UNDER WHITLE PALAEOENVIRONMENTAL REPORT

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Summary

This report provides the results of palaeoenvironmental investigations for the 'Digging Deeper' project, based at Under Whitle farm in the Peak District. It includes work undertaken to identify and take samples from two locations within the study area and their analysis by geoarchaeological and palynological investigation.

The identification of potential palaeoenvironmental sampling sites within the study area included desk-based research and a walkover survey with trial auger work. This initial research identified a small area of wetland in the southern end of the study area as having the highest potential for further work, which will be referred to as 'Under Whitle Bog'. Detailed auger survey undertaken at Under Whitle Bog has established the nature of the stratigraphy of the site, which indicates that peat started accumulating at the site after colluvial action inhibited local drainage to form a small pool at the site of a spring. A core has been taken from the site for further palaeoenvironmental research. The results of initial radiocarbon dating analysis suggests that the core contains a sequence dating from the late-Bronze Age onwards, but the date model for the core suggests either a change in accumulation rate or truncation of the core in the late-9th century. The results of this dating analysis was used to guide the selection of samples for pollen analysis, ensuring that they were contemporary with archaeological remains identified by the Digging Deeper Project.

Geoarchaeological investigations of the lynchet involved careful examination of a test pit excavated over the feature (located in the northern end of the study area), taking an oriented (monolith) sample from the section of the test pit, and non-destructive geoarchaeological analysis. Observations in the field noted the presence of a possible palaeosol (old soil horizon) beneath the lynchet, a possible plough scar which cut through the palaeosol, and colluvial layers infilling the possible plough scar and laying on top of the palaeosol. The lack of any mixing of the deposits forming the lynchet appears to indicate it was formed by erosion of material from arable activities rather than being purposefully constructed. The non-destructive lab-based analysis included a detailed examination of the monolith's stratigraphy and magnetic susceptibility analysis. This analysis provided supporting evidence for the presence of a palaeosol beneath the lynchet, providing information to guide pollen analysis of the environment contemporary with the lynchet's formation.

Although pollen preservation was poor in the samples from the lynchet, samples from the core from Under Whitle Bog indicated excellent pollen preservation. A series of 11 samples were examined from the core from a depth of 44-72cm, roughly covering c.800 years from the late-9th to late-15th centuries. The results of this analysis indicated that the area surrounding Under Whitle Bog was open for the majority of the period investigated, with exceptionally high levels of arable indicators and low percentages of pastoral indicators. The cereal-type pollen identified in the samples are higher than any other pollen study of Medieval deposits identified in the Peak District and Midlands (cf. Hamerow et al. 2020). Proposed correlation with known historic events and climatic change have been hypothesised, linking fluctuations in woodland taxa and farming indicators within the core to the harrowing of the north, the Little Ice Age and the Great Famine/Black death.

The results of pollen analysis provide a good record of environmental change for a community undertaking arable activity at a high intensity. It is extremely rare to find a pollen sampling site

in such close proximity to medieval field systems, making the pollen record of Under Whitle Bog particularly sensitive to variations in arable activity. Despite the relatively localised pollen catchment of the site, its pollen record is very comparable with other studies, indicating that it is representative of environmental changes over the wider region. Although the c.50-100-year sampling interval achieved for the core from Under Whitle Bog is as good as many other sampling sites in the Midlands and Peak District, consideration should be given to seek additional funding to increase its chronological resolution. This could provide a key case study to understand the response of Medieval farming intensity to cultural and climatic variations in England.

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1. Introduction

Background

This report was prepared as part of ongoing community-led archaeological research by the 'Digging Deeper: the Origins of Whitle' project. It provides the preliminary results of palaeoenvironmental investigations of key locations within the study area, which comprises land owned by Under Whitle farm (see Figure 1), near Pilsbury in the Derbyshire Peak District (centred on OS NGR SK 107640). Landscape survey previously undertaken by Rylatt (2005) identified several standing earthworks of mixed date within the study area, including a possible building platform, hollow ways, enclosures, and a field system with lynchets, ditches, banks and areas of ridge and furrow. A more recent LiDAR survey by the Environment Agency Geomatics Group (EAGG 2016) noted additional features associated with those identified by Rylatt, with more extensive areas of ridge and furrow than previously appreciated. Archaeological excavation of some of these features by the Digging Deeper Project identified activity at Whitle dating to at least the Anglo-Saxon period (Parker Heath pers. comm.). In addition to the archaeological features noted above, Rylatt (2005) identified areas with potential for preservation of palaeoenvironmental remains, which could be used to reconstruct past environments. These potential sampling areas are shown in Figure 1 and comprise the main focus of the investigative work presented here.

Topographic and geological setting

Under Whitle farm is located at the base of the south western slopes of a glacially formed, u-shaped valley. Closer to the north east side of the valley, the River Dove marks the northern edge of the study area. The topography immediately to the south of the Dove is steep-sided and lies next to a relatively level plateau overlooking the Dove, which is in turn overlooked by the aforementioned south western slopes of the valley. The study area lies at the boundary between limestone geology to the north east of the Dove and sandstone, mudstone and siltstone bedrock beneath the valley floor and its western slopes.

Scope of the palaeoenvironmental research

As noted above, the current report focuses mainly on the three areas of palaeoenvironmental research potential identified by Rylatt (2005). It also provides the results of the geoarchaeological assessment of a lynchet in the northern end of the study area marked on Figure 1. Tasks undertaken for this work include:

- desk-based research
- fieldwork:
    - walkover survey
    - auger survey
    - palaeoenvironmental sampling
- lab-based assessment/analysis:
    - geoarchaeological assessment
    - radiocarbon dating (in progress)
    - pollen analysis

The methods used in these tasks are described below, followed by the results of this work.

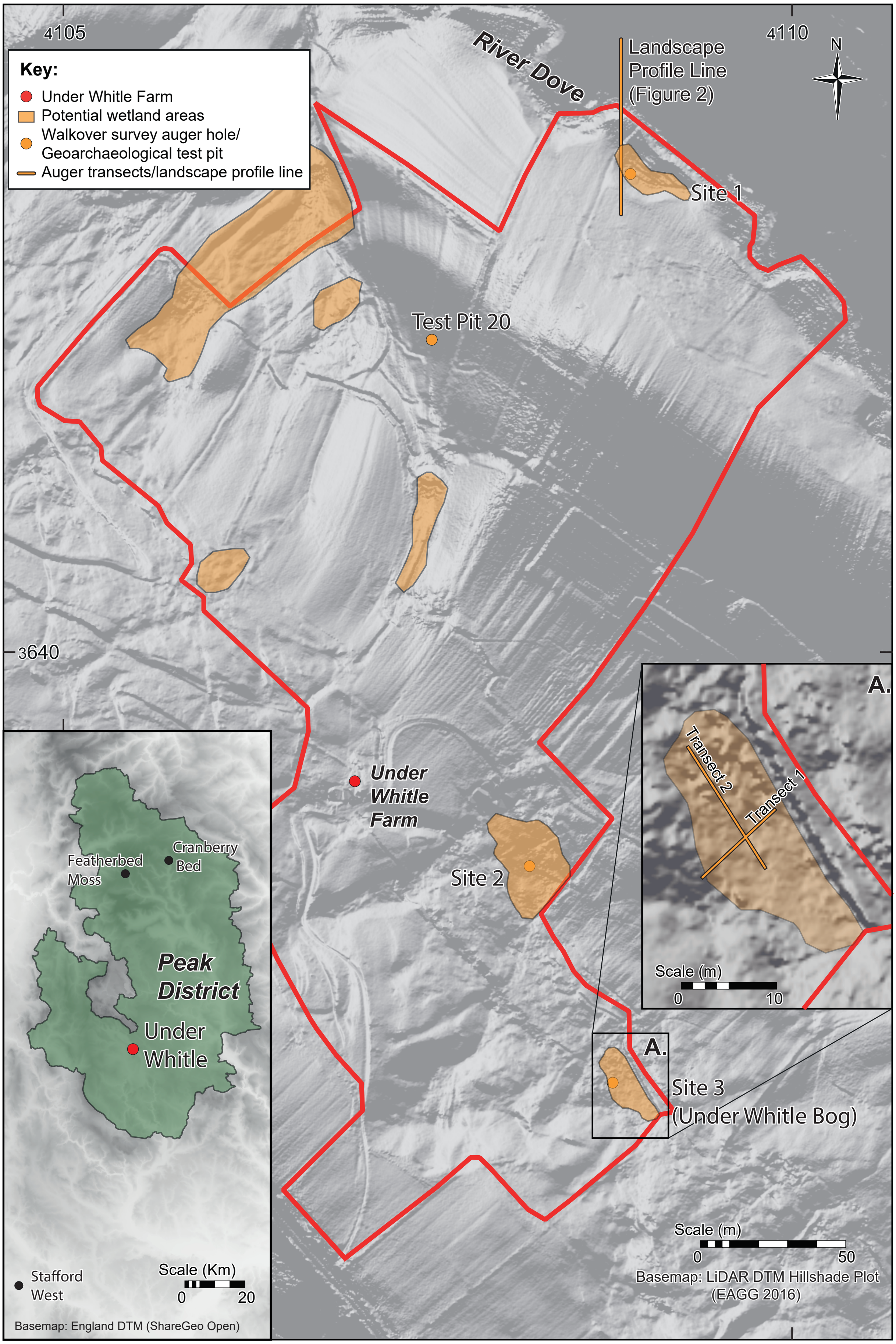


Figure 1. Map of the study area showing the locations of work areas and studies mentioned in the text

2. Methodology

Desk-based research

Prior to undertaking any fieldwork, a desk-based assessment of potential palaeoenvironmental sampling areas was undertaken, comprising a review of cartographic sources and previous research at Whitle, including:

- Ordnance Survey (OS) topographic maps
- British Geological Survey (BGS) geology maps
- Aerial photographs (Google Earth)
- LiDAR data (EAGG 2016)
- Rylatt's (2005) survey data

This process aimed to identify areas of waterlogged ground where conditions might be favourable for pollen preservation, for example peat deposits (cf. Moore et al. 1991: 14). The results of this work are provided in section 3.

Fieldwork

Walkover survey

Initial fieldwork for the project included a walkover survey, consisting of a rapid assessment of potential sampling areas identified during desk-based research. If initial observations suggested the potential for waterlogged sediments, an auger assessment was carried out to examine the nature of sub-surface deposits. Augering was undertaken using a 2cm wide window sampler (aka gouge auger) and the characteristics of deposits were recorded according to variations in depth, texture, colour and inclusions. The locations of augering sites were recorded using a handheld GPS (Garmin GPSMAP 64).

Auger survey

On identifying a site worth detailed investigation (site 3 – hereafter referred to as Under Whitle Bog - on Figure 1), an auger survey was undertaken to gain a more detailed understanding of its stratigraphy. This was carried out in the same manner as the walkover survey, examining the nature and depth of sub-surface deposits every 5-10m along two perpendicular transects across the site. The transects were laid out using hand tapes and their approximate locations were recorded using a handheld GPS. Variations in altitude of the bog surface were recorded using a level. The results of this survey were used to guide the selection of a sampling site within the bog for further research as described below.

Palaeoenvironmental sampling

Palaeoenvironmental samples were collected from two locations within the study area. A core sample was retrieved from Under Whitle Bog whilst an oriented (monolith) sample was taken from Test Pit 20. The sample from Test Pit 20 aimed to investigate the formation processes of a lynchet in the northern portion of the study area (see Figure 1). The core sample was retrieved by hand using a Russian corer (see Photograph 1), taking sequential samples of 50cm depth with at least 10cm of overlap between each sample. The individual core segments were then extracted into plastic guttering and wrapped in cling film to avoid contamination.

Before retrieving the oriented sample from Test Pit 20, the stratigraphy exposed in section was carefully examined and its constituent features and deposits were noted. The test pit was then recorded using a series of photographs to enable the construction of a photogrammetric model of the trench using Agisoft Metashape (see Photograph 2). This model was subsequently used alongside digital survey data, collected using a total station, to produce a section drawing of the trench. An oriented sample from the trench was retrieved by pushing two sections of plastic guttering into the exposed section. Their locations were recorded within the trench before a trowel was used to cut the monolith away from the section. The oriented samples were then wrapped in cling film to avoid contamination. Both the core and monolith samples were subsequently placed in cold storage for preservation.

