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Ombashi, Havananda

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A high-resolution palaeoecological study of land use change during late prehistory on Exmoor

by

Havananda Ombashi

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“*Vatra prindërore çliron gjithnjë ngrohtësi*.”

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Author's declaration

At no time during the registration for the degree of Doctor of Philosophy has the author been registered for any other University award without prior agreement of the Doctoral College Quality Sub-Committee.

Work submitted for this research degree at the University of Plymouth has not formed part of any other degree either at the University of Plymouth or at another establishment.

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Abstract

A high resolution palaeoecological study of land use change during late prehistory on Exmoor – Havananda Ombashi

Palaeoecological studies have proven to make significant contributions to two large ongoing debates that include the influential power of climate and the impact of human land management on the vegetation patterns in certain areas in the UK and Northwest Europe. The need and importance for higher resolution vegetation reconstructions has long been recognised in the wider literature. The main focus of this research is to further understand the relationship between human behaviour, climate and land cover change on Exmoor, of which the upland areas are comparable with others found in Britain and Northwest Europe. High-resolution records of pollen, NPP and charcoal data are presented, stemming from three upland sites on Exmoor: Great Buscombe, Spooners and Codsend Moors. Sequences are dated with the use of radiocarbon dates and recently identified tephra layers, enabling a better comparison between sequences from different sites on Exmoor. Additionally, a long-term climate reconstruction from a fourth site, The Chains, is presented and was produced through peat humification analysis.

Vegetation reconstructions were produced through pollen analysis, whereas archives of past grazing intensities and fire histories were created with the use of NPP (non-pollen palynomorph) and charcoal data. Statistical analyses of pollen, NPP, charcoal and climate data was conducted in order to test the relative importance of grazing, climate and burning on identified changes in the vegetation compositions.

Palaeoecological data from Exmoor shows a general trend of woodland clearance from the late Neolithic onwards, which was largely completed by the late Iron Age. This trend has been associated with an increase in the charcoal data and a coinciding decrease of pastoralism. Results further suggest that climatic changes did not necessarily directly affect the vegetation patterns on a larger, regional scale, but may have played a key role in societal changes. Finally, changes in vegetation patterns and land use on Exmoor did not occur simultaneously across all sites, resulting in a dynamic and heterogeneous landscape from the late Neolithic until the late Iron Age.

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Introduction

Humans have been present within the landscape long before the onset of the Holocene (the current geologic time period); however, their impact has largely been recognised through the middle and late Holocene. These people have influenced their environment, either through accidental, but increasingly through deliberate actions. The archaeological and palaeoecological evidence that has been preserved up until today can be used to reconstruct these interactions in order to understand more of the relationships between past societies and land cover. Several major landscape changes in both Britain and other parts of Northwest Europe occurred during the prehistoric past and have been identified through the research of this archaeological and palaeoecological evidence.

1.1 Field systems of the Bronze Age

One of the most dramatic changes to the British landscape occurred around 1500 cal BC at the start of the middle Bronze Age (see table **1.1** for date ranges). Although Neolithic communities had impacted on vegetation cover with shifts alternating between woodland clearances and expansion (Woodbridge *et al.*, 2014), the middle Bronze Age has long been seen as the marker of the introduction of enclosed areas of relatively open landscapes as fields with either stone banks or hedges and ditches (Darvill, 2010). Stevens and Fuller (2012) have suggested that the introduction of field systems in the landscape support their idea that the ‘real’ agricultural revolution did not occur until the middle Bronze Age (Stevens & Fuller, 2012).

Time period	**Time range in cal BC.**
Early Mesolithic	9660 – 7500
Late Mesolithic	7500 – 4000
Neolithic	4000 – 2300
Early Bronze Age	2300 – 1500
Middle Bronze Age	1500 – 1000
Late Bronze Age	1000 – 800
Early Iron Age	800 – 600
Middle Iron Age	600 – 400
Late Iron Age	400 – 43 AD

Table 1.1. *Zonation of prehistoric time periods according to the South West England chronological 14C dates (Webster, 2008).*

The emergence of field systems have been a large focus of research and the most recent theory suggested by Johnston (2005a) is that they are likely to have emerged as a result of communities working on a localised level, were not a unitary phenomenon (Johnston, 2005b) and were presumably built on field divisions from earlier (less well understood) time periods. The presence of humans during earlier time periods is mainly visible through the remains of burial monuments, but nonetheless also includes e.g. settlement remains, which were widespread over the landscape in Northwest Europe. The Bronze Age, however, is known for the introduction of field systems and linear earthworks that were sometimes associated with settlements in the vicinity (Bewley, 1994). A second remarkable feature of the Bronze Age describes the finds of new types of large stone circles occurring in new situations, especially in the west of Britain, together with stone rows and stone alignments that appeared in the landscape from the second millennium BC onwards. It has been suggested that the appearance of archaeological remains at new locations was a result of people moving into upland areas in Britain (Darvill, 2010).

The organisation of the land into divided areas was an important activity during the Bronze Age and was a widespread feature across Northwest Europe. A great example of the complicated field systems installed during the Bronze Age can be found on Dartmoor. Large areas cover so-called ‘coaxial field systems’ that date to around 1700 cal BC and were thought to be in use for 600 to 700 years (Fleming, 2008).

Many arguments and debates initiated after the discovery of the various field systems and several theories point towards an increased need to manage large numbers of livestock (Fleming, 2008). This is partly based on a remarkable increase of timber longhouses at around 1500 cal BC in many parts of Northwest Europe, supposedly to stall larger numbers of livestock (Tinsley & Grigson, 1981). Other suggested possibilities for the introduction of the field systems argue that they reflect new political economies and/or the emergence of a stratified society (Fleming, 2008; Darvill, 2010). The appearance of new archaeological features in the Bronze Age can be said to reflect a major change in land use over a large area, which has raised the interest of many researchers.

Based on an increase in archaeological finds in the upland areas of Britain, human activity in these areas of western and northern Britain is assumed to have increased after 1500 cal BC. Many pollen studies (at least partially) support this idea (e.g. Huang, 2002) and state that climatic conditions were favourable enough to allow the expansion of settlement onto poorer soils and upland areas at around 1500 cal BC (Darvill, 2010). Whether settlement was permanent or seasonal in upland and other marginal areas in Britain, posed some new questions that were added to the ongoing research of interactions between humans and their environment. For instance, it has been previously suggested that during the transition between the Bronze Age and Iron Age, palaeoclimatic deteriorations were an indirect cause for upland settlement abandonment (Burgess, 1985). More recent studies have suggested otherwise and assumed land-use changes to have occurred instead (e.g. Tipping, 2002). For instance, Tipping (2008) proved there is no consistent evidence for such a general ‘abandonment’ event to have happened in Scotland (Tipping *et al.*, 2008). Matters as these will be discussed in further detail in the next chapter.

1.2 Abandonment of the marginal upland areas?

Regions that were once rich in Bronze Age cairns and urn burials were long assumed to have been abandoned during the later Bronze Age. The sparse evidence for settlements in marginal areas is not only a known feature in Britain, but has also been recorded in other parts of Northwest Europe and has initiated large debates on possible explanations for this event (Darvill, 2010). On many (marginal) upland sites in the UK, archaeological evidence for settlements or land use, including the use of the field systems, was believed to have ceased towards the end of the late Bronze Age, but, as previously mentioned, recent studies suggest otherwise (e.g. Tipping, 2002).

Alongside the changes in archaeological evidence, reconstructions of vegetation cover throughout the Bronze Age have also shown significant shifts. In many upland or marginal areas in Britain and Northwest Europe, woodland cover declined to large extents. By the start of the Iron Age, pollen records from most sites showed the presence of open land, with small numbers of woodland areas remaining across the UK (Broothaerts *et al.*, 2014; Coles & Harding, 2014; Fyfe, Woodbridge & Roberts, 2015; Ghilardi & O'connell, 2013; Woodbridge *et al.*, 2014). Upland areas showed a permanent shift from woodland to heath and bog communities. Lowland areas remained wooded with continuing archaeological evidence for settlements in most areas (Fyfe, Brown & Rippon, 2003).

The discovery of above-mentioned significant changes of the landscape over such a widespread area in northwest Europe added a lot of new material to the debates about the changing conditions of the Bronze Age. Topics of research vary from defining possible factors that may have caused these shifts, and their further development or influence on later time periods, to explaining the recorded differences between lowland areas and upland areas. Studies have focussed on the relationship between climate change and human land use, and in some cases attempted to link this to e.g. social changes during this time period of transition (Darvill, 2010). Climatic shifts have been popular explanations for the suggested retreat of upland settlements and changes in vegetation patterns (Burgess, 1985). Others, however, (e.g. Evans, 1972) have suggested that changes in human land use, or the exploitation of the environment, caused vegetation in uplands to have shifted from woodland covered landscapes to largely open areas (Tinsley & Grigson, 1981).

1.2.1 Gaps in archaeological knowledge

Although many assumptions have initially been based on archaeological evidence from the past, most of our knowledge on archaeological features, such as coaxial fields or burial monuments, is very limited. Many coaxial field systems in Britain are undated, and the remainder show dates of use ranging between 2500 and 500 cal BC (Fleming, 2008; Johnston, 2005a). Certain research questions, such as whether occupation was permanent or intermittent at specific places in the past, are often hard to explain with the rather poor knowledge of archaeological features. This creates huge gaps in the understanding of human land use, and it would be very simplistic and perhaps untrue for some cases to assume that the absence of archaeological remains in the landscape directly reflects land abandonment.

1.3 Palaeoecological studies

A number of techniques have been developed to document past vegetational changes using natural deposits, such as bog or lake cores. The understanding of society-environment relationships requires a detailed understanding of a) the archaeological record, b) land use and management and c) climate/environment change. These factors can be deducted from reconstructions of past vegetation (Birks & Birks, 1980). Most of the developed techniques fall under palaeoecological studies and can be very useful in detecting both changes in past climate as well as changes in vegetation patterns in the landscape (Birks, 1985).

A large number of studies which have recorded the vegetation changes in (upland) landscapes are based on bog cores and include pollen analysis. Plant remains, together with other organic material of the plant species that lived on mires, are preserved in peat. This creates a build-up of information of the flora and fauna that once lived within a mire (Barber *et al.*, 2003). Pollen that have fallen into the accumulating peat are included in the preserved remains as well. The nature of past vegetation cover, together with the reflection of the local or regional environment, can thus be revealed through palaeoecological study (Birks & Birks, 1980). By extracting pollen from core samples taken from specific mires, a representation of the regional vegetation cover can be extracted. The presence or absence of certain plant species in the samples can give indications for human influence on the landscape of Exmoor. Palaeoecological studies can be used to test whether climatic change, pedogenesis or human influence gave rise to vegetational change and peat development (Chambers, 1993). Both palaeoecological and environmental archaeological studies can make significant contributions to two large ongoing debates that include the influential power of climate and the impact of human land management on the vegetation patterns in certain areas. Both of these issues are not only relevant in order to understand past behaviour and environmental conditions and their relative roles on vegetation changes, but are also relevant for current and future nature conservation or environmental management of specific landscapes (Mannion, 1991 in Chambers, 1993).

1.4 Key aims and objectives

This thesis will examine societal and environmental relationships in prehistory, using Exmoor as a case study. The upland areas of Exmoor are comparable with others found in Britain and Northwest Europe, but provides opportunities to expand on previous knowledge, alongside the potential to increase the resolution of palaeoecological work. Previous palaeoecological research suggests different types of land use occurred throughout the late Holocene. Similar changes in vegetation patterns that were found during the Bronze - and Iron Age in other parts of Europe have also been recorded in pollen analyses from Exmoor. Human activities include different practices of agriculture (grazing in particular), the use of fire to control vegetation, mineral extraction and domestic and industrial uses of the landscape (Davies, Fyfe & Charman, 2015). Although Exmoor lacks in clearly visible or large archaeological features in the landscape, there are archaeological remains that show evidence for land use and occupation during prehistoric times. Several coaxial field systems have been found, as well as plenty of stone rows or single standing stones across Exmoor (Gillings, Pollard & Taylor, 2010; Riley & Wilson-North, 2001).

The main focus of this research is directed to palaeoecological data from Exmoor in order to further understand the relationship between human behaviour, climate and land cover change. With recent finds of late Holocene tephra layers in peat bogs from Exmoor (Matthews, 2008), new potentials for better dated sequences have arisen and will be highly significant in order to compare different sites of Exmoor's past (Fyfe *et al.*, 2016).

Several aspects of the long-term vegetation patterns on a local and regional scale will be used in order to test the relative importance of ecological processes and human land management, with the following key aims of the project:

1. To define the past vegetation of Exmoor, where the time period of focus covers the late Neolithic, Bronze Age and Iron Age. The selection of key time periods of focus for this study is based on previous research, where specific time periods of transition have been demonstrated.
2. To test the relative importance of land management and climatic change in vegetation patterns.

To achieve these aims, the following objectives will be carried out:

a) to review the current state of knowledge of long-term vegetation change and land management, in particular the role of fire and grazing;
b) to develop high-resolution vegetation reconstructions for multiple sequences, using pollen analysis;
c) to establish new proxy-based archives of past grazing intensity and fire histories from the same core material used for the vegetation reconstructions;
d) to generate the first long-term climate reconstructions for Exmoor, with the use of peat humification analysis.

The datasets developed through this project will also allow us to understand whether land use has been similarly intense at specific sites on Exmoor throughout the past.

Furthermore, researching the past climatic changes on Exmoor and the relationship with (changes in) land management can also provide a better understanding of long-term drivers of mire vegetation. Drivers of mire vegetation have not been widely researched in South West Britain and researching these aspects could improve the understanding of upland occupation and land use across Britain as a whole.

Finally, identifying land use systems on Exmoor enables a contextualisation of the field archaeology that is present. Palaeoenvironmental studies on sampled peat from Exmoor are highly significant, considering the very limited knowledge of Exmoor's archaeology (Riley & Wilson-North, 2001). A previous lack of excavations on Exmoor has created a gap in the knowledge of people's past behaviour and their land use. Some recent excavations at Lanacombe undertaken by Gillings (2013) are a good example for the potential to tie any new knowledge into ongoing programmes of excavation. The palaeoecological record can thus provide us with possible frameworks for human activities through later prehistory, which can in turn be used to manage future mire vegetation on Exmoor.

Chapter 2 – Literature review

2.1 The contribution of palaeoecological records to understanding the later prehistory

Palaeoecology is the study and understanding of the relationships between past organisms and the environment in which they lived (Birks & Birks, 1980). This can be studied on different scales; from individuals to populations and communities of both plants and animals that interacted with their environment in the past (Delcourt, 1991). In practice, palaeoecology has mostly focused on reconstructing past ecosystems in order to understand their development and to further understand and manage the structure and function of both past and modern ecosystems (Delcourt, 1991).

This section will discuss the contribution that palaeoecology has had on the understanding of the late prehistory of Britain and Northwest Europe. In particular, it will focus on how palaeoecology has allowed for a better understanding of agricultural practices and other forms of land management during late prehistoric times in Britain.

Palaeoecology has been a great contributor into researching the impact of human behaviour on their surroundings and the response of the ecosystem to such changes (Birks & Birks, 1980). It is particularly useful when other types of resources are not available, such as documentary evidence, and it has proven in many cases to enhance historical and modern knowledge on recent vegetation (responses) (Davies, 2016; Moore, 1991). The main form of evidence is the so-called biotic evidence and includes micro fossils/remains, such as pollen and spores, as well as macro fossils;

archaeobotanical remains and charcoal (Birks, 1985). Since the plant community is the most complex part of an ecosystem, reconstructing this is one of the key factors in reconstructing past environments. Reconstructions of past ecosystems through palaeoecology does rely on taxonomic uniformitarianism, which is the assumption that all ecological requirements and tolerances of the identified plant species/communities have not changed over time (Romano, 2015).

2.1.1 Pollen

Quaternary palaeoecology has been dominated by the study of (stratigraphical) pollen analysis. This is mainly due to the fact that pollen grains and spores of vascular plants make up the highest abundant type of preserved fossils in terrestrial Quaternary sediments (Birks, 1985). Pollen studies have proven to be a significant technique in order to understand the environmental, economic and social settings of prehistoric peoples (Dimbleby, 1985). Palynology has been used for a variety of research goals, including past vegetation reconstructions (e.g. David & Haberle, 2012) and providing evidence for prehistoric settlement through vegetation disturbance (Gearey, Charman & Kent, 2000). It has often been used to enhance archaeological interpretations on settlements, woodland removal or the adoption of agriculture, for instance, by providing the environmental context of archaeological artefacts (e.g. Twiddle, 2012). By being able to reconstruct past vegetation changes, and combine this with identified climatic changes, pollen have so far been a very valuable technique to assess human impact on both a local and/or regional scale (Davis & Shafer, 2006). Different types of human impact on the vegetation have so far been identified with the use of pollen studies and include removal of natural vegetation (such as woodland clearance), the presence of cereal cultivation and the presence of pastoral activities. Not only do pollen studies often identify phases of land management or changes therein, it has also been useful in detecting phases of vegetation recovery (which often differs from natural baseline vegetation).

Pollen are often used in combination with other proxies, such as macro remains, to identify influences of human behaviour on the landscape. Examples of pastoral activities that could be identified with these proxies are the presence of grazing, deforestation (in order to create better grazing opportunities for example, or leaf foraging (to use as fodder for domesticated animals) (Mauquoy *et al.*, 2002).

Palynology has been very useful in improving our understanding of agricultural practices during prehistoric Britain. The finds of cereal pollen are often used in attempts to pinpoint the adoption of cereal cultivation at specific sites/regions but have been applied on a larger scale as well. It gives further evidence for understanding the development of an agricultural lifestyle throughout Britain as a whole in comparison to the rest of (Northwest) Europe. Cereal pollen and associated weed taxa have *a*) helped to identify what sort of crops were grown in what parts of Britain, *b*) identify the time period of introduction of cereal production (e.g. Behre, 1981; Innes & Blackford, 2003) and *c*) improved the understanding whether whether woodland clearance occurred in order to create suitable land for cultivation (Woodbridge *et al.*, 2014). Identifying these changes and combining them with archaeological knowledge, as well as climate changes, are key to be able to place the combination of findings in the right contexts.

Apart from just identifying different types of land management, pollen studies can also be useful to identify how plant communities respond to changes in land use. This knowledge is not only necessary to further understand past ecosystem development, but can be applied to modern management by predicting certain species to start dominating after applying specific types of land management to certain ecosystems (Chambers, Mauquoy & Todd, 1999).

2.1.2 Archaeobotanical remains and macrofossils

The study of archaeobotanical remains have been explicitly useful in the further research on agricultural practices in and beyond Britain (Branch, 2005). A large variety of aspects have been studied with the use of archaeobotanical remains from excavations. One of the main subjects of research has been discussed in the previous chapter and focussed on the expansion of an agricultural lifestyle throughout Britain, as well as establishing when a dominance of hunter/gatherer or pastoral lifestyles were (partially) replaced by agricultural lifestyles (Stevens & Fuller, 2015).

In order to understand when this ‘agricultural revolution’ took place, many aspects have been considered. The significance of crops cultivation and pastoralism is discussed in section 2.2. Other aspects include identifying agricultural practices used, such as manuring, hoeing and weeding (e.g. Bogaard *et al.*, 2001), or defining the domestication of agricultural plants (Fuller, 2007). Archaeobotanical remains have also been useful in studying post-cultivation processes such as cereal storage, which can be linked to the economy of past peoples and the (seasonal) reliability on cereals in their diet (Stevens & Fuller, 2015). Defining the sowing season (autumn-sowed or spring-sowed) has had a great impact on our understanding of prehistoric human behaviour, as crops with different sowing seasons have been linked to climatic changes, such as dry to wet shifts (Bogaard *et al.*, 2007). Although the role of climate on vegetation changes will be discussed in further detail in the next section.

By linking archaeobotanical finds to changes in climate, attempts have been made to research how prehistoric peoples altered their agricultural practices, choice of crops and the change in reliability on specific crops. This process lead to an integration of the newly acquired knowledge with demographic data, initiated by theories such as those of Stevens and Fuller (2015): ‘climate does not affect demography directly, but through the medium of food’. The knowledge of adapted strategies and changes therein could also enhance archaeological knowledge on aspects such as understanding the use of enclosed fields and identifying how mobile people behaved across time and space.

A variety of plant macrofossils, often combined with pollen studies and/or archaeobotanical remains have proven to also be useful in the reconstruction of climatic changes, or changes in bog hydrology, together with fungal spore and testate amoebae studies (Wood et al. 2010; Langdon, Hughes & Brown, 2012). Furthermore, studies have also made use of plant macrofossils for reconstructing diets of herbivores, both domesticated (Akeret & Rentzel, 2001) and wild (Aptroot & van Geel, 2006).

2.1.3 Non pollen palynomorphs

A last type of biotic evidence in palaeoecological research discussed here are the non-pollen palynomorphs (here referred to as NPPs), which are in this context predominantly fungal spores. Fungal spores are used in addition to pollen research with increasing frequency, as they often do not require extra lab preparation time and can be identified alongside pollen. It has been shown by many studies that non-pollen palynomorphs can be used independently (e.g. Baker *et al.*, 2016; van Geel & Aptroot, 2006). Clusters of NPP taxa can often be indicative of certain vegetation assemblages (Blackford *et al.*, 2006). Considering the distribution of NPPs is generally limited to a local scale, comparison with pollen data (usually reflecting a regional landscape) can be very useful (e.g. van Geel, 1978).

NPP analysis has been included in palaeoecological studies for varying reasons. Examples include researching the hydrology and vegetation changes (Charman *et al.*, 2007) or reconstructing the diet of past herbivores (Akeret & Rentzel, 2001).

One particular category of NPPs have been most useful in the further understanding of prehistoric land use and land use change. Both humans and domesticated animals are believed to have been able to cause a change in the microflora, which can be reflected by NPP studies (Mauquoy *et al.*, 2002). Coprophilous fungal spores (stemming from fungi living on dung from either wild herbivores or domesticated livestock) have been proven useful in many palaeoecological researches studies. Although some coprophilous fungi are not restricted in habitat to dung (Newcombe *et al*. 2016), several types have shown to be reliable indicators of the presence of dung, and thus indirectly the presence of grazing animals (Davis & Shafer, 2006; Ekblom & Gillson, 2010; van Geel *et al.*, 2003). This has resulted in reconstructions of pastoral activities (Cugny, Mazier & Galop, 2010) or where NPPs could assign valuable ecological details to an archaeological site (Blackford, 2000b).

2.1.4 Charcoal analysis

Because ecosystems are influenced by fire on all spatio-temporal scales, palaeofire has seen a growing interest in the recent past (Blarquez *et al.*, 2014).The occurrence of fire, whether initiated by humans or nature, has been a great subject of focus in attempting to identify periods of land management through the use of fire. In order to identify different events of fire, the quantification of charcoal fragments in pollen preparation has become a common practice in palaeoecological studies (Blackford, 2000a).

Several studies that have focused on landscape change and resource management throughout the prehistoric time periods compared pollen data with charcoal data in their interpretation of the records (Blackford, 2000a). Studies often combine charcoal quantification data with pollen, in addition to NPP data in some cases (e.g. Ryan & Blackford, 2010). This results in the ability to identify (phases of) burning as a type of land management or e.g. the presence of pastoral activity on both a regional and a local scale in the landscape around sites. In some cases this could then be linked to any possible present archaeological evidence in the surrounding areas of the sites.

2.2 Land use and diet changes throughout later prehistory

Through both archaeological and palaeoecological work, an ever-growing understanding of past land use and social organisations during late prehistoric times exists. This next subchapter will discuss the main three themes of land use and impact on vegetation and other landscape aspect humans have had in the past. This will include woodland reduction, as well as pastoral and arable agricultural activities. Changes in these types of land use will be discussed, alongside any possible causes and their subsequent impacts on the surrounding vegetation.

2.2.1 Woodland reduction

The establishment of both pastoralists and arable agriculturists throughout prehistory resulted in a change in the landscape at many sites across northwest Europe. In the majority of cases, openings in the forests or woodlands were either created or exploited (and sometimes expanded) for small-scale arable agriculture or pasture (Kaplan, Krumhardt & Zimmermann, 2009). At some sites, such as on Dartmoor, woodland clearance had already initiated during the Mesolithic period to either improve hunting success, increase the production of nuts/acorns or for driving game animals (Blackford *et al.*, 2006). Other possible reasons for clearing woodland include creating easier ways of transportation during the Bronze Age (e.g. Dark, 2005) or for construction work and tool making (e.g. Parker *et al.*, 2008). Evidence has been found for woodland clearance carried out with the use of axes (e.g. Schauer *et al.*, 2019), as well as through the use of fire (Tipping *et al.*, 2008).

Clearances of primary woodlands were often succeeded by secondary woodland successions (Rasmussen, 2005). Following the Mesolithic onwards, woodland regeneration occurred less frequently and often lacked a complete recovery. As a result, woodlands across large parts of northwest Europe declined throughout the Neolithic. However, a high number of sites showed partial woodland re-establishment around the mid- to late Neolithic.

After an initial or second phase of declined woodland, heathland extended at many sites across the UK. This resulted in increasingly semi-open land-covers towards the late Bronze Age and early Iron Age (Ellis & Tallis, 2001; Gardiner, Megarry & Plunkett, 2019; Oldfield *et al.*, 2003; Smith, Cloutman & West, 1988; Woodbridge *et al.*, 2014). Possible factors that prevented woodland regeneration during the Neolithic and later periods include the use of fire as a management tool, but also factors such as browsing, trampling and grazing of animals, whether this was deliberate or not (Brown, 1997).

Forest clearance (thus assumed to be a reflection of anthropogenic activities) is believed to have caused hydrological changes, eventually resulting in peat growth (Langdon, Barber & Hughes, 2003). Others argued that burning of the vegetation in particular (trees or shrubs), has been linked to peat inception at many sites in Britain and Northern Europe (Chambers, 2012; Straw *et al.*, 1995).

2.2.2 Pastoralism and fire as a management tool

Impacts on woodland regeneration

Pastoral activities may include woodland clearance associated with grazing or leaf-fodder collection (Dark, 2005). Indications of selective cutting of e.g. lime trees by prehistoric peoples was assumed to have been for e.g. fodder, but could also have been for the collection of wood bast fibre (Peglar, Fritz & Birks, 1989). It is widely accepted that fire has been used as a tool to prevent invasions by shrubs and woodland regeneration. People with a pastoral lifestyle would benefit from maintaining heathlands and used it as a pasture for their grazing animals (Groves *et al.*, 2012). The highest nutritional value can be found in young shoots or plants of *Calluna* and were much appreciated as winter fodder (Karg, 2008). Fire can initially be used to clear forests and, following grazing pressure, can prevent woodland regeneration (Moore, 2000). Fire has also been used as a tool for woodland clearance with a purpose to enable arable agriculture (Simmons & Innes, 1996a).

Either fire, grazing or a combination of both can promote soil impoverishment and with that the expansion of heathland (Innes & Blackford, 2003). As a result, the landscape of the UK and other parts of Northwest Europe began to be cleared of trees from the start of the Neolithic. Although this progress took place throughout prehistory in general terms, it did not occur to the same extents across the entire landscapes in the UK and northwest Europe. A variety of examples have shown that patches of woodland remained present, even until the later Iron Age. This has mainly been associated with topography and soil types (Bartley, Jones & Smith, 1990).

Animal husbandry throughout late prehistory

A combination of a lack of archaeological knowledge together with bad preservation conditions on Exmoor, makes it difficult to gain any certainty what livestock animals were kept throughout late prehistory. This section will therefore rely on zooarchaeological data from other sites across the UK, seeking indications of which animals prehistoric people relied on, as well as changes in these compositions through time.

Archaeological evidence from ritual-related monuments and settlements from the wider southwest region, dating to the Neolithic and early Bronze Age, indicate a presence of a wide variety of animals. These are both feral and domesticated and include cattle, pig, sheep, goat, deer, dogs and aurochs (Webster, 2008). Cattle has been widely prominent in the faunal composition of Britain as a whole during the late Neolithic (Viner *et al.*, 2010). Evidence from certain key sites in Britain have shown a shift from cattle dominance during the early and middle Neolithic towards a dominance of pigs during the late Neolithic (Albarella & Serjeantson, 2002), which is regarded to be common across Britain (Grigson, 1982). From a general viewpoint, the Bronze and Iron Age can largely be categorised as the sheep/goat ages (Albarella & Serjeantson, 2002), although pigs are generally seen as more dominant during the late Iron Age in south-east England (Sharples, 2010).

A lack of archaeological sites with large faunal assemblages have resulted in somewhat biased information on animal dominance in the past. There are only a few key sites across Britain where a sufficient amount of animal bones have been preserved and analysed (Viner *et al.*, 2010). This has been used for interpreting other forms of archaeological or palaeoecological data elsewhere, but should be considered with caution. Different contexts in which animal bones are found (ritual, settlement, or unspecified) may influence or bias results of animal species counts. However, other factors can also play a role, such as local or regional variability, the degree of movement in certain groups or societies and the landscape these groups were living in (Fowler, 1983). Pigs, for instance, are generally regarded to be the most dominant animals during late Neolithic. However, they arguably have lower levels of mobility, compared to cattle and sheep/goats, which may have been a deciding factor for them to be less dominant in more mobile groups (Bentley, 2013). Furthermore, prehistoric people did not always necessary rely on domesticated animals. Zooarchaeological data from different sites, covering periods until the later Iron Age, have shown the presence of horse, red deer, bird and other types of wild animals bones (Grant, 1989).

2.2.3 Arable agricultural practices in late prehistory

Woodland clearance, as a partial result of pastoralism, has been a significant driver of vegetation changes to different extents, depending on both time and location.
The process through which these drivers have affected vegetation changes, can be described as non-linear with time and vary greatly, based on the intensity of human land use pressure, climate and other possible external factors such as topography, soil and vegetation responses. It can be argued that the same “non-linearity” also applies

to the development of arable agriculture. The following section discusses the ongoing debates around the agricultural “revolution”.

The Neolithic traditionally marks a shift to agricultural practices, alongside a use of wild resources. Initially, the start of the early Neolithic was assumed to reflect the upcoming of agricultural practices in the form of shifting agriculture on a small scale (Wilkinson & Straker, 2008). A wide body of literature agrees that the largest part of cereal cultivation may have been used as a supplement to wild foods after the first appearances of cereal crops (e.g. Simmons & Innes, 1996b; Stevens & Fuller, 2012; Wilkinson & Straker, 2008) and that it was part of a gradual process with mixed land use (Mosler & Hobson, 2018). Recent evidence from central Europe, Britain and Ireland shows indications for the absence of shifting cultivation. It has been suggested now that, opposite to previous beliefs, farmers during the early Neolithic were practising a more intensive (small scale) form of cereal cultivation (McClatchie *et al.*, 2014).

Archaeological evidence for arable agricultural activities

A large shift in the appearance of prehistoric landscapes in Britain took place at around 2500 cal BC (Woodbridge *et al.*, 2014). This change has often been associated with the believe that the previous relative stability of early farming groups of the 3rd millennium BC had come to an end (Darvill, 2010). The recorded archaeological changes that date to this period of transition range from a shift in form and siting of settlements and monuments, to shifts in pottery types, flint work and material culture finds (Darvill, 2010; Webster, 2008). The dominating evidence of settlements and agriculture from the middle Bronze Age onwards is in contrast with earlier periods, where very visible ritual-related structures dominated the archaeological record. The differences in archaeological remains have resulted in a distinction made between Neolithic and early Bronze Age societies, compared to the later prehistoric time periods from the middle Bronze Age onwards. This transition has often been interpreted as a move from ritual-related activities to rational food-producing societies (Jones, 2008). Ritualized activities have however been recognized in middle Bronze Age sites and relationships between ceremonial monuments from earlier periods and settlement features have often been overlooked (Jones, 2008), even though several aspects of settlements have suggested otherwise (Brück, 2000). Furthermore, metal depositions in wetland areas or rivers across Britain and Northwest Europe in later prehistoric times have been interpreted as parts of ritual events and could reflect a shift to non-visible ritual-related locations (Fontijn, 2007).

A non-linear development of arable agricultural

It was previously assumed that by the end of the early Neolithic, early farmers would progress towards practices that are more intensive during the Bronze Age. The longer-term, fixed agriculture that was practised during the early Neolithic, however, seems to have declined, or potentially completely abandoned, throughout the middle and late Neolithic, predominantly in parts of mainland England (Bevan *et al.*, 2017). Suggestions have been put forward that a shift from an arable to a mobile pastoralist society occurred during the British late Neolithic, likely at around 3350 cal BC (Stevens & Fuller, 2012). The new model, named “Multiple transference”, as proposed by Stevens and Fuller (2012), suggests that foraging remained an important part of the diet during the early Neolithic, but was replaced in most places by pastoralism and wild resourcing during the middle and late Neolithic. This has led to recent belief that the ‘real’ agricultural revolution did not start until the middle Bronze Age. The occurrence of the field systems, enclosures and indications for a more ‘fixed settlement’ from this period onwards has been interpreted to support this theory. It is also noteworthy that from this period during prehistory onwards, pottery and metals started to have an increasingly significant role in everyday activities. Furthermore, archaeologically visible land divisions started to occur from the middle Bronze Age onwards (Yates, 2007).

The movement towards arable agricultural practices

A number of climatic shifts are known from the literature and have been the subject of debate on how climate could have influenced human behaviour and their subsistence strategies. The oldest, globally identified, climatic event discussed in this section dates to 5200 cal BP (3250 cal BC) and is known as the 5.2 ka event, but has been described as a substantial transition in the global climate system during the period of 6000-5000 cal BP (4050 – 3050 cal BC) (Roland *et al.*, 2015). Although this event resulted in a shift to drier periods at a variety of regions, in northern Europe a shift to wetter conditions and an increase in storm frequency followed (Roland *et al.*, 2015). Together with the more spatially complex 4.2ka event (Roland, 2012; Walker *et al.*, 2012), they have formed the basis for a debate on the influencing factor of climatic downturns during the Neolithic.

For instance, Detlef (2009) suggested that the spread of farming in the Neolithic was a response of people to climate-induced crisis periods. This was followed by publications suggesting that a variety of factors, other than changing climatic conditions, could have influenced the nature and spread of the agricultural transition (e.g. Davies, 2007; Tipping *et al.*, 2008; Woodbridge *et al.*, 2014). Verrill and Tipping (2010) identified an abandonment of field systems in Ireland in the time period of identified climatic deterioration, but argued that soil erosion may have played a more significant role in the exact timing of abandonment. It has been argued that different regions responded in different ways, leading to the suggestion that the spread of farming was regionalised (Sheridan, 2012).

Types of crops grown in late prehistoric UK

It must have taken several attempts before agricultural practices were known and put to use throughout Britain (Brown, 2007), but it has strongly been associated with measured increases in population (Woodbridge *et al.*, 2014). With the exception of Scotland, a rather rapid appearance of domestic crops is believed to have taken place in the British Isles, (Stevens & Fuller, 2012). Although most evidence for crop husbandry suggests a presence of only small amounts of cereals, various different crops have been found in Britain and include: emmer wheat, naked barley, hulled barley, einkorn wheat, flax, pea, lentil, chick pea and bitter vetch. Furthermore, settlement waste often included evidence for resourcing of fruit such as crab-apple and bramble, together with finds of hazelnut shells (e.g. McClatchie et al., 2014; Whitehouse *et al.*, 2014).

2.3 From archaeological records to social organisations

Evidence of human presence and their influence on their surrounding landscape are often reflected in archaeological remains. A brief overview of shifting patterns in archaeological sites found on the British/Northwest European landscapes will be discussed in this section, focussing on the late Neolithic, Bronze Age and Iron Age.

2.3.1 Changes in archaeological evidence at 2500 cal BC and 2000 cal BC

Although monuments had already been present in the landscape before 2500 cal BC, a shift in their character reflects a change in the landscape. A supposedly ritual-related feature in the landscape was the development of circular monuments such as henges and round barrows (Darvill, 2010). These started to appear from around 2500 cal BC onwards and are exclusively found in Britain. In the majority of cases, they were found surrounded by a band and internal ditch (Dyer, 1990). The shift towards the increasingly-dominating round barrows as a principal burial monument took over from e.g. long barrows (even though long barrows had been quite popular in certain areas before) (Darvill, 2010). Within burial monuments, grave goods differed and were associated with a greater evidence of differentiation in burials from 2500 cal BC onwards (Darvill, 2010).

Between 2750 and 2500 cal BC, the term Bell beaker was introduced, referring to a certain pottery style found across central and western Europe (Olalde *et al.*, 2018). The finds of bell beakers in the archaeological record initiated many debates on possible immigration of people from what is now mainland Europe (Webster, 2008). This led to further debates on how the Bronze Age societies were structured, the level of exchange networks and theories of prestige items found in burial mounds (Dyer, 1990). Unlike the majority of Europe, it has recently been suggested that the expansion of the Bell beakers in Britain was largely driven by migration. A visible genomic transformation around 2450 call BC had resulted in an increased presence of individuals with a large amount of steppe-related ancestry (Olalde *et al.*, 2018).

Between 2000 and 1800 cal BC, the Wessex ‘culture’ occurred, with great examples of rich grave barrows that included incredible crafted golden objects. Barrows have initially been associated with the rise of elite groups, but more recent literature states this as too simplistic (Jones, 2008). A tendency towards single burials, rather than collective, seemed to have developed and barrows from this culture are believed to have reflected people’s attitude towards the afterlife (Pryor, 2003).

2.3.2 Middle Bronze Age to late Iron Age settlement types

The later Bronze Age and Iron Age are characterised by a variety of settlement types, in contrast to the burial-dominated early Bronze Age. Apart from the very common hut circles and round houses, farmsteads were present in sometimes large numbers, but the limited excavation of these features prevents a full understanding of them. Further north, in Scotland, the landscape was characterised by brochs and duns (Bewley, 1994), which are complex round houses and small stone-walled forts, respectively (Cunliffe, 1995).

A high variety of settlements is known from a large number of sites dating to the later parts of prehistory. The most common type of settlement, the round house, has initially been assumed to depend on the social status of the occupant, which was reflected in its size, but this theory has now been rejected (e.g. Brück, 2000). It is widely accepted that both the size and layout of the houses suggest the occupancy of a single household, or perhaps extended family in most cases (Brück, 2000). It is remarkable that the majority of settled sites only consist of one or two domestic houses. Most of these houses appeared to have functioned as relatively independent self-sufficient socio-economic units. They are often enclosed and associated with enclosed fields in the surroundings. The fact that houses are never remote, but almost always within a relatively small distance from other houses, suggests that the people of these households identified with a larger social space (Ginn, 2011).

2.3.3 Enclosures and field systems

A widespread phenomenon in the UK during the Bronze Age is the presence of enclosures in the landscape (Bradley, 1972). Although land division occurred as early as Neolithic times, it was not as widespread as during the Bronze Age with the rise of extensive field systems in both upland and lowland areas (Brück, 2000; Fleming, 1994; Yates, 1999). A good example is that of the field systems found on Dartmoor, which are dated to 1700 cal BC and were initially believed to have been in use for 700 to 600 years. Dating field systems and enclosures can be very difficult, as some of these are believed to have only been in use for short durations, sometimes even less than a single generation (Whittle, Healy & Bayliss, 2011). Further details are discussed in section 2.4.1.

A particular feature of the fields systems found here is that the boundaries of the enclosures were commemorated by reaves (stone-built walls) and initially suggested to have been aligned along a predetermined axis. Within the field systems, smaller social units were laid out and several walled pastoral enclosures occurred beyond the reave systems. Due to the parallelism of the field boundaries, it has been named a ‘coaxial’ field system and several more examples of such systems are found in other parts of the UK, such as Wessex and Yorkshire (Bewley, 1994; Fleming, 2008). Similar features have also been found in other parts of northwest Europe, although most of the continental features occurred later in prehistory (Nielsen & Dalsgaard, 2017). It appears that in countries such as the UK with a high occurrence of stones in subsoils, the banks are often consisting of stone, whereas in countries lacking stones in the subsoil, banks seem to have primarily consisted of soil (Nielsen & Dalsgaard, 2017).

2.4 Marginal areas and climatic influences

Identified changes in both the archaeological and palaeoecological records have fuelled several debates on how these changes may reflect social organisations and developments therein. A significant focus in the literature has been on the so called "marginal areas". This term often refers to either upland (in the majority of cases) or lowland areas. In many case studies, several differences have been identified between upland and lowland areas and were followed by a range of interpretations and theories. These theories have predominantly focussed on social organisations and the influence of climatic deteriorations.

2.4.1 Upland field systems and enclosures

The mid-second millennium BC characterises a shift in land use, when more prominent landscape division-related features emerged, such as linear boundaries. These features were especially common in Wessex, Dartmoor and Yorkshire (Bewley, 1994). In many upland areas across Britain, stones were cleared from the surface, presumably to improve the land for cultivation and/or pasture (Fyfe *et al.*, 2008). The collected stones were used in the building of cairns and field banks, of which many are still present in the current landscape. The period of around 1500 to 1100 cal BC thus shows a shift towards a divided landscape by boundaries and much of the literature revolves around the social changes that resulted in the creation of these systems. This section will predominantly use Dartmoor as an example case study, but upland field systems found elsewhere are also considered.

Outdated interpretations of upland field systems

Fleming (2008) assumed the systems found on Dartmoor were built in one brief timespan and must have needed a certain degree of social organisation involving the agreement and participation of substantial groups. He suggested that large numbers of collectively owned livestock had to be controlled. Under increasing pressure, the land must have been divided in order to manage the new situation. He further argued that the control of livestock could also have been an expression of a new political economy, such as with the presence of an exploitative elite in a stratified society (Fleming, 2008).

Fleming’s hypotheses agree with a general view on the field systems from the 1960s and 1970s onwards. The organisation of the landscape was believed to no longer be focused on ritual structures, but rather more directed towards survival mechanisms or the improvement and intensification of possible agricultural or pastoralist methods (Cunliffe, 1995). This resulted in the suggestions of top-down structured societies during the middle and late Bronze Age, by many others in the 20th century (Wickstead, 2008). Furthermore, evidence of numerous droves, roads and trackways that connected the fields with each other were interpreted as evidence for a more sedentary way of life (Pryor, 2003). This emphasis on economic growth resulted in theories on prestige-related agricultural production, such as the assumption that marginal areas like the uplands were brought into use in order to get surplus production (Brück, 2000). Barrett, Bradley and Green (1991) suggested that human reproduction as well as agricultural production were used to gain and maintain political power (Barrett, Bradley & Green, 1991).

Recent views on upland field systems

More recent studies on upland field systems argue that previous understandings are based on wrong interpretations of archaeological remains from prehistoric times and the field systems themselves. In a large number of upland areas, from 1500 cal BC onwards, archaeological remains in the landscape consist of earthworks, stone banks and walls (Johnston, 2005b). Landscapes in southwest Britain have been particularly important in these debates, particularly that of Dartmoor.

Firstly, Johnston (2005a) argues that when studying the reaves of Dartmoor on a closer scale, there appear to be mismatches in the coaxial patterns as well as irregularities in their construction and their course. He stated that the field systems on Dartmoor were not a unitary phenomenon, but are more likely to have emerged as a result of communities working on a localised level, reflecting the relationships between land and other communities. This is supported by Jones (2008). Tenure was gained through close ties between occupancy and land (Johnston, 2005b). Johnston further argues that in many cases enclosures were not always fully completed in the middle Bronze Age landscape of Britain and that tenure must be seen as the product of varying agricultural practices and the social networks of which it is part (Johnston, 2001). This is also supported by evidence from field systems in Cornwall, where different dates were found for different boundary constructions, ranging from the Bronze to Iron Age (Vervust *et al.*, 2019).

Secondly, Wickstead (2008) argued that the tenure in Dartmoor was not the result of a top-down structured society, but rather of a more flexibly organised society. Furthermore, a shift from mobile groups to smaller extended families occurred in periods after 1500 cal BC. Wickstead (2008) associated the field systems with shifting settlement patterns and a dominance of pastoral land use. Furthermore, Brück (2000) pointed out the significance of social fragmentation in the second millennium BC, and that there was not necessarily a long-term attachment to places, as was previously argued in less recent studies.

Thirdly, more recent views on the field systems generally agree with the theory that they were not brought into existence with the goal of intensification (Brück, 2000).

Social organisations during late prehistory

There remains a large amount of uncertainty about the social organisation during prehistoric times and the emergence of enclosures during the later prehistory, but also the use of enclosed areas. The majority of known field systems in Britain is undated and not necessarily found on all uplands in the UK. The Dartmoor reaves, for example, rely on a total of three radiocarbon dates and no secure dating exists on the duration of the field systems (Fyfe *et al.*, 2008). This is comparable to the field systems found in the Yorkshire Dales. Field systems here have only recently been suggested to date to the middle Bronze Age, rather than from 1000 years later, as was previously thought.

The most recent description is that field systems in Yorkshire, albeit equally applicable to systems in others areas, are part of a complex landscape, which is poorly understood (Saunders, 2017).

The processes in which enclosures have been formed are still not fully understood, nor is it certain whether they all served the same purpose. An example pointed out by Butler (1997) on Dartmoor, are several boulder-filled enclosures, which would make these unfit for both grazing and arable cultivation. Other examples, such as those of Gardiner *et. al* (2019), suggested that field systems found on the Antrim plateau would have been for pastoral use. Examples like this raise questions on the functions of enclosed land (Butler 1997 in Brück, 2000). Halkon *et al.* (2017) found that field systems in the Yorkshire Wolds appear to be associated with waterways and barrows, as well as with previous earthworks, whereas Long, chambers and Barnett (1997) found evidence for cereal cultivation in field systems located in the uplands of Yorkshire.

It can be stated that views on social organisation and changes therein were reflected (and interpreted) in various ways in the existing literature throughout the past. The second millennium BC seems to represent a very significant shift in landscape appearance and land use. Although one could state that this shift in land division is likely to have created a new base for following generations occupying the uplands and lowlands of Britain, it should equally be pointed out that this shift is part of many other changes that took place throughout prehistoric times. It should perhaps be regarded as part of a developmental process, rather than an evolutionary “sudden” change amongst societies.

2.4.2 Climatic deterioration during the Bronze- to Iron Age transition

Compared to early Holocene climate, the mid- and late Holocene climate has been generally stable, occurring under environmental boundary conditions. It has, however, been punctuated by both gradual and abrupt climatic shifts in the order of one to two degrees (Roland *et al.*, 2014). This section will focus on identified climatic shifts throughout late prehistoric times. In the following section, a discussion will follow on how climate data has been used to associate past changes in human behaviour of Britain and Northwest Europe.

A large part of the current literature has focussed on a climatic decline, succeeding a very brief drier phase, that has been dated during the transition between the Bronze Age and Iron Age (Fyfe, 2012; Roland *et al.*, 2014). According to van Geel and Mauquoy (2010), this subboreal-subatlantic shift was one of the most significant changes in climate and was dated to around 850 cal BC (Geel & Mauquoy, 2010). Older peat stratigraphy studies carried out by Blackford (1990) and Barber (1982) suggested that the climatic shift lasted until 250 cal BC., whereas Berglund (2000) identified the end to date to 550 cal BC, suggesting some possible differences between sites within Northwest Europe. Surface wetness on valley mires could have increased during this time period and potentially limited the reproduction of tree taxa, thus showing a decline of these taxa in pollen diagrams (Mighall & Chambers, 1995). The stacked bog surface wetness proxy-climate records of Charman *et al*. (2006) from Northern Britain suggests complex phases of climatic change through the Bronze Age through to the Iron Age.

The exact dates, nature and impact of this shift have been the subject of many debates (Burgess 1985; Lamb 1981 in Amesbury *et al.*, 2008). Not all studies agree on the exact start of a climatic downturn at 850 cal BC. Many sites in northwest Europe indicate the start to have been at around 700 cal BC. This, however, remains within the transition phase of the late Bronze Age to the Early Iron Age (Van Geel, Buurman & Waterbolk, 1996).

A recent explanation for the cause of this shift has been based on a correlation to an abrupt decline in solar activity which occurred at around 850 cal BC (Geel & Mauquoy, 2010). Earlier attempts in correlating peat-derived climate data and solar activity were carried out on peat bogs from the Scottish sites Temple Hill Moss and Walton Moss (Langdon, Barber & Hughes, 2003). Climatic research on these peat bogs seemed to correspond with climatic cycles that were identified from North Atlantic Deep Water circulation (mainly identified in 1100 year-cycles). A further examination suggested a correlation between changes in the North Atlantic thermohaline circulation were being reflected in the peat bog proxy-climate signal in Northern Britain (Langdon, Barber & Hughes, 2003). Changes in thermohaline circulation were most likely caused by solar activity and could affect the peat bogs indirectly through affecting the character, direction and intensities of storm tracks (Langdon, Barber & Hughes, 2003).

Regardless of the exact time frame or cause of a climatic deterioration, it has long been assumed to have had negative effects on agrarian conditions, such as a reduction of the growing season and an increased precipitation, indirectly causing overgrazing, poor crop returns or overall crop failure (Balaam et al. 1982 in Amesbury *et al.*, 2008). Defined by Barber in a climatic review on evidence found from mires as a ‘’catastrophic decline'', this time period has been the subject of how climate may have played a role in changes in land use and settlement (Dark, 2006). The next section will discuss this in more detail.

2.4.3 A case of land abandonment or land use change in upland areas?

A debate on economic and societal changes, as a result of climatic changes, raised questions on more marginal areas. It is, however, difficult to measure to what extent climate change played a role, compared to the influence of cultural changes. This becomes increasingly difficult with literature showing opposite results in periods of a supposedly negative influence on prehistoric societies.

For instance, lake levels in central Europe showed an increase during periods of climatic downturns and co-occurred with identified abandonment of lake dwellings (Magny *et al.*, 2009). Turney *et al.* (2016) argued that they found evidence for the abandonment of upland areas in Britain as a result of extreme wet conditions. It should be noted, however, that this conclusion was based on archaeological data, which is already sparse in general and that other factors of economic or social aspects, should also be taken into consideration (Amesbury *et al.*, 2008). Furthermore, Turney *et al.* (2006) identified periods of increased settlements with a defensive nature during wet shifts in prehistoric times and suggested that these could indicate the need to defend limited resources or perhaps a development of subsistence strategies in an attempt to avoid societal collapse.

On the other hand, Woodbridge *et al.* (2014), demonstrated that climate records do not show any clear relationship to identified phases of woodland decline and dated increase in human population levels. This is supported by a study of Schulting (2010), who has shown several contradictory palaeoclimate records from the late Mesolithic to early Neolithic time periods (Schulting, 2010). Other examples, such as those from Arbogast *et al*. (2006), argue that climatic downturns resulted in economic changes of Neolithic people in the French Alps, indicated by increased hunting and gathering, in a response to possibly increased crop failures. An example from the Netherlands, suggested by Groenman-van Waateringe (Groenman-van Waateringe & van Geel, 2017), shows that instead of crop failures or overall retreat, people had simply adapted by growing cereals on top of Celtic banks (the mainland European equivalent of field systems). This would have provided the benefit of preventing crops from flooding. Examples like these indicate the capability of both awareness and adaptability of past peoples to changing climates.

At many parts across Northwest Europe, evidence for Bronze Age settlements was widespread, whilst evidence for earlier Iron Age communities had been scarce. This resulted in theories of land abandonment, the movement of people or a reduction in population size (Armit *et al.*, 2014). Burgess (1985) argued this climatic deterioration resulted in both upland and lowland settlement abandonment, and population collapse. Even though evidence of abandonment at some sites in the UK has been found, it is unlikely that the climatic shift resulted in large scale, long-term land abandonment across Britain as a whole (Dark, 2006). Many authors have suggested a movement of people from the uplands back to the lowlands, stating that the climatic deterioration caused soil deterioration in the uplands (Quinell 1986; Todd 1987 in Gearey, Charman & Kent, 2000). A second argument supporting this theory is the deterioration of grazing quality as a factor leading to the abandonment of the uplands (Balaam *et al*. 1982 in Gearey, Charman & Kent, 2000).

Others have questioned the credibility of the abandonment of uplands and stated that past societies would have been capable in adapting to the new climatic conditions (Amesbury *et al.*, 2008). More recent discoveries appear to show that this would indeed have been more likely the case and suggest that “abandonment” was more of a social choice, rather than a necessity as a result of an incapability of adapting to the climate. An example for this change in “marginal” thinking is the recent discovery of late Neolithic/early Bronze Age field systems in areas of the Peak District, which was previously believed to have only been occupied during times of population pressure (Cootes & Quinn, 2018). The new evidence of settlement in these areas suggests that it would be important for future research to remain more open to the possibility that humans were able and willing to occupy areas that were previously considered as “unsuitable”.

Chapter 3 **Exmoor**

This chapter provides background information of Exmoor as a case study area, with details on its geology, peatlands and a brief overview of all palaeoecological knowledge from previously carried out research.

3.1 The geology of Exmoor

Exmoor is an upland region of which its outcropping geology on the surface has been subjected to (aerial) erosion throughout the past. It is almost completely comprised of sedimentary rocks, with the majority of the beds striking from west to east (Steers, 1974). The highest peak in Exmoor is over 500m above sea level, with more than half of Exmoor being above 300m (Riley & Wilson-North, 2001).

The oldest rocks that are exposed on Exmoor are situated at Foreland Point in the North East and date back to the Lower Devonian (Balchin, 1952). Exmoor is founded upon rocks from the Devonian and Carboniferous systems that formed approximately between 400 and 300 million years ago (Laming & Roche, 2016).

The oldest beds date back to the Lower Devonian, which consists of the following beds (see figure **3.1**):

A) <u>Hangman grits</u> – fine grained red sandstones sometimes interfered by shaly beds.

B) Lynton beds – a combination of thinly bedded fine-grained sandstones, siltstones and grey mudstones.

C) Foreland grits – red and grey quartz grits and slates.

