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Palaeoenvironmental Assessment of Deposits at Bingley North Bog, West Yorkshire

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Non-technical summary

Sediment cores were taken from deposits present in the valley at Bingley North Bog. These cores established the depth and extent of the deposits present in the valley basin. The general sedimentary sequence consisted of up to 10m of lake muds capped by up to 3m of brown, fibrous peat with wood remains. This sequence indicates the presence of a lake in the valley basin, which infilled due to the deposition of sediment on the lake bottom. Subsequent colonisation of the emergent muds by fen woodland led to deposition of the brown, fibrous peat. Samples were extracted from the deposits for analysis of the sub-fossil pollen grains preserved in the sediment and also for the purpose of dating the sequence by radiocarbon. Samples were also examined to determine their main macrofossil constituents. Radiocarbon dates indicate that the lake had infilled by around 3,400 years before present (BP). The pollen record suggests sediment accumulation began very soon after the end of the last glacial cold spell in the British Isles, around 10,000BP. The pollen contained in the sequence demonstrates the presence of hazel dominated woodland around the site at around 9,000 years BP, followed by the expansion of oak and elm at 8,000 years BP, with lime and alder migrating into the area at around 6-7,000 years BP. Wood macrofossils demonstrate that alder fen carr became established on the mire surface. The pollen appears to record a continuous sequence of vegetational changes through the prehistoric period until the present day, although the presence of bands of mineral matter towards the top of the sedimentary sequence suggest soil disturbance and inwash, probably due to human activity on the slopes around the mire at some point in the Medieval period or later. The Neolithic Elm Decline (5,000BP) is recorded between 6.8-7.5m and a decline in lime (c.3,000-3,600BP) between 3.6-4.6m and both may represent early human disturbance to the local woodland. The first significant human disturbance in the form of increased representation of grass and other herbs is dated to around 3,100BP, suggesting an Iron Age date, but a gap in the record due to poor pollen preservation means that disturbance could have begun previous to this. The preservation of pollen tends to be good in the lake sediment but less good in parts of the fen peat, probably due to seasonal drying out of the fen during sediment deposition. It is recommended that further, more detailed pollen-analytical investigations be carried out at this site, due to the potential of the site to produce a high resolution record of vegetational change and to elucidate the role of human communities in modifying the environment around the mire from the Mesolithic (10,000BP) through to at least the Medieval period (1000BP).

1.1 Background to the work

The Centre for Wetland Archaeology was commissioned in advance of the A650 relief road project to investigate the deposits present at Bingley North Bog (Figure 1) (GR SE1063980 to 10703970). The project aimed to establish the extent of the wetland deposits at this site and to assess the potential of the sediments for palaeoecological investigation. Coring and sampling work was carried out over the 28th-29th September 1999. Following agreement with Babtie Group, no assessment work was carried out at Bingley South Bog.

2.1 Methods

Two transects (north-south and east-west) were taken across the bog to establish the depth and character of the deposits using an Eijkelkamp gouge auger. Coring intervals were closest at the edge of the mire where stratigraphic variability was highest. Large pools of standing water and an unstable bog surface in the central area of the mire prevented the collection of borehole data at this location. Borehole stratigraphy was recorded in the field and is displayed graphically using the TSPPlus program (Waller *et al.*, 1995). Boreholes are prefixed by the site designation code 'BB'. Samples for pollen analysis were taken at 1.00m intervals and also at the locations of stratigraphic changes, from BB5 which was the deepest organic sequence identified. Sample sizes were approximately 1cm^3. The limitation imposed on the method of sample retrieval meant that insufficient sample sizes could be retrieved for assessment of presence of coleoptera, molluscan or ostracod biota. Pollen preparation followed standard techniques including KOH digestion and acetylation (Moore *et al.*, 1991). Pollen counting continued until a total of 150 dry land pollen grains had been identified although this total except where pollen concentrations were low (see below). Pollen nomenclature follows Moore *et al* (1991), with the modifications suggested by Bennett *et al.* (1994). The 125 μm sieve residues were examined for plant macrofossil content and the possible presence of charcoal. Wood macrofossils were recovered from some of the cores, mounted as thin sections and identified using the key by Schweingruber (1990).

Samples for radiocarbon dating were extracted from three horizons in the upper section of the core. Sediment from the gyttja was not sampled for dating due to the absence of macrofossil remains in the core and subsequent problems of 'hard water' error with bulk samples of this type of sediment (Bayliss *et al.*, 1999; Day, 1995). The samples were sent to Beat Analytic Inc., Florida, USA, for analysis using the AMS process (Accelerator Mass Spectrometry). Dates were calibrated using the cubic spline fit method (Talma & Vogel, 1993).

3.1 Results

The location of the transects are given in Figure 1. The transects are displayed in Figures 2 & 3, with written descriptions given in Appendix 1. The results of the pollen analyses (fig. 3) are given as a pollen diagram produced using the TILIA and TILIA*GRAPH computer programs (Grimm, 1991) and are tabulated in Appendix 2. The pollen diagram has been divided into five local pollen assemblage zones (lpaz) on the basis of pollen stratigraphical changes. These zones are provided to facilitate discussion and should be regarded as highly tentative in the light of the large sampling intervals. Details of sample macrofossil assessment are given in Appendix 3.

3.1.1 Basin profile and extent of mire deposits

The basal profile of the basin is asymmetrical (Fig. 2). At the northern end, the basin sides slope steeply, from less than 0.40m depth (BB2) to 9.00m (BB3) over a distance of *circa* 15 metres. The dry stone wall across the bog in this area thus effectively defines the northern extent of mire deposits, with cores from north of this line (BB1-2) containing no evidence of the brown, fibrous peat or gyttja encountered elsewhere. The situation is slightly different at the southern end, where there appears to be a subsidiary basin. BB6 forms a stratigraphic divide between the deep basin containing gyttja and brown peats and the marl deposits, which are only found in BB7. The present extent of undisturbed mire deposits extends to BB8, with cores BB9-10 consisting either of dist bed deposits or marginal, mire edge sediments.

On the east-west transect (Fig. 3), BB12 defines the eastern limit of the mire deposits with brown, fibrous peat onto basal gravels at 1.35m depth. The basal profile then rises, with only 0.52m of sediment recorded from BB13, before gradually falling from 4.50m (BB14) to 8.40m (BB16) over a distance of some 60m. The western edge of the mire is not clearly defined and appears to extend west beyond the present railway line.

The extant bog vegetation effectively delimits the deepest areas of the mire. The total length of the mire deposits *sensu stricto* along the north-south axis is *circa* 300m and *circa* 150m along the east-west axis, although the western limit of the deposits is unknown. It is possible that the mire may have originally extended up to the edges of the slope on the northern and eastern edges of the basin, with subsequent peat wastage/drainage/cutting reducing the current extent of the deposits at the fringes.

3.1.2 The general sedimentary sequence

The uppermost deposits identified consisted of up to 0.30m of black, peaty top soil. This often contained fragments of coal/coke and other minerogenic remains, some of clearly anthropogenic origin, such as brick. In the areas of the bog where standing water was present, this topsoil was absent, and grey-black coarse, organic clay formed the most recent deposit, in places over a metre in thickness. A grey, sandy clay layer up to 0.20m thick was the next layer identified at 0.20-0.60m depth in most of the cores, although this layer tended to be absent from the cores further toward the mire centre (eg. BB10-11). Up to 3.00m + of brown, fibrous moderately humified peat with frequent wood macrofossils, monocotylodonous and *cf. Phragmites* remains formed the next unit identified (Appendix 3). This deposit attains its maximum thickness towards the northern end of the mire, with 4.20m recorded in BB3. Wood macrofossils from this unit were recovered from BB3 (3.80m), BB4 (3.10m) and BB5 (2.60m) and all identified as *Alnus*.

