Bronze Age and later vegetation history on the limestone Tabular Hills of North-East Yorkshire, UK: pollen diagrams from Dalby Forest.

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(abstract)

This paper presents the results of palynological investigations on the limestone Tabular Hills of the North York Moors in north-east England. These limestone areas have the highest concentration of post-Mesolithic archaeological sites in this upland but because of the geology and paucity of suitable organic deposits have had almost no palynological research with which to assess the land-use history of these cultures, nor their impacts on the vegetation. This lack of palaeoecological information from the Tabular Hills has been addressed, so that the area's environmental history can be added to that of the rest of the North York Moors, which is relatively well known. Three pollen profiles have been examined, Yondhead Rigg providing an early Bronze Age to post-Medieval record, Seavy Slack providing a late Iron Age to post-Medieval record, and Dargate Dykes providing a late Medieval to modern record. The combined vegetation history from the three sites indicates a similar story to that from elsewhere on the Moors, with substantial forest disturbance in Bronze Age and Iron Age times, with significant woodland regeneration after each, but with the first main forest clearance phase for agriculture occurring during the Romano-British period, followed by early Medieval woodland regeneration, then extensive clearance in the later Medieval period for some arable cultivation and extensive animal husbandry on the rich calcareous grassland. In each agricultural phase the scale and intensity of disturbance seems to have been greater in these fertile limestone areas than in the rest of the Moors, with their poorer, more acidic soils, but still with an emphasis on stock-rearing and less extensive cultivation. The results will allow a more comprehensive landscape history of the North York Moors to be understood for later prehistory and more recent times.

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Introduction

The upland of the North York Moors in north-east England (Fig. 1) has been subjected to intensive palynological research over several decades, so that its Holocene vegetational history, including the role of humans in bringing about vegetation change, is generally well understood (Simmons 1995; Innes 1999). Research of the 1960s to 1980s established the broad history of vegetation change throughout the Holocene and was summarised by Spratt and Simmons (1976) and Jones, Cundill, and Simmons (1979) and then by Simmons et al. (1993). Since Simmons et al.'s synthesis, several more papers have been published, but these have mainly focused on the detailed reconstruction of prehistoric human impacts on the vegetation with an emphasis on the Mesolithic and Neolithic archaeological periods and the transition between them around the time of the mid-Holocene Elm Decline (e.g. Innes and Simmons 2000; Innes, Blackford, and Simmons 2010; Innes, Blackford, and Rowley-Conwy 2013; Albert and Innes, 2015). Nevertheless, knowledge of later prehistoric and historic cultures' land use and influence on vegetation change is considerable (Atherden 1976a, 1976b, 1989; Jones 1978; Chiverrell and Atherden 2000), and the overall temporal coverage of the vegetation history and palaeoecology of the North York Moors is quite comprehensive. In contrast, the spatial distribution of palynological work is very uneven. While there are many pollen sites from peat deposits on the central and eastern watershed plateaux of the high moors and the lower northern sandstone plateau of the Cleveland Hills (Fig. 1B), they are almost absent from the limestone Tabular Hills, which form the southern flank of the upland, dipping gradually towards the lowland basin of the Vale of Pickering. On the Corallian limestone, Wheeler (2007, 2008) published short pollen diagrams from lower Rye Dale and the Hambledon Hills and Richards et al. (1987) dated the base of a small bog at the head of Bridestones Griff in Dalby Forest to about 1500 years ago. Otherwise only a few soil pollen analyses associated with archaeological monuments (Dimbleby 1962, 1983), mainly Bronze Age barrows, are available from the limestone country. This clear spatial dichotomy is because of the surface geology, which has defined the distribution of organic deposits, upon which pollen analytical research relies, with very few on the limestone Tabular Hills. This imbalance in data distribution is preventing a fuller understanding of the vegetation history of the North York Moors as a whole. This is particularly unfortunate as these southern limestone areas had high levels of human settlement and land use (Spratt 1993) and hence significant influence on the vegetation, at least in the later Holocene, when it also impacted upon soil profiles as at Levisham Moor where Curtis (1975) recorded episodes of destabilisation and erosion of soils probably due to human activity. This paper presents the results of pollen analytical research on organic sediments from Dalby Forest in the eastern central area of the Tabular Hills, which will go some way towards redressing this imbalance.

Geology and soils

The North York Moors is composed of rocks of the Jurassic system (Fig. 1B). The higher parts of the moors are Middle Jurassic sandstones and shales of the deltaic Ravenscar Group (Livera and Leeder 1981), which form a central plateau dissected by dales where Lower Jurassic liassic clays outcrop (Kent 1980; Hemingway 1993). In the southern, lower parts of the upland Upper Jurassic rocks, calcareous grits and oolitic limestones of the Corallian Group (Powell, Cooper, and Benfield 1992; Hemingway 1993), form an extensive area of low gradient, termed the Tabular Hills, between the central moorlands and the lowland Vale of Pickering, which is occupied by the latest Jurassic deposit, the Kimmeridge Clay. The Tabular Hills, which dip very gradually towards the Vale of Pickering, have a limestone escarpment at their northern and western edge and so form a discrete surface geological unit. As the central and southern North York Moors was ice-free during the last glaciation (Clark, Gibbard, and Rose 2004; Evans, Clark, and Mitchell 2005), there are no significant glacigenic deposits on these areas, although Powell, Ford, and Riding (2016) have suggested there might be patches of diamicton from an earlier glaciation. In places the Tabular Hills have a veneer of sands and clays probably derived from fluvial redistribution of reworked earlier sediments. Because of this lack of glaciation, the soils of the North York Moors reflect the underlying bedrock closely. Thin, highly acidic podsols characterise the higher plateaux of the central moors. The soils developed on the calcareous Corallian are deeper and mostly free-draining rendzinas, however, and while today are somewhat podsolised are of higher nutrient status (Carroll and Bendelow 1981). They developed from woodland brown earths as shown by fossil soils with a pollen assemblage dominated by *Corylus* and other deciduous trees (Dimbleby 1962), preserved beneath Bronze Age tumuli. Therefore, while extensive blanket peat formed on the higher sandstone plateaux of the moors (Cundill 1977), peat sediments are very rare on the calcareous Tabular Hills, and are shallow, of limited extent and restricted to small valleys. Many peat-filled glacial drainage channels (Gregory 1962; Simmons 1969; Jones 1978) cut through the northern areas of the moors as a result of meltwater drainage and overflows from proglacial lakes, but the few drainage channels that cross the Tabular Hills have not preserved organic sediments.

Archaeology and Settlement

The North York Moors are rich in archaeological sites but their distribution is uneven. The number of archaeological sites of the later prehistoric and historic periods on the upland sandstone plateaux and the higher dales is low (Spratt 1993). Later prehistoric sites north of the Tabular Hills tend to be funerary sites, such as Bronze Age barrows, or isolated chance finds, although there are some small field systems of Iron Age and later date (Spratt 1978). In contrast the calcareous Tabular Hills, known as the Hambleton Hills in the west and the Hackness Hills in the east, have a high site density for these periods, particularly sites related to settlement and agriculture, presumably because the deeper, fertile calcareous soils will have been attractive to farmers who had the means of opening and then clearing the denser forest there (Manby, King, and Vyner 2003).

