Environmental changes at the Mesolithic-Neolithic transition from Embleton's Bog, near Lucker, Northumberland

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SUMMARY

A series of major archaeological sites, most seeming to date to c. 4000 cal BC, have been revealed by excavations within the Bradford Kaims Wetland Heritage Project on the edges of Embleton's Bog, near Lucker, in Northumberland. Later Mesolithic flint scatters have also been excavated. This paper presents a detailed pollen record from Embleton's Bog from c. 4200 cal BC until c. 3400 cal BC, across the Mesolithic-Neolithic transition, with the intention of defining woodland disturbance and the local introduction of agricultural elements. On dry soils, the woodland prior to c. 3700 cal BC, was probably dominated by oak and hazel with ash, rowan and aspen, and (more rarely) elm and lime. This woodland was disturbed, probably by people, and the proportions of open-ground herbs increased, but there are no pollen types to suggest this disturbance was purposeful. Woodland disturbance after c. 3700 cal BC was also limited. There was no major creation of open ground or grassland then. Pollen that probably represents wheat is first recorded after the elm decline but crop growing was of limited scale. There is no evidence in the pollen record for pasture.

INTRODUCTION

The nature of the transition from the hunter-gatherer-fisher (HGF) economy of the Mesolithic period to a new, Neolithic agricultural economy in the British Isles is intensely debated. Until recently it was argued to have been gradual and drawn-out, and learnt through a blurred process of cultural diffusion (Whittle 2003; Thomas 2004). The change is now most commonly seen to have been very rapid, an event rather than a transition, with much material culture and agriculture introduced by migrants from the near continent (Rowley-Conwy 2004; Sheridan 2010).

Pollen data have contributed much to this debate. For example, the ability of HGFs to manipulate woodland by burning, intended to encourage the abundance and quality of grasses browsed by wild animals (Simmons 1993), can be taken to emphasise continuity in the mind-set of people from the Mesolithic to the Neolithic because HGFs might be seen to 'alter the earth' (Bradley 1993) almost as effectively as early farmers. Evidence for fire in the Mesolithic, from charcoal records in sediments, is sometimes thus assumed to have been anthropogenic (Caseldine and Hatton 1993). An apparent, slowly increased frequency of woodland disturbance in the few hundred years before *c.* 4000 cal BC is seen by some to represent higher population densities amongst HGFs (Simmons and Innes 1987; Simmons 1996; Zvelebil 1996) and greater environmental stresses. The eventual resolution of these stresses was through agriculture. Cereal-type pollen grains have sometimes been recorded in sediments dated to the Mesolithic and have been interpreted as early and precocious crop-growing (e.g. Edwards

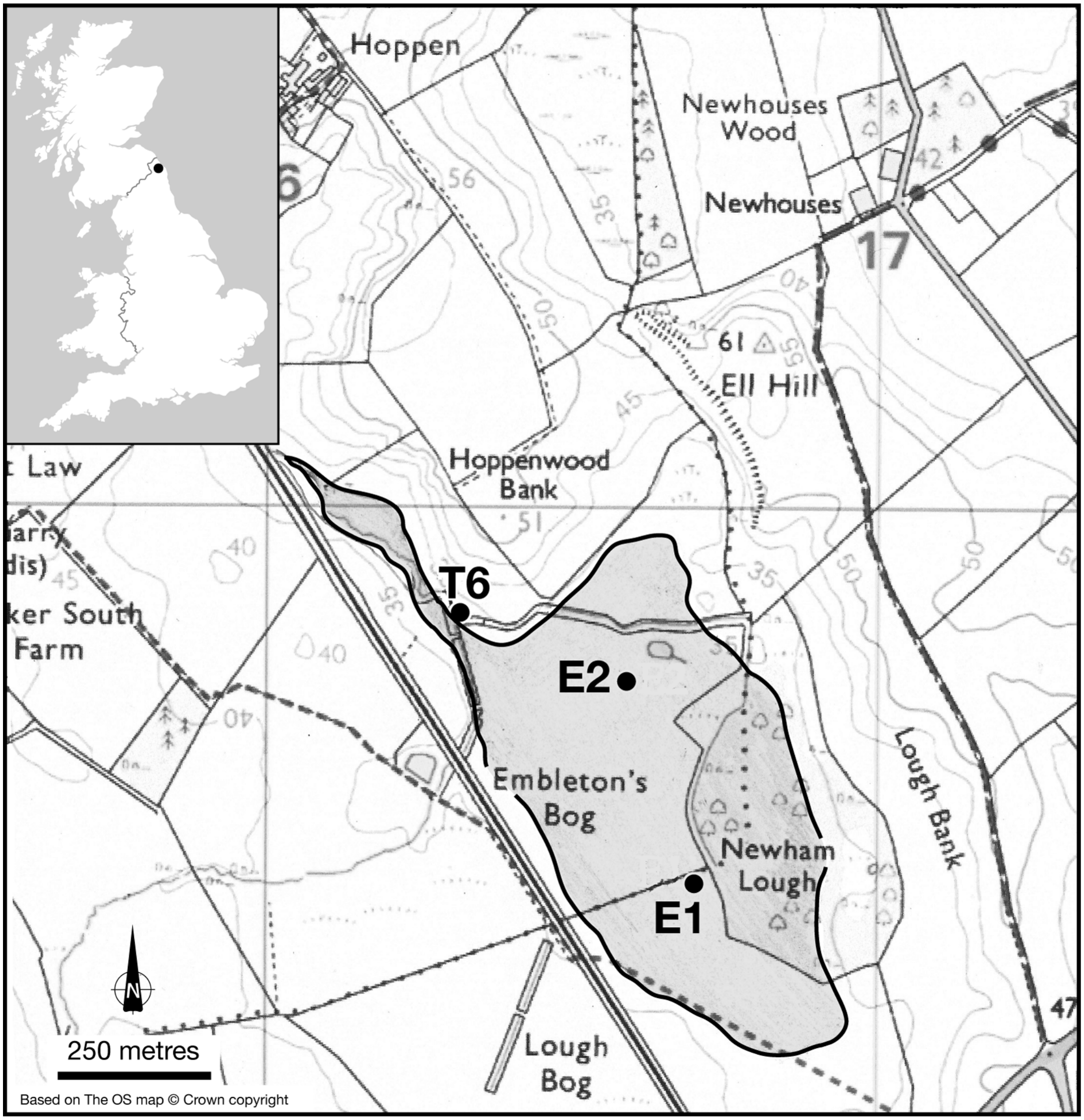


Fig. 1 The location of Embleton's Bog in northern Northumberland, at the southern end of the Bradford Kaims sand-and-gravel ridge. Also shown are: the locations on the bog of Bartley's (1966) site at E1, and E2 (the subject of this paper), as well as Trench 6, opened by the Bradford Kaims Wetland Heritage Research Project, at the edge of the Winlaw Burn. Grid squares are 1.0 km. North is to the top.

and Hirons 1994; Innes, Blackford and Davey 2003), part of an 'invisible' Neolithic before the first monuments. On the other hand, a significant reduction of burning in upland contexts at the Mesolithic-Neolithic transition itself, the 'charcoal fall' (Edwards 1988, 1990; Tipping and Milburn 2000), might be seen as evidence for a rapid economic change as hunting in the uplands was abandoned and farmers focused on lowland environments.

