grew around the edge of the site and were either washed into or blown onto the waste deposits. As well as plants typical of rough and disturbed ground, species indicative of wetter conditions are recorded from the deposits at the dry land edge and probably are derived from the local area. However, as cultivated plants are susceptible to damage from heavy metals, it is likely that the spelt glume bases represent cultivation a little distance from the site itself, perhaps nearer to the enclosure at Ynyscapel.

The medieval trackway
Two of the samples (209, 244) were from beneath timbers in Trench 6 at the terminal end of the trackway, while the remaining four samples (1, 2, 4, 6) were from Trench 5, around 100 metres from dry land. The samples contained charcoal, stone and other minerogenic material, including lead waste, reflecting material dumped on the bog surface, as well as plant remains. Wood fragments from the trackway were also present.

Monocotyledon remains comprising stems, stem bases and rhizomes of grasses and sedges, dominate all the plant macrofossil assemblages but there are some differences between the samples from Trench 6 and Trench 5. Grass (Poaceae) seeds are particularly frequent in samples from Trench 6, especially 244, suggesting wet grassland communities, whilst remains of hare's tail cottongrass (*Eriophorum vaginatum*) occur in Trench 5, reflecting the boggier conditions further into the wetland. Similarly, charred heather (*Calluna vulgaris*) and cross-leaved heath (*Erica tetralix*) remains are scarce or absent in the samples from Trench 6 compared with those from Trench 5. It seems likely that the charred ericaceous remains from Trench 5 represent burning of the contemporary bog surface rather than earlier industrial material, as these remains were not recorded from the earlier industrial samples (Table 1) and semi-charred and waterlogged ericaceous remains are present. Indeed burning of the bog surface may have favoured the spread of cottongrass.

As well as large numbers of grass seeds, sedge (*Carex* sp.) nutlets are also abundant in 244 and seeds of wood rush and bulrush are present. The occurrence of nettle (*Urtica dioica*) and orache (*Atriplex* sp.) in samples from Trench 6 probably reflect disturbed ground habitats, although nettles are also found in fen. Occasional blackberry (*Rubus fruticosus*) seeds in samples from both trenches might also indicate waste ground in the area, but occur in a wide range of habitats. The occasional birch (*Betula* sp.) fruit might have been carried some distance by the wind but suggests birch woodland in the surrounding area, whilst hazelnut (*Corylus avellana*) shell fragments from Trench 5 probably reflect transport either by small mammals or humans, as well as demonstrating the presence of hazel woodland. Equally, small mammals or birds could have transported an elder (*Sambucus nigra*) seed. Wetter conditions and the presence of standing water in the vicinity of Trench 5A, perhaps a pool, is indicated by pondweed (*Potamogeton* sp.) fruits. White beak-sedge (*Rhynchospora alba*) and possibly common reed (*Phragmites communis*) also suggest wet conditions.

Overall the evidence suggests wet grassland communities with sedges and rushes in the area of the industrial deposits at the terminal end of the trackway giving way to wet boggy ground with tussocks of cotton grass, grasses, heather and cross-leaved heath. Permanently waterlogged hollows and bog pools would have occurred amongst the drier hummocks. Some birch woodland may have been present in the area.

Table 1 Plant macrofossils from the industrial deposits at Llangynfelin.

Trench	**4**	**4**	**4**	**6**	**6**	**12**	**12**	**12**	**17**	**21**	**21**	**21**	**21**	**21**	**21**
Context	**27**	**69**	**70**	**1129**	**1130**	**1133**	**1098**	**1134**	**1115**	**1116**	**1085**	**1091**	**1092**	**1093**	**1109**
Weight (kg)	**3**	**2.5**	**2.4**	**1**	**0.5**	**1**	**1**	**1**	**0.2**	**1**	**1**	**1**	**1**	**1**	**1**
Ranunculus repens type (Creeping buttercups) D, Du, F, Gw, Ss, W	1	-	1	1	-	-	-	1	-	-	-	-	-	-	-
Ranunculus sceleratus L. (Celery-leaved buttercup) Gw, P, Ss	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
Ranunculus Subgenus *Batrachium* (DC) A. Gray (Crowsfoot) P, Ss	-	-	17	3	-	-	-	-	-	-	-	-	-	-	-
Ranunculus spp. (Buttercups) C, D, Du, F, G, Ss, W, o,w	1	-	-	1	1	-	-	-	-	-	-	-	-	-	-
Urtica dioica L. (Common nettle) C, D, F, W, n	10	-	8	6	1	-	-	3	-	-	-	-	1	1	-
Chenopodium album L. (Fat-hen) C, D	24	-	12	9	2	2	-	14	-	-	-	1	-	1	-
Chenopodium spp. (Goosefoots) C, D	-	-	2	6	2	-	-	-	-	1	-	-	1	-	-
Atriplex spp. (Oraches) C, D, Sm	2	-	7	-	-	-	-	-	-	1	-	-	2	-	-
Atriplex spp. - charred	-	1	-	-	-	-	1	-	-	-	-	-	-	-	1
Montia fontana ssp. *fontana* L. (Blinks) P, Ss, W	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Stellaria spp. (Stitchworts) C, F, G, Ss, Wo, Ww	-	-	1	-	-	-	-	2	-	-	-	-	3	-	-
Cerastium cf. *arvense* L.	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-

(Field mouse-ear) G															
Persicaria lapathifolia (L.) Gray (Pale persicaria) C, D, o, w	5	2	-	2	-	-	-	-	-	-	-	-	-	-	-
Persicaria hydropiper (L.) Spach (Water-pepper) P, w	7	-	-	1	-	-	-	-	-	-	-	-	-	-	-
Persicaria sp. (Knotweeds) C, D, Ss, o, w	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-
Rumex acetosella L. (Sheep's sorrel) C, D, M, o	7	-	1	-	1	-	-	-	-	-	-	-	-	-	-
Rumex spp. (Docks) C, D, G, P, Ss, W, w	2	-	-	-	-	1	-	14	-	1	-	-	2	6	-
Rumex sp. - charred	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Viola spp. (Violets) C D, Du, F, G, H, M, S, W	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Brassica sp. / *Sinapis arvensis* L. (Cabbage/ charlock) C, D, Sc, Ss	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rubus fruticosus agg. (Brambles) D, Du, G, H, M, S, W, o	-	-	-	3	-	1	-	3	-	-	-	-	-	27	1
Rubus fruticosus agg. - frags.	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-
Potentilla erecta (L.) Raeusch (Tormentil) G, M	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Potentilla spp. (Cinquefoil) D, Du, G, M,	-	-	-	4	-	-	-	-	-	-	-	-	1	-	-

Wc															
Aphanes arvensis L. (Parsley-piert) C, D	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Aphanes inexspectata Lippert (slender parsley-piert) C, D	10	-	4	2	-	-	-	-	-	-	-	-	-	-	-
Rosaceae - thorn H, S, W	-	-	-	1	-	1	-	1	-	-	-	-	-	-	-
Ulex europaeus L. - spines (Gorse) G, M, Wo	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
Hydrocotyle vulgaris L, (Marsh pennywort) F, M, P	-	-	-	9	-	-	-	-	-	-	-	-	-	-	-
Torilis nodosa (L.) Gaertner (Knotted hedge-parsley) C, D	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Apium sp. (Marshworts) F, P, Sm, Ss, o	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
Solanum dulcamara L. (Bittersweet) D, F, H, P, W	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
Galeopsis tetrahit L. (Common hemp-nettle) C, D, F, Wc, w	-	1	1	1	-	-	-	-	-	-	-	-	-	-	-
Galeopsis sp. (Hemp-nettles) C, D, Wc, w	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Prunella vulgaris L. (Sefheal) D, G, Wc	1	-	-	2	-	-	-	-	-	-	-	-	-	-	-
Mentha arvensis L. / *aquatica* L. (Corn/water mint) C, Gw,	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-