Neolithic archaeological sites are concentrated on the Tabular Hills (Spratt 1993; Harding 2003), particularly towards the eastern end. Little Neolithic material occurs to the north of the Tabular Hills, suggesting that Neolithic settlement was predominantly on these southern limestone soils. Finds of Bronze Age beaker pottery and metalwork on the North York Moors are almost confined to the eastern and central Tabular Hills (Spratt 1993), an artefact distribution that continues the Neolithic settlement pattern, with a concentration on the southern limestone areas. The Tabular Hills were the focus of settlement throughout the Bronze Age although the presence of funerary barrows and cairnfields on the higher Moors shows that those areas were also used, for ritual and probably pastoral farming. Many Bronze Age barrows occur on the Tabular Hills (Brewster and Finney 1995), and the area is notable for the presence of late Bronze Age archaeology (Fleming 1971; Manby 1980), particularly long linear earthworks, or dykes. Although there is no direct dating for these dykes, their relationship with other archaeological features, such as barrows, shows that some were constructed in the later Bronze Age but some are later, of mid- to late Iron Age date (Spratt 1978, 1989, 1993), of which the Cleave Dyke on the Hambleton Hills west of Helmsley is a major example. As with the pit alignments that are common in this part of the North York Moors, these earthworks are not all contemporary, although many would have probably remained in use for a long time after their construction. Many dykes are located on Levisham Moor to the west of Dalby Forest, and around Scamridge in north-west Wykeham Forest, to the south-east. Close to the pollen sites in this paper, a major example runs through Grime Moor and Yondhead Rigg, a shorter dyke occurs at Dargate in Dalby Forest and four dykes occur to the south and east of Seavy Slack (Fig. 1C). Others occur to the east, near Scarborough. Their function was probably to divide the fertile agricultural land of the Tabular Hills into farming units. Many pit alignments of this age also occur, probably also forming land division boundary markers.

There are many archaeological sites of the Iron Age on the Tabular Hills (Vyner 2003), and the area was a centre of settlement at that time. Hillforts occur, and square barrows are particularly abundant, with a concentration in the Dalby area and at Wykeham Forest to the east (Spratt 1993; Mytum 1995). Not far to the west of the Dalby Forest study area, several large enclosures of Iron Age date lie on Levisham Moor, connected by a series of dykes. A bloomery was also present and the sites represent a major farming settlement on the calcareous areas of the southern moors. Extensive linear earthworks and pit alignments across the Tabular Hills at this time suggest a well-developed and intensive agricultural economy that required subdivision and allotment of farmland. Roman period archaeology is also well represented here, with Romano-British farmstead sites common and showing continuity with Iron Age settlement, but also Roman military and civil establishments (Hartley 1989; Spratt 1993; Wilson 1983, 1995, 2002a). Of the former, the Romano-British building at Stoneygate (Hayes 1988a) is an excavated example not far from the pollen sites in Dalby Forest presented in this paper. Major civil and military examples are the villa site at Beadlam (Stead 1971) and the fort at Cawthorn Camps (Wilson 2002b). The many field systems and scatters of Roman period pottery throughout the Tabular Hills (Spratt 1993; Horne 2003; Ottaway 2003) suggests a significant density of occupation (Faull 1985), as do the many small square enclosures that are also almost certainly of Roman date (Hayes 1988b), with several examples on Levisham Moor. This archaeological evidence for considerable occupation and utilisation of the Tabular Hills in the Roman period contrasts strongly with the paucity of evidence from the central and northern parts of the North York Moors, and this geographical contrast continued into Medieval times. The development of parishes running north-south across the Tabular Hills in Anglian and Viking times reflects intensive settlement and land division (Faull 1985; McDonnell 1988; Harrison and Roberts 1989; Lang 1989), with Anglian settlement sites at Spaunton and Wykeham (Loveluck 2003). It is matched by monastic establishments and many religious monuments in this area (Hall 2003), in contrast to the central and northern Moors. The great value of the Tabular Hills as part of the agricultural economy of Monastic Houses and granges in the later Medieval period (Waites 1962, 1997; Harrison and Roberts 1989) is a continuation of the land allotment practices of these earlier times (Waites 1967; Wightman 1968), with the Tabular Hills valuable for the arable element of the economy but its rich grazing land particularly important for animal husbandry and the highly profitable wool trade (Waites, 1980). The present-day concentration of villages in these fertile southern limestone areas, in contrast to the dales and higher moors, is one that was established in Medieval and earlier periods (Harrison and Roberts 1989) due to the availability of good farmland. From the Iron Age onwards, but particularly from the Medieval period, other activities that affected the landscape, such as iron working (Hayes 1988c; Wheeler 2007, 2008, 2011), were also important. In the last two millennia, the Tabular Hills have been heavily settled, and intensively used primarily for agriculture. The palynological research in this paper is designed to investigate the environmental context of this long and rich cultural presence on the Tabular Hills.

Materials and Methods

Study sites

The present vegetation of the Tabular Hills is largely agricultural (Eyre 1973), although on steeper valley sides patches of natural calcareous limestone grassland survive (Atherden 1983; Atherden and Simmons 1989), mostly on the Hambleton Hills. Some areas, as on Levisham Moor, are covered by *Calluna*(heather)-dominated heathland on stagnopodsol soils. Many of these heath areas have been planted with extensive coniferous woodland (Perry 1983), particularly Dalby and Wykeham Forests. Field survey of the central Tabular Hills limestone area failed to find deep peat deposits that might provide a long vegetation history. To the east of Lockton Low Moor, however, deposits of thin peat were found in small valleys within Dalby Forest (Fig. 1C). This area contains many archaeological monuments and landscapes of late prehistoric and later periods (Spratt 1978, 1989, 1993), and their distribution is shown on Fig. 1C. Bronze Age sites are mainly tumuli, Romano-British sites mainly farmsteads, and Medieval sites are farmsteads and bloomeries. Three of the short peat profiles were collected for analysis. These deposits lie at the head of Stain Dale and were the closest that could be found to the later prehistoric linear earthworks, or dykes, that occur in this part of the Tabular Hills (Spratt 1989).

Each site was only a few tens of metres in extent and so would have had a mainly local pollen source area. As the sites are about a kilometre apart, these source areas would not have overlapped significantly, so although their landscape setting would have been similar, each site will preserve an individual record of events. At all three sites bulk peat samples were collected in aluminium alloy monolith tins from peat faces exposed in stream sections. The first site examined is at Yondhead Rigg (UK national grid reference SE879913), the second is at Dargate Dykes (SE889909) and the third at Seavy Slack (SE901903). Preliminary pollen diagrams for these sites were shown in Simmons et al. (1993), without radiocarbon dating.

Laboratory analyses

Samples were prepared for palynological analysis using standard laboratory techniques, with alkali digestion, sieving at 180 µm, hydrofluoric and hydrochloric acids and acetolysis (Moore, Webb, and Collinson 1991). Pollen residues were stained with safranin, mounted on microscope slides in silicone oil and counted at x 400 magnification, with higher magnifications used for critical features. At least 300 land pollen grains per sample were counted, and pollen identification and nomenclature follow Moore, Webb, and Collinson (1991). Poaceae grains above 38 µm long diameter are recorded as Cerealia type (Albert and Innes, 2015, 2020), although some wild grass species do produce grains of this size (Andersen 1979; Tweddle, Edwards, and Fieller 2005). The pollen diagrams were constructed using the TILIA program of Grimm (1993, 2004), and pollen percentages were calculated using a total land pollen sum that comprises trees, shrubs and herbs. Although not within the calculating sum, spores are shown as percentages of it. The lithologies of the three profiles are shown on the pollen diagrams and are described in Table 1, including the notation devised by Troels-Smith (1955). Radiocarbon dates are now available for these three pollen diagrams: four at Seavy Slack, three at Yondhead Rigg and two at Dargate Dykes, reflecting the depth of the peat profiles, and details are shown in Table 2.