This peat trends into a green-brown gyttja (*ie.* gelatinous lake mud), up to 10m thick. Plant stem and leaf remains were present toward the top of this deposit, but were not encountered more than 1.00m below the transition with the brown peat. There was no change in the physical characteristics of the lake mud observed down to the base of the sequence. This was confirmed by assessment of the sample macrofossil content (Appendix 3). The only area of the bog where a different stratigraphy was recorded was at the southern end of the mire, where creamy-white marl was recovered from between 2.75m and 4.10m depth in BB7. Marl is clay rich sediment, formed in base enriched conditions, when lime is precipitated from the water by certain aquatic plants, such as *Potamogeton* spp. (pondweeds) (Lowe & Walker, 1997). The appearance of the basal profile (Fig.2) in this area of the bog, and the fact that marl was not observed in any of the other cores, suggests that this area may have been hydrologically separate from the main basin prior to the later encroachment of fen over both.

Due to the limitations of hand augering, the contact between the gyttja and the basal deposits was not observed, except in BB3 where grey clay-silts were recovered. The Babtie Group geotechnical borehole data indicates that silts, clays and eventually gravels underlie the organic sediments, with a maximum thickness of 16m gravels reported. The presence of shallow deposits of sandy silt on the eastern side of the bog in BB13 may reflect the presence of ephemeral channels across the bog surface; a stream currently flows into the north-eastern corner of the bog.

3.1.3 Radiocarbon Dating

The results of the radiocarbon dates are given in Table 1. The samples provided sufficient carbon for reliable measurement and all analytical steps went normally (D.Hood, pers.comm.)

3.1.4 Palynology

The skeleton pollen diagram (Fig. 4) is zoned and described on the basis of changes in the pollen stratigraphy. Samples were generally taken at 1m intervals, and also at the transition from peat to gyttja at 4.40m. The sediment between 12m and 13m was not recovered successfully and there is a subsequent gap in the sampling interval at this point. Percentages are of total land pollen (tlp) unless otherwise stated.

Pollen preservation and relative concentration tended to be good in the gyttja deposit, with the majority (75%+) of pollen grains in a good-very good state of preservation. The situation was slightly different for samples from the brown, fibrous peat. Although this peat was only moderately humified and preservation of macrofossils was good, some of these samples contained relatively low concentrations of pollen, and preservation from these samples could be classed as moderate to poor (<25% grains well preserved). The pollen present was often affected by processes that had resulted in their degradation and corrosion. High concentrations of Pteropsida (monolete) indet. (fern spores) in some of these samples (3.60m, 1.60m) might suggest that these samples were affected by differential preservation, since fern spores tend to be resistant to decay (Havinga, 1984) and are thus often selectively preserved when sediment is exposed to processes that can damage or destroy other palynomorphs.

Two of the samples (2.40m and 4.40m) contained only very sparse numbers of grains. In the case of that from 4.40m, high concentrations of Ascospores were observed on the pollen slides. These were identified as *Diporotheca* sp., typically found in eutorphic-mesotrophic mires (van Geel, 1978). It seems likely that any pollen originally present in the sediment at these levels has been destroyed due to drying out of the mire surface, either at the time of deposition or in a subsequent period. Good preservation of plant macrofossils with correspondingly poor pollen preservation is not without precedent. Although the watertable is sufficiently high in fen peat forming environments for much of the year to enable macrofossil preservation, pollen is released during the spring-summer months when the watertable is often temporarily low, which can lead to selective oxidation of the pollen grains (Barber pers.comm cited in Brown, 1996).

Sample	*Radiocarbon Age (Yrs.BP±1σ)*	*Calibrated Range (2σ)*	*$^{13}C/^{12}C$ Ratio*
0.60m (Beta-136031) Material/Pretreatment: (peat) acid/alkali/acid	**1120±40**	**Cal.AD 815-840 & Cal.AD 855-1005**	**-28.6 o/oo**
3.00m (Beta-136032) Material/Pretreatment: (wood) acid/alkali/acid	**3100±40**	**1435 Cal.BC-1280 Cal.BC**	**-28.6 o/oo**
4.40m (Beta-136033) Material/Pretreatment: (peat) acid/alkali/acid	**3410±40**	**1770-1620 Cal.BC**	**-28.4 o/oo**

Table 1: Radiocarbon Age Estimates (Standard-AMS) for Bingley Bog Samples.

3.1.5 Sample storage and curation

All pollen sample residues are stored in glass vials and wood thin section slides are stored at the Centre for Wetland Archaeology, University of Hull. Samples used for macrofossil assessment have been discarded following examination.

3.1.6 Sample description

BING1 14.8-12.5m *Corylus avellana*-type – *Betula*

This zone reflects the presence of birch-hazel dominated scrub/woodland around the sampling site, with *Betula* increasing to 50% at 13.5m and *Corylus avellana*-type at 76% at 14.8m. Low percentages of *Salix* (willow) may suggest some willow was also present, since this pollen type is poorly dispersed (Bradshaw, 1981). *Pinus* percentages of less than 25% are insufficient to infer local stands of pine (Bennett, 1984) and probably represent long distance transport. Percentages of Poaceae (wild grass family) are low (maximum 5% at 13.5m) and other herb pollen is sparse, suggesting that there was little open ground present locally. The only other herb pollen recorded is that of *Filipendula* (meadowsweet), and is probably referable to *F.ulmaria*, a species commonly found at the wetland-dryland transition and tolerant of some shade (Grime *et al.*, 1988).

BING2 12.5-10m *Corylus avellana*-type – *Betula* – *Pinus* –*Ulmus*- *Quercus*

The arrival of the thermophilous woodland taxa of *Ulmus* (elm) and *Quercus* (oak) is recorded at 11.5m, reflecting the migration of these taxa into the area. Herb pollen remains low and sporadic suggesting that dense canopy woodland was present around the site and open areas remained of limited extent. *Betula* decreases to 12% at the opening of the zone with the arrival of oak and elm, but displays a recovery at 10.5m, at which point there is a corresponding fall in *Corylus avellana*-type from over 70% in the previous sample to 34%. *Pinus* percentages increase to 30% at the same level; high enough to infer the presence of local stands of pine. Both pine and birch are competitively inferior to other forest trees and are initially supplanted by the deciduous taxa of oak and elm. Their subsequent recovery at the top of the zone is notable and may suggest increasingly wet conditions and an expansion of these trees onto marginal soils around the basin. This hypothesis can only be supported by higher resolution sampling to enable biostratigraphic continuity.

BING3 10-7.25m *Alnus* – *Quercus* –*Corylus avellana*-type – *Tilia*

This zone sees the rise of *Alnus* (alder) to over 30% by the top of the zone and the arrival of *Tilia* (lime) in the local woodland, increasing to a maximum of 10%. *Quercus* and *Ulmus* also continue to increase steadily to 17% and 10% respectively, as these arboreal taxa completed expansion into their effective ecological niches. The pronounced falls in *Betula* and *Pinus* at the opening of the zone reflects the exclusion of the light-demanding taxa of birch and pine from the surrounding woodland. Reductions in *Corylus avellana*-type to less than 30% may reflect its status as an understorey shrub, or its presence on marginal soils on the lake edge. Pollination will be suppressed under these conditions. Herb pollen again remains low, although a single grain of *Plantago lanceolata* (ribwort plantain) is recorded along with a small increase in Cyperaceae to 1% at 7.5m. Ribwort plantain is a light-demanding herb rarely found in wetland contexts, and suggests open areas somewhere within the pollen catchment. It would, however, be inappropriate on the basis of only a single grain to suggest this reflects anthropogenic disturbance.

BING4 7.25-4m *Alnus* – *Corylus avellana*-type - *Quercus* – *Tilia*

The opening of this zone is defined by a decline in *Ulmus*, after which this taxon remains low and does not increase to more than 3 % of TLP. *Tilia* and *Alnus* are also reduced to 4% and 16% respectively, whilst *Corylus avellana*-type increases to over 50% at 5.80m. Elm and lime woodland is evidently reduced in extent, with hazel taking advantage of this to increase in abundance on the areas vacated by these taxa. There is little response from herb pollen although low values for Cyperaceae and Poaceae are recorded. Further changes in the composition of the vegetation around Bingley Bog are evident at the top of the zone. *Alnus* attains its highest value of 66% at 4.6m, at which point *Alnus* wood macrofossils are present. These events represent a transition from open water to semi-terrestrial fen-carr communities, dominated by *Alnus glutinosa*. *Corylus avellana*-type falls sharply to 11% and *Ulmus* is reduced to less than 1% at the same level. These reductions may be the result of a reduction in pollen source area, associated with the local growth of dense alder carr (Jacobson & Bradshaw, 1981; Janssen, 1959).