Photograph 1 Sampling using a Russian corer at Under Whitle Bog

Photograph 2 Screen shot of an extract of the photogrammetric 3D model of Test Pit 20

Laboratory-based assessment and analysis

Geoarchaeological assessment

Both samples collected during fieldwork were subjected to a geoarchaeological assessment involving non-destructive techniques, allowing for the retention of material for future analysis as deemed appropriate. This included a description of the core undertaken in a controlled laboratory environment as well as magnetic susceptibility analysis.

The surface of each core and monolith segment was cleaned, photographed and the physical properties of the sediments recorded, making note of variations in texture (sand, silt and clay content), bedding, colour (using a Munsell chart) and inclusions. Full descriptions of the cores' stratigraphy are provided in Appendix B.

Magnetic susceptibility can provide information relating to deposit formation processes and sediment sources. This analysis was undertaken using a Bartington core logging sensor at 1cm intervals along each core and monolith segment.

Radiocarbon dating

Samples to assess the chronological range of the core retrieved from Under Whitle Bog, by radiocarbon dating were analysed by the Chrono Centre, Queen's University Belfast. The dating analysis was undertaken on four samples from organic-rich deposits within the core. The material for dating was taken from 0.5-1cm thick slices, targeting stratigraphic boundaries within the core. Attempts were made to obtain waterlogged plant remains from these levels, which would provide more secure dating material (cf. Walker *et al*. 2001, Bayliss *et al*. 2008), but were only found in sufficient quantity in the top sample (Simmons pers. comm.). Therefore, radiocarbon dating from the other three samples was undertaken on the humic acid content of the sediment from each level.

In addition to providing the chronology of the core, these allow an estimation of the variation in accumulation rates of deposits. These accumulation rates have been established by producing an age-depth model for the core through Bayesian analysis of the dates using "Bacon 4.0.5" (Blaauw & Christen 2011).

Pollen analysis

Pollen analysis was undertaken on the samples from both the Under Whitle Bog and Test Pit 20. This work aimed to reconstruct the environmental setting of Under Whitle and to understand the development of the landscape surrounding the sampling sites. Sampling locations within each core/monolith was guided by the results of radiocarbon dating and geoarchaeological analysis. In the monolith from Test Pit 20, a sample specifically targeted the potential palaeosols contemporary with the creation of the lynchet, whilst the pollen samples from Under Whitle Bog aimed to target deposits contemporary with the medieval archaeological remains identified during excavation.

The eight sub-samples selected for assessment were processed by Dr. Roderick Bale in the laboratory facilities of the Archaeology department at University of Wales Trinity St David, Lampeter, using the standard techniques described by Moore and Webb (1978), Faegri and Iversen (1989) and Moore *et al.* (1991). *Lycopodium* spore tablets were added during the chemical processing to enable the calculation of relative pollen and microcharcoal concentrations. Samples were mounted in silicone oil. Up to 300 pollen grains were counted from each sample using a light microscope at x400 and x1000 magnification. Pollen identification was undertaken using the keys provided by Moore and Webb (1978), Faegri and Iversen (1989) and Moore *et al.* (1991). Cereal-type pollen identification was undertaken using the criteria of Andersen (1979). Pollen nomenclature follows the classifications of Bennett (1994).

3. Results and discussion

Desk-based research

The review of geological data showed that no peat deposits had previously been recorded within the study area but did note the presence of alluvium on the banks of the River Dove, which can include waterlogged sediments and bands of peat. However, waterlogged ground was noted at the south eastern end of the study area in the 2020 OS explorer series map. Rylatt's (2005) survey had previously identified both of these areas as having potential for palaeoenvironmental sampling and also noted a third site closer to the farm buildings in the centre of the study area (see sites 1, 2 and 3 in Figure 1). Additional potential wetland was also identified as part of the current study, based on visible differences in vegetation type and colour on aerial photographs and depressions in the LiDAR data that might imply waterlogged ground. All of the potential wetland areas were examined during a walkover survey of the study area as described below.

Fieldwork

Walkover Survey

After initial examination of the potential sampling sites identified through desk-based survey, the three sites previously identified by Rylatt (2005) appeared to be the best candidates for further examination. The investigation of the stratigraphy of these sites indicated that all three contained waterlogged sub-surface deposits over 1m in depth that would likely preserve palaeoenvironmental remains (see Table 2). A summary description of each of these sites is provided below:

- **Site 1** – Based on the examination of aerial photographs, this site appeared to be a palaeochannel comprising a former meander of the River Dove. On examination of the site's location in the field, the palaeochannel seemed to be located on the highest of a sequence of terraces overlooking the River Dove (see Figure 2). Augering within this meander identified deposits to at least 1.3m below the ground surface, beyond which deposits were too stiff to penetrate with the hand auger. The deposits identified within the auger consisted of two mid-brown clay loam layers separated by a light grey-brown clay with mid-brown mottles. This clay deposit was almost identical to the lowest deposit encountered in the auger hole and was probably formed through the same depositional processes (possibly representing a mixture of colluvial and fluvial activity). Likewise, the similarity of the lower clay loam deposit and the upper topsoil might indicate the presence of a palaeosol (old soil horizon) buried by later alluvial processes. The position of the channel on the upper terrace of this glacially formed valley suggests that it was probably active as long ago as the late glacial or very early Holocene. Although the waterlogged deposits in this area may well provide palaeoenvironmental remains that could be studied further, the likelihood that they will contain deposits contemporary with the medieval archaeological remains at Under Whitle is low.

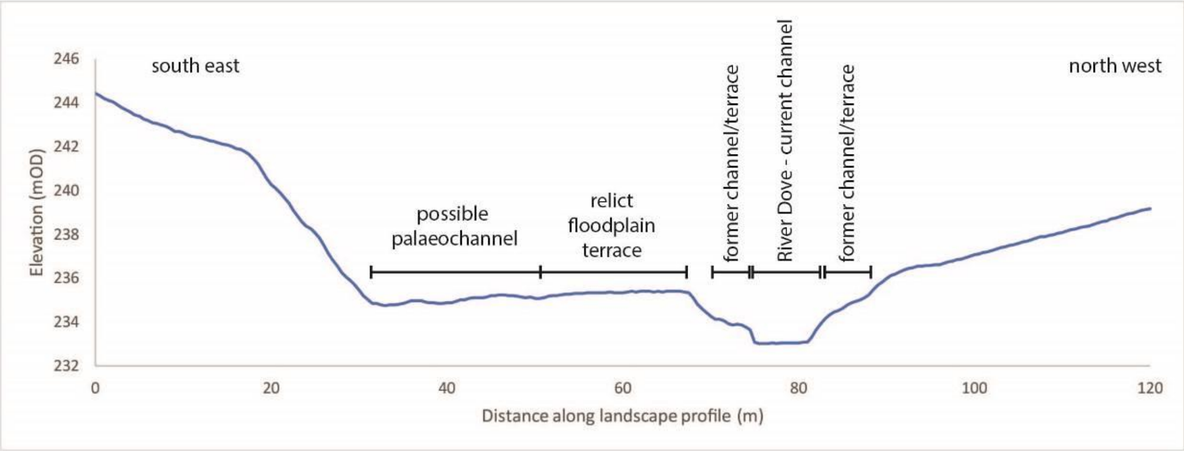


Figure 2 LiDAR Profile of the River Dove (location shown in Figure 1)

- **Site 2** – This wetland area is relatively small, measuring c.50x40m, and located near farm buildings central to the study area. During the site visit, the area underfoot appeared relatively wet, though there were no obvious drainage channels associated with the site. It is possible, however, that the neighbouring field system may have removed any evidence of natural drainage gullies in this area. An auger hole in the centre of this site indicated that its sub-surface deposits consist of an upper clay-loam topsoil overlying a series of clay deposits of varying colour. These deposits reached a depth of at least 1.24m, beyond which the deposits were too stiff for hand augering. It is believed this site represents either an area of impeded drainage or a small spring, where deposits have accumulated through colluvial activity. As with site 1, site 2 has the potential to contain waterlogged remains suitable for palaeoenvironmental analysis. However, organic fragments of plant remains were relatively rare within the deposits, which could lead to problems with radiocarbon dating owing to insufficient carbon 14 in the samples. Without radiocarbon dates it would not be possible provide a robust chronology for palaeoenvironmental analysis.

- **Site 3** (Under Whitle Bog) – This site is located at the very base of the western slope at the southern edge of the study area. The extent of this wetland area was not established during the walkover survey as trees growing across the site restricted access. This also hampered consideration of site formation processes without detailed study of the site's stratigraphy. However, targeted investigation with the auger established the presence of a peat deposit in the upper 0.33m of the site and a waterlogged mid-grey clay deposit to a depth of 1.67m below the surface, after which the auger hit a solid barrier, probably the underlying bedrock. Peat deposits of this kind are ideal for palaeoenvironmental reconstruction purposes, as they usually contain very well-preserved pollen together with organic remains suitable for radiocarbon dating. The peat deposit identified during augering was admittedly shallow in this case but demonstrated the potential for peat accumulation at the site alongside waterlogged clay deposits of probable colluvial origins.

After considering the research potential of each of these three sites, it was decided that site 3 (Under Whitle Bog) was the best candidate for more detailed research. The presence of peat deposits at this site is of great importance for providing both palaeoenvironmental evidence and material suitable for dating, so a robust chronological framework can be established. The softer clay deposits below this peat, which may also preserve pollen and other palaeoenvironmental evidence, would also simplify further auger survey and sampling in comparison with the other two sites. Full details of the additional fieldwork undertaken at this site are provided below.

Under Whitle Bog auger survey and sampling

Detailed descriptions of the stratigraphy encountered during the auger survey of Under Whitle Bog are provided in Table 3 and displayed in graphical form in Figures 3 and 4. The density of woodland growing over the site hampered access to some sections of the bog, but the two transects across the bog provide an approximation of the site's extent and a good indication of the deposits accumulating there. The surface topography of the bog is gently inclined, facing north east, with a much shallower gradient than the neighbouring valley side to the south west. Maximum auger depths varied across the site and in some instances, it was not possible to identify the depth of underlying bedrock because of the stiff nature of deeper sediments. However, it was possible to gain a broad understanding of the base profile of the bog. The results from Transect 1 indicate that the underlying bedrock is inclined to the north east at a slightly greater gradient than the current bog surface. The mudstone bedrock appears slightly degraded at the south west end of the transect, where it was soft enough to be penetrated by the auger. Fragments of this mudstone bedrock were often found in the lower sediments of auger holes (see below). On Transect 2, the depth of the underlying bedrock is relatively consistent across the transect, usually varying between c.1.3 and 1.6m. Auger hole 2.2 was an exception – here there appeared to be a hollow in the bedrock at least 1.3m deeper than at neighbouring augering sites. The deposits infilling the site have been categorised into three separate phases of development. These are described in detail below:

- **Phase 1 – spring deposits –** In the very lowest levels of auger holes 1.3 and 2.4 a series of olive coloured sand and silt deposits were observed that were very different to others noted across the bog. Significantly, these deposits were also very different to the mudstone bedrock observed in auger holes 1.1 and 1.2, and do not derive from this bedrock as a parent material. The coarse texture of these deposits is typical of materials brought to the surface through fissures in more porous bedrock, associated with the action of gravity springs located at the base of hillslopes (cf. Waters 1992: 215). The presence of a spring, as indicated by these deposits, explains the waterlogged nature of the ground at this location.

- **Phase 2 – colluvium –** Immediately above the olive-coloured sediments and mudstone bedrock, the lowermost deposit in each auger hole consisted of a dark or very dark grey clay or silt, often with decayed mudstone fragments of varying size. The poorly sorted nature of these deposits is consistent with colluvial material eroded from the neighbouring slope. This deposit was much thicker at the north east end of Transect 1 in auger hole 1.6. Although its full extent could not be established because of its stiff nature, the colluvial material at auger hole 1.6 appears to form a natural bank at this north eastern end. This bank may have caused water to pool within the bog in the past, inhibiting the decomposition of organic matter and initiating peat formation within the bog (see below).

