

Multi-profile fine-resolution palynology of Late Mesolithic to Bronze Age peat at Cat Stones, Rishworth Moor, Central Pennines, UK.

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Abstract Palynological data from three radiocarbon dated peat profiles at Rishworth Moor in the Pennine hills of northern England provide a record of vegetation change and human impacts in the Late Mesolithic, Neolithic and Bronze Age periods. All three cultures have archaeological sites present in the vicinity, with Late Mesolithic sites by far the most abundant, comprising mainly very late assemblages dominated by ‘rod’-shaped microliths. Pollen evidence of vegetation disturbance occurs during all three archaeological periods, and is attributed to the results of human activity. Microscopic charcoal and non-pollen palynomorph analyses support the pollen evidence. Sites at Cat Stones 2 and Cat Stones 3 record evidence of Neolithic and Bronze Age date only. Cat Stones 1 extends into the Late Mesolithic period, and fine-resolution pollen analyses have been applied in this profile to the Mesolithic-Neolithic transition leading up to the mid-Holocene Elm (*Ulmus*) Decline, which starts here at c.4940 ¹⁴C BP (5670 cal. BP), a typical date for it in the central Pennines. Bayesian age-depth modelling provides precise ages for the vegetation changes and their spatial correlation. The plateau was dominated by scrub and grassy *Calluna* heath from the Late Mesolithic onwards. Elevated microscopic charcoal levels and ruderal herb pollen record phases of fire disturbance below the Elm Decline, including a grain of *Hordeum* cereal-type. Whether this grain represents early cultivation requires further research. Bronze Age impacts are of greater intensity, but disturbances of all three cultural periods are low scale, agreeing with the results of previous research in the Pennines.

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Introduction

In Britain the later mid-Holocene, between about 5500 and 3700 radiocarbon years ago (*c.* 6300–*c.* 4000 cal. BP), contained important environmental and cultural transitions. Deciduous woodland was the natural vegetation, its composition varying with environmental factors (Bradshaw and Hannon, 2004). In the central Pennines hills of northern England the mid-Holocene woodland's upper limit was at *c.*500 m above sea level, based on macrofossil tree remains (Tallis and Switsur, 1983, 1990), above which was scrub, bog and moorland, the 'hyper-forest zone' of Simmons (1975). As well as naturally open areas (Brown, 1997; Fyfe, 2007), mainly wetlands, millennia of disturbance by Mesolithic hunter-gatherers' use of fire might have affected woodland density and composition, encouraging heliophyte trees and shrubs and creating an open woodland with temporary clearings (Caseldine and Hatton, 1993; Jacobi et al, 1976; Simmons and Innes, 1987). Long-term burning by foragers might have changed the woodland's nature and sometimes even converted it to grassland, heathland or bog (Moore, 1975; Moore et al., 1984; Simmons and Innes, 1985, 1987; Simmons 1996). Climate fluctuations during this time were important, with dry conditions before 6000 cal BP, then wet phases at *c.*5900, *c.*5300 and after 4400 cal. BP, with intervening dry periods (Tipping, 1995, 2010; Hughes et al., 2000; Stolze et al., 2012). Climatic fluctuations were influential in regulating vegetation patterns and affecting human responses (Bonsall et al., 2002; Schulting, 2010; Tipping, 1996, 2010; Tipping and Tisdall, 2004). Burning during dry phases could have had a natural cause, and not all woodland disturbances need have had an anthropogenic origin (Grant et al., 2014).

During this period major cultural transitions took place. One was the change from foraging (Mesolithic) to farming (Neolithic) economies and culture, occurring in the centuries leading up to and including the major decline in *Ulmus* (Elm) pollen frequencies that forms a key biostratigraphic marker dated to broadly 5100 radiocarbon years ago (*c.* 5800 cal. BP, Parker et al., 2002) in pollen diagrams. The range of radiocarbon dates for the Elm Decline in northern England is considerable (Griffiths, 2014a), from 5468±80 BP (6410-6004 cal. BP) at Neasham Fen in southeast Durham (Bartley et al., 1976) to 4644±43 BP at Bonfield Gill on the North York Moors (Innes et al., 2013; Innes and Blackford, 2017). It was multi-causal (Parker et al., 2002), with disease, Neolithic farming and climate change all contributory factors. It coincided with an early stage in the Neolithic, with significant elements of Neolithic culture and economy present. However, with a dating variability of several centuries over short distances, it is unlikely that it can be interpreted as marking the first introduction of the Neolithic to a particular location. While the 'full' post-Elm Decline Neolithic was

established by immigrant farmers (Sheridan, 2010), there might have been an ‘initial Neolithic’ before the Elm Decline, with Neolithic elements added to the Mesolithic culture. When that occurred would have varied from place to place (Noble, 2010). The second major cultural transition was the change from Neolithic to Bronze Age, taking place around 4000 radiocarbon years ago (*c.* 4500 cal. BP), and marking the introduction of a more technologically advanced farming society. The replacement of Neolithic populations by immigrating groups accompanied this change (Olalde et al., 2018), after which Bronze Age agriculture and land use expanded under a congenial climate (Tipping, 2005). While the Mesolithic-Neolithic and Neolithic-Early Bronze Age transitions are clearly visible in material culture changes, transformations that occurred in human relations with the land and environment are less so.

We present palynological evidence for land-use and environmental changes through the later Mesolithic, Neolithic and Bronze Age on the high-altitude watershed of the Central Pennine hills, probably marginal for early agriculture in terms of climate, soils and vegetation in the mid- to late Holocene (Young, 2000; Young and Simmonds, 1995; Tipping, 2002). The research aims are (a) to investigate the mid- to later Holocene vegetation of this upland, and to establish whether and to what degree its natural vegetation successions were disturbed, and (b) were any disturbances caused by human land use and if so, was early agriculture involved. Three pollen profiles are analysed, providing spatially comparable data for a better understanding of the transitions into and out of the Neolithic. Fine-resolution palynology is used through the pre-Elm Decline levels to study the Mesolithic-Neolithic Transition in detail.

Materials and Methods

The study area

Rishworth Moor is a flat plateau over 400 m above sea level on the watershed of the Central Pennines to the northeast of Manchester (Figure 1). The plateau is covered by shallow blanket peat, with deeper peat in depressions and in channels at spring heads, where older sediments are preserved. Rishworth Moor has been the subject of previous palynological research (Bartley, 1964, 1975). Current vegetation comprises heath plants *Calluna vulgaris* and other Ericaceae, with *Eriophorum vaginatum*, *Molinia caerulea* and *Sphagnum* spp. in wetter areas. Rarely, wood fragments are present at the base of the peat. The Central Pennines (Figure 1B) contains many archaeological sites (Manby, 1986; Manby et al., 2003; Petch, 1924) and was well exploited by prehistoric communities. Neolithic and

Bronze Age sites are mainly located (Figure 1B) on the lower moors although some occur on the southern edge of Rishworth Moor. Neolithic remains are mainly isolated finds of polished stone axes or leaf-shaped arrowheads (Barnes, 1982). Bronze Age sites are more diverse, including burial monuments, metalwork, pottery, circular enclosures and rock art, indicating a significant occupation of the landscape. Late Mesolithic sites (Wymer, 1977; Barnes, 1982) are abundant at altitude (Figure 1B), and Rishworth Moor lies within the main Pennine distribution area for Late Mesolithic flint microliths (Keighley, 1981; Preston, 2013a, b; Preston and Kador, 2018; Radley et al., 1974; Spikins, 1999; Stonehouse, 1987; Switsur and Jacobi, 1975; Wymer, 1977). These flint scatters were temporary hunting camps within a larger hunter-gatherer territory (Preston, 2013a, b). Mesolithic flint sites occur on and around Rishworth Moor itself (Wymer 1977), including near Cat Stones (Figure 1C). Some are dominated by ‘rod’ shaped microliths. Although rods occurred throughout the late Mesolithic, rod-dominated flint sites are a late variant assemblage (Griffiths, 2014b) representing occupation near the very end of the Mesolithic (Spikins, 2002). Near Rishworth Moor, rod sites have radiocarbon dates on hearth charcoal as late as 5190 ± 30 BP (5993–5910 cal. BP), 5255 ± 30 BP (6178–5929 cal BP) and 5270 ± 45 BP (6183–5934 cal. BP) at March Hill Top (Spikins, 2002) and 5380 ± 80 BP (6306–5948 cal BP) at Dunford Bridge (Switsur and Jacobi, 1975). These two sites, and other sites mentioned in this paper, are located on Figure 2. Griffiths (2014b) calculates that rod microlith use ended in the Pennines between 5900 and 5490 cal. BP, and the Neolithic started between 5870 and 5670 cal BP. The earliest Neolithic dates in the area are 5185 ± 60 BP (6180–5750 cal. BP) at Fox Holes Cave (Hellewell and Milner, 2011) and 5380 ± 90 BP (6313–5938 cal. BP) at Whitwell Long Cairn (Hedges et al., 1994). Some rod sites were therefore contemporaneous with the earliest Neolithic sites, suggesting temporal overlap and cultural coexistence (Keighley, 1981; Griffiths, 2014a, b), probably utilising different parts of the landscape. The environmental context of rod sites is of great interest regarding the palaeoecology of the Mesolithic-Neolithic transition (Albert and Innes, 2015). The transition from Neolithic to Bronze Age in the area occurred around 4450 cal. BP, confirmed by a late Neolithic date of 4060 ± 130 BP (4858–4159 cal BP) at Castle Hill and an early Bronze Age date of 3865 ± 40 (4420–4150 cal BP) at Lindley Moor (Manby et al., 2003). Both sites are only 10 km to the east of Rishworth Moor.

[insert Figures 1 and 2 here]

The research sites

The peat on Rishworth Moor is mostly shallow, but some deeper areas are present and three of these were selected for analysis, at Cat Stones (CS) 1 (SD994172), 2 (SD990172) and 3 (SD999173). All three sites lie between 410 and 420 m above sea level. Their locations are shown on Figure 1C, as is the site of Bartley (1975) near Flint Hill. These sites were in sub-peat depressions, and were chosen to be near to rod sites. Site CS1 contained two metres of peat, but CS2 and CS3 both contained less than a metre. The three cores were collected using a Russian peat borer.

Laboratory methods

The basal parts of the profiles were analysed with varying degrees of fine-resolution sampling. Most of the CS2 sediment was sampled at one cm intervals, increasing to two cm near the top of the sampled core. The base of the CS1 sediment, which covers the terminal Mesolithic to early Bronze Age, comprised very well humified amorphous peat and was sampled at five mm intervals, as was the base of the CS3 profile. The peat from the base of CS1 up to just before the Elm Decline represents the Mesolithic-Neolithic transition and was sampled at contiguous one mm slices. Laboratory preparation followed standard procedures (Moore et al., 1991) using KOH and acetolysis, with HCL and HF in samples with a mineral content. Silicone fluid was used to mount the pollen residue on microscope slides. Pollen identifications and nomenclature follow Moore et al. (1991), except that Poaceae is used rather than Gramineae. At least 800 pollen grains were counted at each level. Poaceae grain frequencies are expressed as different long diameter size-class curves to assist differentiation of grass taxa (Albert and Innes, 2015; Andersen, 1979; Joly et al., 2007), such as *Glyceria*, which can be differentiated from *Hordeum* (Albert and Innes, 2020). Poaceae between 22 and 24 μm include the wetland taxa *Phragmites*, *Deschampsia* and *Molinia*, those between 25 and 27 μm represent *Nardus* (Andersen 1979), those between 28 and 30 μm represent *Glyceria maxima*, and those greater than 30 μm that are not of *Hordeum* type represent *Glyceria fluitans*. Most Poaceae grains recorded were less than 30 μm . Pollen frequencies have been calculated as percentages of a total land pollen sum which comprises trees, shrubs and herbs.