BING5 4-0.60m *Alnus*- *Poaceae* –Pteropsida (monolete) indet.

Alnus percentages are reduced at the opening of the zone, but remain moderately high at 30-50%. *Tilia* disappears from the pollen record at this point, whilst *Quercus* (4-5%), *Betula* (5-6%) and *Corylus avellana*-type (15%) percentages suggest the persistence of limited extents of mixed deciduous woodland. Both Poaceae and Cyperaceae increase at the opening of the zone to 9% and 18% respectively, and Pteropsida (monolete) indet. shows a sudden increase to 40%TLP+spores. Other herb pollen typical of open meadow and possibly slightly disturbed habitats is recorded, with Lactuceae undiff., Cardueae/Asteroideae, *Plantago lanceolata* and Apiaceae all present. Small peaks in *P.lanceolata,* Lactuceae undiff. and Caryophyllaceae are observed at 1.60m. The environment became more open during BING5, with lime no longer present locally or extra-locally and populations of alder reduced. Of the other woodland taxa, probably only oak remained, although in the form of either patchy local woodland or more extensive oak stands at some distance from the sampling site. A low peak of *Salix* at 1.60m suggests some willow was growing on the bog surface. The increase in Pteropsida (monolete) indet. indicates an expansion in ferns, although this may also be related to the preservational problems with the peat above 4.6m. These changes may be associated with a shift in local hydrology, possibly related to increased run-off associated with anthropogenic clearance of dryland woodland. A reduction in *Alnus* to 30% at 0.60m is accompanied by an increase in *Corylus avellana*-type to 25% and a peak in Poaceae undiff. of 20%: these changes probably represent a thinning of the local alder carr, allowing increased influx of pollen from taxa such as hazel, which would have been growing outside the wetland.

3.1.7 Establishing a chronological framework for the Bingley Bog pollen diagram

Although there are a number of palynological studies available for the Yorkshire lowlands, none of them provide a complete Holocene dated sequence. A diagram from Tadcaster (Bartley, 1962) has no radiometric date estimates; those from the Bog at Roos in Holderness (Beckett 1981) and Star Carr in the Vale of Pickering (Day, 1995; Day & Mellars, 1994) provide good Late-glacial/early Holocene dated sequences; whilst a recent diagram from Askham Bog, near York, provides early-mid Holocene palaeoenvironmental data, although some of the radiocarbon dates from this sequence may be unreliable (Gearey & Lillie, 1999). The Gransmoor sequence from the Hull valley provides detailed information on Late-glacial vegetation change (Walker *et al.*, 1993). The palaeoecological study at nearby Bingley South Bog provides some good local information, although the Late-glacial/early Holocene pollen diagram from this site has no absolute dates (Keen *et al.*, 1988).

The lowermost zone from Bingley North Bog pollen diagram (BING1) clearly belongs to the early Holocene rather than the Late-glacial. Data derived from coleoptera indicates that temperatures began to rise rapidly after 10,500BP and by 9, 800BP were comparable to those of the present day (Atkinson *et al.,* 1987). There is no evidence of the characteristic vegetational communities of the Late-glacial interstadial and Loch Lomond stadial, which are recorded in BB1-4 in the Bingley South Bog pollen diagram (Keen *et al.*, 1988). Likewise, the sequence seems to post-date the spread of birch dominated woodland, dated to around 10,100BP at Roos (Beckett, 1981). The expansion of *Corylus avellana*-type occurs at around 9,400BP at Star Carr (Day & Mellars, 1994) and mixed *Corylus avellana*-type – *Betula* woodland was dated to around 9,900BP at Roos (Beckett, 1981). The accumulation of the organic sediments recovered at Bingley North Bog should therefore be assigned to around 9-9500BP or perhaps a little earlier.

The sediment accumulation rate is clearly very rapid. In the absence of a radiometric chronology for the lower section of the sequence, tentative age estimations may be made on the basis of average sedimentation rates (Webb & Webb, 1988) and simple linear interpolation from an estimated age for the base of the sequence of 9,500BP and the radiocarbon date of 3,410±40BP at 4.40m. *Ulmus* and *Quercus* have reached significant percentages at 11.5m in BING2, although due to a gap of 2 metres in the sampling strategy, the specific depth for the initial rise in these pollen types is not evident. The rise in *Quercus* is dated to 8605±50BP (OxA-8261) at Askham Bog (Gearey & Lillie, 1999), although this may be somewhat too old due to a possible 'hard water' error. Working from linear interpolation, the opening of BING2 should fall around 8,000BP, which is therefore broadly consistent with this age.

The *Alnus* rise, which marks the opening of BING3, is a ubiquitous feature of Holocene pollen diagrams in the British Isles: dates of 7720±50BP (Gearey & Lillie, 1999) and 7640±85BP (Day, 1995) are recorded at Askham and Star Carr respectively. However, the spread of *Alnus* does appear to have been erratic both spatially and temporally, with dates of between 5,000 and 9,000 BP recorded (Bennett

& Birks, 1990). A date of 6-7,000BP is suggested for the *Alnus* rise at Bingley on the basis of linear interpolation.

The decline in *Ulmus* pollen, which occurs between 6.8m and 7.5m, is probably the 'classic' Elm Decline, which is a well established eco-cultural benchmark in pollen diagrams from the British Isles (see, for example, Peglar & Birks, 1993 or Edwards, 1988 for discussion) and effectively defines the Mesolithic-Neolithic transition (Smith & Pilcher, 1973), with dates clustering at around 5,000BP (Roberts, 1989). The date for the Elm Decline at Bingley may be estimated at 5-5,300BP using linear interpolation, and is therefore consistent with this age range.

The transition from open water to fen environment represented by the change in the stratigraphy from gyttja to brown fibrous peat at 4.40m and is dated to 3410±40BP (1770-1620 Cal.BC) (Beta-136031). The next date of 3100±40BP (1435-1280 Cal.BC) (Beta-136032) is from *Alnus* wood recovered at 3.00m: if both these dates are accepted as reliable, then this corresponds to an extremely rapid accumulation rate of 450cm/10^3yr between 4.40 and 3.00m, which is an improbably high rate for a deposit of this kind. There is no reason to suspect that either date is in error. Although possible 'younging' of the sample from 4.40m by rootlet penetration cannot be ruled out, the most likely explanation is that the *Alnus* macrofossil recovered from 3.00m is younger than the sediment it was recovered from. This may because the tree it derived from sank into the mire surface following its death, or because the sample was derived from root wood. The uppermost radiocarbon date of 1120±40BP (815-840Cal.AD and 855-1005Cal.AD) (Beta-136031) at 0.60m indicates that the record extends into at least the Medieval period, although there are potential problems of poor pollen preservation affecting the pollen record (see below).

4.1 Synthesis

4.1.1 Preliminary environmental history of Bingley North Bog

The earliest sediments laid down at Bingley North are boulder clay and gravels, which were not observed in the cores taken as part of this study, but are recorded in the core logs from the geotechnical data provided by Babtie Group. These are apparently of a substantial thickness and suggest the basin that the bog now occupies may have its genesis either as a kettlehole or a glacially scoured valley. The gravels and sands are derived from fluvio-glacial activity at the end of the last (Devensian) glaciation, between 14,000-10,000BP. The beginning of organic sedimentation seems to have begun at around 9-9,500BP as soils began to stabilise under the hazel-birch woodland that had spread rapidly into the area (*cf.* Keen *et al.*, 1988). The earliest sediment indicates that a substantial depth of standing water was present in the basin: the gyttja laid down at this time is typical of the sediment from eutrophic-mesotrophic status lakes in the early-mid Holocene (*eg.* Gearey & Lillie, 1999, Day, 1995). This sediment is derived from the comminuted remains of aquatic plants growing in the lake itself. These plants are likely to have included *Potamogeton* (pondweeds), the pollen of which is recorded in the sample from 14.8m. There were no discernible plant macrofossils observed in the core samples or in the sieve remains (Appendix 3), although larger sediment samples might yield identifiable macrofossils (*cf.* Day, 1995).