P, Wc															
Salvia pratensis L. (Meadow clary) D, G, S, Wc	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lamiaceae (Deadnettle) C, D, G, P, S, Wc, w	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-
Plantago major L. (Greater plantain) C, D, o	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Cirsium spp. (Thistles) C, D, F, G, H, Wo, w	1	-	-	2	-	-	-	-	-	-	-	-	-	1	-
Leontodon sp. (Hawkbits) G	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
Sonchus asper (L.) Hill (Prickly sow-thistle) C, D, F	-	-	-	1	-	-	-	-	-	-	-	-	-	1	-
cf. *Sonchus* sp. (Sow-thistles) C, D, Du, F, Ss	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
Juncus sp (Rushes) F, G, M, P, Sm, Ss, Ww	-	-	1	>1000	-	-	>100	-	10	-	-	42	>100	-	-
Juncus sp. - capsule	1	-	4	-	-	-	-	-	-	-	-	-	-	-	-
Schoenoplectus lacustris (L.) Palla (Common Club-rush) F, P, Ss	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-
Carex spp. - biconvex (Sedges) F, G, M, Ss, W, w	3	-	2	19	-	-	-	1	-	-	-	-	1	-	-
Carex spp. - trigonous	1	-	2	14	1	-	-	-	-	1	-	-	-	4	-
Carex spp. - trigonous charred	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Festuca type	9	-	1	1	-	-	-	-	-	-	-	-	-	-	-

(Fescues)G, H, M, Ss															
Triticum spelta - glume base (Spelt wheat) C	2	-	-	1	-	-	-	-	-	-	-	-	-	-	-
Poaceae (Grass) C, D, G, M	1	1	4	29	-	-	6	-	-	-	-	-	1	1	-
*Pteridium aquilinum*L. - leaf frags. (Bracken) M, W, G	3	-	2	4	-	-	-	-	-	-	-	-	1	-	-
Tree buds	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bud scale	3	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Charred seed indet.		-	-	-	-	-	-	-	-	-	1	-	-	1	-

Ecology: C = cultivated; D = disturbed; Du = dunes; F = fens; G = grassland; H = hedges; M = bogs, heath, moors; P = ponds, lakes, ditches; S = scr
Sm = saltmarsh; Ss = streamsides; W = woods; Wc = woodland clearance, margin; n = nutrient enrichment; o = open ground; w = wet/damp ground.

Table 2 Plant remains associated with the medieval trackway at Llangynfelin.

Trench	**5**	**5**	**5**	**5**	**6**	**6**
Sample	**1**	**2**	**5**	**6**	**209**	**244**
Volume (litres)	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**
Ranunculus repens L. (Creeping buttercups) D, Du, F, Gw, Ss, W	-	1	-	-	-	-
Urtica dioica L. (Nettles) W, F, Cn	-	-	-	-	1	-
Betula spp. (Birch) W, w	2	1	4	-	1	2
Corylus avellana L. - nut shell frags. (Hazel) H, S, W	3	2	1	1	-	-
Atriplex spp. (Oraches) C, D, Sm	-	-	-	-	-	2
Calluna vulgaris (L.) Hull - semi-charred leaves (Heather) M	5	-	-	-	-	-
Calluna vulgaris - flower	4	-	-	-	2	-
Calluna vulgaris - charred flowers	17	4	13	31	-	2
Calluna vulgaris - shoot	1	-	-	-	-	-
Erica tetralix L. - leaf (Cross-leaved heath) M	1	-	-	1	-	-
Erica tetralix L. - shoot	-	-	-	2	-	-
Erica tetralix L. - semi-charred leaves	27	-	-	-	-	-
Erica tetralix L. - charred leaves	-	5	15	47	-	-
Rubus fruticosus agg. (Brambles) D, Du, G, H, M, S,W, o	-	1	3	-	1	2
Potentilla sp. (Cinquefoil) D, Du, G, M	4	1	-	1	1	8
Rosaceae type - thorn	-	-	-	-	2	-
Linum catharticum L. (Fairy flax) G, M	-	-	1	-	-	-
Sambucus nigra L. (Elder) H, W, Dn	-	-	-	1	-	-
Eriophorum vaginatum L. - sclerenchymatous spindles (Hare's-tail cottongrass) F	17	16	4	4	-	-
Potamogeton sp. (Pond weed) P	-	8	-	-	-	-
Juncus sp. (Rushes) F, G, M, P, Sm, Ss, Ww	-	1	-	-	1	1
Luzula cf. *campestris* (L.) DC. (Field wood-rush) G	-	-	-	-	-	4
Rhynchospora alba (L.) Vahl (White beak-sedge) M, w	-	-	1	-	-	-

Carex sp. - biconvex (Sedges) F, G, M, Ss, W, w	1	-	-	-	-	-
Carex sp. - biconvex charred	2	-	-	-	-	-
Carex sp. - trigonous	1	-	1	1	3	65
Carex sp. - trigonous charred	1	-	-	-	-	-
Carex sp.	3	-	-	-	-	2
Festuca type (Fescues) G, H, Ss	19	12	16	-	-	-
cf. *Phragmites australis* (Cav.) Trin. ex Steudel (Common reed) G, F	-	2	-	-	-	-
Poaceae (Grass) C, D, G, M	1	3	12	24	60	233
Poaceae - charred	1	-	-	-	-	-
Typha latifolia L. (Bulrushes) P	-	-	-	-	-	3
Eriophorum vaginatum L. - stem bases	+++	+++	++	++	-	-
Monocot. stems and roots	+++++	+++++	+++++	+++++	+++++	+++++
Thorn	-	-	-	-	+	-
Wood & bark fragments	++++	++++	++++	++++	++++	++++
Deciduous leaf fragment	-	-	+	-	-	-
Wood charcoal	++	++	+	+	++	++
Sphagnum sp. - leaves	-	+	+	+	+	+
Moss frags.	-	-	+	+	-	+
Stone/gravel/lead waste	+++++	+++++	+++++	+++++	++	++

Ecology: C = cultivated; D = disturbed; Du = dunes; F = fens; G = grassland; H = hedges; M = bogs, heath, moors; P = ponds, lakes, ditches; S = scrub; Sm = saltmarsh; Ss = streamsides; W = woods; Wc = woodland clearance, margin; n = nutrient enrichment; o = open ground; w = wet/damp ground.

+++++ = very abundant; ++++ = abundant; +++ = frequent; ++ = occasional; + rare

APPENDIX 9: THE INSECT REMAINS FROM THE TRACKWAY AT LLANGYNFELYN, TALYBONT, CEREDIGION

D Smith, C Jolliffe, K. Nayyar, F Sharrock, E Tetlow and D Vaughan
Institute of Archaeology and Antiquity, The University of Birmingham

SAMPLE SELECTION AND RESEARCH QUESTIONS

The insect remains outlined in this report come from a series of bog and fen deposits associated with a medieval timber trackway excavated at the southern edge of Cors Fochno at Llangynfelyn, Talybont, Wales. The trackway consists of wooden timbers underlain by a layer of stones and gravel which rest upon the peat deposits which were sampled as part of this analysis. Two samples of wood were taken from the trackway for ^{14}C dating and these produced similar dates, one of 900-1020 cal AD and the other of 900-1030 cal AD. The site was excavated by Cambria Archaeology in association with the University of Birmingham Institute of Archaeology and Antiquity who provided support funding as part of their archaeological training programme for undergraduate students.

The insects remains examined in this report came from samples from two of the trenches excavated. Trench 5a was cut in 2004 around 100m along the length of the trackway from the dry land edge. A series of continuous 5 cm thick samples were taken for palaeoenvironmental analysis through the peat which lay under the trackway at this location. Radiocarbon dating suggests that these samples span a period of time from the Iron age at the base to when the trackway was constructed. In 2005 a series of trenches were excavated to investigate a Roman industrial site at the southern terminal end of the trackway. This included Trench 20 which contained industrial waste deposits at the dry land edge of the bog. A series of 10cm thick samples were from below this feature by Emma Tetlow. These samples cover the period of time between Iron age at the base of the deposit through to the Roman industrial deposits.