The dominating geological ridge that borders to the south of these beds date back to the Middle Devonian:

A) Ilfracombe beds – silicified limestones, shales, limestones and grits.

B) Morte slates – often smooth and glossy greenish-grey slates

To the south of these slates are beds striking east to west dating to the Upper Devonian:

A) Pickwell Down beds – varied-coloured sandstones and some shales

B) Baggy beds – cross-bedded sandstones, thin-bedded sandstones and siltstones.

C) Pilton beds – slates with thin beds of limestones and sandstones

Apart from a small area in the Southwest of Exmoor with recent and Pleistocene material, the southern part on Exmoor consists of Carboniferous beds (also known as culms):

A) Upper culm measures – consist mainly of shales and sandstones

B) Lower culm measures – dark shales, local slates, lavas, limestones and grits.

To the west of Exmoor the previously mentioned geological formations become overlain by Jurassic and Triassic material.

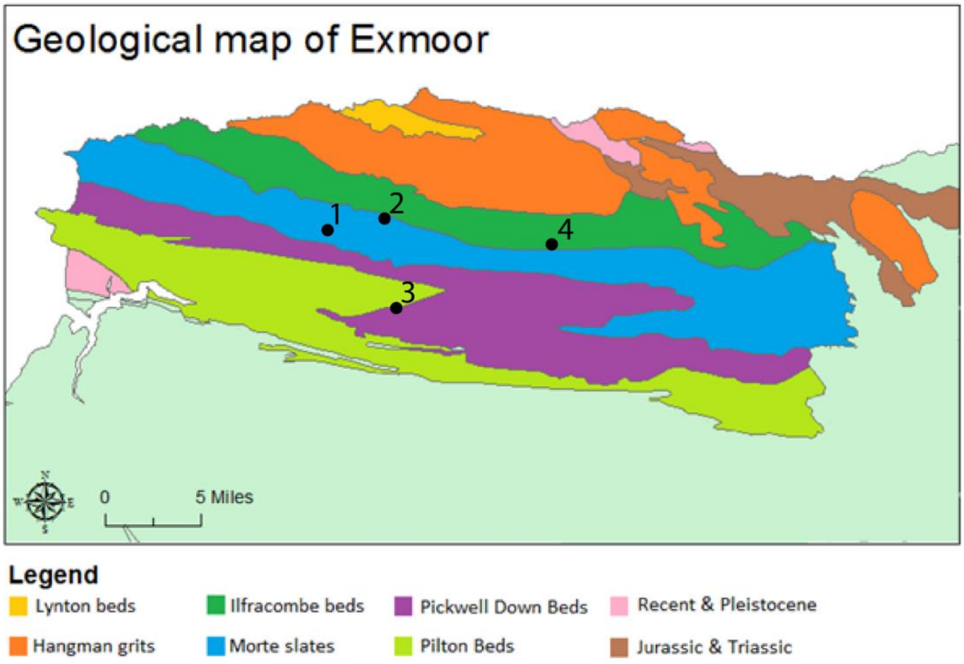


Figure 3.1. *Simplified map of Exmoor's geology after Riley and Wilson-North 2001 and British Geological Survey, UK – Edina geology digimap service, with site locations from this study: 1) The Chains, 2) Great Buscombe, 3) Spooners and 4) Codsend Moors. All rights reserved. Contains Ordnance Survey data © Crown copyright and database right 2007. © third party licensors.*

Currently, two different theories exist of why Exmoor stands out as a plateau in the wider region of Southwest England. The first theory argues that the main reason could be due to the fact it is formed by resistant rocks, giving less chance for erosion to occur and erode the landscape (Steers, 1974). O.T. Jones (Edmonds, Whittaker & Williams, 1985) suggested another possibility, based on how the rivers in central Devon converge before flowing out in the main streams that run through Exmoor. Jones suggested this shows how the surface had been shaped into a basin-like form, due to the folding movements during the Tertiary-time. This would in turn indicate that Exmoor's height was perhaps a result of up-doming instead of rock resistance (Edmonds, Whittaker & Williams, 1985). Recent knowledge tells us that the sandstones in the Exmoor area formed out of river sediment deposits that were hardened by time and uplifted by earth movements, to form the upland areas they are nowadays (Laming & Roche, 2016). However, it does seem that rock resistance played at least some part in the development of Exmoor's landscape, considering the highest point of Exmoor consists of sandstones that are resistant to erosion and weathering. This central ridge also functions as a source of Exmoor's major rivers: the West and East Lyn, the Exe and the Barley (Riley & Wilson-North, 2001).

Not all parts of Exmoor's geology are resistant to erosion or weathering. A good example is the Minehead region, where softer sediments in low-lying areas are enclosed by more resistant (though faulted and tilted) blocks (Edmonds, Whittaker & Williams, 1985). Furthermore, during the last Ice Age, severe climatic conditions altered the landscape. Ice sheets are believed to not have reached Exmoor, with the exception of a possible valley glacier (Harrison, Anderson & Passmore, 1998). However, changes through frost action or turbulent (melt water) streams did occur on Exmoor (Steers, 1974). Apart from erosion, deformation has changed the stratigraphic units, leading to internal deformation within formations and caused a development of slaty cleavage in the fine-grained rocks (*The geology of Devon*, 1982).

3.2 Palaeoecological review of Exmoor

3.2.1 Peatlands of Exmoor

Peatlands can form in different circumstances and can be classified on the basis of many possible variables, such as hydrology, ecology or nutrient status (Elkington et al., 2001 in Bray, Carey & Fyfe, 2015a). The uplands of Exmoor show that a large amount of blanket mires here are usually less than 1 metre thick (Bray, Carey & Fyfe, 2015a), which is not common for an average blanket mire. Smaller soligenous mires can be found fairly often on slopes and around springs, whilst valleys are occupied by flood plain mires (Bray, Carey & Fyfe, 2015a). The valley mires on Exmoor are often much deeper than the blanket mires and can extend to 3 metres deep, as was measured at Moles Chamber (Fyfe, 2012). Most environmental research on Exmoor’s past landscape has been based on samples from upland blanket mires, such as The Chains (Merryfield, 1977), Hoar Moor (Francis & Slater, 1992) and Codsend Moor (Fyfe, Brown & Rippon, 2004). Several recent studies have focused on soligenous and valley mires from the lowlands. Results have shown that the lowlands and the uplands were exploited differently on Exmoor during the last two millennia, although it is unclear to what extent in prehistory (Fyfe, Brown & Rippon, 2004). A discussion of past vegetation changes across Exmoor is included in the next section.

3.2.2 Recorded vegetation changes of Exmoor

Figure **3.2** shows the location of 33 sites on Exmoor where peat samples were taken for previously carried out pollen studies. Although a total of 51 sites were available in the literature, pollen diagrams that were considered to show unreliable radiocarbon dates have been excluded from this section. Table **3.1** correlates with the site numbers and provides further information of the sites. The following paragraphs outline the changes recorded in the pollen diagrams in a chronological timeframe and are summarized in table **3.2**, with corresponding site locations displayed in figure **3.3**.

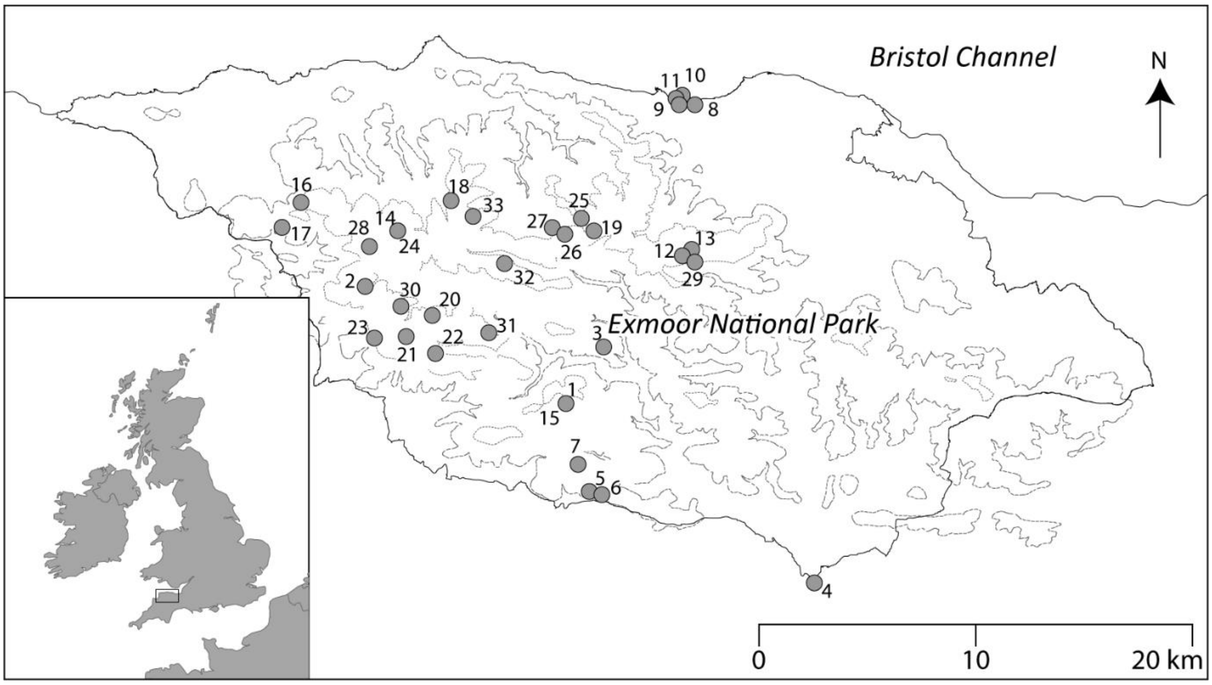


Figure 3.2. *Dated sites, used for pollen studies. Label numbers refer to table **3.1**. Contains Ordnance Survey data © Crown copyright and database right 2007. © third party licensors.*

No.	Site name	NGR easting	NGR northing	Elevation in meters	Number of radiocarbon dates	Calibrated age range of sequence
1	Halscombe Allotment	281900	133470	350	7	6500 cal BC - recent
2	Moles Chamber	271850	139370	425	5	1600 cal BC - recent
3	Brightworthy Farm 1	283330	135960	290	3	7600 cal BC - recent
4	Exebridge spring mire	293600	125270	130	4	9160 cal BC - recent
5	Gourte Mires	282470	129690	190	4	2600 cal BC - recent
6	Anstey's Combe	282740	129680	180	3	50 cal BC - recent
7	Long Breach (Molland)	282070	130660	335	5	3650 cal BC - recent
8	Porlock Marsh (PM4)	287790	147675	5	0	-
9	Porlock Forest Bed (FB7)	287123	147870	coastal core	0	-
10	Porlock Forest Bed (FB4)	287165	147832	coastal core	0	-
11	Porlock Forest Bed (FB2)	287100	147785	coastal core	0	-
12	Hoar Moor	286260	140740	435	4	4460 cal BC - recent
13	Codsend Moor	287010	141060	460	4	790 cal BC - recent
14	The Chains	273455	142000	485	5	2900 cal BC - recent
15	Halscombe Allotment	282000	133700	370	7	6500 cal BC - recent
16	Higher Holworthy	268840	144040	320	3	Cal AD 1200 - recent
17	Twineford Combe Head	267570	142860	330	1	Cal AD 1400 - recent
18	Lanacombe	276600	142500	445	4	Cal AD 1400 - recent
19	Larkbarrow	282500	141800	420	4	Cal AD 20 - recent
20	Roman Lode	275240	138110	440	1	350 cal BC - recent
21	Comerslade	273797	137201	445	7	6300 cal BC - recent
22	Long Holcombe	276944	135651	410	3	3900 cal BC - recent

23	North Twitchen Springs	272620	137090	440	5	2100 cal BC - recent
24	The Chains	273450	141950	487	6	980 cal BC - recent
25	Larkbarrow	282058	142615	375	4	1900 cal BC - recent
26	Swap Hill	281310	141966	410	4	4500 cal BC - recent
27	Beckham	280798	142134	390	4	1500 cal BC - recent
28	Broadmead	272040	141235	400	3	5700 cal BC - recent
29	Codsend Moor (Tinsley section)	287040	140770	425	2	Cal AD 340 - recent
30	Ricksy Ball	273555	138415	412	7	5000 cal BC - recent
31	Spooners	277653	137206	430	3	6000 cal BC - recent
32	Warren Farm	279700	140800	410	1	2850 cal BC - recent
33	Great Buscombe	277460	141855	425	10	1600 cal BC

Table 3.1. *Information of the 33 selected sites from the literature on pollen studies. Site numbers from in this table (#) refer to the numbers in figure* ***3.2****.*

Known vegetation changes on Exmoor during the Mesolithic

Blanket mires from four different upland sites on Exmoor (Halscombe Allotment, Hoar Moor, Comerslade and Exebridge Spring mire) extend back far enough in time to provide vegetation records from the Mesolithic period. Pollen from Exebridge, a spring mire that developed over a late-glacial palaeochannel, shows the development of Early Holocene woodland (Fyfe, Brown & Coles, 2003). *Pinus* and *Betula* species were the first arboreal taxa present around the site, followed by a domination of *Corylus* on the valley floor (Fyfe, Brown & Coles, 2003). It could have been due to the poorer soils that *Pinus* woodland survived until the mid-Holocene in the lowland areas. Pollen records from three other sites suggest a high presence of mixed arboreal woodland in the uplands, mainly dominated by *Corylus, Betula, Quercus*, with *Ulmus* being a major component of the woodland in the lowland Exebridge area (Fyfe, Brown & Coles, 2003). The first appearance of *Alnus* occurs between 5730-5560 cal BC, and is suggested to have dominated the damper valley floor (Fyfe, Brown & Coles, 2003). Tree species could take up as much as 80% TLP, as indicated from pollen records at Hoar Moor. Open ground taxa were present amongst the arboreal pollen, but in significantly lower percentage levels when compared to more recent time periods. Although charcoal analysis was not included in all pollen studies, evidence from Long Breach suggests limited burning in the landscape. Sharp increases of charcoal, together with a steady decline in *Corylus* at Exebridge, did however indicate the presence of human interference with the vegetation as early as around 6650-6440 cal BC. Considering the fact that wetlands such as this site do not fire easily and the charcoal curve was constantly present, a deliberate and repeated burning initiated by humans would have occurred from the Mesolithic onwards (Fyfe, Brown & Coles, 2003). Unrolled microliths were found in a margin of approximately 100 metres from the spring mire margins and thus proves human presence at a certain time during the Mesolithic within the catchment area, supporting but not proving, the statement of human interference with the landscape (Fyfe, Brown & Coles, 2003).

The pollen data of the Mesolithic thus shows a dominance of a varied woodland cover across Exmoor. *Corylus* dominated mainly on the upland sites, whereas *Quercus* and open ground indicators were more important at lowland sites (Fyfe *et al.*, 2013b).

Vegetation changes recorded from the Neolithic

Most pollen diagrams covering the Neolithic (sites mentioned in this section) are largely in agreement that Poaceae values rise coincidentally with a decline in *Quercus, Corylus* and *Betula* pollen. In the transition from the Mesolithic to the Neolithic, a (gradual and sometimes temporary) shift from mixed woodland to more open land took place. First indications of woodland disturbance were recorded at Halscombe Allotment. The first record of low Poaceae levels at the start of the Neolithic were followed by a rise in *Alnus* (Fyfe *et al.*, 2013b). From the beginning of the Neolithic, tree and brush clearance started occurring in several pollen diagrams. Depending on the location, arboreal taxa disappear from the pollen diagram permanently or stay consistent on a low level throughout the sequences after their initial decrease. At Long Breach, a gradual decline of arboreal taxa took place over approximately 1800 years, with no signs of woodland reoccurrence. A long period of gradual woodland reduction is also indicated by the pollen diagrams from Comerslade, but does show a small reoccurrence of arboreal taxa 700 years after the initiation of the decline. At around 3000 cal BC, a strong increase of tree and brush clearance is recorded in the pollen record at Hoar Moor and coincides with the spread of Poaceae (Francis & Slater, 1992). On Molland Common changes from Calluna-dominated to grass-dominated heath are closely associated with the start of significant levels of burning in the palaeoecological record (Fyfe, Brown & Rippon, 2003). The general pattern of a shift from (mixed) woodland to more open land agrees with pollen records from a variety of sites elsewhere in Britain, mainly from the northwest.

The Elm decline is a common feature in pollen records from Britain and Northwest Europe (Parker *et al.*, 2002) and the pollen records from Hoar Moor and in the Lower Exe valley show indications for an Elm decline on Exmoor as well. Considering start dates of Elm decline periods across Britain do not overlap, correlations with the period of decline on Exmoor cannot be made (Fyfe, Brown & Rippon, 2003).

Bronze Age vegetation changes

A reduced woodland cover was very likely to have also occurred or extended at several sites during the Bronze Age. Gourte Mires shows a reduced woodland cover in the period between 2120-1730 cal BC and another decline in combination with a rise in heathland taxa at around 1027-646 cal BC (Fyfe, Brown & Rippon, 2003). The Chains also shows a woodland reduction in the period between 2190 to 1520 cal BC (Fyfe, Brown & Rippon, 2003). Between 2000 and 1500 cal BC, woodland declined at Hoar Moor as well, accompanied by expansion of grasslands. Both The Chains and Hoar Moor are blanket mires, which are assumed to have a regional reflection and thus show a general phase of landscape clearance of the uplands on Exmoor during the Early Bronze Age (Fyfe, Brown & Rippon, 2003).

Poaceae values continued to increase at most upland sites during the Bronze Age. A second decline of arboreal taxa occurred simultaneously with high Poaceae values and increase of heathland taxa at around 1570 cal BC. This change in vegetational components seems to overlap with the increase of heathland taxa (but lower Poaceae levels) at North Twitchen Springs around the same period in time (Fyfe, 2012).

Besides grass-domination during the majority of the Bronze Age, the expansion of heath taxa is revealed by the record from North Twitchen Springs (Fyfe, 2012). Towards the end of the Bronze Age, values of Poaceae show a continuing decrease, whilst the uprising of *Pteridium* and Cyperaceae increase. Although peat inception did not simultaneously occur on all sites across Exmoor, at several sites, such as Moles Chamber, peat inception took place during the Bronze Age.

Recorded changes in vegetation patterns from the Iron Age

Woodland clearance occurred throughout prehistoric times on Exmoor and was largely completed by the Late Iron Age (Fyfe *et al.*, 2013b). The majority of pollen sequences show similar patterns for the Iron Age as they did for the Bronze Age, although few sites are well-dated or analysed at high resolution through this period. Similar to the Bronze Age, peat development took place during the Iron Age at some sites on Exmoor. Fire was still in use as a management tool at several sites and is associated with a reduced woodland cover across Exmoor. Burning also restricts the development of *Calluna vulgaris,* which gives Poaceae a higher chance of growing. This created conditions more suitable for grazing (Fyfe & Head, 2015). *Calluna vulgaris* and Poaceae alternated in dominance alongside peaks of sedge pollen, creating an increasingly more open landscape towards the end of the Iron Age. The increase of heath taxa could also represent periods of less intensive land use (Fyfe & Head, 2015).

The supposed wetter and cooler summer conditions at around 2500 cal BP (section **2.4.3**) may have prevented a reoccurrence of natural tree growth on the uplands of Exmoor (Straw *et al.*, 1995).

Historic Time on Exmoor

During historic time periods on Exmoor, most upland sites were largely cleared from woodland and replaced by heather- or grass-dominated vegetation cover. A shift to wetter conditions correlates with a rise in Ericaceae species at Hoar Moor (Francis & Slater, 1992), but this would not necessarily have been the case for other sites in Exmoor.

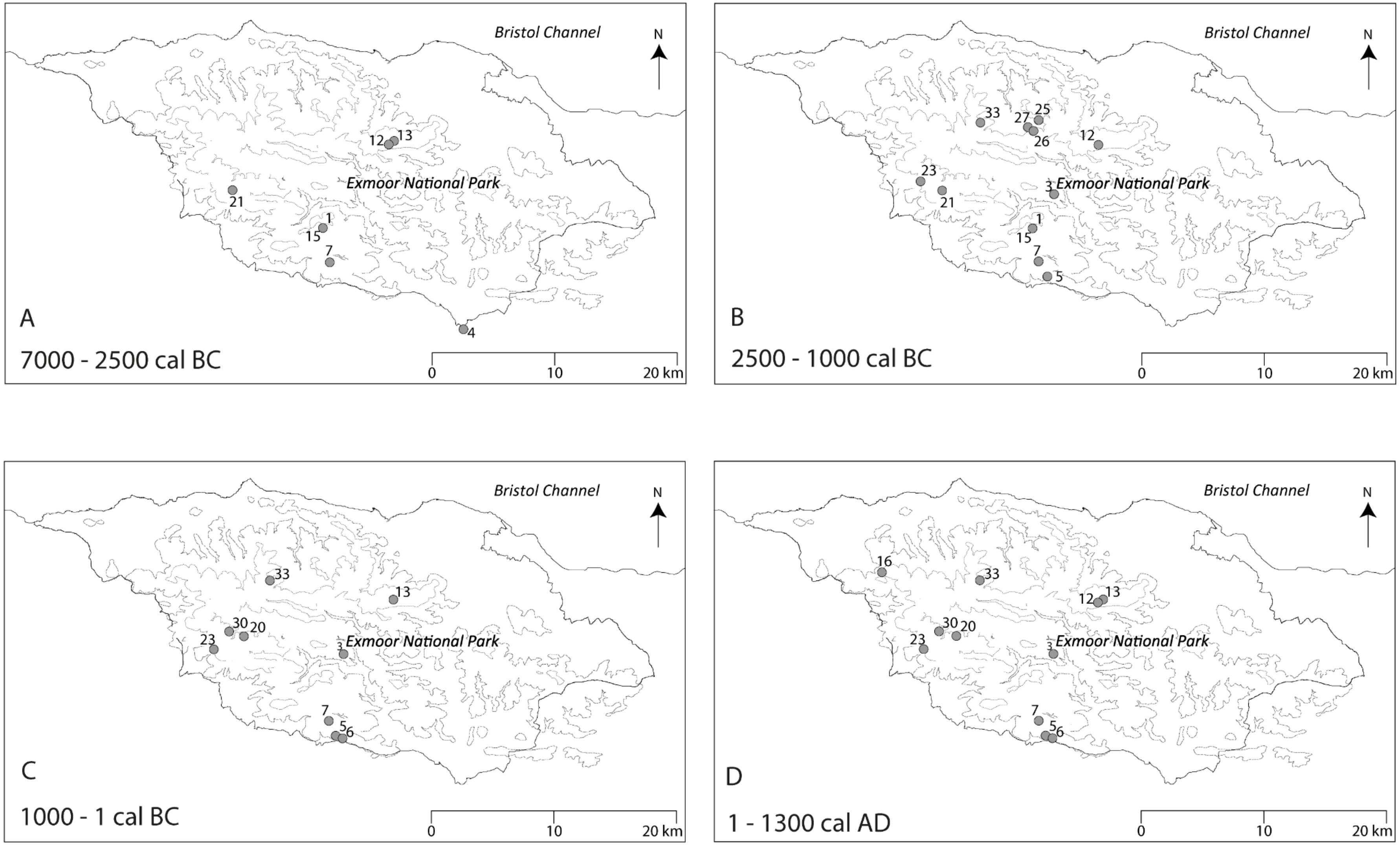


Figure 3.3. *Locations of sites where recorded changes in pollen diagrams occurred, categorised by age ranges A) 7000 -2500 cal BC, B) 2500-1000 cal BC, C) 1000 – 1 cal BC and D) 1 – 1300 cal AD.*

Site no.	Site name	Recorded change pollen diagrams	Starting age / range in cal BC or AD
4	**Exebridge spring mire**	Decline *Corylus* Increase charcoal	6500 – 5600 cal BC
		Increase Poaceae Increase charcoal 10% temporary increase *Alnus*	After 5600 cal BC
1/15	**Halscome Allotment**	*Corylus* from 20% to 45% and back to 20%	6100 – 3600 cal BC
NA	**Exebridge reach**	Poaceae dominance	4000 – 3000 cal BC
		Increase *Alnus*, between 20 and 60%	3600 – 1660 cal BC
		Poaceae dominance with possible cereals present	After 1660 cal BC
12	**Hoar Moor**	Over 80% consists of arboreal taxa: *Quercus*, *Corylus* and *Betula*	4000 – 3000 cal BC
		Ulmus decline	3500 – 3000 cal BC
13	**Codsend Moors**	Tree and brush clearance episode	3000 – 2500 cal BC
21	**Comerslade**	Increase arboreal taxa to 40% Decline Poaceae from 35% to 15%	2700 – 2400 cal BC
7	**Long Breach**	Increase Poaceae to 35% Increase charcoal Increase *Alnus*, but decline *Calluna* and Cyperaceae	2700 – 2290 cal BC
1/15	**Halscombe Allotment**	Increase Poaceae to 45% Probable present cereal type pollen *Alnus* decline to below 10%	After 2400 cal BC
7	**Long Breach**	Gradual decline *Corylus* and *Quercus* Increase Poaceae to 45%	2250 – 450 cal BC
26	**Swap Hill**	Increase Poaceae followed by increase *Calluna* *Alnus* remains around 20%	2250 – 1750 cal BC
27	**Beckham**	Increase Poaceae, *Alnus* declines temporarily	1300 cal BC
3	**Moles Chamber**	Peat inception	At 1270 cal BC
5	**Gourte Mires**	Gradual decline arboreal taxa: *Corylus*, *Quercus*, *Alnus* Rise in *Calluna*	1950 – 1 cal BC
33	**Great Buscombe**	Decline *Alnus* from 60% to below 20% Increase Poaceae to 40%	1350 cal BC
23	**North Twitchen Springs**	Under 100 year episode of decline *Calluna* Increase *Potentilla* and *Plantago*	1980 cal BC
		Increase *Calluna* to 40%	1650-1200 cal BC
25	**Larkbarrow**	Decrease *Alnus* and increase Poaceae	1200 cal BC
33	**Great Buscombe**	Increase Poaceae and charcoal Sporadic presence *Avena triticum*	950 cal BC
		Episode of *Calluna* and *Corylus* increase (both under 20% still) Drop in charcoal	800 – 500 cal BC
		Increase charcoal and Poaceae	500 cal BC onwards

		Decrease *Corylus*	
3	**Moles Chamber**	Sharp decline arboreal taxa Increase Poaceae Dominance fluctuates between *Calluna* and Poacae from here	From 470 cal BC onwards
7	**Long Breach**	Arboreal taxa low, Poaceae dominant, *Calluna* 10% *Avena triticum* present throughout	450 cal BC – 1350 cal AD
13	**Codsend Moors**	Episode of *Calluna* and arboreal taxa increase	390 cal BC – 400 cal AD
20	**Roman Lode**	Peat inception, landscape is open, *Calluna* and Poaceae most dominant	350 cal BC
6	**Anstey's Combe**	*Calluna* increase, Poaceae dominant, but arboreal taxa between 20 and 40%	150 cal BC – 150 cal AD
13	**Codsend Moors**	Drop arboreal taxa and *Calluna* Poaceae increase to over 80% Decrease *Sphagnum*	78 – 653 cal AD
30	**Ricksy Ball**	Poaceae increases from 20 to 80% Decrease aroboreal taxa – *Corylus* and *Quercus* mainly	1 – 1000 cal AD
5	**Gourte Mires**	Second decline arboreal taxa Increase *Calluna*, but Poaceae remains dominant	1 – 950 cal AD

Table 3.2. *Recorded changes in the pollen diagrams across Exmoor, with locations presented in figure 3.3*

Chapter 4 – Methodologies

4.1 Introduction

This chapter discusses the methodologies used in sample preparation, data collection including identification and taxonomy, and data analysis. All sections are categorically themed, discussing each type of methodology undertaken separately. Firstly mentioned are palynological analysis, charcoal analysis and NPP analysis combined, followed by tephra analysis, peat humification analysis and finally multivariate analysis.

4.2 Pollen, Non-pollen palynomorphs and micro charcoal methodology

Peat material was collected with the use of a Russian-type corer at Great Buscombe and with monolith tins from cleaned sections at Spooners and Codsend Moors. Peat cores were subsampled in order to conduct pollen, NPP and charcoal analysis.

Pollen, NPPs and micro charcoal form the basis on which this research project relies. They are necessary for the production of reconstructions of the vegetation, as well as those of past land use patterns, such as fire and grazing. Samples for pollen, NPPs and micro charcoal were prepared simultaneously, although sample preparation of the three key sites were prepared at different stages of the research period. This research builds on the results of previous (unpublished) assessments of some sites: samples from Great Buscombe and Codsend Moors were prepared during the period of this research, whereas 24 of Spooners' samples had been previously subsampled and prepared in the lab. Furthermore the core of Codsend Moors was taken during the period of this research, whereas cores were taken and subsampled into 1cm interval prior to this research. All sites were cored with a Russian corer and further details on each individual site are discussed in sections 5.2, 6.2 and 7.2. Sample preparation of material from all three sites used standard pollen extraction methods, following Moore *et al.* (1991).

All samples were prepared using acetolysis and were mounted in silicon oil. The previously prepared samples of Spooners were treated with HF, but due to its aggressive nature resulting in possible damage or loss of NPPs, HF treatment was left out for all other sample preparations (Van Geel, 2001). All samples contained a known quantity of exotic marker spores of *Lycopodium* in order to enable calculations of concentration values.

A total of 500 land pollen were counted for each sample depth, alongside a total of 100 NPPs. In cases where samples had a low concentration of NPPs, the total amount of spores counted were limited to the amount present on one or two prepared slides, but this was rarely necessary. Pollen identification was carried out using Moore *et al.* (1991), Beug (2004) and, when necessary, the modern reference collection based in the pollen lab of the University of Plymouth. Differentiation of cereal pollen from wild Poaceae follows the work of Andersen (Andersen, 1978). Apart from *Calluna vulgaris*, heather species were all grouped into the Ericaceae family, as this would have no negative consequences for the research. NPP identification was carried out using the unpublished fungal spore guide (Blackford, Innes & Clarke, Forthcoming). A first set of identifications of NPPs were checked in the lab at Royal Holloway, by Dr. Marta Perez and a second set was confirmed during an NPP workshop at Liverpool in 2017. Due to continued and evolving community developments in NPP identifications, spore images and continuous discussions were held with other researchers at conferences, in order to either find confirmation or update any previously made identifications.

Microscopic charcoal shards present on the same slides as pollen and fungal spores were counted. Shards were divided into two categories, based on their size, and classified as micro- or macro- charcoal. The micro charcoal category contains shards with a size ranging between 10 and 50 microns, whereas shards of the macro charcoal category range between 50 and 120 microns in size. Counts were converted into concentrations using the exotic Lycopodium counts and values displayed in the pollen diagrams as shards per cm^3.

Pollen, charcoal and NPP data were processed using the C2 software, and layouts were adjusted in Adobe Illustrator. Pollen and charcoal data were combined in the same diagram and NPPs displayed in separate diagrams, with values expressed as percentages of total NPPs.

4.3 Tephrochronology and radiocarbon dating

4.3.1 Methodology for tephrochronological analysis

Chronology within the thesis are based on a combination of tephrochronology and radiocarbon dating. Peat was cored with a tephra corer at The Chains and peat stratigraphy was described following the Troels-Smith technique. Tephra shards were sub-sampled from peat core material in sections of 5cm, running continuously through the sequence. All subsamples were dried at 105°C overnight in order to extract dry weights. This was followed by being incinerated in a furnace at 550°C for four hours to remove organic matter. Methods of further sample processing follow Blockley *et al.* (2005), with a singular adjustment of the inclusion of a larger sieve range (between 125 and 15 micron), in order to prevent possible loss of tephra shards and the uncertain nature of tephra layers found on Exmoor (Matthews, 2008). The sieving process was carried out in a laminar flow cabinet at Royal Holloway, University of London, to prevent airborne contamination. All processed samples were kept in sealed centrifuge tubes. The material was mounted on slides with the use of Canada balsam and optically examined in the labs of the University of Plymouth. Shards were divided into two categories based on their colour and morphological features. A first category was that of “colourless” shards (looking light-pink in colour), often containing mineral inclusions and with the tendency to be vesicular. A second category was that of either “intermediate” shards, being yellow or light-brown in colour and containing fluted and vesicular morphologies, or those that fell into the class of “brown” shards, showing a darker brown colour and a block-like morphology. Shards of different categories may be found within the same subsample slides, but this was not common. Tephra particles were both found in clusters as well as individually across slides, mainly depending on their quantity. All shard counts were quantified as the number of shards per gram dry weight of the sediment, and diagrams were made with the use of C2 and Adobe Illustrator. Material from Spooners and Great Buscombe had already been analysed prior to this research project by MacLeod *et al*. (in preparation), but followed the same methods. Radiocarbon dates and geochemically identified tephra layers were obtained for Spooners and Great Buscombe and used in this project to produce age-depth models. Due to reasons explained in Chapter 8, further continuation into geochemical analysis was not carried out for material from The Chains during this research project.

4.3.2 Age-depth models

A total of thirteen radiocarbon samples, established during unpublished assessments at Spooners and Great Buscombe, were analysed at the 14Chrono Centre at the University of Belfast. Radiocarbon samples from Codsend Moors (five) and The Chains (four) were analysed by Beta Analytic and were produced for this thesis. Radiocarbon dating results were combined with inferred tephra layers to produce age-depth plots. These are produced in Oxcal and are displayed in the results chapters (**5**, **6**, **7** and **8**) as reversed age-depth plots. See figure **AX1** in the appendix for the code used in Oxcal for all four sites. The following parameters were used in the modelling: for P sequence: *k0*

= 1, *interpolation* = 1, *log10 expression* = U(-2,2). For outlier models: *distribution* = T(5), *magnitude* U(0,4) and *type* = t.

For the sites where official tephra dates were known (Spooners and Great Buscombe), a priority was given to tephra dates over radiocarbon dates in the age-depth models. Considering a recent refinement of identified tephra layers has been published (Plunkett *et al.*, 2004), a higher precision, and therefore reliability, has been assigned to tephra dates, compared to a singular radiocarbon date. This explains two observable occasions in the age-depth models presented in chapter 5 and 6. Results show how the model follows a slight shift to the left (indicating an older age) than would presumably be followed if priority were given to radiocarbon dates. Nevertheless, dates from both sources are still in agreement and do not show an unrealistic model in either case.

4.4 Peat humification analysis

Humification analysis was conducted on peat material from The Chains with the purpose to generate a continuous climatic proxy. Alternative approaches, particularly those based on testate amoebae analysis, were not possible: assessment of the material showed poor or no preservation of tests in the peat. Continuous 1cm samples were taken from the sequence and oven dried at 50°C, prior to peat humification analysis. Loss-on ignition was carried out before peat humification analysis on all subsamples and results are shown in figure **8.4**. A total of 0.2grams of the residue was used for peat humification analysis, following the methodology described in Chambers *et al.* (2010), which are based on methods of Blackford and Chambers (1993) following Aaby and Tauber (1975). A total of 10 samples were processed at a time, and the spectrometer was allowed to stabilise before each measurement-taking session. For each sample, three measurements were taken and the average value was used for further calculations.

To prevent any possible inaccurate readings, cuvettes were discarded after one use each and beakers, flasks and funnels were properly rinsed after each use. MS excel was used for recording the readings and the calculations of detrended residuals and z-scores, in which the values are displayed, against age-depths, in section **8.4**. In order to produce a diagram that includes both peat humification data from Exmoor and testate amoebae from Dartmoor, all data was transformed to z-scores prior. Re-sampling calculations of data from equal time-intervals across different data was calculated in the R software, so data could be plotted along the same y axis.

4.5 Multivariate analysis

A series of multivariate analyses were conducted to explore the NPP data and establish possible relationships between pollen and environmental variables, such as burning, grazing pressures and climatic influence. Principal Components Analysis (PCA) was used for unconstrained ordination to explore the structure in the NPP data, and Redundancy Analysis (RDA) was used for constrained ordination, to describe the amount of variation in the pollen data explained by environmental variables. They are both significant techniques within this study, considering this provides new insights into land use patterns and vegetation shifts across all three sites on Exmoor. Data used as environmental variables (vectors) in the RDAs included charcoal data, coprophilous NPPs and climate z-score data from Greenland Ice cores and Crag Cave material (McDermott *et al.*, 1999; McDermott, Mattey & Hawkesworth, 2001; Vinther *et al.*, 2009; Vinther *et al.*, 2006), discussed in chapter **5** through **8**.

The exclusion of rare pollen taxa or NPP types (species that were present below 2% within samples) was carried as part of the data preparation process for both PCAs and RDAs. Charcoal and climate data were converted into z-scores, using the “scale” function in statistical software “R”, whereas square roots of the pollen and NPP data were converted in C2, prior to conducting the analyses. Data transformation was carried out in order to enable a statistically reliable comparison between data of different sites.

4.5.1 Principal components analysis

PCAs were carried out on NPP data from Spooners, Great Buscombe and Codsend Moors in order to explore trends in NPPs within and between datasets of each site. This was conducted in the “R” software, within the package “vegan” (Okansen *et al.*, 2015). Results plots were also produced in the R vegan package, using scale no. 3, and were further edited in Adobe Illustrator to indicate identified patterns.

4.5.2 Redundancy analysis

RDAs were carried out on coprophilous fungal spores, charcoal data (micro- and macro charcoal combined), NPP type 303 (for Great Buscombe only) and climate proxies from Greenland ice cores and Crag Cave data, across the entire sample set from each site. Climate data was “resampled” into continuous time intervals prior to the analysis, in order to enable comparisons between the two data sets, with the use of R. In addition to undertaking RDA analysis across entire sample sets, a ‘moving time window’ approach was as employed to assess how the strength of explanatory variables (climate, burning, grazing) varied through time, using 20-sample subsets. A range of 20 samples for each subset was chosen in order to have a statistically significant number of samples included, whilst not reflecting too many subsamples, as that would reduce the resolution of the overall recorded changes. Considering the chronology of the cores were relatively consistent, a range of depth-based subsamples was sufficiently effective for this method. This analysis was undertaken on the pollen assemblages from Spooners, Codsend Moors and Great Buscombe. RDAs were also conducted with the use of the “vegan” package in R and results were plotted in MS excel.

Chapter 5 - **Great Buscombe's results**

5.1 Introduction

This chapter presents and discusses the results of detailed non-pollen palynomorph (NPP) research from the site of Great Buscombe, Exmoor and compares these with the findings of a pre-existing pollen record generated in 2015. This site focuses on the time periods ranging from the late Neolithic to the late Iron Age. NPPs, pollen and micro charcoal records are compared and statistically analysed to understand the important controls on vegetation change at this site. Previous palaeoecological knowledge of the area surrounding Great Buscombe, combined with its location in an archaeologically-rich area made this site a suitable choice for this project.

5.2 Introduction to the site of Great Buscombe

5.2.1 Site background information

The Great Buscombe site consists of a small mire in the Lanacombe region and is around 50m x 80m in size (see figure **5.1**). It is situated close to one of a few small sources of springs, leading into a small stream named "Hoccombe water". This mire is located on a north-facing slope, at an altitude of around 430m above sea level. An initial core of 2.15m long was taken for a stage 1 (low-resolution) assessment in 2010, as part of the Exmoor Mires project. Material from the lower half of the core (between

1.50-2.15m) has been used for a stage 2 (high resolution) assessment in 2015, and peat core material of up to a depth of 198cm is included in this research study (Fyfe & Head, 2015). Figure **5.1** shows two aerial images of the area of Great Buscombe, with visible disrupting in the form of past drainage ditches in the landscape.

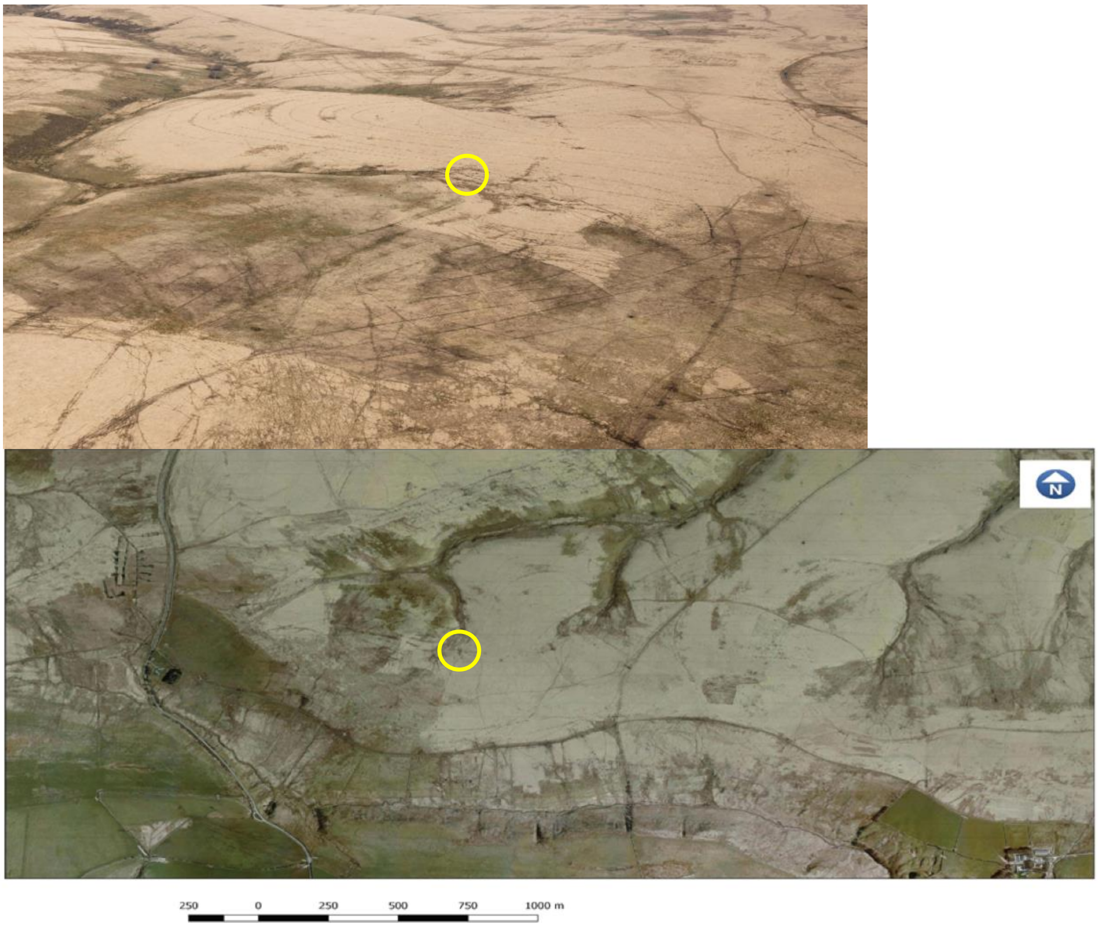


Figure 5.1. *Aerial images of the area of Great buscombe, with the upper image taken from a northwest angle. The coring location is indicated with a yellow circle. © Historic England.*

5.2.2 Archaeology of Great Buscombe

The greater Lanacombe region on Exmoor, of which Great Buscombe is a part of, is rich in a variety of field archaeology (Riley & Wilson-North, 2001). Examples of archaeological features that have been found in the area include miniliths (small prehistoric stone monuments), cairned stones, a cairn and several cairn-defined boundaries, which are comparable with Bronze Age field systems found at Codsend Moors (located elsewhere on Exmoor). The excavation of two cairns in the region concluded them to most likely be of Neolithic age and additionally showed successive phases of activity, where people would return to the cairns in later periods in time (Gillings, 2013).

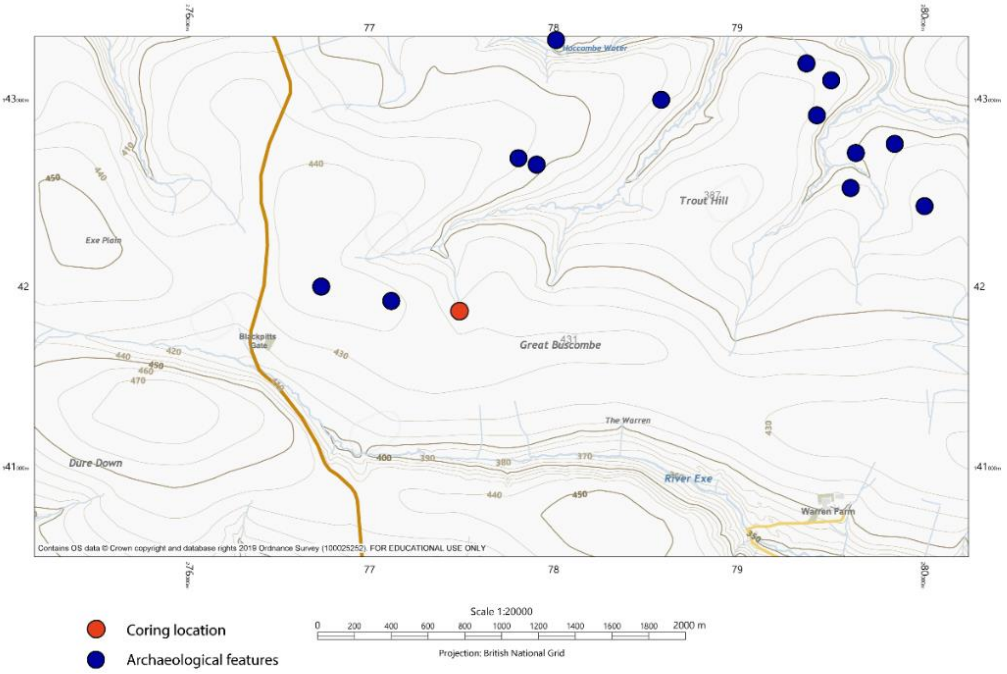


Figure 5.2. *Great Buscombe's coring location depicted on a background vector map from EDINA Digimap Ordnance Survey Service.*

The features that are the closest in proximity from the sequence location are two cairns in the east, as well as a barrow (Rexy Barrow) and a tumulus (burial mound) on the west side, which are located several meters further uphill. As these two particular features, amongst many others on Exmoor, have not been excavated, a specific date cannot be assigned to them. There are, however, two examples of barrow excavations on Exmoor at Bratton down and Shallowmead. In both cases, radiocarbon dates of charcoal samples from the sites suggest use during the middle Bronze Age. The first dated to 1111-896 cal BC and the second to 1501-1187 cal BC (Quinnell, 1997). A third date of an excavated burial 17km south of Shallowmead, although lacking a mound on the surface, dated to 1401-1047 cal BC. Whether all burial mounds on Exmoor date to the middle Bronze Age cannot be said with certainty (Quinnell, 1997).

Due to a lack of full-scale excavation, the chronology of many of Exmoor's barrows are still unknown. It is usually assumed that most barrows originate from the early Bronze Age (2000-1500 cal BC), although there have been examples of barrows dating to the late Neolithic (Yates, 2007). Much about the structural features in the area are yet to be better understood. The identification of some structures is not completely certain (Gillings, Pollard & Taylor, 2010).

A second further investigation of stone settings and the area north-east of Great Buscombe showed the possibility of the presence of prehistoric field systems on Exmoor with a different form to those on Dartmoor, which are characterised by stone banks or earthworks (Gillings, 2013). This was discovered through a geophysical survey and would not be detectable through either traditional field reconnaissance or on aerial maps (Riley & Wilson-North, 2001). There are several examples of field banks being found in association with hut circles across Exmoor, but in the Lanacombe region these have been identified as isolated features (Riley & Wilson-North, 2001). These banks were initially thought to have been the result of small-scale field clearance to enable the creation of arable plots. They are different to earthwork remains of rectilinear field systems as can be found on Dartmoor and some parts of Exmoor, but instead appear to be small fragmentary parts of field systems as described above.

The potential relationship between the prehistoric features and the stone settings found in the region appeared to be more significant than previously thought (Gillings, Pollard & Taylor, 2010). A series of excavations were carried out on Lanacombe with a focus on linear anomalies, cairns and a circular anomaly in 2013 (Gillings, 2013). The two cairns excavated were similar to other cairns found on Exmoor and found in association with stone settings. Whilst one lacked material useable for dating, the second cairn suggested to be of Neolithic age. A cist within one of the cairns contained charcoal and dated material from this cist suggsted that burning events were already taking place in the Lanacombe area at the end of the Neolithic. Features described about the circular anomaly suggested a relatively short-lived period of activity during broadly the 2nd millennium BC, with possible Neolithic activity taking place in the vicinity of the site. Based on the excavation findings, the cairns and linear systems appeared to be associated with each other. Gillings (2013) argued that cairns on Exmoor could either be independent features in the landscape or could be "integral components of more extensive linear boundary systems, but not as discrete clearance-related clusters or cairnfields".

5.2.3 Previous pollen work at Great Buscombe

A high-resolution pollen analysis was carried out in 2015 as a part of Exmoor National Park's mire management project, in order to research the later prehistoric sequence of Great Buscombe (Fyfe & Head, 2015). Pollen and spores were identified for the sequence depths between 150cm and 215cm, along with micro charcoal analysis. Figure **5.3** shows a reconstruction of the produced pollen diagram that was presented in the report for Exmoor National Park, dating from 1303 cal BC to 325 cal BC. The pollen diagram was divided into four main zones, of which the middle two zones are further divided into sub-zones (zones are not included in figure **5.3**).

The first zone (*GBUS Ipaz 1*) represents a large part of the late middle Bronze Age. *Alnus* trees occur in high percentages in the diagram (averaging around 60%) and not many significant fluctuations appear in the pollen composition during this entire zone, which covers a period of around 450 years. The second zone (*GBUS Ipaz 2*) is divided into 4 subzones. The most significant piece of evidence for human land use occurred during the middle Bronze Age. A large decrease in *Alnus* pollen suggests a clearance of *Alnus* trees without the use of burning, considering charcoal levels are very low. Subzone *GBUS Ipaz 2d* revealed evidence for the presence of agricultural activities in close proximity to the site, as well as evidence for the use of burning as a land management tool. This has likely occurred in a period spanning of approximately a 110 years, during the late Bronze Age. *GBUS Ipaz 3* is divided into 3 different subzones and is one of the best examples from the sequence showing a period of decreased intensity of land use, suggested by the regrowth of *Calluna vulgaris* and arboreal taxa. The final zone, *GBUS Ipaz 4*, represents another time period of intensified land use, with a high increase of charcoal counts. Since no cereal pollen were found, it has been suggested that pastoralist activities occurred during this phase (early Iron Age), but since NPP data is necessary to confirm this hypothesis, it will be discussed later in this chapter.

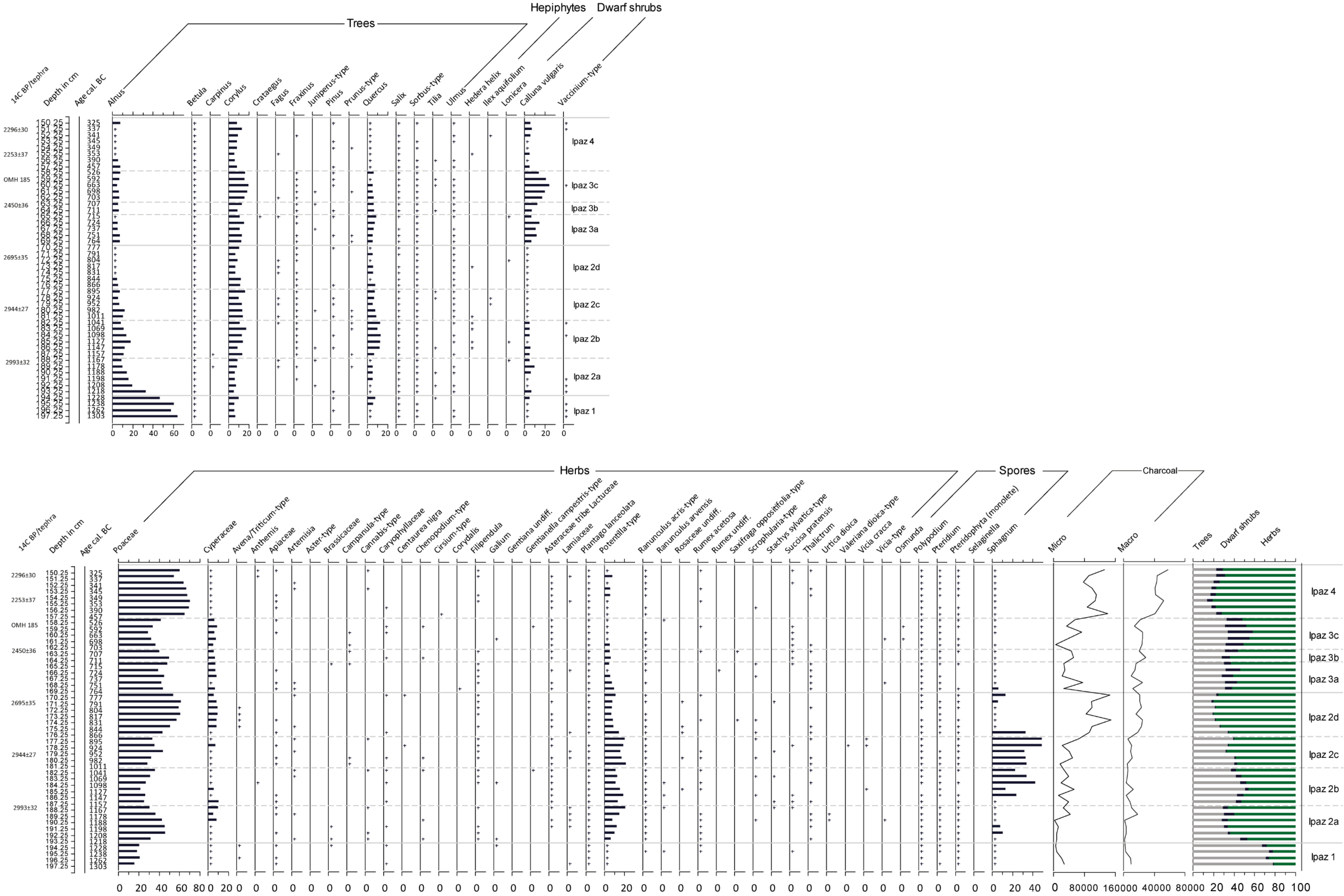


Figure 5.3 *High-resolution pollen analysis. Taken and altered from the Great Buscombe report (Fyfe & Head, 2015).*

5.3 Results

5.3.1 Dating of the Great Buscombe sequence

Radiocarbon and tephra dates were generated during an assessment and report carried out on the peat core from Great Buscombe (Fyfe & Head, 2015). There is no data available on stratigraphy or loss-on-ignition data of the core material. Phase 1 (preliminary assessment on a 2.15m core) produced three radiocarbon dates. The follow up report from 2015 added another seven radiocarbon samples. Four tephra layers were identified during the 2015 research, but were excluded in a provisional age-depth model (not shown here). This model suggested that three of the radiocarbon dates should be excluded from the age-depth model and are thus left out for this research.