Sediment continued to accumulate throughout the early Holocene and the arrival of elm and oak around 8,000BP and the alder and lime around 7-7,500BP is recorded. The woodland around Bingley Bog therefore consisted of hazel, oak, elm, alder and lime; typical constituents of the British mid-Holocene woodland (Rackham, 1980). Lime, which is unable to set seed below a certain temperature, is also slow to colonise new sites (Huntley & Birks, 1983) and is the last of the main woodland taxa to become established in the Yorkshire lowlands (Gearey & Lillie, 1999:118). This tree tends to be heavily under-represented in the pollen record (Huntley & Birks, 1983). Lime was likely to have been a major constituent of the woodlands around Bingley Bog, as is suggested by other researchers in this region (Gearey & Lillie, 1999; Grieg, 1982).

Alder was dominant on areas of damper soils and must have grown as carr woodland around the edges of the lake basin at Bingley during the mid-Holocene, later colonising the fen surface following hydroseral succession. Birch and pine, the pioneer taxa of the early Holocene, were restricted to areas of poorer soils, where they were able to effectively compete with the other woodland taxa. The mid-Holocene Elm Decline is recorded at around 7m depth, with some evidence for lime also declining at this point. This means that a record of vegetation history covering some 5,000 years is preserved in 7.5m of sediment, providing a unique opportunity for detailed palaeoecological analysis.

By the top of BING4, the infilling of the lake basin and the first stages of hydroseral succession are evident (*cf.* Walker, 1970). This is reflected in the stratigraphy of BB6, which demonstrates a transition from the highly organic lake gyttja, fine in texture and containing no recognisable plant material present (Appendix 3), to a detritus gyttja containing plant remains; typical of deposits formed in shallower waters (Lowe & Walker, 1997). This in turn trends into a brown, fibrous peat with an increasing proportion of monocotylodonous root, stem and rhizome fragments from 4.40m (Appendix 3). These macrofossil remains demonstrate the colonisation of the emergent lake muds by sedges and reeds (such as *Carex, Cladium* and *Phragmites*). This is also reflected in the pollen record by increases in Cyperaceae and Poaceae from 4.60m. The presence of *Alnus* wood macrofossils and a marked increase in this pollen type indicate that alder fen-carr became established on the site.

The elm decline around 7.00m, dated to around 5,000-5,300BP, seems to reflect the first evidence of human impact on the local vegetation although the precise nature of any local anthropogenic activity remains unclear. A pronounced decline in *Tilia* is evident between 3.6 and 4.00m, and can be estimated to date to 3-3,600BP. Other researchers have identified a decline in lime around this time and attributed it to anthropogenic activity (eg. Waller, 1994; Turner, 1962). As with the elm decline, there is no other clear evidence for human activity at this point in the form of increased representation of ruderal pollen, with increases in grass and sedge probably due to successional changes in the vegetation on the mire surface. This may, however, be a function of comparatively low pollen counts. Further reductions in tree and shrub pollen and increases in herbs typical of pastoral habitats at 1.60m suggest more pronounced anthropogenic disturbance to the local vegetation. Continuing high levels of *Alnus* suggest that this activity was confined to the dryland around the wetland area. This may be dated to around 2,000BP working on a linear interpolation from the dates at 3.00m and 0.60m, suggesting an Iron Age date for the first clear evidence for substantial human activity in the near vicinity of Bingley Bog. The gap in the pollen record from 1.6 to 3.6m means that human activity may of course commence earlier, but this can only be established by sampling at a finer resolution.

The date of 1120±40BP (815-840 Cal.AD and 855-1055 Cal.AD) suggests an early Medieval date for the close of the diagram. A layer of grey clay seals the brown, fibrous fen peat at around 0.50m depth and is generally best recorded in the cores from near to the edge of the bog. This might therefore may reflect some form of disturbance near to the bog, which resulted in inwash of minerogenic sediment onto the wetland fringes. Such erosion may very well have resulted from farming activities on the surrounding slopes in the Medieval period. The uppermost section of the sequence (from 0.60m to 0m) therefore represents sediment accumulation at a rate of $50cm/10^3yr$. This is somewhat lower than the accumulation rate estimated for the lower section of the sequence and it is possible that sediment accumulation has been discontinuous and/or there is an hiatus present.

5.1 Conclusions and recommendations

The Bingley North Bog sediments have been demonstrated to contain a record of environmental change covering the last 9-10,000 years. Moreover, the depth of sediment at this site means that the record contained therein is highly detailed. An average estimated accumulation rate for the lake sediment from 4.40 to 14. (assuming no major hiatuses in accumulation) is $166cm/10^3$ years, which potentially represents an outstanding degree of resolution. Sequences from elsewhere in Yorkshire, such as the Bog at Roos tend to cover specific parts of the Holocene record; there are no other comparable sequences from West Yorkshire that cover almost the entire Holocene in such detail. Although the depth of sediment is somewhat less, Bingley North Bog might be compared to the meres of Norfolk and East Anglia (see Bennett *et al.,* 1991) such as Hockham (Bennett, 1983) and Diss Mere (Peglar, 1993) with the potential to produce very detailed information concerning events such as the alder rise, the Elm Decline, the lime decline and the possible role of human disturbance in both these events (*eg.* Leah *et al.,* 1997; Tipping, 1995; Hirons & Edwards, 1986; Smith, 1984). No other site with such detailed information is present in the Yorkshire region, and few other comparable sites on the lowland/upland fringe are found in the United Kingdom.

The radiocarbon dates demonstrate that the record extends into the historic period, and the sequence thus has the potential to reconstruct both prehistoric and recent vegetational changes and to characterise and date the environmental impacts of human activity in the Bingley area. The palaeoecological record extends from the Mesolithic to at least the Medieval period. The issue of Mesolithic/Neolithic impacts on the vegetation of the British Isles has been a much debated issue, but most records available are from upland areas (eg Simmons & Innes, 1996; Caseldine & Hatton, 1993). The presence of lithic scatters in the Bingley area (referred to in the Babtie Group Specification for Palaeoenvironmental Sampling) indicates prehistoric activity in the area: more detailed palaeoecological study at Bingley will allow the close integration of palaeoecological and archaeological data. Moreover, the potential for this is enhanced due to the fact that the comparatively small size of the basin means that the pollen record will tend to reflect predominantly local and extra-local environmental change (cf. Jacobson & Bradshaw, 1981). Issues such as the evidence for early agriculture and changing land-use patterns may therefore be addressed in some detail.

An average accumulation rate of 130cm/10^3 years can be estimated for the top 4.40m of fen sediment, which although not as high as estimated for the basal gyttja, still represents a good resolution for palaecological study. Pollen preservation has been demonstrated to be relatively good within the lake gyttja and adequate in the fen peat, although it is possible that the sections of the record between 1.6-3.6m, and 3.6-4.6m might be affected by differential preservation. This may have negative implications for the recovery of the later Holocene segment of the record. Differential preservation might, of course, be restricted to the sampled levels at 2.40 and 4.40m, although this can only be established by sampling at finer resolution.

In conclusion, it is imperative that further work be carried out on this site: in particular, a full palynological analysis of the deposits, supported by radiocarbon dates, would produce palaeoecological information deemed to be of national and perhaps international significance. The analysis of coleoptera, ostracoda, mollusca might prove fruitful but the difficulty of recovering sufficient sediment to reliably assess the presence of these biota means that they could not be assessed through this study. The presence of ostracods and molluscs at Bingley South Bog suggests these biota will be present in the sediments at Bingley North. Further detailed macrofossil work is not recommended: the comminuted nature of the gyttja means that identifiable macrofossils in this sediment would be rare, whilst the uniform nature of the uppermost fen peat would imply that detailed macrofossil analysis would be unlikely to yield particularly useful data.