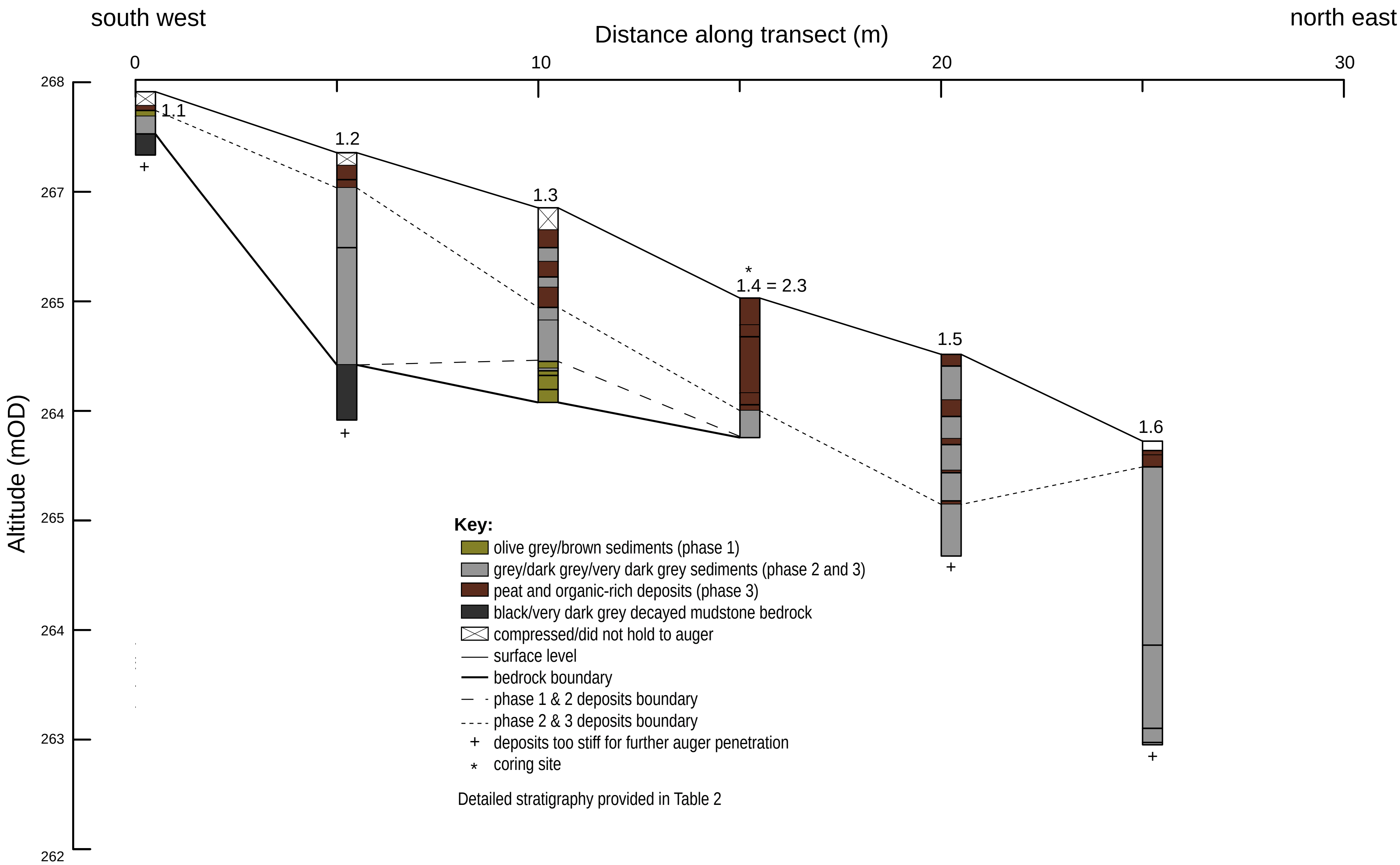


Figure 3. Under Whitle Bog - Transect 1 stratigraphy

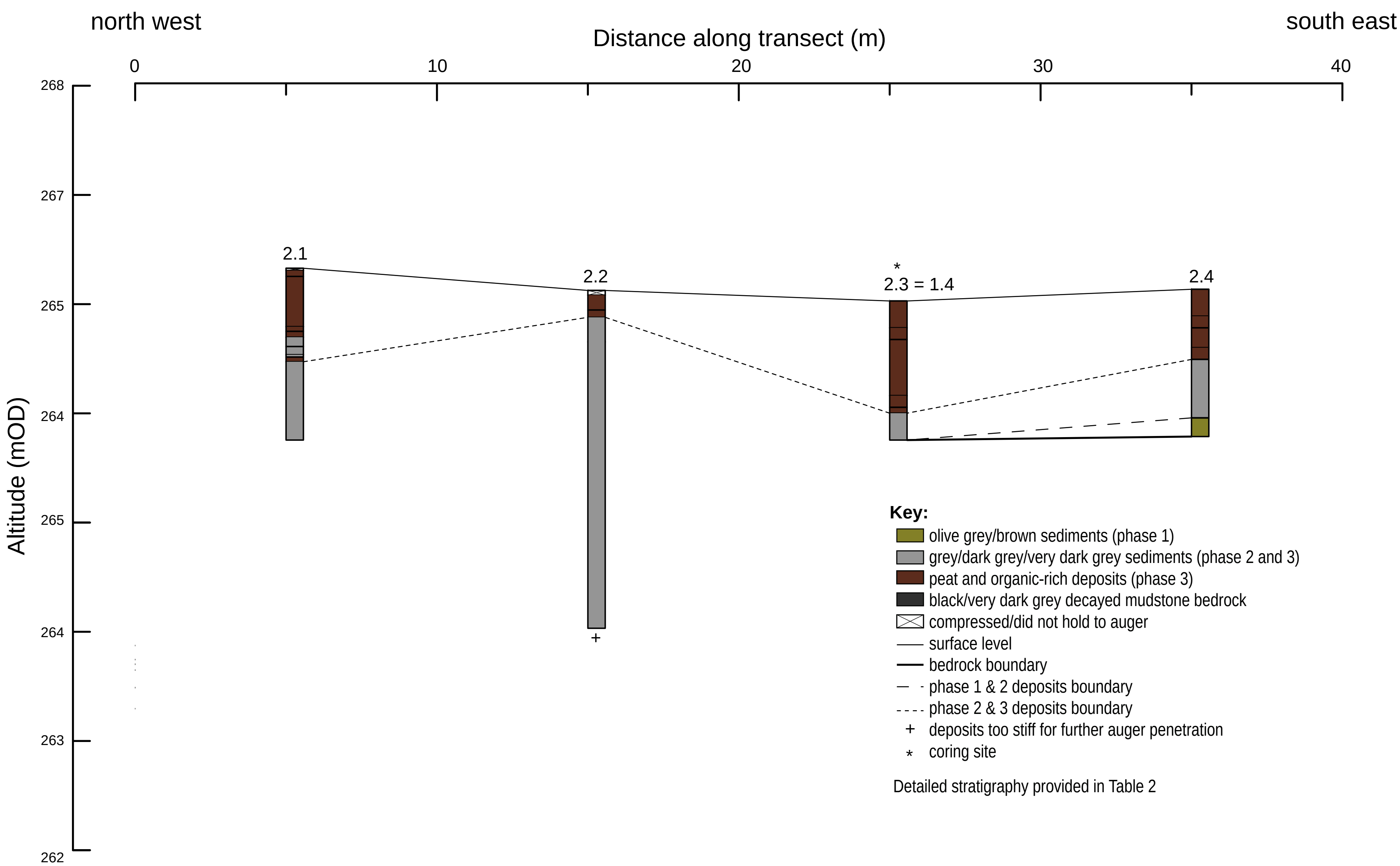


Figure 4. Under Whitle Bog - Transect 2 stratigraphy

- **Phase 3 – organic-rich sediments and colluvium –** The upper deposits within the bog consisted of a mixture of peat deposits, organic-rich silts and grey silt and clay deposits. The organic-rich silt and peat deposits suggest a degree of stability of the bog surface, which allowed the development of peat within a waterlogged environment. That said, the grey silt and clay deposit bear a degree of similarity to lower colluvial layers, suggesting continued erosion of material from the neighbouring valley slope. Given the lack of any waterlogged ground or peat deposits above the site on the valley side, it is likely that these peat deposits and organic-rich sediments developed in situ rather than being eroded and redeposited from elsewhere. The deposits towards the centre of the bog appear to have less grey silt/clay material, suggesting a lower influx of colluvial material and a greater degree of surface stability in that portion of the site.

A 95cm deep core from Under Whitle Bog was extracted from auger hole 1.4 at the centre of the bog. Although deeper areas of the bog might contain a longer time sequence of deposits, a core from this central area was selected because of the lower potential for accumulation of intrusive material eroded from outside of the bog, thereby providing material that is more secure for detailed analysis. The organic-rich nature of material at this site also provided a greater quantity of organic remains suitable for radiocarbon dating.

Test Pit 20

After detailed examination of the exposed section of Test Pit 20, five different deposits and a possible cut mark were observed. Descriptions of these deposits are provided in Table 4 and displayed in Figure 5. The possible cut [055], was observed near the eastern corner of the test pit, cutting through deposits (054), (056) and (057). The lower two of these deposits – (056) and (057) – are a reddish yellow clay and a brown clay with mudstone fragments, that appear to represent the natural sub-soil and possibly degraded mudstone bedrock respectively. Deposit (054) is a greyish brown silty clay, interpreted in the field as a possible palaeosol – i.e. the original soil horizon existing prior to the construction or development of the lynchet. The possible cut is c.13cm deep, of uncertain width and infilled with deposit (053), a brown silt-loam which overlies deposit (054). Deposit (052) is very similar in colour to deposit (053), which it overlies. Without further investigation, the nature of feature [055] is uncertain, but it could plausibly represent the trough of a plough scar cutting into the original hillslope. If these initial interpretations are correct, this suggests that the original slope of the hill was similar to the lynchet's current profile at a c.8° angle. The lack of mixing of sub-soil with deposits (052) and (053) implies that they have naturally accumulated through colluviation, rather than being deliberately placed or used as construction materials for the lynchet. This implies that the lynchet formed as a result of erosion rather than being deliberately built in its current form. The start of this erosional process is likely to relate to the onset of arable activity up-slope from the lynchet, as suggested by the possible plough scar [55]. Additional analysis of the monolith taken through these deposits will investigate this possibility further.

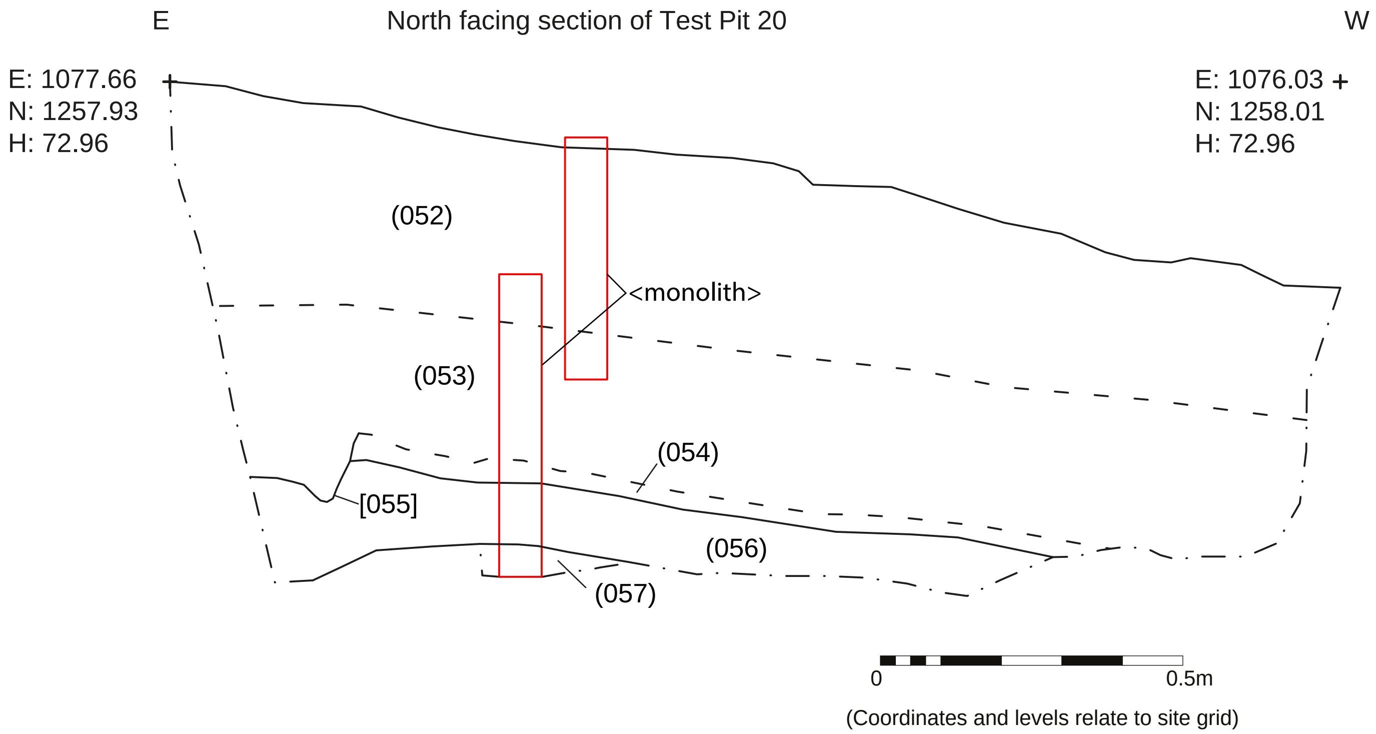


Figure 5. Section drawing and south facing photograph of Test Pit 20

Laboratory-based assessment and analysis

Geoarchaeological Analysis

Detailed examination of the samples under controlled conditions in the lab provided some additional data, which complemented what was observed in the field (see Tables 4 and 5). Although interpretations have not changed significantly as a result, the magnetic susceptibility analysis provided further information relating to the potential formation processes of the deposits identified (see Figure 7). These results are discussed separately for each sampling site below.