SAMPLE SELECTION PROCESSING AND ANALYSIS

The samples for Trench 5a were processed in 2005-2006 by Kalla Nayar and David Vaughan. The insect faunas from the two top samples from the column (0-5cm and 5-10cm), directly below the trackway, were identified by David Vaughan. It was hoped that these two samples might provide a contemporary indication of the local environment and use of the trackway itself. A series of four evenly spaced samples (30-25cm, 50-45cm, 75-70cm and 95-100cm) from the rest of the column were processed and identified by Kalla Nayar in 2006 in order to assess the degree to which the bog surface changed at this location. The samples for Trench 20 (5-22cm, 33-43cm and 63-53cm) were processed in November 2007 by Christina Jolliffe, Kalla Nayyar and Fiona Sharrock in order to see if the character of the environment on the dry land edge differed to that further out in to the bog seen in Trench 5a.

Both sets of bulk samples were processed using the standard method of paraffin flotation as outlined by Kenward *et al.* (1980). Identification of Coleoptera fossils was carried out through reference to the Girling and Gorham Coleoptera collections held at the Institute of Archaeology and Antiquity, University of Birmingham. Insect nomenclature follows Lucht (1987), while plant nomenclature follows Stace (1997).

Where applicable each species of Coleoptera has been assigned to one, or more, ecological grouping(s) and these are indicated in the second column of Table 1.

These groupings are derived from the preliminary classifications outlined by Robinson (1981; 1983). The groupings themselves are described at the end of Table 1. The various proportions of these groups, expressed as percentages of the total Coleoptera present in the faunas, are shown in Tables 2 and 3. The dung/ foul, tree, grassland and moorland groupings are calculated as a proportion of the terrestrial taxa recovered rather than as a proportion of the minimum number of individuals for the whole fauna (effectively excluding the dominant water beetles from this statistic).

Column 13 in Table 1 indicates the comparative modern rarity of each taxon recovered. The scheme used follows the Red Data Book (RDB) classifications of Hymen and Parsons (1992; 1994).

Column 14 in Table 1 lists the host plants used by the various species of phytophage (plant feeding) beetles recovered. The information included is primarily taken from Koch (1992). The plant taxonomy used is that of Stace (1997).

Trench 5

The six samples from Trench 5 (0-5cm, 5-10cm, 30-25cm, 50-45cm, 75-70cm and 95-100cm) produced moderately-sized coleopterous faunas. There appears to be little overall change in the local environment indicated by the insect remains.

The vast majority of these are species associated with shallow, slow flowing or stagnant waters often filled with rotting vegetation and detritus. Species typical of these conditions are hydreanids such as *Hydreana* spp., *Ochthebius* spp. and *Limnebius* spp. (Hansen 1986). Also typical of such situations are the various hydrophilids recovered such as *Enochrus* spp., *Chaetarthria seminulum*, *Coelostoma orbiculare and Cymbiodyta marginella* (Hansen 1986).

There are also indications that stands of sedges (*Carex* spp.) and reeds (*Phragmites australis* (Cav.) Trin. ex Steud.) occurred in the area, especially towards the top of the sequence. This is most clearly suggested by the presence of the 'reed beetle' *Plateumaris sericea* and the weevil *Limnobaris pilustrata* both of which are associated with sedges (*Carex* spp.) and rushes (*Juncus* spp.), as are the *Phalacrus* species (Koch 1992).

There are also clear suggestions that moorland and heathland existed in the area. This is suggested by the small 'diving water beetle' *Hydroporus melanarius,* which is associated with small pools of acidic water in swamps, bogs and marshes (Nilsson and Holmen 1995). Similarly the 'rove beetle' *Cryptobium fracticome* is often associated with pillows of *Sphagnum* moss. Heather (*Erica* spp. and *Calluna* spp.) is indicated by the small 'weevil' *Micrelus ericae* which is found in some numbers (Koch 1992). The latter species does seem to occur more often at the top of the sequence, perhaps suggesting that the bog surface had progressively dried (or periodically dried-out) before the establishment of the trackway. This is confirmed by the pollen and plant macrofossil evidence which also indicates raised bog vegetation in the area at this time (Caseldine this volume).

There is also a suggestion that fen or wet woodland might have occurred later in the sequence represented by these samples. This is suggested by the presence of the Eucnemid *Dirhagus pygmaeus,* a species which is associated with the dead wood of oak and other hard wood trees, and the 'leaf minor' *Rhynchaenus* spp. The information from the pollen and plant macrofossils is much clearer and suggests that alder (*Alnus*) and birch (*Betula*) expanded during this time.

The presence of a number of individuals of *Aphodius* and *Geotrupes* dung beetles, particularly from just below the trackway in samples 0-5cm and 5-10 cm may indicate that large grazing animals were present in the boglands or are associated with the use of the trackway itself, since these species are associated with 'dung pats' lying in the open (Jessop 1986). However, as with the indicators for woodland, this actually represents a very limited number of individuals and should not be overstressed in the interpretation of these faunas and the use of the trackway itself. Equally, dung beetles fly very long distances as they search for new pats to colonise (Kenward 1975, 1978), which means it is just as likely that these individuals could have come from the nearby dry land as the bog itself.

Trench 20

The three samples from below the trackway in Trench 20 (5-22cm, 33-43cm and 63-53cm) produced a series of moderately sized insect faunas that are essentially similar to those from Trench 5a, and to each other. A range of water beetles, for example *Ochthebius* spp, *Hydreana* spp., *Chaetarthria seminulum*, *Coelostoma orbiculare and Cymbiodyta marginella* and *Cercyon convexiusculus,* all indicate the presence of slow flowing or stagnant water (Hansen 1986). Similarly, there is some indication that stands of water reeds and other emergent vegetation occurred in the area. The clearest indication for this is the presence of individuals of the 'reed beetles' *Plateumaris braccata,* which is associated with *Phragmites* water reed (*Phragmites australis* (Cav.) Trin. ex Steud.), and *Donacia impressa,* associated with common club rush *(Schoenoplectus lactustris* (L.) Palla.). Similarly the small weevil *Tanysphyrus lemnae* is associated with duckweeds (*Lemna* spp.).

There are suggestions that acid water and moor conditions occurred throughout the sequence. In the lower samples this is indicated by the presence of *Plateumaris discolour* which is associated with cotton grass (*Eriophorum* spp.)(Koch 1992) and in the upper sample by the small water beetle *Hydroporus erythrocephalus* which is often associated with fen and bog waters (Nilsson and Holmen 1995). In the lower sample from Trench 20 there are a few individuals of elmid 'riffle beetles', including *Elmis aenea, Esolus parallelipipedus and Riolus* spp*.* These taxa are often associated with sandy substrates and flowing water (Holland 1972), but in these circumstances probably occur in gravely areas on the edges of open pools where small waves lap against the shore.

Similar to the insect faunas recovered in Trench 5a, there are again a number of dung beetles present throughout the sequence. This may indicate that animals grazed the moorland, though they also may have flown in from the adjacent dry land.

There also appears to be limited evidence for the presence of deadwood or woodland. This is suggested by the presence of the 'woodworm' *Anobium punctatum*, the 'powder post beetle' *Lyctus brunneus* and the *Cerylon* spp.. These taxa could be associated with woodland communities on the dry land or any fen woodland in the nearby vicinity. The pollen and plant macrofossil remains indicate that in fact alder carr was a dominant feature of the landscape at the dry land edge. Alder is a species of tree which is persistently under represented in the palaeoentomological record probably as a result of the fact that there are very few species of beetle that are specifically associated with it (Girling 1985; Robinson 1993; Smith *et al.* 2000; Smith and Whitehouse 2004).

Discussion

The insect faunas from Llangynfelyn clearly suggest that throughout the period of peat development the area consisted of acidic fen and bog supporting sedge, reeds and cotton grass vegetation. Locally, there appears to have been patches of heather and fen woodland. There are also slight indicators that animals grazed either the open bog or the nearby dry land. The bog surface may also have dried before the establishment of the trackway and there may have been periods when fen woodland occurred in the area. These results are broadly in agreement with the pollen and plant macrofossil evidence.

The insect remains recovered appear to indicate that the deposits sampled were from the later part of the sequence of development identified by Godwin and Newton (1938) and by Hughes and Schulz (2001) from further out in the bog and reflect conditions at the margin.