The application of techniques such as loss-on-ignition and magnetic susceptibility to provide information on disturbance events in the catchment could also be useful in further detailing the environmental history of the site. Loss-on-ignition is used in palaeoenvironmental studies to give an indication of the amount of organic matter present in sediment and conversely an estimation of the quantity of mineral matter. This can therefore be employed to indicate the extent of erosion into a basin and thus as a proxy measure of the disturbance to vegetation and soils resulting from human impacts, as the removal of vegetation cover can lead to the destabilization of soils and an increase in erosion (Edwards *et al.*, 1991; Moore *et al.*, 1986). Magnetic susceptibility measurements can be used alongside LOI as a proxy measure of episodes of catchment erosion resulting from disturbance to soils and can provide detailed information on the nature of the inwashed material (see Hilton, 1987). Both techniques can be employed usefully alongside palynological study to clarify the nature of disturbance to the local environment around a basin. They can, for example, be used to determine whether events such as the Elm Decline and the lime decline directly affected the stability of the soils around Bingley Bog and thus establish whether human communities were exploiting the near vicinity during the Neolithic and later prehistoric period.

Keen *et al.*, (1988) have demonstrated the potential of Bingley South Bog and further, more detailed work at this location is also highly recommended, particularly of the upper layers of sediment. Sampling would be recommended prior to any construction work that would directly affect the hydrology of the site. A costed estimate for further work is included in Appendix 4.

BRG & JRK, CWA, 10/99

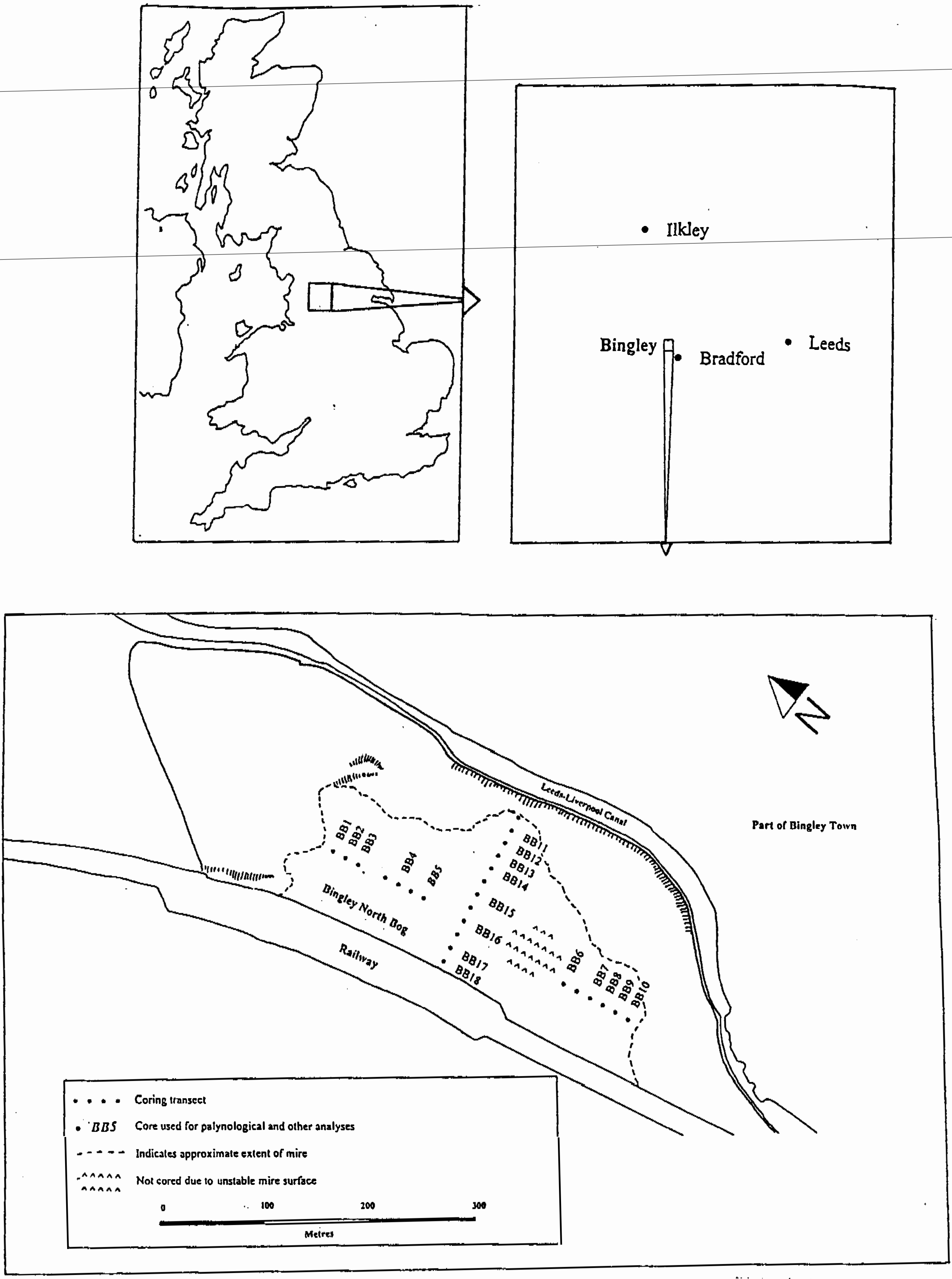


Figure 1: Location maps showing Bingley North Bog and position of coring transects across Bog.