NPPs (non-pollen palynomorphs) were identified using the catalogue developed at the Hugo de Vries Laboratory, University of Amsterdam (van Hove and Hendrikse, 1998) and published illustrations and descriptions (e.g. van Geel, 1978, 1986, 2001; Miola, 2012). A wide range of types was identified in very low values, but only important indicator NPPs are shown on the text diagrams, such as *Gelasinospora* (HdV-1) as an indicator of burning, and *Cercophora* (HdV-112) and

Sporormiella (HdV-113) as indicators of animal dung (van Geel 1986). NPPs are expressed as percentages of total land pollen, although not included in the pollen sum. Full NPP diagrams are shown as supplementary information. NPPs are shown with the conventional ‘Type’ numbering system (Miola, 2012) as well as their taxonomic identification where possible. Microscopic charcoal particles, which passed through the 180 µm sieve during laboratory preparation, were counted on pollen slides (Robinson, 1984) and expressed as percentages of the total land pollen sum. They are divided into size-classes to assist interpretation regarding their likely distance from fire sources (Blackford, 2000). Seven 5 mm thick samples were AMS ¹⁴C dated, comprising bulk peat as levels selected for dating had no terrestrial macrofossils.

Results and Interpretation

Lithostratigraphy

The lithostratigraphies of the sampled parts of the three cores are similar, comprising completely humified black amorphous peat which overlies brown, inorganic sandy mineral soil. Stratigraphic components of the sampled core sections according to Troels-Smith (1955) are shown as Table 1 and as lithostratigraphic columns on the pollen diagrams. They vary in the presence of small macroscopic charcoal pieces in the peat in each core. The peat is described as *Substantia humosa* (Sh) as its environment of deposition is uncertain, but the presence of leaf fragments and aquatic pollen and NPPs (supplementary information files) suggests a partly detrital origin.

Radiocarbon dating

Dating information from the three Cat Stones sites, using Oxcal 4.2 and IntCal13 (Reimer et al., 2013), is presented in Table 2, and the calibrated age range probabilities at the 2σ level are shown in Table 2 and Figure 3a. Three dates are available from Cat Stones 1, and two dates each from Cat Stones 2 and 3. This study covers the basal parts of the profiles, and their mean age-depth model curves are shown as Figure 3b, calculated using Bayesian statistical modelling. A Poisson Sequence was chosen (model parameters: P_Sequence (0.1, 0.4, U(-2,2))) as the most appropriate deposition model as it assumes random deposition, and gives approximate proportionality to depth (Bronk Ramsey, 2008). Age-depth modelled data are shown in supplementary information file S1. The three dates at CS1 appear to be broadly linear (Figure 3a) but the age-depth model (Figure 3b) shows an inflexion in the curve that indicates a doubling in sedimentation rate from c.400 years per cm below 200 cm depth, to c.200 years

per cm above that point (supplementary information file S1). Nevertheless, the overall rate of peat accumulation at CS1 was very slow for three millennia. Peat accumulation rate at CS2 was c.225 years per cm, and at CS3 c.125 years per cm, comparable to the later part of CS1. In all three diagrams the spacing and ages of the available dates suggest no hiatus in peat deposition.

[insert **Figures 3a and b** here]

Palaeogeography

Peat formation began on Rishworth Moor in different places at different times, with a delay of one to two thousand radiocarbon years between initial accumulation at Cat Stones 1 and the basal peat at the other two Cat Stones sites. The bases of CS2 and CS3 are not directly radiocarbon dated, but have modelled ages of 5823 and 5253 cal. BP respectively, suggesting a date around the Elm Decline for CS2 and a clearly post Elm Decline age for CS3. Both sites' pollen assemblages indicate a post-Elm Decline age. The Elm Decline is dated at Cat Stones 1 at 4940±40 BP (modelled 5670 cal. BP). The base of Cat Stones 1 has a modelled age of 6923 cal. BP. The peat profile near Flint Hill on Rishworth Moor (Figure1) investigated by Bartley (1975) also began to form before the Elm Decline, although probably later than at CS1, as the reliability of Bartley's very early radiocarbon date of 5490±140 BP for that feature is highly questionable (Griffiths and Gearey, 2017). There was much spatial variability in marsh and peat formation across the plateau, presumably because of topography, peat forming earlier in basins, often around spring heads (Edwards and Hirons, 1982; Tallis, 1973), whether or not the trigger for peat initiation was climatic (Tipping, 1996) or due to post-disturbance paludification (Moore, 1975; Moore et al., 1984). Highly contrasting dates for peat initiation, very slow early growth, and great variability in peat depth, have been noted over short distances elsewhere in the Pennines, as in the Bleaklow and Kinder areas (Conway, 1954) and at Featherbed Moss in Derbyshire (Tallis, 1973). It is likely to be a common feature of the palaeogeography of the Pennine plateaux (Tallis, 1991; Garton, 2017), as in other British uplands (Cundill, 1977; Tallis, 1991; Tipping, 2008). The extremely amorphous and decomposed nature of the lower peat at all the Cat Stones sites indicates very slow organic accumulation. The sites with pre-Elm Decline peat are in shallow depressions between small knolls, whereas post-Elm Decline peat formation took place on more elevated areas. The basin areas were wetlands in pre-Elm Decline times, marshy or holding shallow open water, and might have been attractive locations for human activity (Albert and Innes, 2015). High frequencies of sedge pollen and *Typha* pollen at the base of Cat Stones 1 support this. Peat accumulation in these basins began very slowly: at Cat Stones 1 several hundred years' accumulation is present in only a few

centimetres of basal peat, and it might well have been the late Neolithic or Bronze Age before the area was fully peat-covered. Records for aquatic pollen of *Nymphaea* and *Typha* in most of the three profiles suggests that bog pools and ponds remained present on the Rishworth Moor plateau well into the Bronze Age. Records of diatoms and other freshwater algae such as *Zygnema* (HdV-58), *Mougeotia* (HdV-313) and *Pediastrum* (HdV-760) in the sediment support this (Supplementary Information Figures S2, S3, S4 and S5).

Palynology

Palynological results at the three Cat Stones profiles are shown in Figures 4–7. For profile CS1, tree and shrub frequencies are shown in Figure 4a, and herb, spore, microcharcoal and selected NPP frequencies are shown in Figure 4b. For profile CS2 pollen and selected NPPs are shown in Figure 5, and those for profile CS3 in Figure 6. The fine-resolution palynology of the pre-Elm Decline phases at CS1 is shown in Figure 7. The diagrams are zoned as disturbance phases in Figure 7 and as pollen assemblage zones in the other diagrams, identified subjectively based on major changes. Descriptions of the zones and phases are given in Table 3, which includes modelled ages derived from supplementary information file S1. Full NPP diagrams are shown as Supplementary Information files S2 (for CS1), S3 (for CS2), S4 (for CS3) and S5 (for CS1 fine resolution).

[insert Figures 4a and 4b here]

Vegetation history

The combined Cat Stones pollen profiles provide a vegetation history extending from c.6900 cal BP at Cat Stones 1 to c.2400 cal BP at Cat Stones 2 (Figure 8). The pollen records overlap chronologically, so that the period from c.5300-4200 cal. BP is represented at all three profiles, the periods from c.4200-3900 and c.5800-5300 cal. BP only in CS1 and 2, the period from c.6900-5800 cal BP only in CS1 and the period after c.3900 only in CS2. The earliest pollen data, from the base of the CS1 profile, indicate paludification and the establishment of a sedge marsh at the site. The surrounding vegetation was dominantly *Corylus* and *Alnus* scrub, perhaps thicker in stream valleys. Hydroseral development saw the sedge marsh replaced by marsh grasses and fen herbs, with a few aquatic taxa, and local increase of *Calluna*. *Alnus* became more common than *Corylus* as local wetness increased. The frequencies of *Ulmus*, *Quercus* and *Tilia* are low and their pollen will have been transported from source areas further away on the plateau-edge slopes, as noted by Tallis and Switsur (1990). When

pollen records from CS2 and CS3 become available, covering post-Elm Decline Neolithic and Bronze Age times, they are very similar to that recorded at CS1, with the same *Calluna*, *Alnus* and *Corylus*-type dominance. *Quercus* does increase slightly from pre-Elm Decline levels, but only to consistently between 10% and 15%, emphasizing its non-local origin. Peaks in individual diagrams of some non-tree taxa, such as Poaceae and *Sphagnum*, do occur but will have been very local changes and not of wider significance, the Poaceae comprising mainly wetland grasses.

[insert Figures 5, 6 and 7 here]

The stability of the vegetation within the pollen source areas of all three cores is notable, as the relative proportions of trees, shrubs, dwarf shrubs and herbs as percentages of total pollen are consistent, at about 40% for trees, 20% for shrubs, 25% for dwarf shrubs and 15% for herbs, with very little fluctuation throughout the combined Cat Stones vegetation history. After the Elm Decline, *Ulmus* percentages remain low in all three profiles. Although disturbances change their percentages slightly, *Alnus*, *Corylus*-type and *Quercus* remain consistent suggesting that little significant change in their distribution occurred. The only exception is just before the Elm Decline when a major expansion of deciduous woodland occurred at site CS1, with heather moorland greatly reduced, although it can not be assumed that this change applied to the whole plateau area.

Vegetation disturbance

Disturbance is registered by increased microcharcoal levels and ruderal taxa, including *Pteridium*, *Melampyrum*, *Artemisia*, Chenopodiaceae, *Senecio*-type and *Silene*-type. The NPP *Glomus* occurs, usually indicating destabilization and erosion of soil after vegetation disturbance (van Geel, 1986). In all cores the highest microcharcoal frequencies are in the smaller size classes, indicating that either burning was very light, or it occurred at some distance from the coring site, with the smaller size particles better transported. Although microcharcoal fluctuates throughout CS1, three disturbance phases of Late Mesolithic age occur, at c.6672–6714, at c.6500 and the third around c.6088 cal. BP, shown on the high-resolution diagram, Figure 7. The oak-alder-hazel scrub was unaffected by it, although *Fraxinus* was encouraged. Fire perhaps took place within grassy *Calluna* heath, rejuvenating it (Davies, 2009; Whittaker and Gimingham, 1962) but not changing overall vegetation distributions. Disturbance occurs at the Elm Decline, but the highest percentages of tree pollen on the diagram occur just before it as woodland spread, perhaps onto the plateau from surrounding slopes, greatly reducing

heather representation as disturbance pressure was relaxed. The period following the Elm Decline has renewed expansion of *Calluna* after burning, with phases of increased disturbance occurring in the Neolithic period at about 5177–5276 cal. BP at CS1, at c.4900 cal BP at CS2, and at c.5005–5129 and c.4800 cal. BP at CS3. Occurring for only a few centuries, these Neolithic phases do not correspond exactly, and are probably discrete local episodes of increased burning, although the c.4800 cal. BP phase at CS2 and CS3 may well record a single larger scale disturbance. Macroscopic charcoal occurs at the level of the earlier phase at CS3, indicating local fire. Disturbances were not plateau-wide but localized events, with low-intensity fire always present somewhere in the catchment. Bartley (1975) noted a big increase in *Calluna* due to disturbance towards the end of the Neolithic at his Flint Hill site, but not registered at the CS profiles, showing that Neolithic disturbances were spatially restricted.