In terms of archaeoentomology, there are very few studies of similar deposits in the area. One notable exception is the series of faunas from Late Mesolithic/ Early Neolithic deposits from the Clettwr River, Ceredigion, West Wales (Jolliffe 2006). The insects from the trackway at Cors Fochno are certainly the only insect faunas from the area of this relatively late date. Although a similar medieval trackway, is known at Llanaber near Barmouth (Musson, Taylor and Heyworth 1974) no insect faunas were associated with it. Other insect faunas associated with trackways in Britain are of a much earlier date, for example the Bronze and Iron age trackways at Goldcliff, Gwent (Smith *et al*. 2000) and the Neolithic and Bronze Age examples from the Somerset Levels (i.e. Girling 1977; 1979; 1980).

RARE SPECIES RECOVERED

Dirhagus pygmaeus is today threatened (Red Book Status 3) and is only found in dead and rotting heart wood in deciduous woodland (Hymen and Parsons 1992).

Table 1: Coleoptera from samples associated with the medieval trackway at Llangynfelyn, Talybont, Ceridigion

Taxa	**Red data book status**	**Ecological code**	**Trench 20**			Trench 5a						**Phytophage host plants (information from Koch 1992)**
			53 - 63	33 - 43	5 - 22	100 – 95 KN	75 – 70 KN	50 – 45 KN	30 – 25 KN	10 – 5 DV	5 – 0 DV	
CARABIDAE												
Nebria brevicollis (F.)	-	-	1	-	-	-	-	-	-	-	-	-
Nebria spp.	-	-	-	-	1	-	-	-	-	-	-	-
Notiophilous spp. Dum.	-	-	1	-	-	-	-	-	-	-	-	-
Elaphrus uliginosus F.	-	ws	1	-	-	-	-	-	-	-	-	-
Elaphrus cupreus Duft.	-	ws	1	-	-	-	-	-	-	-	-	-
Elaphrus spp.	-	-	1	-	-	-	-	-	-	-	-	-
Loricera pilicornis (F.)	-	-	-	-	-	-	-	1	-	-	-	-
Clinina fossor (L.)	-	-	-	-	1	-	-	-	-	-	-	-
Dyschirius globosus (Herb.)	-	-		1		-	-	-	-	1	1	-
Trechus quadristriatus (Schrk.)	-	-	-	-	2	-	-	-	-	-	-	-
Trechoblemus micros (Hbst.)	-	ws	-	-	-	-	-	-	-	-	1	-
Bembidion doris (Panz.)	-	-	-	-	1	-	-	-	-	-	-	-
Bembidion spp.	-	-	1	2	2	-	-	-	-	-	-	-
Harpalus spp.	-	-	-	-	1	-	-	-	-	-	-	-
Stenolophus spp.	-	-	-	1	-	-	-	-	-	-	-	-
Pterostichus strenus (Panz.)	-	ws	-	-	-	-	-	-	-	1	2	-
Pterostichus diligens (Sturm.)	-	ws	-	-	-	-	-	2	-	-	-	-
Pterostichus anthracinus	-	-	5	-	-	-	-	-	-	-	-	-

(Ill.)												
Pterostichus minor (Gyll.)	-	-	4	-	-	-	-	-	-	-	-	-
Pterostichus angustatus (Duft.)	Nb	-	-	-	-	-	-	-	-	1	-	-
Abax parallelepipedus (Pill.Mitt.)	-	-	1	-	-	-	-	-	-	-	-	-
DYTISCIDAE												
Hydroporus erythrocephalus (L.)	-	a	-	-	1	-	-	-	-	-	-	-
Hydroporus melanarius (Sturm.)	-	a –m	-	-	-	-	-	-	-	-	4	Acid water specialist
Hydroporus spp.	-	a	6	2	-	-	-	1	-	-	-	-
Agabus spp.	-	a	3	-	-	-	-	-	-	-	-	-
HYDRAENIDAE												
Hydraena spp.	-	a	10	10	-	-	-	7	-	-	-	-
Ochthebius spp.	-	a	-	6	-	-	-	-	-	-	1	-
Limnebius spp.	-	a	15	-	1	1	-	-	-	-	-	-
Hydrochus elongatus (Schall.)	-	a	-	-	1	-	-	-	-	-	-	-
Helophorus spp.	-	a	-	-	5	-	-	-	-	-	4	-
HYDROPHILIDAE												
Coelostoma orbiculare (F.)	-	a	-	2	-	-	1	4	-	-	-	-
Cercyon impressus (Sturm.)	-	d	-	-	-	-	-	-	1	-	-	-
Cercyon convexiusculus Steph.	-	a	8	-	-	-	-	-	-	-	-	-
Cercyon spp.	-	d	1	3	-	-	-	3	-	-	-	-
Megasternum	-	d	1			-	-	-	1	-	2	-

boletophagum (Marsh.)												
Hydrobius fuscipes (L.)	-	-	4	-	-	-	-	-	-	-	-	-
Enochrus affinis (Thun.)	-	a	-	-	-	-	-	-	-	-	1	-
Enochrus spp.	-	a	-	-	-	1	-	-	-	-	-	-
Cymbiodyta marginella (Fabr.)	-	ws	-	-	2	-	-	-	-	-	2	-
Chaetarthria seminulum (Herb.)	-	a	-	-	1	5	5	-	2	4	5	-
HISTERIDAE												
Acritus spp.	-	-	1	-	-	-	-	-	-	-	-	-
SILPHIDAE												
Silpha spp.	-	-	1	-	-	-	-	-	-	-	-	-
SCYDMAENIDAE (Genus and species indeterminate)	-	-	-	1	-	1	2	6	-	-	-	-
Cephennium gallicum Ganglb.	-	-	-	2	-	-	-	-	-	-	-	-
			-	-	-	-	-	-	-	-	-	-
ORTHOPERIDAE												
Corylophus cassidoides (Marsh.)	-	-	1	-	-	-	-	-	-	-	-	-
Orthoperus spp.	-	df	-	-	-	-	-	1	-	-	-	
PTILIDAE												
Acrotrichis spp	-	-	-	1	-	-	-	-	-	-	-	-
STAPHYLINIDAE												
Micropeplus tesserula Curt.	-	-	1	-	-	-	-	-	-	-	-	-
Micropeplus fulvus Er.	-	-	1	-	-	-	-	-	-	-	-	-
Proteinus spp.	-	-	-	-	-	1	-	2	-	-	-	-

Omalium spp.	-	-	1	-	-	-	-	-	-	-	-	-
Olophrum piceum (Gyll.)	-	ws	6	1		-	-	15	1	-	-	-
Acidota crenata (F.)	-	df	-	-	-	-	-	-	-	-	2	-
Lesteva heeri Fauv.	-	ws	4	-	-	-	-	5	-	-	-	-
Lesteva spp.	-	ws	-	3	-	-	-	2	1	1	-	-
Trogophloeus cf.*rivularis* Motsch.	-	-	-	6	-	-	-	-	-	-	-	-
Oxytelus rugosus (F.)	-	df	-	2	-	-	-	1	-	-	-	-
Platystethus spp.	-	-	-	-	1	-	-	-	-	-	-	-
Stenus spp.	-	-	10	5	1	-	1	2	1	2	9	-
Medon spp.	-	-	-	1	-	-	-	-	-	-	-	-
Lathrobium brunnipes (F.)	-	-	-	-	2	-	-	-	-	-	-	-
Lathrobium spp.	-	-	6	3		1	-	4	1	2	3	-
Cryptobium fracticome (Payk.)	-	m	-	-	-	-	1	-	1	3	-	*Sphagnum* moss
Xantholinus linearis (Ol.)	-	-	-	-	-	-	4	-	-	-	3	-
Xantholinus spp.	-	-	1	1	3	-	-	-	-	6	-	-
Philonthus spp.	-	-	-	2	-	-	-	2	-	6	1	-
Quedius spp.	-	-	9	-	-	-	-	1	-	-	-	-
Tachyporus spp.	-	-	-	2	1	-	-	-	-	-	-	-
Tachinus spp.	-	-	1	-	-	-	1	-	-	-	-	-
Aleocharinae gen. & spp. Indet.	-	-	6	10	1	1	1	6	-	-	-	-
PSELAPHIDAE												
Bryaxis spp*.*	-	-	1	3	-	-	-	-	-	-	-	-
Brachygluta spp.	-	-	-	4	-	-	-	-	-	-	-	-
MALACHIIDAE												
Malachius spp.	-	-	-	-	1	-	-	-	-	-	-	-
ELATERIDAE												
Adelocera murina (L.)	-	-	1	-	-	-	-	-	-	-	-	-