The elm decline, a strong decline in the proportion of *Ulmus* (elm) tree pollen at or close to the first evidence for cereal-type pollen grains (wheat; barley), has long been regarded as anthropogenic in origin (Troels-Smith 1960; Smith 1981), the loss of *Ulmus* pollen being most commonly seen as a product of feeding leaf-fodder to grazing animals. If anthropogenic, the elm decline strongly suggests rapid adoption of at least one key component of an agricultural economy. This rapidity of spread has led to other mechanisms being proposed, such as climate change (Cayless and Tipping 2002; Parker *et al.* 2002) or disease (Peglar 1993), but the very rapid spread in the 38th century cal BC of early Neolithic enclosures across southern Britain and Ireland (Whittle, Healy and Bayliss 2011) indicates that an anthropogenic cause for the elm decline should again be considered.

Bonsall *et al.* (2002), Tipping and Tisdall (2004) and Tipping (2010b) have suggested that climate change was also important in the adoption of agriculture by HGFs. Bonsall *et al.* (2002) envisaged that climate had become advantageous to pastoralists. Tipping and Tisdall (2004) and Tipping (2010b) argued that climatic deterioration at the Mesolithic-Neolithic transition *c.* 4500 to *c.* 3800 cal BC (O'Brien *et al*. 1995; Bond *et al*. 1997, 2001) undermined HGF confidence in nature's 'bounty', drawing them to farming (see also Larsson 2003). The frequency with which woodland patches caught fire, and the 'charcoal fall' itself, might have been determined by periods of relative aridity (Tipping 1996, 2004; Tipping and Milburn 2000).

ARCHAEOLOGICAL DATA FOR THE MESOLITHIC-NEOLITHIC TRANSITION AROUND EMBLETON'S BOG

Archaeological excavations at several sites around Hoppenwood Bank, east of Lucker (NU 1682 2985: fig. 1), on the coastal plain of northern Northumberland, have recovered later Mesolithic flints (Pedersen, pers. comm.), adding significantly to the corpus of finds of this age on the Whin Sill (Buckley 1925). At Hoppenwood Bank, recent excavations in Trench 6 (fig. 1) as part of the Bradford Kaims Wetland Heritage Research Project have revealed timber structures projecting out across the peat-filled valley of the Winlaw Burn from the steep westerly slope of the Bradford Kaims. Within these structures is a piece of shaped wood described as a paddle (*Current Archaeology*, 2014, 10). The timber structures may be the first structural evidence for Neolithic occupation on the coastal plain. The other few finds are portable flint axes (Waddington and Passmore 2012). At the edge of the peat-filled channel of the Winlaw Burn and the timber structures, lying on till, are a series of overlapping burnt mounds that are thought to be of early Neolithic date. Three metres higher up the slope is a hearth structure buried by later colluvium. The hearth has been archaeomagnetically dated to 4468–3995 BC (calendar years: Harris, Karlouvski and Hounslow 2011).

This paper reports pollen data and environmental reconstructions of the Bradford Kaims landscape from a peat and pollen stratigraphy at Embleton's Bog (part of the wetland complex around Bradford Kaims, around 400 m south east of the hearth and timbers), from near the end of the Mesolithic period, from *c.* 4200 cal BC, into the early Neolithic *c.* 3400 cal BC. Embleton's Bog today is very large, partly drained and grazed. Open water across large parts of the bog can persist for months after winter. The eastern part of the bog includes Newham Lough or Fen, a National Nature Reserve designated especially for its alkaline fen plant communities (Wetherell unpub.). The bog is fed principally by alkaline groundwater. Carboniferous limestones of the Alston Group underlie the basin and outcrop on the western side where they support base-rich clays and loams. The well-drained and slightly acid loam from gravel, sand and silt of the Bradford Kaims forms the high ground to the north and east; esker-like ridges represent the casts of meltwater streams flowing in and beneath the last ice-sheet some 20,000–18,000 years ago (Huddart 2002).

METHODS

A series of eight transects (fig. 1) across Embleton's Bog were cored with a Eijelkamp peat gouge, 2.5 cm in diameter and 1.0 m long, to establish the sediment stratigraphy beneath the peat surface. At NU 16590 29620, sediments from the bog surface to the base (at 378 cm) were sampled by a closed-chamber Russian corer, 1.0 m long and 6.0 cm in diameter. Cores were placed in semi-circular gutters, wrapped in plastic sheeting, labelled, sealed with tape and stored in the dark at 4°C.

This site is called Embleton 2 because Bartley published pollen analyses from Embleton's Bog in 1966 (Embleton 1). Bartley (1966) cored at NU 16725 29275, immediately west of Newham Lough and *c.* 400 m from Embleton 2 (fig. 1). From Bartley's analyses, the key bio-stratigraphic marker of the *Ulmus* decline was predicted to be at a depth of around 134 cm. Subsamples for pollen analysis were therefore taken using a razor and fine spatula either side of this depth, at 1.0 cm intervals between 150.0 and 125.0 cm, and at 2.0 cm intervals between 125.0 and 108.0 cm depths. Subsamples were treated by standard methods (Moore *et al.* 1991) and residues kept in silicone oil. Pollen analyses were made using an Olympus BX40 binocular microscope. Counts were made at magnification x400 with critical examinations made at magnification x1000 under oil immersion and sometimes using phase contrast.