All three CS pollen profiles show a phase of disturbance that can be assigned to the early Bronze Age. It is possible that the c.4800 cal. BP phase at CS2 and CS3 might represent the early Bronze Age *Tilia* decline (Turner, 1962), with *Ulmus* also falling, although this would be an early date for it. Although of similar scale, the Cat Stones later Bronze Age disturbances are not contemporaneous and do not represent a single large disturbance, with ranges of 4191–4290 cal. BP at CS1, a slight phase at c.4172 cal. BP at CS2 and 4385–4571 cal. BP at CS3. Macroscopic charcoal occurs in the peat at this level at CS1, indicating local fire. An agricultural phase with *Hordeum*-type occurs at CS2 at c.4200 cal. BP, followed by a prolonged period of burning. A more intensive and longer phase of disturbance occurs in the mid-Bronze Age from 3300–3800 cal. BP at CS2, and macroscopic charcoal occurs at this level, indicating local fire. The CS1 and CS3 profiles do not extend this late, so the extent of this disturbance is unknown and a single large disturbance across Rishworth Moor cannot be assumed. Bartley (1975) did record disturbance of around this date at Flint Hill, so perhaps this phase was of greater extent than the earlier examples. In summary, although several phases of disturbance can be recognized in the Cat Stones pollen record, none are of great intensity or spatial extent, and are probably confined to within the pollen source area of individual cores rather than being plateau-wide. The disturbances are compared chronologically on Figure 8, correlated with phases of wetter and drier climate (Hughes et al. 2000).

[insert **Figure 8** here]

Discussion

As suggested by Bartley (1975) the pre-peat dryland vegetation at Cat Stones was probably similar to that proposed for the Pennine summits in general (Tallis, 1964), open, patchy scrubby woodland with considerable *Calluna* heath and grassy areas. Few wood remains were noticed on Rishworth Moor by Bartley (1975) or in the present study, although they could be concealed below the peat blanket. The Cat Stones pollen data, however, do indicate that open grassy heathland occurred on the flat plateau within alder, birch, and hazel scrub which would have been denser along the drainage channels, and extensive (Brayshay, 1999) on the plateau edge and on the hillslope immediately below the plateau during Late Mesolithic, Mesolithic-Neolithic transition times, and later. To what extent this mix of plateau heathland and open woodland around its edges would have been the ‘natural’ vegetation, or whether a result of a long period of earlier Mesolithic activity (Jacobi et al., 1976; Simmons and Innes, 1985), remains uncertain. The presence of oak and other tree stumps at much higher altitudes in the Pennines than that of Rishworth Moor (Tallis and Switsur, 1983, 1990) suggests that there was no climatic or other reason why closed woodland would not have covered the central Pennines plateaux in the mid-Holocene (Birks, 1988), and so other factors causing depression of the tree line at this time need to be sought. Extensive burning during Late Mesolithic times may have prevented the colonisation of moorland summits by trees in other northern English uplands (Simmons and Innes, 1981, 1988), as well as in the Pennines (Tallis, 1975). The presence of microcharcoal throughout the peat at Cat Stones suggests that fire was responsible. Macroscopic charcoal in the peat, and the presence of *Gelasinospora*, indicates that some of the burning was near the coring sites (van Geel, 1978), although smaller charcoal pieces might have been wind-transported. That the oak, alder and hazel frequencies do not show very major changes indicates that the burning may have been mainly on the heath and scrub vegetation of the plateau summit, and the *Calluna* curve does appear to be the pollen type most responsive to fluctuations in microcharcoal abundance, indicating a direct relationship between burning and heather moor in the mid-Holocene on Rishworth Moor. This close relationship between burning and *Calluna* has been commonly noted elsewhere (Edwards et al., 1995; Odgaard, 1992). At times, as in zone CS2-c where Poaceae values increase and *Calluna* frequencies are depressed, burning of heather may have been too intense and promoted the expansion of grassland at the expense of heathland, although heather eventually recovered. The effects of such disturbance in causing rapid transition from heather to grass dominance in historic times have been observed in palaeoecological studies of South Pennine peats (Davies 2016).

Human activity

The pollen profiles from Cat Stones provide data enabling reconstruction of vegetation history and human land use. Allied to the previous work of Bartley (1975) at Flint Hill, an understanding of human-vegetation relations on this central Pennines summit plateau is possible.

The pre-Elm Decline period

The pre-Elm Decline period will equate with the Late Mesolithic occupation of the area, given the near-basal radiocarbon date of 5884 ± 37 BP at Cat Stones 1 and the modelled age of 6923 cal. BP for peat formation. The presence of Late Mesolithic flint sites close by, including terminal Mesolithic ‘rod’-dominated sites which have been dated well into the Mesolithic-Neolithic transition in this region (Chatterton, 2007; Griffiths, 2014a; Spikins, 2002), supports the probable Mesolithic agency for any activity before the Elm Decline, unless pure rod sites have an association with the earliest Neolithic. Only Cat Stones 1 records pre-Elm Decline vegetation history, but the fine-resolution diagram provides detailed evidence. The Flint Hill profile of Bartley (1975) preserves little pre-Elm Decline peat but records dominance of the woodland of the Rishworth Moor area by *Quercus* and *Alnus*, with substantial *Ulmus* frequencies of almost 10% of tree pollen, and little non-arboreal pollen, with grass and *Corylus*-type the only significant taxa. Other trees, mainly *Tilia* and *Betula*, were present nearby. This agrees with the regional picture of the higher hillslopes of the Pennines, with open oak-alder woodland with moderate levels of hazel understory or scrub and some open, grassy heath areas (Birks, 1988; Tallis, 1991; Tallis and Switsur, 1990). Although Bartley’s pre-Elm Decline record does not contain much Ericaceae pollen, the Cat Stones 1 profile has significant frequencies of *Calluna* except in the period immediately before the Elm Decline (zone CS1-c on Figure 4a). It is probable that the pre-Elm Decline wooded phase at Bartley’s Flint Hill core corresponds to this brief wooded phase in core CS1. Flint Hill is also near the edge of the plateau and close to a stream channel that would be more likely to have supported trees. The high percentages of woodland in both the Flint Hill core and immediately before the Elm Decline at CS-1, completely replacing *Calluna*, require explanation. Although this was a wetter phase (Tipping 2010), climate fluctuation alone seems an unlikely cause of such a transformation. More probable is a temporary withdrawal of human impact from Rishworth Moor for about a century, perhaps a brief temporal hiatus between Mesolithic and Neolithic activities there. Although there was a chronological overlap between the cultures in the

wider region, there may well have been a spatial mosaic of culture change with some areas abandoned before later reoccupation.

Differences between Flint Hill and CS-1 could be accounted for by differing pollen source areas, Cat Stones 1 being more central to the plateau, while Flint Hill is near the plateau edge. Pollen studies on contemporary heather vegetation (Evans and Moore, 1985; Bunting, 2003) have shown that modern *Calluna* pollen frequencies correlate closely to the actual very local land coverage by heather, so that fossil *Calluna* frequencies can be assumed to be an accurate representation of past local heather abundance and distribution. In the case of the Cat Stones sites this would equate to about 25% local ground cover, with the rest grass and nearby scrub. During this pre-Elm Decline period the vegetation was probably a fluctuating mix of open scrub with clearings, in which heather and grasses grew. The proportions of *Calluna* and grasses at Cat Stones are high for its relatively modest altitude, and resemble the records from much higher altitude sites of over 500 m at sites in the southern Pennines (Tallis and Switsur 1990).

The natural mid-Holocene climax vegetation on the Pennine plateaux should have been forest of some type (Birks, 1988), so a mechanism whereby scrub and grassy heather moorland came to dominate Rishworth Moor at this time must be found. Periods of cooler and wetter climate in the mid-Holocene (Langdon et al., 2003; Tipping, 2010; Stolze et al., 2012) may have played a part, and Hughes et al. (2000) in northern England record a wet phase around 7000 cal. BP which might have inhibited tree growth and prompted paludification in the centuries before peat formation on Rishworth Moor. Many workers, however, have called attention to pollen and charcoal evidence of woodland disturbance, often involving fire, at many pre-Elm Decline peat sites in the Pennines and in other British uplands. As at Rishworth Moor, sometimes this burning of Mesolithic age took place within *Calluna*-dominated upland scrubby heath (Squires, 1978; Caseldine and Hatton, 1993; Simmons, 2001; Smith and Cloutman, 1988), where Mesolithic hunters maintained open areas that had been created by previous woodland burning, preventing recolonisation by trees and rejuvenating the grassy heathland for grazing purposes. The alder-hazel scrub present during peat formation at CS1 may itself have been the result of earlier burning on the plateau. Repeated burning of the same site occurred in the late Mesolithic (Simmons and Innes, 1981, 1988). The regional pollen data for the central Pennines include many phases of woodland opening when Late Mesolithic hunter-gatherers were clearly present, judging from their many microlithic flint sites, interpreted as hunting camps in these uplands where there were high populations of deer and other game animals. It has been suggested that Late

Mesolithic hunters may well have been responsible for creating or maintaining many of these upland woodland openings (Jacobi et al., 1976; Simmons, 1996) and it is a model of Late Mesolithic land use that seems persuasive, perhaps as part of postulated hunter-gatherer subsistence and mobility strategies (Donahue and Lovis, 2006; Preston, 2013b).

The pollen and microcharcoal fluctuations in the Cat Stones 1 pollen diagrams, Figures 4 and 7, suggest that in the millennium before the Elm Decline there was limited and localised disturbance of the vegetation three times, with fire as the main agency. The age-depth model suggests pre-Elm Decline disturbance dated to about 6672–6714, around 6500 and 5962–6254 cal. BP. While these fires occurred (Figure 8) during a generally drier climatic phase (Hughes et al. 2000; Tipping 2010), which may have been permissive, it is likely that Mesolithic people might have been deliberately responsible (Brown, 1997) for fire-disturbance such as this in the central Pennine uplands, presumably for economic purposes although social reasons should not be discounted (Davies et al., 2005). The possibility of accidental escape of fire from hunting camp hearths, which have been found on these high altitude plateaux (Spikins, 2002), must also be considered (Bennett et al., 1990). There is evidence that such disturbances were common and modified the mid-Holocene vegetation in this region, as well as elsewhere in the British uplands (e.g. Blackford et al., 2006; Innes and Simmons, 2000; Innes et al., 2010, 2013; Simmons, 1996; Simmons and Innes, 1985, 1987). In the Pennines, Late Mesolithic flints have been found in stratigraphic association with layers of charcoal and pollen evidence of woodland opening, as at Stump Cross (Walker, 1956) and Dunford Bridge (Radley et al., 1974), which strengthens the link between disturbance and hunters. Microscopic and larger charcoal remains have been recorded at several Pennine sites in association with pollen evidence of woodland recession, and Fountains Earth (Tinsley, 1975), Valley Bog (Chambers, 1978), Pawlaw Mire (Sturludottir and Turner, 1985), Malham Tarn Moss (Pigott and Pigott, 1963), Quick Moss (Rowell and Turner, 1985), Gate Gutter (Gear and Turner, 2001), Eshton Tarn (Bartley et al., 1990), Fleet Moss (Honeyman, 1985), Lanshaw on Rombalds Moor (Bannister, (1985) and Great Close Pasture (Smith, 1986) are regional examples. Often at higher altitudes the charcoal occurs at the base of the peat and in the soil beneath, as at Mire Holes in the north Pennines (Squires, 1978), and Late Mesolithic burning of wet, acidic woodland might have led to water surpluses and organic accumulation within the created clearings (Moore, 1975; Simmons, 1996; Simmons and Innes, 1985, 1987) so that, instead of regeneration of tree cover, the spread of marsh, heath and blanket bog was initiated, a long-term process of landscape change that became important in the uplands from this time

onwards (Garton, 2017; Tallis, 1991). This process might have occurred at CS1. The work of Tallis in the Pennines to the south of Rishworth Moor provides examples at Lady Clough Moor (Tallis, 1975) and at Robinson's Moss and Alport Moor (Tallis and Switsur, 1990). Closest to Rishworth Moor, the high-resolution work of Ryan and Blackford (2010) at Black Heath and Williams (1985) at Soyland Moor record significant woodland opening in what, given their respective radiocarbon dates of 5777 ± 37 BP and 5820 ± 95 BP, seem to be close temporal correlatives of the earliest Cat Stones disturbance phase at 5884 ± 37 BP. Also, a disturbance phase at nearby Lanshaw (Bannister, 1985) is dated to 5840 ± 80 BP, and Brown (1982) recorded an expansion of heath vegetation at a rod site at Rocher Moss dated to 5830 ± 100 BP. There were several fire disturbances of Late Mesolithic age in the central Pennines area around *c.* 5800 ^{14}C BP (*c.* 6600 cal. BP), although their similar dating is probably coincidental (Baillie, 1991). Climate was dry at this time in northern England (Hughes et al., 2000), perhaps increasing the natural incidence of fires. Notably, the disturbances at Black Heath, Soyland Moor and Cat Stones 1 contain large cereal-type grass grains, the Cat Stones example being *Hordeum*-type. Wiltshire and Edwards (1993) also recorded cereal-type pollen at nearby Lismore Fields, interpolated to around 5800 ^{14}C BP. It is speculative to interpret this grain at Cat Stones as indicating cereal cultivation (O'Connell, 1987; Griffiths, 2018), and we only record its presence. More research is needed on this topic.