Ctenicera pectinicornis (L.)	Nb	g	-	-	-	-	-	-	-	-	1	-
EUCNEMIDAE												
Dirhagus pygmaeus (F.)	RDB3	t	-	-	-	-	-	1	-	-	-	Range of hard wood trees
HELODIDAE												
Helodiae gen. & spp. Indet.	-	-	3	1	-	-	-	-	-	-	-	-
Cyphon spp.	-	ws	1	-	-	1	3	-	-	-	-	-
DRYOPIDAE												
Dryops spp.	-	ws	2?	1	-	-	-	-	-	-	-	-
Elmis aenea (Müll.)	-	aff	2	-	-	-	-	-	-	-	-	-
Esolus parallelipipedus (Müll.)	-	aff	1	-	-	-	-	-	-	-	-	-
Riolus spp.	-	aff	-	-	2	-	-	-	-	-	-	-
CRYPTOPHAGIDAE												
Atomaria spp.	-	-	-	1	-	-	-	-	-	-	-	-
PHALACRIDAE												
Phalacrus spp.	-	ws	-	-	-	-	-	-	1	-	-	-
LATHRIDIIDAE												
Corticaria spp.	-	df	1	2	-	-	-	2	-	-	-	-
COLYDIIDAE												
Cerylon spp	-	t	1	-	-	-	-	-	-	-	-	Dead hardwoods
LYCTIDAE												
Lyctus brunneus (Steph.)	-	-	-	-	2	-	-	-	-	-	-	-

ANOBIIDAE												
Anobium punctatum (Geer.)	-	t	1	-	-	-	-	-	-	-	-	Dead hardwoods
SCARABEIDAE												
Geotrupes spp.	-	df	1?	-	-	-	-	-	-	-	1	-
Aphodius sphacelatus (Panz.) / *prodromus* (Brahm)	-	df	3	-	-	-	-	-	-	-	-	-
Aphodius foetidus (Hbst.)	-	df	-	-	6	-	-	-	-	-	-	-
Aphodius fimetarius (L.)	Nb	df	-	-	1	-	-	-	-	-	3	-
Aphodius contaminatus (Herb.)	-	df	-	-	-	-	-	-	-	1	2	-
Aphodius spp.	-	df	-	1	-	-	1	-	-	-	-	-
Phyllopertha horticola (L.)	-	g	1?	-	-	-	-	-	-	-	-	-
CHRYOSMELIDAE												
Donacia impressa Payk.	-	ws	-	-	1	-	-	-	-	-	-	*Schoenoplectus lactustris* (L.) Palla (Common Club Rush)
Donacia / Plateumaris	-	ws	1?	-	-	-	-	-	-	-	-	-
Plateumaris discolor (Panz.)	-	ws	2	-	-	-	-	-	-	-	-	Usually on *Eriophorum* spp. (Cotton grass)
Plateumaris sericea (L.)	-	ws	-	-	-	-	-	-	-	1	-	Usually on *Carex* spp. (sedges)
Plateumaris braccata (Scop.)	-	ws	-	-	1	-	-	-	-	-	-	*Phragmites australis* (Cav.) Trin. ex Steud. (water reed)
Plateumaris spp.	-	ws	-	1	-	-	-	-	-	-	-	-
Phaedon spp.	-	g	-	-	1	-	-	-	-	-	-	-
Phyllotreta spp.	-	g	-	-	3	-	-	-	-	1	1	-
Chaetocnema concinna (Marsh.)	-	g	-	-	1	-	-	-	-	5	4	

Chaetocnema spp.	-	g	1	-	-	-	-	-	1	-	-	-
CURCULIONIDAE												
Apion cruentatum Walt.	-	g	1	-	-	-	-	-	-	-	-	Usually on *Rumex spp.* (Dock)
Tanysphyrus lemnae (Payk.)	-	ws	-	2	-	-	-	-	-	-	-	*Lemna* spp. (Duckweed)
Leiosoma deflexum (Panz.)	-	-	-	1	-	-	-	-	-	-	-	*Caltha palustris* L. (Marsh marigold)
Micrelus ericae (Gyll.)	-	m	-	-	-	-	2	-	-	1	1	On *Calluna* spp. and *Erica* spp. (Heathers)
Ceutorynchus spp.	-	g	-	-		-	-	3	-	1	-	-
Gymnetron sp		d	-	-	1	-	-	-	-	-	-	-
Limnobaris ?pilustrata (Steph.)	-	ws	-	-	-	-	-	-	-	3	1	*Juncaceae* (rush family) and *Cyperaceae* (sedge family)
Rhynchaenus spp.	-	t	-	-	-	-	-	4	-	-	-	-

Key for the ecological groupings used in Table 1.

a - aquatic species
aff - Aquatic species associated with fast flowing water
ws - waterside species either from muddy banksides or from waterside vegetation
df - species associated with dung and foul matter
d - species associated with dung
g - species associated with grassland and pasture
t - species either associated with trees or with woodland in general
m - Species associated with moorland

Table 2: The percentage proportions of the ecological grouping of Coleoptera from trench 5

Trench depth of bulk sample	**100-95 cm**	**75-70 cm**	**50-45 cm**	**30-25 cm**	**10-5.01 cm**	**5-0 cm**
Total number of individuals	**12**	**22**	**64**	**11**	**40**	**55**
Number of species	**8**	**11**	**22**	**10**	**17**	**23**
Ecological Grouping						
Aquatic	58.3%	27.3%	18.8%	18.2%	10.0%	27.3%
Aquatic fast flowing	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Waterside	8.3%	18.2%	37.5%	36.4%	22.5%	10.9%
Dung	0.0%	0.0%	10.7%	40.0%	0.0%	5.8%
dung/foul	0.0%	8.3%	14.3%	0.0%	3.7%	23.5%
Tree	0.0%	0.0%	17.9%	0.0%	0.0%	0.0%
Grass	0.0%	0.0%	10.7%	20.0%	25.9%	17.6%
Moorland	0.0%	16.7%	0.0%	0.0%	3.7%	2.9%

Table 3. The percentage proportions of the ecological grouping of Coleoptera from trench 20

Trench depth of bulk sample	**63-53 cm**	**43-33 cm**	**22-05 cm**
Total number of individuals	**137**	**84**	**48**
Number of species	**48**	**32**	**31**
Ecological Grouping			
Aquatic	30.6%	23.8%	18.8%
aquatic fast flowing	2.2%	0.0%	4.2%
Waterside	13.1%	9.5%	8.3%
Dung	2.7%	0.5%	3.0%
dung/foul	5.8%	8.9%	21.2%
Tree	2.7%	0.0%	0.0%
Grass	4.1%	0.0%	15.2%
Moorland	0.0%	0.0%	0.0%

Note: not all taxa have been assigned to an ecological group an as a result percentages do not total 100%

BIBLIOGRAPHY

Alloway, B.J. and Davies, B.E. 1971 Trace element analysis of soils affected by base metal mining in Wales. *Geoderma* 5, 197-208.

Anderberg, A. 1994 *Atlas of seeds. Part 4 Resedaceae-Umbelliferae*. Stockholm, Swedish Museum of Natural History.

Andrew, R. 1984 *A Practical Pollen Guide to the British Flora*. Quaternary Research Association Technical Guide No. 1.

Armstrong, L. 1978 *Woodcolliers and Charcoal Burning*. Horsham, Coach Publishing House Ltd. and The Weald and Downland Open Air Museum.

Baillie M. G. L. (1977) 'Dublin Medieval Dendrochronology.' *Tree Ring Bulletin* **37**: 13-20.

Baillie M. G. L. (1977) 'An oak chronology for south central Scotland.' *Tree Ring Bulletin* **37**: 33-44.

Baillie M. G. L. and J R Pilcher (1973) 'A simple crossdating program for tree-ring research.' *Tree Ring Bulletin* **33**: 7-14.