Figure 2: Bingley North Bog N-S Transect

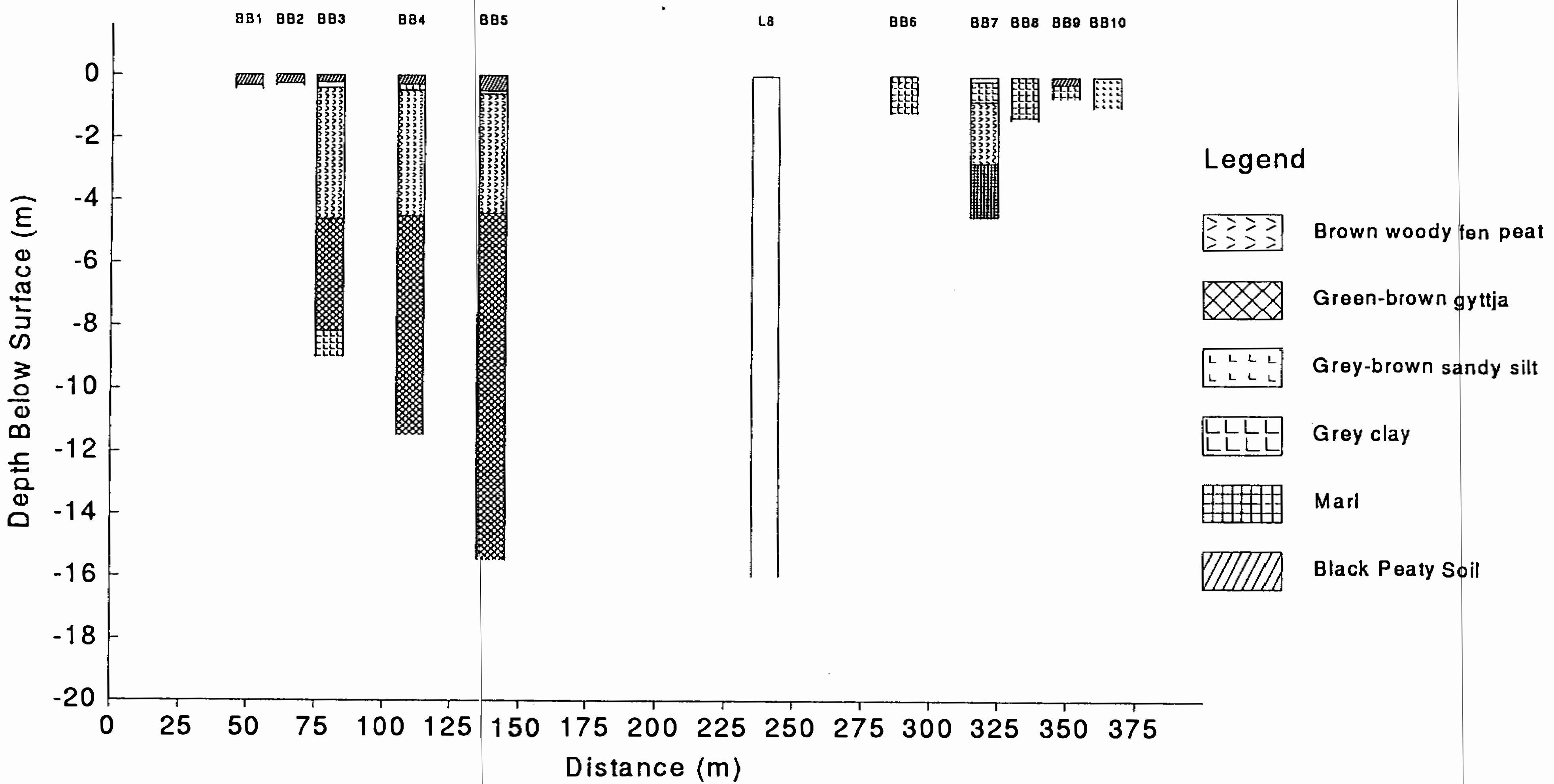


Figure 3: Bingley North Bog E-W Transect

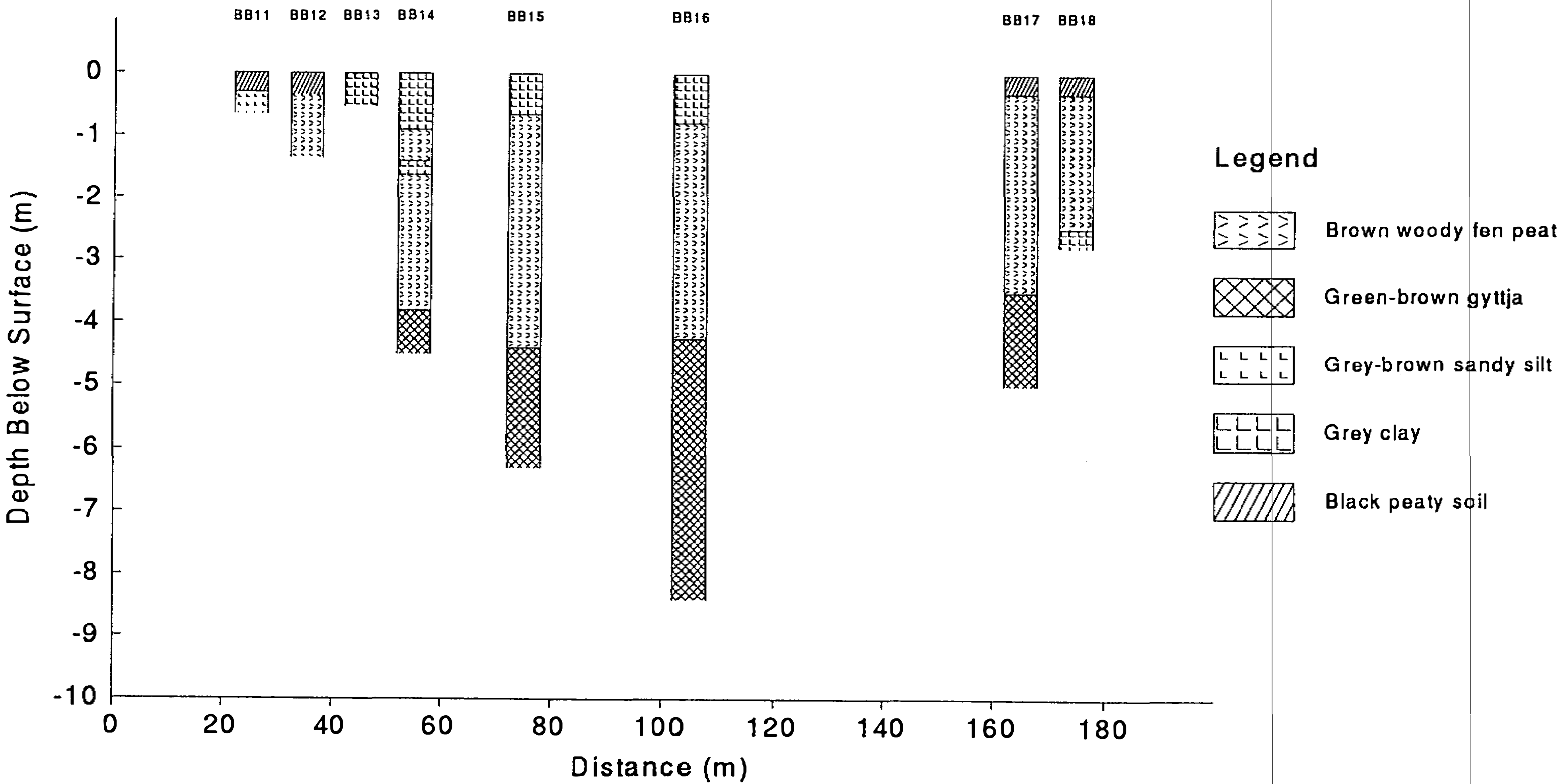
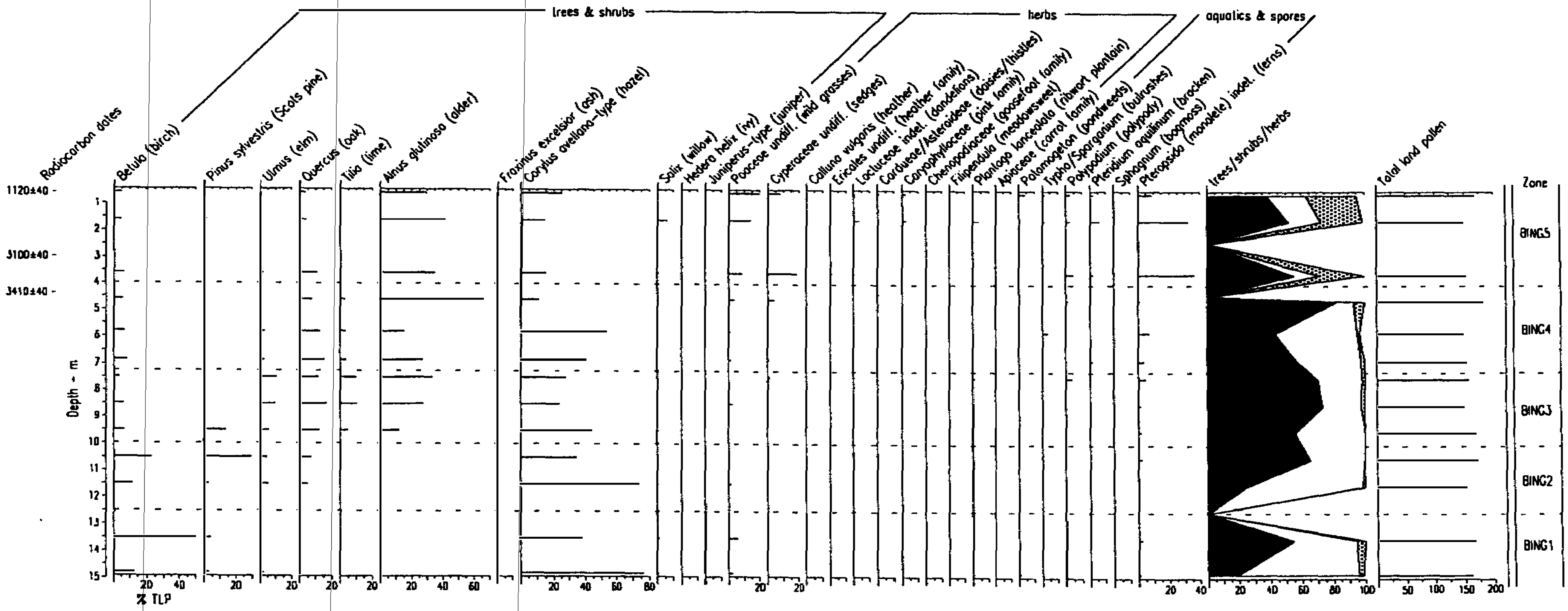


Figure 3: Bingley North Bog Skeleton Pollen Diagram



0-130cm: Grey-orange clay with sand onto dark grey clay.
130-140: Well humified silty peat with some vegetative remains
Bottomed

BB9:

0-25cm: Black peaty top soil with coal and other mineral fragments.
25-70cm: Grey, compact silty clay with sands.
70cm: Gravels and sands.
Bottomed

BB10:

Disturbed ground.