Results and interpretation

Stratigraphy and mire development

All three organic profiles rest upon clayey sand, which in each case is probably fluvially redistributed material lying upon the oolitic limestone base, trapped within small depressions and stream valleys. Such deposits are rare on the Tabular Hills and are the few locations where waterlogging could take place and peat could form. At all three sites organic accumulation was very slow within small marshy areas, with completely humified peat forming the lower part of the profile. As at each site peat formation began during a phase of drier climate (Baker et al. 2015) the stimulus for peat formation was probably local human activity, local woodland clearance leading to increased run-off, water surpluses and paludification in stream channels, a common ecological process (Moore 1975). Each site then formed small wetlands, perhaps flushes, colonised by fen and bog herbaceous vegetation, some quite oligotrophic, until higher water tables during the last millennium caused the occupation of Dargate Dykes and Yondhead Rigg by mosses. Seavy Slack became an acidic channel mire. The lack of wood remains in the profiles indicates that they never passed through a carr stage of wetland plant succession. There are no indications of hiatus and it is assumed that peat formation was continuous.

Palynology

The results of the palynological analyses of the three profiles are shown in Fig. 2 (Yondhead Rigg), Fig. 3 (Dargate Dykes) and Figs. 4a and 4b (Seavy Slack), and detailed descriptions of the pollen assemblage zonations are shown in Table 3, together with their modelled ages. Zonation is based on changes in major, ecologically significant taxa in an interpretative way. A conspectus of the palaeoecological history of the Dalby Forest area by cultural period is shown in Table 4.

Radiocarbon dating

The Radiometric/AMS, calibrated (cal. BP) and modelled ^{14}C dates for the three profiles are shown in Fig. 5. All samples were on bulk peat as terrestrial macrofossils were not available. As each profile has relatively few dates, the age-depth models are constructed using the CLAM version 2.3.2 linear interpolation program (Blaauw 2010). The age-depth model for Yondhead Rigg (Fig. 5a) shows that peat accumulation began at about 3700 cal. yr BP, and occurred at a relatively steady rate of c. 44 years per cm., with an increase in sedimentation rate to c. 25 years per cm. at about 1570 cal. yr BP. Accumulation began at Dargate Dykes (Fig. 5b) at about 1000 cal. yr BP, after which accumulation occurred at c. 17 years per cm. At Seavy Slack (Fig. 5c) accumulation began at about 2300 cal. yr BP and remained steady at c. 43 years per cm until about 660 cal. yr BP, after which accumulation rate increased sharply to about nine years per cm, and then again to about seven years per cm at 440 cal. yr BP until present. The changes in sedimentation rate at Yondhead Rigg and Seavy Slack correlate broadly, although not exactly, with stratigraphic changes from a well humified peat towards a fresher *Eriophorum* or moss peat. Where BC/AD chronology is used in the text, this refers to calendar years. Full age-model data are shown in supplementary file S1.

Discussion

Vegetation history and human Impacts

There are many pollen diagrams from the North York Moors, and several cover the later prehistoric and historic periods, but most have limited or no radiocarbon dating support. The pollen records with which the profiles from the Dalby Forest area of the Tabular Hills can be securely compared chronologically are relatively few (Simmons et al. 1993). Broad comparisons are possible with records on the sandstone plateaux of the Cleveland Hills (Jones 1977, 1978) and the central high moors (Simmons and Cundill 1974). More useful are those from the area of lower moorland in the eastern Moors (Fig. 1B), north of the Dalby Forest study area, where dating control is better, particularly at the well-dated diagram at Fen Bogs (Atherden 1976a, 1976b, 1989; Chiverrell and Atherden 2000), as well as her sites at May Moss, Harwood Dale Bog and Simon Howe Moss. Also available as a site with radiocarbon dating are Wheeldale Gill on the eastern central high moors, which covers the period from the Bronze Age onwards (Simmons and Cundill 1974), and some of Wheeler's (2007) diagrams from lower Bilsdale. In the following period-based discussion, correlations with pollen zones and chronologies refer to tables 3 and 4, and supplementary file S1.

The Bronze Age (pollen zones YR-a and YR-b)

The pattern of vegetation change on the Tabular Hills during the Bronze Age seems to be broadly similar to the evidence from elsewhere on the North York Moors (Simmons et al. 1993), in that there is no evidence of major arable cultivation. Agriculture was mixed but appears to have been primarily of the pastoral kind, although cereal-type pollen is poorly transported and as only Yondhead Rigg covers this period in the study area, only inferences regarding that site can be made. While there is evidence of open grassy areas, these were interspersed with open woodland and heathland, *Calluna* being prominent even at this early stage. The abundance of

Calluna was also noticed in pollen analyses of soils sealed by Bronze Age barrows on the Tabular Hills (Dimbleby 1961, 1962; Steel and Flenley 1995), so is likely to have been common across this area. Although Bronze Age woodland clearance has been considered in part due to an expansion of arable cultivation (Fleming 1971; Atherden 1999), the fleeting appearance of cereal-type pollen in very low frequencies at Yondhead Rigg at about 1369 BC indicates it was not a major element of local land use, and the behaviour of the tree and shrub curves suggests a stock-rearing economy, as suggested by Dimbleby (1961, 1962) and Atherden (1976b), on grassy heathland perhaps within grazed, managed woods which were possibly coppiced. Bronze Age pollen spectra to the north of the Tabular Hills at Fen Bogs, May Moss and Simon Howe Moss do not contain cereal-type pollen, and it does not occur at altitude at Wheeldale Gill either, while at Harwood Dale Bog only a few isolated cereal grains occur at this time. On the higher areas of the moors there was a regeneration of woody vegetation and reduced intensity of land use at the end of this period, and a similar reduction of clearance activity also occurred on this part of the Tabular Hills between about 1325 and 700 BC.

The Iron Age (pollen zones YR-c and YR-d, SS-a and the start of SS-b)