- *Under Whitle Bog core*

Unsurprisingly, the negative and very low magnetic susceptibility values obtained from the upper layers of the core are typical of values for peat and organic-rich sediments (cf. Gale & Hoare 2011: 208-209). The higher magnetic susceptibility values noted below a depth of 25cm could possibly relate to an increased proportion of colluvial material within the sediment (especially the spikes in the data), reflecting a greater intensity of erosion into the bog. However, it should be noted that the magnetic susceptibility readings are not particularly high and still fall into the expected range of values for peat (Gale & Hoare 2011: 208). The possibility that the deeper deposits contain colluvial material, while those in the upper layers are more secure, will, however, be taken into consideration when carrying out further analysis on this core.

- *Test Pit 20*

The magnetic susceptibility values obtained for the lower levels of the monolith provide an understanding of values expected for the parent sub-soil for deposits in this area, which fluctuate at around 0.7 SI. At a depth of 56cm, a spike in magnetic susceptibility values was observed corresponding with the top of the suspected palaeosol that was noted in the field. Although there are a number of factors that could cause an increase in magnetic susceptibility values (e.g. particle size, organic content, provenance of the sediment, or natural processes), these elevated values are consistent with the presence of a soil surface horizon, as pedogenic processes (i.e. soil formation) often cause an increase in magnetic susceptibility (cf. Gale & Hoare 2011: 213).

Other peaks in magnetic susceptibility values were observed throughout the monolith, but these do not correspond specifically with any other stratigraphic markers. Given the aforementioned range of influences on magnetic susceptibility, it is difficult to establish the cause of these raised values. The readings were certainly higher than that of the parent material for the deposits, suggesting that they have been enhanced in some way. One possible hypothesis is that the higher values represent episodes of reduced erosion that enabled pedogenesis to occur during of the formation of the lynchet. Another possibility is that the spikes in magnetic susceptibility represent the erosion and redeposition of magnetically enhanced topsoil during the gradual accumulation of material in this area.

These results provide a guide to the possible formation processes that may have influenced accumulation of deposits within the monolith. The magnetic susceptibility values in the lower sequence support the interpretation that a palaeosol has been preserved within the lynchet. This is highly significant in terms of further palaeoenvironmental research as it provided a horizon to target for pollen analysis. If well preserved, the pollen record from this layer might have reflected conditions contemporary with the onset of local arable farming that led to the formation of the lynchet. If pollen was preserved in the overlying colluvial deposits, this might have also provided a record of environmental changes whilst these deposits were accumulating. However, the results of pollen analysis (see below) indicated relatively poor pollen preservation, limiting the research potential of these deposits.

Radiocarbon Dating Analysis

The results of the radiocarbon dating analysis on samples from the core from Under White Bog are provided in Table 7 and are plotted against their depth within the core in Figure 8. These results suggest that the deposits within the core ranges from the late Bronze age (around the 11th century BC) onwards. Figure 8 shows a relatively constant rate of accumulation from the top of the core to the base of deposit 8 (a peaty silt deposit) to a depth of 72m (around the late-9th century), below which there appears to be a different accumulation rate. The change in accumulation rate appears to occur at or before the transition from lower sediments with decayed mudstone fragments to upper deposits without such inclusions. Therefore, the current results may suggest that the upper deposits have a higher accumulation rate to the lower sediments with mudstone inclusions, or conversely that a hiatus (break in accumulation or truncation) may have occurred in between the two sediment types. In lieu of the results of radiocarbon dating, pollen analysis of the core from Under White Bog targeted the sections of the core dating from the late-Anglo-Saxon/Viking to the later medieval period, reflecting the date range of archaeological material excavated by the Digging Deeper project. These results of the pollen analysis are provided in detail below.

Pollen Analysis

The examination of a sample collected from the top of the possible palaeosol in the monolith from Test Pit 20 (see above) indicated relatively poor preservation conditions. Some pollen grains and spores were identified in the sample, but these consisted of taxa that are known to be less susceptible to oxidation or corrosion (*Alnus glutinosa* – alder, *Cichorium intybus*-type – chicory-type (which includes dandelion), Corylus avellana-type (hazel-type) and *Polypodium* – polypody fern – cf. Havinga 1967) and occurred at a relatively low concentration. These factors indicate poor pollen preservation conditions for this sample and a limited research potential for the monolith taken from Test Pit 20. However, preservation conditions in all the samples from Under White Bog indicated excellent preservation conditions, as demonstrated by high pollen concentrations and a diverse range of pollen taxa that included those more susceptible to decay (cf. Havinga 1967). A total of 11 samples were analysed for Under White Bog. As sampling within the core was undertaken in retrospect of establishing a chronology of the core, it was possible to select samples with approximately 100 and 50 year sampling intervals, covering the mid to late-9th century to the end of the 15th century. A pollen percentage diagram was produced to show the results of pollen analysis from Under White Bog, displaying the data as a percentage of the Total Land Pollen (TLP) (Figure 9). This diagram has been split into vegetation zones based on visual examination of changes observed in the pollen data. Each zone is described in detail in Table 1 and a discussion of the environmental and archaeological significance of the different phases is provided below. Observations relating to anthropogenic indicators and habitat types are based on the work of Behre (1981), Clapham *et al*. (1987), Grime *et al.* (2007), Stace (2010) and Turner (1964).

Based on previous studies of pollen catchments of sampling sites, a small sized sampling site like Under White Bog under closed canopy would favour pollen from a local source area (cf. Jacobson & Bradshaw 1981; Caseldine 1981; Prentice 1985). However, given the very open conditions that are noted throughout the samples examined, a greater influx of pollen from regional sources is likely to have occurred. The presence of colluvial material in the bog would also suggest that that a portion of the pollen derives from plants growing locally (upslope), though the low proportion of damaged grains by splitting (indicative of transport – Moore *et al*. 1991: 168-170), would suggest limited influence from colluvial sources. Variations in pollen taxa that have poor dispersal mechanisms or are insect or self-pollinated would reflect localised changes in vegetation communities. For example, Cereal-type pollen has poor dispersal mechanisms, which often cause it to be underrepresented within pollen assemblages (cf. Vuorela 1973, Hall 1979). However, within the current dataset, Cereal-type pollen percentages are exceptionally high in comparison with the pollen assemblages noted at the majority of British pollen sampling sites (between c.4-12.5%). For example, in Hamerow et al.'s (2020) study of pollen sites dating to the medieval period in the Peak district and east midlands, Cereal-type pollen only rarely reach as high as the sample with lowest percentage of Cereal-type pollen at Under White Bog. It should be noted that some uncultivated grass types fall into the same size classification as Cereal-type pollen (cf. Andersen 1979) and could be misidentified as such. However, the Cereal-type pollen identified include examples of rye grains (*Secale cereale* – see Figure 6), which can be clearly differentiated from wild grass variants that fall within the size range of Cereal-type pollen (e.g. *Glyceria – Sweet-grass* – cf. Andersen 1979). Additionally, the presence of several potential arable indicators (*Achillea*-type – Yarrow-type, Chenopodiaceae – Goosefoot family, *Epilobium*-type – Willowherb-type, *Plantago major* – Greater Plantain) and presence of earthworks representing arable activity in very proximity to the sampling site, suggests that the high Cereal-type pollen at the site is genuinely reflective of arable activity in the neighbouring landscape. The pollen assemblage also contains a diverse range of anthropogenic indicators of pastoral activity and disturbance, such as *Cichorium intybus*-type, Caryophyllaceae (Pink family), *Lotus* (Bird's-foot-trefoils), *Plantago lanecolata* (Ribwort plantain), *Ranunculus acris*-type (Meadow Buttercup-type), *Rumex acetosella* (Sheep's Sorrel), *Rumex acetosa* (Common Sorrel), and *Urtica docia* (Common nettle) and very high microcharcoal concentrations.

It is very rare to be able to investigate the pollen signature of an area undertaking such intensive arable practices, as the majority of pollen sampling sites in Britain are located in upland settings away from the traditional focus of arable activities and core settlement areas (cf. Rippon et al. 2015: 56-7). The low percentages of Cereal-type pollen and other arable indicators at such sites also often make it very difficult to examine trends in arable activities. The high percentages of Cereal-type pollen identified at Under Whittle Bog means that the evidence for variation arable activity is more acute, enabling a more nuanced appreciation of trends in arable farming. Therefore, the environmental sequence at Under Whitle Bog provides an exceptional opportunity to examine the response to farming practices of a local community to environmental and cultural factors during the medieval period.

Table 1 Pollen zone descriptions

Pollen assembly zone	Core depths (cm)	Approximate date	Description
1	72-65	Late-9th – mid-11th century	Initial conditions indicate an open landscape with NAP (Non Arboreal Pollen) at c.65%, which largely consist of herb taxa. Herb taxa dominated by Poaceae (grass), with relatively high levels of Cereal-type, Cyperaceae (Sedge), *Plantago lanceolata, Rumex acetosa* and lower levels of Apiaceae (Carrot family), *Cichorium intybus*-type, Caryophyllaceae, Chenopodiaceae, *Lotus, Ornithopus perpusillus* (Bird's Foot), *Potentilla* (Cinquefoils*)*, Rubiaceae (Bedstraw family), *Rumex acetosa* and *Urtia Docia*. *Alnus glutinosa* (alder) pollen dominates woodland taxa, with lower levels of *Quercus* (Oak), *Corylus avellana*-type (Hazel type) and *Betula* (Birch), and rare grains of other tree taxa. Spore types include high levels of *Sphagnum* (moss) and relatively high *Pteropsida* (mono) indet (ferns). Fluctuations in woodland taxa later in the zone include reduced woodland in the mid to late 10th century (*Betula, Quercus, Alnus glutinosa*) alongside increased Cereal-type pollen and reduced *Cichorium intybus*-type, *Plantago lanceolata, Potentilla, Rubiaceae, Rumex acetosa, Rumex acetosella, Urtica docia, Pteridium aquilinum* (bracken) and Sphagnum spores. At a depth of 66cm (early to mid-11th century) an increase in woodland taxa (*Betula, Alnus glutinosa, Quercus, Fraxinus excelsior - Ash*) is noted alongside reduced percentages of many herb types (Poaceae, Cereal-type, Caryophyllaceae, *Lotus, Plantago lanceolata, Ranunculus acris*-type, *Rumex acetosa*).
2	65-57	Mid-11th – mid-13th century	Gradual decrease in woodland taxa (*Alnus glutinosa*, followed by *Betula*, then *Quercus*) from 66-60cm (c.150 years). A similar, gradual increase in Cereal-type and *Urtica docia* pollen observed, but other herbs show a more rapid increase (*Lotus, Plantago lanceolata, Rumex acetosa*)
3	57-44	Mid-13th – late-15th century	Extremely open conditions indicated by the continued low level of woodland pollen (18-19% of TAP). A slight increase in *Betula* and *Quercus* occurs alongside reduced *Alnus, Fraxinus* and *Salix* (willow). Herb taxa remain at a similar overall percentage from the end of the previous zone but show increased Cyperaceae and decreased *Plantago lanceolata* and *Urtica docia* percentages. Later in the zone, at a depth of 53cm (early to mid-14th century), a slight spike in woodland pollen (*Alnus glutinosa* and *Corylus avellana*-type) occurs alongside a trough in Cereal-type pollen. At the top of pollen the sequence, a slight increase in Cereal-type pollen Caryophyllaceae and *Urtica Docia* is noted alongside decreased percentages *Plantago lanceolata, Plantago major* and *Ranunculus acris*-type pollen.