East-West Transect

BB11:

0-30cm: Black, peaty top soil.
30-53cm: Brown, organic silt with coal and other mineral fragments.
Bottomed

BB12:

0-135cm: Black peaty top soil grading into brown, fibrous peat.
Bottomed

BB13:

0-52cm: Dark brown, sandy organic clay.
Bottomed

BB14:

0-90cm: Dark grey, sandy organic clay.
90-140cm: Brown, moderately humified fibrous peat with wood remains and *Phragmites.*
140-163cm: Grey clay with some organics including *Phragmites*.
163-380cm: Brown, moderately humified fibrous peat with wood remains and *Phragmites*
380-450cm: Gyttja with shell fragments.
Bottomed but lower section not recovered.

BB15:

0-65cm: Grey, coarse grained clay.
65-440cm: Brown, fibrous clayey peat. .
440-630cm: Green/brown detritus gyttja.
Bottomed

BB16:

0-78cm: Grey-black organic clayey peat.
78-425cm: Brown, moderately humified fibrous peat with wood remains and *Phragmites.*
425-840cm: Green/brown detritus gyttja with ?shell fragments, rootlets and other vegetative remains towards top of sequence.
Bottomed

BB17:

0-30cm: Black, peaty top soil.
30-350cm: Brown, moderately humified fibrous peat with wood macrofossils.
350-500cm: Green/brown detritus gyttja.
Bottomed

BB18:

0-30cm: Black, peaty top soil.
30-246cm: Brown, fibrous peat with *Phragmites* and wood remains.
246-278cm: Grey, sandy clay.
Bottomed

Appendix 2

Bingley North Bog: Pollen Samples 0.60-6.80 metres

Pollen Taxon/ **Trees &shrubs**	Sample-Depth (m) 0.60	1.60	2.40	3.60	4.40	4.60	5.80	6.80
Betula	5	5		7		6	7	8
Pinus sylvestris	-	1	N	1	N	-	1	-
Ulmus	-	1	O	2	O	1	3	3
Quercus	4	4		11		7	13	15
Tilia	-	-		-		3	3	4
Alnus	30	41		35		66	16	27
Fraxinus excelsior	-	-		-		-	1	-
Corylus avellana-t.	25	14	P	15	P	11	53	40
Salix	-	6	O	1	O	-	-	-
Calluna	1	1	L	-	L	-	-	-
Ericales undiff.	1	-	L	1	L	-	-	-
Hedera helix	-	1	E	-	E	-	-	-
Herbs Poaceae undiff.	20	16	N	9	N	3	1	1
Cyperaceae undiff.	8	-		18		4	1	1
Filipendula	-	-		-		-	-	1
P.lanceolata	-	4		-		-	-	-
Lactuceae undiff.	1	3		1		-	-	-
Caryophyllaceae	2	3		-		-	-	-
Carduceae/ Asteroideae	1	1		-		-	-	-
Apiaceae	-	1		-		-	-	-
Aquatics *Typha/ Sparganium*	1	1		-		-	3	-
Potamogeton	4	-		-		-	-	-
Spores *Sphagnum*	-	-		-		-	-	-
Polypodium	3	2		4		1	-	-
Pteropsida	9	32		37		1	-	7
Pteridium aquilinum	2	6		2		1	-	2
Trees	38	52		55		82	43	57
Shrubs	25	21		16		11	53	40
Herbs	32	26		29		7	1	3
Aquatics	5	1		-		-	3	-
TLP	168	149		153		183	148	155
TLP+spores	193	253		272		187	159	164

NB: All figures are percentage total land pollen (tlp) and percentage tlp+spores, rounded up to nearest whole integer.

Appendix 2

Bingley North Bog: Pollen Samples 7.50-14.80 metres

Pollen Taxon/ Trees &shrubs	Sample – Depth (m) 7.5	8.5	9.5	10.5	11.5	13.5	14.8
Betula	4	7	7	23	12	50	13
Pinus sylvestris	2	-	14	30	3	4	3
Ulmus	10	10	6	5	5	1	3
Quercus	12	17	12	7	5	1	-
Tilia	10	10	5	-	-	-	-
Alnus	33	28	12	1	-	-	-
Fraxinus excelsior	-	1	-	-	-	-	-
Corylus avellana-t.	27	24	44	34	73	38	76
Salix	-	-	1	-	1	1	1
Hedera helix	1	-	-	-	-	-	-
Herbs Poaceae undiff.	-	3	-	1	1	5	3
Cyperaceae undiff.	1	-	-	-	-	-	-
Filipendula	-	-	-	-	-	1	1
Chenopodiaceae	-	-	-	-	1	-	-
P.lanceolata	1	-	-	-	-	-	-
Aquatics *Potamogeton*	-	-	-	-	-	-	1
Spores *Polypodium*	4	-	1	-	-	-	-
Pteropsida	5	2	2	2	1	2	1
Trees	70	73	56	65	24	54	19
Shrubs	28	24	44	43	74	40	77
Herbs	2	3	-	1	2	6	3
Aquatics	-	-	-	-	-	-	1
TLP	157	150	169	172	153	167	161
TLP+spores	171	153	173	176	154	171	163

Bingley North Bog Appendix 3

Sample macrofossil Assessment

0.60m Monocotylodonous leaf, stem and rootlets (c.70%). Bryophyte leaf and stem remains (30%)..

1.60m Monocotylodonous %). Wood fragments (20%). Some unidentifiable organic matter (20%).

2.40m Monocotylodonous leaf, stem and rootlets (c.60%). Wood fragments (20%). Some unidentifiable organic matter (20%).

3.60m Abundant wood fragments (70%) with monocotylodonous stem, leaf and root remains (30%).

4.40m Monocotylodonous leaf, stem and rootlets (c.80%) with wood fragments (20%).

4.60m Monocotylodonous leaf, stem and rootlets (c.80%) with wood fragments (20%).

5.80m Unidentifiable organic matter with very fragmentary monocotylodonous? remains.

6.85m Unidentifiable organic matter.

7.85m Unidentifiable organic matter.

8.5m Unidentifiable organic matter. Some fine sands.

9.5m Unidentifiable organic matter. Some fine sands.

10.5m Unidentifiable organic matter.

11.5m Unidentifiable organic matter.

12.5m Unidentifiable organic matter.

13.5m Unidentifiable organic matter.

14.8m Unidentifiable organic matter.

Appendix 4

Estimated costing for full analysis of sequence from Bingley North Bog and Bingley South Bog

4.1 Method Statement

4.1.1 **Sampling** of a full sequence from the site will utilise a large pattern Russian corer or percussion coring equipment. It is anticipated that 2 full cores will be recovered from Bingley North Bog and one full core from the upper sediments (4m) of Bingley South Bog. Cores will be extruded into plastic pipe, wrapped in foil and stored in the dark at 4°C prior to analyses. One of the cores will be utilised for palynological analysis and radiocarbon sampling (below 4.1.2), and one for sedimentological analyses (below, 4.1.3 and 4.1.4). Full stratigraphic description will be carried out using the Troels-Smith (1955) system.