The Iron Age is represented on the limestone hills mainly by Yondhead Rigg, with the record from Seavy Slack only beginning in the very late Iron Age at about 184 BC. Research elsewhere on the Moors indicates a considerable level of clearance, including limited cereal cultivation. The radiocarbon dated Fen Bogs diagram (Atherden 1976a) which acts as the standard diagram for the eastern central moorland, has very low tree pollen frequencies and a low but consistent cereal pollen curve in the later Iron Age, with a wide range of ruderal and grassland herb types suggesting mainly pastoral activity within a very open landscape. The evidence from May Moss and Simon Howe Moss (Atherden 1976b, 1979; Chiverrell and Atherden 2000), Jugger Howe Beck (Bunting, Langrick, and Rumsby 2007) and Harwood Dale Bog (Atherden 1989), also in this area of eastern low moorland (Fig. 1), is very similar in recording the first major deforestation at this time, but with only isolated cereal pollen records and so probably mainly for grassland. Pollen data from Gormire Lake at the western edge of the Hambledon Hills, the western extension of the Tabular Hills, also record the first significant deforestation for mixed agriculture in the late Iron Age (Innes and Morriss 2002; Oldfield et al. 2003), while Blackford and Nelson-Ackers (2002) dated a phase of burning, clearance and cereal cultivation to a similar age at Potter House Bog near the foot of the Rievaulx Moor limestone escarpment north of Helmsley. The Yondhead Rigg diagram contains no cereal-type pollen in the Iron Age levels between about 700 BC and 11 AD, nor does the brief late Iron Age record from Seavy Slack which starts around 184 BC, although it must be remembered that together these sites represent only a relatively small sample. This apparent lack of cereal cultivation may be due to local factors, but the new pollen evidence does not support Iron Age cereal cultivation in the central limestone areas of the moors. Presumably some must have occurred somewhere on the Tabular Hills, but in at least this part of the Dalby Forest area the evidence is for a landscape dominated by heathland and grassland, and presumably a stock-rearing pastoral economy, a similar Iron Age record to that reported by Wheeler (2007) on the limestone at Ashberry Hill in lower Rye Dale north of Helmsley. The continued use of dykes for land division in the Iron Age might well reflect the need to control high stock populations (Spratt 1978, 1989). The very high *Calluna* frequencies in the Dalby Forest diagrams during the Iron Age will reflect local podsolisation of soils as well as some colonisation of the mire surface, although *Calluna* macrofossils do not occur in the examined peat profiles. Based upon the evidence of increased deforestation, Spratt (1993) suggested that there was a major population increase during the Iron Age on the North York Moors, especially on the Tabular Hills. While the pollen data from Yondhead Rigg and Seavy Slack do suggest considerable deforestation of this part of the limestone hills from 700 BC onwards, it is possible that short-cycle coppicing of woodland for iron working, which would have suppressed pollination, might partly account for the very low pollen representation of trees (Waller, Grant, and Bunting 2012).

The earlier Iron Age was a time of severe climatic deterioration (Baker et al. 2015), when mire surfaces became considerably wetter (Blackford 2000; Chambers and Blackford 2001), which must have had an impact on human land use (Barber et al. 1993; Dark 2006). Peat humification and microfossil studies on the eastern North York Moors at May Moss (Chiverrell 2001a, 2001b; Chiverrell and Atherden 1999) show this increased wetness, also identified in peat profiles on the high moors of the central plateau, as at Howdale Hill and Glaisdale Moor (Simmons and Cundill 1974), at the same time as significant clearance and the establishment of a *Calluna* and ruderal weed pollen assemblage. Although not securely dated, this may well correspond to the Iron Age climatic deterioration and pastoral human activity. Jones (1977, 1978) also noted this deforestation and switch to a *Calluna* and ruderals assemblage at sites on the Cleveland Hills on the northern moors, and attributed the change to the Iron Age. This colder, wetter climate would have restricted arable cultivation and encouraged pastoralism during the earlier Iron Age (Dark 2006), on the Tabular Hills as much as elsewhere on the North York Moors upland, and caused the spread of podsolisation and heathland. There is evidence in zone YR-d, from about 434 BC, of a distinct increase in ruderal weeds and pastoral land use intensity, and the recolonisation of heathland by woodland. These changes will reflect the change to a milder, drier climate which occurred from about this time (Baker et al. 2015), and is recorded in all the climate studies cited above.

Romano-British period (pollen zones YR-e and SS-b)

The centuries of the Roman occupation were characterised by a continuation of the warmer and drier climate of the late Iron Age (Baker et al. 2015; Chiverrell 2001a, 2001b, 2001c) during which agriculture increased in intensity and extent. This agricultural expansion is clearly manifest on the pollen diagrams from most areas of the moors. Harwood Dale Bog and Fen Bogs, the well dated profiles in the eastern moors to the north of the Tabular Hills (Atherden 1976a, 1989), show this reduction in woodland and expansion of open vegetation very well. The Dalby Forest diagrams at Yondhead Rigg, up to 443 AD, and Seavy Slack, up to 293 AD, also show this deforestation and increase in *Calluna* and grassland. Both profiles show some cereal cultivation later in the period, at about 393 AD at Yondhead Rigg and at about 163 AD at Seavy Slack, but to a limited extent. Oldfield et al. (2003) recorded a major fall in tree pollen frequencies during this period at Gormire Lake at the limestone fringe of the Hambledon Hills west of Helmsley, with an expansion of *Calluna* and bracken moorland as well as many pastoral and cultivation pollen indicators. Even on the high altitude areas there is evidence of significant vegetation clearance, probably for animal husbandry, as at Wheeldale Gill (Simmons and Cundill 1974). It appears that the clearances of the later Iron Age were continued into the Romano-British period and intensified, with pastoral agriculture dominant and an expansion of moorland and grassland, until some cereal cultivation later in the period.

Early Medieval (pollen zones YR-f, YR-g and YR-h, and SS-c)

Atherden (1999) noted that there was pollen evidence of a partial regeneration of woodland cover in Yorkshire in the early Medieval period, between about 500 and 1000 AD, particularly at mid- to higher altitudes in the North York Moors (Simmons and Cundill 1974; Jones 1978; Atherden 1979, 1989), but also at lower altitude as at Gormire Lake (Oldfield et al. 2003). The data from Yondhead Rigg between 443 and 994 AD and Seavy Slack between 293 and 1246 AD agree with this, with the replacement of much of the heathland established in the Romano-British period with mainly deciduous woodland, although open areas remained and a phase of agriculture occurs at Yondhead Rigg between 668 and 843 AD, with cereals around 700 AD in early zone YR-g. Not recorded at Seavy Slack, this difference between the Dalby Forest profiles emphasises the local nature of their pollen records. The general expansion of woodland during this period will have been caused by a reduction in the intensity and extent of human settlement and agriculture in most places on the moors. It coincides with a period of climatic cooling that started with a severely cold century starting around the mid-sixth century AD (Baker et al. 2015; Büntgen et al. 2016), and remained cool until about 950 AD. It is recorded as a phase of accelerated peat bog growth in several areas of the North York Moors (Blackford and Chambers 1991, 1999a, 1999b; Chiverrell 2001a, 2001b, 2001c; Chiverrell and Atherden 1999, 2000). The consequences of this climate deterioration apparently affected the well drained Tabular Hills as well as the acidic moors to the north, and it might be that social disorganisation and a reduced requirement for intensive farming following the Roman withdrawal contributed to this agricultural decline and expansion of woodland. A radiocarbon date of 1060±160 (which because of its large standard deviation calibrates to a wide range of 698–1279 cal. yr BP, but with a mid-point of 988 cal. yr BP; 962 AD) at Fen Bogs (Atherden 1976a) has been taken as marking the end of this period of reduced agricultural activity (Jones, Cundill, and Simmons 1979), and although some variability will have existed across the North York Moors, this corresponds well with the modelled date of 994 AD obtained from Yondhead Rigg, where the expansion of woodland in zone YR-h was more marked than in the later part of zone SS-c at Seavy Slack. The devastation of northern England by Norman forces in the late 11th century would have increased this regeneration of woodland and expansion of waste land, although the effects in the Tabular Hills area were apparently locally variable (Vyner 2009).