Bell, M., Caseldine, A. and Neumann, H. 2000 *Prehistoric Intertidal Archaeology in the Welsh Severn Estuary*. CBA Research Report 120.

Bennett, K.D. 1994 *Annotated catalogue of pollen and pteridophyte spore types of the British Isles.* Department of Plant Sciences, University of Cambridge.

Bennett, K.D., Whittington, G. and Edwards, K.J. 1994 Recent plant nomenclatural changes and pollen morphology in the British Isles. *Quaternary Newsletter* 73, 1-6.

Berggren, G. 1969 *Atlas of seeds and small fruits of Northwest-European plant species with morphological descriptions. Part 2. Cyperaceae*. Stockholm, Swedish Museum of Natural History.

Berggren, G. 1981 *Atlas of seeds and small fruits of Northwest-European plant species with morphological descriptions. Part 3. Salicaceae-Cruciferae*. Stockholm, Swedish Natural Science Research Council.

Bostock, J.L. 1980 *The history of the vegetation of the Berwyn Mountains, North wales, with emphasis on the development of the blanket mire*. Unpublished Ph.D. thesis, University of Manchester.

Buckley, S.L. 2000 *Palaeoecological investigations of blanket peats in upland Mid-Wales*. Unpublished PhD thesis, University of Wales.

Buckley, S.L. and Walker, M.J.C. 2001 The Flandrian vegetation history of upland mid-Wales: Bryniau Pica. In Walker, M.J.C. and McCarroll, D., *The Quaternary of West Wales Field Guide,* QRA 93-102.

Butler, S. 1984 Preliminary investigation of the pollen record from Tally lakes. *Carmarthenshire Antiquary* 20, 3-14.

Buurman, J., van Geel, B. and van Reenen, G. B. A. 1995 Palaeoecological investigations of a Late Bronze Age watering-place at Bovenkarspel, The

Netherlands. In G. F. W. Herngreen and L. van der Valk (Eds.), *Neogene and Quaternary Geology of North-West Europe*, Mededelingen Rijks Geologische Dienst 52, 249-270.

Caseldine, A. E., walker, M. J. C., James, J. H., Johnson, S. and Robinson, M. 2002 Palaeoecological investigations. In James, H., Murphy, K. and Page, N., *The Discovery and Investigation of a Roman Road West of Carmarthen*. Cambria Archaeological report 2002/4, 33-45.

Chambers, F. M. 1982 Environmental history of Cefn Gwernffrwd, near Rhandirmwyn, Mid-Wales. *New Phytologist* 92, 607-615.

Chambers, F. M. 1999 The Quaternary history of Llangorse Lake: implications for conservation. *Aquatic Conservation: Marine and Freshwater Ecosystems* 9, 343-359.

Chambers, F. M. 2003 Setting the scene. In Murphy, P. and Wiltshire, P.E.J. (Eds.), *The Environmental Archaeology of Industry*. Symposia of the Association for Environmental Archaeology No 20, Oxbow, Oxford, 4-8.

Charman, D. J., Hendon, D. and Woodland, W. A. 2000 *The Identification of Testate Amoebae (Protozoa: Rhizopoda) in peats.* QRA Technical Guide No. 9, Quaternary Research Association.

Coles, B. and Coles, J. 1986 *Sweet Track to Glastonbury*. London, Thames and Hudson.

Coles, J. M. and Orme, B. J. 1976 The Abbot's Way. *Somerset Levels Papers* 2, 7-20.

Cowgill, J. 2003 The iron production industry and its extensive demand upon woodland resources: a case study from Creeton Quarry, Lincolnshire. In Murphy, P. and Wiltshire, P. E. J., *The Environmental Archaeology of Industry*. Symposia of the Association for Environmental Archaeology 20, 48-57. Oxbow Books

Craddock, P.T. 1995 *Early Metal Mining and Production*. Edinburgh, Edinburgh University Press.

Cranstone, D. 2001 Indusrial archaeology – manufacturing a new society. In Newman, R. (Ed.) *The Historical Archaeology of Britain c. 1540-1900*. Sutton Publishing, Stroud, 183-122.

Davis, O.K. 1987 Spores of the dung fungus Sporormiella: Increased abundance in historic sediments and before Pleistocene megafaunal extinction. *Quaternary Research* 28, 290-294.

Dumayne, L., Stoneman, R., Barber, K. and Harkness, D. 1995 Problems associated with correlating calibrated radiocarbon-dated pollen diagrams with historical events. *The Holocene* 5, 118-123.

English Heritage 1998 *Dendrochronology: guidelines on producing and interpreting dendrochronological dates*. London.

Gale, R. 2003 Wood-based industrial fuels and their environmental impact. In Murphy, P. and Wiltshire, P.E.J., *The Environmental Archaeology of Industry*. Symposia of the Association for Environmental Archaeology 20, 30-47. Oxbow Books

Girling, M. A. 1977 'Fossil insect assemblages from Rowland's track'. *Somerset Levels Papers* 3, 51-60.

Girling, M. A. 1979 'Fossil insects from the Sweet Track'. *Somerset Levels Papers* 5*,* 84-93.

Girling, M. A. 1980 'The fossil insect assemblage from the Baker Site'. *Somerset Levels Papers* 6, 36-42.

Girling, M. A. 1985 *An 'old forest' beetle fauna from a Neolithic and Bronze Age peat deposit at Stileway.* Somerset Levels Papers *11, 80-5.*

Godwin, H. 1943 'Coastal peat beds of the British Isles and the North Sea'. *Journal of Ecology* 31, 199-247.

Godwin, H. 1981 *The Archives of the Peat Bogs*. Cambridge University Press, Cambridge.

Godwin, H. and Newton, L. 1938 'The submerged forest at Borth and Ynyslas, Cardiganshire: data for the study of post-glacial history'. *New Phytologist* 37, 333-344.

Godwin, H. and Willis, E. H. 1969 'Borth Bog, Cardiganshire'. *Radiocarbon* 6, 128.

Görres, M. and Frenzel, B. 1997 'Ash and metal concentrations in peat bogs as indicators of anthropogenic activity'. *Water, Air and Soil Pollution* 100, 355-365.

Groves, C. 1992 'Tree-ring analysis of timbers'. *Excavations at 33-35 Eastgate, Beverley, 1983-86*. D. H. Evans and D. G. Tomlinson. Sheffield. **3:** 256-65.

Hansen, M. 1986 *The Hydrophilidae (Coleoptera) of Fennoscandia and Denmark Fauna* (Fauna Entomologyca Scandinavica 18). Leiden: Scandinavian Science Press.

Heyworth, A. 1985 *Submerged forests: a dendrochronological and palynological investigation.* Unpublished PhD thesis, University of Wales.

Hillam, J. 1992 *Tree-ring analysis of timbers from The Brooks, Winchester, Hampshire*, Anc Mon Lab Rep.

Holland, D.G. 1972. *A Key to the Larvae, Pupae and Adults of the British Species of Elminthidae.* Freshwater Biological Association Scientific Publication 26*.* Ambleside: Freshwater Biological Association.

Homer, R. F. 1991 ,Tin, lead and pewter,. In Blair, J. and Ramsay, M. (eds.), *English Medieval Industries.* London, The Hambledon Press. 57-80.

Horne, L. 1982 'Fuel for the metal worker'*. Expedition*. University of Pennsylvania Museum, 25, 6-13.

Hopewell, D. 2006 'Geophysical survey at Trawscoed Roman Fort and Erglodd Fortlet, Ceredigion'. *Archaeology in Wales* 46, 167-170.

Hughes, P.D.M. 1997 *The palaeoecology of the fen-bog transition during the early- to mid-Holocene in Britain.* Ph.D. thesis, University of Southampton.

Hughes, P.D.M. 2000 A reappraisal of the mechanisms leading to ombrotrophy in British raised mires. *Ecology Letters* 3, 7-9.

Hughes, P.D.M. and Schulz, J. 2001 The development of the Borth Bog (Cors Fochno) mire system and the submerged forest beds at Ynyslas. In Walker, M.J.C. and McCarroll, D. (eds.), *The Quaternary of West Wales: Field Guide*. Quaternary Research Association, London.