Pollen was identified by reference to Moore *et al.* (1991) and the University of Stirling pollen reference collection. Counts were a minimum of 500 grains of total land pollen (tlp) except for one level, 129 cm, where the count was 452 grains. Pollen nomenclature follows Bennett (1984) and plant nomenclature follows Stace (1991). Separation of Poaceae to cereal type groups follows Andersen (1979). Separation of *Corylus avellana* and *Myrica gale* remains controversial (Edwards 1981). Three categories were used in this study: (a) *Corylus*, (b) *Myrica*, and (c) *Corylus avellana* type to include grains not positively identified as either. Microscopic charcoal was divided into five size classes (10–25 µm, 25–50 µm, 50–75 µm, 75–100 µm and >100 µm) to provide evidence of vegetation burning. Pollen diagrams were plotted on TILIA software (Grimm 2002).

Fig. 2 is a percentage-based diagram of pollen types (taxa) from Embleton 2, spanning the depths from 150.0 (*c.* 4200 cal BC) to 108.0 cm (*c.* 3400 cal BC), across the Mesolithic-Neolithic transition. The percentages are calculated as percentages of total land pollen (tlp), which means that all trees, shrubs, dwarf shrubs and herbs assumed to have grown on dry ground away from the bog surface add up to 100% tlp. Several taxa, however, like *Alnus* and Cyperaceae (sedges) will grow in many different habitats. Pollen of aquatic plants and spores of Pteridophytes are calculated differently. The pollen diagram is divided into three local pollen assemblage zones (lpaz) E2 1–3: each zone is further divided into two sub-zones (a and b), marking major and minor changes in the pollen stratigraphy respectively, interpreted from stratified cluster analysis (Grimm 1987). Fig. 3 is a diagram of pollen concentration values for major pollen taxa. Pollen concentrations are measures of the absolute numbers of grains in a sediment slice, expressed as grains per cm^3.

THE CONSTRUCTION OF A CHRONOLOGY

Radiocarbon assays from which to construct a chronology for sediments at Embleton 2 have not been obtained, and neither were they obtained at Embleton 1 (Bartley 1966). This section explains how an absolute chronology was applied to the Embleton 2 sequence.

There is one clear and undoubtedly synchronous sediment-stratigraphic correlation between Embleton 1 and Embleton 2, when siliceous lake clay is overlain by marl: at Embleton 1 at a depth of 490 cm, and at Embleton 2 at 346 cm. This is the climato-stratigraphic boundary between the Devensian Lateglacial and Holocene at *c.* 9750 cal BC, on sedimentological criteria and pollen assemblages at Embleton 1 that are very clearly of earliest Holocene age, with successive peaks of *Juniperus* (juniper) at 455 cm, of *Betula* (birch) at 410 cm and of *Corylus* [*sic* hazel] at 370 cm depth (Bartley 1966). From radiocarbon-dated pollen analyses elsewhere in the region, summarised by Tipping (2010a), the expansion of *Corylus* has a calibrated radiocarbon age of *c.* 9150 cal BC. The first appearances of *Ulmus* and *Quercus* (oak) pollen at Embleton 1, at a depth of between 350 and 340 cm, have a calibrated radiocarbon age of *c.* 8150 cal BC (Tipping 2010a). There are no younger palynological markers at Embleton 2.

The core from Embleton 2 is from a shallower part of the same lake as Embleton 1. Assuming that sedimentation rates above the first appearances of *Ulmus* and *Quercus* at Embleton 1 are proportionally the same between the sites, and are linear (the simplest assumption), then the depth of the *Ulmus* decline at Embleton 2 can be predicted. This was at a depth of 134 cm (above: Methods). Fig. 2 shows the *Ulmus* decline to be at 142 cm depth, very close and suggesting a robust chronology.

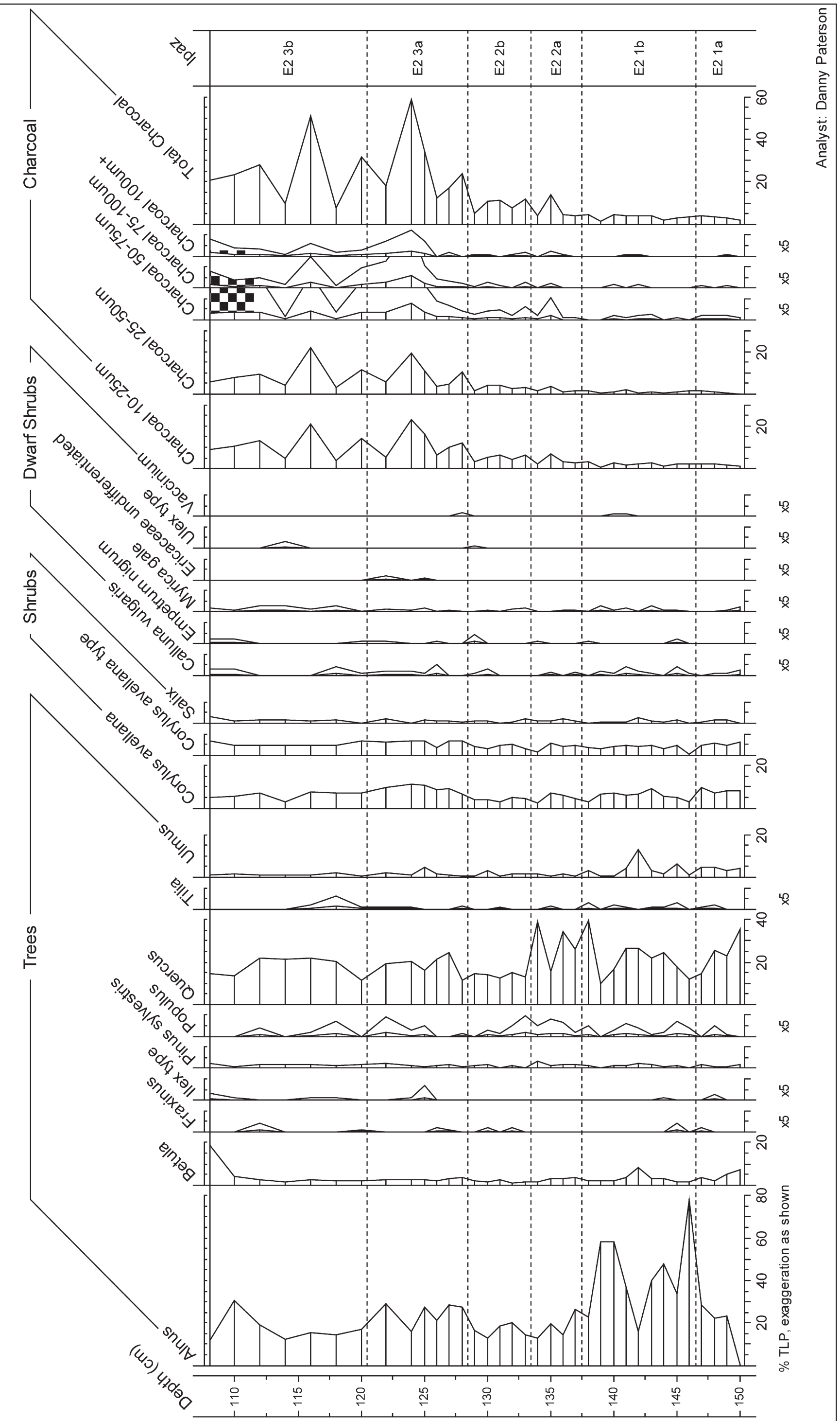
Linear interpolation suggests the Ulmus decline at Embleton 2 to have an age of *c.* 4100 cal BC. In their review of the *Ulmus* decline, Parker *et al.* (2002) suggested that across the British Isles the decline began at *c.* 4393–4357 cal BC and ended *c.* 3340–3470 cal BC. Elm declines in northern England and southern Scotland appear diachronous over short distances as well as across the region (Tipping 1997, 2010a) with the mean age of the oldest elm declines at *c.* 4150 cal. BC. Waddington and Passmore (2012) give age-ranges for the start and the end of the *Ulmus* decline in northern Northumberland from 4295–4180 cal BC to 3825–3540 cal BC. We take the *Ulmus* decline at Embleton Bog to have a calibrated radiocarbon age of *c.* 4100 cal BC.