The Elm Decline and the Neolithic

Bartley (1975) recorded very little indication of human activity or other disturbance in the Neolithic part of his Flint Hill core, with only a single *Plantago lanceolata* grain occurring immediately after the fall of elm. The Elm Decline itself, at around 5100 ^{14}C BP (*c.* 5800 cal. BP., Parker et al., 2002), is considered to lie within the early Neolithic period, and often pollen evidence of woodland opening and even cultivation coincides with it (Innes, 2002). Bartley found almost no such evidence and his fall in elm frequencies itself is not clear. Its date of 5490 ± 140 BP is very early and it might not be the true Elm Decline, as Tallis and Switsur (1990) suspected, which is probably higher in Bartley's core. The date for the start of the Elm Decline at Cat Stones 1, at 4940 ± 40 BP, is much later than that at Flint Hill but is much closer to the usual date for the feature in the Pennine uplands, as at 4855 ± 50 BP (5710–5470 cal. BP) at Alport Moor and 4875 ± 60 BP (5740–5470 cal. BP) at Robinson's Moss (Tallis and Switsur, 1990), at 4990 ± 140 (6008–5449 cal. BP) at Tootley Moss (Hicks, 1971), at 4740 ± 70 (5593–5319 cal. BP) at Black Brook, Anglezarke Moor (Bain, 1991; Walker et al., 1987) and at

4865±50 (5716–5476 cal. BP) at Soyland Moor (Williams, 1985), not far from Rishworth Moor. Although the present study employs a much finer sampling interval than Bartley did, the Elm Decline at Cat Stones 1 also has little evidence of Neolithic activity or interference with the local vegetation, with only a few grains of *Plantago lanceolata* and Chenopodiaceae present in the levels just above the elm pollen fall. This suggests that Bartley was correct in describing Neolithic impacts as slight. Microscopic charcoal frequencies of all size classes rise at the Cat Stones 1 Elm Decline, but the smallest size class most distinctly, and this may best be interpreted as transport from a distance (Blackford, 2000), perhaps from the higher slopes on the edge of the plateau. That the increase in woodland pollen at the expense of *Calluna* heath that occurs just before the Elm Decline (zone CS1-c and at Flint Hill) is reversed as *Calluna* expands again just after it, suggests some human impact on the plateau and at its margins associated with the Elm Decline event.

For the Elm Decline and for the Neolithic period as a whole, this record of low levels of impact on Rishworth Moor seems typical of the higher Pennines. The three Cat Stones profiles all cover the Neolithic and so allow a spatial investigation of environmental history, but there is little spatial variation recorded. The summary curves on the pollen diagrams show that tree and tall shrub frequencies at all three profiles are consistently around 60% of total pollen throughout the Neolithic levels, with the majority of the remaining pollen contributed by *Calluna*, with some wetland herbs like grass and sedge. All of the central Pennine Neolithic pollen assemblages between c.5000 (c.5750 cal. BP) and c.4000 ¹⁴C BP (c.4450 cal. BP) (Hicks, 1971; Tallis and McGuire, 1972; Tinsley, 1975) are similar to Rishworth Moor in this respect. The high altitude pollen records closest to Rishworth Moor, at Soyland Moor (Williams, 1985) and Black Heath (Ryan and Blackford, 2010) do not extend far into Neolithic age peat. Only in the higher altitude limestone areas with better soils, as above Wensleydale (Honeyman, 1985) or in Craven (Bartley et al., 1990; Smith, 1986) is there evidence of significant forest clearance in the Neolithic. It is likely that Neolithic farming in the Pennines followed a ‘forest farming’ strategy rather than a more intensive one with ‘landnam’ style forest clearance (Edwards, 1993). A lower-scale ‘within woodland’ type of farming would be less visible in the pollen record and would account for the ephemeral signature of Neolithic farmers in this upland. There is a Neolithic-age episode of burning at all three Cat Stones profiles, however, so some Neolithic activity did occur on and around the Rishworth plateau. The identification of *Cercophora* and *Sporormiella* in CS3-e, for example, suggests the presence of animals, perhaps indicating low intensity stock herding. Similarly, Garton (2017) recorded charcoal layers of Neolithic age at altitude above Tintwistle 20 km south of

Rishworth Moor, and it is clear that some fire-disturbance of the upland vegetation did take place in the millennium following the Elm Decline in parts of the central and southern Pennines.

The Bronze Age

The consensus of previous palaeoecological research in the central Pennines, and in all of the uplands of northern England, is that the early to mid-Bronze Age was the period when the first substantial clearances of woodland took place, causing long-lasting changes in upland vegetation communities (Tallis and McGuire, 1972; Barnes, 1982; Birks, 1988). This agrees with the Pennine archaeological record (Figure 1B), as Bronze Age sites are common (Barnes, 1982; Burgess, 1995; Manby, 1986; Manby et al., 2003) and occur on Rishworth Moor and its environs (Figure 1C), mainly as stray finds. They prove presence if not settlement. At CS2 the phase of disturbance which includes *Hordeum*-type pollen and ruderal weeds at about 4200 cal. BP probably relates to the early Bronze Age as it is contemporary with the Bronze Age archaeological site of Lindley Moor only a few kilometres to the east (Manby et al., 2003). As frequencies for *Alnus*, *Quercus* and *Corylus*-type decline, this disturbance probably took place within the scrub and woodland around the plateau edge although there were areas of alder and hazel scrub on the plateau. As microcharcoal increases only moderately, this might be an agricultural episode that did not involve major burning. The new Cat Stones data confirm the evidence presented by Bartley (1975) from his site at Flint Hill that some woodland opening, with oak being replaced by heather, took place on Rishworth Moor in the early Bronze Age, although it was not very intensive. The presence of cereal-type pollen, with the possible arable weed Chenopodiaceae, suggests a mixed cultivation and pastoral land use, although of limited intensity. As cereal-type pollen grains are not well dispersed (Hall et al., 1993; Vuorela, 1973), the activity was probably not far from the site, as is supported by the presence of small macroscopic charcoal.

The rises in microcharcoal and disturbance taxa around 3875±30 BP (4416–4164 cal. BP) at Cat Stones 1 and after 3660±35 BP (between 3900 and 3300 cal. BP) at Cat Stones 2 suggest major burning. This might have included opening of woodland, although the tree and shrub curves are little affected. Cereal-type pollen is absent during this phase at CS2 and most burning was within the plateau's grassy heather moorland, which was rejuvenated. This might have been its purpose, to improve grazing. The already open nature of the Rishworth Moor vegetation meant that renewed burning, occurring within open communities, had little effect on arboreal/non-arboreal ratios. The Cat Stones modelled dates give a more accurate age context for that phase of activity and are well within

the age range for previously recorded Bronze Age agricultural impacts in the Pennines. The Flint Hill and Cat Stones 2 Bronze Age disturbances are both near the western edge of the Rishworth Moor plateau, so the activity might have been concentrated in that area. The pollen records at CS1 and CS3, in the central and eastern areas, do not extend to the Bronze Age however, so it may be that Bronze Age disturbance affected the whole of the plateau. The introduction of the Bronze Age at Rishworth Moor can be characterised as increased impacts on the vegetation and the introduction of cereal cultivation as a small part of a mixed, but mainly pastoral, economy. As noted by Bartley (1975), these Bronze Age impacts were of low intensity and the very low values for dung fungi spores *Cercophora* and *Sporormiella*, as in CS2-f, suggests low concentrations of animals.

The Cat Stones Bronze Age disturbance phases join a large number of regional examples where the spread of open grassland, heath and bog vegetation at the expense of light woodland (Birks, 1988) took place after Bronze Age clearance phases. The first significant woodland clearances took place well after 4000 ¹⁴C BP (c.4400 cal. BP) at the pollen sites of Leash Fen (Hicks, 1971, 1972), Deep Clough (Tallis and McGuire, 1972) and Fountains Earth (Tinsley, 1975, 1976), and therefore in the early and middle Bronze Age. At Leash Fen the clearances are dated to between 3740±100 (4412–3859 cal. BP) and 3450±110 BP (4057–3446 cal. BP). At Skell Moor Tinsley noted major clearance at 3880±100 BP (4568–3984 cal. BP). At Deep Clough the clearance is dated to 3540±120 BP (4151–3485 cal. BP). Similar evidence occurs throughout the central Pennines (Tallis and Switsur, 1973). To the north, Honeyman (1985) recorded major woodland clearance in Wensleydale at 3850±50 (4416–4099 cal. BP) and 3930±50 BP (4520–4184 cal. BP), while the first major clearance event occurred at Eshton Tarn in Craven (Bartley et al., 1990) at 3600±100 BP (4224–3638 cal. BP). At lower altitude than Rishworth Moor, Eshton Tarn is on the flanks of the Pennines and its significant levels of cereal-type pollen indicate the different distribution of early Bronze Age settlement and agriculture, with more established and extensive arable cultivation at lower altitudes and much lower scale cultivation on the Pennine high plateaux. Cereal-type pollen occurs at most higher altitude sites in this period, and so a mixed economy with some cultivation was carried out even at high altitudes, which supports the *Hordeum* records at Cat Stones. While a warmer, drier climate in the Bronze Age (Burgess, 1985; Tipping, 2002) will have encouraged the spread of agriculture up the Pennine hillslopes, animal husbandry and pastoralism was the main agricultural pursuit on Rishworth Moor at this time, as at most summit plateau sites in the central Pennines and in other English uplands (Bradley, 1972; Fleming, 1971; Manby et al., 2003).

Conclusion

The research at Cat Stones has demonstrated that fine-temporal and fine-spatial analyses greatly enhance the detail and the intelligibility of palynological data. Taking more than one core in even a small area will provide a fuller understanding of vegetation change than a single core. Using a fine sampling interval gives a much clearer picture of short-term environmental change, revealing evidence that might well be missed at coarser sampling. Methodologically, separation of the microcharcoal data into size classes has enhanced understanding of the particles' taphonomy and of the spatial location of the burning relative to the pollen sampling sites, and its use in palaeofire studies is recommended. The division of Poaceae grains into size classes has also been useful, as it showed the relative proportions of various wetland wild grasses in the assemblages, with the low percentages of very large grass grains other than those identified as of cereal type reducing scope for confusion at that end of the size scale. The addition of NPP counts to the pollen data has proved useful and, although in low percentages, they have enhanced the interpretation of local environments.