Hyman, P. and Parsons M.S. 1992 *A review of the scarce and threatened Coleoptera of Great Britain* (U.K. Nature Conservation 3). Peterborough: UK Joint Nature Conservation Committee.

Hyman, P. and Parsons M.S. 1994 *A review of the scarce and threatened Coleoptera of Great Britain* (U.K. Nature Conservation 4). Peterborough: UK Joint Nature Conservation Committee.

Jessop, L. 1986 *Coleoptera: Scarabaeidae*.(Handbooks for the Identification of British Insects 5/11). London: Royal Entomological Society of London.

Jolliffe, C. 2006 *The Mesolithic-Neolithic Transition of the Peat Bog on the River Clettwr, Ceridigion, West Wales* (unpublished B.A. dissertation thesis): Birmingham: University of Birmingham.

Jones, G. 1965 Agriculture in North-West Wales during the Late Middle Ages. In Taylor, J.A. (ed.), *Climatic change with special reference to Wales and its agriculture*. Memo. No. 8, Geography Department, U.C.W., Aberystwyth.

Jones, J. M. and Hao, J. 1993 Ombrotrophic peat as a medium for historical monitoring of heavy metal pollution. *Environmental Geochemistry and Health* 15, 67-74.

Jones, R. 2004 *Archaeological evaluation and salvage recording at Llangynfelyn, Talybont*. Cambria Archaeology report for Cadw.

Jones, R., Benson-Evans, K. and Chambers, F.M. 1985 Human influence upon sedimentation in Llangorse Lake, Wales. *Earth Surface Processes and Landforms* 10, 227-235.

Kenward H.K. 1975 Pitfalls in the environmental interpretation of insect death assemblages. *Journal of Archaeological Science* 2. 85-94.

Kenward H. K. 1978 *The Analysis of Archaeological Insect Assemblages: A New Approach*. Archaeology of York, 19/1. London: Council for British Archaeology for York Archaeological Trust.

Kenward H. K., Hall A.R., and Jones A.K.G. 1980. A tested set of techniques for the extraction of plant and animal macrofossils from waterlogged archaeological deposits. *Scientific Archaeology* 22, 3-15.

Koch, K. 1992. *Die Kafer Mitteleuropas* (Ökologie Band 3). Krefeld: Goecke and Evers.

Laxton, R. R. and C. D, Litton (1988) *An East Midlands master tree-ring chronology and its use for dating vernacular buildings*. University of Nottingham, Dept of Classical and Archaeological Studies, Monograph Series.

Livett, E. A. 1988 Geochemical monitoring of atmospheric heavy metal pollution: theory and applications. *Advances in Ecological Research* 18, 65-177.

Livett, E. A., Lee, J. A. and Tallis, J. H. 1979 Lead, zinc and copper in analysis of British blanket peats. *Journal of Ecology* 67, 865-891.

Lomas–Clarke, S. H. and Barber, K. E. 2007 Human impact signals from peat bogs – a combined palynological and geochemical approach. *Vegetation History and Archaeobotany* 16, 419-429.

Lucht, W.H. 1987 *Die Käfer Mitteleuropas* (Katalog). Krefeld: Goecke and Evers.

Lundqvist, N. 1972 *Nordic Sordariaceae S.Lat*.. Uppsala, Acta Universitatis Upsaliensis. Symbolae Botanicae Upsalienses.

Martinez Cortizas, A., Pontvedra-Pombal, X., Nóvoa Muños, J.C. and García-Rodeja, E. 1997 Four thousand years of atmospheric Pb,Cd and Zn deposition recorded by ombrotrophic peat bog of Penido vello (northwestern Spain). *Water, Air and Soil Pollution* 100, 387-403.

Mighall, T.M., Dumayne-Peaty, L. and Cranstone, D. 2004 A record of atmospheric pollution and vegetation changeas recorded in three peat bogs from the Northern Pennines Pb-Zn orefield. *Environmental Archaeology* 9, 13-38.

Mighall, T. M., Timberlake, S., Jenkins, D. A. and Grattan, J. P. 2006 Using bog archives to reconstruct palaeopollution and vegetation change during the late Holocene. In Martini, I. P., Martinez Cortizas, A. and Chesworth, W. (Eds.), *Peatlands: Evolution and Records of Environmental and Climatic Changes*. Elsevier, 413-434/5.

Mighall, T. M., Timberlake, S., Singh, S. and Bateman, M. 2008 Records of palaeo-pollution from mining and metallurgy as recorded by three ombrotrophic peat bogs in Wales, UK.

Moore, P. D. 1963 *An investigation of the stratigraphy and water content of Borth Bog, Cardiganshire*. Unpublished BSc Thesis, University of Wales. In Slater F.M., Contributions to the ecology of Borth Bog, Wales. I. General considerations. *Proceedings of the 4th International Peat Congress I-IV*, Helsinki, 277-288.

Moore, P. D. 1966 *Investigations of peats in central Wales*. Unpublished Ph.D. thesis, University of Wales.

Moore, P. D. 1968 Human influence upon vegetational history in north Cardiganshire. *Nature* 217, 1006-1007.

Moore, P. D. and Chater, E. H. 1969 The changing vegetation of west-central Wales in the light of human history. *Journal of Ecology* 57, 361-379.

Moore, P. D, Merryfield, D. L. and Price, M. D. R. 1984 The vegetation and development of blanket mire. In Moore, P. D. (ed.), *European Mires*, 203-235. London, Academic Press.

Moore, P. D., Webb, J. A. and Collinson, M. E. 1991 *Pollen Analysis* (2nd edn.) Oxford, Blackwell Scientific Publications.

Morriss, S. H. 2001 *Recent human impact and land use change in Britain and Ireland: a pollen analytical and geochemical study*. Unpublished Ph.D. thesis, University of Southampton.

Munro, M. A. R. 1984 'An improved algorithm for crossdating tree-ring series.' *Tree Ring Bulletin* **44**: 17-27.

Musson, C., Taylor, J. A. and Heyworth, A. 1989 Peat deposits and a Medieval trackway at Llanaber, near Barmouth, Gwynedd. *Archaeology in Wales* 29, 22-26.

Nicholson R A and J Hillam (1987) A dendrochronological analysis of oak timbers from Dundas Wharf, Bristol, 1982-83, Anc Mon Lab Rep.

Nilsson, A. N. and Holmen, M. 1995. *The Aquatic Adephaga (Coleoptera) of Fennoscandia and Denmark II. Dytiscidae* (Fauna Entomologyca Scandinavica Vol. 35). Leiden: E. J. Brill.

Page, N. 2005 *Excavation of a medieval timber trackway at Llangynfelyn, Talybont*. Cambria Archaeology report for Cadw.

Page, N. 2006a Excavation of a medieval timber trackway & possible Roman lead smelting site at Llangynfelin, Talybont: interim report. Llandeilo. Cambria Archaeology report for Cadw.

Page, N. 2006b 'Industrial complex and timber trackway at Llangynfelin, Ceredigion'. *Archaeology in Wales* 45, 2005, p103-104.

Porter, V. 1990 *Small woods and hedgerows*. Pelham Books.

Price, M. D. R. and Moore, P. D. 1984 Pollen dispersion in the hills of Wales: a pollen shed hypothesis. *Pollen et Spores* 26, 127-136.

Reimer, P. J., Baillie, M. G. L., Bard, E., Bayliss, A., Beck, J. W., Bertrand, C.J . H., Blackwell, P. G., Buck, C. E., Burr, G. S., Cutler, K. B., Damon, P. E., Edwards, R. L., Fairbanks, R. G., Freidrich, M., Guilderson, T. P., Hogg, A. G., Hughen, K. A., Kromer,B. G. M., Manning, S., Ramsey, C. B., Reimer, R. W., Remmele, S., Southon, J. R., Stuiver, M., Talamo, S., Taylor, F. W., van der Plicht, J., and Weyhenmeyer, C. E. 2004 Intcal04 terrestrial radiocarbon age calibration, 0-26 cal kyr BP. *Radiocarbon* 46 (3), 1029-1058.

Redknap, M. 1991 Newton Moor. *Archaeology in Wales* 31, 42-43.

Redknap, M. 1992 Excavations at Newton Moor, South Glamorgan: an interim statement. *Severn Estuary Levels Research Committee Annual Report 1991*, 23-26.