Later Medieval (pollen zones YR-i, DD-a, DD-b and early DD-c, and SS-d and SS-e)

Pollen diagrams covering the Later Medieval period on the North York Moors all record a significant human impact, with phases of deforestation and the expansion of open vegetation. To the north of Dalby forest on the siliceous rocks of the Ravenscar Group around Fylingdales Moor Atherden (1989) recorded major clearance which lasted until about 1500 AD, dated at Harwood Dale Bog. A comparison of her three sites in this area indicates a major expansion of *Calluna* moor, and some limited cereal cultivation during this period. Nearby, at Jugger Howe Beck, Bunting, Langrick, and Rumsby (2007) recorded removal of the last woodland at this time. Atherden (1979) found a similar record of greatly expanded agriculture and woodland clearance in the four centuries after 1000 AD in the eastern-central moorland area, although less marked at higher sites like May Moss than at lower altitudes as around Fen Bogs (Atherden 1976a), where the vegetation change is dated. The research of Jones (1977, 1978) in the Cleveland Hills and dales in the northern moors records similar woodland recession and expansion of open vegetation, mainly *Calluna* and grass, during the Later Medieval. On the edge of the Hambledon escarpment on the south-west margin of the limestone hills Oldfield et al. (2003) noted that major woodland clearance occurred in the Later Medieval period after about 1200 AD. This conversion of wooded areas to grassland and moorland at this time was a landscape change that occurred throughout the upland as the new data from the three Dalby Forest profiles, although differing in timing and detail, also record replacement of woodland by open vegetation. In contrast to the rest of the moors, however, where pastoral indicators such as *Plantago lanceolata* are more common, cereal cultivation was a significant aspect of this clearance phase at the Tabular Hills sites. At Yondhead Rigg between 994 and 1595 AD the cereal curve is continuous, as it is at Seavy Slack between 1246 and 1513 AD, while cereal pollen occurs around 1200 AD at Dargate Dykes. An expansion of settlement and agriculture would have been the driving force behind this North York Moors-wide phase of clearance and agriculture, and permissive would have been the change to the warmer and mostly drier climate of the Medieval Climate Anomaly (Medieval Warm Period), which lasted until about 1450 AD (Baker et al. 2015), and is recorded in the study area (Blackford and Chambers (1999a, 1999b, 2001; Chiverrell 2001a). There were phases of wetter climate during this period (Chiverrell and Atherden 2000) which are recorded in written sources (Menuge 1997) and there is documentary evidence (Baker 1966) of reductions in cultivated land in the northern moors and even in the south-western limestone Hambledon Hills in the first half of the 14th century that these climatic deteriorations might have caused, coupled with the effects of the Black Death at that time (Campbell 2016). During these centuries of generally benign climate, however, and in the stable political conditions under the Normans from about 1100 AD onwards, Monastic Houses' agricultural estates were able to expand greatly (Waites 1962, 1967, 1997) until later in the period the whole of the upland was utilised within the farming system of Cistercian monastic granges (Farra 1961; Platt 1969). The better soils of the lower slopes of the Tabular Hills were used for some cereal cultivation but the limestone area was mainly for intensive grazing on the rich grassland, and the rest of the upland was also used for animal husbandry, mostly for sheep (Waites 1980). This land-use pattern is apparent in the palynological evidence, at least for the later part of the period, and is confirmed by historical sources (Wightman 1968). The area of modern Dalby Forest was part of the Royal Forest of Pickering from the 12th century (Harrison and Roberts 1989; Counsell 1998; Turner 1987), however, and this may explain why tree and shrub levels remained relatively high at the Dalby Forest pollen sites, up to 40% and more of total pollen, as the Forest of Pickering was notable for having a high density of woodland cover (Dormor 2003). Generally, the characteristic rich grassland on the limestone and calcareous grits of the Tabular Hills was established at this time under high grazing pressure which prevented any tree and shrub regeneration. Not all of the limestone area was turned over to intensive agriculture after woodland clearance in the Later Medieval, however. An alternative use was the maintenance of the natural ash-hazel woods on valley sides and in Royal Forest areas through a coppicing regime (Gledhill 1998, 2003) for the manufacture of charcoal, a practice present since the Iron Age in places like lower Bilsdale, but greatly expanded there into an industry during Late Medieval times around the great abbey at Rievaulx (Wheeler 2007). Wheeler's pollen diagrams on the limestone slopes of Bilsdale and the Hambledon Hills do not show the deforestation that occurred on the Dalby Forest limestone Hills, and the preservation and management of woodland for the charcoal industry of lower Bilsdale indicates a different land-use priority there (Wheeler 2007, 2008, 2011).

Post-Medieval and Modern (pollen zones YR-j, late DD-c and DD-d, and SS-f)

The three diagrams from Dalby Forest all contain records which cover the post-Medieval and modern period, with Seavy Slack extending into the late 16^{th} century, Yondhead Rigg into the late 17^{th}, and Dargate Dykes well into the 19^{th} century. The absence of any increase in the *Pinus* curve at the top of any of the diagrams, however, and no records of non-native conifers, indicates that the pollen records cease before the modern conifer plantations which so characterise the area of Dalby, Wykeham and Broxa forests today (Perry 1983; Statham 1989), and which occurs in some moors diagrams, as at Gale Field at Fylingdale (Atherden 1989), West House Moss (Jones 1977) and Ewe Crag Slack (Jones 1978). All three Dalby Forest pollen diagrams record a major increase in pollen indicators of cultivation, with continuous Cerealia pollen curves but also with arable, grassland and ruderal weeds such as Cruciferae, *Artemisia*, *Rumex* and *Centaurium*. This is despite the change to a much wetter and colder climate after c. 1500 AD as the Little Ice Age commenced (Baker et al. 2015), although Chiverrell and Atherden (2000) note from studies of bog stratigraphy at May Moss that there was considerable wet/dry variability during this period, confirmed by documentary sources (Menuge 1997), and Baker et al. (2015) also record brief periods of warmer climate, such as in the mid-17th century. Although tree pollen percentages remain moderate in the Yondhead Rigg and Dargate Dykes diagrams, they are extremely low at Seavy Slack, and considerable variation in the survival of woodland must have occurred. Generally, there was deforestation and an extension of open agricultural land in the Dalby Forest area, with trees perhaps confined to the many steep-sided valleys, or griffs, cut through the Corallian limestone. The protection to woodland afforded by the Medieval Forest of Pickering had lapsed by the start of the post-Medieval period and the decline of charcoal-burning led to reduced woodland management for fuelwood (Wheeler 2011) and the progressive enclosure of the area for arable and, especially, grazing on the rich limestone pastures (McDonnell 1989; Butlin 2003). This process occurred throughout most of the Tabular Hills, although to a lesser extent in areas around Helmsley and Rievaulx (McDonnell 1963), where managed woodland cover was largely maintained (McDonnell 1989; Gulliver 1998), and can be seen in the pollen data from that area (Wheeler 2007). A feature of all North York Moors pollen records, including the Tabular Hills examples, is the great increase in *Calluna* frequencies near the top of the diagrams, which represents increased soil podsolisation but also the expansion and management of moorland for shooting estates (Statham 1989).

Comparison with other areas of the North York Moors

The main insight from the new pollen evidence from the Tabular Hills is somewhat surprising, as the level of human impact on the vegetation on these limestone areas appears to be greater than that which occurred in other parts of the North York Moors, but not considerably so. The archaeological evidence for greatly increased settlement and land use in late prehistoric and historic times is not really represented in the palynological data. While evidence of cereal cultivation occurs in the Dalby Forest pollen profiles, it is at a relatively low level and is even less than occurs in places on the non-calcareous areas of the upland. Some elements of a limestone calcicole flora are recorded in the Tabular Hills diagrams, such as *Poterium sanguisorba*, which signifies base-rich soils, and occurs regularly at Seavy Slack and Yondhead Rigg in low frequencies. Other taxa appearing in the Dalby Forest diagrams that indicate basic calcareous soils include the herbs *Mercurialis*, *Helianthemum*, *Hypericum perforatum*, *Ononis*, *Centaurea nigra*, *Geranium* and *Linum catharticum*, and the trees and shrubs *Taxus*, *Sambucus* and *Viburnum*. A characteristic of the modern day 'unimproved' calcareous grassland of the Tabular Hills is its species richness (Atherden 1983; Atherden and Simmons 1989) and this is reflected in the high number of taxa recorded in the Dalby Forest diagrams relative to diagrams from other parts of the moors. An unexpected feature of the Dalby Forest data, however, is the abundance of *Calluna* pollen which contributes over 60% of total land pollen throughout all three diagrams, sometimes much more. The lack of *Calluna* macrofossils in the profiles suggests *heather* was not growing on the mires themselves, but that these small wetlands were probably surrounded by dry, *Calluna*-dominated heath, as such percentages must represent very local heather growth (Evans and Moore 1985). This is similar to most other sites in the North York Moors during the last two millennia, and the vegetation composition on the Tabular Hills, assuming these three sites are representative, was comparable to the rest of the upland.