INTERPRETATION

The surface of Embleton's Bog at the Mesolithic-Neolithic transition was probably much smaller than it is today. It may have had a surface area of around 15 km^2. The Embleton 2 site is toward the south west end of a confined embayment some 200 m across. The coring site probably lay around 100 m from dry ground. Pollen recruitment to the coring site will have changed as plants on the bog surface approached and receded through lake level change. In periods of low water table, with *Alnus* carr on the bog, most pollen will have come from the bog surface, with dry land taxa from the great bowl made by Embleton's Bog into the Bradford Kaims. When open water repelled trees and shrubs from near the coring site, most pollen will have come from a much larger area, perhaps several kilometres round.

Sediment at a depth of between 150 and 108 cm, across the Mesolithic-Neolithic transition, does not change significantly (Table 1). Herb peat with common Cyperaceae (sedge) stems gives way at 128 cm to a herb peat with no Cyperaceae stems, and above 120 cm depth to herb

Figure 2a Embleton 2, percentage pollen diagram, trees, shrubs, dwarf shrubs and charcoal.



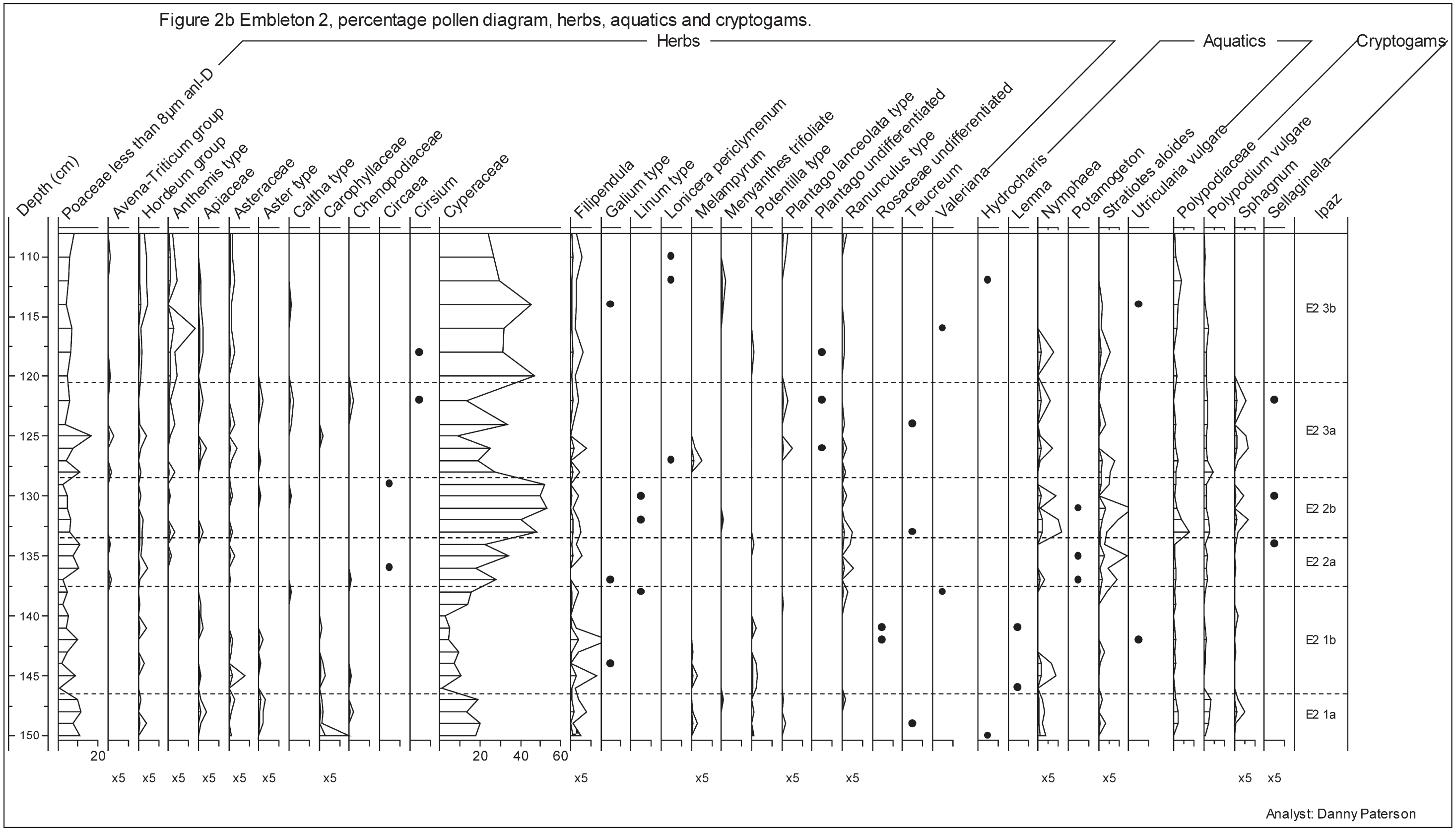


Fig. 2 A percentage-based record of pollen types (taxa) recorded more than once in the sediment stratigraphy at E2, together with data on different size fractions of microscopic charcoal. The shaded areas represent a 10x magnification of the values for greater clarity. (opposite page): Tree, shrubs, dwarf shrubs and charcoal percentage diagram. (this page): Herbs, aquatics and cryptogams percentage diagram.