Cat Stones supports previous study in showing that human impacts in this upland area were low scale and mainly pastoral, although the finding of *Hordeum*-type pollen shows that limited cultivation probably extended to high altitude during the Neolithic and Bronze Age, unless these pollen grains were carried to this altitude from elsewhere, which seems unlikely. Pastoralism (Fleming, 1971) was the main land-use method, even though grazing indicators are few. Perhaps livestock were released onto the plateau and dispersed rather than herded. There is no clear relationship between disturbances and climate fluctuation, so they are most likely to record human activities. Disturbance before the Elm Decline, and the presence of *Hordeum*-type pollen, adds Cat Stones to a local group of sites, including Soyland Moor (Williams, 1985), Black Heath (Ryan and Blackford, 2009) and Lismore Fields (Wiltshire and Edwards, 1993), where cereal-type pollen might record a phase of cultivation very early in the Pennine Mesolithic-Neolithic Transition. The Cat Stones record of these *Hordeum*-type grains adjacent to rod flint sites, as recorded in the North York Moors (Albert and Innes 2015), suggests that the cultural affinities of rod flint sites during the transition require further investigation. If these grains were not cereals, but wild grasses, the fire disturbance still places Cat Stones with the larger group of pre-Elm Decline disturbances attributable to Late Mesolithic activity (e.g. Simmons, 1996; Simmons and Innes, 1987). Rishworth Moor requires more high-resolution palaeoecological scrutiny of the Mesolithic-Neolithic Transition.

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References

Albert BM and Innes JB (2015) Multi-profile fine-resolution palynological and microcharcoal analyses at Esklets, North York Moors, UK, with special reference to the Mesolithic-Neolithic Transition. *Vegetation History and Archaeobotany* 24: 357–375.

Albert BM and Innes JB (2020) On the distinction of pollen grains of early varieties of *Hordeum* from *Glyceria* species: addressing the early cereal cultivation problem in palynology. *Palynology* 44: 369–381.

Andersen ST (1979) Identification of wild grass and cereal pollen. *Danmarks Geologiske Undersøgelse Årbok 1978*: 69–92.

Baillie MGL (1991) Suck in and smear: two related chronological problems for the 90s. *Journal of Theoretical Archaeology* 2: 12–16.

Bain MG (1991) Palaeoecological studies in the Rivington Anglezarke uplands, Lancashire. Unpub. PhD Thesis, University of Salford.

Bannister J (1985) The vegetational and archaeological history of Rombalds Moor, West Yorkshire. Unpublished PhD. Thesis, University of Leeds.

- Barnes B (1982) *Man and the Changing Landscape. A Study of Occupation and Palaeo Environment in the Central Pennines*. Liverpool: Merseyside County Museums and University of Liverpool.
- Bartley DD (1964) Pollen analysis of organic deposits in the Halifax region. *Naturalist* 89: 77–87.
- Bartley DD (1975) Pollen analytical evidence for prehistoric forest clearance in the upland area west of Rishworth, West Yorkshire. *New Phytologist* 74: 375–381.
- Bartley DD, Chambers C and Hart-Jones B (1976) The vegetational history of parts of south and east Durham. *New Phytologist* 77: 437–468.
- Bartley DD, Jones IP and Smith RT (1990) Studies in the Flandrian vegetational history of the Craven District of Yorkshire: the lowlands. *Journal of Ecology* 78: 611–632.
- Bennett KD, Simonson AB and Peglar SM (1990) Fire and man in postglacial woodlands in eastern England. *Journal of Archaeological Science* 17: 635–642.
- Birks HJB (1988) Long-term ecological change in the British uplands. In: Usher MB and Thompson DBA (eds.) *Ecological Change in the Uplands*. Oxford: Blackwell Scientific Publications, pp. 37–56.
- Blackford JJ (2000) Charcoal fragments in surface samples following a fire and the implications for interpretation of subfossil charcoal data. *Palaeogeography, Palaeoclimatology, Palaeoecology* 164: 33–42.
- Blackford JJ, Innes JB, Hatton J et al. (2006) Mid-Holocene environmental change at Black Ridge Brook, Dartmoor, SW England: a new appraisal based on fungal spore analysis. *Review of Palaeobotany and Palynology* 141: 189–201.

- Bonsall C, Macklin MG, Anderson DE et al. (2002) Climate change and the adoption of agriculture in north-west Europe. *European Journal of Archaeology* 5: 9–23.
- Bradley R (1972) Prehistorians and pastoralists in Neolithic and Bronze Age England. *World Archaeology* 4: 192–204.
- Bradshaw RHW and Hannon GE (2004) The Holocene structure of North-West European Temperate Forest induced from palaeoecological data. In: Honnay O, Verheyen K, Bossuyt B et al. (eds.) *Forest Biodiversity: Lessons from History for Conservation*. Oxford: CABI Publishing, pp. 11–25.
- Brayshay B (1999) Some palaeoenvironmental evidence for marginality in the Upper Mersey basin. In: Nevell M. (ed.) *Living on the Edge of Empire: Models, Methodology and Marginality*. Manchester: Council for British Archaeology North-West, pp. 82–89.
- Bronk Ramsey C (2008) Deposition models for chronological records. *Quaternary Science Reviews* 27: 42–60.
- Brown AG (1997) Clearances and clearings: deforestation in Mesolithic/Neolithic Britain. *Oxford Journal of Archaeology* 16: 133–146.
- Brown RL (1982) The palaeoecology of three archaeological sites in the central Pennines. In: Barnes B *Man and the Changing Landscape. A Study of Occupation and Palaeo Environment in the Central Pennines*. Liverpool: Merseyside County Museums and University of Liverpool, pp. 86–96.
- Bunting J (2003) Pollen-vegetation relationships in non-arboreal moorland taxa. *Review of Palaeobotany and Palynology* 125: 285–298.
- Burgess C (1985) Population, settlement and upland landscapes. In: Spratt D and Burgess C (eds) *Upland Settlement in Britain: the 2nd Millennium BC and After*. Oxford: British Archaeological Reports British Series 143, pp. 195–219.

- Burgess C (1995) Bronze Age settlement and domestic pottery in northern Britain: some suggestions. In: Kinnes I. and Varndell G. (eds.) *Unbaked Urns of Rudely Shape*. Oxford, Oxbow Monograph 55, pp. 145–158.
- Caseldine C and Hatton J (1993) The development of high moorland on Dartmoor: fire and the influence of Mesolithic activity on vegetation change. In: Chambers FM (ed.) *Climate Change and Human Impact on the Landscape*. Chapman and Hall: London, pp. 119–131.
- Chambers C (1978) A radiocarbon-dated pollen diagram from Valley Bog, on the Moor House National Nature Reserve. *New Phytologist* 80: 273–280.
- Chatterton R (2007) South Haw, Northern England. An upland Mesolithic site in context. In: Waddington C and Pedersen K (eds.) *Mesolithic Studies in the North Sea Basin and Beyond*. Oxford: Oxbow Books, pp. 69–80.
- Conway VM (1954) Stratigraphy and pollen analysis of southern Pennine blanket peats. *Journal of Ecology* 42: 117–147.
- Cundill PR (1977) The distribution, age and formation of blanket peat on the North York Moors. *Proceedings of the North of England Soils Discussion Group* 9: 25–29.
- Davies GM, Legg CJ, Smith AA et al. (2009) Rate of spread of fires in *Calluna vulgaris*-dominated moorlands. *Journal of Applied Ecology* 46: 1054–1063.
- Davies P, Robb JG and Ladbrook D (2005) Woodland clearance in the Mesolithic: the social aspects. *Antiquity* 79: 280–278.
- Davies R (2016) Late Holocene regime shifts in moorland ecosystems: high resolution data from the Pennines, UK. *Vegetation History and Archaeobotany* 25: 207–219.

- Donahue RE and Lovis WA (2006) Regional settlement systems in Mesolithic northern England: Scalar issues in mobility and territoriality. *Journal of Anthropological Archaeology* 25: 248–258.
- Edwards KJ (1993) Models of forest farming for north-west Europe. In: Chambers FM (ed.) *Climate Change and Human Impact on the Landscape*. London: Chapman and Hall, pp. 134–145.
- Edwards KJ and Hirons KR (1982) Date of blanket peat initiation and rates of spread as a problem in research design. *Quaternary Newsletter* 36: 32–37.
- Edwards KJ, Whittington G and Hirons KR (1995) The relationship between fire and long-term wet heath development. in South Uist, Outer Hebrides, Scotland. In: Thompson DBA, Hester AJ and Usher MB (eds.) *Heaths and Moorlands: Cultural Landscapes*. Edinburgh: Scottish Natural Heritage, pp. 240–248.
- Evans A and Moore PD (1985) Surface studies of *Calluna vulgaris* (L.) Hull and their relevance to the interpretation of bog and moorland pollen diagrams. *Circaea* 3: 173–178.
- Fleming A (1971) Bronze Age agriculture on the marginal lands of north-east Yorkshire. *Agricultural History Review* 19: 1–24.
- Fyfe R (2007) The importance of local-scale openness within regions dominated by closed woodland. *Journal of Quaternary Science* 22: 571–578.
- Garton D (2017) Prior to peat: assessing the hiatus between Mesolithic activity and peat inception on the Southern Pennine moors. *Archaeological Journal* 174: 281–334.
- Gear A and Turner J (2001) Palynological evidence for changing patterns of land use. In: Vyner BE (ed.) *Stainmore: the Archaeology of a North Pennine Pass*. Hartlepool: Tees Archaeology Monograph Series 1, pp. 23–34.

- Grant MJ, Hughes PDM and Barber KE (2014) Climatic influence upon early to mid-Holocene fire regimes within temperate woodlands: a multi-proxy reconstruction from the New Forest, southern England. *Journal of Quaternary Science* 29: 175–188.
- Griffiths S (2014a) A Bayesian radiocarbon chronology of the early Neolithic of Yorkshire and Humberside. *Archaeological Journal* 171: 2–29.
- Griffiths S (2014b) Points in time: the Mesolithic-Neolithic transition and the chronology of late rod microliths in Britain. *Oxford Journal of Archaeology* 33: 221–243.
- Griffiths S (2018) A Cereal Problem? What the Current Chronology of Early Cereal Domesticates might tell us about changes in Late Fifth and Early Fourth Millennium cal BC Ireland and Britain. *Env Arch* DOI: 10.1080/14614103.2018.1529945
- Griffiths S and Gearey B (2017) the Mesolithic-Neolithic transition and the chronology of the “Elm Decline”: a case study from Yorkshire and Humberside, United Kingdom. *Radiocarbon* 59: 1321–1345.
- Hall VA, Pilcher JR and Bowler M (1993) Pre-elm decline cereal-size pollen: evaluating its recruitment to fossil deposits using modern pollen rain studies. *Biology and environment: Proceedings of the Royal Irish Academy* 93B: 1–4.
- Hedges REM, Housley RA, Bronk Ramsey C and van Klinken GJ (1994) Radiocarbon dates from the Oxford AMS system: Archaeometry datelist 18. *Archaeometry* 36: 337–374.
- Hellewell E and Milner N (2011) Burial practices at the Mesolithic-Neolithic transition in Britain. *Documenta Praehistorica* 38: 61–68.
- Hicks SP (1971) Pollen analytical evidence for the effect of prehistoric agriculture on the vegetation of north Derbyshire. *New Phytologist* 70: 647–667.

- Hicks SP (1972) The impact of man on the East Moor of Derbyshire from Mesolithic times. *Archaeological Journal* 129: 1–21.
- Honeyman A (1985) Studies in the Holocene vegetational history of Wensleydale. Unpublished PhD thesis, University of Leeds.
- Hughes PDM, Mauquoy D, Barber KE et al. (2000) Mire development pathways and palaeoclimatic records from a full Holocene peat archive at Walton Moss, Cumbria, England. *The Holocene* 10: 465–479.
- Innes JB (2002) Introduction to the Flandrian. In: Huddart D and Glasser NF (eds.) *Quaternary of Northern England*. Peterborough: Geological Conservation Review Series 25, pp. 351–365.
- Innes JB and Simmons IG (2000) Mid-Holocene charcoal stratigraphy, fire history and palaeoecology at North Gill, North York Moors, UK. *Palaeogeography, Palaeoclimatology, Palaeoecology* 164: 151–165.
- Innes JB and Blackford JJ (2009) An evaluation of palaeoecological data as evidence of cultural transition in the final Mesolithic millennium of northern and north-western Europe. In: Crombé P, van Strydonck M, Sergant J et al.(eds.) *Chronology and Evolution in the Mesolithic of N(W) Europe*. Cambridge: Cambridge Scholars Publishing, pp. 573–590.
- Innes JB, Blackford JJ and Simmons IG (2010) Woodland disturbance and possible land-use regimes during the Late Mesolithic in the English uplands: pollen, charcoal and non-pollen palynomorph evidence from Bluewath Beck, North York Moors, UK. *Vegetation History and Archaeobotany* 19: 439–452.
- Innes JB, Blackford JJ and Rowley-Conwy PA (2013) Late Mesolithic and early Neolithic forest disturbance: a high resolution palaeoecological test of human impact hypotheses. *Quaternary Science Reviews* 77: 80–100.