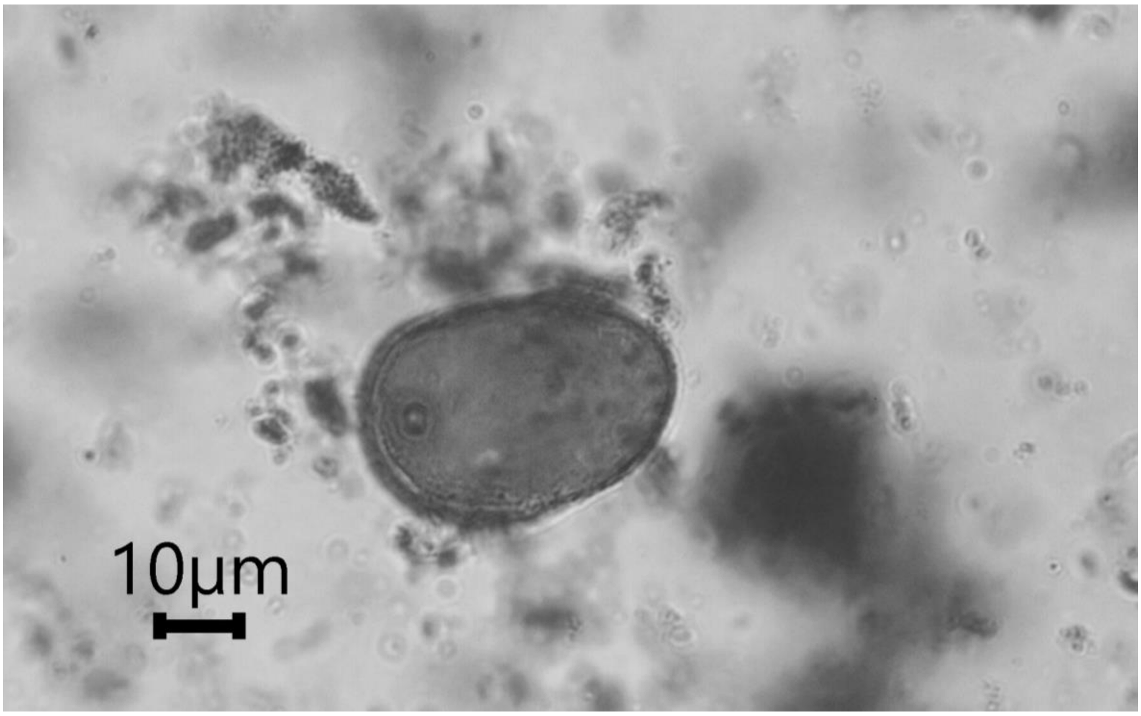


Figure 6 Greyscale image of a Rye (Secale cereale) pollen grain identified at a depth of 72cm in the Under White Bog core at x400 magnification

By the time the deposits analysed formed in the late 9th century, a substantial degree of woodland clearance had already been undertaken in the area surrounding under Whitle Bog. As noted above, the pollen record also indicates that the surrounding area was heavily used for arable farming and also indicates the presence of pastoral and disturbance indictors. Quite significantly, some of the pastoral indicators also include pollen taxa either insect or self-pollinated (*Cichorium intybus*-type and *Lotus*) are also present within the pollen assemblage, indicating that animal grazing also occurs in the immediate locality. However, the dominance of arable pollen taxa amongst the herb types suggests that arable activities are the main focus of farming. Evidence indicative of woodland clearance are observed in pollen zone 1 in the mid to late-10th century, accompanied by a possible localised shift in farming priorities in favour of arable activities. This is indicated by a cereal-spike and reduced pastoral indicators (*Plantago lanceolata* and *Rumex acetosa*) and taxa indicative of ruderal habitats (*Cichorium intybus*-type, *Urtica docia*). A significant reduction in *Sphagnum* spore percentages could also indicate reduced localised wetland indicators, possibly indicating a deliberate attempt to drain local wetland. These changes could theoretically be indicative of different farming regimes that might have been introduced after the cessation of Viking rule in Derbyshire and the Danelaw, after the unification of England by Æthelstan of Wessex in 927 AD. Conversely, the data could also reflect changes occurring at a much earlier date with the establishment of Danish rule over the area with the formation of the Danelaw in 886 AD. Unfortunately, the pollen sampling intervals in this part of the core too sparse to further explore these issues to assess whether either could be true.

Towards the end of pollen zone 1 in the mid-11th century (66cm), woodland regeneration is observed alongside reduced Cereal-type pollen and further declines in taxa indicative of pastoral and ruderal habitats. These changes suggest abandonment of settlement and/or farming land and a reduction in the intensity of the farming economy. Although the current model suggests a slightly earlier date, when considering the potential error from the mean date (Figure 8), these changes could be contemporary with harrowing of the North by the Normans. In response to revolt by northern lords, William the Conqueror implemented the devastation of the north of England, including Yorkshire, Cheshire, Staffordshire and Derbyshire, with measures that included burning crops, livestock and food (Pallister 1993: 3). This devastation was so severe that areas of Yorkshire were recorded as unproductive almost 60 years later by William of Malmesbury (Donkin 1978: 56-8). This devastation could well explain the changes observed in the pollen record at Under Whitle Bog at this time. Similar interpretations have been suggested for phases of woodland regeneration and agricultural decline on the north York Moors (Chiverell 1998). It is also possible that the reduced farming indicators and increased woodland percentages was caused by environmental factors. These changes occur alongside higher percentages of Cyperaceae (sedge) and the increased tree taxa consists largely of *Alnus glutinosa* pollen, both of which grow well in wetter conditions. Climate studies do not indicate any specific increase in regional precipitation levels at this time, indicating that the increase in wetland habitats could well be localised in nature. On the other hand, this increase in wetland pollen taxa could also be linked to the abandonment or neglect of drainage systems, which could well be compatible with the impacts of the harrowing of the North or indeed an unrelated and undocumented impact on settlement and agriculture in the area.

Irrespective of the possible cause of the changes observed in the mid-11th century, some of its effects appear relatively short-lived as c.50 years later, evidence for woodland clearance (Alnus glutinosa) and a resurgence in pastoral indicators (*Lotus, Plantago lanceolata, Rumex acetosa*) in pollen zone 2 is observed alongside a more gradual increase in arable indicators. This staged recovery in cereal-type pollen could, however, indicate that the arable economy suffered a greater impact by process or event which impacted the environment surrounding the sampling site. A reduction in woodland levels and increase in percentages of farming indicators in the late 11th or early 12th century is also observed at Featherbed Moss. In fact, the trends observed at Under Whitle Bog are remarkably similar to those of Featherbed Moss from the early 11th century onwards (see Figure 10). The data at Featherbed Moss shows higher percentages of woodland and heath and much lower Cereal-type pollen levels, but the AP/NAP ratios and fluctuations in farming indicators are very similar to shoes observed at Under Whitle Bog. This consistency across such a broad area suggests that the environmental record provided by the Under Whitle Bog pollen diagram are also reflective of changes occurring on a broader, regional level. The patterns in arable and pastoral indicators would, therefore, provide a useful comparison for studies of Medieval farming intensity on a national basis.

By the end of pollen zone 2 in the mid-13th century, the pollen record at Under Whitle bog indicates extremely open conditions with very high Cereal-type pollen percentages. One might be tempted to equate this time with the possible establishment of the field system of medieval terraced fields and ridge and furrow at Under Whitle, but we should not forget the fact that evidence for a high intensity of arable activity is present in the Under Whitle Bog from at least the late 9th century onwards. Domesday records indicate the presence of open fields and the use of the heavy mouldboard plough (which would create ridge and furrow field systems) by at least the late 11th century (Williamson 2022: 219), whilst archaeological evidence suggests the use of the mouldboard plough as early as the seventh century (cf. Thomas et al. 2016). In light of these facts, it is difficult to assess the origins of the Under Whitle field systems based on the pollen record. However, the extremely open conditions indicated by NAP values at Under Whitle at the end of pollen zone 2 would indicate that the majority of woodland had been cleared within the valley floor by this time. This would be consistent with conditions produced by the formation of the extensive field systems surrounding Under Whitle Bog, which could be treated as a *terminus ante quem* (latest possible date) for their establishment.

At the onset of pollen zone 3 in the mid-13th century, evidence for a possible climatic downturn and reduced pastoral activity is observed at Under Whitle Bog, as suggested by the increasing percentages of Cyperaceae pollen and reduced *Plantago lanceolata* respectively. These changes occur contemporaneously with evidence for climatic downturn during a global phenomenon known as the 'Little Ice Age' (LIA), which specifically included wetter and colder conditions in north-western Europe (Büntgen *et al*. 2011: 580). A similar response to this change in climate is observed at other pollen studies in the region, with increased wetland herb taxa at Stafford West (Hamerow et al. 2020) and increased heather at Featherbed Moss (Tallis & Switsur 1973; Figure 10) and Cranberry Bed (Hamerow et al. 2020) The heath increase could also be indicative of increased surface wetness and peat formation or could alternatively relate to the abandonment of land or changes in grazing regimes. The lack of any obvious reduction in Cereal-type pollen and other arable indicators at Under Whitle at this time suggests that the local population were able to successfully maintain arable output despite the challenges of climate change. However, elsewhere in the region at Cranberry Bed, reduced arable indicators and pastoral indicators are recorded (Hamerow et al. 2020), indicating a more severe impact on the farming economy during the LIA in other areas in the Peak District.

In the mid-14th century, a possible decline in settlement and arable activity is suggested by a small spike in woodland pollen (*Alnus glutionsa* and *Corylus avellana*-type) and a trough in Cereal-type pollen. At Featherbed Moss, no overall increase in woodland is observed, but a similar increase in *Alnus glutinosa, Corylus avellana*, and decreased percentages of Cereal-type, *Plantago* sp., *Urtica* sp., *Rumex* sp., Chenopodiaceae. These trends at Featherbed Moss indicates a decline in both arable and pastoral farming across a wider area beyond Under Whitle. At Featherbed Moss, the results were interpreted by Tallis and Switsur (1973) as possibly representing the impact of the Black death on the population and environment of the Pennines. But, given the potential margin of error of dating models for both Under Whitle Bog and Featherbed Moss, these changes could equally relate to the great famine of 1315-22, when successive crop failures and animal disease led to significant population decline across Europe (Jordan 1997). Similar, short-term impacts on the environment possibly caused by the Black death and/or Great Famine have also been noted by other regional studies of later medieval pollen sequences in Wales (Davies 2022) and are likely to be observed in the pollen record elsewhere in England and further afield.

Towards the end of pollen zone 3, in the late-15th century, changes in the composition of the herb pollen assemblage at Under Whitle Bog indicates a possible shift towards an increased focus on arable rather than pastoral activities, as indicated by increased percentages of Cereal-type pollen and decreased Plantago lanceolata and Ranunculus acris-type pollen. Intriguingly, the opposite trend is observed at Featherbed Moss, where decreased Cereal-type pollen coincides with increased pastoral indicators (*Plantago sp.*, Rumex sp.) (Tallis & Switsur 1973). These divergent results may indicate a move towards specialist farming practices in different areas of the landscape, with upland areas with poorer draining soils focussing on pastoral activities, while better draining soils of the Dove valley increasingly focussing on arable farming.

The results of the pollen analysis of the core from Under Whitle Bog have provided an impressive record of palaeoenvironmental change in the medieval period, with an unprecedented record of intensive arable farming practices in the Midlands and Peak District. The current c.50 and c.100-year sampling frequency of the core provides a good understanding of environmental change for c.800 years surrounding the site. However, the accumulation rate of the core shown in the age-depth model (Figure 8) indicates that an even greater degree of understanding could be attained, potentially achieving a sampling interval as low as c.10-13 years. This would provide an even greater grasp of environmental change for Under Whitle in relation to cultural and environmental changes during the medieval period.