Table 1 The sediment stratigraphy at Embleton 2.

Depth (cm)	Sediment description
27.0–116.0	dark brown to black moderately humified herb peat with common to many vertical Cyperaceae stems, rare wood but with one large fragment at 85 cm and one very large fragment 103–116 cm; gradual to
116.0–128.0	dark brown to black moderately humified herb peat; gradual to
128.0–163.0	dark brown to black moderately humified herb peat with common vertical Cyperaceae stems; gradual to
163.0–225.0	dark brown to black moderately humified herb peat; gradual to
225.0–243.0	dark brown to black moderately humified herb peat with occasional to common vertical Cyperaceae stems; gradual to
243.0–249.0	dark brown to black moderately humified herb peat; gradual to
249.0–253.0	black densely matted herb peat with abundant fine fleshy (Poaceae?) stems; sharp to
253.0–271.0	dark brown to black moderately humified herb peat; gradual to
271.0–287.0	dark brown to black moderately humified herb peat with common to many vertical Cyperaceae stems; gradual to
287.0–292.0	dark brown to black moderately humified herb peat; gradual to
292.0–297.0	dark brown to black Cyperaceae peat; gradual to
297.0–301.0	dark brown to black moderately humified herb peat with common vertical Cyperaceae stems; sharp to
301.0–309.0	black highly humified amorphous peat with common herb stems; sharp to
309.0–317.0	dark brown horizontally layered Cyperaceae peat; sharp to
317.0–319.5	dark brown horizontally layered Cyperaceae peat; sharp to
317.0–319.5	olive green coarsely crystalline marl with abundant horizontal layers of Cyperaceae stems and occasional small to very large (4 mm) mollusc shells, intact and not fragmented; gradual to
319.5–340.0	pale grey, faintly colour-laminated (cream and pale grey) with occasional small to very large (4 mm) mollusc shells and occasional vertical Cyperaceae stems; gradual to
340.0–346.0	olive green coarsely crystalline marl with abundant horizontal layers of Cyperaceae stems and occasional small to very large (4 mm) mollusc shells, intact and not fragmented; sharp to
346.0–361.5	mid-grey clay with occasional silt with many horizontally layered Cyperaceae stems, rare to occasional fragments of calcium carbonate (smashed shells?); sharp to
361.5–366.5	mid-grey faintly laminated clay; gradual to
366.5–377.0+	mid- to dark grey faintly laminated and structureless silt with rare vertical Cyperaceae stems and horizontally layered fine fleshy herb stems.

peat with Cyperaceae stems (common to many) and wood (rare). It is assumed here that the sediment accumulation rate was constant in the period covered here, and that the pollen record at Embleton 2 stops at around 3400 cal BC. Figs. 2 and 3 are interpreted together in chronological order. For each local pollen assemblage zone, plant communities that probably grew on the mire are described first, before the wider, dryland landscape is considered.

Lpaz E2 1a (150.0–146.5 cm): c. 4200 cal BC to c. 4150 cal BC

From their abundance in the pollen record, it is very likely that sedges were growing on the peat around the coring site. Aquatic plants are also recorded, suggesting some open water, including *Hydrocharis* (frogbit), *Menyanthes* (bogbean), *Stratiotes* (water soldier) and *Nymphaea* (water-lily). *Hydrocharis* looks like a small water-lily. It can be submerged or floating, forming dense mats on the surface in the summer in alkaline water. The pollen of *Stratiotes aloides* is an extraordinary find because it is only rarely recorded. The plant floats on the water surface but is submerged in winter, typically growing in slow-moving meso-eutrophic waters, most common in base-rich water, mainly in sheltered bays of larger lakes, precisely the setting of Embleton's Bog at this time. *Nymphaea* is a floating plant tolerant of neutral pH, growing in *c.* 30–150 cm of water. *Menyanthes* would grow in soils permanently submerged in 20 cm or more of water. *Filipendula* (meadowsweet) probably grew with *Menyanthes*, perhaps with some wild grass species (Poaceae <8µm anl-D) including wetland grasses like *Glyceria* within *Hordeum* type (barley plus some wild grasses) (Spence 1964, 350). *Sphagnum* (bogmoss) also grew, probably indicating that peat grew between open water ponds. *Alnus* was probably present locally, possibly on the bog surface and probably on its edge, with *Salix* (willow). With such low values, *Betula* (birch) need not have been locally present unless it was a small part of the dry woodland cover.

Quercus (oak) is likely to have occupied drier areas on the slopes around the bog, with *Corylus* (hazel). *Ulmus* may also have been present within this woodland, possibly with *Tilia* (lime) on local base-rich soils. *Populus* (aspen) was a component of this woodland, and with *Sorbus* (rowan) and *Fraxinus* (ash) at the zone boundary it suggests some woodland disturbance. Herbs that might have benefitted from woodland disturbance include members of the Asteraceae (daisy family), Caryophyllaceae (pinks) and Chenopodiaceae (fat hen, goosefoots).