- Jacobi RM, Tallis JH and Mellars PA (1976) The southern Pennine Mesolithic and the ecological record. *Journal of Archaeological Science* 3: 307–320.
- Joly C, Barillé L, Barreau M et al. (2007) Grain and annulus diameter as criteria for distinguishing pollen grains of cereals from wild grasses. *Review of Palaeobotany and Palynology* 146: 221–233.
- Keighley JJ (1981) The Palaeolithic and Mesolithic periods. In: Faull ML and Moorhouse SA (eds.) *West Yorkshire: an Archaeological Survey to AD 1500*. Wakefield: West Yorkshire Metropolitan County Council, pp. 75–89.
- Langdon PG, Barber KE and Hughes PDM (2003) A 7500-year peat-based palaeoclimatic reconstruction and evidence for an 1100-year cyclicity in bog surface wetness from Temple Hill Moss, Pentland Hills, southeast Scotland. *Quaternary Science Reviews* 22: 259–274.
- Manby TC (1986) The Bronze Age in western Yorkshire. In: Manby TC and Turnbull P (eds) *Archaeology in the Pennines: Studies in Honour of Arthur Raistrick*. Oxford: British Archaeological Reports British Series 158, pp. 55–126.
- Manby TC, King A and Vyner B (2003) The Neolithic and Bronze Ages: a time of early agriculture. In: Manby TC, Moorhouse S and Ottaway P (eds.) *The Archaeology of Yorkshire. An Assessment at the Beginning of the 21st century*. Leeds: Yorkshire Archaeological Society Occasional Paper 3, pp. 35–116.
- Miola A (2012) Tools for non-pollen palynomorphs (NPPs) analysis: a list of Quaternary NPP types and reference literature in English language (1972–2011). *Review of Palaeobotany and Palynology* 186:142–161.
- Moore PD (1975) Origin of blanket mires. *Nature* 256: 267–269.
- Moore PD, Merryfield DL and Price MDR (1984) The vegetation and development of blanket mires. In: Moore PD (ed.) *European Mires*. London: Academic Press, pp. 203–235.

Moore PD, Webb JA and Collinson ME (1991) *Pollen Analysis*, 2nd edn. Oxford: Blackwell.

Noble G. (2010) 'Islanding' the Mesolithic-Neolithic transition: approaches to landscapes of contact and transformation in Northwest Europe. In: Finlayson B and Warren G (eds.) *Landscapes in Transition*. Oxford: Council for British Research in the Levant and Oxbow Books, pp. 125–132.

O'Connell M (1987) Early cereal-type pollen records from Connemara, western Ireland, and their possible significance. *Pollen et Spores* 29: 207–224.

Odgaard B (1992) The fire history of Danish heathland areas as reflected by pollen and charred particles in lake sediments. *The Holocene* 2: 218–226.

Olalde I, Brace S, Allentoft ME et al. (2018) The Beaker phenomenon and the genomic transformation of northwest Europe. *Nature* 555: 190–196.

Parker AG, Goudie AS, Anderson DE et al. (2002) A review of the mid-Holocene elm decline in the British Isles. *Progress in Physical Geography* 26: 1–45.

Petch JA (1924) *Early Man in the District of Huddersfield*. Huddersfield: Tolson Memorial Museum Handbook 3.

Pigott CD and Pigott ME (1963) Late-Glacial and Post-Glacial deposits at Malham, Yorkshire. *New Phytologist* 62: 317–334.

Preston PR (2013a) New perspectives and suggested directions for future research on Central Pennine Mesolithic lithic scatters. *The Archaeological Forum Journal: CBA Yorkshire* 2: 1–20.

Preston PR (2013b) Bones, stones or ethnography: challenging the Mesolithic mobility models for northern England. In: Preston PR and Schörle K (eds.) *Mobility, Transition and Change in*

Prehistory and Classical Antiquity. Oxford: British Archaeological Reports International Series 2534, pp. 29–48.

Preston PR and Kador T (2018) Approaches to interpreting Mesolithic mobility and settlement in Britain and Ireland. *Journal of World Prehistory* 31: 321–345.

Radley J, Tallis JH and Switsur VR (1974) The excavation of three ‘narrow-blade’ Mesolithic sites in the southern Pennines, England. *Proceedings of the Prehistoric Society* 40: 1–19.

Reimer PJ, Bard E, Bayliss A et al. (2013) IntCal13 and Marine13 radiocarbon age calibration curves 0–50,000 Years cal. BP. *Radiocarbon* 55: 1869–1877.

Robinson D (1984) The estimation of the charcoal content of sediments. A comparison of methods on peat sections from the Isle of Arran. *Circaea* 2: 121–128.

Rowell TK and Turner J (1985) Litho-, humic- and pollen stratigraphy at Quick Moss, Northumberland. *Journal of Ecology* 73: 11–25.

Ryan PA and Blackford JJ (2009) Late Mesolithic environmental change in the upland zone of Britain. In: Crombé P, van Strydonck M, Sergeant J et al.(eds.) *Chronology and Evolution in the Mesolithic of N(W) Europe*. Cambridge: Cambridge Scholars Publishing, pp. 591–613.

Ryan PA and Blackford JJ (2010) Late Mesolithic environmental change at Black Heath, south Pennines, UK: a test of Mesolithic woodland management models using pollen, charcoal and non-pollen palynomorph data. *Vegetation History and Archaeobotany* 19: 545–558.

Schulting R (2010) Holocene environmental change and the Mesolithic-Neolithic transition in north-west Europe: revisiting two models. *Environmental Archaeology* 15: 160–172.

- Sheridan A (2010) The neolithisation of Britain and Ireland: the 'Big Picture'. In: Finlayson W and Warren G (eds) *Landscapes in Transition*. Oxford: Council for British Research in the Levant and Oxbow Books, pp. 89–105.
- Simmons IG (1975) Towards an ecology of Mesolithic man in the uplands of Great Britain. *Journal of Archaeological Science* 2: 1–15.
- Simmons IG (1996) *The Environmental Impact of Later Mesolithic Cultures*. Edinburgh: Edinburgh University Press.
- Simmons IG (2001) Ecology into landscape: Some English moorlands in the Later Mesolithic. *Landscapes* 2: 42–55.
- Simmons IG and Innes JB (1981) Tree remains in a North York Moors peat profile. *Nature* 294: 76–78.
- Simmons IG and Innes JB (1985). Late Mesolithic land-use and its impacts in the English uplands. *Biogeographical Monographs* 2: 7–17.
- Simmons IG and Innes JB (1987) Mid-Holocene adaptations and Later Mesolithic forest disturbance in northern England. *Journal of Archaeological Science* 14: 385–403.
- Simmons IG and Innes JB (1988) Studies in the Late Quaternary vegetational history of the North York Moors. X. Investigations on East Bilsdale Moor. *Journal of Biogeography* 15: 299–324.
- Smith AG and Cloutman EW (1988) Reconstruction of Holocene vegetation history in three dimensions at Waun-Fignen-Felen, an upland site in South Wales. *Philosophical Transactions of the Royal Society of London B: Biological Sciences* 322:159–219.

- Smith RT (1986) Aspects of the soil and vegetation history of the Craven district of North Yorkshire. In: Manby T and Turnbull P (eds.) *Archaeology in the Pennines: Studies in Honour of Arthur Raistrick*. Oxford: British Archaeological Reports British Series 158, pp. 3–28.
- Spikins PA (1999) *Mesolithic Northern England: Environment, Population and Settlement*. British Archaeological Reports, British Series 283. Oxford: Archaeopress.
- Spikins PA (2002) *Prehistoric People of the Pennines*. Leeds: West Yorkshire Archaeological Service.
- Squires R (1978) Conservation in Upper Teessdale: contributions from the palaeoecological record. *Transactions of the Institute of British Geographers New Series* 3: 129–150.
- Stolze S, Dörfler W, Monecke T and Nelle O (2012) Evidence for climatic variability and its impact on human development during the Neolithic from Loughmeenaghan, County Sligo, Ireland. *Journal of Quaternary Science* 27: 393–403.
- Stonehouse P (1987) Mesolithic sites on the Pennine watershed. *The Greater Manchester Archaeological Journal* 3: 5–17.
- Sturludottir SA and Turner J (1985) The elm decline at Pawlaw Mire: an anthropogenic interpretation. *New Phytologist* 99: 323–329.
- Switsur VR and Jacobi RM (1975) Radiocarbon dates for the Pennine Mesolithic. *Nature* 256: 32–34.
- Tallis JH (1964) Studies on southern Pennine peats I. The general pollen record. *Journal of Ecology* 52: 323–331.
- Tallis JH (1973) Studies on southern Pennine peats. V. Direct observations on peat erosion and peat hydrology at Featherbed Moss, Derbyshire. *Journal of Ecology* 61: 1–22.
- Tallis JH (1975) Tree remains in southern Pennine blanket peats. *Nature* 256: 482–484.

- Tallis JH (1991) Forest and moorland vegetation in the south Pennine uplands in the mid-Flandrian period. III. the spread of moorland – local, regional and national. *Journal of Ecology* 79: 401–415.
- Tallis JH and McGuire J (1972) Central Rossendale: the evolution of an upland vegetation. I. the clearance of woodland. *Journal of Ecology* 60: 721–737.
- Tallis JH and Switsur VR (1973) Studies on southern Pennine peats. VI. A radiocarbon dated pollen diagram from Featherbed Moss, Derbyshire. *Journal of Ecology* 61: 743–751.
- Tallis JH and Switsur VR (1983) Forest and moorland in the south Pennine uplands in the mid-Flandrian period. I. Macrofossil evidence of the former forest cover. *Journal of Ecology* 71: 585–600.
- Tallis JH and Switsur VR (1990) Forest and moorland in the south Pennine uplands in the mid-Flandrian period. II. The hillslope forests. *Journal of Ecology* 78: 857–883.
- Tinsley HM (1975) The former woodland of the Nidderdale Moors and the role of early man in its decline. *Journal of Ecology* 63: 1–26.
- Tinsley HM (1976) Cultural influences on Pennine vegetation with particular reference to North Yorkshire. *Transactions of the Institute of British Geographers New Series* 1: 310–322.
- Tipping R (1995) Holocene evolution of a lowland Scottish landscape: Kirkpatrick Fleming. Part I, peat- and pollen-stratigraphic evidence for raised moss development and climatic change. *The Holocene* 5: 69–81.
- Tipping R (1996) Microscopic charcoal records, inferred human activity and climatic change in the Mesolithic of northernmost Scotland. In: Pollard A and Morrison A (eds.) *The Early Prehistory of Scotland*. Edinburgh: Edinburgh University Press, pp. 39–61.