Table **5.1** lists all radiocarbon dates and tephra dates. Three of these have not been used in the model. The first (UBA_27962) is statistically similar to the one above (UBA24407) and a linear interpolation of dates suggests that the UBA_27962 date may be too young. The bottom two (UBA-27955 and UBA-17954) show overlap in their calibrated age ranges with that of UBA_24408. However, the date of UB_24408 is based on a short-lived twig and is thus considered the most reliable and accurate age range for the base of the model (Fyfe & Head, 2015). Thus, the remaining two base samples were considered unhelpful in the construction of the model. Several tests that included and excluded these bottom dates showed that an exclusion did not affect the current model. Current tephra dates were geochemically identified by MacLeod *et al.* prior to this research project (MacLeod *et al.*, in prep) and thus provide more reliable dates (see also section 4.3) for the production of an age-depth model.

This model integrates five radiocarbon dates combined with the four identified tephra dates and confirms that the sequence used in this research project ranges between the middle Bronze Age (mid-second millennium BC) and the late first millennium BC. See figure **5.4** for the age-depth model.

Depth (cm)	Material	Lab code	14Cdate BP	Tephra date BC/AD	Calibrated age BC/AD
20-21	tephra	Hekla AD 1510	NA	440±10	cal AD1508-1512
39-40	tephra	BMR-90	NA	1030±100	Cal AD914-1204
77-71	tephra	AD860a	NA	1090±10	cal AD840-881
100-101	humin acid	UBA-24406	1223±10	NA	cal AD688-850
150-151	humin acid	UBA-24407	2296±30	NA	400-230 cal BC
155-156	*humin acid*	*UBA-27962*	*2253±37*	*NA*	*405-237 cal BC*
160-161	tephra	OMH-185	NA	2667±38	755-635 cal BC
165-166	humin acid	UBA-27960	2450±36	NA	770-651 cal BC
175-176	humin acid	UBA-27958	2695±35	NA	911-801 cal BC
185-186	humin acid	UBA-27957	2944±27	NA	1223-1050 cal BC
195-196	humin acid	UBA-27956	2993±32	NA	1381-1130 cal BC
200-201	Betulaceae twig	UBA-24408	3217±31	NA	1491-1417 cal BC
205-206	*humin acid*	*UBA-27955*	*3185±32*	*NA*	*1497-1429 cal BC*
210-211	*humin acid*	*UBA-27954*	*3162±29*	*NA*	*1502-1434 cal BC*

Table 5.1 *Results of radiocarbon analysis and tephra analysis from Great Buscombe, Exmoor. The three dates written in italic are excluded from the age/depth model. Calibration of all dates are done in OxCal and the chosen calibrated ages are within a 95% range of possibility.*

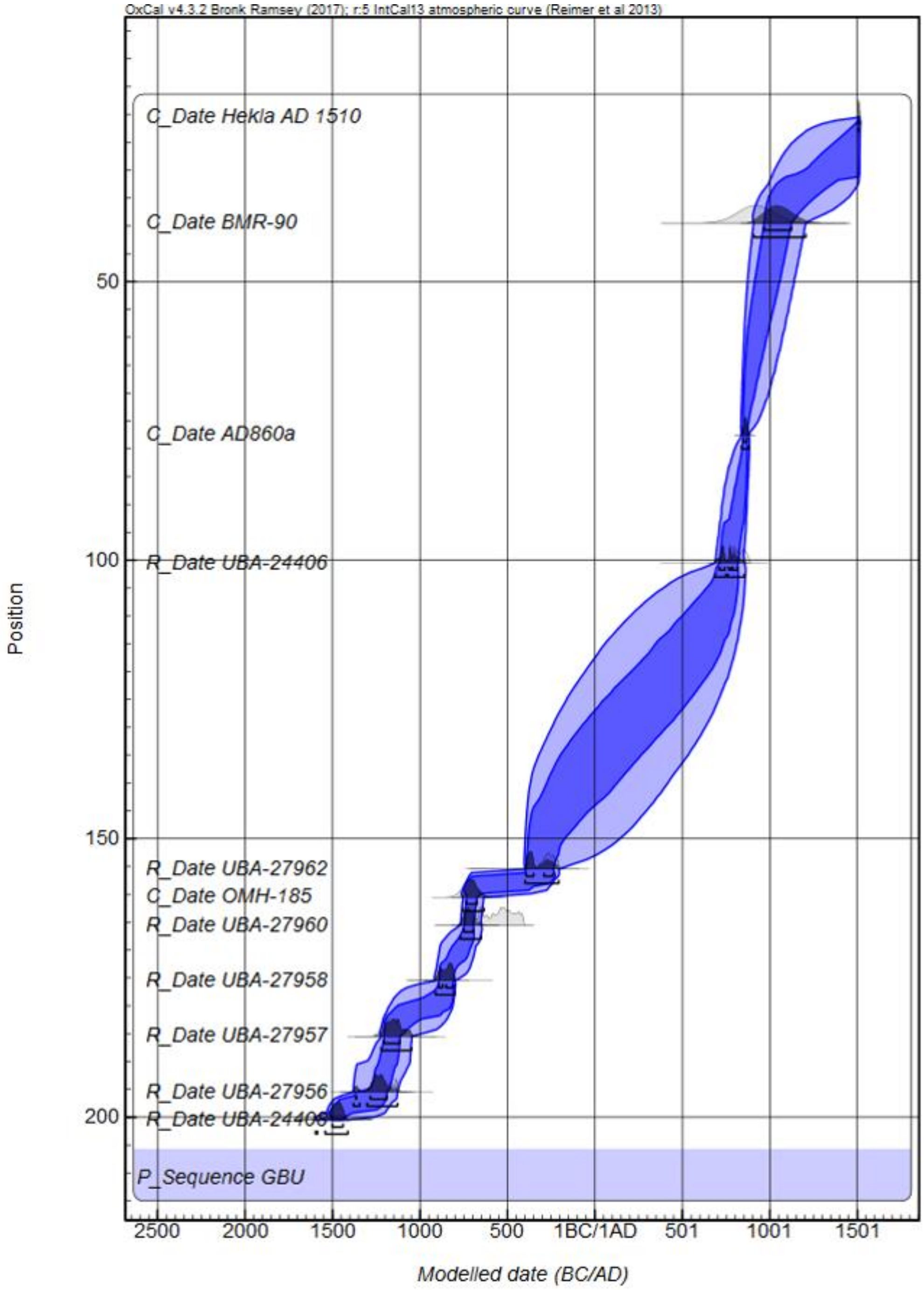


Figure 5.4. Bayesian *Age-depth model of Great Buscombe, based on tephra and radiocarbon dates shown in table 5.1. For the creation of this model OxCal was used (IntCal13). The dark blue area reflects a 68.2% age range and the lighter blue a 95.4% age range.*

5.3.2 Non-pollen palynomorphs results

The NPP diagram (see figure **5.5**) is divided into eight different NPP zones, based on observed patterns and/or changes in type presence. These observations were established by eye, and not by numerical analysis.

GBU NPP zone1 197.25 – 190.25cm (1300-1190 cal BC) starts with a drop of T19 from 60% to 25%, as it is replaced by T145 (*undiff.*). T19 disappears initially in the middle of zone 1 before it reoccurs at 25% again. T145 shows a high dominance in this zone, with values ranging around 70% for the majority of the zone. Values of *Sordaria* sp. and T55B (categorised here as Sordariaceae) are the only coprophilous NPPs that are frequently present in this zone and are relatively high, compared to the rest of the sequence. *Arnium*-type is the third coprophilous NPP that is present in this zone, but only occurs once with a value below 3%. T10 shows continuously present values of below 5% throughout the zone. *Gelasinospora* sp. occur once at a value below 5% at around 1200 cal BC.

Interpretation

The small presence of T10 could suggest a light presence of heather in the local surroundings, as previous studies have shown this type to be growing on *Ericales* roots and has clearly been associated with *Calluna vulgaris* (Van Geel, 1978).

T19 was initially associated with *Sphagnum* peat (*Sphagnum papillosum* and *Sphagnum imbricatum*) by Van Geel (1978). Innes *et. al* (2009) found T19 to be present in surface samples where *Calluna vulgaris* dominates alongside a dense ground cover of *Hypnum* (Innes, 2009). Both the upper and middle part of zone 1 show high values for T145, which may be explained by its association with a high percentage of tree pollen in a previous study (Van Der Wiel, 1982). A small indicator for fire in the later part of zone 1 is presented by the identification of *Gelasinospora* sp. However, this type has also been associated with local dryness, and can thus not exclusively be assigned to indicate burning/fire (Van Der Wiel, 1982; Van Geel, 1978).

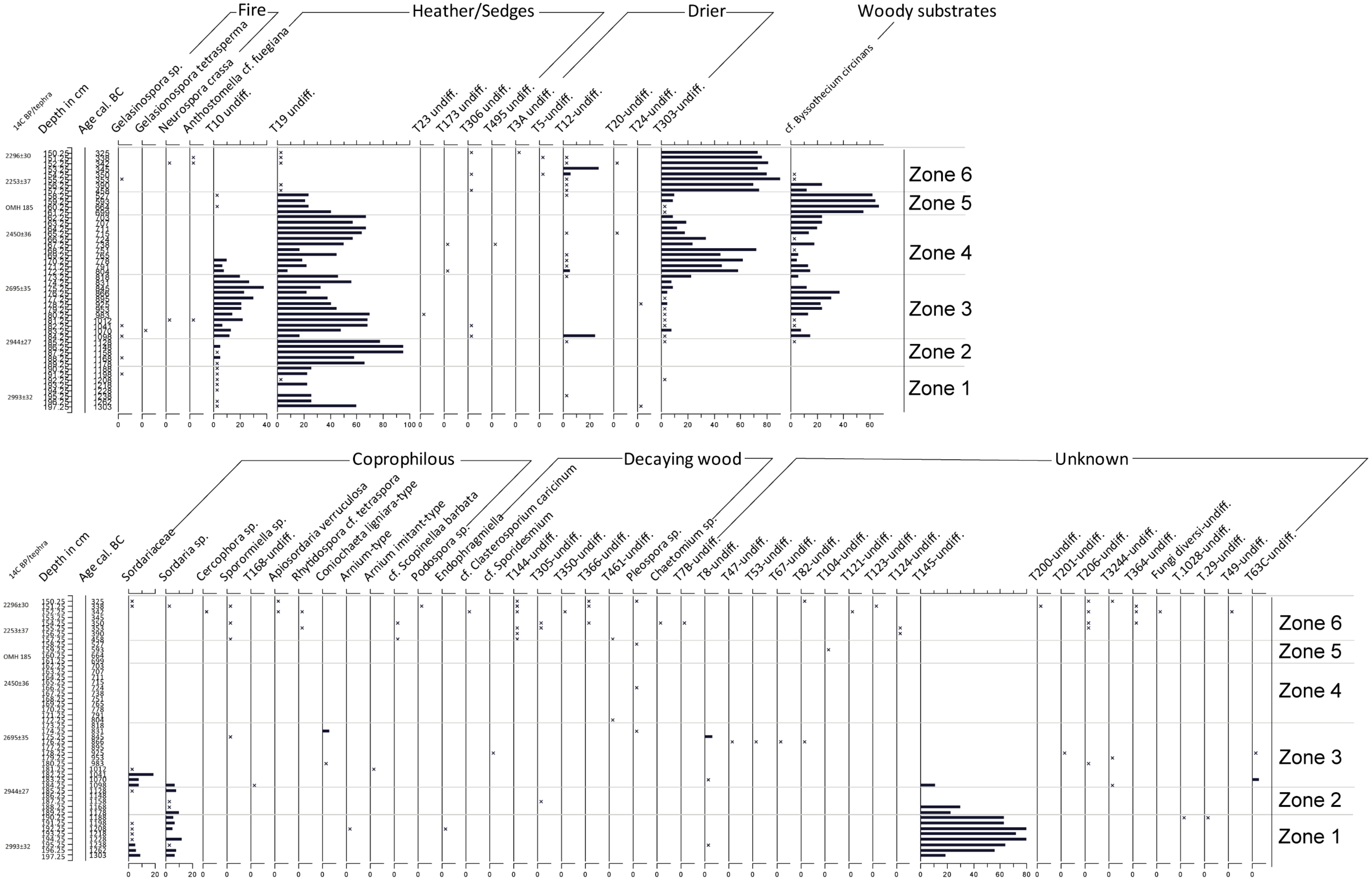


Figure 5.5. *Non-pollen palynomorph diagram of Great Buscombe. Spores that are not identified to species level are given a type number ("T"), which refers to the "HdV" types of Van Geel (1978 and beyond). A total of a 100 spores were counted and identified per cm depth*

GBU NPP zone 2 190.25 – 184.25cm (1190-1100 cal BC) covers the second half of the middle Bronze Age and shows a remarkable increase in T19, reaching values of 70% at the start of the zone. A further increase over the course of this zone shows that T19 values reach over 90%. T10 remains at similar levels compared to GBU NPP zone 1. T145 disappears at the top half of the zone and shows values of a maximum of ±30% at its occurrence of around 1160 cal BC. *Sordaria* sp. values are infrequent in this zone. Values ranging around 10% only occur at the top and bottom of the zone. Sordariaceae (T55B) values also show a drop since the previous zone and occur once at the top of the zone, but remain below 3%.

Interpretation

The NPP data suggests that the local surroundings of Great Buscombe during the second half of the middle Bronze Age was likely dominated by heather and/or sedges. The high dominance of T19 suggests that heather and/or sedges remained the dominant vegetation types throughout this zone. A disappearance of T145 could be associated with the decline of *Alnus* in the pollen data. This would also explain why no high reoccurrence of T145 appears in the NPP diagram. Although this zone spans a shorter amount of time, NPP data does suggest that grazing activities may have been less intense than before. *Sordaria* sp. suggest that mainly at around 1180 and 1130 cal BC some relatively higher grazing pressure occurred in the landscape.

GBU NPP zone 3 184.25 – 173.25cm (1100-800 cal BC) represents the onset of many new types appearing in the diagram. This is one of the few zones where all three possible fire-indicating types occur (although these do not exceed 1% values).

Although T19 shows an initial drop at the start of the zone, values increase back to over 70%. T10 also shows a large increase throughout this zone and reaches its highest values of 40% at around 830 cal BC. At around 1100 cal BC, a percentage value of over 20% is reached by T12 *(undiff.),* after which it only recurs at around 820 cal BC (below 3%). T303 *(undiff.)* shows a relatively low presence throughout the majority of the zone, but increases to ±30% at around 820 cal BC. A first appearance of *Byssothecium circinans* in the NPP sequence starts at values of just below 20%. An increase in values starts from around 980 cal BC, where values gradually incline to over 40%, before decreasing again from 870 cal BC onwards. After disappearing from the diagram in zone 2, Sordariaceae (T55B) spores reappear at values ranging between 8% and 20% until approximately 1010 cal BC. *Sordaria* sp. only appears once during this zone at the start, showing values of around 8%. Three other coprophilous NPP types occur once or twice at background level at different times in this zone and include *Sporormiella* sp., T168 (*undiff*.) and *Coniochaeta lignaria*-type.

Interpretation

A dominance of T19 in the NPP data in combination with T10 and *Byssothecium circinans* would suggest for mesotrophic conditions during this zone. Although T10 has been associated with drier phases of peat growth and *Calluna vulgaris* roots (Van Geel, 1978), neither option is indicated by the pollen diagram, where relatively low levels of *Calluna vulgaris* occur during this time, alongside relatively high levels of *Sphagnum*. The rise in *Byssothecium circinans* could initially be associated with a rise in grasses, but when compared to the pollen data, it would be more likely to represent mesotrophic conditions. It could however also be the case that the NPP data indicate changes in vegetation compositions on a different scale.

GBU NPP zone 4 173.25 – 162.25cm (800-700 cal BC) starts off with a large decline of T19 and T10 NPPs. Even though T10 does not reappear in this zone after 760 cal BC, T19 shows an incline to values ranging between 60% and 70% from 730 cal BC onwards. T303 shows values roughly ranging between 45% and 70% during the first half of the zone. After 740 cal BC values decline and range between 10% and 30%. T12 reappears during this zone, but values do not exceed 5% at any point. *Byssothecium circinans* values range at around 20% during the top half of the zone, but show values below 20% until 710 cal BC. The most interesting result from this zone, however, is the complete absence of any coprophilous species or types.

Interpretation

NPP data suggests this zone to represent a change to probably drier conditions, based on a large increase of T303 and a (relatively lower) presence of T12. A decline in *Byssothecium circinans* alongside a rise in T19 could further suggest a decline in local grasses, as they were replaced by heather. The remarkable fact that no coprophilous NPPs have been found during this zone could indicate that grazing activities mainly took place elsewhere or at a low intensity.

GBU NPP zone 5 162.25 – 158.25cm (700-530 cal BC) covers the majority of the early Iron Age and its transition into the middle Iron Age, with a time span of approximately 170 years. This zone shows relatively low values of T303, which do not exceed 10% at any point. A large decrease in T19 is also visible in the NPP data, with values starting at approximately 40% and decreasing to 20% for the remainder of the zone. A large peak in *Byssothecium circinans* shows values ranging between 50% and 70% during the entire zone. Finally, this zone has the least variety in the NPP composition compared to the rest of the sequence, and shows a lack of coprophilous NPPs.

Interpretation

A high dominance of *Byssothecium circinans* could be associated with an increase of local *Calluna vulgaris,* as is indicated by the pollen diagram. Based on a decline in T303 and T12, conditions during this short time frame could have been slightly wetter than during zone 4. A dominance of *Bysscothecium circinans* over T19 is rather interesting, and difficult to explain, considering both can be associated with heather growth. This phase could represent a time period of lower-intensity land use, based on heather growth and the lack of coprophilous NPPs.

GBU NPP zone 6 158.25 – 150cm (460-330 cal BC) covers the transition period of the early Iron Age into the middle Iron Age and sees a significant change in the composition of the fungal spores. T19 declines to levels of 5% and lower, whereas T303 returns and peaks at 70% and above. A high variety of coprophilous species occur during several stages of this zone, although they show low values on an individual level. Along with the coprophilous spores, a high variety (of individually low values) of species, indicative of decaying wood, appear at this zone. Furthermore, GBU NPP zone 6 contains the highest variety of NPPs compared to the rest of the sequence, but it is yet unclear what factor(s) may have caused this.

Interpretation

The identified changes in the NPP composition, are in agreement with the pollen data, which show a shift towards a domination of grassland, possibly explaining the large decline of T19 NPPs. The high and continuous presence of T303 could indicate drier local conditions in the surroundings of Great Buscombe. The NPP data suggests that some form of land use change took place during this zone. Coprophilous NPPs occur in a higher variety, as do many indicator types for decaying wood. Perhaps grazing activities increased by the transition into the middle Iron Age, or occurred more frequently in the vicinity of Great Buscombe. A high variety in the unknown NPP types suggests some change in the vegetation pattern from 460 cal BC onwards.

5.3.3 Summary pollen and NPP results of Great Buscombe

Both pollen and NPP results of the sequence of Great Buscombe have been individually presented so far. However, their catchment areas differ in size, where pollen reflect a regional landscape and NPPs are representative of a more local signal, due to limited travel of fungal spores compared to pollen (e.g. Van Geel, 1978). Therefore, a brief summary of recorded changes in the pollen and NPP data is presented in this section.

Pollen and NPP results from the sequence of Great Buscombe suggest several phases of land use types took place during late prehistory in the region. Pollen data at the base show a decline of *Alnus* from 60% to under 20% between 1350 and 1210 cal BC, alongside an increase of Poaceae and *Potentilla*-type. This phase is represented in the NPP diagram by a drop of the previously dominant T145, at a slightly later date of 1160 cal BC. Until 910 cal BC, both pollen data shows relatively stable values. NPP results show a disappearance of *Sordaria* sp. at 1100 cal BC, alongside a significant increase of T10 and *Byssothecium circinans*. The time period between 910 – 800 cal BC shows an increase in Poaceae (reaching 60%) and charcoal, with a simultaneous decline in *Calluna vulgaris*, arboreal taxa and *Potentilla*-type. NPP results remain relatively similar after 1100 call BC until the end of this zone. Between 800-480 cal BC, Poaceae declines to 40%, alongside a decrease in charcoal and an increase in *Calluna vulgaris* and arboreal taxa (predominantly *Quercus*, *Corylus* and *Alnus*). NPP data show a sudden dominance of T303 at the start of this period, being initially replaced by T19 until 700 cal BC, followed by a dominance of T16 between 700 and 460 cal BC. A final phase of increased Poaceae, reaching 60%, together with a second increase of charcoal values.

Arboreal taxa and *Calluna vulgaris* decrease once again, but *Potentilla*-type values remain similar to previous values. This phase is marked by an increase of T303 from 460 cal BC onwards in the NPP data. This is the only zone where high varieties of spores are identified, albeit in low numbers.

5.4 Multivariate analyses on Great Buscombe's pollen and non-pollen palynomorph data

A multivariate analysis on both the NPP and pollen data has been carried out in order to *a*) further explore patterns within the NPP data and *b*) to explore to what extent NPP and charcoal data are capable of explaining any identified variation within the pollen data. Both unconstrained and constrained ordination has been carried out and the results will be discussed in separate sections.

5.4.1 Unconstrained ordination of the NPP data

A PCA (principal components analysis) was carried out on the NPP data from Great Buscombe in order to gain insights into the correspondence between taxa within the NPP assemblage itself (see figure **5.6**). The first axis (PC1) explains a total of 37.9% of the variability within the NPP sequence, whereas the second axis (PC2) explains a total of 30.2% of the variability. Thus, only 32% of the variability in the entire NPP sequence is left unexplained. PC1 could very possibly explain the degree of wetness in a certain habitat, or may be (indirectly) related to the presence of fire. T303 is known as an indicator for drier habitats, together with the closely related T12 (Van Geel, 1978), but often occur in the NPP diagram where charcoal levels are high. Both are negatively correlated with possible indicators for increased wetness, such as T19. T19 was initially only observed in peat formed of *Sphagnum papillosum* and *Sphagnum imbricatum* (Van Geel, 1978). In a more recent study, surface samples showed T19 to be associated with an affinity for heathland, where *Calluna vulgaris* dominates (Innes, 2009). T10 moves in the same direction as T19 on the PC1 (axis), and can also be regarded as a type that is associated with *Calluna vulgaris* (roots) (Kuhry, 1985; Van Geel, 1978).

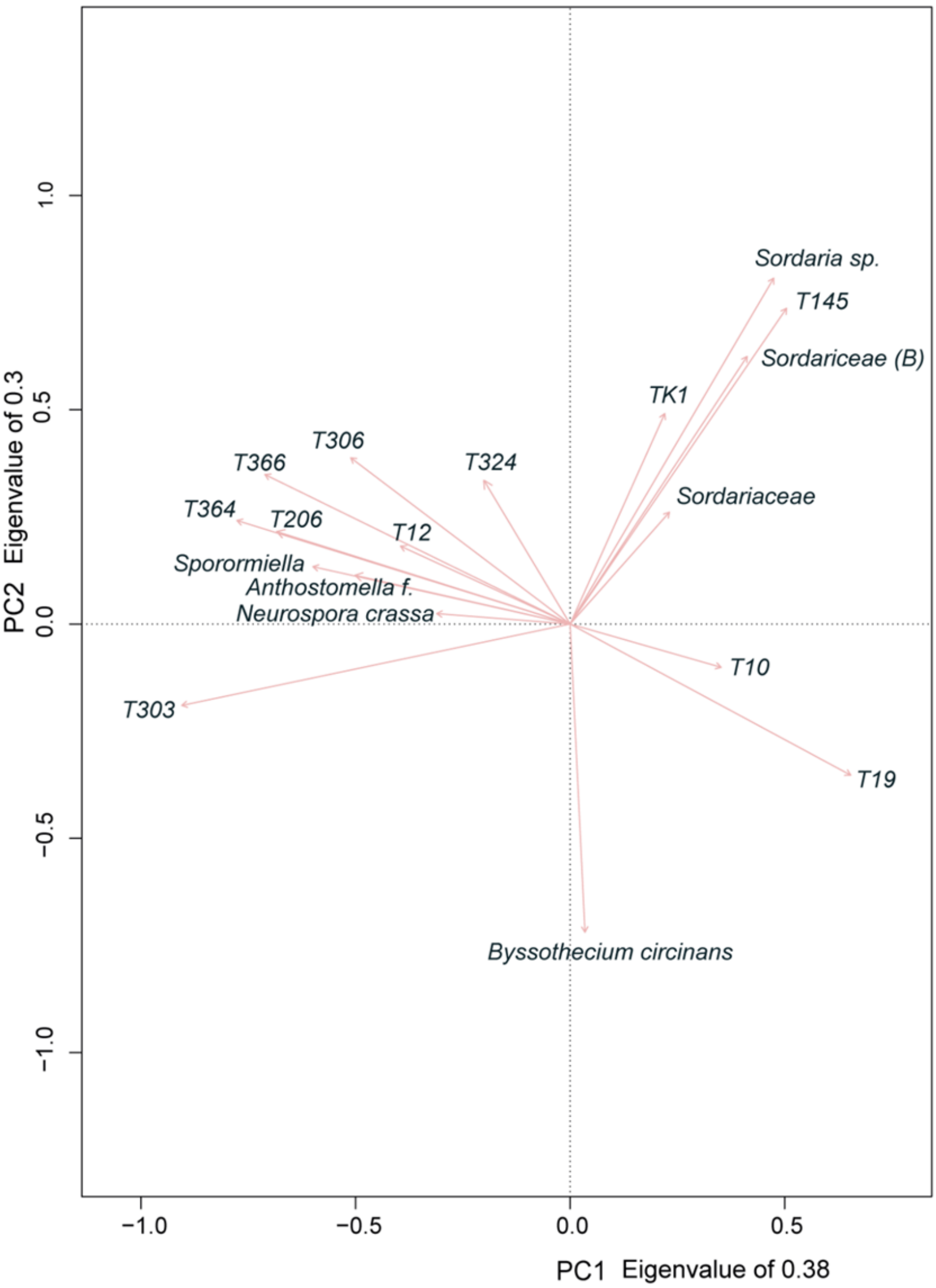


Figure 5.6. *Principal component analysis of the main NPPs recovered from the entire NPP dataset of Great Buscombe.*

Byssothecium circinans is located in the middle of the PCA plot between these two “extremes” but has been recorded in mesotrophic and dry phases of bog development. It is assumed to be a parasite on woody substrates and has been associated with grasses growing in the mires. In the NPP diagram, it mainly occurs in a period preceding a phase of intensified land use. The distribution of these different indicator types would suggest that the gradient in wetness could account for a certain amount of variability that would explain PC1 in the PCA plot. A different pattern can be spotted in the PC2 (second axis). A highly noticeable trend along this line is the divide of indicator types for specific types of land use against types that are not necessarily associated with this. Most types that fall within positive values on the PC2 are categorised under dung fungi, e.g. *Sordaria* sp. and *Sporormiella* sp. or are related to fire, e.g. *Neurospora crassa*. NPPs that show negative values on the PC2 are associated with heathland, e.g. T19 and T10, or are not distinct indicators for any sort of land use (change), e.g. T303. Perhaps this could also explain why T145 scores so highly on this axis. It was previously suggested that T145 could have been linked with the *Alnus* decline. Considering its high value on the PC2, it could indeed confirm that this type can be associated with either a change or occurrence in land use during the middle Bronze Age at Great Buscombe.

5.4.2 Constrained ordination of pollen, NPP and charcoal data

Following the PCA based on the NPP data, a redundancy analysis (RDA) was carried out. The RDA is a statistical tool that helps to explain any underlying variation in the pollen data, based on the NPPs and charcoal. The latter two are regarded by the RDA as environmental (independent) variables. RDA values thus describe to what extent certain environmental conditions can explain the variation of pollen throughout the sequence. Two different types of RDA were run on the data. The first type is an RDA carried out on pollen data of the entire sequence used for this study, with selected NPP/charcoal data included as the environmental vectors. These are shown in **5.7, 5.8** and **5.9**. Three RDA’s of this type were carried out, which included different combinations of environmental data.

The second type of RDA presented here is based on a moving window approach on a set covering 20 samples each time. This type can be used to show how pre-defined environmental data can explain variation in pollen data at different time periods throughout the sequence. RDAs were carried out running from the top to the bottom of the sequence, resulting in a list of eigenvalues per 20cm range depths each. This type of RDA has also been carried out three times. For each RDA, a different combination of environmental data has been used. Results are presented in three graphs (see figure **5.10**). See the methods section **4.5.2** for further explanation of the RDA’s carried out.

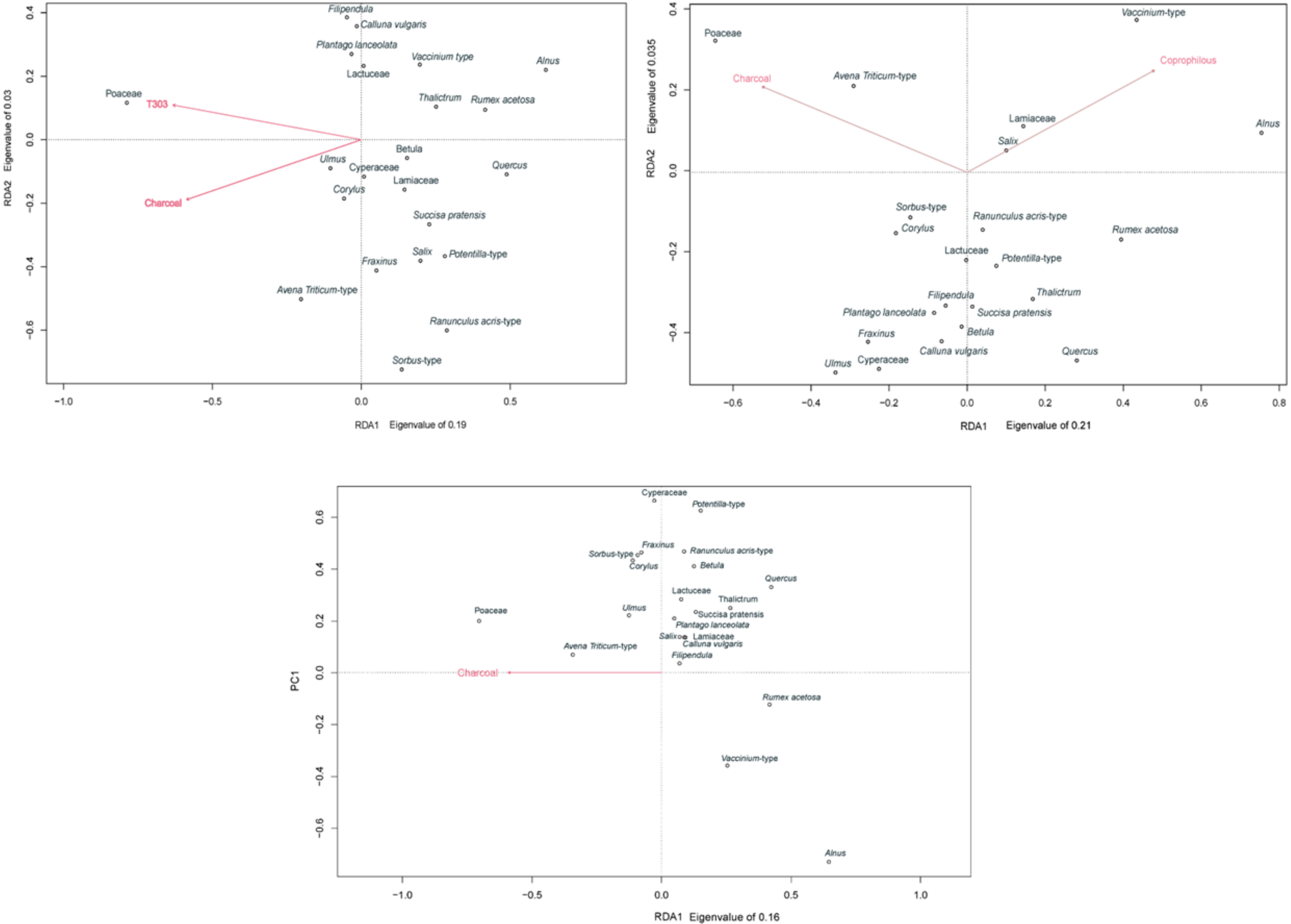


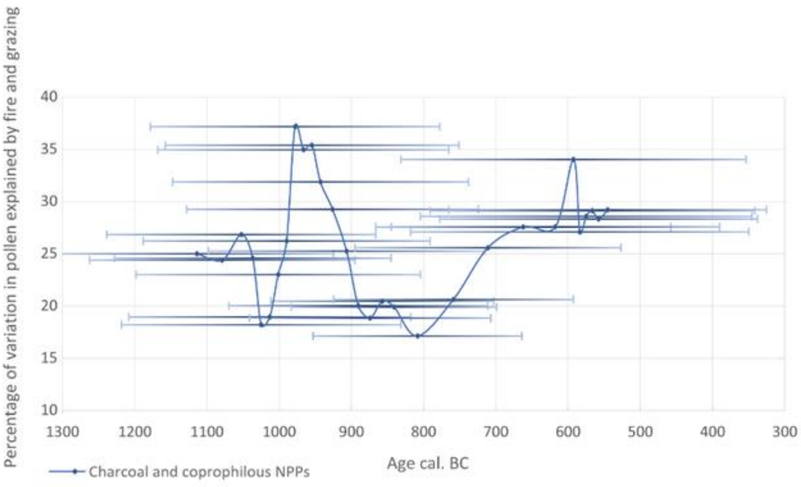
Figure 5.7, **5.8** and **5.9**. *RDA plots produced from pollen and NPP data of the entire sequence. Each figure shows a different combination of NPPs and charcoal used as environmental vectors, indicated by the pink arrows.*

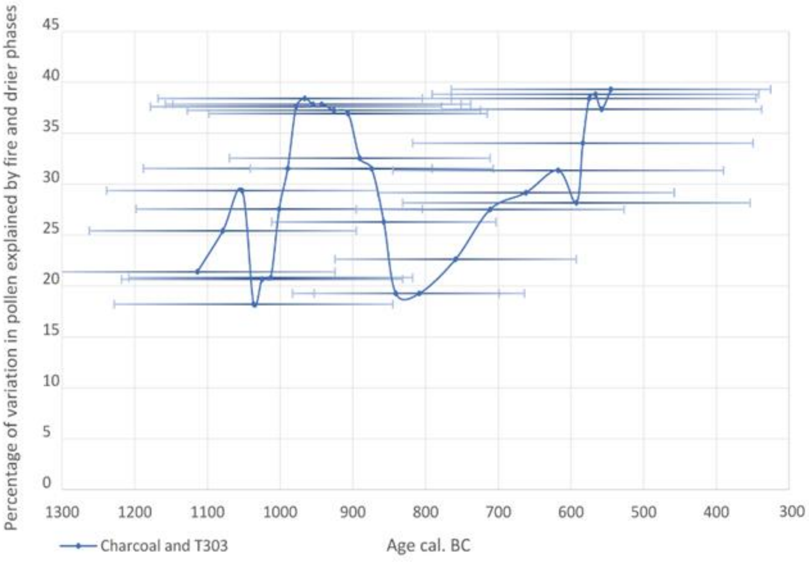
Figure **5.7** and **5.8** both show how variation in the usable pollen dataset can be partially explained based on the presence of fire (indicated by charcoal) and drier conditions (indicated by NPP T303). Charcoal and T303 combined, explain a total of 22% of the pollen distribution in figure **5.7**, whereas charcoal on its own explains a total of 16% in figure **5.8**. In both figures, *Alnus* (along with *Rumex acetosa* and *Thalictrum*) is negatively correlated to the presence of fire, whereas *Avena triticum* (a cereal pollen type) shows a somewhat positive correlation to charcoal. Poaceae (grass) pollen suggest a strong positive correlation to T303, which is an indicator of drier phases of peat growth. This NPP type shows a negative correlation with *Quercus* and to a lesser extent with *Betula* pollen. In figure **5.8**, charcoal lays directly on the RDA1 (x axis) which means that axis 1 is associated with the presence of fire and explains around 19% of the variation of pollen throughout the sequence. Apart from Poaceae and *Avena triticum*, not many pollen show a positive correlation with charcoal and most species remain located in the middle of the plot. Some light negative correlations exist between *Filipendula* and *Calluna vulgaris* or *Salix*.

Relationships between pollen and NPPs can change through time, which may explain fluctuations in the RDA plots of the moving window method. Another factor to consider is that T303 represents a local change of conditions, whereas the pollen represent vegetation changes on a larger geographical scale. This difference could perhaps have limited the value of explanatory NPPs. In figure **5.9**, charcoal remains are associated with the presence of grasses and cereal pollen and almost directly negatively associated with *Rumex acetosa*. Coprophilous NPPs (here regarded as grazing indicators) move in a different direction than charcoal or T303 do and show a positive association with *Salix*, Lamiaceae and, to a less significant level, with

Vaccinium-type. Coprophilous NPPs and charcoal explain a total of 24% of the pollen distribution in the RDA plot of figure **5.9**. Based on the pollen and NPP diagrams, it would be expected to see positive correlations between coprophilous spores and *Plantago lanceolata*, as well as *Potentilla*-type pollen. This expected association does however not come forth in the RDA plot. As a matter of fact, the majority of the pollen fall within the range of negative correlation to coprophilous NPPs. A discussion on the moving window RDA's in the following section can partially clarify the reason for these rather unexpected results.

Figure **5.10** (**a**, **b** and **c**) shows changes in the percentage of variation in pollen explained in RDAs, using a moving window approach. The association between certain NPP types and variation in pollen is thus not static over time. The RDA eigenvalues of the combination of charcoal and coprophilous NPPs (figure **5.10a**) show fluctuations between 17% and 37% of explanatory significance. An initial (average) time period between 325-711 cal BC shows a rather steady explanatory percentage value average of 30% with a peak of 34% at the average age of 600 cal BC. A similar average for this time period exists for the RDA's that included charcoal as a single environmental variable (figure **5.10c**), and a slightly higher average exists for the combination of charcoal and T303 (approximately 36%) (see figure **5.10b**).





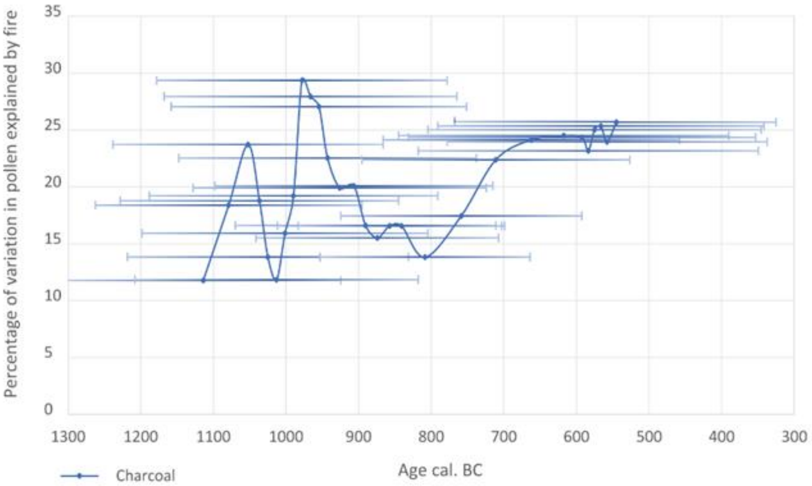


Figure 5.10 *Variation in pollen explained by three different environmental variable combinations through time, expressed in percentages. A moving window approach was used, meaning that the ages given in the horizontal axis represent the middle ages per set of 20 samples. The entire age range represented by each percentage point is indicated by the blue bars attached to each marker point.*

All three graphs show similar changes in values throughout time, with some minor differences in the charcoal-only graph (figure **5.10c**) compared to the remaining two. All figures show a rise in percentages during the middle Bronze Age. In the transition into the late Bronze Age (*1000-800 cal BC*), percentages drop to one of the two lowest dips visible in the graphs. The late Bronze Age suggests to have been a time period with the highest levels of extremes. Starting with very low values, fast increases of percentage levels resulted in peaks of around 30% to 34% at the average age of 978 cal BC. The combination of charcoal and T303 (**5.10b**) shows an average time period of around 80 years where these values remain alike, whereas in the other two graphs (**5.10a** and **c**) a direct decrease sets in. The environmental combination of charcoal and coprophilous NPPs and charcoal and T303 (**5.10a** and **b**) both show a relatively fast decrease to a second low, over an average time span of a 100 to 180 years. The charcoal data (**5.10c**) shows a similar drop in values over time, with some minor fluctuations throughout the second part of the late Bronze Age. A more gradual rise occurs during the early Iron Age (*800-600 cal BC)*. Values increase by 10% to 15% in all graphs. The period of transition from the early into the middle Iron Age (*around 600 cal BC*) suggests small decreases in percentage values, but in less extreme forms compared to the Bronze Age fluctuations. The combination of coprophilous spores and charcoal data (**5.10a**) shows the highest level of decrease during a short (average) period in time of around 10 years.

5.5 A synthesis of land use and prehistoric environmental changes at Great Buscombe

This section integrates the various strands of palaeoenvironmental evidence that have been collected from the core at Great Buscombe, drawing on the multivariate analyses to understand the extent to which evidence for changing land management practice, local conditions and vegetation change can be drawn from the record, and related to the local known archaeology. A fuller discussion of prehistoric land use and land cover dynamics for the wider region is presented in chapter **7**.

Most zones of the NPP diagram generally agree with the three identified zones of intensified land use in the pollen data and their succeeding zones of vegetation recovery (Fyfe & Head, 2015). The first section in this chapter will discuss the NPP data compared to the pollen data by following the three identified phases of more intense land use and their following recovery zone, of which each have been assigned to their own "GBU" phase.

GBU phase 1, 193.25 – 186.25cm, 1220-1150 cal BC

The main period of the distinct *Alnus* clearance that preceded the GBU phase 1 is covered by the NPP diagram and suggests that the co-occurring decline of T145 could be the best reflection of the changing landscape that was likely to follow the change in the area of Great Buscombe. A combination of pollen and NPP data shows that the local landscape around Great Buscombe included wet woodland dominated by *Alnus*.

A decline of *Alnus* that followed was either caused the more local NPP composition to have changed, or a yet unknow reason for why these changes occurred simultaneously. Although the first half of this phase is represented by the decline in T145, the second half is represented by a rise in T19. The latter could reflect the increase in Cyperaceae visible in the pollen diagram, or just general wetness in the local surroundings, considering *Calluna vulgaris* was not present at a high level around this time. GBU phase 1 overlaps with a large part of the middle Bronze Age (1500-1000 cal BC) (Webster, 2008). This time period can be associated with a wider social change (the introduction to field systems and land enclosure on Exmoor). Furthermore, the NPPs do confirm the suggested theory of pastoral lifestyle around this time, as *Sordaria* sp. occur throughout the entire time period and disappear at around 1100 cal BC (which is around 50 years after the end of the suggested land use zone). It could either mean that NPPs show the more local situation, where pastoralism perhaps continued for another 50 years, whereas the pollen data indicate an earlier end, on a wider regional scale.

There are few indications from both the pollen data as well as the NPP data for the use of fire as a land management tool after the *Alnus* clearance. Even though this phase contains the highest amount of *Gelasinospora* sp. types in the NPP diagram overall, they remain at low values. The fact that these species have been associated with three different types of habitat, cannot give any certainty of what they could indicate in this context. Lundqvist (1972) suggested that they are mainly *fimicolous* (coprophilous), but they could also be *carbonicolous* (depending on fire to initiate ascospore germination) or *lignicolous* (living on dead organic matter) (Lundqvist, 1972 in Van Geel, 1978; Wicklow & Zak, 1979). A possible preference for local dryness has been suggested, alongside an association of the genus with Lichens (Stevenson & Rhodes, 2000). Considering they did not occur in high amounts in the sequence, they were excluded from the statistical analysis, to prevent any skewed data and biased results.

During the latest time period of the moving window, charcoal explains 25% of the plot (see **5.10**). This relatively low value would initially suggest that the occurrence of *Gelasinospora* sp. during this time period are associated with a different type of habitat. A similar suggestion can be made for the appearance of *Neurospora crassa* in this part of the sequence. Although it is often found on burned vegetation, studies suggest that *Neurospora crassa* is saprotroph (living on decaying organic matter) and has been observed as an endophytic (hosted within a plant, living in symbiosis) in Scots pine. Furthermore, it could also enter a pathogenic lifestyle (causing a disease within its living host (e.g. Kuo *et al.*, 2014). When looking at figure **5.7**, *Neurospora crassa* and TK1 (categorised as *Gelasinaspora* sp.) go in nearly opposite directions and are both in close proximity to coprophilous spores. *Neurospora crassa* closely follows *Sporormiella* sp., whereas TK1 stays in close proximity to e.g. *Sordaria* sp. Thus, from a statistical perspective, both NPP types that were classified as “associated with fire”, suggest to be more associable with coprophilous spores in this context.

GBU phase 2, 186.25 – 17.25cm, 1150-860 cal BC

GBU 1 is followed by a phase of approximately 250 years in duration, spanning the latter part of the middle Bronze Age and the majority of the late Bronze Age. Directly after the end of phase 1, a large peak in T19 and a small (temporal) decline of *Sordaria* sp. may indicate an increase in local wetness (also confirmed by an increase of *Sphagnum*), or the presence of heath taxa in the local surroundings at around 1160 cal BC. This carries on for about 30 years. *Sordaria* sp. reoccur in the diagram after this small “intermezzo”, but no indications of pastoralism occur after 1100 cal BC. The high abundance of T19 only seemed to have lasted for a period of ±10 years, after which the local area either became mesotrophic, or had intermittently wetter and drier phases as indicated by the presence of both dry and wet indicating NPPs, alongside the presence of sphagnum between 1170 and 840 cal BC. Whether it was seasonally wetter or consistently wetter during this time, it may have been a result of the climatic deterioration (cooling) that took place at either 2750 cal BP in Northwest Europe and potentially on a global scale (e.g. Chambers *et al.*, 2007; Plunkett & Swindles, 2008; Swindles, Plunkett & Roe, 2007). This climatic deterioration has shown trends of wetter and/or cooler climates in Britain and may have resulted in wetter conditions in the uplands of Exmoor (Charman *et al.*, 2009). The remainder of GBU phase 2 overlap with NPP zone 3 and the majority of zone 4. The appearance and increase of *Byssothecium circinans* in the NPP diagram is presumably associated with small increases of local *Alnus*, *Corylus* and *Quercus* throughout the entirety of GBU phase 1.

GBU phase 3, 176.25 –170.25cm 860-780 cal BC

GBU phase 3 comprises of a shorter period, lasting for approximately 80 years. It covers the end of the late Bronze Age and parts of the early Iron Age. At the start of GBU phase 3, the pollen record showed a shift towards two new types of land use; small-scale arable cultivation alongside pastoral activities, supported by a regime of moorland burning. Despite the suggestion of pastoralist activities, the NPP diagram shows no significant signs for the presence of coprophilous spores throughout this time period. The only possible indicator might be the presence of *Coniochaeta ligniaria* at the start of GBU phase 3. Although this species has been added to the coprophilous spores in the diagram, it must be noted that it is not a guaranteed coprophilous spore. Mahoney and Lafavre (1981) found *Coniochaeta lignaria* to be either lignicolous (living on dead or decayed plant material), coprophilous or humicolous (growing on humus) (Checa *et al.*, 1988). With this species being the only possible dung indicator appearing during this period, no certainty of grazing animals can be assumed, although Cugny, Mazier and Galop (2010) suggested the need for further research into this species and the relation with dung, before entirely excluding this species from the coprophilous class (Cugny, Mazier & Galop, 2010). GBU phase 3 appears to be slightly shorter in duration than GBU phase 1 with up to around 60 or 70 years, based solely on the NPP data. Data suggests that a large change in local vegetation composition occurred at around 800 cal BC, simultaneously with a drop in T10 and T19, as well as an increase in T303. *Calluna vulgaris* is hardly present throughout this time period, which is possibly the result of burning as a land management tool. The gradual decline of T10 co-occurs with the end of the GBU phase 3 and is largely replaced by a significant increase of T303 between 800 and 750 cal BC. An increase of T303 to such an extent, in combination with a small presence of T12, would most probably indicate local dryness (Van Geel, 1978). However, it could be a result of burning as a land management tool, applied in the region. The fact that it has not previously occurred in such high numbers during any earlier prehistoric periods from the NPP sequence could suggest that either a change in land use or a change in climate has resulted in different types of vegetation or fungal spore composition in the area. Assuming that T303 is influenced by the presence of fire is even more convincing when compared to GBU phase 4. During this period (between ±460 cal BC and 330 cal BC) T303 increases to very high values, alongside grass pollen and increases in charcoal counts.

GBU phase 4, 170.25 – 158.25 cm, 780 – 500 cal BC

GBU phase 4 spans a time frame of approximately 280 years, which overlaps with the latter part of the early Iron Age. It represents the second phase of less intense land use and is in line with NPP zones 5 (for the majority) and the entirety of NPP zone 6. The main reason for two different NPP zones during GBU phase 4 is due to a shift at around 700 cal BC. An initial increase of T19 occurred at the first half of GBU phase 3, which could be explained by high values of *Calluna vulgaris*. *Byssothecium circinans* then dominates during the second half until the start of GBU phase 4. Interestingly, it would have been more logical to see a domination of T19 in the second half, given that *Calluna vulgaris* values increase even more around this time. Perhaps a change in either local wetness would allow *Byssothecium circinans* to thrive, rather than T19. *Byssothecium circinans* may be associated with woody substrates, provided by perhaps *Calluna vulgaris* or *Corylus,* which pollen showed a peak during NPP zone 6. Another interesting aspect from the NPP diagram during GBU phase 4 is the lack of coprophilous NPPs. It may indicate that the local surroundings of Great Buscombe were not in use to an extent that would leave any signs of pastoral land use behind. One of the most significant features is the difference between this phase and GBU phase 2. Phase 2 showed a regeneration of shrubs and tree pollen, thus reflecting a reappearance of a vegetation composition similar to conditions that preceded the middle Bronze Age. GBU phase 4, however, resulted in a growth of heather, but tree regeneration does not occur to the same level as during phase 2. A probable cause for this phenomenon is the difference of intensified land use between GBU phase 1 and 3. Phase 3 marks the use of burning as a land management tool, as well as (arable) agricultural activity. Both of these types of land use could have led to a deterioration in soil quality.

GBU phase 5 – 500 cal BC – 50 cal AD

GBU pollen phase 5 agrees with GBU NPP zone 7 and shows the highest variety of NPPs in the sequence. When compared to GBU phase 3, it would be expected to see similar types or species in both periods of intense land use, but this is not the case. Pollen data shows no evidence for cereal cultivation during this phase, but the charcoal data indicates that fire was still in use as a land management tool. It can be assumed that during GBU phase 5 represents a dominance of pastoralism in the local area, considering the fact that a high variety of low-value coprophilous spores are found. However, it has to be taken into account that few of NPP types that are classified in the diagram as coprophilous, may also be indicative of other habitat types. This zone contains a variety of NPP types which are known to live on decaying wood (Van Geel, 1978). Since several coprophilous spores have more than one substrate necessary to survive, they could also have been living on decaying wood, rather than animal dung. The presence of *Sporormiella* sp. creates a small amount of certainty for the presence of grazing animals, considering this type is regarded as a reliable dung indicator (Van Geel, 1978). A high variety of low-value NPP types with unknown habitats are frequently present in this zone. Interestingly, they also seem to have been present in GBU phase 2, albeit in lower frequencies.

Although not all unknown species were included in the PCA (see figure **5.6**), due to their low presence values, a small amount did get included. An interesting aspect is that all types categorised as “unknown” follow a similar direction in the PCA. They tend to form a cluster together with T12, *Sporormiella* sp.*, Neurospora crassa* and *Anthostomella cf. fuegiana.* A combination of their location in the PCA plot, together with their peak time of presence, during which indications for land use exists, would suggest that some, if not all, can be associated with either drier conditions (perhaps associated with frequent fire) or disturbance (caused by human land use in perhaps the form of grazing). Although the majority of the “unknown” types are located closest to T12 (indicator for drier periods) in the PCA plot, a possible association with *Anthostomella cf. fuegiana* should also be considered. This would suggest an association with sedges in the local area of the site.