Lpaz E2 1b (146.5–137.5 cm): c. 4150 cal BC to c. 4000 cal BC

Changes in this sub-zone are indicative of an encroachment of wet woodland onto a drying mire surface. *Alnus* was probably the main colonist, with the large peak at the base of the zone in fig. 2 possibly representing the incorporation of a catkin into the peat at the coring site. The peak of *Alnus* in pollen concentrations (fig. 3) is very clear evidence of this. *Myrica gale* (bog myrtle) probably grew on the bog surface. *Calluna* is recorded, with *Empetrum*. If these grew on the bog surface they suggest some parts of the surface were very dry and acid. *Myrica* grows on substrates <pH6.5. *Calluna vulgaris* is rarely recorded when the substrate exceeds pH5 and *Empetrum* most common at <pH5. The small increases in *Salix* may also be indicative of encroachment onto the mire around the core site: *Salix* has low pollen productivity and, being insect-pollinated, it is under-represented in a pollen diagram. The lower values of

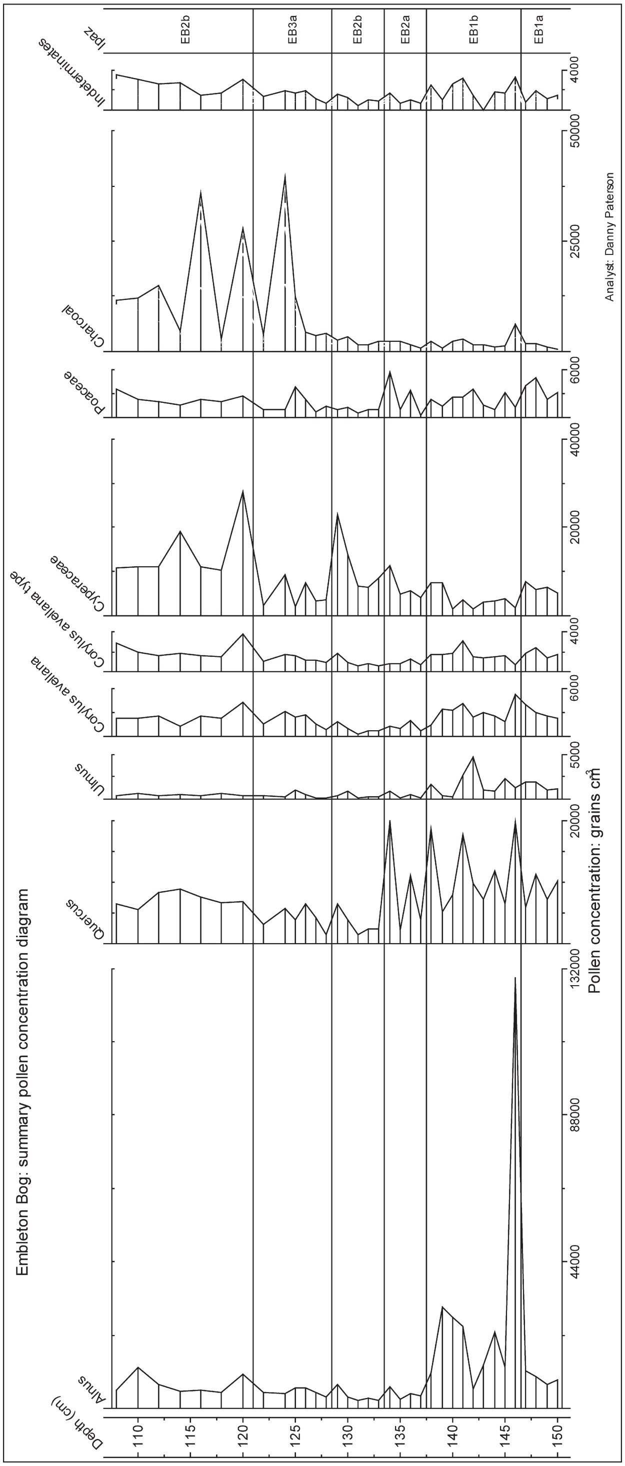


Fig. 3 Pollen concentration data for the major pollen taxa and for charcoal

Cyperaceae and Poaceae <8μm anl-D may be through shading by *Alnus* or may be associated with a drying mire surface.

The erratic representation of *Alnus* (figs. 2, 3) makes it difficult to understand woodland dynamics, probably because density and location of *Alnus* trees near the coring site fluctuated and, as they did so, the deposition of pollen of dryland trees was either excluded or made easier. *Betula* trees might have taken advantage for a few decades in the local *Alnus* canopy. It is unlikely that *Ulmus* did so because *Ulmus* would not have occupied the bog surface. Instead, its pollen might have drifted in from surrounding slopes (figs. 2, 3). The peak deposition of *Ulmus* pollen at 142.0 cm, and its subsequent fall as *Alnus* re-established itself, may have been simply through thinning of the tree canopy over the surface of the bog, but this depth is taken as the start of the regionally significant *Ulmus* decline: above lpaz E2 1b *Ulmus* pollen is represented at very low percentages and was probably absent from local woodland. The scarcity of *Ulmus* pollen concentrations above 141.0 cm supports this (fig. 3). *Quercus*, together with *Corylus*, remained important on drier ground. *Quercus* would not have grown on the bog surface. The exaggerated and apparently regular peaks in *Quercus* pollen concentrations in this zone and in lpaz E2 2a (fig. 3), and only in *Quercus*, are difficult to explain. They indicate an approximate doubling of the pollen 'rain' at discrete intervals, probably too short to represent increased numbers of trees. The explanation may lie in fluctuating pollen productivity, perhaps in mast years. No single dryland tree taxon seems to have taken advantage of the decline and probable absence of *Ulmus*.

Lpaz E2 2a (137.5–133.5 cm): c. 4000 cal BC to c. 3900 cal BC

The *Alnus* canopy on the bog surface was either reduced or the trees receded from the coring site. *Myrica* pollen is not recorded. Nor above 136 cm is *Calluna*, and *Filipendula* values fall, suggesting marked re-organisation of bog surface plant communities. Increases in Cyperaceae suggest either increased flowering, as *Alnus* receded, or increased wetness. The common occurrence of *Stratiotes* and *Potamogeton* (pondweed) might together indicate a water table higher than the peat surface, a lacustrine phase. The undifferentiated *Ranunculus* (buttercups) records only in this sub-zone might then be from aquatic buttercups.

Percentages and concentrations of wild grass (Poaceae <8μm anl-D) increase (figs. 2, 3). Two pollen grains of *Avena-Triticum* (probably wheat) are recorded, the oldest demonstrable cereal grains. There are several herb taxa associated with disturbance (e.g. Asteraceae, Apiaceae, Caryophyllaceae). Crop growing did not disturb the dry woodland canopy greatly, however. It may have been small in scale or some distance away. The percentages of microscopic charcoal particles increase (though not the concentrations: fig. 3), but this is largely true only of the smallest particles, 10–50μm, which may have come some distance (Higuera *et al.* 2007).