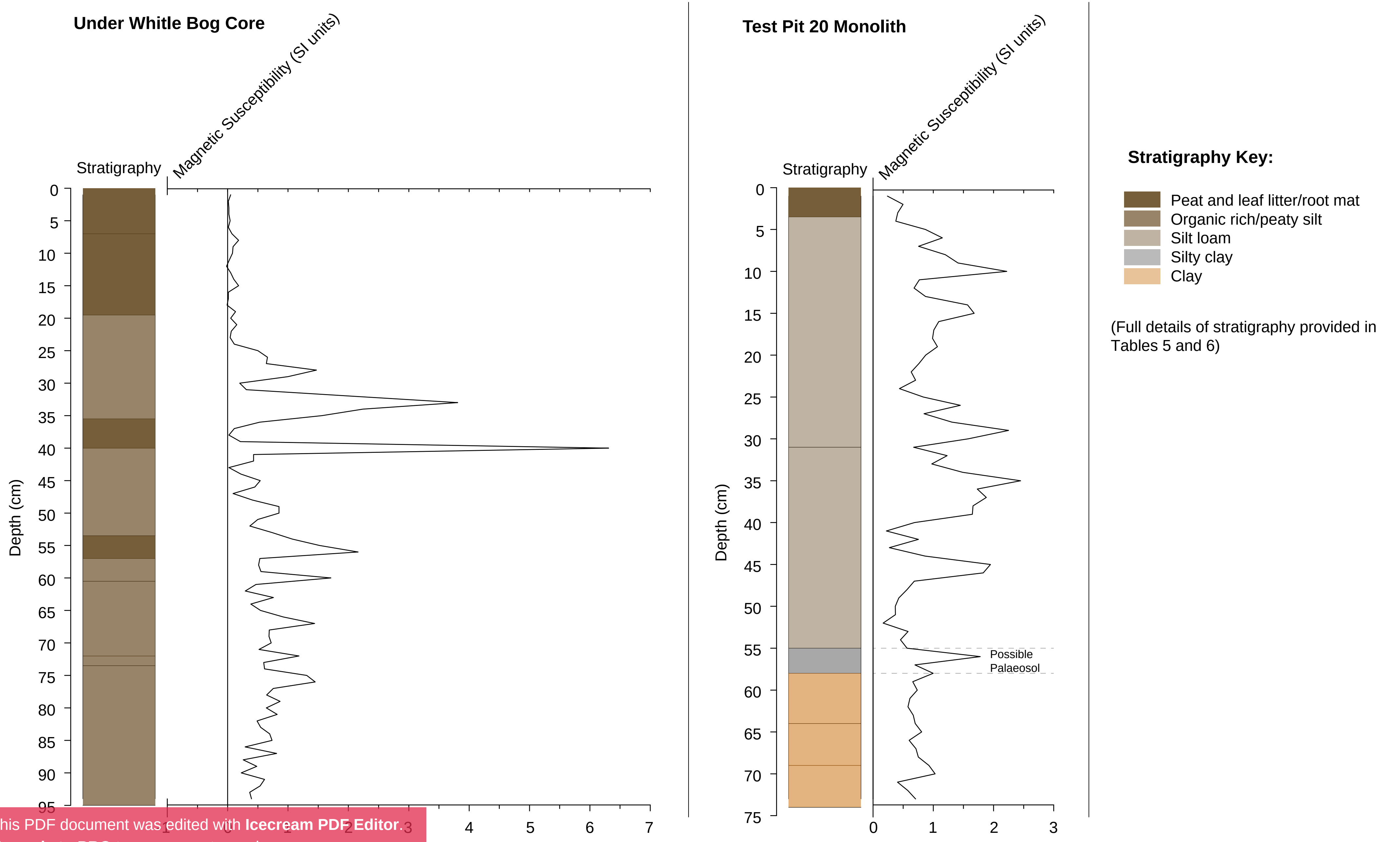


Figure 7. Magnetic susceptibility results from palaeoenvironmental samples

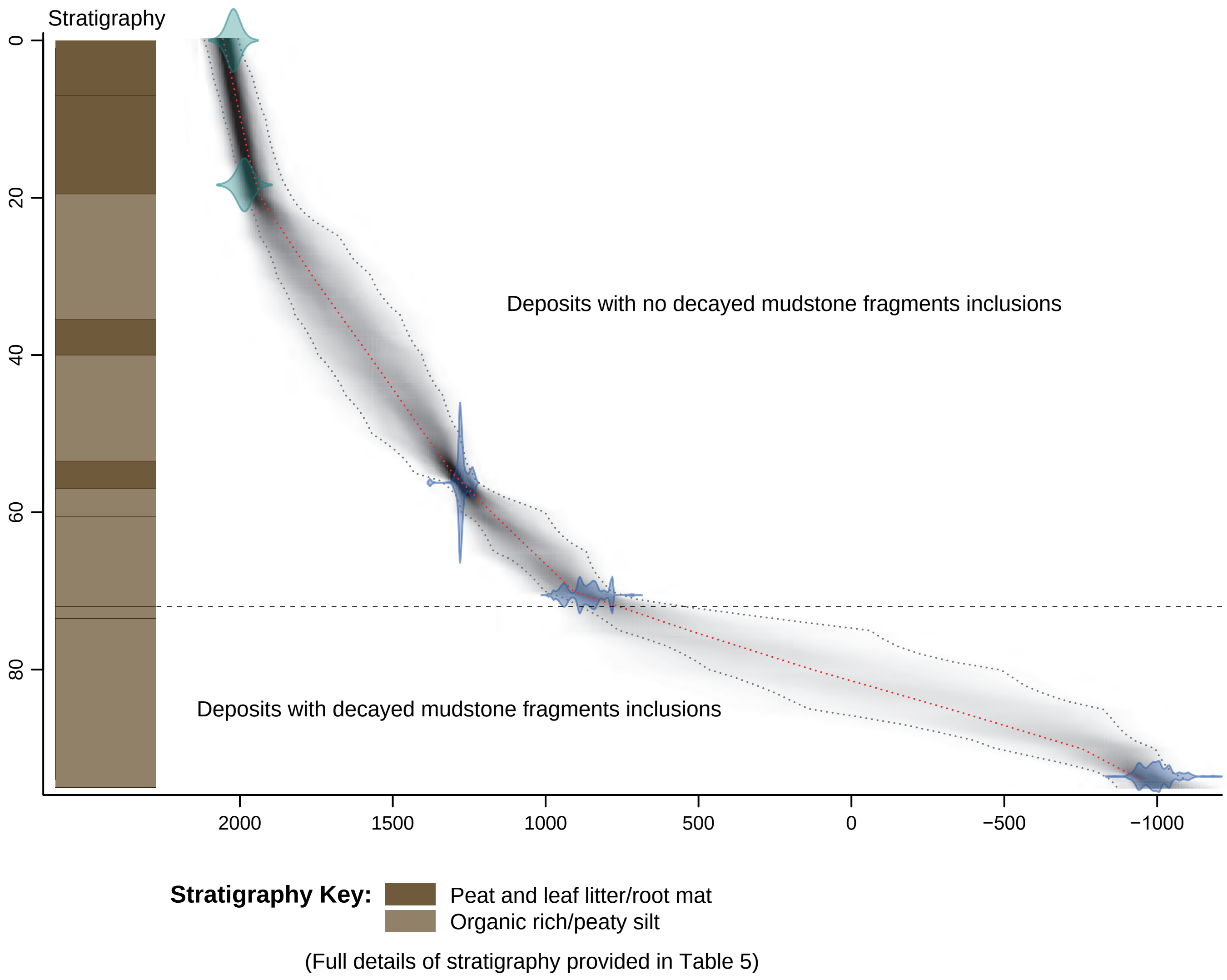


Figure 8. Bayesian age-depth model for the core from Under Whitle Bog

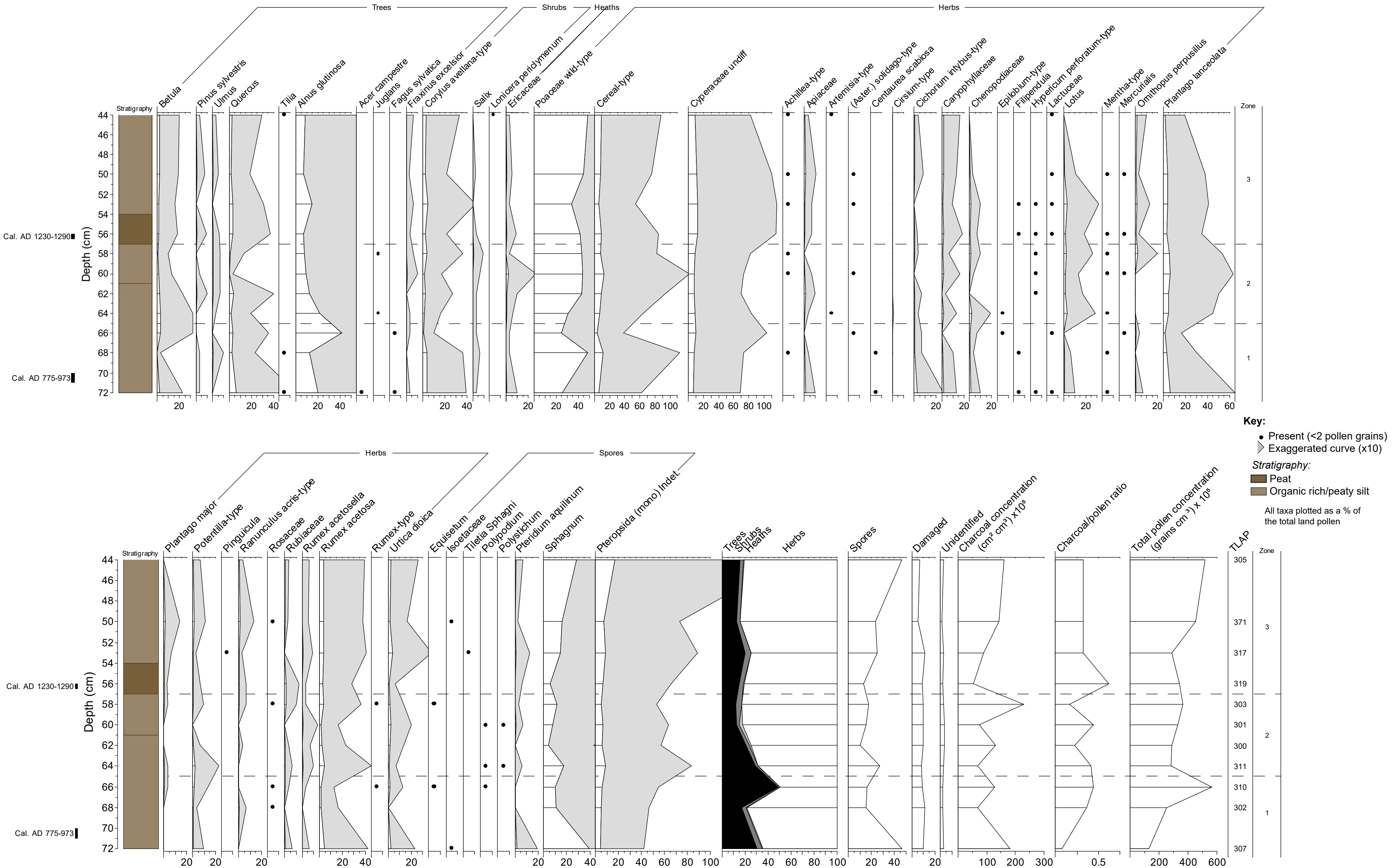
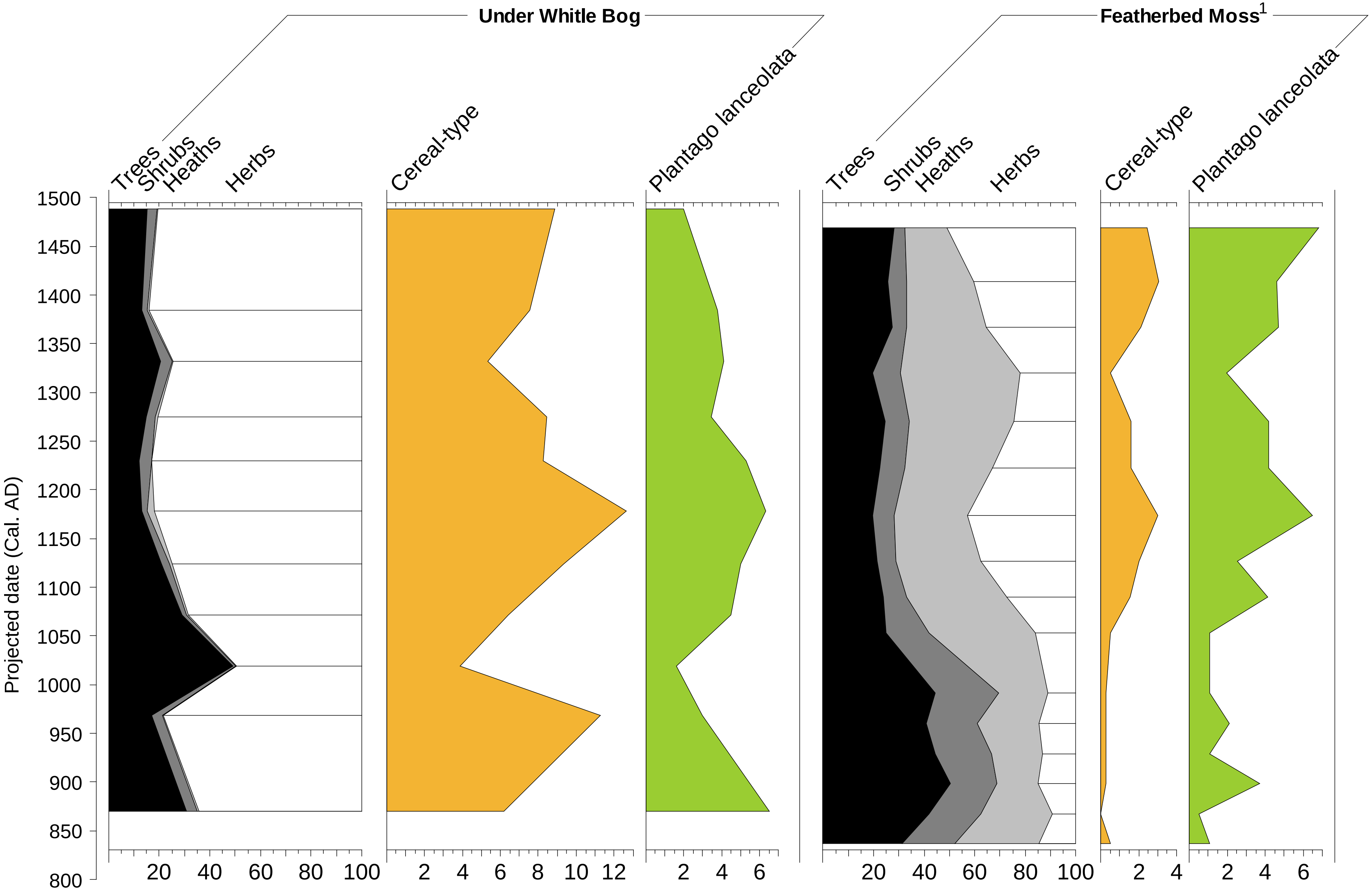