5.6 Summary

Prior to 1200 cal BC, the environment immediately surrounding Great Buscombe was characterised by wet woodland, mainly *Alnus* dominated, but with several other trees present. At 1220 cal BC, a period of around 70 years (up until 1150 cal BC) showed an increase of land use intensity in both the pollen and NPP data. Pollen data show a clearance of *Alnus* trees in the lower (wet) valleys around Great Buscombe without the use of fire, alongside an increase of grass pollen. NPP data show a decline in T145, which may be associated with tree pollen and a possible presence of grazing animals in the vicinity of the site. What followed was a period that, based on the pollen data, indicated less intense land use, which allowed tree species to develop (to a limited extent). *Byssothecium circinans* may have been associated with the regrowth of trees. *Sphagnum* peaks indicated an increase of local wetness, which was also visible in the NPP diagram by a peak of T19 and T10, mainly. GBU phase 3 started at ±860 cal BC and lasted for about 80 years. Burning and cereal cultivation are the only types of land use that could have been identified from the pollen data and no indications for pastoralist activities were visible in the NPP data. T303 suggested a period of local dryness, although a possible association with fire would be interesting to analyse. GBU phase 4 showed a different composition of NPPs compared to the first time zone of less intense land use. Pollen data showed a higher presence of *Calluna vulgaris*, which was suggested to possibly have been a result of soil deterioration following the burning. Burning and pastoralism are the main aspects identified for GBU phase 5, alongside a domination of grasses in the region and NPP types indicative of the presence of a large range of possible habitats or substrates.

Chapter 6 – Spooners' results

6.1 Introduction

This chapter presents and discusses the results of high-resolution non-pollen palynomorphs (NPP) and pollen research from the site of Spooners. The study of this site focuses on the time periods ranging between ca. 3100 cal BC and 49 cal AD. NPPs, pollen and micro charcoal records are compared and statistically analysed in order to understand the important controls on vegetation change at this site. Previous palaeoecological knowledge of the area surrounding Spooners, alongside its location in an archaeologically rich area and a chronological extension into the late Neolithic, provide useful material to include in this study. Figure **6.1** shows a panoramic view of the landscape surrounding Spooners.

Figure 6.1. *Landscape view of Spooners, taken from Horsen (an area to the south of Spooners). ©English Heritage.*

6.2.1 Introduction to the site of Spooners

Spooners is a soligenous mire, located on open moorland at an altitude between 415m and 430m above sea level. The peat body is approximately 500m wide and 300m long and has peat depths ranging between 1.5m and 1.9m (Fyfe *et al.*, 2013a). A 1.6m long section was recovered at an altitude of 411m OD in the year 2012 as part of an assessment of the palaeoecological potential of the sequence for the Exmoor MIRE project. The assessment included radiocarbon dating and identification of tephra horizons in the sequence, as well as a skeleton pollen diagram. The 2012 section has been used for pollen, NPP and charcoal analysis of this study. The coring location and surrounding areas are presented in figure **6.2**. The peat depth survey of Bowes (2006) has indicated that Spooners forms an isolated mire and is surrounded by thin-soiled moorland, containing organic layers that are less than 25cm deep.

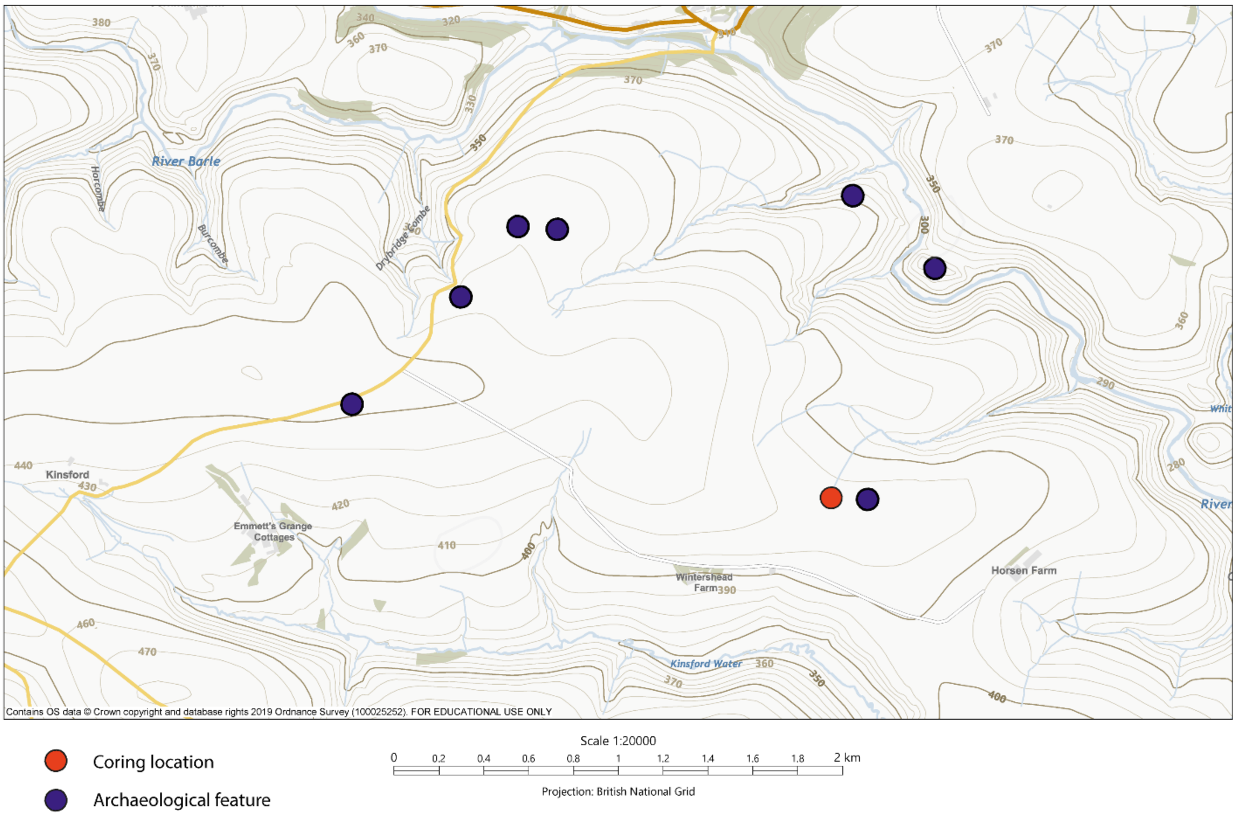


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Figure 6.2. *Spooners' coring location and archaeological featuers in the surroudning area depicted on a background vector map from EDINA Digimap Ordnance Survey Service.*

6.2.2 Archaeology of Spooners

There are a wealth of recent archaeological features across Spooners relating to nineteenth century drainage and mineral prospecting. Additionally, there are several important prehistoric features more relevant to this particular study.
A recent survey carried out by Exmoor Mires Project resulted in the finds of a prehistoric cairn and a standing stone (Bray, Carey & Fyfe, 2015). Another walkover survey to the west of Spooners in Deer Park, found a small area in which surface stone is abundant and appeared to have some spatial association with prehistoric cairns. Furthermore, a post-restoration survey carried out by the Exmoor Mires Project revealed a find of a stone artefact and what is assumed to have functioned as a hammer, dating to the Mesolithic period (Bray, Carey & Fyfe, 2015b).

One of the most significant finds in the area of Spooners was the discovery of a burnt mound (Carey, 2017), which is dated to approximately 1700 cal BC. Burnt mounds are a common phenomenon across northern Europe. They can be best described as a deposition of ash, charcoal and fire-cracked rocks, as a result of the process of heating water (Gardner, 2019). Although it purpose is not yet entirely clear, suggestions range between them being used for cooking or bathing (Drisceoil, 1988). Although the burnt mound near Spooners was initially interpreted as a cairn, its location near a stream in the base of a valley hinted at a different type of feature. The 16m long mound has since undergone a gradiometer survey, of which the results suggested significant heating of the material within the mound. A further excavation of the burnt mound confirmed this hypothesis and showed the mound to consist of a mixture of fragments of heated rock and quartz, and charcoal. The main reason for the high significance of this discovery is that this burnt mound is only the second one found on Exmoor and may suggest there are more to be found (Bray, Carey & Fyfe, 2015b).

6.3 Results

6.3.1 Dating of the Spooners sequence

Three radiocarbon dates were provided from the assessment carried out for Exmoor National Park (Fyfe *et al.*, 2013a). Four subsequent tephra layers have been geochemically identified by MacLeod *et. al* (in preparation) over the length of the entire sequence and extend into the prehistoric period (Macleod *et al.*, in preparation). Further details on these dates and layers are presented below in table **6.1.** Details used in the production of the age depth model are mentioned in section 4.3. For this study, there was no data available on stratigraphy or loss-on-ignition data of the core material.

Depth (cm)	Material	Lab code	14Cdate BP	Tephra date BP/AD	Calibrated age BC/AD
20-25	Tephra	AD860-A /BMR 90	-	1090±20/ 1030±100	cal AD840-881 cal AD914-1204
45-50	Tephra	OMH185	-	2667 ±38	755-635 cal BC
50-51	Humin acid	UBA-21452	2410±34	-	*750-400* cal BC
92-93	Humin acid	UBA-21451	4493±31	-	*3350-3040* cal BC
105-110	Tephra	Lairg A	-	6930 ±47	-
147-148	Humin acid	UBA-21450	7610±36	-	*6560-6410* cal BC

Table 6.1 *Results of radiocarbon analysis and tephra analysis from Spooners. Calibration of all dates are conducted in OxCal with the chosen calibrated ages being within a 95% range of possibility. AD860 is used in the current age-depth model shown in figure* ***6.3***

The age-depth model was used to identify the period of the sequence that dates to the late Neolithic through to the late Iron Age. At Spooners, this is between 91cm (3100 cal BC) and 40cm (260 cal BC). The detailed pollen, NPP and charcoal analyses were undertaken on this particular section of the core, using contiguous 1 cm samples, to address the aims of this thesis. The age depth model was produced with the use of AD860-A, instead of BMR after several model tests were ran and no obvious differences were visible. This means that either AD860-A or BMR 90 could have been used in the creation of the model, without resulting in any significant differences.

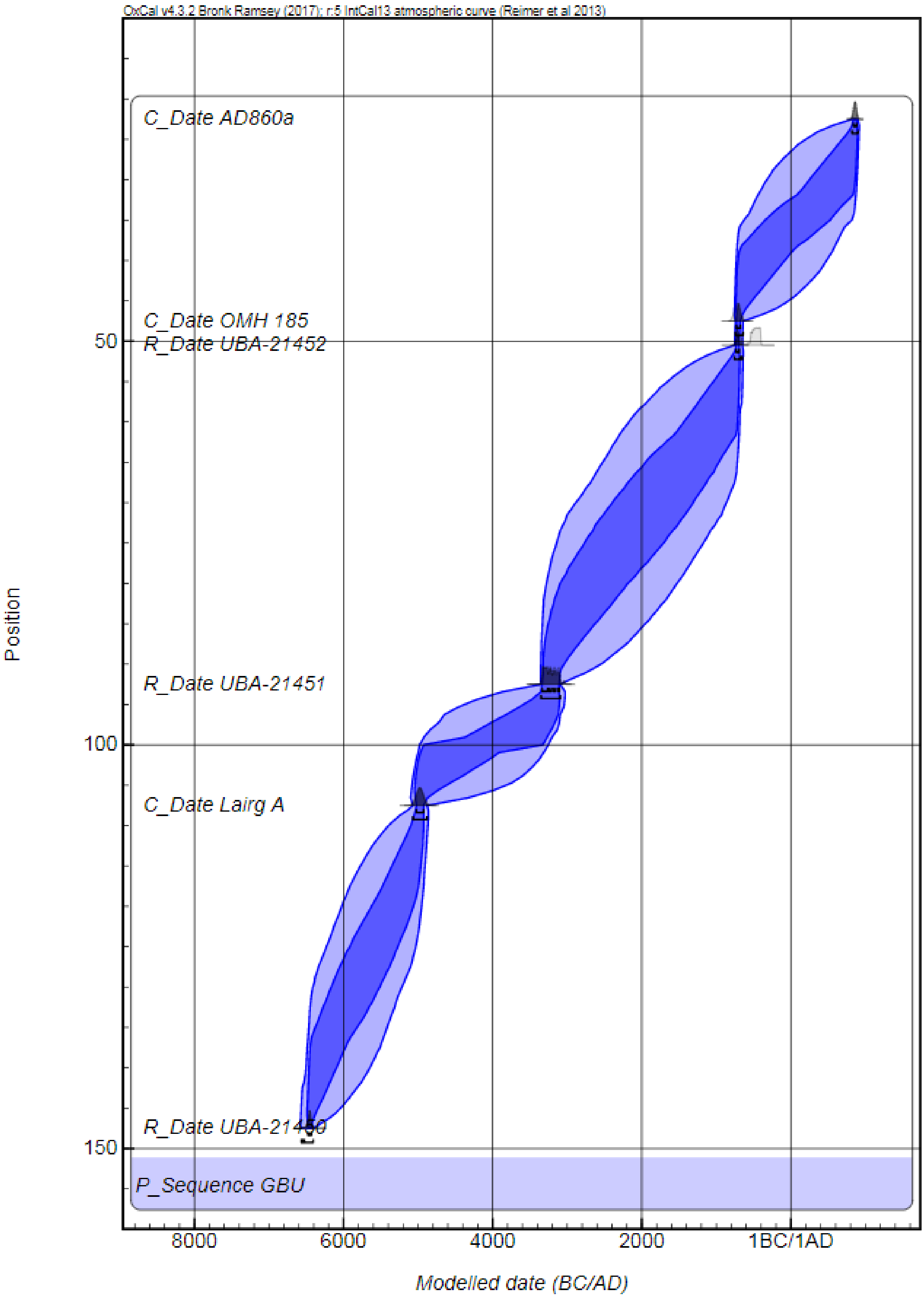


Figure 6.3. *Age-depth model of Spooners, based on tephra and radiocarbon dates shown in table **6.1.** For the creation of this model, OxCal was used (IntCal13). The dark blue area reflects a 68.2% probability age range and the lighter blue depicts a 95.4% probability age range.*

6.3.2 Pollen results

The high-resolution pollen diagram (see figure **6.4**) is divided up into six different pollen zones, based on observed patterns and/or changes in the pollen assemblage. These observations were established by eye, and not by numerical analysis.

SPO P-zone 1, 90.5-77.5cm, 3100-2330 cal BC is the basal pollen zone of the studied section of the Spooners sequence and covers a large part of the late Neolithic. *Corylus* values show a gradual increase over the length of the zone and go from roughly 20% at the start to 40% in the middle. After around 2800 cal BC, values decrease and average around 30%. Poaceae pollen start at around 40%, but decline with roughly 20% after approximately 3000 cal BC. Values range between 20% and 30% for the remainder of the zone. *Calluna vulgaris* values consistently range around 15% throughout the entire zone, with one peak of ±35% at around 3000 cal BC and a second peak of 30% at around 2600 cal BC.

Small background values of several tree taxa occur throughout the zone and fluctuate around values of 10% (e.g. *Alnus* and *Quercus*) or below 5% (e.g. *Salix*, *Tilia* and *Ulmus*). *Plantago lanceolata* and *Potentilla*-type pollen also show low values during the entire zone, but do not exceed values of 5%. From approximately the second half of the zone, Lactuceae pollen occur in the pollen diagram at values of 3% or lower.

Charcoal values show a sharp rise from ±2900 cal BC onwards, with particularly high values of micro charcoal. A temporal decrease in charcoal values at around 2600 cal BC coincides with a noticeable increase in shrubs in the TLP diagram.

Interpretation

This zone is likely to represent a phase of relatively consistent land use intensity. Disturbance indicator pollen remain consistent throughout the entire zone and grass/heather ratios remain similar. Suggestions for the use of burning as a tool for land management are evident in the charcoal diagram from approximately 2900 cal BC onwards. Two brief time periods of potentially lower intensity land use occurred at around 3000 cal BC and 2600 cal BC, where *Calluna vulgaris* show small peaks alongside a decrease in the charcoal data. Pollen data suggests that grass dominated from the very start of the zone and suggests that the vegetation surrounding Spooners had already been influenced by land use, other than burning, from approximately 3100 cal BC onwards. Both grazing activities and tree (predominantly *Corylus*) clearance or coppicing are plausible options of land use during this period.

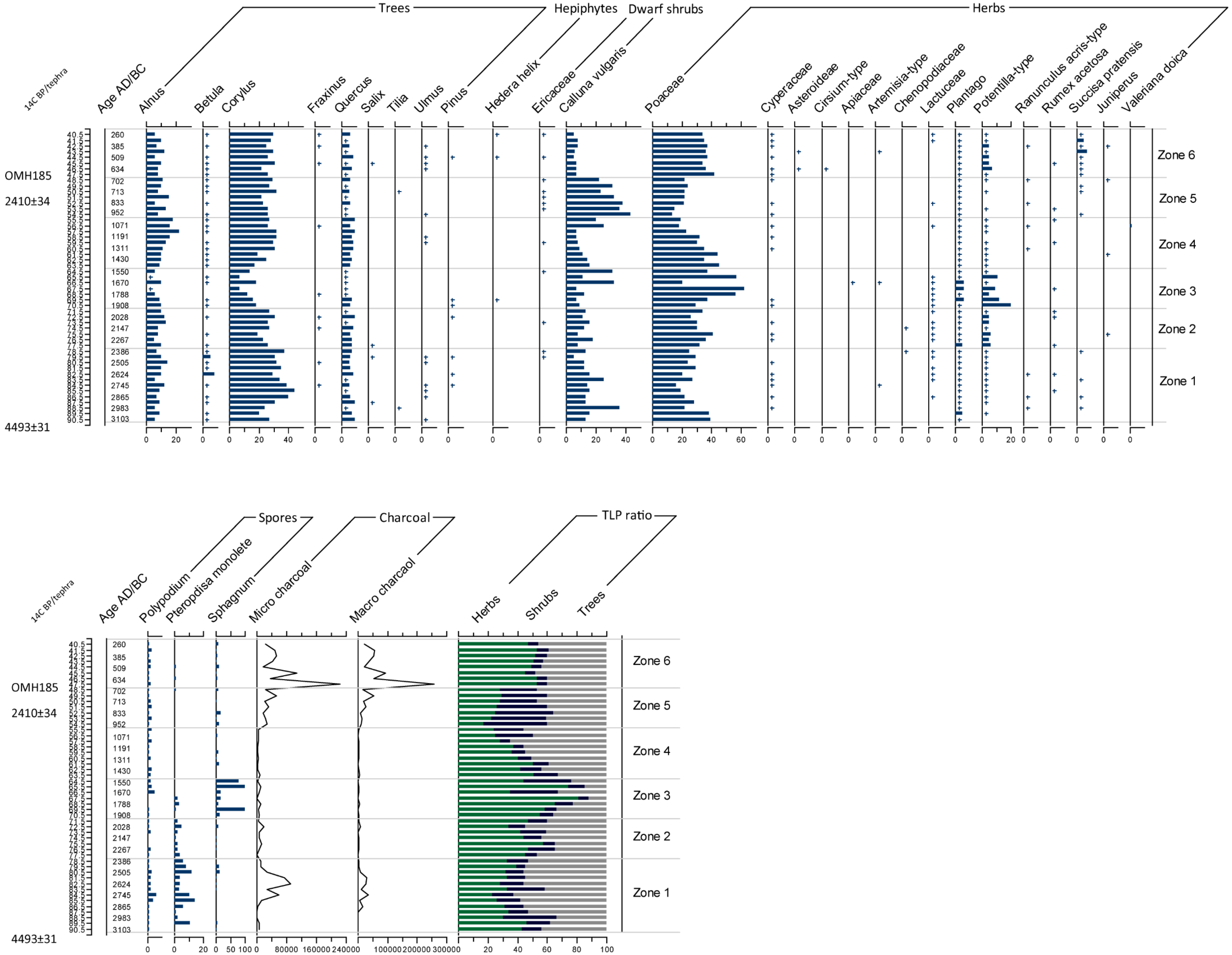


Figure 6.4 *High-resolution pollen analysis on Spooners' pollen and charcoal dataset.*

SPO P-zone 2, 77.5-70.5cm, 2330-1910 cal BC covers the majority of the early Bronze Age and shows a general change in vegetation composition in the second half of the zone. The bottom half represents a small increase of Poaceae levels rising from 30% to 40%. A small drop in *Corylus* initially occurs at the start of this zone, but values increase again in the second half to values close to 30%. Trees such as *Tilia* and *Ulmus* no longer occur on the background in this zone and *Betula* (background) values also declined in frequency. *Calluna vulgaris* values remain similar to the previous zone and range between 10% and just below 20%. Disturbance indicators Lactuceae and *Plantago lanceolata* also show values similar to zone 1, but *Potentilla*-type shows a small increase during the majority of this zone (2). Charcoal values have dropped back to relatively lower values for the entirety of the zone.

Interpretation

The pollen data suggests that SPO P-zone 2 also represents a period where some form of land use must have been present in the near vicinity of Spooners. Charcoal data indicates that burning was not the most frequently used type of land management during this period, but several pollen taxa suggest for some form of (human) disturbance during this zone. At the start of this zone a small drop in mainly *Alnus* and *Corylus* could indicate tree clearance, but grazing activities are very likely to have occurred throughout this entire period.

SPO P-zone 3, 70.5-63.5cm, 1910-1490 cal BC spans the last stage of the early Bronze Age and shows the most drastic changes in the pollen diagram. All tree taxa decrease in values throughout the entire zone and Poaceae show an increasing dominance from the start of this zone. Poaceae values rise from around 30% to 60% in the majority of the zone, but decrease back to 40% in the final ±130 years. *Calluna vulgaris* values remain around 10% during this zone, but show a sharp increase to 30% coincidentally with the drop in Poaceae values. Small increases of *Plantago lanceolata* pollen occur simultaneously with a large increase of *Potentilla-type* pollen (up to 20% at the start of this zone). *Rumex acetosa* pollen do not show any positive change in frequency compared to previous zones and remain very infrequent and scarce throughout the entirety of the sequence. Charcoal values are similar or lower than zone 2 for the majority of zone 3. Two small peaks in the micro charcoal are visible at around 1680 cal BC and 1560 cal BC. *Sphagnum* spores show very high values at around 1700 cal BC and from 1560 to 1300 cal BC.

Interpretation

Pollen from SPO-P zone 3 indicate the highest level of land use intensity of the sequence. Disturbance indicator pollen reach their highest values and remain rather consistent throughout the zone. Poaceae dominated the landscape and *Calluna vulgaris* decreased even more after a phase during the late Neolithic period. A sharp decrease in arboreal taxa, mainly *Alnus* and *Corylus*, suggests tree clearance took place during this early Bronze Age phase. Given the high values of Poaceae, but relatively low charcoal values, it is very likely that pastoralism was the main cause for the vegetation patterns detected in this zone. Burning shows a decreased intensity during this phase. Lastly, two peaks of *Sphagnum* values suggest a large increase of local bog wetness at around 1700 cal BC and 1500 cal BC.

SPO P-zone 4, 63.5-54.5cm, 1490-952 cal BC covers approximately the entirety of the middle Bronze Age as well as the transition into the late Bronze Age. Both Poaceae and *Calluna vulgaris* show a gradual decline in values, simultaneously with the increase of values of the three most dominant tree taxa, namely *Corylus* (40%), *Alnus* (20%) and *Quercus* (10%). It furthermore includes a small reoccurrence of *Ulmus* and *Betula* pollen. Poaceae remains to be dominant over *Calluna vulgaris* values during the entire zone. Poaceae values decrease from c. 50% to c. 20%, whereas *Calluna vulgaris* starts the zone with values of c. 20%, gradually declining to 10%. In the final c. 250 years of this zone, *Calluna vulgaris* reaches values of 30% and thus initiates a shift to a higher dominance over Poaceae. Both *Plantago lanceolata* and *Potentilla*-type values do not exceed 5% at any point in this zone, but do remain consistently present. Lactuceae background values have also decreased since zone 3 and show a single occurrence during this zone (4). Charcoal values are relatively the lowest compared to other zones and remain consistent throughout.

Interpretation

SPO P-zone 4 represents a period of tree regrowth, with mainly *Alnus* and *Corylus* recurring back in the landscape to levels similar to zone 1 and 2. The vegetation around Spooners was dominated by grasses, until a short period of heath-domination from 920 cal BC onwards. Although disturbance indicator taxa are lower compared to zone 3, they do suggest a continuous presence of relatively lower disturbance throughout the entire middle Bronze Age. Similar to the previous two zones, zone 4 also suggests pastoralism to be the main activity in the surroundings of Spooners, alongside indications for a low intensity of burning.

SPO P-zone 5, 54.5-47.5cm, 952-697 cal BC covers both the early and middle Iron Age and shows a large increase of *Calluna vulgaris,* reaching values over 40% at the start. A gradual decrease shows values to reach 20% at the end of the zone. Poaceae values remain very constant at an average of 20% during this zone. *Corylus* values consistently range around 25%. Other tree taxa such as *Alnus* and *Quercus* show more variety within the zone and show relatively lower values compared to zone 5. *Plantago lanceolata* pollen remain consistent at 4% and lower. *Potentilla*-type pollen are less frequent during this time period, whilst other herb taxa start to (re)appear, e.g. *Succisa pratensis* and *Ranunculus acris*-type.

Charcoal values show a rise from the start of the zone and show small fluctuations throughout this time period.

Interpretation

SPO P-zone 5 is likely to represent a time period where land use was of a relatively lower intensity. *Calluna vulgaris* dominated the vegetation surrounding Spooners throughout the entire early and middle Iron Age. Even though charcoal indicated a higher intensity of burning during this zone, it still allowed for *Calluna vulgaris* regrowth. Pollen disturbance indicators suggest a lower intensity of land use in general during this zone, which agrees with the overall suggestion for a low-intensity land use phase.

SPO P-zone 6, 47.5-40.5cm, 697 cal BC- 260 cal BC. This final zone covers the late Iron Age. Poaceae values persist around 40%, whilst *Calluna vulgaris* values do not exceed 10% at any given time. Tree taxa pollen remain at similar values compared with zone 5, with a TLP percentage of approximately 40. *Corylus* shows the highest values of all arboreal taxa, of just under 30%. There is a small increase in *Potentilla*-type background numbers, together with those of *Succisa pratensis*, Cyperaceae and *Ulmus*. Charcoal values increase to the highest values of the sequence from the start of this zone onwards. Values show a decrease at around 350 cal BC, after which two smaller peaks occur towards the end of the zone.

Interpretation

Pollen data from the last zone (6) suggest a grass-dominated landscape with relatively high intensities of burning throughout the late Iron Age. Land use would have been intense/frequent enough to not allow for much heather regrowth in the area. Arboreal taxa pollen suggest that they were relatively less targeted for either burning or clearance, given that values remain relatively high and stable throughout the zone. Several disturbance indicator pollen suggest a medium to high level of land use intensity, but this would have been either different or of a lower intensity that zone 3. It is possible that burning was the main tool of land management, but that e.g. grazing became less relevant during this zone.

6.3.3 Non-pollen palynomorphs results

The NPP diagram (see figure **6.5**) is divided up into six different NPP zones, based on observed patterns and/or changes in type presence. These observations were established by eye, and not by numerical analysis. Each zone is separately described below.

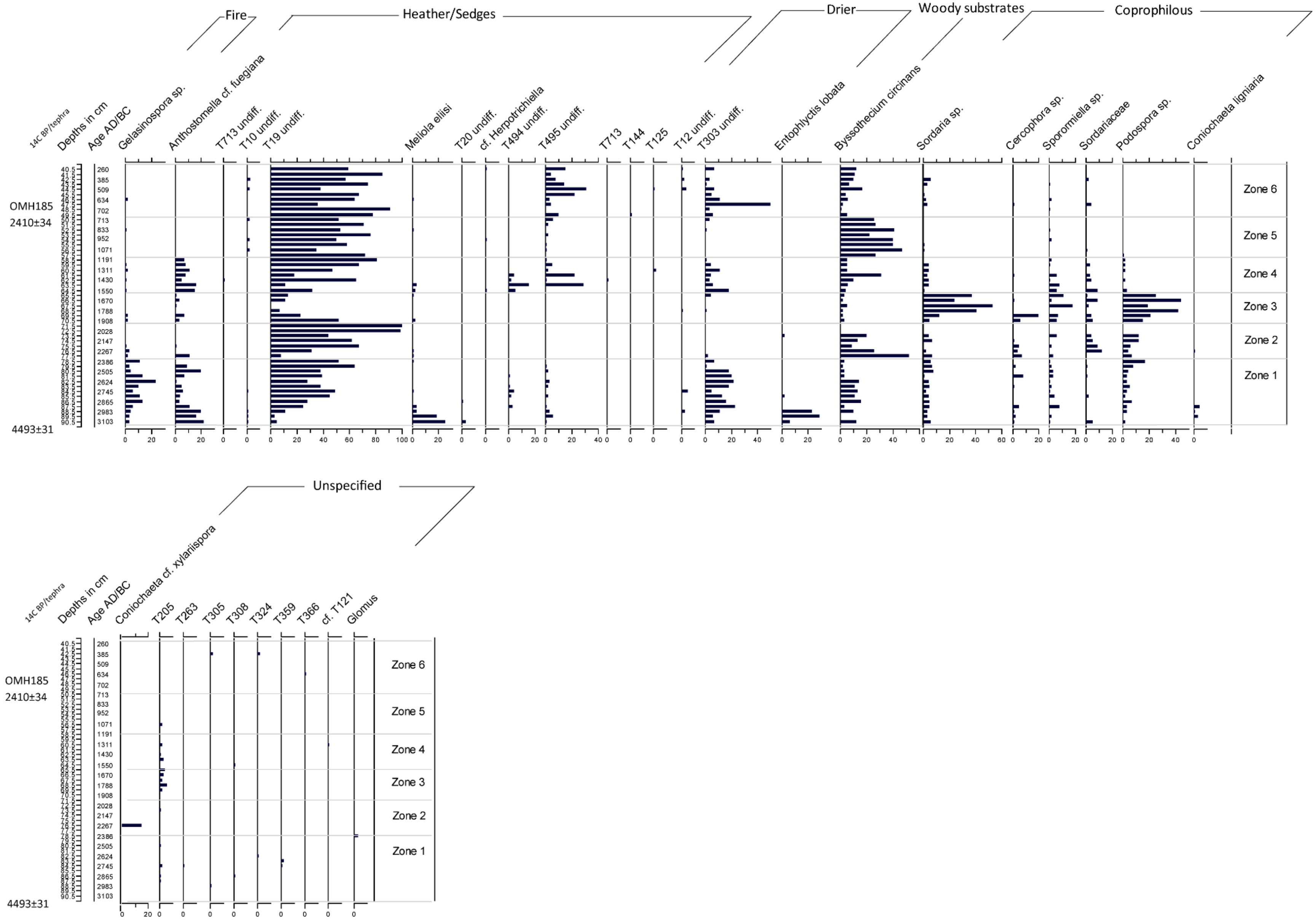


Figure 6.5. *Non-pollen palynomorph diagram of Spooners. Spores that are not identified to species level are given a type number ("T"), which refers to the "HdV" types of Van Geel.*

SPO NPP-zone 1, 90.5-77.5cm, 3100-2330 cal BC represents the late Neolithic period. The bottom part of this zone shows the presence *of Entophlyctis lobata* and *Meliola eliisi* both reaching values over 20%, before decreasing to 0, from c. 2800 cal BC. Constant background values of all five main coprophilous spores remain present throughout the entire zone, but do not exceed 10% at any given time. The only exception is that of *Podospora* sp. reaching a percentage of around 20 at the top of the zone. A similar, yet less consistent background presence of T494 *undiff.* and T495 *undiff*. occur throughout this zone at around 5%. *Gelasinospora* sp. show a similar pattern, but do peak at around 2600 cal BC, where they briefly reach values of over 20%. *Byssothecium circinans* follows a similar pattern as well, but values decrease by half at c. 2450 cal BC. *Anthostomella* cf. *fuegiana* shows percentages of around 20 until 2850 cal BC and drops to values below 5% afterwards. T19 *undiff*. shows a gradual increase from the bottom of the zone onwards and reaches 50% at around 2700 cal BC. It then continues to increase and reaches values of over 60% at around 2450 cal BC. T303 *undiff.* shows fluctuations within this zone, as it increases towards 20% at around 2850 cal BC. Following a small decline hereafter, values re-occur at the 20% mark at around 2500 cal BC.

Interpretation

NPP zone 1 suggests to represent a time period of both stability of certain NPP indicator types, alongside several sudden changes within the NPP composition. The majority of coprophilous NPPs remain frequently present throughout the entire zone, suggesting a consistent presence of grazing animals in the surroundings of Spooners.

Gelasinospora sp. also shows a continuous presence throughout this zone, but does increase at around 2860 cal BC and again at around 2600 cal BC. This would suggest that fire/burning events took place in the local surroundings to the extent that it would have influenced the NPP composition. T303 shows a continuous presence with simultaneous increases in values. The first increase takes place where *Entophlyctis lobata* (supposedly a dry indicator as well), disappears from the zone. Although this shift may indicate more local differences in the NPP composition, T303 suggests that this zone covers a time period of relatively drier peat growth.

<ins>SPO NPP zone 2, 77.5-70.5cm, 2300-1910 cal BC</ins> covers the first half of the early Bronze Age and commences with a large increase of *Byssothecium circinans* values, which rise from approximately 5% up to c. 50%. This soon declines to approximately 20% and lower for the remainder of the zone. T19 *undiff.* shows an opposite movement as levels hardly reach 10% at the start of the zone. Values of T19 do show an increase up to 70% over the span of c. 200 years. Furthermore, at the top of the zone, between 1940 and 1810 cal BC, T19 reaches even higher values that approach the 100% maximum. Both *Gelasinospora* sp. and *Anthostomella* cf. *fuegiana*, as well as T303 *undiff*. are present at the start of this zone, but disappear from the diagram for the remainder. *Podospora* sp. and T55B (Sordariaceae) remain relatively consistent at levels of around 5% to 10% throughout this zone. The three remaining dominant coprophilous spores show relatively more inconsistencies in their presence during this zone.

Interpretation

Suggestions for pastoralism remain present in the NPP diagram during the first half of the early Bronze Age, but indicate for less frequent/consistent patterns. The disappearance of *Gelasinospora* sp. could indicate that burning did either not take place in the local vicinity of the site, or suggest a change in conditions, causing burning to be undetected within the NPP data. A combination of a disappearance of dryness indicator T303 and a large increase of *Byssothecium circinans,* suggest local conditions became wetter during the transition of the Neolithic into the Bronze Age at Spooners. A large increase of T19 towards the top of the zone suggest a time period of increased levels of either heather or sedges, and perhaps indirectly a period of less intense land use in the local vicinity of Spooners.

SPO NPP zone 3, 70.5-64.5cm, 1910-1550 cal BC covers the second half of the early Bronze Age as well as approximately the first 50 years of the middle Bronze Age. T19 *undiff*. no longer dominates the diagram during this time period as values drop from 50% to under 20% at the beginning of the zone. Very low values of *Anthostomella* cf. *fuegiana* and *Byssothecium circinans* occur in the diagram throughout zone 3, but hardly reach levels of over 5%. This zone, however, is the only zone where coprophilous spores occur in high quantities. *Sordaria* sp. and *Podospora* sp. dominate the coprophilous group with levels ranging between 20% and 50% throughout this zone. *Cercophora* sp. peak at a 20% level at around 2200 cal BC, but disappears after. *Sporormiella* sp. peak at the start of the middle Bronze Age with a value of around 20%, but remains at lower levels during the rest of NPP zone 3. T55B (Sordariaceae) spores fluctuate between 5% and 10% during this zone.

Interpretation

SPO NPP zone 3 represents a time period with clear indications for pastoralism taking place in the local surroundings of Spooners. This period covers approximately 300 years during the early Bronze Age and shows continuous relatively high levels of a variety of coprophilous NPPs. There are minor background indications for the presence of fire/burning at the start of this zone based on *Gelasinospora* sp. The low values of *Anthostomella* cf. *fuegiana* alongside relatively low values of *Byssothecium circinans* suggest a continuation of relatively wetter bog conditions.

SPO NPP zone 4, 64.5cm-57.5cm, 1550-1130 cal BC covers the large majority of the middle Bronze Age. Coprophilous spores no longer dominate the diagram, as all species within this category do not exceed values of 10% during the course of this zone. *Sordaria* sp. are the only consistently present spores of the coprophilous group. Both T303 *undiff.* and *Anthostomella* cf. *fuegiana* reoccur in the sequence and show consistent values that range between 10% and 20%. *Byssothecium circinans* peaks with a percentage of 30 at around 1300 cal BC, but it does not reach levels higher than 10% for the remainder of the zone. Both T494 *undiff*. and 495 *undiff*. show peaks at the middle of the zone and reach percentages of 20 to 30, after which both decline back to values below 5%. T19 *undiff*. does not appear to dominate the zone until after around 1170 cal BC, when it reaches levels of 60% to 80%.

Interpretation

After a period of 300 years of clear indications for pastoralism, NPP zone 4 suggests a shift back to relatively low levels of grazing intensity at Spooners. A relatively high reappearance of *Anthostomella cf. fuegiana* suggests an increase of sedges in the near vicinity. Relatively equal values of T303 (dryness indicator) and *Byssothecium circinans* suggest a relatively drier period of peat growth with perhaps a larger presence of grasses growing on the mire. The high (briefly present) values of T495 *undiff.* and T494 *undiff*. could indicate a temporary increase of *Molinia* tussocks at around 1400 and 1300 cal BC.

SPO NPP zone 5, 57.5-50.5cm, 1130-710 cal BC covers the majority of the late Bronze Age, the entirety of the early Iron Age, as well as the start of the middle Iron Age. A clear division between this zone and the previous one in the NPP diagram is visible, based on the lack of *Anthostomella* cf. *fuegiana*, T303 *undiff*., T494 *undiff*. and nearly all coprophilous spores. Instead, *Byssothecium circinans* consistently ranges between values of 30% to 50% throughout the zone. T19 *undiff*. shows slightly more fluctuation during the zone, but remains at values between 40% and 70%. A few very small occurrences of T10 *undiff*. are present during this zone, but do not exceed values of 5%. This is however one of the few zones where T10 *undiff*. occurs.

Interpretation

NPP data from zone 5 show a shift towards a period that was likely representing a time in prehistory where land use intensity around Spooners had decreased. Low levels of coprophilous NPPs suggest a lack of pastoralism and a large lack of *Gelasinospora* sp. suggests either undetected burning or very low intensity levels of burning in the local surroundings of Spooners. A lack of T303, but a high presence of *Byssothecium circinans* may suggest a relatively larger presence of woody substrates, rather than grasses growing in drier conditions. T19 values would also suggest a period of *Calluna vulgaris* regrowth. It is also likely that the dominance of T19 and *Byssothecium circinans* spores cause a decrease in the variety of NPP data, as NPPs that occur in lower amounts may not have been detected.

SPO NPP zone 6, 50.5-40.5cm, 710-260 cal BC represents the last zone of the Spooners NPP diagram and covers a very small part of the middle Iron Age and the majority of the late Iron Age. The majority of coprophilous spores remain largely absent during this zone. *Sordaria* sp. show low background values in the middle part of this zone, but remain below 10%. T495 *undiff*. shows a large increase during this last zone, where values of 20% to 30% are reached at around 350 to 70 cal BC. *Byssothecium circinans* has decreased from the previous zone and remains at consistent values between 5% and 15%. T303 *undiff*. shows a similar pattern throughout the zone, but has one large peak at around 350 cal BC, where values increase over 40%. T19 *undiff*. fluctuates throughout the entirety of this final zone, with percentages ranging between 70 and 40.

Interpretation

The final NPP zone of Spooners possibly represents a time period where pastoralist activities did not take place at a high-intensity level. Only *Sordaria* sp. suggests a relatively low intensity/frequency level of grazing took place over the course of this zone. The reoccurrence of T495, from 350 cal BC onwards in particular, may suggest an incline of *Molinia* grasses in the local area of Spooners. T303 implies that drier conditions occurred during the start of the late Iron Age. A high peak of T303 values co-occur with a peak found in the charcoal data and are perhaps associated in a certain way with each other. A decline in *Byssothecium circinans* NPPs could be linked to the decline in *Calluna vulgaris*.

6.3.4 Summary of pollen and NPP results of Spooners

Both pollen and NPP results of the sequence of Spooners indicate that changes in vegetation occurred around similar times. This implies that changes in vegetation occurred within the pollen catchment area, resulting in a good reflection in the NPP data. Below is a brief summary of recorded changes in the pollen and NPP data to compare the pollen and NPP zones. A synthesis of all data is presented in section **6.5**.

The first two pollen and NPP zones, covering a period between 3100 and 1900 cal BC, show few distinct changes and are mainly differentiated after 2330 cal BC by the decrease of charcoal in the pollen diagram and a decrease in *Gelasinospora* sp. and T303 in the NPP diagram. A gradual decrease of coprophilous spores occurs after 2330 cal BC of *Sordaria* sp., *Podospora* sp. and *Cercophora* sp., respectively. Zone 3 presents the most remarkable change in both diagrams. Between 1900 and 1500 cal BC, a large increase of Poaceae and *Potentilla*-type and *Plantago lanceolata* in the pollen data are accompanied by an increase of *Sordaria* sp., *Podospora* sp. and *Sporormiella* sp. in the NPP data. Simultaneously, *Alnus*, *Corylus* and *Calluna vulgaris* all remain under 20%. Between 1500 and 1100 cal BC, arboreal taxa gradually establish a dominance. Values of both Poaceae and *Calluna vulgaris* remain low. Coprophilous fungal spores have dropped to levels similar to the start of the sequence. In the time period ranging between 1100 and 700 cal BC, *Calluna vulgaris* and charcoal increase, whereas Poaceae, *Potentilla*-type and, to a smaller extent, *Alnus* decrease. Coprophilous spores sporadically occur during this time period and are predominantly replaced by *Anthostomella* cf. *fuegiana*, T16 and T19. The final phase starts at 700 cal BC and is marked by a small recurrence of *Sordaria* sp., T495 and T303 in the NPP data. Pollen data shows small increases of *Potentilla*-type and *Succisa pratensis* as well as significant increases in charcoal and Poaceae. *Calluna vulgaris* declines to under 10%, but arboreal taxa remain present, predominantly *Corylus*.

6.4 Multivariate analyses on Spooners' pollen and non-pollen palynomorph data

Multivariate analyses have been carried out on pollen and NPP data from Spooners in order to identify new patterns in the NPP data as well as to explore associations between taxa and how these relate to environmental factors.

6.4.1 Unconstrained ordination of the NPP data

In an initial phase of statistical exploration of the NPP data, a PCA (principal components analysis) was carried out on the NPP dataset of Spooners. Figure **6.6** shows the PCA plot where all main and frequently occurring NPP types have been included. Genus or species names were used for the NPPs when known, otherwise identification follows the NPP guide (Blackford, Innes & Clarke, Forthcoming).

The first axis in figure **6.6** (PC1) explains a total of 34% of the data variance, whereas the second axis (PC2) explains 16% of the NPP distribution. The plot suggests a distribution along the first axis based on the degree of disturbance in an otherwise "natural" occurring vegetation. The majority of types and species located on the right half of the plot are mostly species that are considered indicative of either grazing or post-fire regeneration. The left half of the PCA plot contains a high quantity of NPP types that would indicate a regrowth of *Calluna vulgaris* or *Sphagnum*. Axis 2 appears to be related to certain levels of decomposition and/or levels of wetness in the local area. Indicator types for drier conditions, such as T12, T10 and T303 are positioned near the bottom of the plot. No wet indicator types are showing high positive values, which may explain why axis 2 only accounts for 16% of the distribution of NPP types.

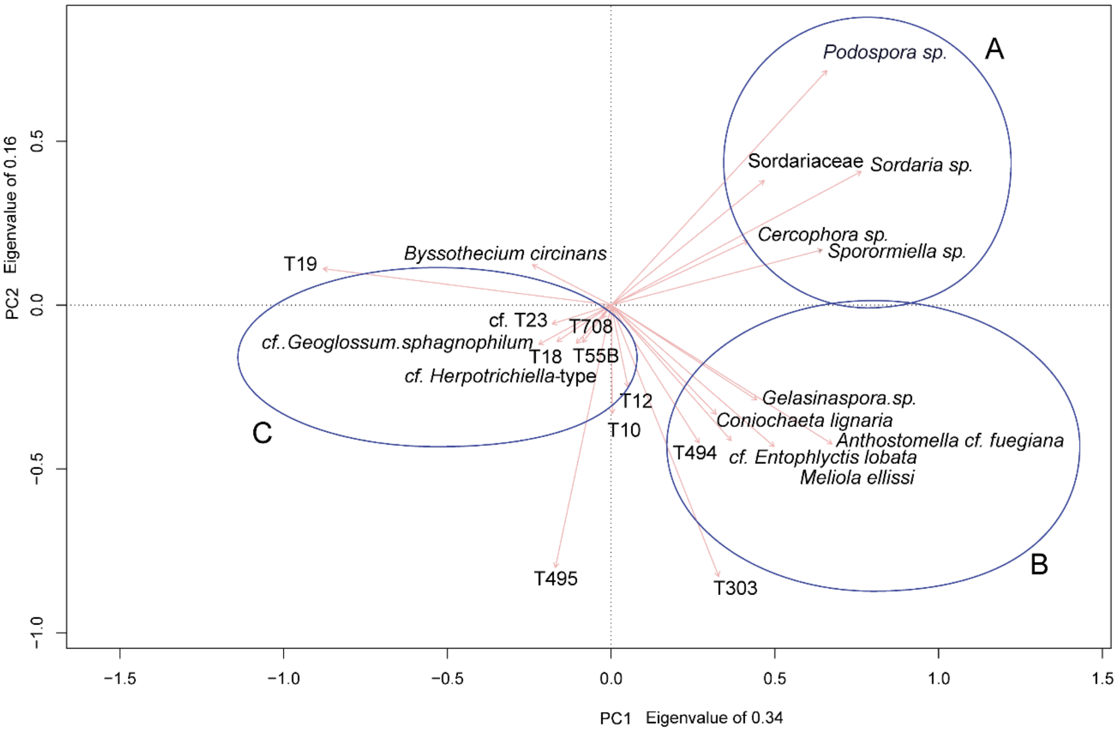


Figure 6.6. *Principal component analysis of the main NPPs found in the entire sequence of Spooners. PC1 explains 34% and PC2 explains a total of 16%. Cluster names (letters A to C) are located next to each indicated cluster, following a clock-wise order.*

An interesting aspect about the PCA plot is that it seems to divide NPP types into three separate clusters, defined by the two axes. The clusters are named A, B and C (see letters in each corner of the PCA plot in figure **6.6**). The types occurring in each "cluster" are presented in table **6.2**, along with their preferred habitat.

Cluster	**Genus/Species/Type**	**Indicative of**
Cluster A – Grazing indicators	*Sordaria* sp.	Grazing
	Podospora sp.	Grazing
	T55B	Grazing
	Cercophora sp.	Grazing
	Sporormiella sp.	Grazing
Cluster B – Early phase of post-disturbance (fire/grazing) regeneration	*Anthostomella cf. fuegiana*	*Eriophorum* and Cyperaceae Well decomposed peat
	Entophlyctis lobata	Woodland/Heathland transition Relatively dry soil samples (*Aquatic saprotroph*)
	Gelasinospora sp.	Post-fire regeneration (Pyrenomycetes) Grazing (levels increase with dung presence)
	Coniochaeta lignaria	Post-fire regeneration (Pyrenomycetes) Grazing (levels increase with dung presence)
	Meliola ellisii	*Calluna vulgaris*, with possible relations with *Vaccinium vitis-idaea*
	T494	*Molinia caerula* tussocks
	T303	Drier phases of peat growth
	T12	Drier phases of peat growth
Cluster C – Poorer soils or perhaps drier conditions	T495	epidermal remains of *Molinia* Well decomposed peat Pocaceae/Cyperaceae pollen
	cf. *Geoglossum sphagnophilum*	Mesotrophic conditions Drier phases of hummock formation
	cf. T23	Associated with *Erica tetralix* and ombrotrophic sphagnum peat
	T18	*Eriophorum vaginatum* Raised bog peat Moist climate
	T708	Eutrophic to mesotrophic conditions Raised and valley mire sites

Table 6.2. *NPPs occurring in the PCA plot, arranged by cluster (A, B and C). Habitats and/or conditions that NPPs are indicative of, are given in the second column and shows how the PCA divides specific types into different clusters each (Blackford, Innes & Clarke, Forthcoming).*

Cluster **A** contains coprophilous fungi types only, which results in a rather straightforward conclusion for this cluster. The second cluster (**B**) presents a mixture of types that could reflect stages in vegetation recovery in the early phases of post-disturbance such as fire or grazing. Other types suggest drier episodes where perhaps *Molinia* grasses and *Calluna vulgaris* are some of the first taxa to dominate the overall vegetation. Cluster **C** is very similar to cluster **B**, but may represent types that appear in a phase following perhaps a long time period of disturbance. The majority of types that are located in this cluster possibly indicate either mesotrophic or eutrophic conditions. This could both be the result of drier climatic conditions, as well as a result of more intense periods of land use and management practices, followed by soil degradation.

6.4.2 Constrained ordination of pollen and NPP data

Following the PCA, a redundancy analysis (RDA) was carried out on the pollen data. The RDA is a statistical tool used in this context to help explain any underlying variation in the pollen data, based on environmental vectors. The first results are from an RDA carried out on the entire studied sequence of Spooners, with charcoal and coprophilous NPPs included as independent variables (environmental vectors) representing burning and grazing, respectively. The second half of the results presented are from sequential RDA's carried out on sets of 20cm depths (a 'moving window approach') to understand the extent to which the strength of explanatory power of the environmental variables change through time. Different sets of 20cms are compared to each other (see also chapter **5.4.2** for more detailed explanations).

Figure **6.7** shows the results of an RDA run on the entire pollen sequence with coprophilous spores and charcoal (z-scores) as environmental variables. A total of 15% is explained by these variables in the plot, where coprophilous spores account for 11.5% of the total. This suggests that grazing was a more dominant driver of the pollen record than the occurrence of fire or the use of burning, but that 85% of the variation in the pollen dataset is not explained by either the coprophilous NPPs or charcoal record. Results of an RDA with all environmental variables included (not presented in this chapter) resulted in a total of 31% explanatory power by the NPP types used as environmental vectors on the total pollen sequence. 69% is thus not directly explained by any identified NPP type, and a part of this percentage could be appointed to both climatic conditions, as well as soil quality. Herbs are largely positively correlated with coprophilous spores (grazing indicators) in the plot of figure **6.7**. The classic disturbance indicator pollen, *Potentilla*-type (Behre, 1981), together with Poaceae pollen, appear to be close to grazing indicators, with Lactuceae to a lesser extent. *Calluna vulgaris* and two arboreal taxa (*Corylus* and *Alnus*) are negatively correlated with grazing conditions. A grass-dominating landscape would have thus been the result of grazing activities altering the landscape from what previously would have been more heath-dominated conditions. Other herbs that could have been expected to show associations with coprophilous spores, such as *Plantago lanceolata* and *Chenopodiaceae*, do not show convincing correlations in the plot when the analysis includes all samples. The only pollen taxon that is closely related to charcoal in the plot is *Succisa pratensis*. The single strong negative correlation with charcoal is that of *Quercus*. Since charcoal explains a total of 3.8% on the entire sequence, RDAs on specific periods in time are necessary to further explore the relations between the pollen assemblage and fire/burning.

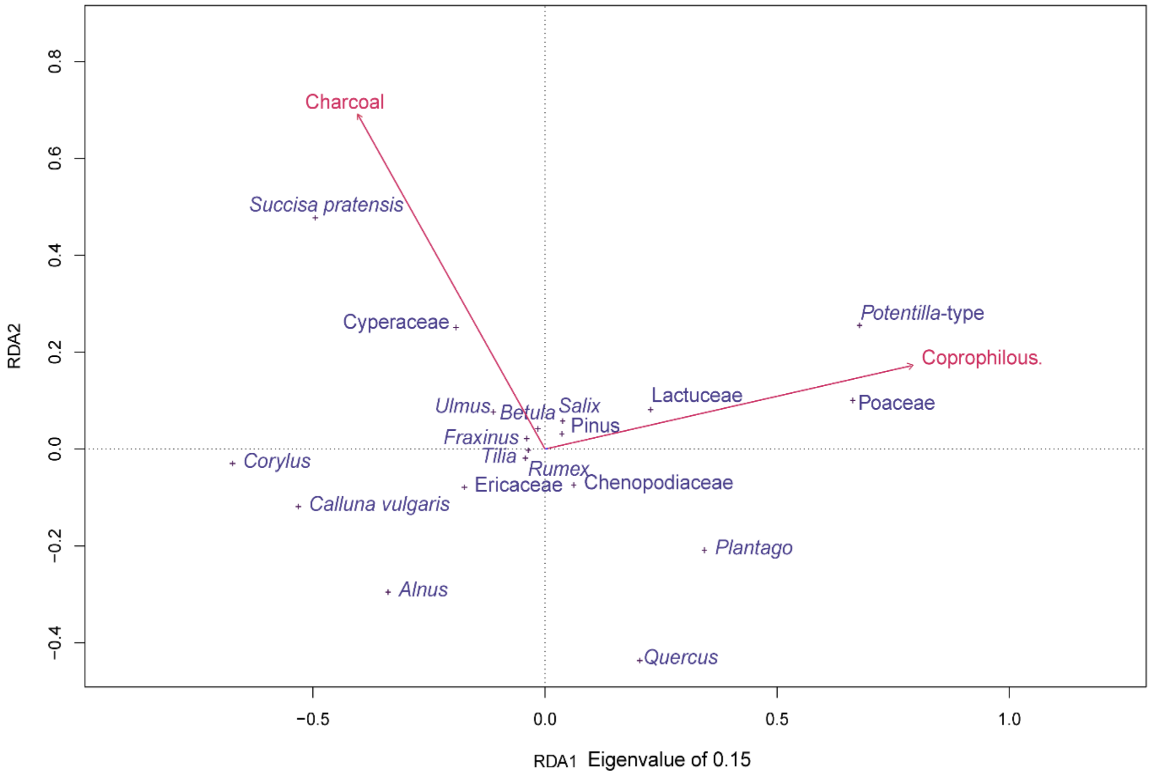


Figure 6.7. *An RDA plot produced from pollen and NPP data of the entire sequence.*

A selection of three plots based on the moving time windows are presented in figure **6.8** (**a**, **b** and **c**). These plots show the explanatory power of different combinations of environmental variables through the moving-window approach to the RDA. It is noticeable that for each combination of environmental variables included, changes occur in the power of explanatory power of vectors through time and are thus not static. Furthermore, results show that the inclusion of charcoal as a single environmental vector has the lowest significance of explanation from all three vector combinations.