- Tipping R (2002) Climatic variability and ‘marginal’ settlement in upland British landscapes: a re-evaluation. *Landscapes* 3: 10–28
- Tipping R (2005) Coping with climatic stresses: climate change, prehistoric farmers and the transmission of knowledge. *Landscape Archaeology and Ecology* 5: 90–95.
- Tipping R (2008) Blanket peat in the Scottish Highlands: timing, cause, spread and the myth of environmental determinism. *Biodiversity and Conservation* 17: 2097–2113.
- Tipping R (2010) The case for climatic stress forcing choice in the adoption of agriculture in the British Isles. In: Finlayson W and Warren G. (eds) *Landscapes in Transition*. Oxford: Council for British Research in the Levant and Oxbow Books, pp. 66–76.
- Tipping R and Tisdall E (2004) Continuity, crisis and climate change in the Neolithic and early Bronze Age periods of North-West Europe. In: Shepherd IAG and Barclay G (eds.) *Scotland in Ancient Europe. The Neolithic and Early Bronze Age of Scotland in their European Context*. Edinburgh: Society of Antiquaries of Scotland, pp. 71–82.
- Troels-Smith J (1955) Characterisation of unconsolidated sediments. *Danmarks geologiske Undersøgelse* Series IV, 3: 38–73.
- 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.
- van Geel B (1986) Application of fungal and algal remains and other microfossils in palynological analyses. In: Berglund BE (ed.) *Handbook of Palaeoecology and Palaeohydrology*. Chichester: John Wiley, pp. 497–505.

- van Geel B (2001) Non-pollen palynomorphs. In: Smol JP, Birks HJB and Last WM (eds.) *Tracking Environmental Change Using Lake Sediments, Terrestrial, Algal and Siliceous Indicators, vol. 3*. Dordrecht: Kluwer, pp. 99–119.
- van Hove ML and Hendrikse M (1998) A study of non-pollen objects in pollen slides. The types as described by Dr. Bas van Geel and colleagues. Unpub. MS Utrecht.
- Vuorela I (1973) Relative pollen rain around cultivated fields. *Acta Botanica Fennica* 102: 1–27.
- Walker AJ, Keyser RS and Otlet RI (1987) Harwell Radiocarbon Measurements V. *Radiocarbon* 29: 78–99.
- Walker D (1956) A site at Stump Cross, Grassington, Yorkshire and the age of the Pennine microlithic industry. *Proceedings of the Prehistoric Society* 22: 23–29.
- Whittaker E and Gimingham CH (1962) The effects of fire on the regeneration of *Calluna vulgaris* (L.) Hull. from seed. *Journal of Ecology* 50: 815–822.
- Williams CT (1985) *Mesolithic Exploitation Patterns in the Central Pennines: a Palynological Study of Soyland Moor*. Oxford: British Archaeological Reports, British Series 139.
- Wiltshire P and Edwards KJ (1993) Mesolithic, early Neolithic, and later prehistoric impacts on vegetation at a riverine site in Derbyshire, England. In: Chambers FM (ed.) *Climate Change and Human Impact on the Landscape*. London: Chapman and Hall, pp. 157–168.
- Wymer J (1977) *Gazeteer of Mesolithic sites in England and Wales*. London: CBA Research Report 20.
- Young R (2000) Continuity and change: marginality and later prehistoric settlement in the northern uplands. In: Harding J and Johnston R (eds.) *Northern Pasts: Interpretations of the Later*

Prehistory of Northern England and Southern Scotland. Oxford: British Archaeological Reports
302 pp. 71–80.

Young R and Simmonds T (1995) Marginality and the nature of later prehistoric upland settlement in the north of England. *Landscape History* 17: 5–16.

Captions to figures

Figure 1.

Map showing the location of Rishworth Moor (section C) within the Central Pennine Hills (section B). The distributions of archaeological sites are derived from Wymer (1977) and Barnes (1982) and are not comprehensive, showing main sites only. Site symbols are shown as open circles (Late Mesolithic sites dominated by rod microliths), yellow circles (other Late Mesolithic sites), green diamonds (Neolithic) and red triangles (Bronze Age). In section C the three Cat Stones pollen diagrams are shown as black stars and labelled CS1-CS3. The previously published pollen site of Bartley (1975) is shown as a black triangle and is labelled RM. Contours are in metres above mean sea level.

Figure 2.

Locations of the Pennine sites mentioned in this paper, sources are cited in the text. 1. Quick Moss 2. Mire Holes 3. Valley Bog 4. Pawlaw Mire 5. Gate Gutter 6. Fleet Moss 7. Malham Tarn Moss 8. Great Close Pasture 9. Fountains Earth 10. Skell Moor 11. Stump Cross 12. Eshton Tarn 13. Lanshaw 14. Black Brook 15. Deep Clough 16. Soyland Moor 17. Black Heath 18. March Hill Top 19. Rocher Moss 20. Dunford Bridge 21. Robinson's Moss 22. Tintwistle 23. Bleaklow 24. Alport Moor 25. Lady Clough Moor 26. Featherbed Moss 27. Kinder 28. Lismore Fields 29. Totle Moss 30. Leash Fen. The black star is the location of Rishworth Moor.

Figure 3.

a) Calibrated (95%) radiocarbon age range probabilities at Cat Stones. Calibrations use Oxcal 4.2 and IntCal13 (Reimer et al., 2013). Details of the radiocarbon dates are shown in Table 2. b) Age-depth model curves from the three cores at Cat Stones, using Bayesian statistical modelling. A Poisson Sequence (P_Sequence) was chosen (model parameters: P_Sequence (0.1, 0.4, U(-2,2))) as the most appropriate deposition model as it assumes random deposition, and gives approximate proportionality to depth (Bronk Ramsey, 2008). Position and details of radiocarbon dates are shown. For modelled ages see supplementary information file S1.

Figure 4.

Pollen diagram from the base of Cat Stones 1, sampled at five millimeter intervals. Tree and shrub percentages are shown on Figure 4a, and herbs, spores, microcharcoal and selected NPPs on Figure 4b. Frequencies are shown as percentages of a total land pollen sum which includes trees, shrubs and herbs, but excludes spores and NPPs. Taxa represented in the various Poaceae size classes in this and other diagrams are listed in the laboratory methods section. A modelled calibrated ages BP scale is shown. Details of AMS date calibrations are

shown on Table 2. Lithology symbols are: dots (sand), horizontal dashes (amorphous peat) and black triangles (small charcoal pieces). See table 1.

Figure 5.

Pollen, spores, microcharcoal and selected NPPs diagram from the base of Cat Stones 2, sampled at five millimeter intervals. Frequencies are shown as percentages of a total land pollen (TLP) sum which includes trees, shrubs and herbs, but excludes spores and NPPs. A modelled calibrated ages BP scale is shown. Details of AMS date calibrations are shown on Table 2. Lithology symbols are: dots (sand), horizontal dashes (amorphous peat) and black triangles (small charcoal pieces). See table 1.

Figure 6.

Pollen, spores, microcharcoal and selected NPPs diagram from the base of Cat Stones 3, sampled at five millimeter intervals. Frequencies are shown as percentages of a total land pollen sum which includes trees, shrubs and herbs, but excludes spores and NPPs. A modelled calibrated ages BP scale is shown. Details of AMS date calibrations are shown on Table 2. Lithology symbols are: dots (sand), horizontal dashes (amorphous peat) and black triangles (small charcoal pieces). See table 1.

Figure 7.

Fine resolution pollen, spores, microcharcoal and selected NPPs diagram between 2003 and 2025 mm from zone CS1 at Cat Stones 1, sampled at contiguous 1mm intervals. Frequencies are shown as percentages of a total land pollen sum which includes trees, shrubs and herbs, but excludes spores and NPPs. A modelled calibrated ages BP scale is shown. Details of AMS date calibrations are shown on Table 2. The start of the Elm Decline occurs at 2000 mm (Figure 3), and is dated to 4940 ± 40 BP (modelled age of 5670 cal. BP). Lithology symbols are: dots (sand), horizontal dashes (amorphous peat) and black triangles (small charcoal pieces). See table 1.

Figure 8. Correlation of burning history and disturbance phases at Rishworth Moor from the three sites in this paper (CS1-3) and the site of Bartley (1975) at Flint Hill. CS1 to CS3 use modelled ages, while the ages of disturbances at Flint Hill are interpolated from Bartley's radiocarbon dated pollen diagram. Disturbance phases are shaded. Wetter and drier climate phases are also shown, following Hughes *et al.* (2000), with wetter phases shaded diagonally.

Table 1. Lithostratigraphy of the sampled Cat Stones cores.

Depth (cm)	Description
Cat Stones 1	
192-193	Black amorphous peat with very small charcoal pieces Sh4, anth+ nig.4, strf.0, elas.0, sicc.2
193-197	Black amorphous peat Sh4 nig.4, strf.0, elas.0, sicc.2, lim. sup. 0
197-202	Black amorphous peat with occasional very small charcoal pieces Sh4, anth+ nig.4, strf.0, elas.0, sicc.2, lim. sup. 0
202-203	Black amorphous peat with occasional leaf fragments and a slight mineral fraction at the base of the unit Sh4, Dh+, Ag+ nig.4, strf.0, elas.0, sicc.2, lim. sup. 0
203 →	Silty brown sand Ga4, Ag+ nig. 2+, strf.0, elas.0, sicc.2, lim. sup. 2
Cat Stones 2	
62-70	Black amorphous peat Sh4 nig.4, strf.0, elas.0, sicc.2
70-73	Black amorphous peat with many small charcoal pieces Sh4, anth+++ nig.4, strf.0, elas.0, sicc.2, lim. sup. 0
73-79	Black amorphous peat with occasional leaf fragments Sh4, Dh+ nig.4, strf.0, elas.0, sicc.2 lim. sup. 0
79-80	Black amorphous peat with very small charcoal pieces Sh4, anth+ nig.4, strf.0, elas.0, sicc.2, lim. sup. 0
80-84	Black amorphous peat with occasional leaf fragments Sh4 nig.4, strf.0, elas.0, sicc.2 lim. sup. 0
84 →	Silty brown sand Ga4, Ag+ nig. 2+, strf.0, elas.0, sicc.2, lim. sup. 2
Cat Stones 3	
59.5-60.5	Black amorphous peat Sh4 nig.4, strf.0, elas.0, sicc.2
60.5-61.5	Black amorphous peat with occasional small charcoal pieces Sh4, anth+ nig.4, strf.0, elas.0, sicc.2, lim. sup. 0
61.5-63.5	Black amorphous peat Sh4 nig.4, strf.0, elas.0, sicc.2 lim. sup. 0
63.5-64.5	Black amorphous peat with small charcoal pieces Sh4, anth++ nig.4, strf.0, elas.0, sicc.2, lim. sup. 0
64.5-66.5	Black amorphous peat with occasional leaf fragments Sh4, Dh+ nig.4, strf.0, elas.0, sicc.2, lim. sup. 0
66.5-67.5	Black amorphous peat with many small charcoal pieces Sh4, anth+++ nig.4, strf.0, elas.0, sicc.2, lim. sup. 0
67.5 →	Silty brown sand Ga4, Ag+ nig. 2+, strf.0, elas.0, sicc.2, lim. sup. 2

Table 2. Results of AMS ¹⁴C dating at Cat Stones, Rishworth Moor, North Yorkshire

Site	Depth (cm)	lab code	¹⁴ C date (yr BP)	Age range (cal. BP)	Mean age (cal. BP)
Cat Stones 1	193	SUERC-36701	3875 ± 30	4,416 – 4,164	4,290 ± 126
Cat Stones 1	200	Poz-36627	4940 ± 40	5,744 – 5,597	5,670 ± 73
Cat Stones 1	202.5	SUERC-42139	5884 ± 37	6,792 – 6,637	6,714 ± 77
Cat Stones 2	74	Poz-73356	3660 ± 35	4,089 – 3,889	3,989 ± 100
Cat Stones 2	79	Beta-298434	4330 ± 30	4,969 – 4,844	4,906 ± 62
Cat Stones 3	64	Beta-298435	4240 ± 30	4,860 – 4,654	4,757 ± 103
Cat Stones 3	67	Poz-73358	4460 ± 35	5,290 – 4,967	5,129 ± 162

^aAge range (2σ) and mean derived from calibration results using Oxcal 4.2 and IntCal13 (Reimer et al., 2013)

Table 3. Zone and disturbance phase descriptions and modelled age ranges at Cat Stones (CS) profiles 1, 2 and 3.