Quercus percentages increase markedly, seemingly again as *Alnus* percentages decline (fig. 2), although it is unlikely that these two genera were in direct competition. There may simply have been more *Quercus* trees around the bog. The increase in numbers of spores of *Polypodium vulgare* (polypody) may be related to there being more *Quercus* trees. Polypody is an epiphyte, and *Quercus* is one genus that it favours. Increased *Quercus* pollen productivity from the same number of trees is also feasible. An increasingly open woodland canopy, with gaps following limited clearance might result in this and in the presence of spores of *Polypodium vulgare*, but percentages of tree genera like *Fraxinus*, *Corylus* and *Populus*, that might have benefitted from woodland clearance, do not increase. *Tilia* pollen became less common.

Lpaz E2 2b (133.5–128.5 cm): c. 3900 cal to c. 3800 cal BC

At and close to the coring site, Cyperaceae continued to expand. Aquatic pollen was more common. *Stratiotes* continued to be relatively abundant, accompanied in this sub-zone by *Nymphaea* (water-lily). Open water existed, and it was possibly deeper because *Nymphaea* grows in *c.* 30–150 cm of water. The growth of Cyperaceae between the coring site and the lake shore will have affected the representation of dryland plants. The area around the mire is likely still to have been wooded, though the abundance of *Quercus* was sharply reduced, best seen in fig. 3. The re-appearance of *Fraxinus* might also suggest this as the light-sensitive ash grows better in a thinner tree canopy. *Avena-Triticum* (cf. wheat) is not recorded in the five analyses in this sub-zone. There is no change in the representation of microscopic charcoal.

Lpaz E2 3a (128.5–120.5 cm): c. 3800 cal BC to c. 3600 cal BC

Open water existed near the coring site, with *Stratiotes* and *Nymphaea* recorded, though at much lower frequencies. Cyperaceae values are also sharply reduced at the zone boundary and Cyperaceae stems are not found in the sediment. These changes may represent a lower water table and a decrease in the wetness of the surface of the bog that may have allowed *Alnus* to return to the peat surface. *Calluna* is recorded again, with *Empetrum* (cowberry, another heath plant) and the grains of other heaths (Ericaceae undiff.) suggesting some very dry parts of the bog. The sediment surface may have developed a hummock-hollow topography with low but dry mounds being colonised by a variety of heath plants. Hollows between the mounds still contained some aquatic genera, and *Sphagnum* which is consistently recorded. It is usually acidophilous, as is *Menyanthes*, which is also present.

The percentage and concentrations of Poaceae <8μm anl-D values increase for a short time before declining. Some grasses may have grown on the bog surface but *Anthemis* type, Apiaceae, Asteraceae and Chenopodiaceae indicate dry grassland soil disturbance, possibly through disturbance by cultivation as *Avena-Triticum* group is recorded again. *Cirsium* (thistle) is recorded but this genus has a range of habitats. *Plantago lanceolata* is the only herb in this sub-zone to suggest grazing but this herb is equally at home on bare ground. *Quercus* values increase slightly as do those of *Corylus avellana*: both stabilise above 125 cm, after *c.* 3700 cal BC. The appearance in the pollen record of *Ilex* type (holly) may represent a more open woodland. After *c.* 3700 cal BC the proportions of *Pinus* and *Populus* pollen increase slightly. The nearest *Pinus* trees probably grew in the Durham uplands (Turner and Hodgson 1979; 1981; 1983). *Populus* need not by this time have grown locally so the reason for these far-travelled pollen grains to be better represented is through an increasingly open woodland cover.

The large quantities of charcoal present in this zone indicate a major change in the fire regime. Particles <50μm increase at the base of the zone, reflecting a regional increase in fire frequency or magnitude, but above 125 cm (*c.* 3700 cal BC) larger particles become more common and this probably relates to fires set nearer the coring site (fig. 2), possibly on the dry surface of the bog. Microscopic charcoal is also more abundant when the percentages of wild grasses (Poaceae <8μm anl-D) decline.

Lpaz E2 3b (120.5– 108.0 cm): c. 3600 cal BC to c. 3400 cal BC

Of the aquatic plants in this sub-zone, *Nymphaea* and *Stratiotes* are recorded until 114 cm (*c.* 3450 cal BC). *Hydrocharis* is recorded after this. Cyperaceae values recover. *Menyanthes* is recorded. *Myrica* is common, with *Filipendula*. Heaths are not, though, and neither is *Sphagnum*. Open water remained, probably as small ponds across a bog surface which was probably wetter than in the preceding phase, lpaz E2 3a. Microscopic charcoal particles remain very common but particles >50µm are fewer. Fires, perhaps on the bog surface, became fewer as that surface became wetter. On dry land, grains of *Avena-Triticum* are far fewer. The extent of grassland remains largely unchanged. *Ulex* (gorse) is recorded, probably in acid dry grassland. `The remaining woodland, still >60% tlp, was also unchanged except that after 116.0 cm (*c.* 3600 cal BC) *Tilia* was not recorded. *Alnus* populations expanded once more after this and *Betula* probably grew locally perhaps for the first time.

DISCUSSION

Archaeological excavation has already demonstrated the activities around Embleton's Bog of people at the Mesolithic-Neolithic transition. Concentrations of later Mesolithic flint tools and debitage are as yet not closely dated, and the date of 4468–3995 BC (cal) for the hearth in Trench 6 could not be much more ambiguous in its cultural association; no diagnostic finds are associated with it. In northern Northumberland the start of Neolithic activity has recently been defined from Bayesian ^{14}C analyses to 4080–3790 cal BC, and probably 3900–3850 cal BC (Waddington and Passmore 2012, 144). It is possible, therefore, that the series of archaeological sites around Embleton's Bog were continuously used from the final centuries of hunting, gathering and fishing through the introduction of farming.

The pollen record at Embleton 2 is very detailed. Over the period of about 850 years analysed, from *c.* 4200 cal BC to *c.* 3400 cal BC, there are 35 separate analyses. Assuming a constant sediment accumulation rate over this period, the environments on and around Embleton's Bog have been sampled at intervals of approximately 25 years.

Within the assemblage of aquatic pollen and spores (fig. 2) there is considerable evidence for short-lived changes in the level of the lake. Perhaps a metre or so of open water was present until *c.* 4000 cal BC. The sediment surface became drier after *c.* 4000 cal BC until *c.* 3900 cal BC when aquatic pollen re-appear in comparative abundance. Water may have deepened until *c.* 3800 cal BC when heath plants colonised a dry or partly dry sediment surface, which then became slightly wetter after *c.* 3650 cal BC. These fluctuations in water depth do not relate to the relatively minor changes in the dry land tree cover. Significantly reduced evapo-transpiration from partial woodland clearance on slopes above the bog is an unlikely cause. Groundwater recharge under Embleton's Bog is unlikely to have fluctuated significantly over this short a period.