All three plots generally show similar patterns of percentage increases and decreases through time. At around the end of the Neolithic (until *2300 cal BC*), charcoal shows a relative high value of approximately 10%, whereas coprophilous NPPs show a steady increase from 10% to 30%. Both variables lose significant influence on the pollen assemblage during the first half of the early Bronze Age (*2300-1500 cal BC*), whereas a rise in values occurs towards the start of the middle Bronze Age. The highest percentages are reached during the middle Bronze Age (*1500-1000 cal BC*). The combination of coprophilous NPPs and charcoal reach a value of 51% at its peak, revealing the change in relevant influence fire/burning and grazing can have on the surrounding vegetation. However, this peak consists of a short life span and percentage values half in numbers during the second half of the middle Bronze Age. A difference between the two environmental variables is evident during the late Bronze Age (*1000 to 800 cal BC*). Around this time period, coprophilous NPPs only decrease in value. Charcoal exhibits a relatively small, but continuous, increase from 8% to 13% percent.

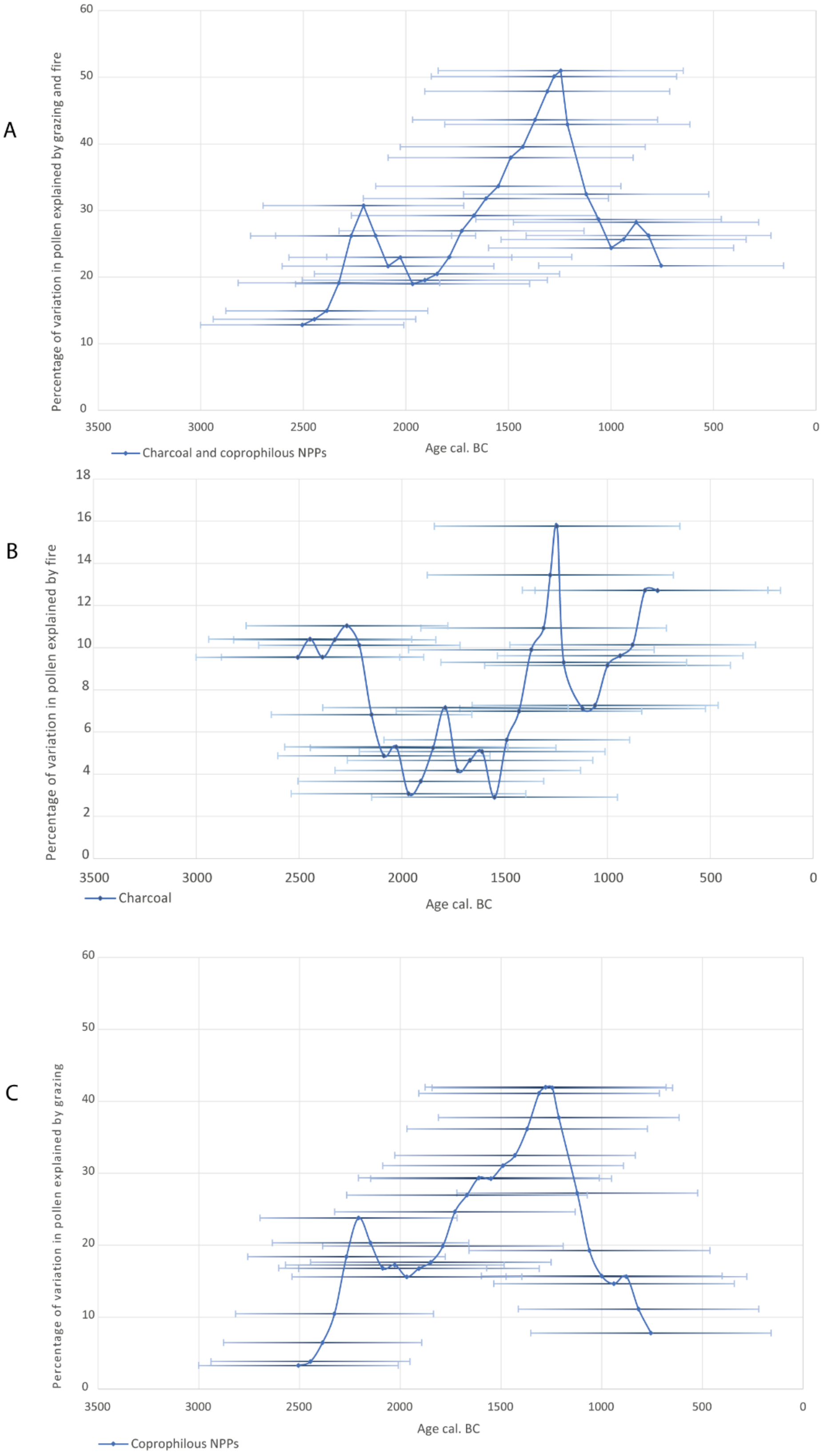


Figure 6.8. *(**a**, **b** and **c**). Variation in pollen explained by three different environmental variable combinations through time, expressed in percentages. A moving window approach was used, meaning that the ages given in the horizontal axis represent the mean ages per set of 20 samples. The entire age range, represented by each percentage point, is indicated by the blue bars attached to each marker point.*

Three different RDAs were produced in order to better visualise the data presented in figure **6.8c** (showing the moving time window values of coprophilous NPPs). Figures **6.9 a**, **b** and **c** show three separate RDA 'species biplots' produced with the pollen data, where coprophilous NPPs were included as an environmental variable. **6.9a** depicts the RDA taken on the set of sample depths of 48.5cm to 68.5cm (c. 430 - 1680 cal BC), with an exploratory value of 42%. This is the time frame associated with the highest explanatory value.

Disturbance indicators *Potentilla*-type, *Rumex acetosa*, *Plantago lanceolata* and Chenopodiaceae pollen show positive correlations to coprophilous NPPs to different extents. Lactuceae pollen, regarded as indicators for open habitats and pastoralism (Florenzano *et al.*, 2015), show positive correlations to the presence of coprophilous NPPs. The high associations with Poaceae would suggest that grazing mainly resulted in a grass-dominated landscape. Tree pollen *Alnus* and *Corylus*, as well as shrub *Calluna vulgaris* are negatively associated with coprophilous NPPs. All (indicator) pollen taxa that are positively associated with coprophilous NPPs, shifted position in the second RDA plot (figure **6.9b**). Whilst there are still positive associations, the significance is lower than in **6.9a**; the total value of explanation of coprophilous NPPs on pollen variation has decreased to 24% and for samples between 65.5cm to 85.5cm (1430 – 2730 cal BC).

The most significant difference between plot **6.9a** and **b** are the missing high positive associations between Poaceae and grazing, alongside an increased negative correlation between grazing and *Calluna vulgaris*. Values for Chenopodiaceae and *Rumex acetosa* pollen have shifted as well, resulting in a neutral and negative correspondence, respectively. Comparisons between the first two RDA plots and the third (figure **6.8c**) show few similarities in pollen distribution. This third RDA has been produced on the pollen samples from depths ranging between 70.5cm to 89.5cm (1815 – 2990 cal BC), with an exploratory value of only 4%. The pollen distribution on the plot shows a positive correlation of *Plantago lanceolata* and Chenopodiaceae. It is however, questionable how reliable these associations appear to be, as *Alnus, Salix*, Ericaceae, Cyperaceae and *Succisa pratensis* also show (low) positive associations with coprophilous spores. It could also be possible that these taxa are part of a specific type of vegetation that was promoted by low-intensity grazing activities prior to the middle Bronze Age. *Potentilla*-type, *Rumex acetosa* and Poaceae show either neutral or negative associations with pastoralism, suggesting that a different environmental factor has a larger influence on the pollen variation during this time period.

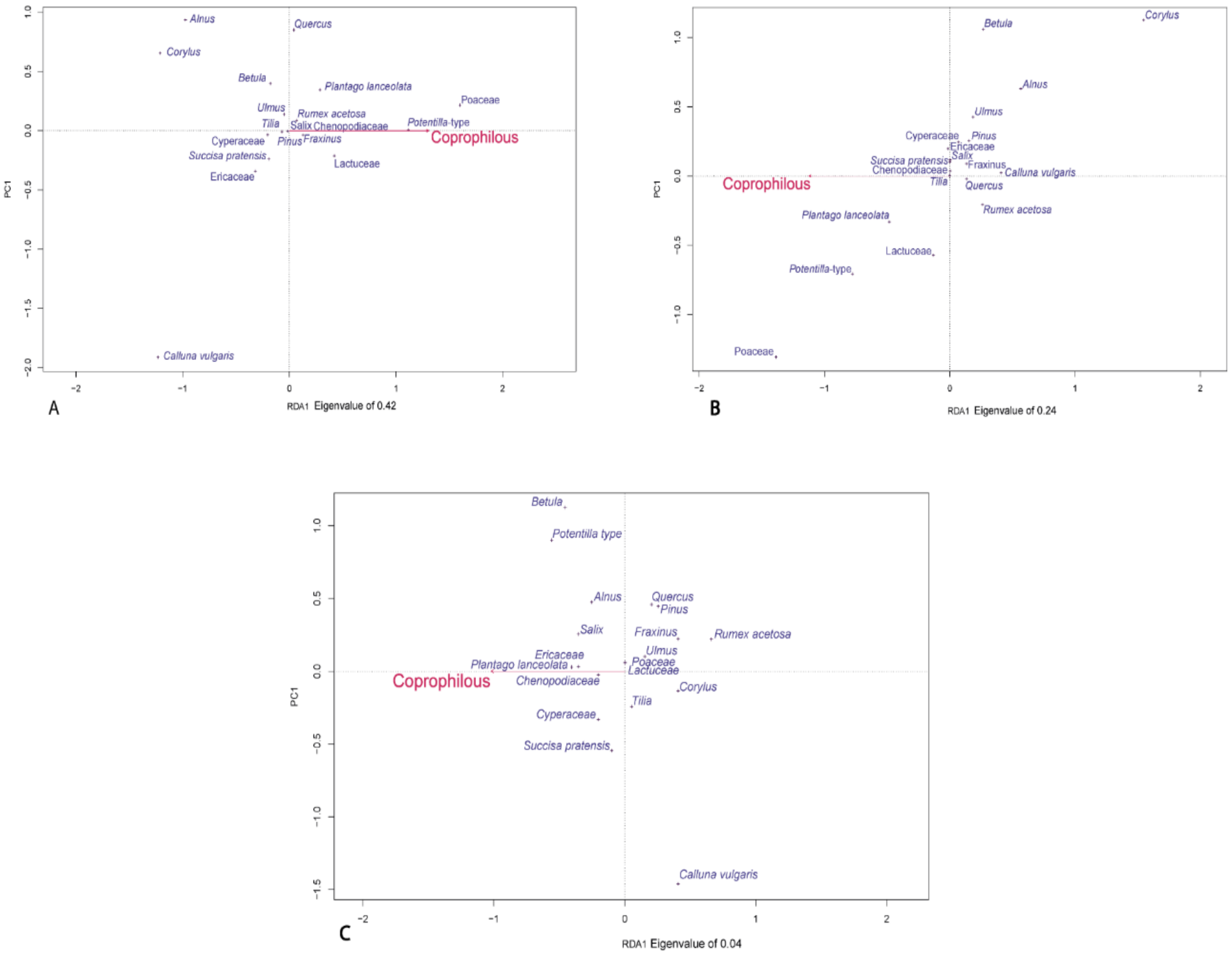


Figure 6.9. (**a**, **b** and **c**). *RDA plots produced from pollen and coprophilous NPP data at three different stages in time, based on the RDA moving window results. Each plot represents the following time frames: A) 710-1850 cal BC, B) 1130-2330 cal BC and C) 1910-3100 cal BC.*

6.5 Evaluating prehistoric land use and environmental changes at Spooners

A total of six distinct phases of land use are identifiable in the combination of pollen and NPP data from the sequence at Spooners. The majority of the phases are reflected in both the pollen and NPP diagrams, which are often in agreement at this site. The phases are identified by eye, and not with any statistical analysis or other method.

SPO phase 1, 90.5-77.5cm, 3100 – 2330 cal BC

Phase 1 covers the end of the Neolithic period and shows a low background level of coprophilous NPPs. This phase represents an initial increase followed by a decrease in *Corylus*, together with other, more background tree taxa, e.g. *Alnus*. Poaceae show little fluctuation. *Calluna vulgaris* shows little fluctuation in general as well, apart from two peaks. The presence of local burning is indicated by high levels of micro charcoal. *Gelasinospora* sp. confirm the presence of burning on a local scale, with peaks of the species found at similar depths as the peaks found in micro charcoal, at around 2600 cal BC. *Calluna vulgaris* could have been a target species for burning, considering a drop in its values appears at a similar time as the charcoal and *Gelasinospora* sp. peak. Although this phase might not show a high level of intense land use, the low, but consistent, values of coprophilous spores indicate a perhaps discontinuous use of the local area for grazing. Stone settings, alongside several other archaeological features mentioned in section **6.2.2** suggest land use during the late Neolithic close to Spooners (Bray, Carey & Fyfe, 2015b; Riley & Wilson-North, 2001). Burning could have been used as a tool to control the growth of heather and promote grazing, but perhaps interchangeably with other local areas within the region.

SPO Phase 2, 77.5-70.5cm, 2330 – 1910 cal BC

Phase 2 represents the first half of the early Bronze Age and could be identified as a zone of less intense land use. The lack of *Gelasinospora* sp. and a great drop in the (micro) charcoal data suggests that burning was no longer/frequently in use to control vegetation growth during this phase. It appears from the NPP diagram that pastoralist activities remained present also during this phase at Spooners. There is, however, a shift in the composition of coprophilous spores. During phase 1, *Sordaria* sp. (T55A) were the dominant type, but during phase 2 this shifted to a dominance in *Podospora* sp. The identified change in composition could have several possible causes. One of these options could be that *Podospora* sp. represents the presence/grazing of a different type of animal than T55A does, considering studies have found statistical evidence for groups of fungal species to be associated with different types of herbivores (Richardson, 2001). In this context, it is impossible to research this, as NPPs are only identified to type number and not species. Another likely option is that *Podospora* sp. thrives better in the changed conditions of the area, due to an increase of heather, or perhaps a decrease in burning intensity. These changed conditions are also reflected in other types of NPPs. For instance, a combination of the large increase in T19 and the disappearance of T303 could indicate wetter conditions in the local vicinity of the site. The higher levels of *Byssothecium circinans* might confirm this hypothesis, as it likely indicates a regrowth of local heather. It appears to have been especially the case at the end of this phase, as T19 increased to over 100%.

SPO Phase 3, 70.5-63.5cm, 1910 – 1430 cal BC

Phase 3 covers the last part of the early Bronze Age. This phase represents a time period of approximately 480 years where an increase in intensity of land use took place. This change is mainly reflected in the NPP diagram, but to a lesser extent in the pollen diagram as well. It is the only phase of the studied sequence where coprophilous NPP values exceed the 50% mark. *Sordaria* sp. and *Podospora* sp. dominate the coprophilous group, but increases are also visible in *Sporormiella* sp. and *Cercophora* sp. A rise in *Potentilla-type* pollen and a smaller incline in *Plantago lanceolata* suggest a higher level of disturbance during this period. The difference with phase 1 is that there is very little indication for the presence of fire and thus indicate that burning was not (regularly) used to control heather or tree growth around this time. The pollen in this phase do show a large decline in all tree species. *Corylus* remains the best represented taxon, but is largely under 20% TLP. *Calluna vulgaris* stays relatively similar compared to previous phases. A drop in T19 in combination with a rise in Poaceae suggests that local heather was mainly replaced with open grassland. The continuity of the NPP coprophilous spores around this time suggest that at around 1550 cal BC, pastoral activities remained present as a dominant type of land use at Spooners.

SPO Phase 4, 63.5-54.5cm, 1430 – 800 cal BC

The whole of the middle Bronze Age, alongside the transition into the late Bronze Age is reflected in phase 4. A gradual regeneration of the dominating tree taxa, particularly *Corylus*, *Alnus* and in lower values, *Quercus,* take place during this time period. A small reappearance of *Ulmus* and an increased frequency of low-value *Betula* also emerge during this phase. The recurrence of T494 and T495 could be associated with an increase in arboreal taxa pollen, particularly with *Corylus*. Poaceae values gradually decrease over the length of phase 4, as do *Calluna vulgaris* values. However, the dominance of coprophilous spores in the NPP diagram shows a sudden drop from the very start of this phase. For the majority of phase 4, the total values of all coprophilous spores combined remains around 10%. A similar drop in *Potentilla-type* pollen values occur at the start of this phase and do not show any increase until phase 6 (late Iron Age).

The reappearance of both T303 and *Anthostomella cf. fuegiana* appear to be slightly contradictive in the first instance, since the first is considered an indicator of drier periods, whilst the latter has been regarded as a proxy for Cyperaceae (Van Geel, 1978). They could however simply reflect smaller fluctuations within this phase of what seems to be a period of less intensive land use. Very low levels of charcoal counts suggest that burning was not intensely in use as a tool during this phase. Conditions are comparable to those of phase 1, before the charcoal peaks, with a grass-dominated local landscape. *Alnus* would have occurred more frequently than during phase 1, and would have most likely occupied the lower-elevation area around Spooners. A small exception on the dominance of heather could be assigned to a period at around 1300 cal BC. A short-lived increase of *Byssothecium circinans* suggests a local increase of heather, but values in the time period of around 1170 cal BC show similar levels as the rest of the phase.

SPO Phase 5, 54.5-47.5cm, 800 – 400 cal BC

Phase 5 represents a period of relatively lower levels of intense land use. It covers the early Iron Age. The main indicator for a period of less intense land use lies in the pollen data, shown by a large increase of *Calluna vulgaris*. Compared to almost all previous phases, percentages double in values during this phase and reach a high of 43% at around 800 cal BC. Furthermore, there are hardly any counts of coprophilous spores during this phase, and in the rare occasion they do occur on the diagram, values remain under 3%. Instead, *Byssothecium circinans* shows a large increase, which could be associated with a local increase of heather. T19 is the most dominant NPP type during this phase, whilst both T303 and *Anthostomella cf. fuegiana* disappear from the NPP diagram. *Potentilla*-type pollen show an even greater absence than in phase 4 and suggests, in combination with heather regeneration, that the area was relatively less (frequently) disturbed by human land use and/or management. It could have been the case that the local surroundings were used or occupied in ways that remain undetectable in the pollen or NPP data. A second option could be that phases of intensified land use were only of short life-spans, or that the area was only seasonally occupied. The single possible piece of evidence for land use in the vicinity of Spooners, is the increase in charcoal values during this phase. The pollen diagram suggests that heather species were not greatly impacted by burning, as was the case in phase 1.

Instead of heather plants, certain arboreal taxa, such as the declining *Alnus*, or perhaps other types of shrubs/herbs, were targeted by burning during this phase. This would allow for more time and space for heather regrowth.

SPO Phase 6, 47.5-40.5cm, 400 cal BC – 49 cal AD

Phase 6 is the last phase identified in the high-resolution Spooners sequence and covers a large part of the late Iron Age. It covers a period of around 400 years with a relative increased level of land use intensity. T495, which has been associated with certain *Molinia* grasses, shows a rise in the NPP diagram. Furthermore, a sharp rise in Poaceae alongside a major decrease in *Calluna vulgaris* occurs at the immediate start of phase 6. The fact that a similar drop in *Byssothecium circinans* occurs, could imply that *Calluna* became less dominant on both a local and a wider scale. A peak of the highest charcoal levels of the sequence occurs at around 350 cal BC. A similar peak of T303 around the same time, may indicate an association between T303 and perhaps overall drier conditions as a result of burning. It could also be possible that fire and T303 increase around this time due to drier climatic conditions. This would in turn enable burning to a higher extent. Interestingly, *Gelasinospora* sp., which are associated with fire and showed relatively high values during phase 1, only show a value of 2% at around 350 cal BC and are furthermore absent for the remainder of the phase. Charcoal counts do show lower values for the remainder of phase 6, but are still showing a higher presence than in phase 3, 4 and 5, respectively. A low value presence of *Sordaria* sp. reappear in the data during this phase, but remain very low at values of under 10%, whereas other coprophilous species show an even higher level of absence during this phase.

6.6 Summary

By the end of the Neolithic, local burning around Spooners had already started taking place. The surrounding area of Spooners has been dominated by Poaceae around this time as a probable result of the burning of heather. Small hints of pastoralist activities were found in the NPP data and suggest either low-intense grazing or seasonal/temporal grazing in the immediate surroundings of Spooners. With a shift to the early Bronze Age, a drop in the charcoal data suggested fire/burning had become less frequent around Spooners. NPP data indicates a continuum of moderate or short-term episodes of pastoralism, alongside increased local wetness. Whilst a decrease in fire/burning is noticeable in the data, grass remained the most dominant vegetation type and a complete regrowth of heather did not occur during the early Bronze Age. Phase 3 presents a period of around 400 years where strong evidence for pastoralism is detectable in the NPP data. As a result of intensified grazing in the local surroundings, the landscape around Spooners was dominated by Poaceae, with a low presence of fire/burning activities. Whilst a decline in trees occurred, herb taxa, indicative of disturbance, increased in quantity during this phase. Throughout the middle and late Bronze Age, similar conditions to that of late Neolithic landscape took place at Spooners. A drop in coprophilous NPPs, a decrease in disturbance indicator pollen taxa and a lack of evidence for burning, points towards a period of less intense land use. *Alnus* re-appeared in a higher frequency, but *Calluna vulgaris* remained less dominant than Poaceae. During the majority of the early Iron Age, a shift to *Calluna vulgaris* dominance occurred, alongside an increase in fire/burning. With these two contradicting events, it could be possible that any type of land use that would alter the vegetation composition happened on a too low intensity to become detectable in the pollen or NPP data, suggesting a period of less intense land use. A final phase covers a 400 year period at Spooners where grasses once again dominate the vegetation. A peak in the charcoal data shows that the highest levels of burning took place during the second half of the Iron Age in and around the site area. Although not much evidence can be found on pastoralist activities during this period in time, NPP data does suggest that local conditions had become drier around Spooners.

Chapter 7 – Codsend Moors' results

7.1 Introduction

This chapter presents and discusses the results of the high-resolution non-pollen palynomorph (NPP) and pollen analyses carried out on peat samples from the site Codsend Moors. The chapter focuses on a comparison between indicators of land management (through NPPs and charcoal data) and vegetation patterns (through pollen). It includes a statistical analysis of pollen, NPP and charcoal data in order to further understand the vegetation composition and how changes therein occur due to changing environmental factors. Similar to Great Buscombe and Spooners, previous palaeoecological knowledge of the area surrounding Codsend Moors, together with its close proximity to field systems, were significant deciding factors for the addition of this site to the project. Figure **7.1** shows a view of the landscape of Codsend Moors, taken from the hill opposite to the area.

Figure 7.1. *View of Codsend Moors, taken from Kitnor Heath (located to the south of Codsend Moors). ©English Heritage.*

7.2.1 Archaeology of Codsend Moors

Field archaeology on Codsend Moors, and its neighbouring area Hoar Moor, has been the subject of several studies in the past decades. The area contains the most visible and best-preserved prehistoric field systems on Exmoor. A study published in 1989 at Codsend Moors focussed on the prehistoric earthworks visible in the field. It appeared that many stony banks and lynchets that were found in the area had been extensively robbed, and thus must have attracted people long after their time of creation (Patterson & Sainsbury, 1989). Apart from stony banks and lynchets, many so-called “stone heaps” were found, which are usually identified as clearance cairns in later field surveys. The study assumed that most archaeological field features are of a later Bronze Age date. However, earlier studies linking woodland clearance to agricultural activity during the early Bronze Age, as well as the late Iron Age, suggest that the area had been inhabited throughout prehistoric times (Patterson & Sainsbury, 1989).

The first palaeoecological research was carried out by Francis and Slater in 1992, where a 91cm deep core was collected on the hillslope. The bottom of the core dated to approximately 470 cal BC. This lead to the suggestion that peat inception took place during a time of climatic deterioration (Francis & Slater, 1992). Based on the fossil pollen data, the general vegetation community was described to have mainly consisted of rather open forest and scrubland. There is no clear evidence for any arable cultivation being carried out during the earliest levels of the peat core, and peat formation was suggested to have either been directly caused, or partially stimulated, by forest and brush clearance as a result of livestock grazing activities (Francis & Slater, 1992).

Two more recent field surveys have been carried out in the area of Hoar Moor and Codsend Moors in order to identify and locate any possible archaeological features in the field. A 2008 survey enabled the discovery of more archaeological features in the surrounding area of Codsend Moors. These features include stone cairns, hillslope enclosures and hut circles. One of the most significant outcomes in the field was the detailed mapping of both aggregate and coaxial-type field systems. These were defined by either stony banks or lynchets. In some cases, hillslope enclosures were found to have been built over parts of the field systems. The majority of stone cairns found have been directly associated with the relict field systems and are often believed to be the result of field clearance (Riley, 2009).

The most recent field survey in the same area was carried out in 2016 and included the findings of previously unrecorded prehistoric field boundaries and burial mounds (Riley, 2016). A new number of stony banks were recorded during this survey that may have been part of coaxial field systems in the area of Codsend Moors. Further results from the 2016 survey include a small number of (possible) upright stones, of which one would have been part of a stone setting. Although all previously mentioned features were assumed to date back to prehistoric times, not many have been dated. On a distance of 1km away from the area of survey lies Dunkery Beacon, where at least one funerary cairn was found, assumed to date to 2500 -1500 cal BC (Riley, 2009).

7.2.2 Fieldwork on Codsend Moors

A ground-penetrating radar (GPR) assessment was carried out in order to obtain an insight into peat depths across Codsend Moors, as well as to find the most appropriate core location (Fyfe & Ombashi, 2018a). The assessment showed an average peat depth of 0.56m in the area, but this was highly variable along the assessed transects of the survey. The peat formation is believed to have been formed from a spring, which was spreading both down the slope as well as laterally across the slopes (Fyfe & Ombashi, 2018a). Locations of the spring mire were identifiable in the field through small raised areas that enabled growth for greater amounts of *Sphagnum*. A second stage of the peat depth assessment took place higher up the slope, further removed from a prehistoric field system, where the GPR transects were located. Results from the probing include a few transects that are in close proximity to the area once used for peat sampling in 1992, at an altitude of 461m OD (Francis & Slater, 1992). The peat was collected in the most open section, along the manual coring line that ran west/north-west – to east (see figure **7.1**). Samples were collected in 30x10x5 and 50x10x5 monolith tins and resulted in a total peat depth to 1.15m (Fyfe & Ombashi, 2018a).

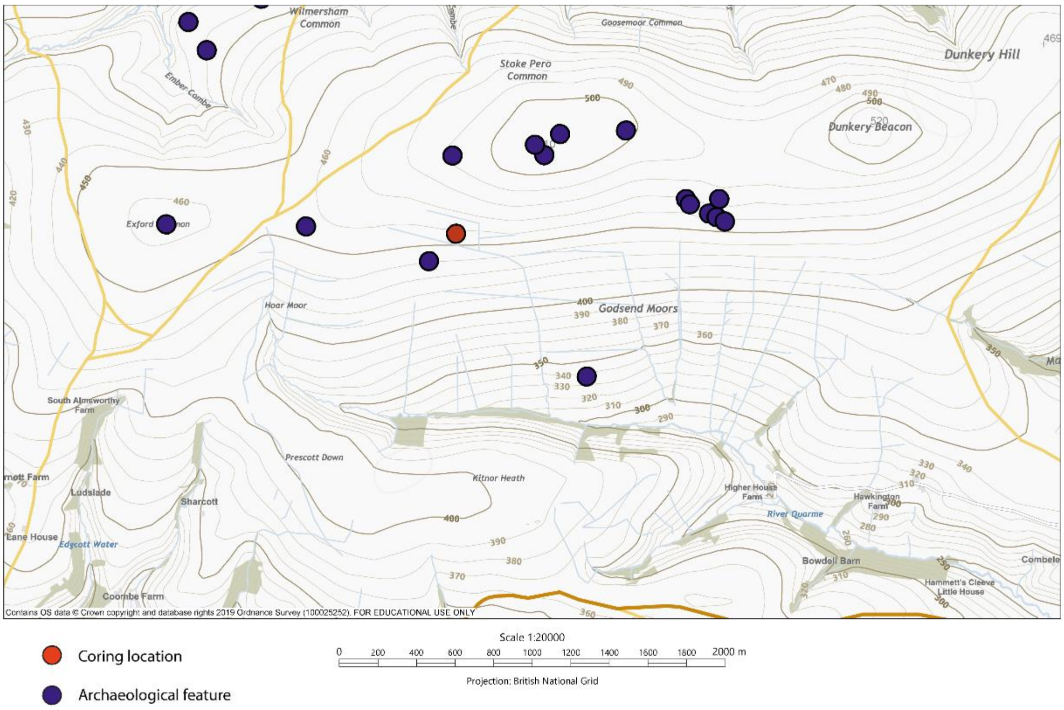


Figure 7.2. *Coring location of samples at Codsend Moors and archaeological features in the surrounding depicted on a background vector map from EDINA Digimap Ordnance Survey Service.*

7.3 Results

7.3.1 Dating results

Following the peat depth assessment and collection, described in section **7.1**, five subsamples were collected from the monolith tins to be used for producing radiocarbon dates. Table **7.1** presents the results and further necessary details of these radiocarbon dates. The dates were used to identify the section of the cored sequence that spanned the time period of this study (late prehistory). The radiocarbon date stemming from the top sample is not included in the age-depth model shown in figure **7.3**, considering it does not change the model, but is not included in the time period of interest. No stratigraphy or loss-on-ignition data was available of this site, and is thus not presented in this study.

Depth (cm)	Lab code	14Cdate BP	Material	Calibrated age BC/AD
49-50	BETA-487789	1230±30	Humin acid	AD 690-880
75-76	BETA-487790	1860±30	Humin acid	AD 80-230
95-96	BETA-487791	2310±30	Humin acid	410-230 BC
104-105	BETA-487792	2520±30	Humin acid	790-540 BC
110-111	BETA-497793	2900±30	Humin acid	1210-1000 BC

Table 7.1 *Results of radiocarbon analysis. Calibration of all dates are carried out in OxCal and the chosen calibrated ages are within a 95% range of possibility.*

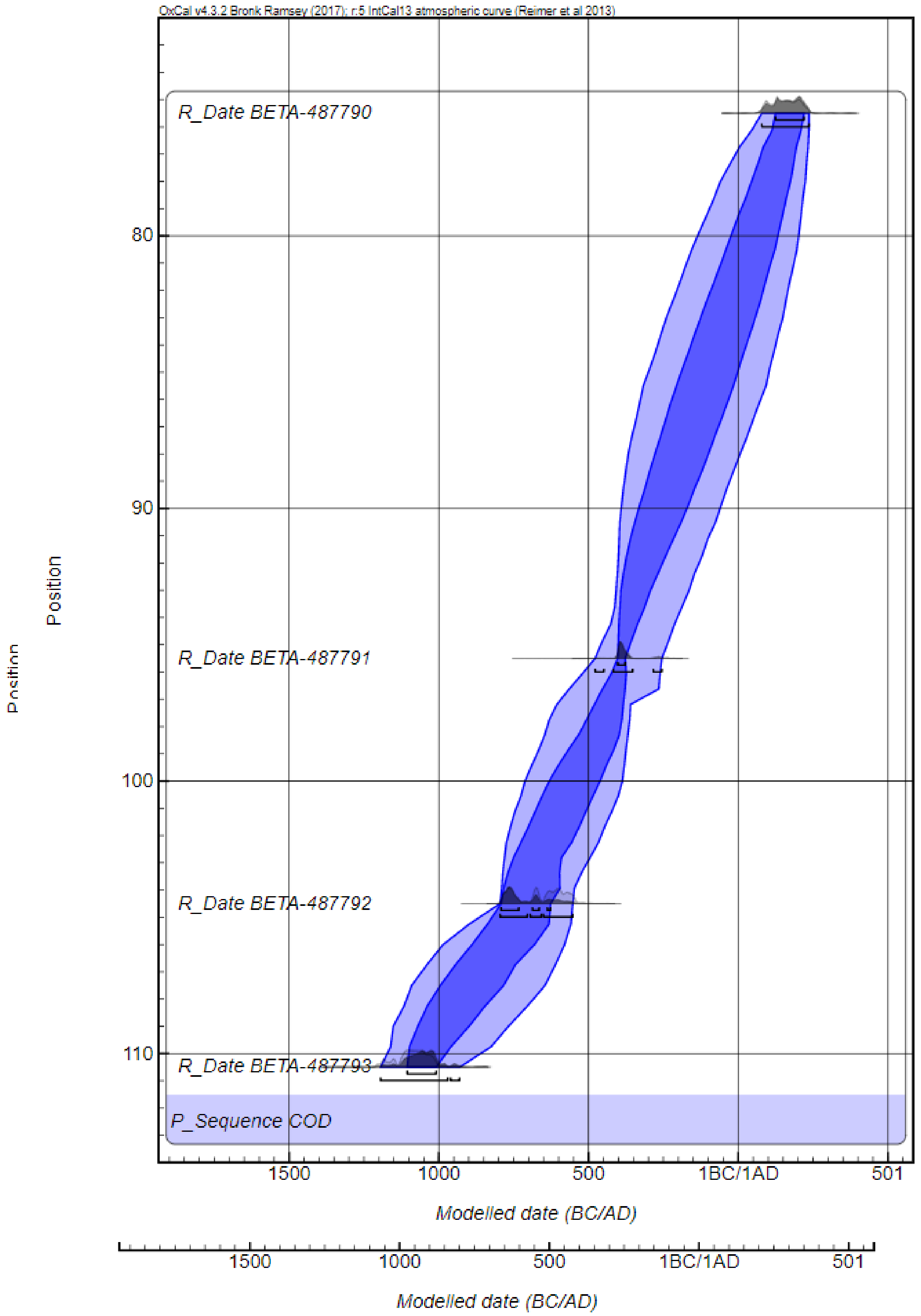


Figure 7.3. *Age-depth model of Codsend Moors, based on four out of five radiocarbon dates shown in table* 7.1 *For the creation of this model, OxCal was used (IntCal13). The dark blue area reflects a 68.2% probability age range and the lighter blue depicts a 95.4% probability age range.*

7.3.2 Pollen data results

Results of the pollen data are shown in figure **7.4**, covering 30 samples, and have been divided into zones, based on visually-identified shifts in species composition. The descriptions below present the pollen data per pollen zone.

COD P-zone 1, 114.25-108.25cm, (1180-920 cal BC) represents a time period of around 260 years, taking place in the later stage of the middle Bronze Age (*1500-1000* cal *BC*) and the transition into the late Bronze Age (*100-800* cal *BC*).

Calluna vulgaris' values range around 10% throughout the first half of the zone, but increase up to 40% in the second half. Poaceae values remain relatively consistent throughout the entire zone, but drop around 5% during the last ±90 years of this zone. Disturbance indicators *Potentilla*-type and *Plantago lanceolata* show values of up to 3% higher in the first half, until around 1120 cal BC and during the last 90 years of this zone. Charcoal data shows a peak during the first half of zone 1, but remain present towards the end of this zone. A larger decrease is noticeable in the macro charcoal at around 1040 cal BC, but shows an increase from this point onwards until the end of this zone.

Arboreal taxa make up 25% of the total land pollen during the second half of this zone, whereas the beginning of the zone shows a 50% tree taxa value of the TLP. This decrease is mainly noticeable in the three most dominant tree taxa: *Corylus* (losing 10%), *Alnus* and *Quercus*, although nearly all "background" arboreal taxa decline.

Interpretation

A combination of high charcoal values, relatively high disturbance indicator taxa and relatively low values of *Calluna vulgaris* suggest that the first half of COD P zone 1 was part of a phase of more intense land use. Relatively high charcoal values during the first half of COD P zone 1 suggest that burning was already in use as a land management tool during the middle Bronze Age at Codsend Moors, with *Calluna vulgaris* as the most plausible main target of burning.

The intensity could have declined during the second phase of this zone, as lower charcoal values suggest less fire events. This would have given *Calluna vulgaris* more space and/or time to regrow in the region around Codsend. This pattern is reflected in the pollen diagram in the sense of a 30% increase of *Calluna vulgaris* from c. 1080 cal BC onwards.

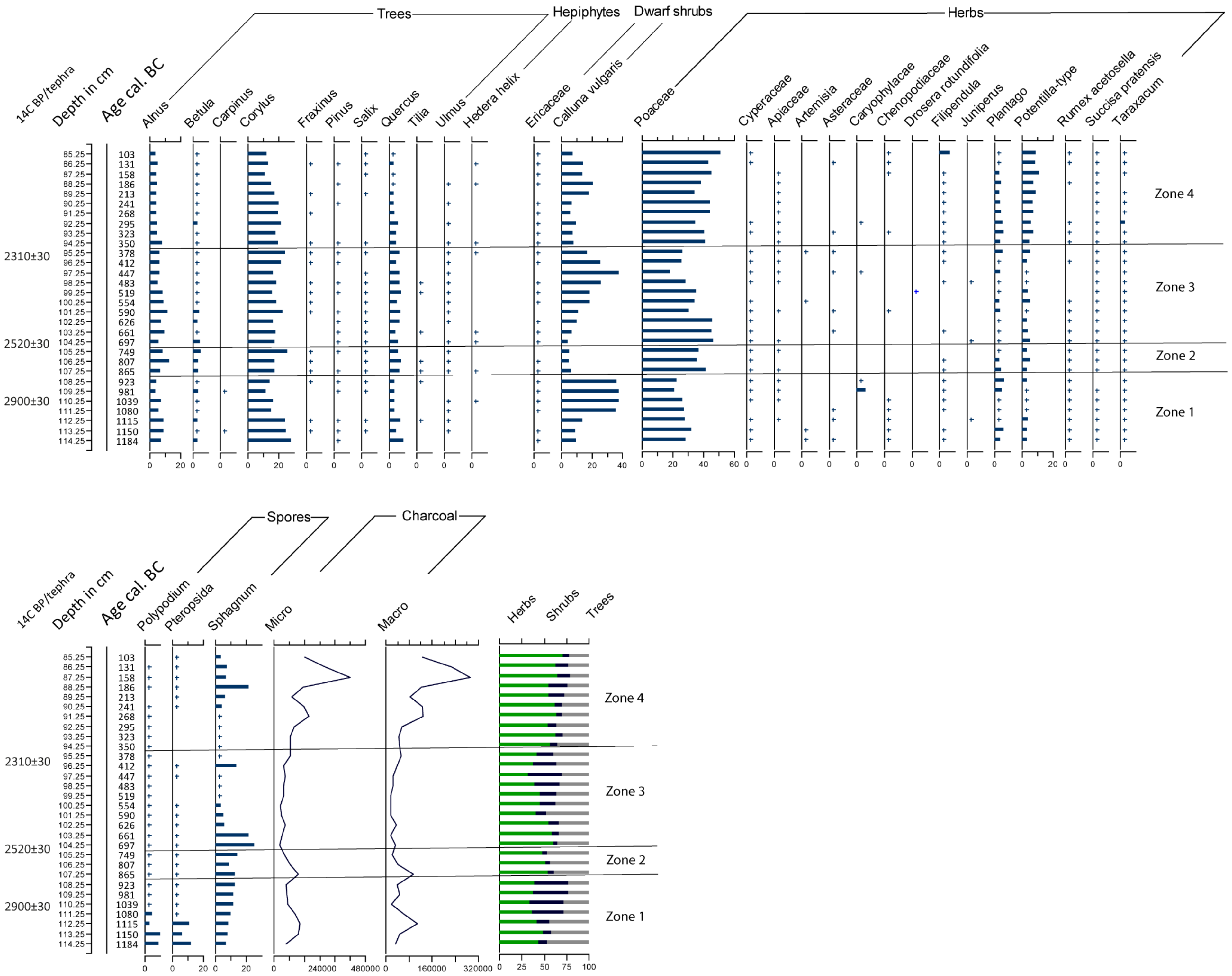


Figure 7.4. *High-resolution pollen analysis on Codsend Moors' pollen and charcoal dataset.*

COD P-zone 2, 107.25-102.25cm, (865-630 cal BC) covers the second half of the late Bronze Age, as well as the majority of the early Iron Age. A time period spanning around 230 years is represented in this pollen zone. *Calluna vulgaris* levels are at 10% or lower during this phase, whereas Poaceae values range between 40% to 50%. Arboreal taxa remain under 50% of TLP, but show minor value increases since the start of this zone. *Corylus*, *Alnus* and *Quercus* all show minor, although uncorrelated, fluctuations during this zone. A relatively sudden rise in the charcoal values appear at the start of this zone, but gradually decrease back over the span of COD P zone 3. Although percentages of *Plantago lanceolata* remain under 3% for the second half of zone 3, *Potentilla*-type remains around 4% to 5% during the entire zone. Lastly, this zone also covers a large rise in *Sphagnum* spores. A period of around 20 to 30 years at the top of the zone show *Sphagnum* values of around 25%, which is the highest value found in the entire pollen dataset. Charcoal values initiate with a relatively small peak at the beginning of this zone, but show a gradual decline over the course, with the lowest point occurring at around 700 cal BC.

Interpretation

COD P-zone 2 suggests to have been a period of relatively intense land use on Codsend Moors. It is, however, slightly different in character from the land use phase occurring in the first half of COD P-zone 1. During this zone, not as much evidence in the charcoal is present to suggest a similar amount or intensity of burning used as a land management tool. The landscape was most likely grass-dominated, with perhaps a small increase of trees in the surrounding areas of Codsend Moors. A relatively sudden drop in *Calluna vulgaris* from the start of this zone onwards, does suggest that some form of land use took place and alternated the vegetation patterns. Considering no cereal pollen have been found and fire intensity being lower than during COD P-zone 1, grazing would be the most likely reason to explain the sudden drop in heather during this entire zone. Lastly, at around 700 cal BC, conditions would have become slightly wetter, indicated by an increase of *Sphagnum* alongside a drop in charcoal values.

COD P-zone 3, 101.25-95.25cm, (590-380 cal BC) represents a time period of around 200 years, covering the first half of the middle Iron Age (*600-400* cal *BC*). Although a rise in *Calluna vulgaris* is visible from the base of the zone, peak values aren't reached until 450 cal BC. At 450 cal BC, a percentage value of 50 is reached, preceding a decrease to 15%. Poaceae values show a minor drop in the middle of this zone, where the lowest values are around 20%. In the periods both before and after this drop, Poaceae values average around 30%. Tree taxa do not show any major shifts since COD P-zone 2 and are a few percentages lower than in the previous zone. Charcoal values are comparable to those of the lowest values of COD P-zone 2 and remain consistent throughout the entire of zone 3. High *Sphagnum* levels showing at the final stage of COD P-zone 2 (25%) have now decreased to below 3% from the beginning of this zone. The main disturbance-indicator pollen types, such as *Plantago lanceolata* and *Potentilla*-type and *Rumex acetosa*, all range between 3% and 0%.

Interpretation

COD P-zone 3 shows a shift of a grass-dominated to a *Calluna*-dominated landscape. This is likely to have been the result of a phase of relatively less intensive land use, where *Calluna vulgaris* regrowth occurred over the course of a few decades. Low charcoal values suggest that burning was not intensively used as a type of land management. A possible small increase of burning, however, did likely occur from approximately 400 cal BC onwards. Several indications for perhaps lower-intensity disturbance are given by temporarily inclines in *Potentilla*-type and *Plantago* pollen. This could suggest that within this zone, land use intensity may have altered on a low scale. A short period at the top of this zone indicates for a temporal period of wetter/moister conditions, occurring at around ±410 cal BC.

<u>COD P-zone 4, 94.25-85.25cm, (350-100 cal BC)</u> covers a period of approximately 250 years, spanning the majority of the Iron Age. Although a decline of heather pollen initiated approximately a hundred years before the start of this zone, values were still relatively high, compared to values from 350 cal BC onwards. Values double from approximately 200 cal BC onwards, but show a decline in the final 30 years of this zone. Poaceae also show an increase from the start of COD P-zone 4, with values rising from 30% to 40%. They remain around the 40% value for the entirety of zone 4. An initial rise in both macro- and micro charcoal values takes place from the start of this zone, with a second larger increase at around 160 cal BC. Both main disturbance-indicator taxa (*Plantago* and *Potentilla*-type) show increased values ranging between 3% an 8% throughout the zone, with a small decline in *Plantago*

towards the top of the zone. The total amount of tree taxa reach a percentage of 30 of TLP, predominantly caused by the onset of a gradual decline in *Corylus* from the base of this zone onwards. A further decline of around 5% occurs during approximately the second half of this zone. *Pteropsida* spores remain largely absent during this time zone, although it hardly exceeds background values during the majority of this sequence. *Sphagnum* percentages also show low values of 3% or lower, up until ±240 cal BC. A sudden and short-term peak in *Sphagnum* occurs a final time at around 200 cal BC.

Interpretation

This final pollen zone shows a shift back to a grass-dominated landscape around Codsend Moors. Even though *Calluna vulgaris* levels do show a small increase during the second half of this phase, Poaceae values suggest they remain to be the most dominant taxa throughout the Iron Age in the surroundings of Codsend Moors. This entire zone suggests to have been a phase of higher levels of intense land use, with a change in vegetation response from approximately 240 cal BC onwards. During the entirety of the zone, charcoal values suggest that burning was in use as a tool to manage heather growth and show an intensified period during the second half of the zone. In the first ±100 years of this zone, *Calluna vulgaris* values remain relatively low, but show almost double the values during the second ±100 of this zone. This could perhaps reflect a change in the intensity of burning events during the second half of the Iron Age. Another possible explanation for this shift could, however, be that heather became less of a target for burning during the final half of the Iron Age at Codsend Moors. *Sphagnum* values suggest relatively drier local bog conditions in the first half, with an increase towards wetter conditions (especially at around c. 180 cal

BC). A change in wetness could have also played at least part of a role in the observed changes that initiated at around 200 cal BC.

7.3.3 Non-pollen palynomorph results

The NPP diagram (see figure **7.5**) is divided into seven different NPP zones, based on observed patterns and/or changes in type presence. These observations were established by eye, and not by numerical analysis. Below are the composition changes in the NPP dataset described per established zone.

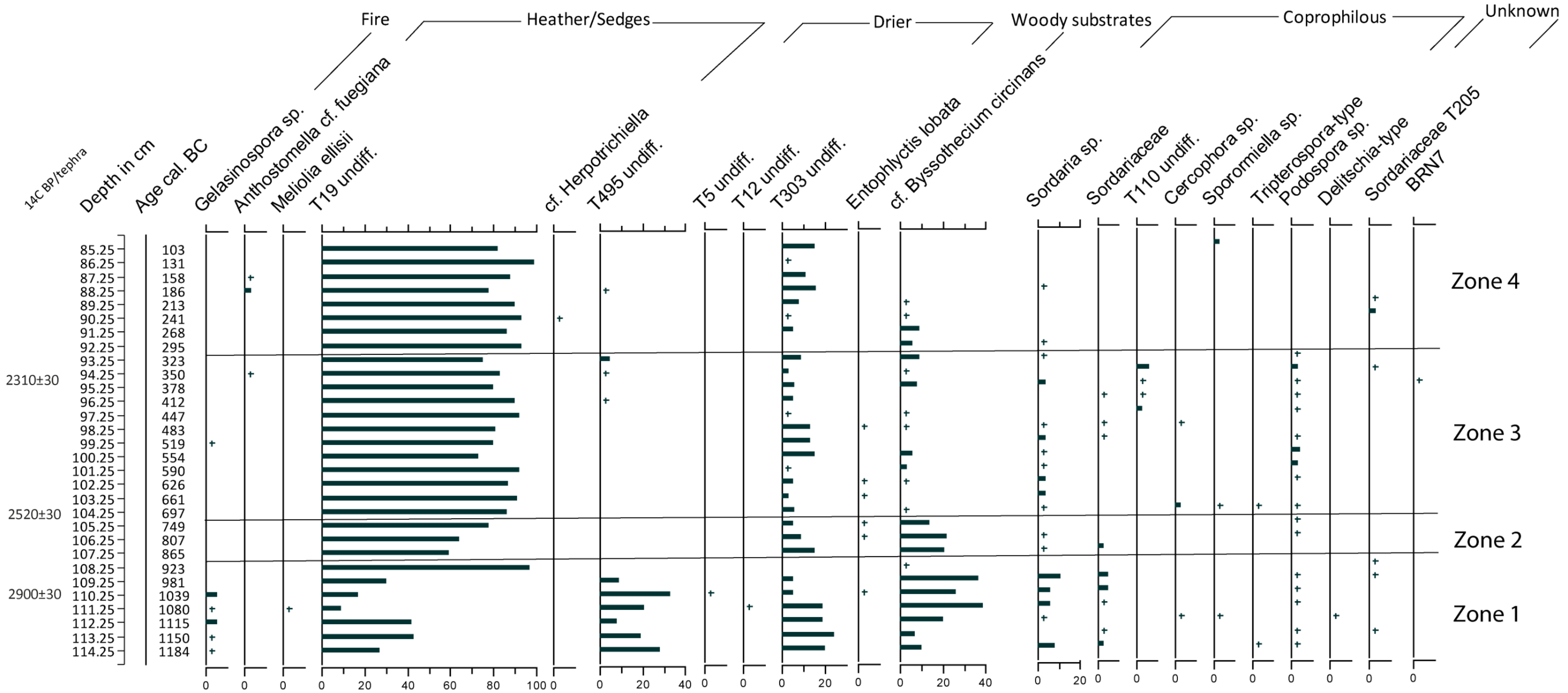


Figure 7.5. *Non-pollen palynomorph diagram of Codsend Moors. Spores that are not identified to species level are given a type number ("T"), which refers to the "HdV" types of Van Geel.*

COD NPP-zone 1, 114.25-108.25cm, (1180-920 cal BC) covers a time period of about 260 years, representing a large part of the middle Bronze Age. This zone is rather dissimilar in NPP composition from the rest of the sequence. T19 (*undiff.*), which is highly dominant in the majority of this sequence, does not exceed approximately 40% during this zone, but outcompetes any other spores at the top. T19 shares its dominance with the T495 (*undiff*.), which shows similar values ranging between 10% and 40%. T303 (*undiff.*) remains at 20% values for the majority of the zone. However, during the last 40 years, it declines to 5%. *Byssothecium circinans* shows a reverse shift with values of 10% for the first 30 years, after which it increases to 20% or 40% for the remainder of the zone. Zone 1 is the only zone in the sequence where *Gelasinospora* sp. are continuously present. Values do remain below 5%, but such a consistent presence is not found in any following zones in the NPP dataset. A final feature adding to this zone's dissimilarity to others, is that the coprophilous NPPs show the highest peak in the sequence. This is mainly based on *Sordaria* sp. with values of 6% to 11%, but lower background values of under 3% are visible for *Podospora* sp. and T55B (classified as "Sordariaceae" in the diagram).

Interpretation

This zone is likely to represent a phase wherein large compositional shifts took place, which can be linked to several changes in the vegetation patterns. The high presence of T495 could either be associated with the grass-domination, as was indicated by the pollen diagram, or could be indicative of the presence of epidermal *Molinia* remains. A combination of T303, T12 and T5 suggest drier phases of peat growth during this time period. An incline of *Byssothecium circinans* half way during the zone can be associated with the sudden, but simultaneous *Calluna vulgaris* incline, visible in the pollen diagram.

A continuous presence of several coprophilous NPPs suggests that pastoralist activities would have taken place relatively intensely throughout this time in prehistory.

The final ±50 years could have been a relatively short-term period of extreme local heather growth and/or increased local wetness, as suggested by a sudden rise of T19. There are, however, no clear indications from the pollen diagram for this period to have been very different on a regional scale.

COD NPP-zone 2, 107.25-105.25cm, (870-750 cal BC) starts at 870 cal BC and lasts for a period of 120 years. It represents the transition of the late Bronze Age into the early Iron Age. The main dominating NPP is T19, starting with values of 60% at the bottom of the zone and showing a continuous rise towards values of 80%, approximately. *Byssothecium circinans* consistently ranges around the 20% mark. T303 (*undiff*.) shows a gradual, linear decline from 15% to 3% over the course of this time period. *Sordaria* sp. and *Podospora* sp. are the only present coprophilous spores during this zone, but none of their values exceed the 3% mark.

Interpretation

This zone in the NPP diagram is likely to represent a phase where local wetness increased, as suggested by a decline in T303, alongside an increase of T19. A combination of the increasing levels of T19 and *Byssothecium circinans* could also reflect a gradual increasing dominance of heather and/or sedges in the near vicinity of Codsend Moors. Although there is a lower level of diversity in the coprophilous NPPs found in this zone, it nevertheless indicates that grazing still occurred at some times during the transition of the Bronze Age into the Iron Age.

COD NPP-zone 3, 104.25-93.25cm, (700-300 cal BC) is the zone with the longest time-span, lasting for approximately 400 years. It covers the transition of the early Iron Age into the middle Iron Age, as well as the first ±80 years of the late Iron Age. Although small fluctuations do occur, T19 shows to be very dominant throughout the entire zone with values ranging between 70% and 90%. T303 (*undiff*.) shows values ranging around 5% for the majority of this zone, but these increase to 15% during the first half of the middle Iron Age. A small reoccurrence of T495 appears at the second half of this zone, but remains relatively low compared to zone 1, under 3%. The first occurrence (low value) of *Anthostomella* cf. *fuegiana* appears during this zone, as well as the only occurrence of NPP type "BRN7".