Robinson, M. A. 1981 'The use of ecological groupings of Coleoptera for comparing sites' pp. 251–86 in M. Jones and G. Dimbleby (eds), *The Environment of Man: The Iron Age to the Anglo-Saxon Period* (British Archaeological Reports, British Series 87). Oxford: British Archaeological Reports.

Robinson, M.A. 1983 'Arable/pastoral ratios from insects?' pp. 19–47 in M. Jones (ed.), *Integrating the Subsistence Economy* (British Archaeological Reports, International Series 181). Oxford: British Archaeological Reports.

Robinson, M. 1993 'The Iron Age environmental evidence' pp. 101–20 in T. G. Allen and M. A. Robinson (Eds) *The Prehistoric Landscape and Iron Age Enclosed*

Settlement at Mingies Ditch, Hardwick-with-Yelford,Oxon (Thames Valley Landscapes: The Windrush Valley Volume 2). Oxford: Oxford Archaeological Unit, Oxford.

Rodwell, J. S. 2000 *British Plant Communities*, Volume 5. *Maritime Communities and Vegetation of Open Habitats*. Cambridge, Cambridge University Press.

Schoch, W., Heller, I., Schweingruber, F. H., Kienast, F. 2004 *Wood Anatomy of Central European Species*. Online version: www.woodanatomy.ch

Schoch, W. H., Pawlik, B. and Schweingruber, F. H. 1988 *Botanical macro-remains*. Berne and Stuttgart, Paul Haupt.

Schulz, J. 2002 *Late Holocene mire development and conservation of the intact peatlands of Cors Caron and Cors Fochno: a palaeoecological approach using high resolution plant macrofossil analysis*. Unpublished Ph.D. thesis, University of Southampton.

Schweingruber F. H. 1978 *Microscopic Wood Anatomy*.

Seymour, W.P. 1985 *The environmental history of the Preseli region of south-west Wales over the past 12,000 years*. Unpublished Ph.D. thesis, University of Wales.

Shi, Z. and Lamb, H. F. 1991 Post-glacial sedimentary evolution of a microtidal estuary, Dyfi estuary, west Wales, U.K. *Sedimentary Geology* 73, 227-246.

Shotyk, W. 1988 Review of the inorganic geochemistry of peats and peatland waters. *Earth Science Reviews* 25, 95-176**.**

Shotyk, W. 1996 Peat bog archives of atmospheric metal deposition: geochemical evaluation of peat profiles, natural variations in metal concentrations, and metal enrichment factors. *Environmental Reviews* 4, 148-183.

Shotyk , W., Cherburkin, A. K., Appleby, P. G., Fankhauser, A. and Kramers, J. D. 1997a Lead in three peat bog profiles, Jura Mountains, Switzerland. Enrichment factors, isotopic composition and chronology of atmospheric deposition. *Water, Air and Soil Pollution* 100, 297-310.

Shotyk, W., Norton, S. A. and Farmer, J. G. 1997b Summary of the workshop on peat bog archives of atmospheric metal deposition. *Water, Air and Soil Pollution* 100, 213-219.

Slater F.M. 1972 Contributions to the ecology of Borth Bog, Wales. I. General considerations. *Proceedings of the 4th International Peat Congress I-IV*, Helsinki, 277-288.

Smith, A. G. and Cloutman, E. W. 1988 Reconstruction of Holocene vegetation history in three dimensions at Waun-Fignen-Felen, an upland site in south Wales. *Philosophical transactions of the Royal Society London* B 322, 159-219.

Smith, D., Osborne, P. and Barratt, J. 2000. 'Beetles and evidence of past environments at Goldcliff' pp. 245–60 in M, Bell, A. Caseldine and H. Neumann (eds.), *Prehistoric Intertidal Archaeology in the Welsh Severn Estuary.* (CBA Research Report 120). London: Council for British Archaeology.

Smith, D. N. & Whitehouse, N. 2005. 'Not seeing the Trees for the Woods; a palaeoentomological perspective on Holocene woodland composition' pp. 136-161 in D. N. Smith, M. B. Brickley and W. Smith (eds.) *Fertile Ground: Papers in Honour of Professor Susan Limbrey* (AEA symposia no. 22). Oxbow books, Oxford.

Stace, C. 1991 *New Flora of the British Isles*. Cambridge, Cambridge University Press.

Stuiver, M. and Reimer, P. J. 1993 A computer program for radiocarbon age calibration. *Radiocarbon* 35, 215-230.

Stuiver, M., Reimer, P. J., Bard, E., Beck, J. W., Burr, G. S., Hughen, K. A., Kromer, B., McCormac, F. G., v.d. Plicht, J. and Spurk, M. 1998 INTCAL98 radiocarbon age calibration 24,000-0 cal BP. *Radiocarbon* 40, 1041-1083.

Taylor, J. A. 1973 'Chronometers and chronicles: a study of palaeoenvironments in west central Wales'. *Progress in Geography* 5, 247-334.

Taylor, M. 1981 *Wood in Archaeology*. Princes Risborough, Shire Publications.

Telford, R. J., Heegaard, E. and Birks, H. J. B. 2004 'All age-depth models are wrong: but how badly?' *Quaternary Science Reviews* 23, 1-5.

Tetlow, E., Jolliffe, C. and Hurst, S. 2007 'The insect remains from late Holocene peats beneath the River Clettwr, Ceredigion, Mid Wales'. *Quaternary Newsletter* 113, 40-45.

Timberlake S. 2003 'An archaeological examination of some early mining leats and hushing remains in upland Wales'. *Archaeology in Wales* 43, 33-44.

Timberlake, S. 2006 'Excavations of early mine workngs at Twllymwyn (Cwm Darren) and Erglodd, Ceredigion'. *Archaeology in Wales* 46, 79-86.

Tyers, I. 1999 *Tree-ring analysis of oak timbers from Peterborough Cathedral, Peterborough, Cambridgeshire: Structural timbers from the Nave Roof and North-West Portico*, Anc Mon Lab Rep.

Tyers, I. 1999 *Tree-ring analysis of the bell tower of the Church of St Mary, Pembridge, Herefordshire*, Anc Mon Lab Rep.

Tyers, I. 2004 *Dendro for windows programme guide* 3rd edn.

van Geel, B. 1978 'A palaeoecological study of Holocene peat bog sections in Germany and the Netherlands'. *Review of Palaeobotany and Palynology* 25, 1-120.

van Geel, B., Bohncke, S. J. P. and Dee, H. 1981 'A palaeoecological study of an upper Late Glacial and Holocene sequence from 'De Bochert', The Netherlands'. *Review of Palaeobotany and Palynology* 31, 367-448.

van Geel, B., Buurman, J., Brinkemper, O., Schlevis, J., Aptroot, A., van Reenen, G. and Hakbijl, T. 2003 'Environmental reconstruction of a Roman period settlement site in Uitgeest (The Netherlands), with special reference to coprophilous fungi'. *Journal of Archaeological Science* 30, 873-883.

Walker, M. J. C. 1993 'Flandrian vegetation change and human activity in the Carneddau area of upland mid-Wales'. In Chambers, F.M. (ed.), *Climate change and human impact on the landscape*, 169-183. Chapman and Hall, London.

Wedepohl, K.H. 1995 'The composition of the continental crust'. *Geochimica et Cocmochimica Acta* 59, 1217-1232**.**

West, S. Charman, D. J., Grattan, J. P. and Cherburkin, A. K. 1997 Heavy metals in Holocene peats from south west England: detecting mining impacts and atmospheric pollution. Water, Air, and Soil Pollution 100, 343-353.

Wilks, P.J. 1979 ,Mid-Holocene sea-level and sedimentation interactions in the Dovey Estuary area, Wales,. *Palaeogeography, Palaeoclimatology, Palaeoecology* 26, 17-36.

Williams-Parry, M. and Parker, L.A. 1939 ,A general investigation of Cors Fochno. Unpublished B.Sc. thesis, University of Wales,. In Slater F.M.,Contributions to the ecology of Borth Bog, Wales. I. General considerations. *Proceedings of the 4th International Peat Congress I-IV*, Helsinki, 277-288.