The changes in water level were probably climate-driven: either through lower temperatures reducing evapo-transpiration or directly through changes in precipitation, or both. The period *c.* 5400 to 4000 cal BC is thought from pollen-analytical data to have been 1–2°C warmer than at present in NW Europe (Davis *et al.* 2003). Three aquatic taxa at Embleton's Bog have southern distributions today (*Stratiotes*, *Hydrocharis*, *Lemna*: Fitter 1978). From these taxa it might be inferred that temperatures were probably warmer than today throughout the record at Embleton 2. Water level changes at Embleton's Bog are not readily recognised in palaeo-climatic indicators but few such analyses are this detailed. A fall of about 2°C in mean July air temperatures at *c.* 4200 cal BC, identified from *Pinus* tree-rings in northern Scandinavia (Grudd *et al.* 2002; Helama *et al.* 2002) might have lowered evapo-transpiration rates sufficiently to create wetter soils, but temperatures ameliorated after *c.* 4100–4000 cal BC (Cheddadi *et al.* 1997; Grudd *et al.* 2002; Karlen and Larsson 2007) and soils may have become drier. This may perhaps have been the case at Embleton's Bog after *c.* 3800 cal BC.

The microscopic charcoal record shows a marked increase in burning after *c.* 3800 cal BC, and even more so at *c.* 3700 cal BC when the fires were closer to, or on, the bog surface itself. There is no reduction in fire frequency and/or intensity with the arrival of farming. Indeed, exactly the opposite happened. Burning after *c.* 3800 cal BC might be associated with a drier environment (Tipping 1996; Cayless and Tipping 2000). The earlier small increase in microscopic charcoal in lpaz E2 2a may also be linked to relative drought, though there is no reduction in microscopic charcoal when soils became wetter in lpaz E2 2b. If anthropogenic in origin, then the microscopic charcoal record after *c.* 3800 cal BC might reflect settlement and domestic hearths, including fires associated with the several burnt mounds, or woodland reduction by burning.

Interpretation of fluctuations in the proportions of trees is complicated by at least one abundant genus, *Alnus*, which was probably growing close to the coring site at times. When trees were on or near the coring site it is harder to sense plant communities on dry ground. The *Quercus-Fraxinus* woodland was disturbed prior to the *Ulmus* decline, though it cannot be said that this was purposeful. The woodland then was not altered by fire because microscopic charcoal values are very low. Despite calcareous soils around Embleton's Bog, *Ulmus* was not abundant in the late Mesolithic woodland. The brief increase in *Ulmus* pollen percentages at 144.0 cm is probably due to a temporary fall in values of *Alnus*. This disguises the character of the *Ulmus* decline. Only one decline, in lpaz E2 1b, is clearly seen. There is no increase in the grass cover, and human impact is not demonstrable in the *Ulmus* decline. No change in the abundance or composition of the woodland cover is seen. The rarity of *Betula* pollen may indicate that local dry woodland had few edges to it or clearings within it. No tree taxa benefit immediately from the reduction of *Ulmus* pollen, as was the case in the Merse (Tipping 2010a, 166–7), although some decades later *Quercus* values increase slightly. *Quercus* woodland on slopes around the basin were then partly cleared at *c.* 3800 cal BC, quite abruptly, over a period of 25 years at most, the time-interval between analyses. This is when charcoal values begin to rise, and fire may have been used in facilitating the clearance.

There is no increase in Poaceae <8µm anl-D (wild grasses), however, so this is not a significant expansion of grassland. Wild grass pollen could have been derived from pasture for livestock (e.g. Stallibrass and Huntley 1996), but there is no evidence in the pollen record for plants promoted by grazing like the Plantaginaceae (plantains), dry-land species of buttercups (Ranunculaceae), *Rumex* (docks, sorrels), *Cirsium* (thistles), Apiaceae and *Pteridium* (bracken). Their pollen grains are dispersed more and further than that of cereal types but they are very rarely recorded at Embleton 2 (fig. 2). The dry land around Embleton's Bog was, seemingly, not given over to livestock. Without such indicator-taxa for pasture, grass pollen at Embleton 2 is taken to indicate grasses growing on the bog surface and not grasses from field and woodland edges or around settlements. The slopes above the bog appear to have been geomorphologically stable in the period analysed and this is probably indicative of the limited impact people had on plant communities on these soils. This is true also for transects across the peat from Trench 6 across the narrow peat-filled Winlaw Burn.

Palynological evidence for crop-growing on slopes around Embleton's Bog is first recorded in lpaz E2 2a at a depth of 137 cm, stratigraphically after the *Ulmus* decline, but possibly very early, at *c.* 4000 cal BC. *Hordeum* group pollen in this environmental setting cannot be used as an indicator of cultivation: *Glyceria* is strongly associated today with many of the plant communities of the bog surface suggested from the pollen record. *Avena-Triticum* group pollen is an indicator of crop growing. The pollen grains are very probably of *Triticum* (wheat) because there is no evidence for *Avena* (oats) having been cultivated at this time. Brown (2007) has suggested from the radiocarbon dating of charred cereal macrofossils that the earliest of these appeared in the British Isles at *c.* 4000 cal BC but became prominent only after *c.* 3800 cal BC. *Avena-Triticum* pollen is found twice in the four subsamples spanning, roughly, a century (*c.* 4000 cal BC to *c.* 3900 cal BC) in lpaz E2 2a, but *Avena-Triticum* pollen is not recorded in the five subsamples in lpaz E2 2b, maybe a century later. The significance of this is unclear but need not be more than that pollen from dry ground is less likely to be recorded when the contribution of Cyperaceae pollen from plants probably growing at the coring site is very high. There is probably no relation between crop growing and changes in soil hydrology recorded on the bog.

CONCLUSION

The very rich early Neolithic archaeological record at Embleton's Bog can be related to economic activities recorded in pollen assemblages, and specifically with farming communities from *c.* 4000 cal BC onwards. Limited clearance of *Quercus* woodland from *c.* 3800 cal BC may have been facilitated by fire. However, burnt mounds at the edge of Embleton's Bog, apparently of early Neolithic date, may have been the focus for fires and the consumption of wood. Other poorly understood activities involved constructing timber platforms into stream channels. The data reported here on short-lived fluctuations in lake level provide a complex, ever-changing context to these activities.

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