Figure 9. Under Whitle Bog pollen % diagram



1. Pollen data obtained from the supplemenetary material provided by Hamerrow *et al*. (2020). Projected chronology obtained from a depth model produced in Bacon 4.0.5 (Blaauw & Christen 2011) from the original radiocarbon dates provided by Tallis & Switsur (1973).

Figure 10. Comparative pollen summary diagrams for Under Whitle Bog and Featherhead Moss plotted against projected chronology

4. Conclusions

After undertaking desk-based research and preliminary fieldwork in the study area, it was decided to focus on Under White Bog for more detailed fieldwork and palaeoenvironmental sampling. This site had a greater depth of sediment than other potential wetland areas that were considered, together with evidence for peat formation within the bog. Detailed examination of the bog's stratigraphy through an auger survey has increased our understanding of the bog's formation processes. The stratigraphy of the site suggests that colluvial deposits have accumulated in this area over a gravity spring. When this colluvial material formed a natural bank on the north eastern portion of the area, it may have produced conditions suitable for peat formation alongside continuing colluvial activity. A 1m core has been collected from the site to provide material for detailed analysis. Radiocarbon dating has established that the core dates from the late-Bronze Age period onwards, with a possible shift in accumulation rates or truncation occurring in the mid to late-9th century.

Sampling for geoarchaeological analysis has also been undertaken on Test Pit 20, which aimed to establish the formation processes of a lynchet in the north of the study area. The examination of the deposits present within this test pit suggest that the lynchet formed as a result of erosion, probably stimulated by the onset of arable activity further up the slope. Preliminary geoarchaeological analysis of samples from this area supports the presence of a palaeosol surviving beneath the standing earthwork of the lynchet.

Pollen analysis unfortunately established that the possible palaeosol identified in test pit 20 had poor pollen preservation, limiting its research potential for additional palaeoenvironmental analysis. However, samples extracted from the core from Under White bog had excellent pollen preservation. The detailed analysis of this core focussed on examining deposits of more secure date, ranging from the late 9th to late 15th century, with sampling intervals of c.100 and c.50 years between successive samples.

The proximity of the ridge and furrow and terraced field system to our sampling site appears to have made Under White Bog particularly sensitive to fluctuations in arable activity. Its percentages of Cereal-type pollen in the medieval period are higher than any other pollen study identified in the Midlands and Peak District (cf. Hamerow 2020). Indeed, as far as the current research has been able to establish, these circumstances are unprecedented in northern England and the Midlands. The exceptionally high levels of Cereal-type pollen, make the detection of variations in the arable economy in relation to climate and cultural changes much clearer than at other sites, where Cereal-type pollen often only occurs rare, isolated grains. Although arable activity appears dominant in Under White Bog, evidence of pastoral activity and other indicators of disturbance and settlement are also present in its pollen record. Furthermore, it has been demonstrated that despite the relatively localised pollen catchment area of Under White Bog, its pollen record is also reflective of changes occurring at a broader scale across the region. Possible correlations with known historic events and climate change have been proposed, with episodes of woodland regeneration or downturns in the farming economy being linked with the harrowing of the north, the Little Ice Age and the Great Famine or Black Death. However, given the relatively fast accumulation rate of the deposits at Under White bog (Figure 8), a much finer pollen sampling resolution could be completed, achieving a potential sampling resolution of c.10-13 years (every 0.5cm). This would contribute even further to our understanding of palaeoenvironmental change in response to the cultural, political and climatic developments of the medieval period. Potential cultural or environmental phenomena that might have sort or long-term effects on this record include:

- The 'medieval warm period' (c.1000-1200 AD) and 'little ice age' (starting c.1300)
- The establishment and decline of the Danelaw and the unification of England under the kings of Wessex (late-9th to early 10th century)
- The Norman Conquest and the harrowing of the north (1066-70)
- The anarchy of Stephen and Matilda (1138-1153)
- The Great Famine (1315-1322)
- The Black death (1348-9)
- The Wars of the Roses (1455-87)
- The construction/establishment of archaeological features near the sampling site, including:
    - medieval settlement at Under Whitle (late Saxon onwards)
    - the ridge and furrow and terraced field system (currently undated)
    - Pilsbury Castle (believed to have been constructed either in the early Norman period or during the 'anarchy' – Langdon et al. 2006)

In short, further study of this palaeoenvironmental sequence would have the potential to make it a key case study for our understanding of medieval England. Therefore, it is strongly recommended that additional funding should be sought to increase the pollen sampling resolution for this core to at least c.20-25 years (1cm sampling interval), and higher if suitable funding can be sought. This should be accompanied by an additional phase of radiocarbon dating to strengthen the age-depth model for the site in between the levels currently dated. As it stands, the core from Under Whitle bog has provided a good record of palynological changes for an upland arable community in the peak district during the medieval period, but it has the potential to be an exceptional study of national importance.

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Appendix A - Field records

Table 2 Walkover survey - auger records

Auger site/ stratigraphic unit	Top depth (m)	Base depth (m)	Unit thickness (m)	Description
1.1	0.00	0.10	0.10	Brown clay loam – top soil.
1.2	0.10	0.12	0.02	Light grey-brown clay with mid-brown mottles
1.3	0.12	0.24	0.12	Brown clay loam – possible palaeosol
1.4	0.24	1.30	1.06	Light grey-brown clay with mid-brown mottles getting darker with depth. Rejection below[1]
2.1	0.00	0.06	0.06	Mid to dark brown clay loam – top soil
2.2	0.06	0.13	0.07	Mid grey clay with rare sandstone gravel fragments (<8mm)
2.3	0.00	0.58	0.58	Mottled orange and light grey-brown clay with rare organic fragments
2.4	0.58	1.24	0.66	Mid-dark grey sandy clay with rare organic fragments, becoming a darker shade of grey with depth. Hit stone at base
3.1	0.00	0.33	0.33	Dark brown peat
3.2	0.33	1.67	1.34	Mid grey clay with rare mudstone gravel fragments (<5mm). Hit stone at base

1. Auger could not penetrate any deeper due to the stiff nature of deposits.

Table 3 Under White Bog – auger survey records

Transect/ auger hole/ stratigraphic unit	Distance along transect (m)	Top depth (m)	Base depth (m)	Unit thickness (m)	Top altitude (mOD)	Base altitude (mOD)	Description	Phase
1.1.1	0	0.00	0.13	0.13	267.91	267.78	Did not hold/compressed	n/a
1.1.2	0	0.13	0.17	0.04	267.78	267.74	Very dark greyish brown (2.5Y 3/2) silty peat	3
1.1.3	0	0.17	0.22	0.05	267.74	267.69	Light olive brown (2.5Y 5/3) slightly sandy silty clay	2/3
1.1.4	0	0.22	0.38	0.16	267.69	267.53	Dark grey (5Y 4/1) slightly sandy silty clay with a few small organic fragments	2
1.1.5	0	0.38	0.57	0.19	267.53	267.34	Very dark grey (5Y 3/1) platy decayed mudstone. Rejection below	0
1.2.1	5	0.00	0.12	0.12	267.36	267.24	Did not hold/compressed	n/a
1.2.2	5	0.12	0.25	0.13	267.24	267.11	Dark grey-brown (10YR 3/2) peat	3
1.2.3	5	0.25	0.32	0.07	267.11	267.04	Very dark grey (5Y 3/1) peaty silt	3
1.2.4	5	0.32	0.87	0.55	267.04	266.49	Dark grey (5Y 4/1) clay silt with some organic fragments and rare decayed mudstone fragments	2
1.2.5	5	0.00	1.07	1.07	266.49	265.42	Very dark grey (5Y 3/1) clay silt with many small decayed mudstone fragments	2
1.2.6	5	1.07	1.58	0.51	265.42	264.91	Black (5Y 2.5/1) platy decayed mudstone. Rejection below	0
1.3.1	10	0.00	0.20	0.20	266.85	266.65	Did not hold/compressed	n/a
1.3.2	10	0.20	0.36	0.16	266.65	266.49	Very dark greyish brown (10YR 3/2) peat	3
1.3.3	10	0.36	0.49	0.13	266.49	266.36	Dark grey (5Y 4/1) silt with many organic fragments and rare small decayed mudstone fragments	3
1.3.4	10	0.49	0.63	0.14	266.36	266.22	Dark brown (7.5 YR 3/2) peat	3
1.3.5	10	0.63	0.73	0.10	266.22	266.12	Very dark grey (5Y 3/1) silty clay with some small decayed mudstone fragments	3
1.3.6	10	0.73	0.91	0.18	266.12	265.94	Very dark brown (10YR 2/2) peat with rare small decayed mudstone fragments	3
1.3.7	10	0.91	1.03	0.12	265.94	265.82	Very dark grey (5Y 3/1) silt with some organic fragments and a few small decayed mudstone fragments	2