Comparison with other limestone regions of northern England

There are pollen diagrams from other areas of calcareous geology, mainly limestone and chalk, in northern England (Parker and Goudie 2007) with which the pollen data from the Tabular Hills can be compared. Although a mid-Holocene vegetation history of the Tabular Hills before the Bronze Age is not available, the area is likely to have been covered with mixed deciduous forest in which base-demanding trees like *Fraxinus*, *Ulmus*, *Tilia* and *Corylus* were prominent, with some limited open areas caused by Neolithic farmers. A good analogue might be the woodland on the steep limestone ridges of south Cumbria (Birks 1982), which apparently remained mostly undisturbed during the mid- and late Holocene, if Birks' local record at his site at Roudsea Wood is representative of that area as a whole. In contrast, on the Magnesian limestone of the south-east Durham plateau, not far to the north of the North York Moors, major forest clearance during the Bronze Age converted the landscape permanently to grassland with some cereal cultivation, but with very little *Calluna* (Bartley, Chambers, and Hart-Jones 1976). Nearest to the Tabular Hills is the chalkland of the Yorkshire Wolds, which supports species-rich calcareous grassland, although today little remains because of conversion to arable (Bush and Flenley 1987; English Nature North and East Yorkshire Team 1997). The pollen and propagule evidence from Willow Garth (Bush 1993) shows the presence of chalk grassland from the Bronze Age onwards, as well as cereal cultivation and pasture. As with the Tabular Hills, grazing seems to have preserved species-rich grassland in late prehistoric and historic times. It is notable that in all of Bush's data from the calcareous Wolds, there is no evidence of *Calluna* whatever, and the soils there must have been very different to those of the Tabular Hills. In this regard the Dalby Forest sites might be more like the situation found in the Pennines, where at Scar Close, Ingleborough (Gosden 1968) peat apparently formed directly upon limestone pavement or upon a thin clay layer above it now removed by solution, and this peat is today very dry and dominated by *Calluna*. The Carboniferous limestone plateau of Derbyshire is also comparable to the Tabular Hills in that the limestone there is covered by a thin loessic loam which affects the base content of the soils and allows the formation of acidic podsols. Although *Fraxinus* and *Corylus* woods, today restricted to steep-sided valleys (Merton 1970) similar to Bilsdale, had originally characterised the Derbyshire limestone (Oybak 1993; Taylor et al. 1994), from Late Medieval times onwards much of the limestone area was covered by *Calluna* heath where uncultivated (Merton 1970), analogous to the Tabular Hills. In contrast the limestone area of upland Craven (Smith 1986; Atherden 2006), in West Yorkshire, seems never to have supported much *Fraxinus*, but base-demanding *Tilia*, *Ulmus*, *Corylus* and *Taxus* were important. As with the Tabular Hills, major Iron Age human impact followed by intensive sheep pasturing by monastic holdings during Late Medieval times in a transhumance system removed tree cover and produced rich limestone grassland (Atherden 2013). Similar early spread of grassland, maintained through grazing, after human clearance activity was recorded by Turner et al. (1973) and Squires (1978) on the limestone uplands of the northern Pennines. Pollen analysis by Pigott and Pigott (1963) also recorded little *Fraxinus* until forest clearance in the limestone areas around Malham Tarn, after which it increased greatly until it dominates the limestone area today (Atherden 2013). Calcicole taxa present in the Dalby Forest diagrams also occurred there, such as *Taxus*, *Poterium* and *Helianthemum*, a history analogous to that of the limestone of the North York Moors. This pattern of *Fraxinus* expansion after woodland clearance followed by species-rich grassland with calcicole herbs like *Helianthemum* has also been recorded for the limestone uplands of south Cumbria (Skinner and Brown 1999).

Conclusions

The archaeological and historical evidence shows that from later prehistoric times onwards the limestone Tabular Hills have been by far the most attractive area of the North York Moors for settlement and farming. However, despite extensive palynological research in this upland, the vegetation history of these southern limestone hills has been virtually unknown. The vegetation histories from the three sites in this paper allow comparisons to be made between the Tabular Hills and the rest of the North York Moors from the mid-Bronze Age onwards. While there are differences between them in the timing and magnitude of vegetation changes, the records from the three sites are sufficiently similar to suggest that they are generally representative of the limestone area, although their location within the Late Medieval Forest of Pickering might have made their vegetation history less representative of the limestone hills for that period. From the Bronze Age onwards, however, the vegetation history of the Tabular Hills seems to have been similar in kind to that of the rest of the North York Moors upland, although with agricultural impacts of rather greater scale than elsewhere. The timing of periods of woodland clearance and regeneration, for example, match between the limestone sites and other areas of the moors, and so are perhaps driven by climatic as much as social factors. The dominance of *Calluna* in the three Dalby Forest pollen diagrams, even in the Bronze Age and increasingly so in later periods, is surprising as the calcareous rendzina soils of the Tabular Hills might be expected to have supported woodland or species-rich grassland rather than *Calluna* moor. There are no *Calluna* macrofossils in the profiles, although *Eriophorum* and other acidophiles are common, so *Calluna* must have been growing on drier soils in the vicinity of the three sites. This might be a local response to major human woodland clearance, and while nearby Levisham Moor and extensive areas of the central Tabular Hills are today covered by *Calluna* heathland on podsolised soils, this might already have been the case in later prehistory, earlier than might be expected given the calcareous substrate in the area. Perhaps the thin veneer of sands or clays redeposited on the limestone was enough to allow acidification and podsolisation due to climate and human activity. It seems that arable cultivation played a lesser role in the mixed farming regime of this area of the limestone hills than might have been conjectured, even allowing for the poor pollen production and wind transport ability of cereal pollen (Vuorela 1973), as cereal pollen curves are uniformly low at a few percent of total pollen. Even when rising to about 4% in post-Medieval times, it only indicates significant rather than extensive or intensive cereal cultivation, at least in the Dalby Forest area. Pastoralism, as in the other parts of the North York Moors, was probably the major element of the farming system in the Tabular Hills from the Bronze Age until modern times. The Bronze Age and Iron Age enclosures and linear dykes in Dalby Forest, on Levisham Moor and elsewhere are likely to have primarily been for boundary division and stock control, an economic emphasis in the landscape that continued into the times of the Medieval granges and vaccaries and their rich grassland grazing. Any assumption that the calcareous Tabular Hills supported significant arable cultivation before modern times seems to be only partly the case, at best. Intensive stock grazing has probably comprised the major part of land use in the Tabular Hills, with limited arable, at least until very recent times, with settlement concentrated in the area and the higher parts of the Moors used seasonally in a form of stock-rearing transhumance system (McDonnell 1988).