All coprophilous NPP types that are identified for this sequence occur at least once during this zone. The most dominant, as well as continuous, types are *Sordaria* sp. and *Podospora* sp. In the part of this zone that covers the middle Iron Age, both *Entophlyctis lobata* and *Gelasinospora* sp., occur in the NPP diagram for a final time, with values remaining below 3%.

Interpretation

Consistently high levels of T19 during this zone, with only minor fluctuations in values, suggests this to have been a phase of relatively low-changes in local patterns, perhaps as the result of lower fire activity, as is indicated by consistently low charcoal values throughout this phase. Apart from T19, the most dominant coprophilous NPPs also indicate relative stability during this phase. Low levels of *Byssothecium circinans* do not show any direct association with the presence of relatively higher *Calluna vulgaris* pollen. Perhaps the large dominance of T19 would make it harder to detect any smaller changes in the NPP composition. Peaks of T303 at around the middle Iron Age could indicate a c.100 time period where bog conditions were relatively drier, before returning back to the average taken over the entire zone.

COD NPP-zone 4, 92.25-89.25cm, (300- 100cal BC) covers a time period of approximately 200 years and represents the majority of the late Iron Age. The zone begins with an instant increase of T19 to values averaging around 90%. T303 shows a peak of values ranging around 15% during the top half of the zone with a small interruption at around 130 cal BC. *Byssothecium circinans* values are higher in the first half of the zone (c.7%) but decline to values below 3% after ±240 cal BC, after which it does not recur in the NPP data. This zone shows to have a large absence of coprophilous NPPs. *Sordaria* sp. occur twice at background values and *Sporormiella* sp. occur once with a value below 5%. This final NPP zone contains little variation within NPP types, but do show a single appearance of *Anthostomella* cf. *fuegiana*, T495 (*undiff*.) and cf. *Herpotrichiella* sp. The most likely reason for such a low variety or low values of most types may be related to the strong dominance of T19.

Interpretation

The final zone of this diagram shows very few indications for the continuation of grazing activities taking place. Even though pollen data indicated a domination of Poaceae, there is no reflection in a rise of *Byssothecium circinans*. T19 reaches a high dominance during this period in time and could perhaps have been the result of *Calluna vulgaris* remaining unaffected by the low grazing intensity, compared to previous zones. T303 indicate a drier phase from ±210 cal BC onwards. It cannot be said with certainty if the interruption at around 130 cal BC is caused by changed wetness levels or whether high levels of T19 preventing a detection of other NPP types. These high levels do however co-occur with the highest peaks in the charcoal data and could perhaps be related to drier conditions as a result of burning.

7.3.4 Summary of pollen and NPP results of Codsend Moors

Both pollen and NPP results of the sequence of Codsend Moors indicate that changes in vegetation occurred around similar times. This implies that changes in vegetation occurred in an area large enough to cover the landscape close to the sequence location, or that the sequence location was close to the centre of recorded pollen, resulting in a good reflection in the NPP data. Below is a brief summary of recorded changes in the pollen and NPP data to compare the pollen and NPP zones. A synthesis of all data is discussed in section **6.5**.

From 1200 until 1080 cal BC, Poaceae dominates, alongside a strong presence of *Alnus*, *Corylus* and *Quercus*. *Calluna vulgaris* shows low values. After 1080 cal BC, *Calluna* *vulgaris* dominates, whilst a decrease is evident in charcoal levels, arboreal taxa and *Potentilla*-type pollen. A shift in the NPP data occurs within a similar time frame, where a dominance of T19, T303 and T495 are replaced by T16. *Sordaria* sp. and *Podospora* sp. remain present until c. 880 cal BC. *Sordaria* sp. shows an increase after 1080 cal BC. The time period between 880 and 590 cal BC is marked by an increase of charcoal values and *Potentilla*-type. *Calluna vulgaris* remains under 10% and is replaced by arboreal taxa and Poaceae. Shifts in the NPP data entail a combination of T19, T16 and T303 at the start of this zone, but T19 established dominance after 700 cal BC. Coprophilous spores remain consistently present, albeit under 10%. Between 590 and 350 cal BC, *Calluna vulgaris* reaches values between 20% and 40%, whereas Poaceae remains around 20%. Charcoal and *Alnus* values decline during this phase. The NPP data shows no significant shifts during this phase and remains relatively consistent until 325 cal BC, showing only minor fluctuations between T19 and T303 only. This may suggest that changes recorded in the pollen diagram did not necessarily took place within the local surroundings of Codsend Moors, but more across a regional area. Zone 4 shows similarities with zone 1, in the sense that the first half (from 350 to 200 cal BC), Poaceae dominates, *Calluna vulgaris* is under 10% and *Potentilla*-type and *Plantago lanceolata* show increased values. Charcoal values have increased since zone 3, but reach their peak after 200 cal BC, where *Calluna vulgaris* dominates and Poaceae and arboreal taxa decline. *Potentilla*-type and *Plantago lanceolata* remain at similar levels until 100 cal BC. This final phase shows small amounts of change in the NPP data. However, the sporadic appearance of coprophilous spores throughout the rest of the sequence does not occur from 300 cal BC onwards.

7.4 Multivariate analyses on Codsend Moors' pollen, non-pollen palynomorph and charcoal data

A multivariate analysis on both the NPP and pollen data has been carried out in order to a) further explore patterns within the NPP data and b) to explore to what extent NPP and charcoal data are capable of explaining any identified variation within the pollen data. Both unconstrained and constrained ordination has been carried out and the results will be discussed in separate sections.

7.4.1 Unconstrained ordination of the NPP data

A PCA (principal component analysis) was carried out in the first, exploratory, phase of analysing the NPP data. Figure **7.6** shows the PCA plot of all frequently occurring NPPs from the entire dataset of Codsend Moors, along with the eigenvalues of the axes.

PC1 (the first axis) explains a total of 31%, whereas PC2 (the second axis) explains a total of 13% (see figure **7.6**). T19 suggests a direct association with PC1 and thus indicates that the distribution of the NPPs along this axis is based on their level of co-occurrence with T19. With T19 lying directly on the PC1 line, indications for either relations with wet or dry conditions would explain the distribution along this axis, or the presence/absence of high levels of heather or sedges. This hypothesis is encouraged with the close association of T19 with *Anthostomella* cf. *fuegiana*, which is an indicator of Cyperaceae or *Eriophorum vaginatum*.

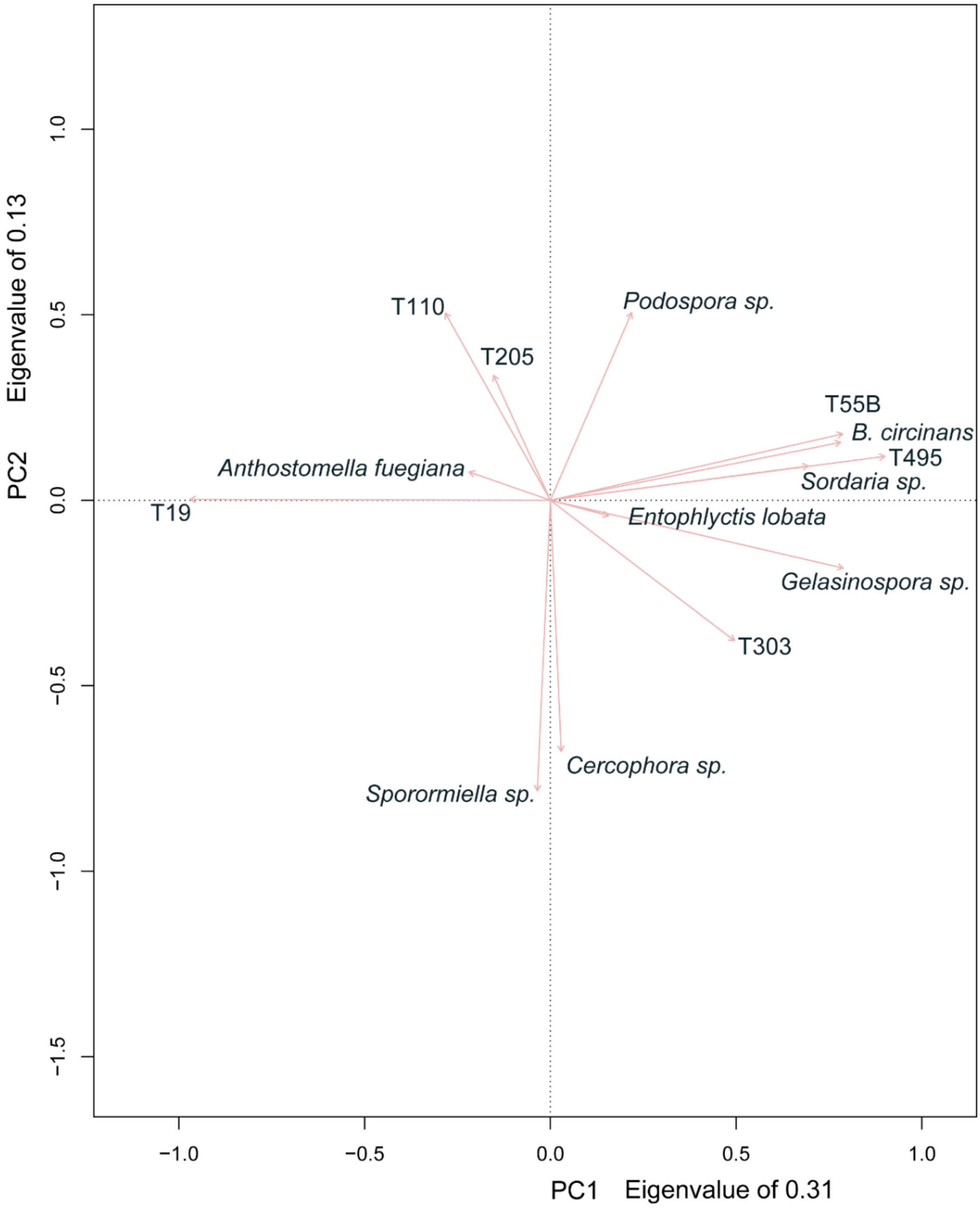


Figure 7.6. *Principal components analysis of the frequently present NPPs found in the entire sequence of Codsend Moors.*

Several NPPs move in an opposite direction from T19, although none of these are directly aligned with PC1. The four types closest to PC1 are *Entophlyctis lobata*, *Gelasinospora* sp., *Sordaria* sp. and T495. The latter two are separated from the first two by PC1, but all four types indicate that positive PC1 values can be linked to either grass-dominating land, or drier conditions of peat development. It is also noteworthy to mention that both pairs are directly aligned with each other. T303 is closely related to *Entophlyctis lobata* and *Gelasinospora* sp., suggesting drier phases of peat growth. Two other types of NPPs that go in similar directions are T55B (non-obligate coprophilous fungal spore) and *Byssothecium circinans*. Considering they are both closely located to T495 and *Sordaria* sp.*,* it can be assumed that they represent grazing in grass-dominated (perhaps *Mollinia*-dominated) landscapes. It is apparent that coprophilous NPPs are not all following similar directions, as was visible in the PCA plots of both Spooners and Great Buscombe. Instead, *Podospora* sp. shows a higher correspondence to PC2, as does T110. Both NPP types show different associations with PC1. Perhaps the degree of wetness or grass-abundance can explain why these coprophilous NPPs do not occur in similar conditions. Two other coprophilous NPPs move in an opposite direction and do not show any significant association with PC1, but a negative correlation to PC2. *Cercophora* sp. and *Sporormiella* sp. show a direct relationship, but no other NPP type shows any sign of association with them. Both types do not appear at simultaneous times of peaks in *Sordaria* sp. and *Podospora* sp. in the NPP diagram. This may explain why they show these different PCA results, although any immediate reason cannot be stated exclusively based on the diagram or PCA of the NPP data.

7.4.2 Constrained ordination of pollen, NPP and charcoal data

Succeeding the exploratory phase of the NPP data using a PCA, a redundancy analysis (RDA) was carried out on the pollen data. NPP and charcoal data was used as environmental vectors in the RDAs. Specifically selected NPP or charcoal data is used to attempt to explain any underlying variation within the pollen data of Codsend Moors. Whilst micro charcoal may also include natural fire, by the late Bronze Age in Britain this is largely thought to reflect human-induced burning.

The RDA plots presented in figures **7.7 A**, **B** and **C** are the results of RDAs run on pollen data from the entire sequence, with coprophilous NPPs, charcoal z-scores and a combination of both included as environmental vectors in each plot. Coprophilous NPPs are used as grazing indicators, whereas charcoal data represents past fire activity in the area of Codsend Moors.

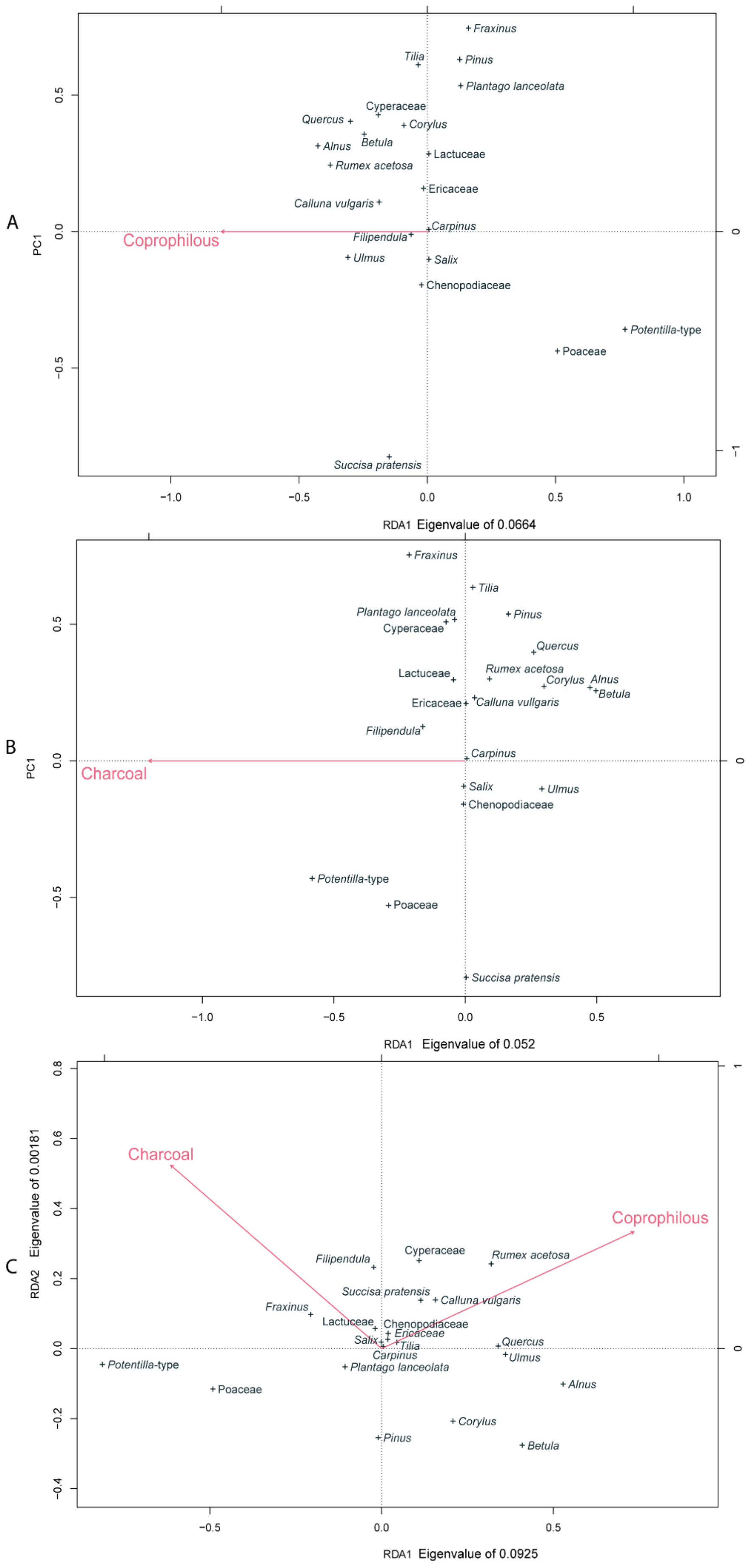


Figure 7.7 ***A***, ***B*** *and* ***C.*** *RDAs of percentage pollen explained by coprophilous NPPs and/or charcoal data, based on the entire sequence.*

Figure **7.7A** shows the results of the RDA where coprophilous NPPs were the single environmental vector included and explain a total of 6.6% of variation in the pollen data. The main taxa showing positive associations with coprophilous NPPs are *Calluna vulgaris*, *Ulmus*, *Filipendula* and to a lesser extent, *Rumex acetosa*. Two main taxa that show a negative correlation with grazing are Poaceae and *Potentilla*-type. A total of 93% is unexplained in this plot. This suggests that grazing is not a strong determinant of vegetation patterns from the entire dataset. A higher-detailed examination of the influence of grazing on the pollen data at different points in time may show patterns.

Figure **7.7B** show the RDA results where charcoal z-scores is included as a single environmental factor and shows an even lower percentage for the overall sequence. A total 5.2% of pollen variation is explained by micro charcoal concentrations, with Poaceae, *Potentilla*-type and *Filipendula* as the only three taxa showing a positive, albeit weak, correlation. The majority of taxa with negative associations are arboreal taxa, along with *Calluna vulgaris*. Results of the RDA where both grazing and fire are included as environmental vectors are presented in figure **7.7C.**

The third RDA analysis (figure **7.7C**) uses both coprophilous NPPs and charcoal concentrations as explanatory variables for the pollen data. A total of 9.2% variation in pollen can be explained. Associations stay relatively similar to results shown in the previous RDA plots. *Potentilla*-type and Poaceae pollen remain positively associated with charcoal and negatively associated with coprophilous NPPs. *Calluna vulgaris* remains positively correlated to grazing, but shows a more neutral correlation with charcoal in this plot, compared to figure **7.7B**. Arboreal taxa show an intensified negative correlation to fire compared to the plot in **7.7B**, and remain lightly associated with coprophilous NPPs. A final remark on this plot is that coprophilous NPPs and charcoal run in almost opposite directions and thus do not correlate with each other.

As with previous analysis and using the approach described in section **4.5.2**, a moving time window approach was used. Figure **7.8** shows the fluctuation of RDA eigenvalues based on the moving time windows. The graph including both environmental vectors shows a high comparison with the graph of coprophilous NPPs and an even greater similarity with the charcoal-only graph. It presents small fluctuations during the early Iron Age, followed by a small drop around the 600 cal BC average period. During the middle Iron Age (*600-400* cal *BC*), plot **A** shows an incline starting from ±9% to 15%. Plot **B** shows a similar increase, going from 5% to nearly 9%, but shows a slight drop of 1% before reaching the 400 cal BC average. During the early Iron Age (*800-600* cal *BC*), higher fluctuations in the coprophilous plot (**B**) exist, compared to plot **A**. Where early Iron Age fluctuations remain within a one percent range in plot **A**, they fluctuate within a range of three percent in plot **B**. Fire shows a small (±1%) loss of significance during the early Iron Age and an increase of ±2% during the transition into the middle Iron Age. After a small stagnation of approximately 50 years on average, the increase in significant percentage carries on until the 400 cal BC average marker point in the graph. Although slightly lower in values than plot **A**, the line in plot **B** shows a very similar movement after the start of the middle Iron Age onwards in particular.

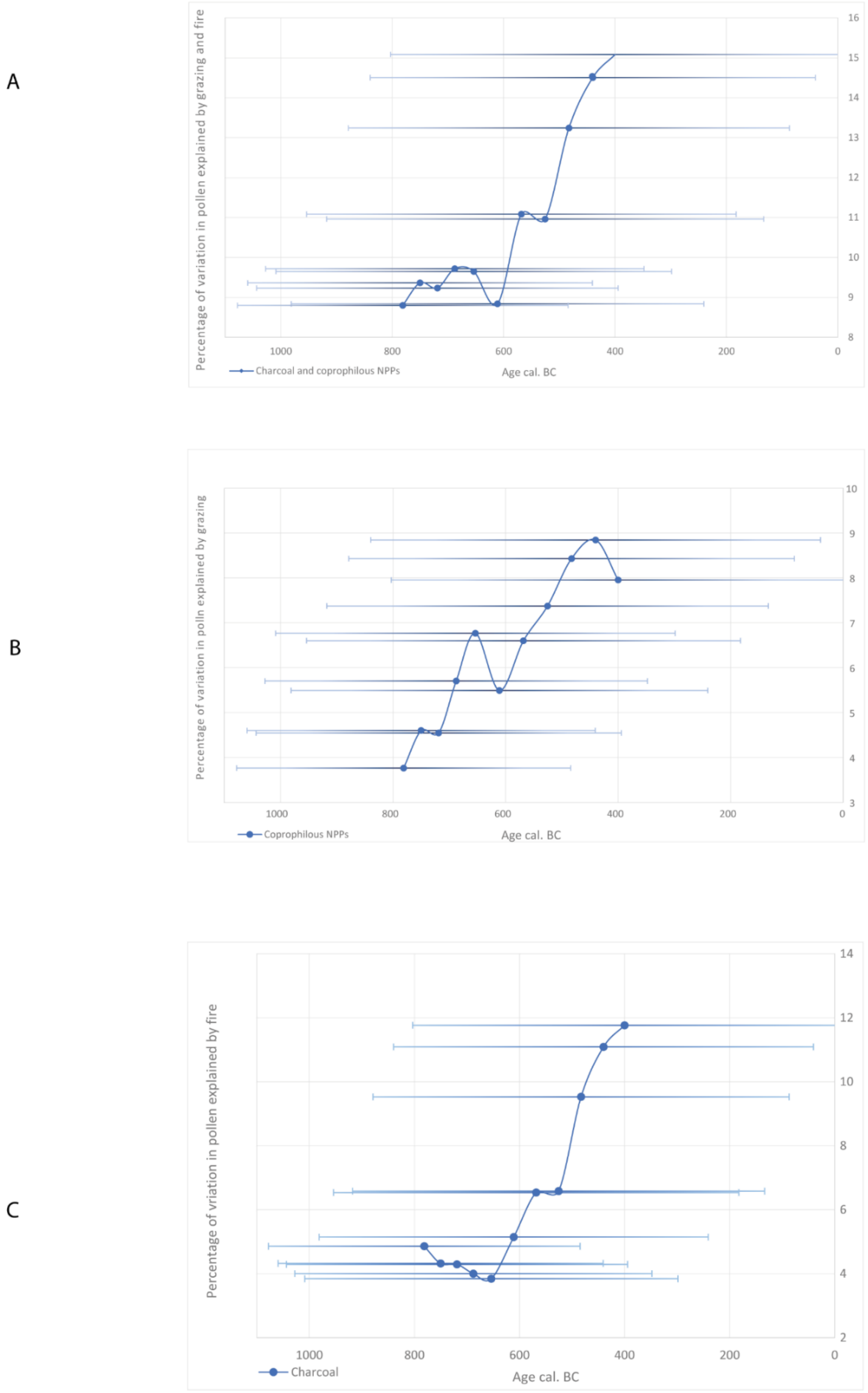


Figure 7.8 ***A***, ***B*** *and* ***C****. Variation in pollen explained by three different environmental variable combinations through time, expressed in percentages. A moving window approach was used, meaning that the ages given in the horizontal axis represent the mean ages per set of 20 samples. The entire age range represented by each percentage point is indicated by the blue bars attached to each marker point.*

A second series of redundancy analyses was carried out on the pollen data, but was only based on the 20cm moving time window sets. Each RDA analysis includes both coprophilous NPPs and charcoal data as environmental vectors and is based on a data set of 20 samples with either high or low relative significance (see figure **7.9 A** and **B**). Plot **A** spans a period of ±600 years between 105 and 700 cal BC (*Iron Age*), whereas plot **B** is representative of a time period of ±800 years, between 380-1180 cal BC (*middle Bronze Age to middle Iron Age*). The plots show grazing to have had a slightly higher significance on the pollen variation observed, predominantly during the (late) Iron Age, from around 500 cal BC onwards. Explanatory percentage values of coprophilous NPPs range from 12% to 5.2%. The majority of tree taxa show a positive correlation with grazing, together with *Rumex acetosa* during its highest level of significance. However, during earlier stages of prehistory (plot **B**), this correlation remains barely observable. This occurs when grazing has a lower significance value and only *Rumex acetosa* remains somewhat positively correlated. Charcoal (*3.5% significane*) shows a weak positive association with *Potentilla*-type and Poaceae in plot **A**, with the remainder of pollen taxa having a neutral or negative (e.g. arboreal taxa) associaton to fire. In plot **B** the pollen taxa that are now positively correlated to fire include Cyperaceae, *Filipendula, Quercus* and Lactuceae. *Ulmus* is the single taxon on the plot that is negatively associated with fire in plot **B** (*3.6% significance*). A last observable shift is the direction of both environmental vectors as the significance changes. Following the order from plot **A** to **B**, both vectors move in almost opposite directions. With a significance decrease in mainly coprophilous NPPs, the distance between the two vectors declines as well. Finally, *Calluna vulgaris* shows no strong association with either environmental vector, regardless of their significance values.

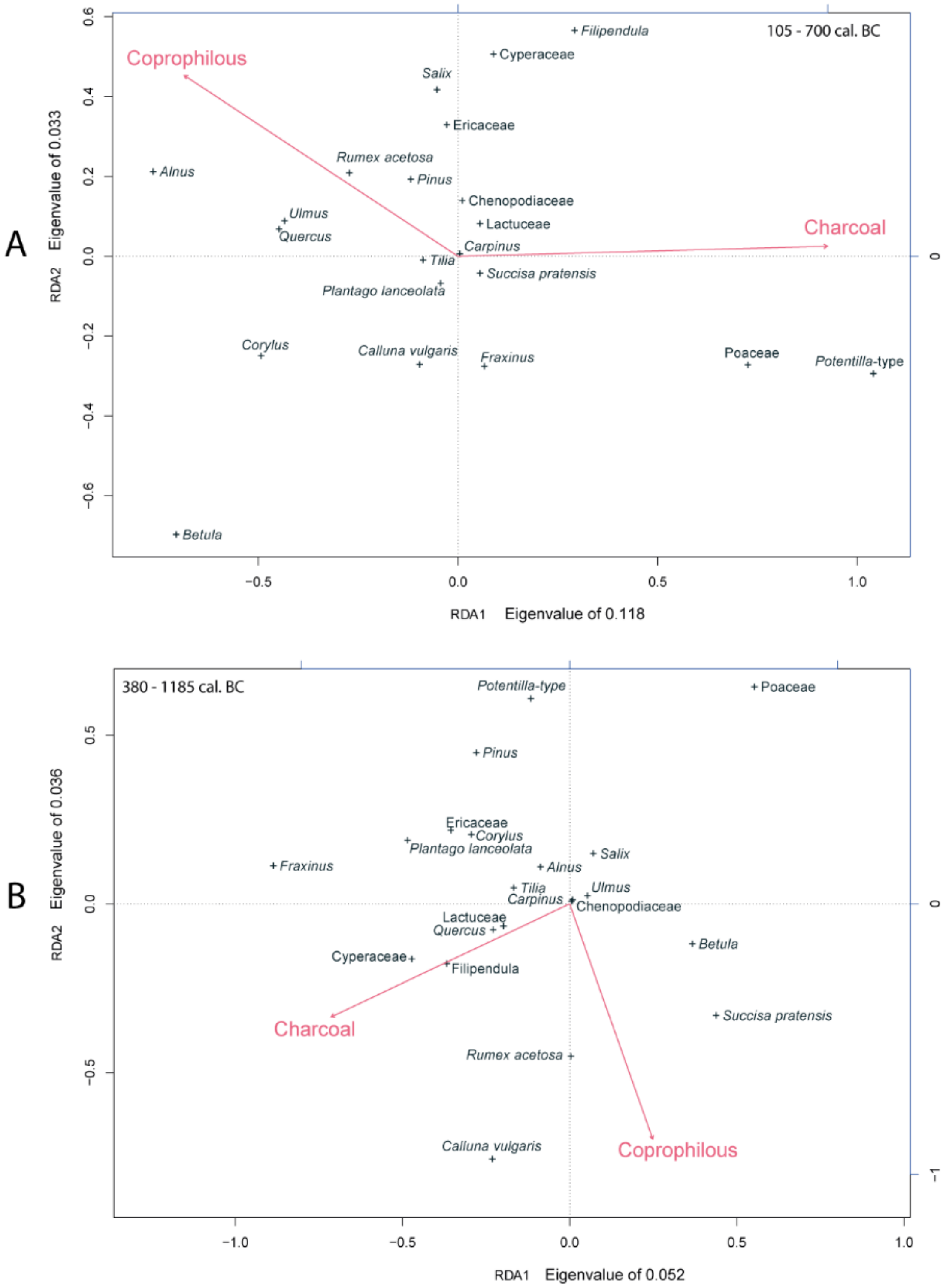


Figure 7.9 ***A*** *and* ***B****. RDA results plots produced from pollen, coprophilous NPPs and charcoal data at three different stages in time, based on the RDA moving window results of Codsend Moors.*

7.5 An evaluation of prehistoric land use and environmental changes at Codsend Moors

The results from the detailed analysis of NPPs (figure **7.4**) and pollen (figure **7.3**) show clear variations throughout the prehistoric period at Codsend Moors. The results of the multivariate analysis (figure **7.7**) also show significant changes in the relationship between land management practices and vegetation. This section will attempt to explain these patterns, and place them within the context of the known field archaeology.

A total of four phases of land use changes are identifiable in the combination of pollen and NPP data. The majority of phases overlap with the pollen zones, but frequently agrees with shifts observable in the NPP diagram. Even though a large part of the NPP diagram is dominated by the T19 NPP, subtle shifts still show an overall agreement with pollen data. There is, however, a small delay visible in the NPP data, compared to identified changes in the pollen data. Overall, both datasets show several periods of land use of different levels of intensity, along with changes in types of land use or management.

Codsend phase 1 – 114.25-112.25cm – 1180-920 cal BC

The first phase identified in the datasets indicate a time period of a relatively more intense land use followed by a short period of what seems to represent heather regrowth in the area around Codsend Moors. Low values of *Calluna vulgaris* in combination with high charcoal values indicate a use of burning as a land management tool. Although the first phase identified in the NPP dataset covers a larger part of the sequence, a clear shift in composition is visible from approximately 1080 cal BC onwards. Charcoal data indicate a continuity of burning events, but heathland dominated the regional vegetation during this period. A similar trend in the NPP data is visible, where *Byssothecium circinans* shows a large incline at around the same time in the sequence.

A small volume of coprophilous NPPs can be associated with this phase, but these remain very low during a period of high intensity burning. The palaeoecological data thus suggests that the burning of heathland in particular was the main type of land use, with very few indicators for pastoralist activities. Coprophilous NPPs after ±1080 cal BC, *Sordaria* sp. in particular, indicate an increase in grazing pressure in the local area. This implies that the land surrounding Codsend Moors remained predominantly used for pastoral activities. Another plausible scenario is that grazing pressure was sufficiently low for *Calluna vulgaris* to recover and remain the dominating taxon in the pollen composition.

Codsend phase 2 – 107.25-102.25cm – 865-630 cal BC

Covering much of the late Bronze Age to the early Iron Age, this phase spans a period of approximately 200 years. Pollen data show a brief period of increased land use, with grass-dominating conditions. The phase starts with a small peak in charcoal values, but a gradual decline may indicate a lesser reliance on burning towards the end of the early Iron Age. Coprophilous NPPs suggest either a discontinuation or decreased intensity of pastoralist activities throughout this phase. Wetter local bog conditions are indicated by an increase in T19 and *Byssothecium circinans*, alongside a decline in T303.

Codsend phase 3 – 101.25-96.25cm – 590-380 cal BC

Codsend phase 3 spans a period of around 200 years. The majority of the three different proxy datasets suggest a period of less intense land use. Charcoal shows the lowest values during this phase, with very few suggestions of burning used as a type of land management in the area. *Calluna vulgaris* has regained dominance in the vegetation. Values fluctuate over the length of this phase and differ from the consistent values during the second half of phase 1. Disturbance indicators in the pollen dataset suggest only light levels of disturbance, either as a result of less continuous disturbance, or potentially caused by seasonal/temporary periods of disturbance with intermittent periods of recovery. Grazing indicator NPP types, however, are present throughout the entire phase, with the highest values during the start of phase 4. A combination of these proxy results suggest that this phase represents a period where pastoralist activity was the main form of land use, alongside low-intense forms of burning in a partially heather-dominated landscape.

Codsend phase 4 – 95.25-90.25 – 350-100 cal BC

Phase 4 is shorter than its preceding phase and spans a time period of ±170 years, during the late Iron Age. This phase sees a sharp rise in charcoal values alongside an almost sudden drop of *Calluna vulgaris* in the pollen data. Two main disturbance indicators *Potentilla*-type and *Plantago* show increased values throughout the entirety of this phase. NPP data shows a local change at around 320 cal BC. This marks the approximate point in time where coprophilous NPPs become nearly absent from the sequence and are replaced with a dominating T19. This implies that the landscape was mainly dominated by grasses as a result of a negative influence on heather (*Calluna vulgaris*), predominantly caused by burning. No strong evidence can be distracted from the NPP data that indicate pastoralist activities in the local vicinity of Codsend during this part of the late Iron Age. As Poaceae remained dominant throughout the second half of this phase, a higher intensity of burning occurred. Pollen data suggests that heathland was given more regrowth time, since *Calluna vulgaris* values show an increase. A total tree percentage value below 20% may incline that perhaps alongside heather, trees had also become a (larger part of) target of burning. However, as visible in the RDA results of **7.8**, there are no apparent indications that an increase of fire/burning can be related to an increasing negative correlation with any tree taxa in particular. Considering the fact that no cereal type pollen were found during this time period, it cannot be stated that burning was used to clear the landscape to enable arable agricultural activities. The lack of evidence does, however, not provide evidence to state the opposite either.

7.6 Summary

The area surrounding Codsend Moors shows to have been in use by people during the Bronze- and Iron Age with different levels of intensity. A combination of charcoal data, pollen data and non-pollen palynomorph data suggest four main changes in land use and responses in the vegetation accordingly. A first phase, starting at around 1180 cal BC presented a time period where burning was likely already in use as a land management tool. As burning decreased in intensity from around 1080 cal BC onwards, NPP data suggest a continuation of grazing activities taking place in the local vicinity since the start of phase 1. Indications for grazing decreased rapidly, alongside a decline in charcoal data during phase 2. This ±200 year period represented a grass-dominated landscape, with a relatively lower intensity of land use, and a high rise in T19 NPPs. A period of relatively low burning intensity followed as phase 3. This phase showed a gradual increase of heather in the near vicinity of Codsend Moors. NPP data indicated that pastoralist activities would have been the main type of land use during this phase, which spans a period of approximately 200 years. A final phase, spanning a period of around ±170 years, showed an increase of burning used as a land management tool. Grasses dominated the landscape and tree pollen taxa reached their lowest percentage during this phase. Although this phase did show a small increase of *Calluna vulgaris* in the second half, no indications were detectable to suggest a shift to relatively lower intensities of land use.

Chapter 8 – Climate change in the South West with evidence from Dartmoor and results from The Chains, Exmoor

8.1 Introduction

This chapter discusses the climatic fluctuations detected in humification analysis data from peat material from The Chains, Exmoor. Results from The Chains are compared to published humification data from Tor Royal Bog, Dartmoor. Furthermore, two testate amoebae-based water table depth reconstructions from Tor Royal Bog were produced using transfer functions based on a European- and a British training set are included in the comparison by Amesbury *et al.* (2008). The final section discusses published wide-scale indirect climate data, consisting of precipitation and temperature reconstructions, and is used for further analysis on the role of climate in past vegetation changes in the next chapter.

8.2.1 The Chains – Site Introduction

The Chains is the only (ombrotrophic) blanket peat site found on Exmoor. Water tables in ombrotrophic peat, such as present at The Chains, are believed to be predominantly driven by precipitation reinforced by temperature (Barber & Langdon, 2007; Blackford & Chambers, 1993; Chambers, Beilman & Yu, 2011; Charman *et al.*, 2009). They do not generally receive surface runoff due to their flat or slightly convex surface profiles. The Chains was thus targeted as the key site for providing (indirect) climate proxies of Exmoor for this study. Previous research had also suggested that the peat extended considerably into the prehistoric period (Merryfield, 1977). The Chains' area covers the largest part of level ground on Exmoor (see figure **8.1**), with varying altitudes between 459m to 489m above sea level (Merryfield, 1977). In width, it ranges from 270m to 450m at the south-eastern side, but has increased up to 1100 meters in the north-western side. Samples were taken at the narrower part of a higher altitude of The Chains and are thus more likely to reflect direct precipitation than the wider, lower-lying areas described above. The deepest recorded peat from The Chains is located in a peat-filled depression at a depth of 3.28m, but average peat depths at The Chains range between 1.8 to 2 meters (Merryfield, 1977). The Chains is one of the most remote peat areas on Exmoor, with the nearest roads being at least 2.5km away. Several small scale peat cutting has taken place in the area during historic times. Shallow drainage ditches have also been found in the area and presumably relate to the enclosure of the Knight Family in the early 19th Century. Moreover, The Chains also serves as a catchment area and source of four different rivers that run through Exmoor; The West Lyn, The Hoaroak Water, The Exe and The Barle (Merryfield, 1977).

8.2.2 Fieldwork on The Chains

An initial phase of peat coring was undertaken at The Chains for this study, with the aim of finding the deepest peat for core extraction. Predefined survey lines were informed by a previous peat-depth survey, as well as a previous GPR survey of The Chains (Bowes, 2006). A total of 11 cores, along mentioned pre-defined lines, were extracted with a Russian corer. All cores were measured and their stratigraphy was recorded according to the Troels-Smith technique. Figure **8.1** presents their stratigraphy, depths and location in the form of a fence diagram and presents the sample core separately from the assessment cores.

A representative sample core was extracted on the basis of the stratigraphic survey with a length of 2.28m. A Russian corer with a diameter of 10cm was used for this extraction. The sample core location is indicated by the black arrow in figure **8.1**.

Material from the entire core was taken with the intention of producing a proxy-climate record, using testate amoeba, supported by a combination of tephra analysis and radiocarbon dating to generate an age-depth model. However, after an initial assessment for the presence of testate amoebae, results showed that preservation of tests within the peat was insufficient. Instead of developing a testate amoebae-based proxy climate record, the core has been subjected to peat humification analysis (Blackford & Chambers, 1991) in order to develop a complete and high-resolution humification-based past climatic reconstruction. No further palaeoecological work has been conducted with material from The Chains, as radiocarbon date results showed that material from this core did not fall within the time frame of study.

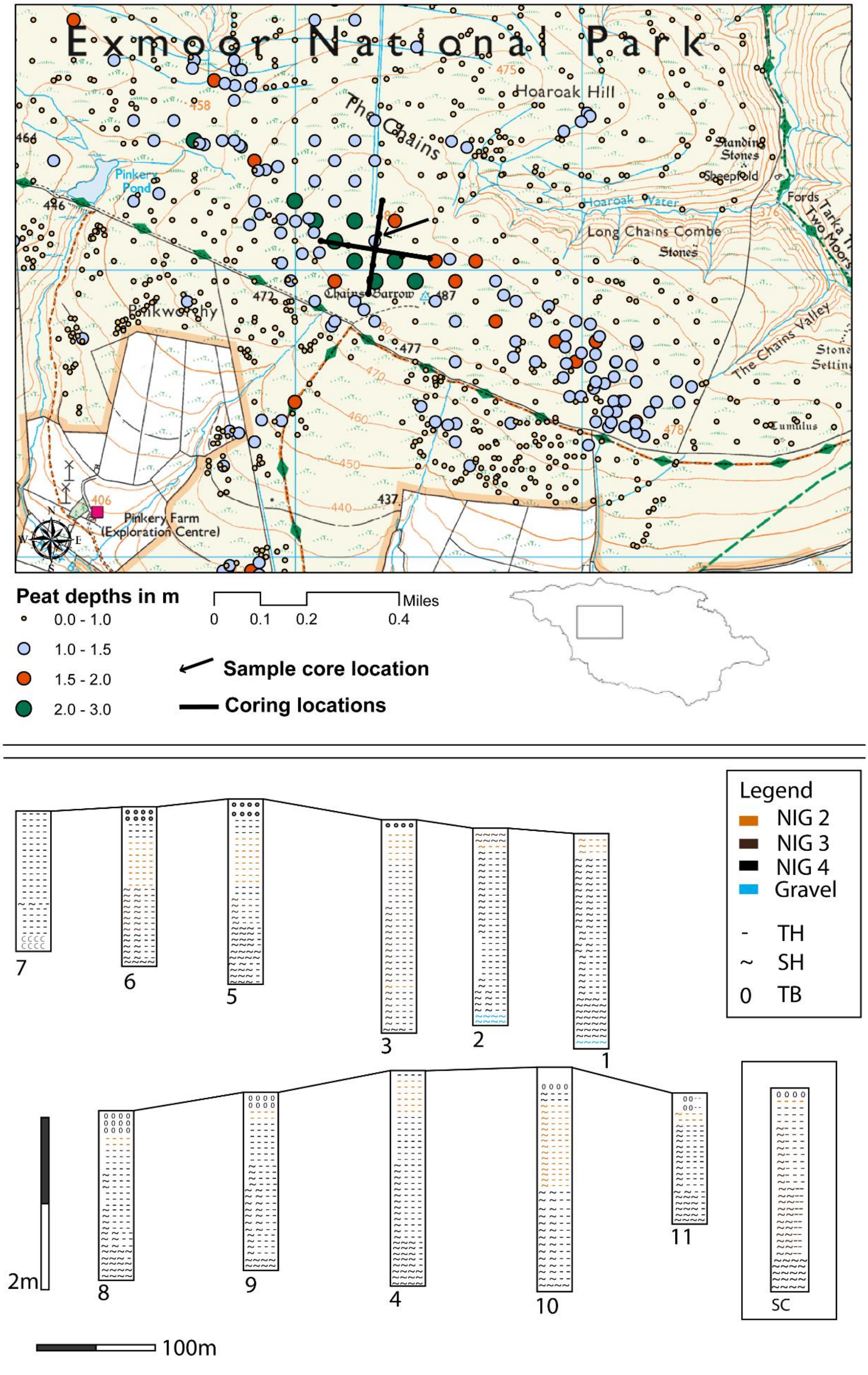


Figure 8.1. *Coring locations and peat depths from the Bowes survey data (upper half) along with stratigraphy description (Troels-Smith) for each core separately (bottom half). The black arrow indicates the coring location of the sample core, which is named "SC" in the stratigraphy diagram.*

8.3 Dating results from The Chains

8.3.1 Radiocarbon results of The Chains

A total of four radiocarbon dates were taken from the same peat sequence at different depths. Further details are presented hereunder in table **8.1**.

Depth in cm	**LAB-code**	**Age cal BP**	**Calibrated age cal BC/AD**	**Material dated**	**Calibrated age cal BP**
60-61 cm	UBA-38053	498±29	cal AD 1400-1437	Humin acid	515-550 cal BP
120-121 cm	UBA-38054	1249±46	cal AD 671-882	Humin acid	1068-1279 cal BP
180-181 cm	UBA-38055	1868±34	cal AD 71-233	Humin acid	1717-1879 cal BP
220-221 cm	UBA-38056	2715±37	927-805 cal BC	Humin acid	1023-1145 cal BP

Table 8.1. *Results of radiocarbon analysis from The Chains. Calibration of all dates are done in OxCal and the chosen calibrated ages are within a 95% range of possibility.*

Radiocarbon date results from this research are younger than what could have been expected from the literature. A dated pollen diagram from Merryfield and Moore (1974) and Moore *et al.* (1984) provided a basal radiocarbon date (UB-821) of 4170±75BP, which calibrates to 2920-2500 cal BC. This date was given for a depth of 240cm. An unpublished basal peat sample at 170cm depth (UBA 8573) from a site closer located to the Chains Barrow (grid reference of 273450; 141950), resulted in a date of 2748±33 cal BP (Fyfe, pers. comm.). This final date lies in close agreement with the basal peat date of this study.

Merryfield's basal peat sample originated from a significantly lower depth. The much older date may suggest that the sample comes from a shallow mineral peat soil, which developed before the true peat growth, which may have been mistaken for having been part of the ombrotrophic peat and used for dating.

Other given dates and depths from around the same site imply that peat from The Chains most likely started to develop at around 2800 cal BP (approximately 800 cal BC). Conversely, it is also possible that the (two) base radiocarbon dates are slightly too young for their true age. This may also be supported if the tephra layers were correct, showing an older age around a depth of 210cm. However, the most plausible reason for this true ombrotrophic peat to have started to develop was the wet climate shift described in chapter **2** that occurred at around 2800 cal BP in combination with human modification of soils and other types of inference, as can be indicated by the presence of the Chains Barrow. The potential causes of blanket peat initiation remain complex (Charman, 2002).

8.3.2 Tephra results

Following the peat collection with the Wide Russian corer, 5cm consecutive subsamples were taken from all cores to be scanned for tephra layers. A total of four layers containing high amounts of tephra shards were identified throughout the peat sequence. Count results are presented in figure **8.2** alongside five probable tephra identifications.

As the radiocarbon sample results showed that only the bottom 20cm of this core would fall within the time period of focus of this research, namely the period from 3000 cal BC to the end of the Iron Age, it was therefore deemed unnecessary at this stage to develop or improve the age-depth model. Geochemical analysis and typing of the tephra layers was therefore not undertaken. Nonetheless, the tephra layers have been assigned (probable) identifications that are currently based on the physical features of the shards in combination with chemically identified layers found at similar stratigraphic positions at other sites on Exmoor (MacLeod, A., pers. comm.).

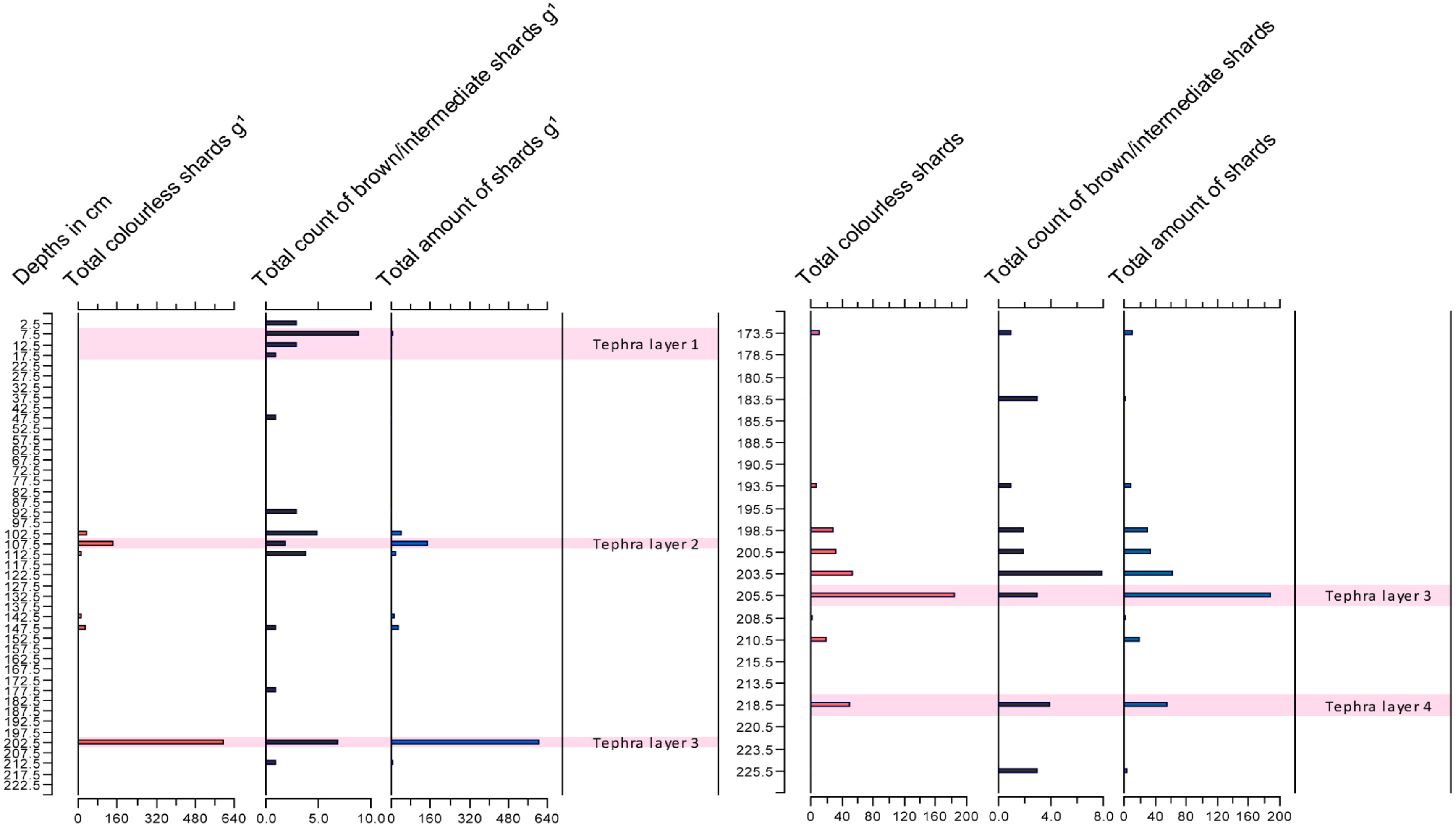


Figure 8.2. *Tephra shard counts of top cores (presented as number of shards per gram of dry sediment) and bottom cores (presented as number of shards per microscopic slide). Four detected tephra layers are indicated with numbered labels.*

Tephra layer 1 – Hekla AD1510

The top tephra layer found in the sequence is located at a depth that ranges between 5cm to 20cm. Shards found in this section are of an intermediate colour of appearance and would most likely belong to the Hekla 1510 event. Similar shards (identified as Hekla AD1510) have been found at other sites on Exmoor, such as Roman Lode (at a depth of 12-13cm) and have shown a similar appearance to those found in The Chains sequence (Matthews, 2008). Hekla shards date to between 1508 and 1512 cal AD.

Tephra layer 2 – AD860a

The second layer of tephra shards found in the sequence are very likely to represent shards from the AD860a event. The majority are deposited at depths ranging between 100cm and 110cm, with the bottom five cm of this section showing the highest counts. Tephra shards of the same identification may have possibly been deposited at Spooners as well (MacLeod, unpublished), but at a much higher depth (between 20-25cm). However, AD860a tephra shards date to cal AD840-881 and show in figure **8.3** to fit well within the age-depth model 95% possibility range.

Tephra layer 3 – OMH185

A third layer of tephra shards found in the sequence presumably belong to the OMH185 tephra identification. A combination of overall appearance of the shards supports this hypothesis. The majority of shards are larger than the average tephra shards found in other parts of this sequence. A high amount of the shards counted contained observable mineral inclusions, which is a characteristic for OMH-185 (also nicknamed as “microlite tephra”, due to these inclusions) (Bogaard & Schmincke, 2002). The shards found in material from The Chains occur in high quantities at a depth ranging between 200cm and 208cm. Figure **8.3** does show that this tephra identification partially falls outside of the age-depth model’s 68.5% possibility range and thus suggests a slightly younger age (755-635 cal BC) than the radiocarbon dates do. This may also suggest that a reconsideration of the age-depth model is necessary.

Tephra layer 4 – GB4-150

The final layer of tephra shards were found at a depth ranging between 216cm and 221cm. Shards of similar appearance have been found in the peat sequences in Ireland, are of a dark brown colour and fit the description of being “fine-grained” and “slightly vesicular” (Plunkett *et al.*, 2004). This tephra identification dates to 800-785 cal BC. It falls outside of the 68.5% possibility range of the age-depth model. A reconstruction of the age-depth model would thus be advisable after a confirmation of geochemical analysis of this bottom tephra layer.

The age-depth model presented in figure **8.3** is based on the four radiocarbon dates presented in table **8.1**. The positions of the tephra layers are indicated with black squares, but were not included in the age-depth model, as geochemical analysis was not carried out and certainty of their actual ages can thus not be given.