Depths (mm)	Main phase characteristics - % values are of total land pollen (TLP), microcharcoal values are as a combined percentage of all size classes.
Profile CS1 (Figures 4a and 4b)	
CS-1-a: 2030-2027.5 6923-6819	Characterised by high <i>Corylus</i> -type and Cyperaceae values, with lesser values for <i>Alnus</i> , <i>Quercus</i> and <i>Ulmus</i> . All other TLP types are poorly represented. Of the taxa outside the TLP sum, <i>Polypodium</i> and Filicales occur in high frequencies.
CS1-b: 2027.5-2002.5 6819–5775	The phase is characterized by high frequencies of <i>Alnus</i> , <i>Corylus</i> -type and <i>Calluna</i> pollen, with lesser values for <i>Quercus</i> and <i>Ulmus</i> . A rise in tree pollen, mainly <i>Alnus</i> and <i>Betula</i> but also <i>Quercus</i> , occurs at the end of the phase, <i>Polypodium</i> increases. Microcharcoal frequencies are low.
CS-1c: 2002.5-1997.5 5775-5621	This zone records a peak in tree and shrub frequencies, comprising increased <i>Betula</i> , <i>Alnus</i> and <i>Corylus</i> -type as well as <i>Quercus</i> . <i>Calluna</i> percentages are greatly reduced to less than 5%.
CS1-d: 1997.5-1972.5 5621–5128	<i>Calluna</i> frequencies return to high values of up to 40%, while <i>Betula</i> , <i>Alnus</i> , <i>Ulmus</i> and <i>Corylus</i> -type are diminished greatly. Microcharcoal frequencies in all size classes fluctuate but are mostly high. Herb pollen percentages are low but include the ruderals Chenopodiaceae, <i>Silene</i> -type and <i>Senecio</i> -type.
CS1-e: 1972.5-1932.5 5128–4339	<i>Calluna</i> percentages decline although remaining high. <i>Quercus</i> and <i>Alnus</i> frequencies are unchanged but <i>Corylus</i> -type increases. <i>Ulmus</i> frequencies remain very low, and. <i>Fraxinus</i> appears late in the zone. Poaceae is very low, but several herb taxa occur with <i>Plantago lanceolata</i> , <i>Potentilla</i> -type, <i>Melampyrum</i> and <i>Succisa</i> present while Chenopodiaceae, <i>Silene</i> -type and <i>Senecio</i> -type are consistently recorded. Cyperaceae rises near the top of the zone. Microcharcoal values are low at about 60%.
CS1-f: 1932.5-1925	Most tree and shrub values are unchanged but <i>Betula</i> rises to 10%. <i>Calluna</i> rises to about 30% and <i>Hedera</i>

4339-4191	occurs. Poaceae and Cyperaceae values are low. <i>Silene</i> -type, <i>Senecio</i> -type and <i>Plantago media</i> are present. <i>Sphagnum</i> rises sharply to almost 50%. Microcharcoal frequencies rise to around 160%.
 Profile CS2 (Figure 5)	
CS2-a: 840-805 5823-5181	This zone is characterized by tree, shrub and dwarf shrub pollen, mainly <i>Alnus</i> , <i>Corylus</i> -type and <i>Calluna</i> , which reaches around 40%, with lower values for <i>Quercus</i> , <i>Betula</i> , <i>Tilia</i> and <i>Ulmus</i> . Herb pollen values are low and are contributed mainly by Poaceae, as well as wetland taxa <i>Potentilla</i> -type, <i>Succisa</i> and <i>Typha</i> . Microcharcoal frequencies are low at around 60%.
CS2-b: 805-785 5181-4815	Tree and shrub frequencies are unchanged except that <i>Quercus</i> declines. Poaceae increases but there are few other herbs except for <i>Typha</i> . <i>Pteridium</i> occurs and microcharcoal rises to over 200%.
CS2-c: 785-755 4815-4264	<i>Ulmus</i> percentages fall to very low values and <i>Tilia</i> ceases to be recorded. <i>Quercus</i> declines through the zone while <i>Alnus</i> and <i>Betula</i> frequencies rise. <i>Alnus</i> , <i>Corylus</i> -type at 20% and <i>Calluna</i> at 30% are the main other taxa. Other than Poaceae, herb pollen is poorly represented, mainly by wetland taxa Cyperaceae and <i>Typha</i> . <i>Sphagnum</i> is present while microcharcoal frequencies are moderate at around 100%.
CS2-d: 755-735 4264-3898	<i>Quercus</i> values remain low and <i>Alnus</i> percentages fall. <i>Lonicera</i> occurs but other tree, shrub and dwarf shrub values are unchanged. Poaceae rise sharply to over 20% and a <i>Hordeum</i> -type grain occurs. Ruderal herb taxa <i>Plantago lanceolata</i> , <i>Plantago major</i> , Chenopodiaceae and <i>Senecio</i> -type occur, with <i>Potentilla</i> -type. Values for microcharcoal are very low at 20%.
CS2-e: 735-690 3898-3164	Most tree and shrub taxa are unchanged, although <i>Calluna</i> rises gradually through the zone. Herb pollen frequencies are low and Poaceae returns to around 20%. <i>Sphagnum</i> occurs. There is some <i>Pteridium</i> and a grain of <i>Melampyrum</i> . Microcharcoal values, including large size classes, rise sharply and are very high late in the zone, peaking at almost 600%.
CS2-f: 690-630 3164-2614	Tree and shrub frequencies are unchanged except for a major decline in <i>Calluna</i> percentages to less than 20%. Frequencies of Poaceae of the small size class rise to over 20%. <i>Typha</i> is consistently present and other herbs include <i>Plantago lanceolata</i> and <i>Senecio</i> -type. Microcharcoal frequencies rise to mid-zone, peaking at 230%, when <i>Gelasinospora</i> , <i>Cercophora</i> and <i>Sporormiella</i> occur. They then decline to near absence.
CS2-g: 630-620 mm 2614-2522	Little change occurs except for a marked rise in <i>Calluna</i> percentages to almost 50% and a fall in Poaceae. <i>Quercus</i> also declines. Other than <i>Typha</i> , the only other herbs recorded are <i>Plantago lanceolata</i> and <i>Cirsium</i> -type. Microcharcoal frequencies are very low. <i>Sporormiella</i> , <i>Gelasinospora</i> and <i>Cercophora</i> occur.
 Profile CS3 (Figure 6)	
CS3-a: 675-672.5 5191-5160	Tree pollen accounts for 40% and <i>Corylus</i> -type is low at less than 20%. Poaceae is high at 30% and a grain of <i>Plantago lanceolata</i> occurs. Most herbs are wetland types, <i>Succisa</i> , <i>Mentha</i> -type, <i>Potentilla</i> -type and <i>Typha</i> . Microcharcoal frequencies are moderate at 120%.
CS3-b: 672.5-662.5 5160-5036	<i>Alnus</i> and <i>Corylus</i> -type show low peaks at the start of the zone as <i>Quercus</i> declines, and <i>Salix</i> and <i>Lonicera</i> occur. <i>Calluna</i> rises as Poaceae falls. Several herb taxa occur but all are wetland types. <i>Pteridium</i> occurs and microcharcoal frequencies are very high at 300%.
CS3-c: 662.5-642.5 5036-4788	All tree, shrub and dwarf shrub frequencies are almost unchanged. <i>Fraxinus</i> and <i>Salix</i> are recorded. Wetland and aquatic taxa are the most common but open ground herbs <i>Plantago lanceolata</i> , <i>Artemisia</i> , <i>Melampyrum</i> and Chenopodiaceae also occur. <i>Pteridium</i> and the fungal spores <i>Gelasinospora</i> and <i>Sporormiella</i> are recorded. Microcharcoal begins the zone high at about 140% but declines to very low values at the end.

- CS3-d: 642.5-630
4788-4633 Tree, shrub and dwarf shrub percentages are almost unchanged, although *Alnus* and *Betula* increase slightly at the start of the zone and *Ulmus* falls at the end. *Salix* appears. A grain of *Hordeum*-type occurs at the start of the zone and *Plantago lanceolata* is present throughout. *Rumex* and *Pteridium* also occur. Aquatic pollen is common. Total microcharcoal values are high at 190% and include large size classes.
- CS3-e: 630-600
4633-4261 There is little change in tree and shrub percentages. *Calluna* rises to almost 50% as Poaceae frequencies fall to low values of less than 10%. Other taxa are almost unchanged. Several herb taxa occur including *Plantago lanceolata*, *Plantago major*, Chenopodiaceae and *Melampyrum* in very low frequencies. The NPPs *Cercophora*, *Gelasinospora* and *Sporormiella* are present. Moderate total microcharcoal percentages of around 140% are maintained, including larger size classes.

Profile CS1. Fine-resolution phases within phase CS-a (Figure 7)

- CS1a-1: 2025-2023.5
6714-6651 Tree, shrub and dwarf shrub frequencies comprise 80% of total land pollen, dominated by *Calluna* at almost 40% and *Corylus*-type with lesser *Alnus*. Open ground herbs Chenopodiaceae, Ranunculaceae and *Rumex acetosella* occur, with a grain of *Hordeum*-type. *Polypodium* frequencies are very high at 40%, and the aquatic taxa *Typha* and *Zygnema* occur. Microcharcoal frequencies, particularly for smaller size classes, are high at 200%.
- CS1a-2: 2023.5-2021.5
6651-6568 Pollen frequencies are largely unchanged, although a rise in *Calluna* to over 40% occurs in late phase as *Alnus* declines slightly. Open ground herb taxa no longer occur and frequencies for the small microcharcoal sizes are reduced although still high at almost 100%.
- CS1a-3: 2021.5-2018.5
6568-6443 Tree pollen frequencies rise to 40%, contributed mainly by *Alnus* and *Betula*. *Fraxinus* occurs. *Calluna* percentages decline to only 20%, and shrubs remain unchanged although *Salix* is now recorded. Herbs are mainly wetland types. *Calluna* frequencies are reduced. Few open ground herbs are recorded. Microcharcoal frequencies are extremely low at about 25%.
- CS1a-4: 2018.5-2016.5
6443-6359 There are almost no changes in the tree and shrub frequencies. *Calluna* increases slightly. Herb taxa are only wetland types, including *Typha* and *Filipendula*. Microcharcoal frequencies are high at around 180% and include large size class. *Gelasinospora* is present.
- CS1a-5: 2016.5-2014.5
6359-6276 *Calluna* rises slightly as Poaceae declines. Tree and shrub taxa are unchanged. Occasional open ground weeds are present, including *Artemisia*, *Taraxacum*-type and *Melampyrum*. The aquatic taxa *Pediastrum* and *Typha* occur. Microcharcoal frequencies are very low, at less than 20%.
- CS1a-6: 2014.5-2010.5
6276-6109 Total microcharcoal values rise to over 100%, with some large size class present. *Calluna* rises to over 40%, while *Alnus* and *Corylus*-type decline. *Salix* and *Erica*-type are consistently present. The open ground herbs Chenopodiaceae and *Silene*-type occur. The fungal type *Cercophora* is present.
- CS1a-7: 2010.5-2006.5
6109-5942 Apart from one level, microcharcoal frequencies are high, reaching almost 300% late in the phase, with large size classes present. Tree, shrub and dwarf shrub values are unchanged, although *Calluna* reaches 40% late in the phase. *Typha* is consistently present.
- CS1a-8: 2006.5-2003
5942-5795 Microcharcoal values are reduced to around 40%. Tree and shrub frequencies are unchanged while *Calluna* declines through the phase to only 20%. All herbs are wetland types, with *Typha* prominent. *Pteridium* occurs early in the phase.