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Captions to figures

Fig. 1. The geology of the North York Moors (1B), showing the location of the Tabular Hills and the study area (1C) in Dalby Forest. The locations of pollen sites on the North York Moors are shown as red dots on Fig. 1B, and five pollen diagrams with secure chronologies to the north of the eastern Tabular Hills which are discussed in the text are larger dots and are numbered: 1, Wheeldale Gill 2. Simon Howe Moss 3. Fen Bogs 4. May Moss 5. Harwood Dale Bog. Fig.1C shows the location of the three pollen sites presented in this paper, marked by stars, and major nearby earthwork/dykes as follows: 1. Horcum Dyke 2. East Toft Dyke 3. Newgate Moor Dykes 4. Dargate Dyke 5. Cross Dyke 6. Ebberston Common Dykes and Snainton Dykes 7. Red Dyke and Jingleby House Dyke. Bronze Age tumuli are shown as black dots, other Bronze Age archaeological sites as open circles, Romano-British sites as black squares and Medieval sites as open diamonds. Shaded areas are currently forested.

Fig. 2. Pollen diagram from Yondhead Rigg. Frequencies are calculated as percentages of total land pollen. Lithostratigraphy follows the symbols of Troels-Smith (1955) and is described in table 1.

Fig. 3. Pollen diagram from Dargate Dykes. Frequencies are calculated as percentages of total land pollen. Lithostratigraphy follows the symbols of Troels-Smith (1955) and is described in table 1.

Fig. 4a. Tree and shrub pollen diagram from Seavy Slack. Frequencies are calculated as percentages of total land pollen. Lithostratigraphy follows the symbols of Troels-Smith (1955) and is described in table 1.

Fig. 4b. Herb pollen and spores diagram from Seavy Slack. Frequencies are calculated as percentages of total land pollen. Lithostratigraphy follows the symbols of Troels-Smith (1955).

Fig. 5 Age-depth curves from Yondhead Rigg (5a), Dargate Dykes (5b) and Seavy Slack (5c). Calibrated radiocarbon date ranges are derived from Calib 7.1 and IntCal13 (Reimer et al. 2013). For each dated depth the calibrated age range (BP) is shown with the modelled age (BP) in parentheses. Age-depth models are constructed using the CLAM version 2.3.2 linear interpolation program (Blaauw 2010). The shaded areas represent the 95 % probability range confidence interval.

Table 1. Lithostratigraphies of the three profiles. Descriptions include the stratigraphic notation system of Troels-Smith (1955).

Depth (cm)	Description
Yondhead Rigg (fig. 2)	
0 – 30	Disturbed, oxidised surface peaty soil *Stratum confusum*
30 – 42	Light brown, poorly humified moss peat $Tb^2 4$ nig.3, strf. 1, sicc.2, elas.2, lim.sup. 0
42 – 52	Brown, well humified moss peat $Tb^3 4$ nig.3, strf.1, sicc.2, elas.1, lim sup.0
52 – 53	Brown, amorphous, well humified peat with herbaceous and woody roots Sh2, $Th^3 1$, Tl1 nig,3, strf.0, sicc.2, elas.0, lim sup.1
53 – 73	Brown, humified turfa peat with *Eriophorum* and moss roots Th (*vagi*)^{2}2, Sh1, Tb1 nig.3, strf.0, sicc.2, elas.0, lim sup.0
73 – 101	Brown, humified amorphous peat with herbaceous roots $Th^2 2$, Sh2 nig.3, strf.0, sicc.2, elas.0, lim sup. 0
101 – 130	Black, well-humified amorphous peat Sh4 nig.4, strf.0, sicc.2, elas.0, lim sup.0
130+	Sand Ga+
Dargate Dykes (fig. 3)	
0 – 10	Disturbed, oxidised surface peaty soil *Stratum confusum*
10 – 23	Light brown, poorly humified moss peat $Tb^2 4$ nig.3, strf. 1, sicc.2, elas.2, lim.sup. 0
23 – 32	Brown, well humified moss peat $Tb^3 4$ nig.3, strf.0, sicc.2, elas.0, lim sup. 0
32 – 58	Black, well humified amorphous peat with herbaceous roots Sh2, $Th^3 2$ nig. 3, strf.0, sicc.2, elas.0, lim sup.0
58+	Sand Ga4
Seavy Slack (figs. 4a and 4b)	
0 – 6	Disturbed, oxidised surface peaty soil *Stratum confusum*
6 – 24	Brown, humified *turfa* peat with *Eriophorum* roots $Th^3 2$, Th (*vagi.*)^{2}2 nig.3, strf.0, sicc.2, elas.0, lim sup.0
23 – 26	Light brown, coarse, fresh *Eriophorum turfa* peat Th (*vagi.*)^{2}4 nig.2+, strf.0, sicc.2, elas.0, lim sup.0
26 – 34	Brown humified *Eriophorum turfa* and moss peat Th (*vagi.*)^{3}2, $Tb^3 2$ nig.3., strf.0, sicc.0, elas.0, lim sup.0
34 – 48	Dark brown well humified amorphous and *turfa* peat Sh2, $Th^3 2$ nig.3, strf.0, sicc.2, elas.0, lim sup.0
48 – 76	Black amorphous peat Sh4 nig.4, strf.0, sicc.2, elas.0, lim sup.0
76+	Sand Ga4

Table 2. Results of radiocarbon dating. Age ranges (2δ) and means are derived from calibration results using Oxcal 4.2 and IntCal13 (Reimer et al. 2013). All dates are on bulk peat. The upper and lower dates at Seavy Slack are radiometric dates, the rest are AMS dates on thin bulk peat slices.

Depth cm.	Lab. code	^{14}C date (yr. BP)	Age range (cal.BP)	Mean age (cal. BP)
Yondhead Rigg				
52	Poz-57096	900±30	910–739	824±85
82	Poz-57097	1675±25	1690–1525	1608±82
122	Poz-57098	3145±30	3446–3272	3359±87
Dargate Dykes				
20	Poz-82063	255±30	429–151	290±139
50	Poz-57099	885±30	909–731	820±89
Seavy Slack				
6–8	UB-3753	318±44	486–298	392±94
18	Wk-10806	369±60	520–300	410±110
42	Wk-10807	718±58	740–550	645±95
74–76	UB-3754	2109±47	2302–1950	2126±176

Table 3. Pollen assemblage zone ages and descriptions at Yondhead Rigg, Dargate Dykes and Seavy Slack.