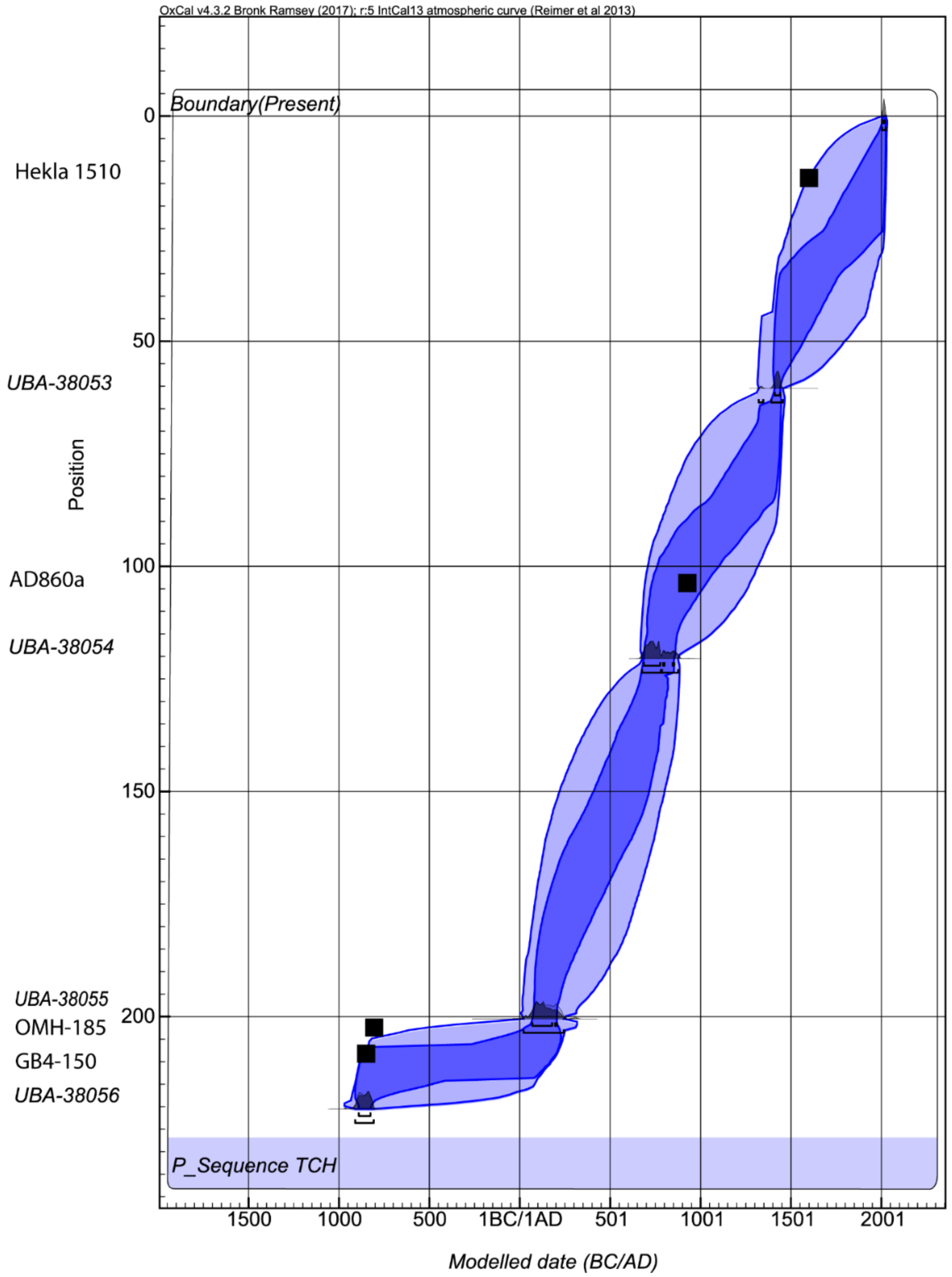


Figure 8.3. *Agedepth model of The Chains, based on four radiocarbon dates shown in table* ***8*.1** *For the creation of this model, OxCal was used (IntCal13). The dark blue area reflects a 68.2% probability age range and the lighter blue depicts a 95.4% probability age range. The four black squares represent the four tephra layers found, but these were* ***not*** *included in the model.*

8.4 Humification analysis results from The Chains

Peat humification analysis was carried out on all subsample of peat material from The Chains in order to reconstruct local bog surface wetness levels. Peat humification has been widely used amongst other methods to indirectly indicate regional climatic changes (Charman *et al.*, 2009). Material used for peat humification analysis has been subsampled from the same cores that were used for tephra shard counts. 1 cm consecutive subsamples were taken from the peat sequence until a depth of 221cm was reached. Results are presented in figure **8.4** and include raw percentage transmission values, residual values of a detrended line, Z-scores and loss-on-ignition percentages. Z-scores are used due to the importance to base any type of comparison between results of different sites/proxies on their z-scores, rather than absolute values, in prevention of any possible misinterpretation and to focus on directional shifts (Amesbury *et al.*, 2016).

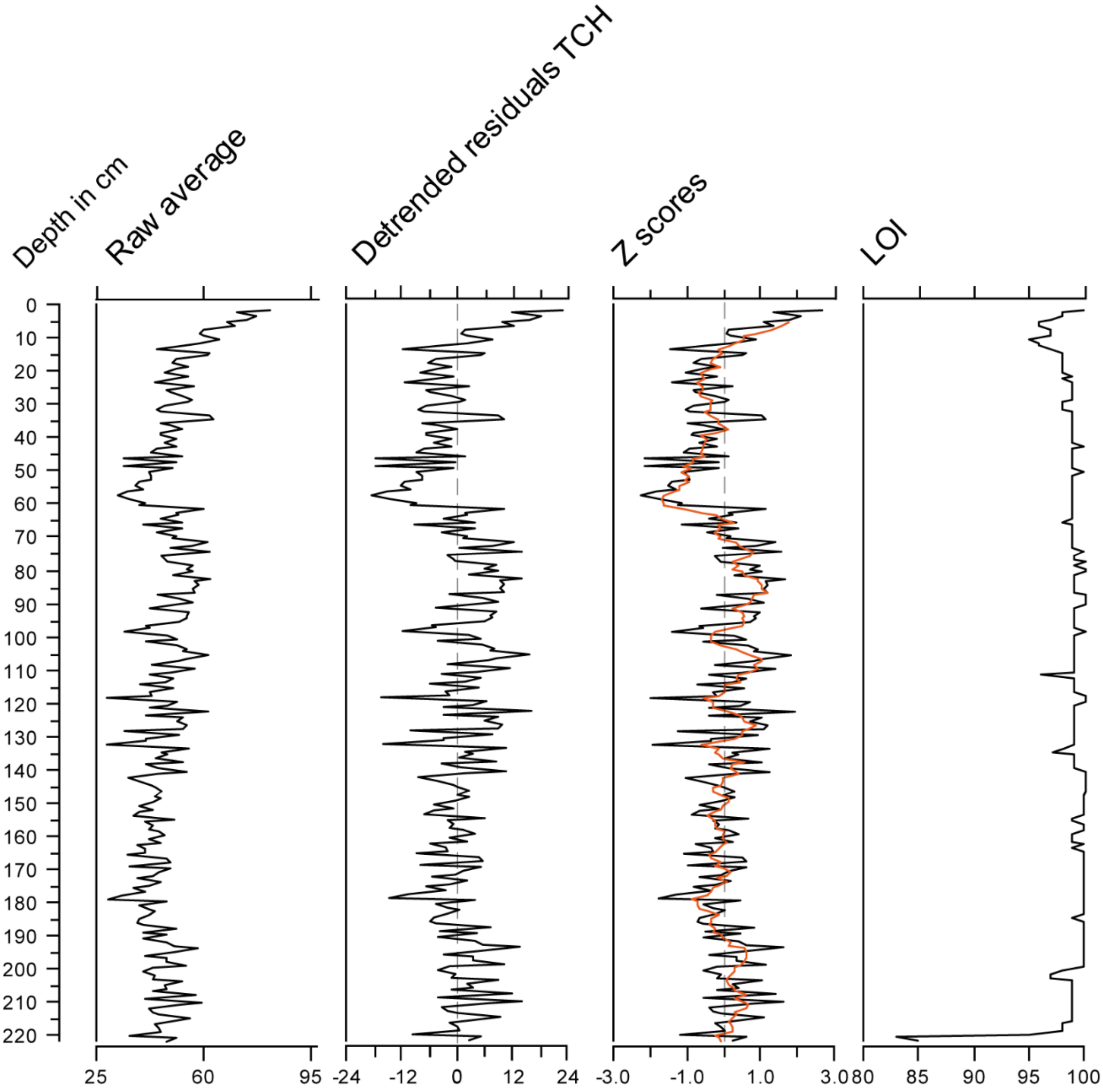


Figure 8.4. *Peat humification results from The Chains presented in different values, including a 5-point moving average line in the Z-score diagram (orange line).*

A shift indicating drier conditions at the bottom of the sequence (which dates to around 800 cal BC) could be explained by a decrease in organic matter of nearly 20%, which is visible in the loss-on-ignition results, and should therefore be interpreted differently from the remainder of the data. After this initial shift, the data shows a trend towards wetter/cooler conditions for the bottom cm up until 190cm (dating to c. 210 cal AD). Drier/warmer conditions are then indicated by the data for a period up until 140cm (dating to c. 600 cal AD). From this point in time onwards, the majority of the data suggests a general trend towards wetter/cooler conditions up to 70cm (1300 cal AD) with several small events of drier/warmer conditions at 130cm (685 cal AD), 115cm (820 cal AD) and 100cm (982 cal AD). From a depth of approximately 65cm (1365 cal AD) onwards, a large shift towards drier/warmer conditions is shown in the data, with z-score values remaining negative (indicating warmer/drier conditions) until the top 20/10cm has been reached. Several short-term peaks towards wetter/cooler conditions are noticeable during this time period. A trend towards a wet shift appears to be present in the top 20cm of the peat, but similar trends to these are often perceived in results of peat humification analyses and have been linked with a difference in decomposition between the acrotelm and the catotelm (upper layer and bottom layers of peat) (Chambers, Beilman & Yu, 2011).

8.5 Comparison of The Chains humification record with regional palaeoclimate datasets

Humification results from The Chains are compared to other regional palaeoclimate datasets in this section. However, the only regionally-based data available is that of Tor Royal Bog, Dartmoor. Tor Royal Bog is a site on Dartmoor and covers 58 of hectares at an altitude of ca. 390m (Woodland, Charman & Sims, 1998). Apart from several shallow drainage channels running across the mire, not many other forms of human disturbance are present at the site (Amesbury *et al.*, 2008). With low disturbance levels at this ombrotrophic peat, it can be considered regionally relevant paleoclimate data and comparable to data from The Chains. A peat core reaching to 5.65m depth was taken with a Russian-type corer at Tor Royal Bog by Amesbury *et al.* (2008). Subsamples for both peat humification analysis, as well as testate amoebae analysis, were taken every 16cm between 0cm and 464cm and every 4cm between 208cm and 320cm, with the bottom sample dating to 5645 cal BP (3695 cal BC). Two separate water table depth reconstructions were produced based on the testate amoebae analysis (Amesbury *et al.*, 2008). The first reconstruction was calculated with the use of the UK transfer function of Woodland *et al*. (1998), whereas the second reconstruction was calculated using the European transfer function of Charman *et al.* (2007).

Figure (**8.5**) shows The Chains z-scores results in comparison with peat humification z-scores results, as well as z-scores of the water table depth reconstructions from Tor Royal Bog, Dartmoor. Comparisons between several wet/cold shifts and dry/warm shifts in all proxy results will be discussed below, starting from the prehistoric time period and then moving upwards towards present day. Unlike in the rest of this thesis, results are discussed in calibrated years before present (BP), following the convention in palaeoclimate research. “cal BC” dates are added in brackets behind each mentioned date in sections **8.5.1** and **8.5.2**.

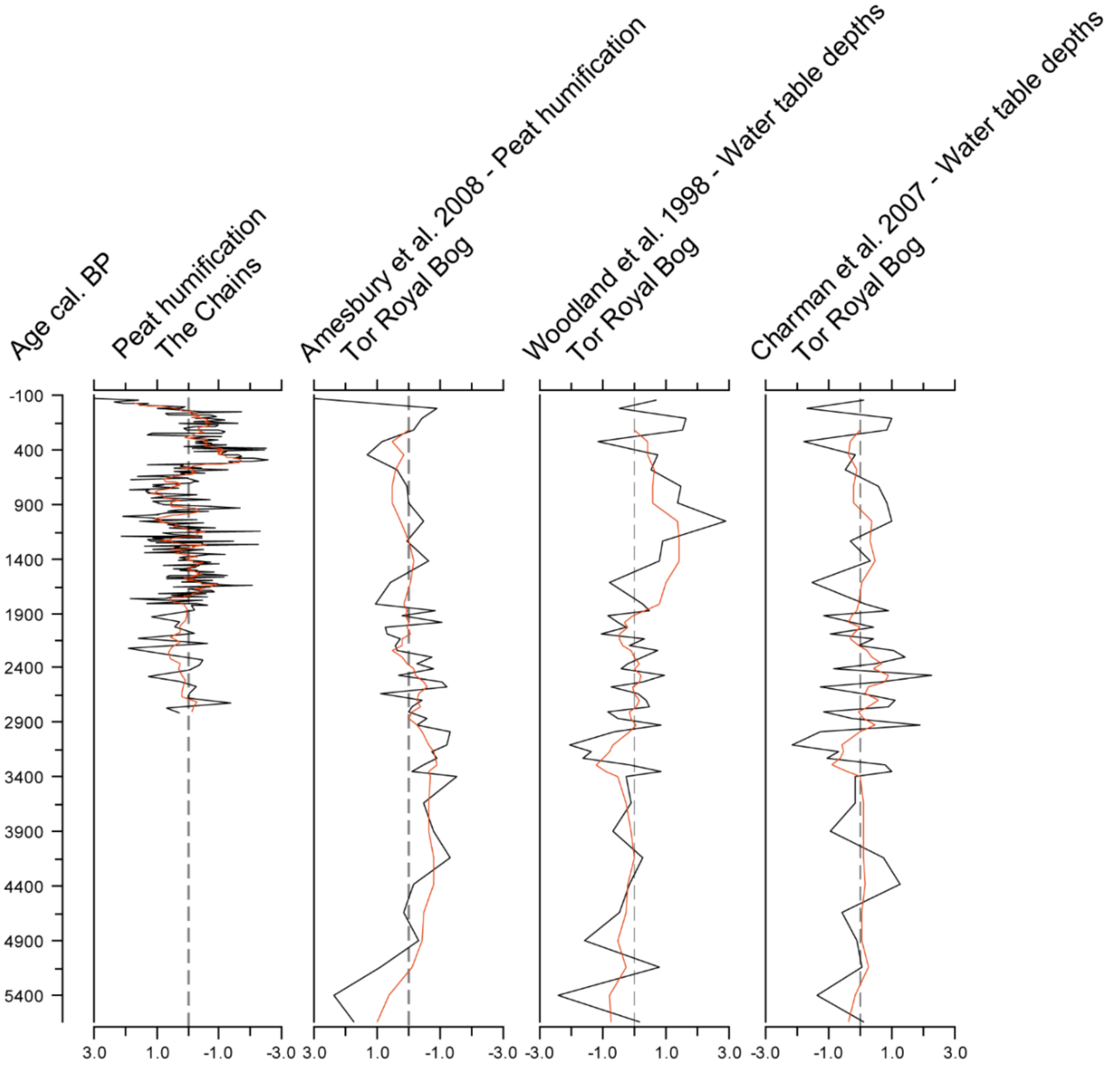


Figure 8.5. *Indirect climate multi-proxy data. Columns 1 and 2 present z-scores of the detrended residual results of humification analysis from The Chains (1) and Tor Royal Bog (2). Column three and four show water table depth reconstructions based on testate amoebae from Tor Royal Bog, Dartmoor, on a British (3) and European (4) scale. References in the final two column titles refer to the transfer functions used to calculate the reconstructions with.*

8.5.1 Prehistoric climatic conditions

Water table depth reconstructions (from here onwards referred to as WTD) from Tor Royal Bog suggest a wet/cool period occurred at around 3400 cal BP (1450 cal BC), after which a general trend towards warmer/drier conditions followed until around 3000 cal BP (1050 cal BC). A known climatic shift to a wetter/cooler climate is believed to have initiated shortly after the warm/dry phase at around 3000 cal BP (1050 cal BC) (Wanner *et al.*, 2015) and is also visible in the WTD of Tor Royal Bog. A period up to approximately 2900 cal BP (950 cal BC) shows to have been part of this cool/wet shift, before returning to relatively warmer/drier conditions. A second, previously acknowledged, shift to a relatively wetter/cooler climate took place at around 2800 cal BP (850 cal BC) and is also reflected in the WTD (Berglund, 2003). Subtle signs for these shifts are also noticeable in the peat humification data of Tor Royal Bog. Data from The Chains does not start until c. 2800 cal BP (850 cal BC), but positive values in the diagram imply that a wetter/cooler period took place at the onset of peat development.

A shift to wetter/cooler conditions in The Chains data is suggested at around 2700 cal BP (750 cal BC), and a similar, perhaps delayed, shift is visible in the Tor Royal Bog humification data at around 2600 cal BP (650 cal BC). Both shifts could be explained by a general change in northwest European climate, which is assumed to have changed from a warmer, continental climate to an oceanic climate between 2800 and 2600 cal BP (850-650 cal BC) (Van Geel, Buurman & Waterbolk, 1996). It is assumed to have been the result of a change in solar activity, indirectly causing a rise in 14C content of the earth's atmosphere (Mauquoy *et al.*, 2004). A range of authors have linked this climate shift to major reorganisations and/or disruptions in societies across Europe (van der Plicht, 2005; van Geel & Renssen, 1998; Van Geel *et al.*, 1997).

Several fluctuations are noticeable in the data of both The Chains and Tor Royal Bog in the period between 2600 cal BP (650 cal BC) and 1950 cal BP (AD). At 2300 cal BP (350 cal BC), WTD of the European reconstruction-scale (Charman *et al.*, 2007) suggest a period of cooler/wetter conditions. Peat humification data from both sites indicate a trend towards cooler/wetter conditions as well. However, several fluctuations in The Chains data show two short events of warmer/drier peaks in the period up until 1900 cal BP (50 cal AD). A second and third shift to relatively warm/dry conditions occurred at around 2100 cal BP (150 cal BC) and 2000 cal BP (50 cal BC) at The Chains. Similar shifts are noticeable in the Tor Royal Bog diagrams, but often at time periods of approximately 50 years later than at The Chains.

In the period running up to 1950 cal BP (AD), a final shift towards a climate with a warmer/drier character is visible in both WTD data as well as humification data of Tor Royal Bog, which is also visible in humification data from The Chains.

8.5.2 Climate events in the historic period

The first century of the historic period (2000-1900 cal BP) show similar shifts in the WTD data along with the humification data of both sites.

In the succeeding period between 1900 cal BP (50 cal AD) and 1600 cal BP (350 cal AD), data of all four diagrams indicate a general shift towards relatively warmer/drier conditions at around 1800 cal BP (150 cal AD). Although Tor Royal Bog humification data shows this trend towards relatively warmer/drier conditions as well, values do remain positive and thus perhaps indicate a shift towards relatively more neutral conditions on a local scale. Following this short peak, all data indicate a shift back to wetter/cooler conditions.

Both the WTD data, as well as a general trend in The Chains' humification data, show a shift back to wetter/cooler climatic situations that dates to around 1400 cal BP (550 cal AD). This period falls under two separately classified climatic events/periods, which often overlap in dates across the literature. A term "Dark Ages Cold Period" has often been used for a climatic cooling event that took place at 1400 cal BP (550 cal AD), with a later shift at around 1200 cal BP (750 cal AD). It has been linked to a North Atlantic ice-rafting event (Blundell & Barber, 2005). A more recently introduced term for an abrupt climatic cooling at around 1400 cal BP (550 cal AD), based on multi-proxy and tree-ring dated evidence, has been termed the "Late Antique Little Ice Age" (Büntgen *et al.*, 2016; Büntgen *et al.*, 2011; Wanner *et al.*, 2015). It was most likely enforced by a combination of changes in solar activity alongside unknown large volcanic eruptions, dated to 536 cal AD, 540 cal AD and 547 cal AD (Büntgen *et al.*, 2016; Wanner *et al.*, 2015). Although many previous studies resulted in indications for wet/cold conditions to have occurred at around 1400 cal BP (550 cal AD) (e.g. Blackford & Chambers, 1991; Ljungqvist, 2010), these events have not always been specifically pinpointed to the same age-range (Helama, Jones & Briffa, 2017). In The Chains data, two events leading to wetter/colder conditions are apparent in the diagram and date to approximately 1400 and 1200 cal BP (550 to 750 cal AD). The Chains data also shows two shifts back to warmer/drier conditions, shortly after each decline. This may suggest that any type of climatic deterioration on Exmoor was of a brief duration.

WTD data from Tor Royal Bog show a general warming/drying in the period between 1200 and c. 650 cal BP (1950 and 1300 cal AD), peaking at around 1100 /1050 cal BP (c.850/900 cal AD). This aligns with the Warm Medieval Climate anomaly that took place between 1000 and 700 cal BP (950 and 1250 cal AD) (Mann *et al.*, 2009). Although data from The Chains also shows an initial peak of a warmer/drier climate at around 900 cal BP (1050 cal AD), a shift back to a cooler/wetter climate shows to have followed this up at around 750 cal BP (1200 cal AD). Due to a resolution difference in the data, or perhaps due to the use of two different types of proxies, this small cooling event is not detectable in the testate amoebae data.

Humification data from Tor Royal Bog and The Chains show cooling events at 750 cal BP (1200 cal AD) and just before 500 cal BP (1450 cal AD), which could be linked to the onset and intensification period known as the "Little Ice Age" (Svarva *et al.*, 2018)

The period between 500 cal BP (1450 cal AD) and 100 cal BP (1850 cal AD) shows many fluctuations in The Chains data, but with overall values indicating relatively warmer/drier conditions. This however does include a peak towards less warm/dry conditions at around 300 cal BP (1650 cal AD). In this same period, all three diagrams presenting data from Tor Royal Bog show a general trend towards cooler/wetter conditions, as could be expected with the little Ice Age climatic cooling event. Although it is odd that results from The Chains are almost the opposite at this point in time, the so-called "Maunder Minimum" is believed to have taken place at around 250/300 cal

BP (1650/1700 cal AD) and could explain the cooling trend at Tor Royal Bog and to a lesser extent, The Chains (Mauquoy *et al.*, 2004). The abrupt shift to cooler/wetter conditions at The Chains dating to c. 200 cal BP (1750 cal AD) could perhaps be linked to the so-called "Little Ice Age Maximum", which is assumed to have taken place at 202 cal BP (1748 cal AD) (Svarva *et al.*, 2018).

In the final century towards 100 cal BP (1850 cal AD), data from all four proxies seem to re-align and show a shift back to warmer/drier conditions. This could partially reflect the disruption in the global carbon cycle that started taking place ever since the industrial revolution (Rustad, Huntington & Boone, 2000).

8.6 Wider-scale climate proxies for further analysis

In order to find out what possible roles the climate could have had on past vegetation changes, it is necessary to use climatic data that is suitable for comparison and several statistical analyses in combination with the pollen data (discussed into further detail in Chapter **10**). Due to the sequence of The Chains not covering the time period of research focus, and the lack of high-resolution data from Tor Royal Bog through this period, reliable replacement proxies are necessary. Two published climate proxies that are widely used within the broader literature are presented in this section (figure **8.6**) and their data will be used for any further analysis and comparison studies with the pollen/NPP data from Exmoor. However, these two climate reconstructions are limited in their applicability to this particular study. The first data set stems from Greenland ice cores and is limited in applicability due to its large distance from Exmoor and a general reflection of air temperatures, rather than precipitation. The second dataset originates from Crag Cave (Ireland) data and is limited in reliable applicability due to similar reasons as the previous set. However, the site of Crag Cave is located relatively closer to Exmoor than the data of Greenland and has a higher representation of precipitation. Further details of these datasets are mentioned in the sections below. Despite a lack of high-resolution data from Dartmoor, or any data covering the required time period from Exmoor, the replacing datasets of Greenland and Crag Cave are not entirely appropriate replacement proxies and should only be regarded as a temporary solution, until more applicable data becomes available.

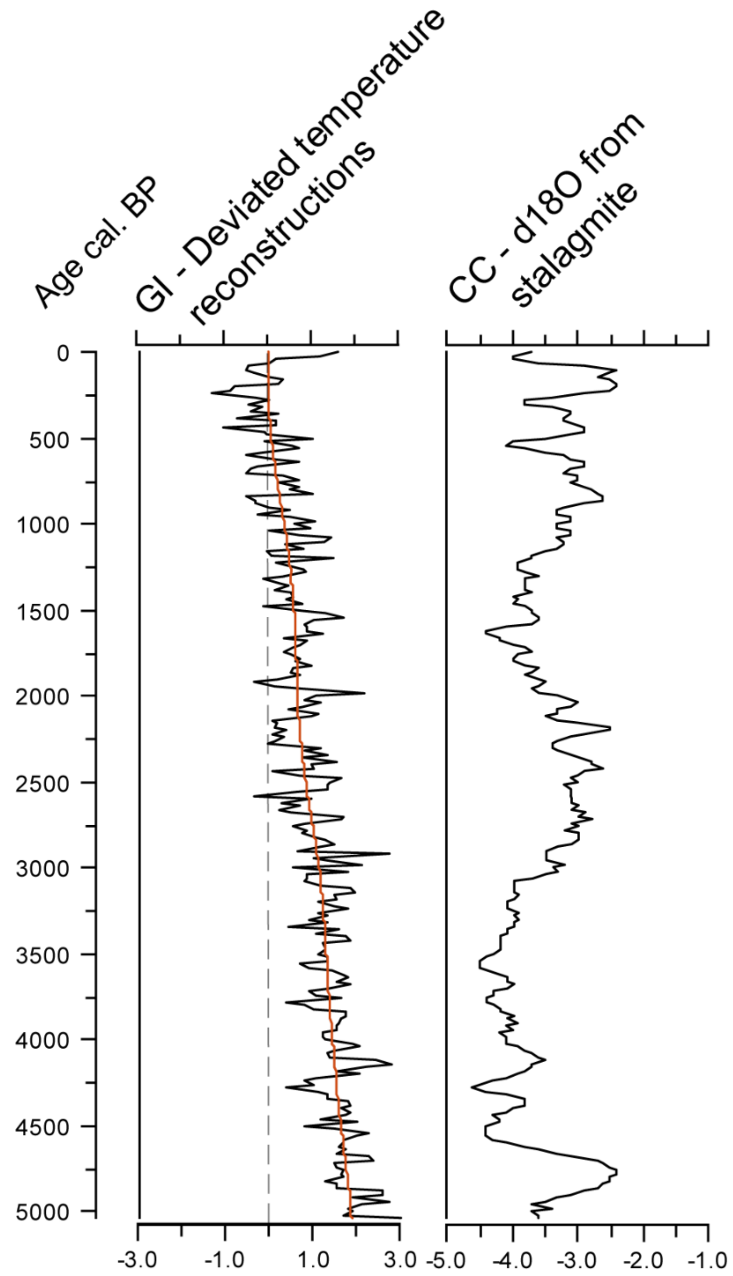


Figure 8.6. *Deviated temperature reconstructions of 20-year averages values, derived from δ18O data from Greenlandic ice cores (left column). The orange line represents the data as a smoothed and filtered line (left column). The right column presents high-resolution δ18O data derived from a speleothem from Crag Cave, Ireland.*

8.6.1 Oxygen isotopes from Greenland ice cores

The first proxy represents average deviated temperatures over periods of 20 years, ranging from 1960 cal AD (-100 cal BP) until 3090 cal BC (5040 cal BP) (Vinther *et al.*, 2006). Temperature reconstructions are based on an average of uplift corrected d18O data (oxygen isotopes) from Greenland Ice cores. The data is taken from Agassiz and Renland and is presented in Vinther *et al*. (2009). Uplift corrections are derived from Funder (1978). Average values have been corrected for changes in the d18O of seawater and are calibrated to borehole temperatures from four ice cores, taken at four different sites in Greenland: Camp Century, NGRIP, GRIP and DYE-3 (Vinther *et al.*, 2009). The temperature reconstruction data are all presented as deviations from the smoothed estimate of present temperatures in Greenland and are shown in diagram 1 in figure **8.6.** Within this diagram, a second line of data is shown, presenting smoothed temperature reconstruction data that was produced with a Gaussian filter, with a width of 2700 years and an amplitude damping of 50% for cycles with a 2000 year period (Vinther *et al.*, 2009).

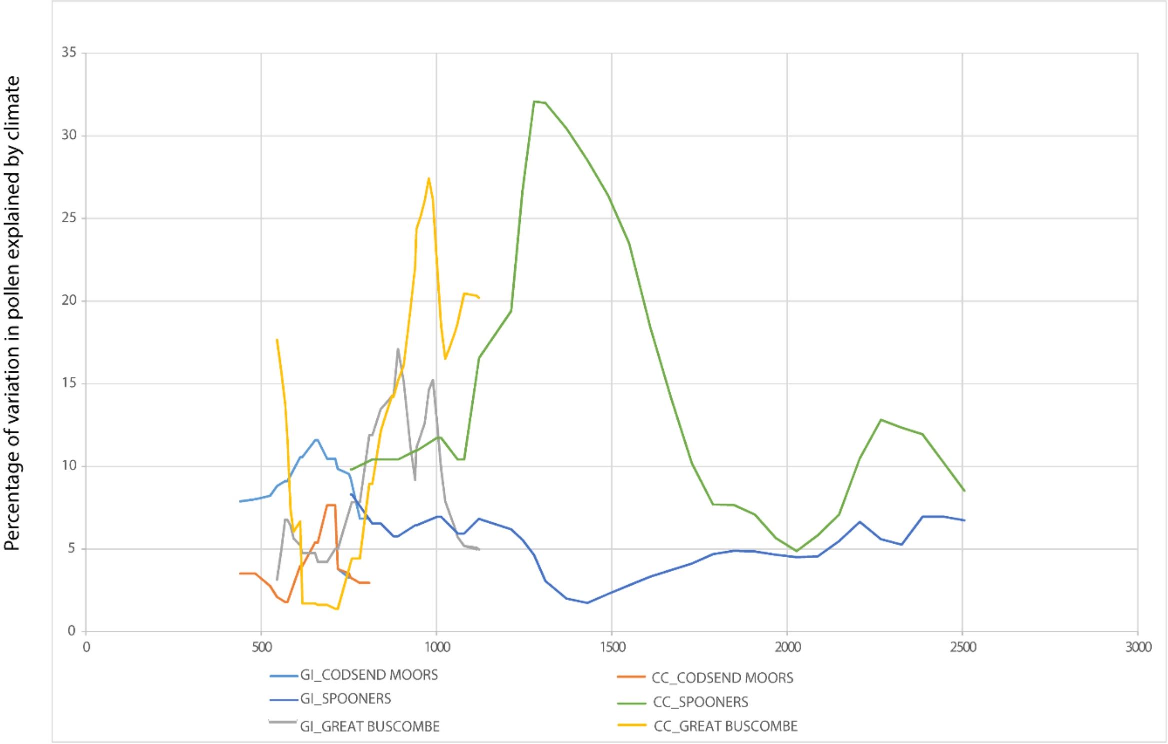
8.6.2 Oxygen isotopes from a speleothem record in Crag Cave, Ireland

The second proxy presented in figure **8.6** represents a high-resolution U-series dated oxygen isotope record from a speleothem in Crag Cave, Ireland (McDermott *et al.*, 1999). Subsamples of calcite were drilled along the central growth axis of the recorded speleothem (McDermott *et al.*, 1999). Variations in precipitation source water (δ18Op) are partially reflected in changes in the drip water (δ18O) and can be measured in the recorded speleothem (McDermott, 2004). Data derived from this proxy has been interpreted as a reflection of changes in air temperatures, total precipitation and changes in the isotopic signature of the moisture source (McDermott, Mattey & Hawkesworth, 2001).

8.6.3 Constrained ordination of climate data

Climate data from both Greenland ice cores and Crag Cave, Ireland, are used in this study in an attempt to identify the driving force of climate, represented by precipitation and air temperatures, on the variation of pollen found at Great Buscombe, Spooners and Codsend Moors, Exmoor. As previously mentioned, climate data from Greenland ice cores and Crag Cave were used here, due to a lack of more appropriately suited material, and results of this analysis should thus be treated with caution. Nevertheless, the RDA results plots (see figure **8.7**) show several interesting aspects that are discussed in this section.

As with previous analysis and using the approach described in section **4.5.2**, a moving time window approach was used. Figure **8.7** shows the fluctuation of RDA eigenvalues based on the moving time windows from Crag Cave and Greenland ice cores data.



Figures 8.7. *Variation in pollen of Spooners, Great Buscombe and Codsend Moors, explained by two different sets of climate proxy data from Crag Cave (CC) and Greenland (GI), expressed in percentages. A moving window approach was used, meaning that the ages given in the horizontal axis represent the mean ages per set of 20 samples. The entire age range represented by each percentage point is indicated by the blue bars attached to each marker point.*

RDA moving time window values of Crag Cave and Greenland Ice cores presented in figure **8.7**, show that the explanatory value of climate did not exceed 15% at Spooners and 16% at Codsend Moors during the earlier Iron Age. RDA moving time window values from Great Buscombe, however, show an explanatory value of climate, primarily from Crag Cave (29%) and less from the Greenland Ice cores (16%), at around 970 cal BC. Values from Crag Cave show a very low explanatory power (<5%) at approximately 750 cal BC. A small second peak in the Greenland Ice core data of roughly 16% occurs at the average time of 880 cal BC (figure **8.7**). Considering the fact that the RDA moving time window covers a large amount of time per set, it is difficult to pinpoint whether climatic deterioration during the middle Bronze Age or the earlier

Iron Age both influenced these values or not. They do show that climate, presumably primarily associated with levels of precipitation, had an increased effect on the vegetation composition in the surroundings of Great Buscombe, but may not have played such a significant role at other sites on Exmoor, as shown by RDA values from Spooners and Codsend Moors. A lack of simultaneous increases of climatic explanatory power at all sites further suggests that a wide-scale event such as climatic deterioration did perhaps not play a very large role on the vegetation across Exmoor as a whole. However, climate data from both sites might not properly reflect Exmoor's regional climate throughout prehistory.

Chapter 9 - The applicability of non-pollen palynomorph analysis

9.1 Introduction

This thesis has generated NPP assemblage data from multiple sites through prehistory. Unlike pollen analysis, there is still some uncertainty around the ecology and indicative meaning of some NPP taxa, although much progress has been made in recent years (Cugny, Mazier & Galop, 2010; Innes, Blackford & Simmons, 2010; Prager *et al.*, 2012; Revelles & van Geel, 2016; Ryan & Blackford, 2010; Van Geel, 2001). This chapter will examine the NPP assemblages, and discuss their interpretation, drawing on the multivariate work presented in chapters **5.4**, **6.4** and **7.4**. A range of non-pollen palynomorphs identified in this study can function as indicators for certain local changes in vegetation patterns, sometimes as a consequence of a change in land-use in the area.

The most significant group of NPPs within this study consist of the coprophilous fungi, of which their spores can be found in sedimentary sequences, such as peat (van Asperen, Kirby & Hunt, 2016). Coprophilous fungi grow on animal dung and include a variety of genera stemming of different taxonomic groups (van Asperen, 2017). There has been an increase in the use of coprophilous fungi as a proxy for large herbivore presence/abundance or density, as well as an indicator of biomass (Baker *et al.*, 2016; Blackford & Innes, 2006; van Asperen, Kirby & Hunt, 2016). In this study, coprophilous spores are used to identify pastoral activity on Exmoor. It is often difficult to identify such an activity in the pollen record, due to the fact that many plant types associated with pastoral activity are usually ruderal types and can indicate a wide variety of environments (Long, Chambers & Barnatt, 1998). It is therefore important to assess the extent to which these supposed coprophilous NPPs do indeed co-vary.

The first part of this chapter discusses the position of coprophilous NPPs on the PCA plots from chapters **5.4**, **6.4** and **7.4** and associations between (coprophilous) NPPs and other grazing-indicator pollen taxa, in order to support the discussions on the role of grazing on the vegetation that will be developed and discussed in chapter **10**. This will be done by comparing PCA and RDA results with known vegetation patterns as a result of grazing in the wider literature.

The second part of this chapter focusses on the groupings and ecological interpretation of other NPP-types identified in the PCA plots of Spooners, Great Buscombe and Codsend Moors. Since the majority of the NPPs discussed in the second section of this chapter have previously been associated with multiple different ecological conditions, that part of the chapter is dedicated to comparing findings from the Exmoor sites with associations established in previous studies.

9.2 The application of principal components analysis on the NPP data

9.2.1 Summary of previously presented PCA results

Principal components analysis was presented in sections **5.4.2**, **6.4.2** and **7.4.2** in an attempt to find patterns within the NPP distribution, before using redundancy analysis to assess the role of grazing on vegetation assemblage(s) at the three sites on Exmoor. It is important to consider that pollen largely reflect the vegetation on a regional scale, whereas the majority of (coprophilous) fungal spores do not travel more than a few metres (Baker, Bhagwat & Willis, 2013; Jackson & Lyford, 1999). For this reason, NPPs are usually more representative of local scale changes.

PCA is a useful tool for exploratory data analysis and to visualise correlations or covariance in multivariate data, without the inclusion of explanatory variables (Zuur, 2007). The PCA work discussed here focusses on identifying clusters of NPPs with specific indicator values or other forms of associations with certain habitat types.

A composite figure of all three PCA plots presented in chapter **5.4.2**, **6.4.2** and **7.4.2** are shown once more in figure **9.1**. It is clear from the results that the PCA axes 1 and 2 were able to explain the majority of the variability within the NPPs (a combination of PC1 and 2 would explain 68% at Great Buscombe, 50% at Spooners and 44% at Codsend Moors).

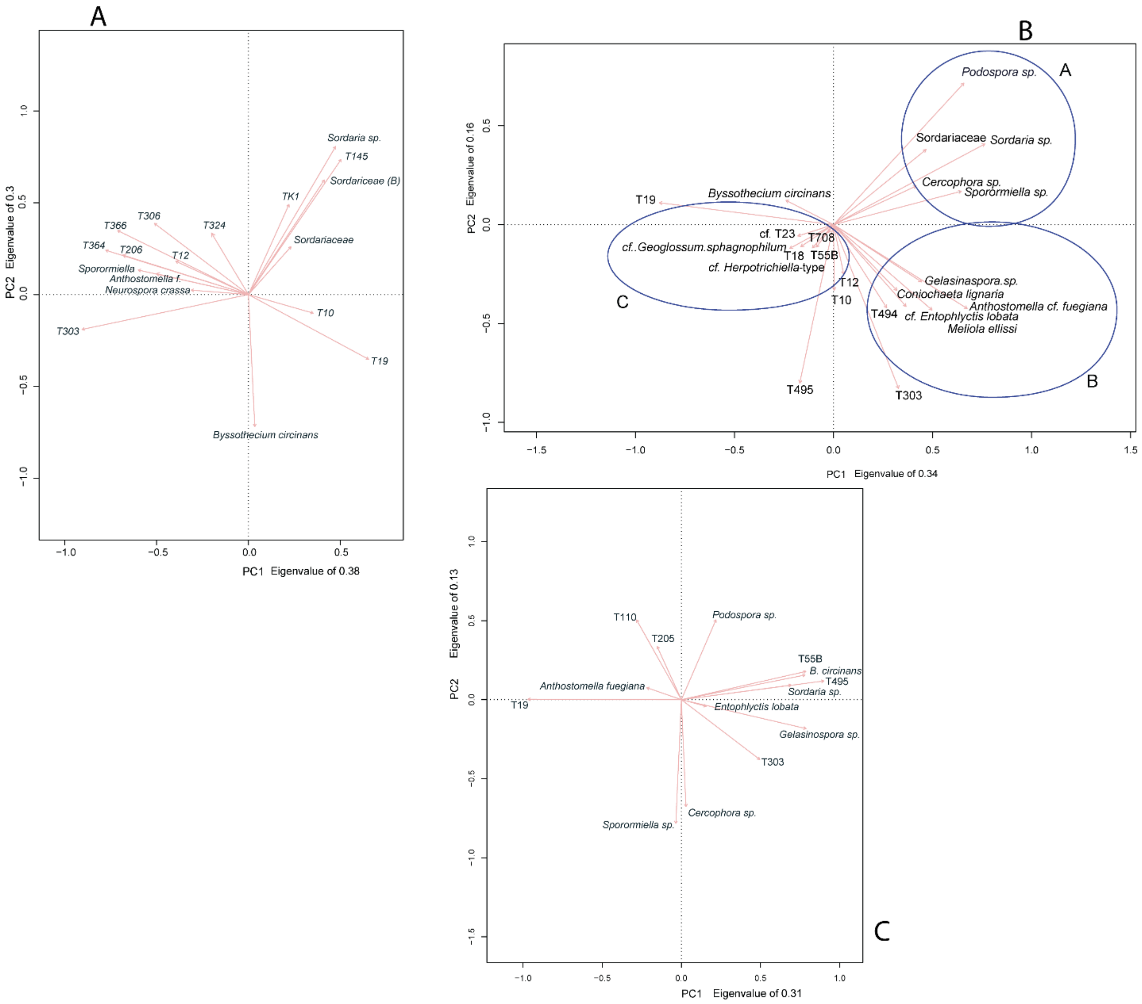


Figure 9.1. *PCA plots, as represented in chapters 5, 6 and 7.* ***A*** *is from Great Buscombe,* ***B*** *represents Spooners and* ***C*** *shows the PCA plot of Codsend Moors.*

The PCA axes often represent the degree in wetness, or level of (vegetation) disturbance reflected by NPP-indicator types. At Spooners (figure **9.1, B**), a total of three clusters is identifiable from the plot, showing one consisting of coprophilous spores only, and two of different phases of post-disturbance. At Great Buscombe (figure **9.1, A**), a total of two clusters are visible, containing coprophilous spores or a combination of mixed indicator types. Along these clusters, several types are distributed over the remainder of the plot without any direct association with other types. At Codsend Moors (figure **9.1 C**), only a single cluster can be identified, containing a mixture of coprophilous and disturbance-indicator types. An interesting difference with the plots from Codsend compared to those from Spooners and Great Buscombe is that the coprophilous NPPs move in different directions from one another, and show little association with each other.

9.2.2 – Detailed information derived from NPP clusters in the PCA plots

The PCA plots from all three studied sites show that the only identifiable cluster that exclusively contains coprophilous NPPs, occur in the Spooners data. At Great Buscombe and Codsend Moors, several grazing-associated NPPs are included in different clusters. At Great Buscombe they occur as part of a mixed NPP-indicator group, alongside NPPs that are associated with *Carex*, human disturbance and well-decomposed peat. At Codsend Moors, there is no direct correlation between coprophilous NPPs as a whole. *Sordaria* sp. (as mentioned above) is associated with drier conditions, and *Podospora* sp. occurs by itself on the plot. Furthermore, *Sporormiella* sp. and *Cercophora* sp. are positioned closely together, but on the opposite end of the plot to *Podospora* sp. This could indicate that different coprophilous NPPs may be associated with different periods of grazing or different levels of intensity. Additionally, Wood and Wilmshurst (2012) have argued that *Sporormiella* sp. abundance may fluctuate according to local hydrological changes and that interpretations should be made with caution. It is difficult to state what the most likely option is in the context of Codsend Moors, considering the majority of coprophilous NPPs do not co-occur with other NPPs on the PCA plots. Only two small clusters of other NPP types are visible in this plot, of which the largest one consists of NPPs that are affiliated with fire and drier periods of peat growth. This cluster could be associated with the presence of *Sordaria* sp., but shows no strong correlation with *Podospora* sp., *Sporomiella* sp. or *Cercophora* sp.. All grazing-related NPPs found in the Great Buscombe PCA plot (figure **5.5**) show to be associated with relatively drier periods, although the largest indicator of drier peat growth, T303, does not directly fall within any of the grazing-related clusters.

9.3 – Coprophilous fungal spores and grazing-indicator pollen taxa

The results of the PCA broadly confirm the grouping of key NPP types associated with grazing. A second critical approach is to consider the impact that grazing should have on upland vegetation, based on existing ecological studies and to use this to recognize the key pollen indicator types and patterns that might be expected with grazing. Previous studies have also used this approach to confirm the ecological interpretation of coprophilous NPPs based on correlation (Doyen & Etienne, 2017). Whilst there is a risk of circular reasoning in using correlation with pollen to confirm the interpretation of the NPPs, before then using the NPPs as grazing indicators to explain variation in the pollen, the approach used here is confirmatory rather than explanatory. Key indicator types are here critically correlated with the coprophilous NPP types through examination of the RDA results presented in chapters **5**, **6** and **7**.

Both NPP and pollen data from the studied sites have suggested that pastoralist activities took place at different parts of Exmoor, with irregular levels of intensity throughout the prehistoric period. Grazing or browsing of animals can alter the local vegetation and soil in several ways, which is largely based on the grazing intensity and the age of the herbivores, as well as site-based factors, such as soil-type and altitude (Palmer *et al.*, 2003). For instance, upland grazing is suggested to have been a critical factor for an increased difficulty of prehistoric woodland regeneration elsewhere in Britain (Long, Chambers & Barnatt, 1998). Grazing can influence the vegetation by affecting growth and reproduction systems of individual plants. Furthermore, the competitive balance between species can result in a shift in community compositions and are often the result of selective grazing (Augustine & McNaughton, 1998).

9.3.1 Grazing and grass-dominated vegetation compositions

A presence of grazing animals usually results in a decrease of *Calluna vulgaris* and other dwarf-shrubs, causing a replacement of shrubs with acidic grasslands (Bardgett, Marsden & Howard, 1995; Thompson *et al.*, 1995). Although light or intermediate grazing has been associated with an increase of *Calluna vulgaris* on well drained soils of the Exmoor uplands and uplands in general, heavier grazing is known to have encouraged the growth of grasses on Exmoor as well (Davies & Dixon, 2007; Hallam, 1978). Examples of both situations occurring on Exmoor are shown in the different PCA results of the studied sites and mentioned below.

The presence of grazing causes an increase in nutrient levels from dung and urine and results in a higher disturbance due to trampling from animals. Most importantly, a medium or heavy grazing pressure opens up the *Calluna vulgaris* canopy (Medina-Roldán, Paz-Ferreiro & Bardgett, 2012). In a response to this, *Calluna vulgaris* can no longer outcompete the faster growing grasses. These grasses can take their advantage of the more nutrient-rich soil once gaps in the *Calluna* canopy have been formed by herbivores (Alonso, Hartley & Thurlow, 2001; Hartley & MIitchell, 2005). Such relations between the increase of grasses and increased grazing are visible in the RDA plot of Spooners (figure **6.6**), showing a positive association between coprophilous NPPs and both Poaceae and *Potentilla*-type (a disturbance indicator pollen type). At Great Buscombe and Codsend Moors, however, such associations are not visible in the RDA plots. Results of Codsend Moors even show a positive association with *Calluna vulgaris*, which will be further discussed in section **9.3.2**.

Within the grasslands that usually form as a result of grazing, several pollen herb taxa are known to have been associated with the presence of herbivores. They have often been used as indicators of pastoral activities in palaeoecological research, although the majority of them can also occur in otherwise disturbed land or play a role in the recolonization of abandoned cultivated land (Behre, 1981). The most commonly used species is *Plantago lanceolata*, which is usually regarded as an indicator of pasture land, but at times is also associated with cultivation (Behre, 1981). Other taxa whose presence or increase have been associated with grazing include *Juniperus*, *Rumex acetosa*, *Succisa pratensis*, *Ranunculus*-type, *Cichorium intybus*-type and *Potentilla*-type, of which the latter is unpalatable to stock (Behre, 1981; Davies & Dixon, 2007).

Apart from the associations with Poaceae and *Potentilla*-type in the RDA plot of Spooners, less strong positive correlations are also shown with *Lactuceae* and *Plantago lanceolata*. Taxa such as *Rumex acetosa* and *Succisa pratensis* seem to, however, not show any positive correlations with grazing at Spooners (figure **6.6**). RDA results plots from Great Buscombe (figure **5.7**) and Codsend Moors (**7.7A**) both show a weak positive correlation with *Rumex acetosa*, but with no other taxa that is known from the literature to indicate pasture land.

9.3.2 – Reversed vegetation patterns

An exclusion of grazing often results in reversed vegetation patterns (regeneration) to those discussed in section **9.3.1**, with an increase in the relative abundance of *Calluna vulgaris* and a decrease in Poaceae (Medina-Roldán, Paz-Ferreiro & Bardgett, 2012). Such reversal shifts in vegetation have been found to also result in a slow-down of the soil nutrient-cycling, as well as an increased aboveground biomass (due to the increased plant litter of dwarf-shrubs) (Medina-Roldán, Paz-Ferreiro & Bardgett, 2012). PCA results from Codsend Moors (see figure **7.6**) could be interpreted to represent (intervals of) decreased grazing intensity, as it shows that *Sordaria* sp. (a grazing-related NPP) falls within the same cluster as T495 and *Byssothecium circinans*. The RDA plot from Codsend Moors (figure **7.7**), shows a weak positive correlation between coprophilous NPPs and *Calluna vulgaris*, rather than with Pocaeae. This suggests that the cluster containing *Sordaria* sp. in the PCA plot might reflect a combination of low-intensity grazing in a relatively drier habitat, as is indicated by the presence of T495 and *Byssothecium circinans*, implying that *Calluna vulgari*s would outcompete Poaceae.

Coprophilous NPPs in the PCA plot of Great Buscombe (figure **5.6**) show no correlation to the presence or increase of Poaceae or *Calluna vulgaris*, but instead show a correlation with the presence of *Alnus* in surrounding wetland areas, as indicated by T145. A direct positive association with *Alnus* is visible in the RDA results (figure **5.7**), suggesting that a particular period of grazing took place before the *Alnus* decline, which is confirmed by the pollen data (figure **5.3**). An association of TK1 with *Sordaria* sp. suggest that fire or burning occurred during this period in the area surrounding Great Buscombe, although charcoal data shows low values until the start of zone IPaz2 (see section **5.2.3**).

A second cluster containing a variety of NPP disturbance- and grazing indicator-types in the PCA plot of Great Buscombe (figure **5.6**) are most likely to reflect zone IPaz4 of figure **5.3.** During this period, an increased variety in coprophilous NPPs is also visible in the NPP diagram (figure **5.5**) and correlates to a period of a Poaceae dominance. Considering the majority of coprophilous NPPs consist of *Sordaria* sp., which occur in larger numbers during zone IPaz1, the RDA and PCA may reflect two different periods of increased grazing, but where each period influences the landscape differently.

9.4 NPPs with a variety of hosts

Three NPP types will be briefly discussed individually, due to previously made associations in the literature compared to the study on Exmoor NPP data. These types are T55B (*Sordaria* sp.), *Gelasinospora* sp. and *Byssothecium circinans*.

Type 55B (Sordaria sp.*)*

Type 55B has been previously associated with meso- eutrophic and minerotrophic conditions by Van Geel (1978), Kuhry (1985) and Innes and Blackford (2003). Willemsen, van ‘t Veer and Van Geel (1996) regarded T55B as a dung indicator, but not all *Sordaria* sp. are obligate dung fungi (Ellis & Ellis, 1998). Doyen and Etienne (2017) clearly associated *Sordaria* sp. with grazing activities through association with ruderal pollen taxa.

NPP types in the PCA plot of Spooners are the least divided and have provided a more clear view on what possible habitats they may reflect. As mentioned in chapter **6.4.1**, three clusters show a division of grazing-related NPPs with early post-disturbance regeneration NPPS and drier conditions on relatively poorer soils. T55B falls within the third cluster, instead of the grazing-related cluster, whereas T55B does fall within grazing-related clusters in the PCA plots of Great Buscombe and Codsend Moors. Thus, PCA results from Spooners, Great Buscombe and Codsend Moors confirm that T55B does not show a consistent association with one or the other previously suggested conditions and that they can both be associated with increased grazing pressure, as well as meso- to eutrophic and minerotrophic conditions.

Type 1 and 2 (Gelasinospora sp.*)*

Blackford, Innes and Clarke (Forthcoming) describe *Gelasinospora* sp. as most commonly associated with the presence of fire, but it has also been argued to have a variety of hosts (Ellis & Ellis, 1998), and has furthermore been associated with drier conditions (Blackford, Innes & Clarke, Forthcoming). It is difficult to state whether *Gelasinospora* sp. found in peat sequences from Exmoor can be regarded as fire-indicators. They show strong correlations with *Entophlyctis lobata* and T303 at Codsend (figure **7.6**) and Spooners (figure **6.6**), which are both regarded as indicators for drier peat growth. The reliability of T303 as an indicator for drier periods is however also questionable, considering it often (but not always) shows increased numbers in the NPP diagrams simultaneously with increased levels of charcoal, visible in the pollen diagrams of Spooners, Great Buscombe and Codsend Moors. It is possible that drier phases of peat growth are associated with increased fire frequency, but this has not been examined within this thesis.

Type 16A/B/C (cf. Byssothecium circinans)

T16, referred to in this thesis as *Byssothecium circinans,* is a distinctive ascospore that has previously been regarded as a host on woody substrates (Boise, 1983; van Geel & Aptroot, 2006), but has also been associated with grasses growing in mire communities (Innes & Blackford, 2003; Van Geel, 1978). Since this type frequently occurs in the NPP data of all three sites, it would be useful to understand its habitats (or preference). However, *Byssothecium circinans* shows no direct relationship with any other NPPs in the PCA plot of Great Buscombe (figure **5.6**), and only a single direct relationship to T19 in the PCA plot of Spooners (figure **6.6**). T19 has been associated with a high presence of *Calluna vulgaris* pollen with a dense ground cover of *Hypnum* (Innes *et al*. 2009). Its correlation with T16 might thus show that *Byssothecium circinans* can also be associated with the presence of *Calluna vulgaris*, as a provider of the woody substrate. However, in the PCA plot of Codsend Moors (figure **7.6**), *Byssothecium circinans* falls within the cluster that also includes *Sordaria* sp. and T495. This cluster thus contains grazing indicators, but also T495, which is believed to be associated with dominant pollen of Cyperaceae and Poaceae (Blackford, Innes & Clarke, Forthcoming). Increased levels of *Byssothecium circinans* in the NPP data from Codsend Moors (figure **7.5**) do show a simultaneous occurrence of higher levels of Poaceae in the pollen diagram (figure **7.4**). Data from Spooners show a lack in any consistent association between increased levels of *Byssothecium circinans* and Poaceae (figures **6.4** and **6.5**). This implies that within the wider region of Exmoor, the frequently found T16 cannot consistently be assigned to a single habitat and can increase together with grasses, sedges and heather.

9.5 Inferences made on NPPs within this study

A small amount of NPPs found within this study occurred frequently enough across the three sites to draw new conclusions off their possible indicator values. This section will briefly outline this selection of NPPs and compare new suggestions from this study to those known from the literature.