Transect/ auger hole/ stratigraphic unit	Distance along transect (m)	Top depth (m)	Base depth (m)	Unit thickness (m)	Top altitude (mOD)	Base altitude (mOD)	Description	Phase
1.3.8	10	1.03	1.40	0.37	265.82	265.45	Dark grey (5Y 4/1) silty clay with rare organic fragments	2
1.3.9	10	1.40	1.46	0.06	265.45	265.39	Olive (5Y 4/3) sand	1
1.3.10	10	1.46	1.48	0.02	265.39	265.37	Dark grey (5Y 4/1) silty clay with rare organic fragments	1
1.3.11	10	1.48	1.53	0.05	265.37	265.32	Olive (5Y 4/3) sand	1
1.3.12	10	1.53	1.66	0.13	265.32	265.19	Olive (5Y 5/3) silty clay with rare organic fragments	1
1.3.13	10	1.66	1.77	0.11	265.19	265.08	Olive (5Y 4/3) sandy silt. Hit stone	1
1.4.1	15	0.00	0.25	0.25	266.03	265.78	Very dark brown (7.5 YR 2.5/2) peat	3
1.4.2	15	0.25	0.35	0.10	265.78	265.68	Very dark grey (5Y 3/1) organic-rich silt	3
1.4.3	15	0.35	0.87	0.52	265.68	265.16	Very dark grey (2.5Y 3/1) silty peat	3
1.4.4	15	0.87	0.98	0.11	265.16	265.05	Very dark grey (2.5Y 3/1) peaty silt with rare decayed mudstone fragments	3
1.4.5	15	0.98	1.03	0.05	265.05	265.00	Black (2.5Y 2.5/1) organic-rich silt	3
1.4.6	15	1.03	1.27	0.24	265.00	264.76	Very dark grey (5Y 3/1) clay silt with rare organic fragments and some small decayed mudstone fragments. Hit stone	2
1.5.1	20	0.00	0.11	0.11	265.52	265.41	Very dark brown (7.5 YR 2.5/3) peat	3
1.5.2	20	0.11	0.42	0.31	265.41	265.10	Laminated – grey silt (2.5Y 5/1) with black (2.5/N) silt and frequent organic fragments	3
1.5.3	20	0.42	0.57	0.15	265.10	264.95	Very dark greyish brown (2.5Y 3/2) silty peat	3
1.5.4	20	0.57	0.78	0.21	264.95	264.74	Dark grey (5Y 4/1) silt	3
1.5.5	20	0.78	0.83	0.05	264.74	264.69	Very dark grey (5Y 3/1) peaty silt	3
1.5.6	20	0.83	1.06	0.23	264.69	264.46	Dark grey (5Y 4/1) silt with many organic fragments and rare small decayed mudstone fragments	3
1.5.7	20	1.06	1.09	0.03	264.46	264.43	Very dark grey (2.5Y 3/1) peaty silt	3
1.5.8	20	1.09	1.34	0.25	264.43	264.18	Dark grey (5Y 4/1) silt with many organic fragments and rare small decayed mudstone fragments	3
1.5.9	20	1.34	1.38	0.04	264.18	264.14	Very dark grey (2.5Y 3/1) peaty silt	3
1.5.10	20	1.38	1.85	0.47	264.14	263.67	Dark grey (5Y 4/1) silt with many organic fragments and many	2

Transect/ auger hole/ stratigraphic unit	Distance along transect (m)	Top depth (m)	Base depth (m)	Unit thickness (m)	Top altitude (mOD)	Base altitude (mOD)	Description	Phase
							small decayed mudstone fragments . Rejection below	
1.6.1	25	0.00	0.08	0.08	264.72	264.64	Did not hold/compressed	n/a
1.6.2	25	0.08	0.13	0.05	264.64	264.59	Very dark brown (2.5Y 4/1) peat	3
1.6.3	25	0.13	0.23	0.10	264.59	264.49	Dark grey (Gley 1 5/10Y) organic-rich silt	3
1.6.4	25	0.23	1.86	1.63	264.49	262.86	Dark grey (5Y 4/1) clay silt with rare small decayed mudstone fragments	2
1.6.5	25	1.86	2.62	0.76	262.86	262.10	Greenish grey (Gley 1 5/10Y) clay silt with many organic fragments and some small decayed mudstone fragments	2
1.6.6	25	2.62	2.75	0.13	262.10	261.97	Dark grey (Gley 1 4/N) clay with many small decayed mudstone fragments	2
1.6.7	25	2.75	2.77	0.02	261.97	261.95	Dark grey (Gley 1 3/N) clay silt with many small decayed mudstone fragments. Rejection below	2
2.1.1	5	0.00	0.02	0.02	266.33	266.31	Did not hold/compressed	n/a
2.1.2	5	0.02	0.08	0.06	266.31	266.25	Very dark brown (10YR 2/2) peat	3
2.1.3	5	0.08	0.54	0.46	266.25	265.79	Grey (5Y 4/1) clay silt with some organic fragments and few small decayed mudstone fragments	3
2.1.4	5	0.54	0.58	0.04	265.79	265.75	Black (10YR 2/1) peat	3
2.1.5	5	0.58	0.63	0.05	265.75	265.70	Dark olive grey (5Y 3/2) peaty silt	3
2.1.6	5	0.63	0.72	0.09	265.70	265.61	Dark grey (5Y 4/2) clay silt	3
2.1.7	5	0.72	0.79	0.07	265.61	265.54	Grey (Gley 1 5/N) silty clay with many small decayed mudstone fragments	3
2.1.8	5	0.79	0.82	0.03	265.54	265.51	Dark grey (Gley 1 4/N) clay silt with some small decayed mudstone fragments	3
2.1.9	5	0.82	0.86	0.04	265.51	265.47	Very dark grey (Gley 1 3/N) organic-rich silt with some small decayed mudstone fragments	3
2.1.10	5	0.86	1.58	0.72	265.47	264.75	Dark grey (Gley 1 4/N) clay silt with many small decayed mudstone fragments. Hit stone	2
2.2.1	15	0.00	0.05	0.05	266.13	266.08	Did not hold/compressed	n/a

Transect/ auger hole/ stratigraphic unit	Distance along transect (m)	Top depth (m)	Base depth (m)	Unit thickness (m)	Top altitude (mOD)	Base altitude (mOD)	Description	Phase
2.2.2	15	0.05	0.21	0.16	266.08	265.92	Dark brown (10YR 2/2) peat	3
2.2.3	15	0.21	0.27	0.06	265.92	265.86	Very dark grey-brown (10YR 3/2) peaty silt	3
2.2.4	15	0.27	2.89	2.62	265.86	263.24	Dark grey (5Y 4/1) clay silt with many small decayed mudstone fragments and rare organic fragments. Mudstone fragments increase in size and frequency with depth. Rejection below	2
2.3.1	25	0.00	0.25	0.25	266.03	265.78	Very dark brown (7.5 YR 2.5/2) peat	2
2.3.2	25	0.25	0.35	0.10	265.78	265.68	Very dark grey (5Y 3/1) organic-rich silt	2
2.3.3	25	0.35	0.87	0.52	265.68	265.16	Very dark grey (2.5Y 3/1) silty peat	2
2.3.4	25	0.87	0.98	0.11	265.16	265.05	Very dark grey (2.5Y 3/1) peaty silt with rare decayed mudstone fragments	2
2.3.5	25	0.98	1.03	0.05	265.05	265.00	Black (2.5Y 2.5/1) organic-rich silt	2
2.3.6	25	1.03	1.27	0.24	265.00	264.76	Very dark grey (5Y 3/1) clay silt with rare organic fragments and some small decayed mudstone fragments. Hit stone	3
2.4.1	35	0.00	0.25	0.25	266.14	265.89	Dark brown to black (10YR 2/2 - 10YR 2/1) peat	3
2.4.2	35	0.25	0.36	0.11	265.89	265.78	Dark brown (10YR 2/2) silty peat	3
2.4.3	35	0.36	0.54	0.18	265.78	265.60	Very dark grey (Gley 1 3/N) organic-rich silt	3
2.4.4	35	0.54	0.65	0.11	265.60	265.49	Very dark grey (10YR 3/1) silty peat	3
2.4.5	35	0.65	1.18	0.53	265.49	264.96	Dark grey (Gley 1 4/N) clay silt	2
2.4.6	35	1.18	1.35	0.17	264.96	264.79	Olive (5Y 4/3) sandy silt. Hit stone	1

Table 4 Test Pit 20 Context descriptions

Context	Top depth (m)[1]	Base depth (m)[1]	Unit thickness (m)	Description
(052)	0.00	0.37	0.37	Layer – dark greyish brown silt loam with many mudstone fragments. Overlies (2). Interpretation: Probable colluvial layer
(053)	0.37	0.58	0.21	Layer – brown silt loam with many mudstone fragments. Underlies (1), overlies (3), fills [4]. Interpretation: Probable colluvial layer
[054]	0.58	0.63	0.05	Layer – greyish brown clay. Overlies (5), cut by [4]. Interpretation: Possible palaeosol
(055)	0.58	0.70	0.12	Cut – only visible on side of trench. Steep-sided with a pointed base, becoming near flat to the east. Cuts (3), (5) and (6). Filled by (4). Interpretation: Possible plough scar
(056)	0.63	0.78	0.15	Orange clay. Overlies (6), cut by [4]. Interpretation: Natural sub-soil
(057)	0.78	0.83	0.05	Reddish brown clay with many decayed mudstone fragments. Overlain by (5), cut by [4]. Interpretation: Natural sub-soil
1. Refers to depth below surface at the south eastern corner of the trench				

Appendix B – Laboratory records

Table 5 Under Whitle Bog core stratigraphy

Unit	Top depth (m)	Base depth (m)	Unit thickness (m)	Description
1	0.00	0.07	0.07	Very dark grey (10YR 3/1) leaf litter
2	0.07	0.20	0.13	Very dark brown (10YR 2/2) peat
3	0.20	0.30	0.16	Dark grey (10YR 4/1) organic-rich silt
4	0.355	0.4	0.045	Very dark grey (10YR 3/1) peat
5	0.40	0.54	0.14	Dark grey (10YR 4/1) organic-rich silt
6	0.54	0.57	0.03	Very dark grey (10YR 3/1) silty peat
7	0.57	0.61	0.04	Dark grey (10YR 4/1) organic-rich silt
8	0.61	0.72	0.12	Very dark grey (10YR 3/1) peaty silt
9	0.72	0.74	0.02	Grey (10YR 5/1) organic-rich silt with rare small (<2mm) decayed mudstone fragments
10	0.74	0.95	0.22	Very dark grey (10YR 3/1) organic-rich silt with some small (<5mm) decayed mudstone fragments

Table 6 Test Pit 20 monolith stratigraphy

Unit	Top depth (m)	Base depth (m)	Unit thickness (m)	Description
1	0.00	0.04	0.04	Dark greyish brown (10YR 4/2) root mat
2	0.04	0.31	0.27	Dark greyish brown (10YR 4/2) silt loam with many angular mudstone fragments (<15mm)
3	0.31	0.55	0.24	Brown (10YR 4/3) silt loam with many angular mudstone fragments (<15mm) frequent roots above c.0.42m
4	0.55	0.58	0.03	Greyish brown (10YR 5/2) silty clay with mottles of (7.5YR 3/2) dark brown clay
5	0.58	0.64	0.06	Grey (10YR 6/1) clay with mottles of (10YR 6/8) brownish yellow clay
6	0.64	0.69	0.05	Reddish yellow (7.5YR 6/8) clay with mottles of (10YR 6/1) grey clay
7	0.69	0.74	0.05	Brown (5YR 5/4) clay with many small (<3mm) decayed mudstone fragments – possible layer of decayed oxidised mudstone bedrock

Table 7 Radiocarbon dating analysis results

Lab ID	Depth (m)	Material	Radiocarbon age (BP)	Calibrated date (IntCal20)[1]
UBA-47483	0.18-0.19	3x Carex spp. seeds	MODERN (F14C: 1.0846 ± 0.0026)	Cal. AD 1957-2002[2]
UBA-47484	0.56-0.565	peat - humic content	745 ± 21	Cal. AD 1230-1290
UBA47847	0.70-0.71	Sediment – humic content	1167 ± 23	Cal. AD 775-973
UBA-47485	0.93-0.94	sediment - humic content	2839 ± 24	1105-917 Cal. BC

1. Calibrated using Bacon 4.0.5 (Blaauw & Christen 2011).
2. Calibrated using OxCal 4.4 – Bomb 21 NH1