Pollen zones (cm)	Modelled zone boundary dates (calendar years BC/AD) and main zone characteristics
Yondhead Rigg (figure 2)	
YR-j 33–30	1595–1670AD. *Calluna* rises to very high frequencies of almost 90% of Total Land Pollen (TLP), while all other taxa except *Alnus* decline. Herbs are restricted to low values of Poaceae, Cyperaceae and *Plantago lanceolata*.
YR-i 57–33	994–1595AD. *Calluna* values increase through the zone, but frequencies of most tree taxa remain high, although *Betula* falls sharply and *Corylus*-type decline through the zone. Poaceae increases, as do some ruderal herbs including *Rumex* and Cruciferae. A continuous Cerealia curve occurs. *Sphagnum* values are high
YR-h 63-57	843–994AD. Tree and shrub values are substantial, mainly *Alnus*, *Corylus*-type and *Betula*, with a peak of *Ulmus*. with *Calluna* maintained at about 50% of TLP. Herb indicators of disturbance are almost absent, and NAP is contributed mainly by Cyperaceae and Poaceae.
YR-g 70–63	668–843AD. *Calluna* declines sharply to about 40% of TLP, and tree and shrub values remain high, with *Betula* greatly increased. Poaceae and Cyperaceae rise, there are peaks of *Artemisia* and *Plantago lanceolata*, a low Cerealia peak and a high peak of *Sphagnum*.
YR-f 79–70	443–668AD. *Calluna* frequencies decline *Quercus*, *Alnus* and *Corylus*-type all rise, and a peak of *Fagus* occurs. Poaceae and *Plantago lanceolata* decline and few other herbs are recorded.
YR-e 90–79	11–443AD. *Calluna* values increase again, to 80% of TLP, while other tree and shrub frequencies are reduced. Poaceae and *Plantago lanceolata* frequencies are maintained and there are peaks of Cerealia and *Rumex*.
YR-d 100–90	434BC–11AD. *Calluna* values fall but still represent 50% of TLP, while *Corylus*-type, *Quercus* and *Alnus* all increase. Poaceae and *Plantago lanceolata* values rise and several ruderal herbs increase in value near the start of the zone. *Pteridium* values increase.
YR-c 106–100	701–434BC. Characterised by *Calluna*, which rises to 70% of TLP. Ericaceae values rise to a peak but all other tree and shrub taxa are greatly reduced in frequency. Poaceae and *Plantago lanceolata* values rise but few other ruderal herbs are recorded.
YR-b 120–106	1325–701BC. Characterised by *Calluna*, *Corylus*-type and *Alnus*, with increased *Betula* and *Fraxinus*. Poaceae and *Plantago lanceolata* values fall, and total herb pollen frequencies are very low.
YR-a 130–120	1770–1325BC. Characterised by *Calluna* and *Corylus*-type, with lesser frequencies of *Alnus*, *Quercus* and Poaceae. *Plantago lanceolata* and *Pteridium* are present in high frequencies, Cereal-type occurs near the end of the zone and several ruderal herbs occur. NAP accounts for 80% of TLP.
Dargate Dykes (figure 3)	
DD-d 20–10	1664–1838AD. *Calluna* declines but remains in very high frequencies, while *Betula*, *Quercus*, *Alnus* and *Fraxinus* all increase. Poaceae rises sharply, while Cerealia, *Plantago lanceolata* and *Rumex* increase.
DD-c 40–20	1314–1664AD. Dwarf shrubs dominate the assemblage, with *Calluna* at almost 80% of TLP and other Ericaeae showing a high peak before declining. All trees and shrubs except *Betula* fall to low values. Poaceae, *Plantago lanceolata* and *Pteridum* show low but consistent values. Few other herb pollen taxa occur.
DD-b 50–40	1140–1314AD. Dominated by *Calluna* which rises to 60% of TLP. *Quercus*, *Alnus*, *Corylus*-type and *Betula* decline in frequency but remain important. Poaceae falls sharply, while Cyperaceae shows a peak. Ruderal herb types increase, with a *Rumex* peak and *Plantago lanceolata* consistent. A low peak of Cerealia occurs. *Sphagnum* rises to a sharp peak..

DD-a	58–50	1000–1140AD. Dominated by tree and shrub pollen, with *Corylus*-type and *Calluna* most abundant and *Alnus*, *Quercus* and *Betula* also in high values. Poaceae is the most important herb type at 30% of TLP, with *Plantago lanceolata* also important.

Seavy Slack (figures 4a and 4b)

SS-f	17– 6	1513–1587AD. *Calluna* increases to over 70% of TLP and all other tree and shrub types are in very low values. There is little change in the herb assemblage, with Poaceae, Cyperaceae and *Plantago lanceolata* remaining the major taxa. Cerealia pollen is still recorded.
SS-e	37–17	1335–1513AD. *Calluna* rises to about 70% of TLP, with *Corylus*-type and *Quercus* also prominent. Poaceae and Cyperaceae remain the most abundant herbs, with *Plantago lanceolata* and a wide range of ruderals, including a low but consistent cereal-type curve. A high peak of *Sphagnum* occurs.
SS-d	43–37	1246–1335AD. *Calluna* falls to about 20%, while *Corylus*-type, *Quercus* and *Alnus* show peaks in frequency. Poaceae and *Potentilla*-type rise sharply and a wide range of ruderal herbs occurs, including Cerealia.
SS-c	65–43	293AD–1246AD. Characterised by *Calluna*, which rises to around 60% of TLP, with reduced *Corylus*-type values and lesser values of *Quercus*, *Alnus* and *Betula*. Poaceae and Cyperaceae are the main herb taxa, and a wide range of other types occurs.
SS-b	73–65	54BC–293AD. *Corylus*-type frequencies are greatly reduced, and *Quercus* and *Alnus* percentages also fall. Poaceae values initially rise to a peak, followed by a peak in *Calluna*. *Plantago lanceolata* and *Pteridium* values are increased, and a grain of Cerealia is recorded. Other ruderal weed taxa values rise late in the zone, including *Polygonum aviculare*, *Plantago coronopus*, *Matricaria*-type and *Urtica*. A consistent *Artemisia* curve begins at the start of the zone.
SS-a	76–73	184–54BC. Characterised by *Calluna* and *Corylus*-type, with lesser values of *Quercus*, *Alnus* and Poaceae. Herb values are low, with only *Plantago lanceolata*, *Potentilla*-type, Rosaceae and *Rumex* significant.

Table 4. Conspectus of palaeoecological history of the Dalby Forest area, using modelled date ranges (Table 3) for Yondhead Rigg (YR), Dargate Dykes (DD) and Seavy Slack (SS) to correlate with cultural periods.

Period	Site pollen zones	Interpretation
Modern	DD-d	Modern mixed farming. Heather dominance with grassland pasture and cereal cultivation.. Some regeneration of mixed deciduous woodland.
Post Medieval	YR-j Late DD-c SS-f	A massive expansion of heather moor and heathland and a major decline in woodland. Some rough grassland but no arable cultivation.
Late Medieval	Early DD-c YR-i DD-b SS-e DD-a SS-d	Major cereal cultivation at YR with heather expansion but no decline of woodland. Woodland clearance for cultivation at DD with a major heather moorland expansion. Woodland regeneration at SS followed by clearance, heather moorland expansion and extensive cereal cultivation.
	YR-h	An expansion of deciduous woodland at YR, with some heathland, few open areas, no evidence of arable cultivation.
Early Medieval	YR-g SS-c YR-f	A major reduction in heather moorland, with increases in both deciduous woodland and some damp grassland. Some disturbance and arable cultivation occurs in YR-g.
Romano-British	YR-e SS-b	A major reduction in deciduous woodland and an expansion of heather moorland and grassland. Cereal cultivation occurs later in the period.
Late Iron Age	YR-d start of SS-b SS-a	Expansion of deciduous woodland, particularly hazel, and a reduction in heather moorland. Some open grassland, with a species-rich phase at the start at the start of the zone, but no evidence of arable cultivation
Early Iron Age	YR-c	Major reduction in woodland and major expansion of heather moorland. Increased grassland but no evidence of cultivation.
Later Bronze Age	YR-b	Woodland regeneration although still very open heather moorland vegetation. No record of clearance or agriculture
Earlier Bronze Age	YR-a	Very open vegetation following clearance for mixed farming. Heather and grassland with some scrubby woodland, mainly pastoral farming with cereal cultivation late in the period.