4.1.2 **Palynological analysis** will be carried out at 8cm intervals (total 188 samples) with closer 4-2cm sampling intervals around events of special interest identified by the initial analyses (estimated 32 extra samples) and 8cm intervals on the core from Bingley North and 8 cm intervals (total 50 samples) from Bingley South Bog, with closer 4-2cm sampling for events of special interest (total 24 extra samples). Pollen preparation using standard techniques including HF treatment, micro-sieving and Acetylation (Moore et al., 1991). *Lycopodium* spores will be added to allow calculation of pollen concentrations (Stockmarr, 1971). A minimum of 300 total land pollen will be counted for each sample. Results will be presented as a pollen diagram produced using TILIA and TILIA*GRAPH (Grimm, 1991).

4.1.3 **Loss-on-ignition** will be carried out at 8cm intervals using standard techniques (Gale & Hoare, 1991). Sub-sampling will be undertaken at the same sampling intervals as that for pollen analysis. Results will be presented as a graph alongside the palynological data.

4.1.4 **Magnetic susceptibility** measurements will be carried out at 8cm intervals using the facilities available at the Environmental Magnetism laboratory at the Department of Geography, University of Liverpool. Volume mass susceptibility will be measured along with any other magnetic parameters, depending on the results of the former analyses. Results will be presented as graphs alongside results of LOI and palynological analyses.

4.1.5 **Radiocarbon Dating** will be carried out on horizons of palaeoecological interest identified by palynological and other techniques, as outlined above. A maximum of 10 AMS dates utilising sediment from the core used for palynological analyses will be submitted to Beta Analytic, Florida, USA.

4.2 Staffing and Equipment

All equipment and resources needed are at the University of Hull, except for that required for the magnetics analyses, which is available through the Department of Geography at the University of Liverpool.

Function/Specialism	Name	Initial	Organisation
Sampling, pollen analysis, data analysis and production of report	Dr Ben Gearey	BRG	CWA
Sampling, pollen preparation,LOI/ Magnetics lab analyses	Various support staff/Research Assistant	RA1	University of Hull
Overall management	Robert Van de Noort	RVdN	CWA

4.3 Task table

1.1	Sampling at site	BRG, RA1	2
1.2	Subsampling and pollen preparation	RA1	20
1.3	Pollen counting	BRG	150
1.4	Loss-on-ignition and magnetic analyses	RA1	20
1.5	Data analyses and report writing	BRG	20
1.6	Report checking	RVdN	1

4.4 Timetable

Week (from commissioning)	Task number	Staff involved	No of person days
1	1.1	BRG, RA1	4
1-3	1.2	RA1	20
2-30	1.3	BRG	150
3-7	1.4	RA1	20
31-34	1.5	BRG	20
35	1.6	RVdN	1

Grime, J.P., Hodgson, J.G. and Hunt, R. 1988. *Comparative Plant Ecology: a functional approach to common British species.* London: Unwin Hyman

~~Grimm, E.C. 1991. *TILIA: a program for analysis and display.* Springfield: Illinois State Museum.~~

Havinga, A.J. 1984. A 20-year experimental investigation into the differential corrosion susceptibility of pollen and spores in various soil types. *Pollen et Spores* **26**, 541-558Hirons, K.R. and Edwards, K.J. 1986. Events at and around the first and second *Ulmus* declines: palaeoecological investigations in Co. Tyrone, Northern Ireland. *New Phytologist* **104**, 131-153

Hilton, J. 1987. A simple model for the interpretation of magnetic records in lacustrine and ocean sediments. *Quaternary Research* **27**, 160-166.

Huntley, B. and Birks, H.J.B. 1983. *An Atlas of Past and Present Pollen Maps for Europe: 0-13,000 years ago.* Cambridge: Cambridge University Press

Jacobson, G.L. and Bradshaw, R.H.W. 1981. Selection of sites for palaeovegetational studies. *Quaternary Research* **16**, 80-96

Janssen, C.R. 1959. *Alnus* as a disturbing factor in pollen diagrams. *Acta Botanica Neerlandica* **8**, 55-58

Keen, D.H., Jones, R.L., Evans, R.A. and Robinson, J.E. 1988. Faunal and floral assemblages from Bingley Bog West Yorkshire and their significance for Late Devensian and Early Flandrian environmental changes. *Proceedings of the Yorkshire Geological Society* **47**, (2), 125-138

Leah, M.D., Wells, C.E., Appleby, C. and Huckerby, E. 1997. *North West Wetlands Survey 4: The wetlands of Cheshire.* Lancaster: Lancaster Imprints 5.

Lowe, J.J. and Walker, M.J.C. 1997. *Reconstructing Quaternary Environments. 2nd Edition.* London: Longman

Moore, P.D., Evans, A.T.and Chater, M. 1986. Palynological and stratigraphic evidence for changes in mires associated with human activity. In Behre, K.-E. (Ed.) *Anthropogenic Indicators in Pollen Diagrams.* Rotterdam: A.A.Balkema.

Moore, P.D., Webb, J.A. and Collinson, M.E. 1991. *Pollen Analysis.* Oxford: Blackwell

Peglar, S.M. 1993. The mid-Holocene *Ulmus* decline at Diss Mere, Norfolk UK: a year by year pollen stratigraphy from annual laminations. *The Holocene* **3**, (1), 1-13

Peglar, S.M. and Birks, H.J.B. 1993. The mid-Holocene *Ulmus* fall at Diss Mere, South-East England - disease and human impact. *Vegetation History and Archaeobotany* **2**, 61-68

~~Rackham, O. 1980. *Ancient Woodland: Its history, vegetation and uses in England.* London: Edward Arnold~~

Roberts, N. 1998. *The Holocene: An environmental history, Second Edition.* Oxford: Blackwell

Simmons, I.G. & Innes, J. 1996. Disturbance phases in the mid-Holocene vegetation at North Gill, North York Moors: form and process. *Journal of Archaeological Science* **23**, 193-197.

Smith, A.G. 1984. Newferry and the Boreal-Atlantic transition. *New Phytologist* **98**, 35-55

Smith, A.G. and Pilcher, J.R. 1973. Radiocarbon dates and vegetational history of the British Isles. *New Phytologist* **72**, 903-914

Stockmarr, J. 1971. Tablets with spores used in absolute pollen analysis. *Pollen et Spores* **13**, 614-621.

Talma, A.& Vogel, B. 1993. A simplified approach to calibrating C14 dates. *Radiocarbon* **35**, (2), 317-322.

Tipping, R. 1995. Holocene landscape change at Carn Dubh, near Pitlochry, Perthshire, Scotland. *Journal of Quaternary Science* **10**, 59-73

Troels-Smith, J. 1955. Characterisation of unconsolidated sediments. *Danmarks Geologiske Undersogelse* 4, 1-73.

Turner, J. 1962. The *Tilia* decline: an anthropogenic interpretation. *New Phytologist* 61, 328-341.

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.

Walker, D. 1970. Direction and rate in some British Post-glacial hydroseres. In: Walker, D. and West, R.G. (Eds.) *Studies in vegetational history of the British Isles.* pp. 117-139. Cambridge: Cambridge University Press

Walker, M.J.C., Coope, G.R. and Lowe, J.J. 1993. The Devensian (Weichelian) Late-glacial palaeoenvironmental record at Gransmoor, East Yorkshire, England. *Quaternary Science Reviews* 12, 659-680

Waller, M.P. 1994. Flandrian vegetational history of south-eastern England. Stratigraphy of the Brede valley and pollen data from Brede Brdige. *New Phytologist* 126, 369-392.

Waller, M.P., Entwistle, J.A. and Duller, G.A.T. 1995. TSPPlus- A menu driven program for the display of stratigraphic data. *Quaternary Newsletter* 77, 32-39

Webb, R.S. and Webb, T., III. 1988. Rates of sediment accumulation in pollen cores from small lakes and mires of eastern North America. *Quaternary Research* 30, 284-297