A table, similar to that presented in chapter **6**, is presented below. It includes a selection of NPPs that showed some form of possible relation to other NPPs and/or pollen in the PCA and RDA plots. Each number in the fourth column of the table refers to the numbered NPP types discussed individually in this section.

Category	**Genus/Species/Type**	**Indications/associations known from literature:**	**Associations found within this study:**
Category A – Grazing indicators	*Sordaria* sp.	Grazing	Grazing
	Podospora sp.	Grazing	Grazing
	T55B	Grazing	Grazing/meso-eutrophic and minerotrophic soils
	Cercophora sp.	Grazing	Grazing[1]
	Sporormiella sp.	Grazing	Grazing[1]
Category B – Heathland Drier conditions Poorer soils	*Anthostomella cf. fuegiana*	*Eriophorum* and Cyperaceae Well decomposed peat Wide range of hosts possible	Wide range / inconsistent
	Entophlyctis cf. *lobata*	Woodland/Heathland transition Relatively dry soil samples (*Aquatic saprotroph*)	Found in clusters with NPPs indicative of disturbance (burning or grazing)[2]
	Gelasinospora sp.	Post-fire regeneration (Pyrenomycetes) Grazing (levels increase with dung presence)	With NPP types indicative of heathland and drier conditions. Associated with grazing indicators[3]
	Coniochaeta ligniaria	Dead wood Background indicator for grazing	With NPP types indicative of heathland and drier conditions[4]
	Meliola ellisii	*Calluna vulgaris*, with possible relations with *Vaccinium vitis-idaea*	With NPP types indicative of heathland and drier conditions

	T494	*Molinia caerula* tussocks	With NPP types indicative of heathland and drier conditions.[5]
	T145	Unspecific spore type *Tilia-Quercus* dominance on dryland *Alnus* dominance on wetland	Found in grazing cluster[6]
	T303	Drier phases of peat growth	No direct association, small positive association with *Gelasinaspora* sp[7]
	T12	Drier phases of peat growth	Uncertain
	T495	Epidermal remains of *Molinia caerula* Well decomposed peat Pocaceae/Cyperaceae	Inconsistent[8]
Category C – Remaining types	T19	*Calluna vulgaris* presence Sphagnum	Uncertain[9]
	Byssothecium circinans	Woody substrates Mesotrophic and dry phase bog development Grasses in mire communities	Inconsistent[10]

Table 9.1. *Inferences made on main NPP types found within this study, compared to habitats/substrates known from the literature.*

The data presented in table **9.1** shows the main NPP types that were found at one or more sites within this study, categorised in possible habitats. Each type is associated with certain substrates or environmental conditions through previous studies and is compared to indications identified within this study. Although a few key types have already been discussed in section **9.4**, additionally, there are several more aspects around NPP signals presented in table **9.1** worth discussing into further detail. Numbers in the following list refer to the fourth column in the table.

1. Both *Cercophora* sp. and *Sporormiella* sp. are associated with grazing indicating types, both in the literature (e.g. Innes & Blackford, 2003; Ralska-Jasiewiczowa & van Geel, 1992) and within this study. However, these two types only occur in the grazing-NPP cluster in the PCA plot of Spooners. In the PCA plot of Codsend Moors, they form a cluster that shows no direct association with any other NPP types. In the PCA plot of Great Buscombe, *Sporormiella* sp. move in an almost opposite direction from other grazing-related types, and appears to be associated with types that suggest a wide range of environmental conditions. This is rather interesting and may suggests that these types could either have a range of hosts or are perhaps found on dung from different animals to those of *Podospora* sp., for example. Cugny, Mazier and Galop (2010) did not find a direct positive association of *Cercophora* sp. with grazed areas, but suggested that this may be explained by a variety of species within the genus that are affiliated with a range of habitats.
2. *Enthoplyctis* cf. *lobata* was found in material from Spooners and Codsend Moors. From its location in the PCA plot of Spooners, it suggests that this type was found in a cluster that may represent earlier phases of disturbance (through e.g. fire) and is indicative of heathland and drier conditions. In the PCA plot of Codsend Moors, it is closely related to *Gelasinospora* sp. and appears to be centred in between grazing-related NPP types. This suggests that *Entophlyctis* cf. *lobata* in itself might not be indicative of disturbance, but could be regarded as an additional confirming species where other, more reliable types, have already been found.

3. *Gelasinospora* sp. and its potential indicator value has been briefly discussed in section **9.4**. Additionally, in the PCA plots of both Great Buscombe and Codsend Moors, it appears to be somewhat related to grazing-related NPPs. Although previous research has suggested that *Gelasinospora* sp. can increase alongside grazing-indicators, research here suggests that *Gelasinospora* sp. may increase alongside coprophilous NPPs, where fire was used to open up the vegetation (for grazing improvement). In order to test this, *Gelasinospora* sp. could be included in a statistical analysis with both pollen and charcoal data.
4. Although previous literature suggests that *Coniochaeta ligniaria* live on dead wood and may be background indicators for grazing, results from this study suggest otherwise. Although it solely occurs in material from Spooners, it did occur in the cluster B of the PCA plot, which is associated with fire, heath, *Molinia caerula* and drier conditions. More data would be necessary to make any further statements or to make a reliable comparison to previous research on this species.
5. T494 occurs in material from Spooners only and is included in the cluster indicative of heath, fire and drier conditions. T494 is associated with the growth of *Molinia caerula* in previous research. Considering *Molinia caerula* more commonly grows on wetter areas, the find of T494 might indicate that spores arrived from areas directly associated with the bog, or may have grown in perhaps seasonally more wet phases. Another suggestion could be that the T494 spores indicate that *Molinia caerula* formed tussocks in drier phases of peat growth, and may have been a result of burning regimes. More data would be necessary to test this hypothesis.

6. Although T145 only occurs in the material from Great Buscombe, it is directly associated with grazing indicators. In previous literature, T145 is suggested to be indicative of woodland, with a *Tilia-Quercus* dominance in drier woodland and an *Alnus* dominance in wetter areas. A combination of results and prior knowledge may suggest that T145 was associated with a higher level of *Alnus* in the pollen diagram. It appears that T145 decreases in a similar timeframe as *Alnus* pollen do. Furthermore, its association with grazing-related NPPs in the PCA plot of Great Buscombe may show that T145 occurred at the time where *Alnus* was cleared to create new grazing areas for livestock. Considering the other two sites in this research did not have a high percentage of *Alnus* during the period of focus, it would have to be tested elsewhere or perhaps in material from earlier time periods.
7. Although T303 has been highly abundant at all three sites researched, not many inferences can be made on its indicator value. Previous research suggests T303 is indicative of drier phases of peat growth (Van Geel, Bohncke & Dee, 1980), but no such concluding statement can be made based on results from this study. As mentioned in section **9.4**, T303 would be an interesting candidate for further statistical testing, alongside charcoal data in particular.
8. T495 appears to show inconsistent results between the PCA plots of Spooners and Codsend Moors. In PCA plots of Spooners, it does not show any direct correlation to other NPPs, whereas it shows a close association with *Sordaria* sp. and *Byssothecium circinans* in the PCA plot of Codsend Moors. Neither of these results directly reflect a similarity with suggestions made in previous studies and more tests would be needed to improve knowledge on T495.

9. Previous studies suggest that T19 is either associated with *Calluna vulgaris* or with *Sphagnum.* Despite the fact that T19 is very abundant on all three sites in this research, no coherent conclusion can be drawn from the analyses. The only consistent finding is that this type never appears to be in association with disturbance-indicator NPPs. T19 is the dominant NPP type throughout Codsend Moors and partially in phases in Spooners and Great Buscombe. A test against pollen may improve the knowledge on T19 in the context of this study and perhaps wider applications.
10. As previously discussed in section **9.4**, *Byssothecium circinans* is also a very abundant NPP type. It is present at all three sites, but lacks any indication for a specific host, habitat or other environmental condition. Information derived from both T19 and *Byssothecium circinans* may be improved by including them in statistical analyses focussed on pollen and charcoal data, as grazing-related NPPs do not seem to be (consistently) associated with these two NPP types.

9.6 Summary

This chapter has shown evidence for the importance of including NPPs into palaeoecological research. Results of PCA and RDA analyses that combine NPPs with pollen data have shown how they can enhance a further understanding with how certain NPPs relate to each other and to the vegetation in different grazing conditions. The analyses of coprophilous NPPs have shown associations both with an increase of Poaceae and other disturbance indicator pollen taxa, but also with *Calluna vulgaris*, suggesting either high or low grazing pressure. PCA results from all three sites have furthermore shown that only in the case of high grazing pressure, as was present at Spooners, coprophilous spores fall within the same cluster on PCA plots. In cases of lower grazing pressure, such as at Great Buscombe and Codsend Moors, coprophilous spores are somewhat related to disturbance-indicator types, or move in separate ways, showing little to no correlation with each other. The second part of this chapter has shown the importance of analysing NPPs and comparing them to the wider literature in order to interpret NPP data properly. Key associations of several different NPP types were discussed and suggested to have a variety of hosts.

Chapter 10 - Impact of human land use on the vegetation of Exmoor during late prehistory

10.1 Introduction

This project has developed detailed records of late prehistoric vegetation history from three sites on Exmoor (chapters **5**, **6** and **7**), and presented proxies that represent potential drivers (or controls) on vegetation change through micro charcoal and NPP work (chapters **5**, **6** and **7**) and a synthesis of past climatic changes (chapter **8**). This chapter will summarise those findings and place them within a broader framework of research on the main drivers of upland vegetation change throughout prehistory. The first section will deal with a broader reconstruction of vegetation change on Exmoor from the late Neolithic to the late Iron Age, bringing together the detailed results from this work and previously published datasets, before discussing the likely drivers of these changes. All sections are structured by archaeological period, of which the first part will discuss the main forms of vegetation compositions and changes therein.

Each section includes a synthetic view of the role of three main disturbance factors: grazing, burning and climate through prehistory.

The chapter is structured by archaeological time period. These periods are based on the archaeological periods suggested for South West England (Webster, 2008) and continuities in land use across traditional archaeological divisions suggested by the results of this study. The late Neolithic and early Bronze Age (pre-2300 – 1500 cal BC) are discussed together, due to their similar forms of settlement, as known from archaeological evidence (Webster, 2008). The middle Bronze Age and late Bronze Age (1500 – 800 cal BC) are discussed as separate periods, due to both changes in settlement form, as well as new forms of land use and an overall sedentary life style, as has been suggested by archaeological field structures and palaeoecological data (Webster, 2008). The Iron Age is divided into two sections (earlier and later Iron Age – 800 to 400 cal BC and 400 cal BC to 43 cal AD, respectively), rather than the more traditional "early, middle and late Iron Age". This twofold division is mainly based on the suggestions of a revision of the start of the late Iron Age (Webster, 2008). Traditional divisions are primarily based on pottery and other forms of cultural changes that took place in southeast England. A much clearer and more recently discussed division, evident from archaeological work on past settlements, suggests widespread changes in society at around 400 cal BC in southwest England (Webster, 2008). Therefore, the "earlier" Iron Age will cover the period between 800 and 400 cal BC, whereas the "later" Iron Age will cover the period ranging from 400 cal BC to 0 cal AD in this chapter. The second part of this chapter will, as previously outlined, present a thematic discussion on the roles of different forms of land use and climate on vegetation composition and change. References on how this may apply to other upland areas are included in this section.

10.2 Vegetation and land use on Exmoor during the late Neolithic and early Bronze Age

10.2.1 Vegetation changes and evidence of human land use during the late Neolithic and earlier Bronze Age (c. 2500 cal BC to 1500 cal BC)

Spooners is the only site within this study that includes material dating from the Neolithic period. Pollen data from Spooners indicates that a gradual opening up of the landscape had already started taking place by the Neolithic period. Around 50% of the TLP of Spooners consisted of tree pollen. An opening up of the landscape suggested by pollen data from Spooners has also been identified at other sites on Exmoor, indicating that woodland disturbance initiated from the start of the Neolithic period, although earlier examples of woodland disturbance are known from the Mesolithic, such as at Exebridge on the southern edge of Exmoor (Fyfe, Brown & Coles, 2003). Pollen data from Long Breach suggests an increase of grasses in the period between 4650-4240 cal BC. A decline of arboreal taxa succeeded the period of grass dominance until 2400 cal BC, with no reoccurrence in the pollen curve (Fyfe, Brown & Rippon, 2003). At Long Breach, therefore, disturbance resulted in a permanent reduction in tree cover. At other sites, such as Exebridge, woodland regeneration occurred (Fyfe, Brown & Coles, 2003). At Comerslade, approximately 3.9 km west of Spooners, there was a period of increased arboreal values at around 2600 cal BC, following a phase of grass dominance (Fyfe, 2012).

Tree/brush clearance at 4000 cal BC is also suggested by pollen studies from Hoar Moor (Francis & Slater, 1992), and shows that the trend seen at Spooners is relatively common on Exmoor during the late Neolithic. However, at some upland sites on Exmoor, woodland disturbance or clearance had not (yet) occurred, as suggested by the *Alnus*, *Betula* and *Corylus* dominance at Great Buscombe (see figure **5.3**) and Swap Hill (Davies, Fyfe & Charman, 2015).

Two periods of heath expansion, occurring at c. 3000 cal BC and c. 2600 cal BC. took place at Spooners, indicating that heathland became more common throughout the Neolithic period. Data from The Chains shows that in the period of 2910-2500 cal BC the central uplands of Exmoor were already dominated by (wet) heath communities (Moore & Merryfield, 1974). A decline in the charcoal data from Spooners coincides with a second phase of heath expansion, at c. 2600 cal BC, suggesting that a decline in burning may have triggered the growth of *Calluna vulgaris*. At Long Breach increases in charcoal were strongly associated with the development of grass-heath (Fyfe *et al.* 2003; Fyfe *et al.* 2018).

The general trend of woodland clearance in the uplands of Exmoor carried on into the early Bronze Age, largely based on evidence from blanket mires (with a regional pollen source area) such as The Chains and Hoar Moor (Francis & Slater, 1990; Fyfe, 2012; Moore & Merryfield, 1974) and similar phases of clearance are also found in uplands elsewhere (e.g. McCarroll *et al.*, 2016; Turner, Swindles & Roucoux, 2014). Although data from a large number of sites on Exmoor (discussed below) indicate a continuation or increase of woodland clearance, data from some sites on Exmoor show that local patches of woodland remained present in the landscape of the early Bronze Age. A possible phase of increased human land use at Spooners, dated to the period between 2300 to 1900 cal BC, is suggested by a gradual increase of mainly Poaceae (40%), but of *Potentilla*-type values as well (see figure **6.4**). The second phase (from c. 1900 to 1500 cal BC) shows a decline in *Corylus* (from 20% to 10%) and *Alnus* (from 10% to below 5%), alongside a further increase of herbaceous taxa, primarily *Plantago lanceolata* and *Potentilla*-type (see figure **6.4**). An active form of woodland reduction is also evident from the pollen data from The Chains, in the period between 2190-1520 cal BC (Moore & Merryfield, 1974). A similar trend is known to have occurred at Hoar Moor during the period between 2000-1500 cal BC and at Gourte Mires during 2120-1730 cal BC (Francis & Slater, 1990; Fyfe, Brown & Rippon, 2003). Data from Long Holcombe shows that even though Poaceae dominated the vegetation composition at that site at 2200 cal BC, arboreal taxa remained consistently present (Fyfe, Gehrels & Vickery, 2008), suggesting that woodland reduction did not occur everywhere on Exmoor simultaneously.

There is a large and compelling body of evidence for increasing opening up of the landscape during the early Bronze Age; however, pollen data from several sites on Exmoor suggests that pockets of woodland persisted. Pollen data from Great Buscombe indicates that arboreal taxa remained dominant until 1300 cal BC. *Alnus* consistently dominates the TLP with 70% during both the late Neolithic and early Bronze Age at Great Buscombe (figure **5.3**). An increase in *Alnus* is visible in the data from Swap Hill during the early Bronze Age and its dominance carried on into the middle Bronze Age, followed by a grass-dominated landscape (Davies, Fyfe & Charman, 2015).

Phases of heath expansion took place at c. 1570 cal BC across several sites on Exmoor as well. At Comerslade this coincided with an increase in Poaceae and a decline in arboreal taxa, whereas at North Twitchen Springs a decline in Poaceae took place alongside an episode of heath expansion (Fyfe, 2012). Based on a mixture of indications visible in the pollen data from several sites on Exmoor, it is therefore likely that a mosaic landscape of heath, grass and tree dominance existed during both the Neolithic and early Bronze Age, but with a general trend towards increased openness. A significant number of sites show that woodland reduction, most likely as a result of active clearance episodes, continued during the transition from the Neolithic into the early Bronze Age. However, examples remained present of areas where arboreal taxa such as *Alnus* and *Corylus* remained dominant.

10.2.2 Grazing activities during the late Neolithic and early Bronze Age

Grazing activities are thought to have been a potential driver of changes in the vegetation composition on Exmoor throughout prehistory (Fyfe *et al.*, 2018). Vegetation at Long Breach, for instance, is suggested to have been influenced by grazing since the start of the Neolithic (Fyfe, Brown & Rippon, 2003) although this has, to date, not been evidenced. The coprophilous fungal spores in the NPP assemblage of Spooners suggest a presence of regular grazing during the late Neolithic. A continuous presence of the grazing-associated taxa (Blackford, Innes & Clarke, Forthcoming)

Sordaria sp., *Podospora* sp., *Cercophora* sp. and *Sporormiella* sp. occur in the NPP data in the period between 3100 to 1950 cal BC (figure **6.5**). This suggests that grazing took place throughout this period in the local surroundings of Spooners with little variation in intensity during this time period. Archaeological evidence from both ritual-related monuments as well as settlements from the wider southwest region dating to the Neolithic and early Bronze Age indicate a presence of a wide variety of animals, both feral and domesticated, such as cattle, pig, sheep, goat, deer, dogs and aurochs (Webster, 2008). It is possible that this wider variety of (grazing) animals could be associated with different types of coprophilous fungal spores found at Spooners. Previous coprophilous NPP studies (e.g. Baker, Bhagwat & Willis, 2013) have shown that specific coprophilous spores might be directly associated with specific animals and may imply that a broader set of grazing-related NPPs found at Spooners might reflect a variety of animals that were grazing in this areas. Unfortunately direct evidence of animal husbandry is lacking from Exmoor owing to preservation issues for bone in soils (Riley & Wilson-North, 2001), thus this cannot be directly tested. The RDA moving time window analysis (shown in figure **6.7**) suggests that grazing can explain some of the variation in the vegetation cover during the late Neolithic but this does not exceed 10% of the variation in the pollen dataset. The explanatory power increases towards the transition into the early Bronze Age (to around 25%). Thus whilst animals were most likely herded on Exmoor during the late Neolithic and early Bronze Age, grazing intensity alone was not sufficient to have had a major impact on the character of the upland vegetation, either due to a low number of animals or high mobility of animals, having little impact on the local vegetation at a measurable level.

Between 1800-1450 cal BC, in the early Bronze Age, a large peak of coprophilous NPPs (namely *Sordaria* sp., *Sporormiella* sp. and *Podospora* sp.) is visible in the Spooners data (figure **6.5**), suggesting a c. 300-year long period of increased intensity grazing took place (a sustained increase noticeable across six samples). This could have encouraged the loss of local *Calluna vulgaris* (Medina-Roldán, Paz-Ferreiro & Bardgett, 2012), which was replaced by an increase of 40% to 60% of Poaceae (figure **6.4**). Disturbance-indicating herbaceous taxa *Plantago lanceolata* and *Potentilla*-type co-occurred during this episode of intensified grazing pressure, with *Potentilla*-type reaching values of almost 20% at the start of this phase (figure **6.4**). Evidence from North Twitchen Springs, around 5km southwest of Spooners, shows a 100-year period from c. 1980 to 1890 cal BC with a notable increase of disturbance-indicator taxa *Plantago lanceolata* and *Potentilla*-type, alongside a decline in heath taxa (Fyfe, 2012). This was interpreted as a similarly short-lived, but significant, phase of human activity on this southern margin of Exmoor.

The increase in moving time-window RDA scores at Spooners to 30% to 40%, using coprophilous spores as the explanatory variable, clearly demonstrate that grazing had a major impact on vegetation composition (figure **6.8c**). Considering there are few other types of land use or management evident from all proxy data, grazing was thus the dominating factor that shaped the vegetation composition around Spooners during the early Bronze Age. The decline in *Corylus* may have partially been the result of tree clearance. It is impossible to state at this stage whether this phase of increased intensity grazing levels also took place elsewhere on Exmoor, due to a lack of NPP data from previous studies on other sites on Exmoor. However, a possible reduction in grazing pressure has been suggested by pollen data from the site Shovel Down on

Dartmoor (Fyfe *et al.*, 2008). At Whitehorse Hill on Dartmoor, analysis of samples adjacent to a burial monument showed a clear and sustained increase in grazing-related NPPs (particularly *Sordaria* sp. and Type 206), lasting around 100-150 years and dating to the early Bronze Age (Fyfe *et al.*, 2016). At Sittaford Tor, examination of a sample dating to 1870-1540 cal BC recovered during excavations of a stone circle in 2016, included only minimal grazing-related NPPs, in spite of good preservation (Fyfe & Ombashi, 2018b). Grazing may therefore not have been ubiquitous across the southwest uplands throughout the late Neolithic and Early Bronze Age. It is however assumed that pastoralism was the dominant lifestyle during both the late Neolithic and early Bronze Age and may be associated with a measured peak in population in archaeological radiocarbon date series of Britain and Ireland at 2000 cal BC (Bevan *et al.*, 2017).

10.2.3 Fire regimes during the late Neolithic and early Bronze Age

Charcoal values from Spooners suggest that burning took place from 2800 to 2400 cal BC, but evidence for burning regimes from as early as the Mesolithic period are known (Fyfe, Brown & Rippon, 2003). Charcoal data from various sites on Exmoor suggests that the presence of fire played a large role in the vegetation composition, such as at Long Breach during the Neolithic (Fyfe, Brown & Rippon, 2003). A close association between the expansion of grass, following a phase of heath dominance, and the introduction of significant burning levels are known from the area surrounding

Molland Common, during the period between 3360-2640 cal BC (Fyfe, Brown & Rippon, 2003), showing an example of an even earlier prehistoric impact of fire on the vegetation composition.

The values in the moving RDA plots of Spooners indicate that burning had an average significance level of around 10% and 11% during the late Neolithic on the pollen assemblage. Frequent levels of burning would have taken place to regularly keep heather under control (Alday *et al.*, 2015; Rippon, Fyfe & Brown, 2006). A continuous presence of *Gelasinospora* sp. can be seen at Spooners in this time period (figure **6.5**), and may confirm the hypothesized correlation between these species and the presence of burning events (as discussed in chapter **9** and previous studies (e.g. Simmons & Innes, 1996a).

Burning regimes declined during the transition into the early Bronze Age, as suggested by charcoal data from Spooners (figure **6.4**). A decline in the average values to below 8% of the charcoal-based RDA moving time window analysis (figure **6.8b**) suggests that whilst fire may have played a small role in vegetation changes, overall it was not a large influence during the early Bronze Age at Spooners. At Great Buscombe charcoal levels are also low throughout this period, relative to the rest of the sequence, and are accompanied by consistently low values of Poaceae, *Calluna vulgaris*, possible disturbance-indicator taxa such as *Potentilla*-type or *Plantago lanceolata* and a dominance of arboreal taxa ranging between 60 to 80% of TLP (see figure **5.3**).
Low charcoal levels during the early Bronze Age from both Great Buscombe and Spooners imply that burning was a significant land management tool at these sites at

this time. However, a strong negative correlation was found between charcoal data and *Calluna vulgaris* for the period between 2150-1650 cal BC at Gourte Mires and a strong positive correlation between charcoal data and *Calluna vulgaris* was found at Beckham during the period between 1550 and 550 cal BC (Fyfe *et al.*, 2018). This implies that burning activities did not decrease during the early Bronze Age everywhere on Exmoor, but that rather a mixture of land use / management practices was present at different locations during the early Bronze Age, causing a variety of changes in the vegetation at the local scale.

10.3 Different land use phases reflected in Exmoor's vegetation during the middle Bronze Age (1500-1000 cal BC)

10.3.1 Cultural changes influencing the vegetation of Exmoor in the middle Bronze Age

Spooners and Great Buscombe are the only sites that contain material dating to back to the middle Bronze Age. The sequence from Codsend Moors starts towards the end of the middle Bronze Age, and so that material will be drawn in where appropriate. The start of the middle Bronze Age has been long recognised as marking a significant shift in cultural and agrarian practice across Europe (Stevens & Fuller, 2012; Webster, 2008), with evidence from southwest Britain, and specifically Dartmoor, making significant contributions to the understanding of this period (Fleming, 2008). Exmoor preserves similar field systems that are similar, but more fragmented than the Dartmoor Reaves, and are broadly understood to date to the middle Bronze Age (Riley & Wilson-North, 2001).

10.3.2 A development of varying vegetation patterns during the middle Bronze Age

A continuity of a mosaic, wider landscape of Exmoor carried on from the Neolithic into the middle Bronze Age. Three major vegetation trajectories have been identified from sites on Exmoor:

a) scrub regeneration in several areas, *b*) clearance of woodland in other areas and *c*) phases of replacement of grasses by heather in areas that are already open.

a) The evidence for a closing up of the landscape is detectable in the pollen data from Spooners (figure **6.4**), which show an almost linear increase of arboreal taxa, primarily *Alnus* (reaching 20%) and *Corylus* (reaching 40%). This occurred alongside a decline in both Poaceae (from 45% to 35%) and *Calluna vulgaris* (from 40% to 10%), although the ratio between the two remained the same.

b) A variety of sites on Exmoor describe an opening up of the landscape, mainly through declines in arboreal taxa. Pollen data from Great Buscombe (figure **5.3**) indicates an opening up of the landscape surrounding this site from c. 1300 cal BC onwards. *Alnus* pollen declined from 60% to 10%, over a period spanning approximately 100 years (shown in figure **5.3**) and allowed for an expansion of grasses and other herbaceous taxa, mainly *Potentilla*-type (ranging between 5% to 20%). Data from Halscombe Allotment indicates that a major shift towards a domination of grasses took place 200 years prior to the *Alnus* decline at Great Buscombe, at 1500 cal BC (Fyfe *et al.*, 2013b). Alongside an increase of charcoal levels, grasses also became dominant at Swap Hill at 1300 cal BC (Davies, Fyfe & Charman, 2015). Other studies on Exmoor suggest a gradual continued opening up of the landscape throughout the middle Bronze Age (Fyfe, 2012).

Charcoal data from Codsend Moors shows increased levels during the middle Bronze Age but, following a decline in charcoal values at c. 1080 cal BC, changes in the vegetation composition resulted in an incline of heath expansion (see figure **7.4**). At a similar period in time, pollen data from Moles Chamber also suggests an increase of heath taxa in the site's regional environment (Fyfe, 2012). This shows that there is no specific generic, homogeneous vegetation composition for all sites on Exmoor during this period in prehistory either, and this was presumably the case during the late Neolithic and early Bronze Age as well.

10.3.3 Land use and management on Exmoor during the middle Bronze Age

Proxy data from Spooners, Great Buscombe and Codsend Moors show that the local landscapes around these sites were the subject of low intensity levels of land use and land management during the middle Bronze Age. NPP evidence from all three sites suggests low-intensity grazing throughout the middle Bronze Age (figures **5.5**, **6.5** and **7.5**). The relative intensity between Spooners and Great Buscombe/Codsend Moors may however vary significantly. For instance, at the latter two sites, grazing could have affected the herbaceous taxa composition differently, as suggested by episodes of increased disturbance-indicator taxa, such as *Plantago lanceolata* and *Potentilla*-type. These disturbance-indicator taxa remain relatively lower at Spooners (background values; shown in figure **6.4**), compared to Great Buscombe (levels ranging between 10% and 20%; shown in figure **5.3**) and Codsend Moors (ranging around 3% to 5%, shown in figure **7.4**) and may indicate lower-impact grazing during this time period at Spooners. RDA moving time window values (figure **6.8B and 7.8B**) of coprophilous spores show that grazing during the middle Bronze Age at Spooners and Codsend Moors had significant values, ranging between 3% and 4%. This implies that grazing had minimal influence on the vegetation composition in the local surroundings, although it should be noted that NPP data from Codsend Moors does not represent the entire middle Bronze Age.

Low charcoal concentrations suggest that fire was used at a low intensity, with little variation over time, in the area during the entire middle Bronze Age at Spooners (figure **6.4**) and between 1300 and c. 1200 cal BC at Great Buscombe (figure **5.3**). The remainder of the middle Bronze Age, in the period between 1200 to 1000 cal BC, shows only a subtle increase in charcoal values at Great Buscombe (figure **5.3**). This implies that burning was of a low intensity at Great Buscombe, with only a small statistical impact on the pattern of vegetation. This is confirmed by an average RDA moving time window value of approximately 12% during the end of the middle Bronze Age (figure **5.10C**). Charcoal concentrations from Codsend Moors indicate that burning was used as a land management tool in this area from 1180 cal BC onwards, but became less intensely used during the transition into the late Bronze Age. RDA moving time window values (figure **7.8C**) show that the impact value of burning on the pollen assemblage remained below 6%, confirming that low-impact burning regimes took place at Codsend Moors during the middle Bronze Age. Findings from Spooners, Great Buscombe and Codsend Moors show slightly similar results compared to charcoal data from Swap Hill, Larkbarrow and Beckham. At the latter three sites, rapidly increasing charcoal levels were noticed from the middle Bronze Age onwards, although high concentrations were not present in the charcoal data until the later Iron Age (Davies, Fyfe & Charman, 2015). This suggests that during the middle Bronze Age, burning was used as a tool for land management across Exmoor, but did not play a large role in the vegetation composition and would likely have had a similar explanatory significance value on the vegetation composition as pastoralism.

10.3.4 Field systems and climate changes during the middle Bronze Age

Palaeoclimatic reconstructions based on Scottish bog surface wetness levels (Brown, 2008), as well as the water table depth reconstructions from Tor Royal Bog mentioned in chapter **8.5,** have indicated that there was a shift to a cooler/wetter climate during the middle Bronze Age (Amesbury *et al.*, 2008), dating from 1395 until 1155 cal BC. Furthermore, the middle Bronze Age has also been associated with a shift towards an overall more sedentary lifestyle and social changes reflected by the introduction of land division in the shape of field systems, such as those found on Dartmoor (Fleming, 2008) and Exmoor (Fyfe *et al.*, 2008). More recent research on the field systems on Dartmoor argue that the field systems were not "planned" systems, but rather built on previously prehistoric arranged boundary constructions (Johnston, 2005a).

An increased phase of grazing intensity, identified in pollen data of Stone Tor Brook, Dartmoor, lasted between 1480 and 1080 cal BC and is associated with the use of sub-divided coaxial fields in close proximity to the site (Fyfe *et al.*, 2008). This greater intensity has not been found at any of the Exmoor sites, which is particularly interesting in the case of Codsend Moors, considering this site is also in close proximity to field systems that are believed to be prehistoric (Riley & Wilson-North, 2001). It can be argued that the pollen sequence of Codsend Moors does not reflect the entirety of the middle Bronze Age, resulting in an incomplete representation.

Whilst the age of the Dartmoor prehistoric field systems is broadly accepted, the dating rests on just three radiocarbon dates from two stone boundaries at Shaugh Moor and Holne Moor, which may cast uncertainty over the accuracy for the period of when these land divisions were in use (Fyfe *et al.*, 2008). In addition, pollen data from previously mentioned sites on both Exmoor and Dartmoor, do not show any sign of cereal cultivation, even though less recent research has proven that cereals were grown within the systems on a small scale (Caseldine & Hatton, 1994). Furthermore an upsurge of cereal cultivation is argued to have occurred during the middle Bronze Age across Britain, although this does not necessarily apply to upland areas (Stevens & Fuller, 2012). This could imply that upland land use on Exmoor changed neither drastically, nor “suddenly”. Instead, a continuous reliance on pastoralism would have been a more likely situation with perhaps some small-scale events of cereal cultivation that remained undetectable in the pollen data. The lack of evidence for large changes in land use may confirm that the introduction of field boundaries merely formalised already existing divisions (Johnston, 2005a), instead of reflecting abrupt social and land use changes on a large scale.

The RDA moving time window of Spooners (figure **8.7**) shows increased values of explanatory power of the climate proxy taken from Crag Cave (interpreted as reflecting precipitation: (Swindles *et al.*, 2013)), mentioned in chapter **8.6,** reaching a percentage of approximately 33%. RDA values based on inferred temperatures from the Greenland Ice cores (Vinther *et al.*, 2006), however, show lower values of around 6%. This implies that average temperatures may have had less effect on the vegetation composition on Exmoor than increased precipitation. Considering the sets within the RDA moving time windows cover a large period in time, it is difficult to identify at what point in time climate had the largest impact on the vegetation composition. Identifying this period, or several periods in time, are however significant in order to further understand the broader role of climate as a major driver of changes in vegetation. Data points that fall within both the early Bronze Age and late Bronze Age are included in the RDA set that centres around the middle Bronze Age, and thus periods of both relative stable climates and less favourable climatic conditions are included in the analysis.

To summarise, palaeocological data from Spooners and a variety of other sites on Exmoor and Dartmoor show that there was a continuation of a reliance on pastoralism during the middle Bronze Age, with differing levels of intensity across Exmoor and between Exmoor and Dartmoor. RDA values of Crag Cave climate (precipitation) data against Greenland Ice core climate (temperature) data, suggest that precipitation may have had an increased impact on the general vegetation composition during later prehistory. The main changes reflected in the pollen data were presumably caused by changes in human land use that can perhaps be associated to social changes, as a results of an increased overall sedentary lifestyle. Furthermore, charcoal values from the Exmoor sites mentioned above show that burning became a more important management tool during the middle Bronze Age, and is associated with a further increase of woodland clearance across Exmoor.

10.4 Late Bronze Age vegetation and land use conditions on Exmoor (1000-800 cal BC)

10.4.1 Vegetation patterns during the late Bronze Age

Palaeoecological data from Exmoor sites suggest that from the late Bronze Age onwards, the general landscape became increasingly open (Davies, 2012; Fyfe, Brown & Rippon, 2003; Fyfe, 2012). The pollen data from the published Exmoor sites indicate a mixture of open, grass- or heather dominated landscapes alongside a continuous presence of arboreal taxa at the majority of sites (discussed below). Pollen data from Great Buscombe (figure **5.3**) and Codsend Moors (figure **7.4**) suggest a dominance of Poaceae (60%TLP and 40% TLP, respectively) and a low presence of *Calluna vulgaris* (below 3%TLP and 5%TLP, respectively) in their local surroundings during the late Bronze Age. On the contrary, pollen data from Spooners suggests that the local landscape around the site was dominated by *Calluna vulgaris* (c. 30%) (figure **6.4**). Gourte Mires' pollen data shows a decline in grass dominance (30% TLP), but an increase in cereal pollen, alongside low values of arboreal taxa (30% TLP) and significantly low charcoal values (Fyfe, Brown & Rippon, 2003).

Alnus and *Corylus* values at Codsend Moors range between 5% and 25% (figure **7.4**) and values for these taxa range between 20% and 30% at Spooners (figure **6.4**). In contrast, *Alnus* values do not exceed 5% and *Corylus* values remain under 15% (figure **5.3**) at Great Buscombe during the late Bronze Age.

Pollen data thus shows a slightly more open landscape at Great Buscombe, whereas higher concentrations of trees remained present in the surroundings of Spooners and Codsend Moors. This is also noticeable at various other sites on Exmoor during the late Bronze Age. Pollen data from both Moles Chamber, as well as from North Twitchen Springs shows that values of arboreal taxa ranged around 40% TLP and primarily consisted of *Corylus* and *Quercus* (Fyfe, 2012). Low levels of *Corylus*, *Quercus* and/or *Alnus* woodland also remained present on steeper-sided valleys, on often poorly-drained valley side soils at sites in Snowdonia (Woodbridge *et al.*, 2012), Mid-Devon (Rippon, Fyfe & Brown, 2006) and Dartmoor, during the earlier Bronze Age (Fyfe *et al.*, 2008) indicating that the topography of sites played a key role in the absence or presence of trees (Rippon, Fyfe & Brown, 2006). Similar situations are recorded in upland areas elsewhere in Britain. For instance, Bartley, Jones and Smith (1990) found that extensive woodland clearance took place on the lime soils during the Bronze Age, but on the heavy clay soils of the lowland site in Northwest Yorkshire, woodland clearance did not start until Anglo-Saxon times(Bartley, Jones & Smith, 1990). Similar patterns were also found in Durham, where an almost complete woodland clearance occurred during the middle Bronze Age Bisshop, Midleham near Magnesian lime soils. On the other hand, heavy clay soils in the lowland areas of the Tees were not cleared until A.D. 1200. Extensive woodland clearance has also been identified at the uplands of the North York Moors and has been associated with cereal production (Simmons, 1993), whereas at upland areas in South Wales, for instance, woodland clearance was associated with increased grazing and hillslope erosion (Ellis and Tallis, 2001). Other palaeoecological studies based in the uplands of Wales indicate a heterogeneous landscape, similar to that of Exmoor throughout the middle Bronze Age, as a result of asynchronous woodland clearance. For instance, Crampton (1966) found one of the sites in this region was cleared of *Quercus*, which was associated with the clearance of cairns. Some sites formed a dominance of *Calluna vulgaris* after woodland clearance, although several others suggested small temporary recoveries of *Alnus*, presumably as hill slope shrubs (Chamber, 1982; Chambers, 1983).

10.4.2 A mixture of land use (intensities) during the late Bronze Age

The late Bronze Age reflects a period in prehistory with very little evidence in the NPP data for the presence of grazing, but an increase in burning at a variety of sites on Exmoor, indicated by higher charcoal values. In the case of all three Exmoor sites, coprophilous spores only sporadically occur in the NPP diagrams (figures **5.5**, **6.5** and **7.5**) and suggest that pastoralism may have been less intense on a wider-scale across Exmoor during the late Bronze Age. Both pollen and charcoal data from Spooners suggest a period of low intensity land-use, with perhaps seasonal pastoralism and low-level intensity burning, used to manage or maintain heather growth (figure **6.4**). Furthermore, higher levels of *Pteridium* at Moles Chamber and North Twitchen Springs suggests that grazing intensity was very low during the late Bronze Age at these sites (Fyfe, 2012), a phenomenon also visible in the pollen data from Codsend Moors (figure **7.4**). The decline or absence of pastoralist activities, suggested by pollen and NPP data from the majority of sites on Exmoor, might be associated with a climatic deterioration that presumably took place at around 850 cal BC (Geel & Mauquoy, 2010). However, interpretations of pollen data from Snowdonia of the late Bronze Age has shown that different pollen records were not necessarily driven by climate (Woodbridge *et al.*, 2012), but were perhaps an indirect effect, reflecting how climate affected populations' choices to keep grazing stock elsewhere. Current archaeological interpretations of the uplands during the late Bronze Age suggest that uplands were used for seasonal grazing, with no permanent settlement (Webster, 2008). A similar correlation between the climate and populations on Exmoor may have been the case, but a larger body of information, particularly in the form of archaeological information, is necessary for a broader understanding of societies and changes during the earlier Iron Age.

Pollen and charcoal data from Codsend Moors (figure **7.3**) suggests a phase of increased burning starting around 900 cal BC and lasting for approximately 120 years, resulting in the reduction of *Calluna vulgaris* in the surroundings of the site. The moving time window RDA value, nevertheless, shows that burning had a low explanatory power on the vegetation <6% (figure **7.8c**). Burning was also used in the area surrounding Ricksy Ball on central Exmoor, although it co-occurred with a reduction in *Corylus* woodland (Fyfe *et al.*, 2014), indicating that fire resulted in a loss of tree cover rather than heather. A burning pattern similar to Codsend Moors is also visible in the pollen and charcoal data of Great Buscombe (figure **5.3**), along with the additional finds of small amounts of *Avena/Triticum* cereal pollen. Burning was thus likely used to target and prevent the growth of local heather, in order to improve growing conditions for cereals. This may explain why the moving time window RDA charcoal value averages for Great Buscombe (figure **5.10c**) show an increase from 12% to c. 30% during the late Bronze Age, confirming that burning played an increased role in the vegetation composition of Great Buscombe. Low cereal-type values are also evident in the pollen data from Moles Chamber and North Twitchen Springs, but are relatively low compared to values in these sequences during later (pre)historic periods (Fyfe, 2012).

The absence of cereal pollen types at Codsend Moors is, on the face of it, curious given the proximity of the prehistoric field systems on the lower slopes at Codsend (section **7.2.1**). This could imply that the fields were used for stock keeping, rather than arable agricultural activities, or that cereal pollen did not reach the coring site, given that cereal pollen do not tend to travel far from their source (Behre, 1981). On the contrary, the field systems in the vicinity may have once been used for agricultural purposes (which seems less likely to be the case), but were abandoned by the end of the middle Bronze Age, as is believed to have been the case for the field systems at Dartmoor (Fleming, 2008). Fleming (2008) argued that a climatic deterioration during the middle Bronze Age was the main cause for the abandonment of the field systems. However, evidence from the analysis of archaeological radiocarbon dates in Ireland and Britain show an inferred population decline between 1000 and 800 cal BC (Bevan *et al.*, 2017). This is likely to be associated with social changes and may have played a larger role than climate. That is if one can speak of abandonment in the first place, for which there is no certainty (Tipping *et al.*, 2008).

Pollen and charcoal data from Exmoor sites do suggest that perhaps a shift from pastoralism to other forms of agricultural activities, such as arable agriculture, took place during the late Bronze Age. However, all pollen and NPP records show that at least some form of (low) intensity grazing remained present across Exmoor uplands. This supports the idea that although field systems were perhaps no longer in use (for reasons similar to those during the middle Bronze Age), the areas surrounding the sites were not ‘abandoned’. A decline in population and perhaps to some extent the climatic deterioration prior to that may have altered people’s choice of life style, shifting from pastoralism to other forms of agricultural activities. This theory would so far only be supported by data from Great Buscombe, as there are no indications from other sites on Exmoor where cereal cultivation took place. Another possible reason could be found in the example of NPP data from Sittaford (Dartmoor), where grazing-related NPPs increased during the late Bronze Age (Fyfe & Ombashi, 2018b). The increase at Sittaford has been associated with the emergence of aggregated forms of enclosure, which have a different nature to co-axial field systems. Finally, a broader shift in settlement patterns during the late Bronze Age from enclosed towards unenclosed settlement may have had a significant impact on the surrounding vegetation and thus pollen and NPP data (Webster, 2008).

10.5 Vegetation and land use changes on Exmoor during the earlier Iron Age (800-400 cal BC)

10.5.1 Vegetation changes during the earlier Iron Age on Exmoor

Pollen assemblages from both Spooners and Codsend Moors show a continuity of the low intensity land use into the earlier Iron Age that started during the late Bronze Age. The landscape surrounding Spooners was dominated by *Calluna vulgaris* (figure **6.4**). Pollen data from Codsend Moors (figure **7.4**) shows an even larger dominance of Poaceae than during the late Bronze Age (increasing from 30% to 40%), although this dominance is replaced by *Calluna vulgaris* (reaching 40%) after c. 500 cal BC.
A decline in Poaceae from 60% to 40%, alongside a rise in *Calluna vulgaris* from 5% to c. 20% is also visible in the pollen data of Great Buscombe (figure **5.3**), which took place between 800 and 500 cal BC. A shift to heath dominance is also visible in the NPP data from Great Buscombe and Codsend Moors, indicated by a high presence of T19 at Great Buscombe until c. 700 cal BC (figure **5.5**) and at Codsend Moors throughout the entire Iron Age (figure **7.5**), suggesting that the earlier Iron Age also represents a phase of lower land use activity at Great Buscombe.

Pollen data from both Great Buscombe and Codsend Moors show phases of increased levels of *Sphagnum* at c. 700 cal BC at Great Buscombe and between 800 to 600 cal BC at Codsend Moors, which might indicate wetter local conditions at the two sites. A similar trend is also indicated by a significant increase in Cyperaceae at North Twitchen

Springs (Fyfe, 2012). This agrees with the wider climatic event dated to 850 cal BC (van Geel & Renssen, 1998) and previously discussed in chapters **2** and **8** of this thesis. The shift to wetter/cooler conditions is reflected in the water table depth reconstruction of Tor Royal Bog (figure **8.5**) at around 850 cal BC, in the peat humification from Tor Royal Bog at 650 cal BC and in the peat humification data from The Chains at c. 850 cal and 750 cal BC (figure **8.4**).

The majority of pollen data suggests that the landscape was similar to that of the late Bronze Age in terms of "openness". There are, however, still examples of patches of trees (primarily *Corylus*, *Alnus* and *Quercus*), presumably associated with a steeper topography of the surrounding area of Codsend Moors, where trees were possibly maintained as a resource in parts of the landscape less suited to open grazing.

10.5.2 Decreasing land use intensity on Exmoor during the earlier Iron Age

Evidence for intense land use at Spooners (figure **6.4**) was already rare from the late Bronze Age, and continued into the earlier Iron Age. Lower intensity land use is also inferred from the palaeoecological evidence at Great Buscombe (figure **5.3**) and Codsend Moors (figure **7.4**). At North Twitchen Springs an increase in *Pteridium* in the period between 820 to 385 cal BC could suggest a significant decrease in grazing intensity around the site (Fyfe, 2012), showing that a similar trend of decreased land use intensity took place at that location as well. Evidence for the sporadic cereal cultivation identified at Great Buscombe during the late Bronze Age ceases (figure **5.3**) and an increase in *Calluna vulgaris* suggests longer periods of non-disturbance, allowing for more heather regrowth.

These broad indicators imply that a decrease in land use took place over the course of the earlier Iron Age and may suggest some form of transhumance instead of permanent settlement on the upland, as has been suggested as a late Holocene farming method (Feeser & O'Connell, 2010). A similar decrease, from 800 cal BC onwards, in the use of burning as a land management tool, is evident in the charcoal data from Codsend Moors (figure **7.4**). This could explain why *Calluna vulgaris* (suggested to have originally been the main target of burning regimes) gradually increased from 5% to 40% over the course of the earlier Iron Age at this site (figure **7.4**).

It was previously thought that the widely recognised climatic deterioration that took place at around 850 cal BC was the main cause for land abandonment on marginal areas such as the uplands in the UK (Groenman-van Waateringe & van Geel, 2017). With settlement and craft production being generally elusive in the archaeological records across northwest Europe, assumptions were often made between a retreat from marginal areas as a result an inability to cope with climatic deterioration (Van Geel, Buurman & Waterbolk, 1996). Although it is evident from the palaeoecological data that land use and management were of low intensity during the earlier Iron Age relative to earlier periods across Exmoor, there is no direct evidence that can demonstrate that climate was the main driver for this, nor is there any signal suggesting total land abandonment throughout the earlier Iron Age (e.g. regeneration of woodland taxa). Furthermore, endogenous factors such as social destabilization have to be taken into account as possible drivers for lower land use intensity on the uplands as well. Armit *et al.* (2014) argued that the introduction of iron undermined previously established wide-scale Bronze Age trade networks, causing disruptions in Iron Age societies and perhaps reformations within regions. In addition, other studies have shown that prehistoric societies were capable of surviving wide-scale climatic deterioration (e.g. Magny *et al.*, 2009).

Although the majority of palaeoecological data suggests that land use intensity decreased across Exmoor during the earlier Iron Age, several small indications of perhaps seasonal land use are still evident from the pollen, charcoal and NPP data. For instance, continuous background values of coprophilous NPPs *Sordaria* sp., *Podospora* sp. and a few appearances of T110, *Cercophora* sp. and *Sporormiella* sp. at Codsend Moors (figure **7.4**) may suggest that pastoralist activities remained present in the local surroundings throughout the earlier Iron Age. This shows that previous theories on land abandonment due to climatic stress are not applicable to Exmoor, as is also shown to have been the case at various other sites across the UK (Tipping, 2002; Tipping *et al.*, 2008) and further supports the argument made by Dark (2006) that this particular climatic event did not results in a uniform and wide-scale pattern of land use change across the UK.

10.6 Vegetation and land use during the later Iron Age (400 cal BC-40 cal AD)

10.6.1 The predominantly open later Iron Age landscape on Exmoor

Pollen data from all three sites presented in this thesis suggests that a rapid shift in the vegetation composition occurred over a time period of approximately 20 to 30 years, indicating that the majority of the landscape on Exmoor became predominantly open. A large decline in tree taxa, predominantly of *Corylus* (from 20 to 10%) and *Alnus* (from c. 10% to below 3%) is shown in the pollen data of Great Buscombe (figure **5.3**). A gradual small decline in dominant tree taxa *Corylus* (from 20% to 10%) and *Alnus* (from 10% to below 5%) took place at Codsend Moors (figure **7.4**) over the course of the later Iron Age. A further decline, following a phase from the earlier Iron Age, in arboreal taxa is also found at Moles Chamber and accompanied by a dominance of grassland (Fyfe, 2012). A larger trend of woodland clearance is apparent in the pollen data and is also confirmed by other pollen sequences that show phases of clearance, such as at Hoar Moor (Francis & Slater, 1990) and The Chains (Rippon, Fyfe & Brown, 2006). However, there are still several sites where pollen data suggests that small patches of arboreal taxa remained present throughout the later Iron Age. Pollen data from Spooners (figure **6.4**) show that *Corylus* values remain between 20% to 30% and *Alnus* values remained approximately the 10% mark during the later Iron Age. At Anstey's Combe, woodland persisted in the steep-sided valley (Rippon, Fyfe & Brown, 2006) and low levels of *Corylus*/*Quercus* woodland persisted during the later Iron Age in the lowlands to the south of Exmoor from sites such as Middle North Combe and Hares Down (Fyfe, Brown & Rippon, 2004).

Data from Great Buscombe record a large variety of NPP types during the later Iron Age (figure **5.5**). The majority are classed as fungi living off decaying wood, although a large amount stem from unknown habitats. Local conditions at Great Buscombe were thus different in some (currently unexplainable) way compared to previous phases of grassland domination which had much lower diversity of NPPs. Alongside a higher variety of NPP types, a large increase of T495 at Great Buscombe suggests that a more local increase of grassland affected the fungal assemblage in a different way than other prehistoric time periods. Conditions appear to have been slightly wetter at Codsend Moors (figure **7.4**) in the second phase of the later Iron Age (from c. 200 cal BC onwards), but pollen data from Spooners (figure **6.4**) and Great Buscombe (figure **5.3**) do not show such indications. Pollen data from The Chains show an increase in Cyperaceae, which may have been indicative of a wetter environment (Merryfield, 1977). Evidence in the pollen sequences around Molland Common also suggest wetter conditions by showing a shift to wetter heath during the later Iron Age (Rippon, Fyfe & Brown, 2006). This implies that a regional wet shift in the climate may have taken place, but may not have been evident from the pollen data from Great Buscombe and Spooners.

10.6.2 Increased land use intensity on Exmoor during the later Iron Age

The later Iron Age represents a period of increased land use intensity. Burning would have become more intense at all three sites, as charcoal values all reach their highest levels during this period. A similar trend is also visible in the charcoal data from Molland Common (Fyfe, Brown & Rippon, 2003) (Rippon, Fyfe & Brown, 2006). *Calluna vulgaris* is most likely to have been the main target species for the burning regimes, but a clear decline in arboreal taxa at many sites (mentioned above) suggests that woodland clearance increased as the result of burning as well. A phase of increased *Calluna vulgaris*, alongside a decline in arboreal taxa and high values of charcoal in the data from Codsend Moors (figure **7.4**) suggests that from 200 cal BC onwards trees may have been a more frequent target for burning than heather.

Woodland clearance is not only common at Exmoor, but has also often been recorded in pollen studies across northern and western Britain (Fyfe, Brown & Rippon, 2004). An increase in population and/or economic pressures on the landscape presumably took place at c. 250 cal BC (Bevan *et al.*, 2017) and has been suggested as the most likely cause for this period of increased woodland clearance (Fyfe, Brown & Rippon, 2004). No evidence for the presence of cereal cultivation is found at any of the sites during this period, but grazing intensity did increase at all three sites.

Coprophilous NPPs at Spooners suggest that the grazing intensity remained relatively low during the later Iron Age, compared to previous prehistoric periods. Coprophilous spores from Codsend Moors suggest an ever lower intensity of grazing than at Spooners, thus indicating that burning was the dominant and often only type of vegetation-disturbing component caused by humans during the later Iron Age on Exmoor.

10.7 Summary

10.7.1 Vegetation patterns throughout prehistory

Pollen, NPP and charcoal data from numerous sites on Exmoor and Dartmoor have shown that human interference with the vegetation caused a series of landscape changes throughout prehistory. A conceptual model is presented in figure **10.1** and attempts to visualise the relative roles of climate, fire and grazing influencing changes made in the vegetation of Exmoor throughout prehistory. An additional figure **10.2** is presented underneath figure **10.1**, in order to provide an overall view of all main indicator taxa or types in the pollen, NPP and charcoal data across all three sites.
It has been inferred from pollen data that episodes of woodland clearance took place during the late Neolithic and early Bronze Age, although some upland sites remained dominated by trees. This resulted in permanent woodland reduction at several sites. Some woodland regeneration took place on some Exmoor sites, but an increase of opening up of the landscape persisted into the early Bronze Age. A continuation of a mosaic, wider landscape on Exmoor carried on into the middle Bronze Age, where scrub regeneration would often replace previously woodland-dominated landscapes. Another theme apparent in the vegetation changes of the middle Bronze Age is the replacement of Poaceae by *Calluna vulgaris*.

The main changes in the pollen data during the middle Bronze Age are believed to have been the result of social changes, following an increased overall sedentary lifestyle with the introduction of field systems. The end of the middle Bronze Age presumably marks the end of the use of field systems, alongside a new shift of social changes. Inferred population declines between 1000 and 800 cal BC are now associated with a lower demand of food supply, reflected in a lower stocking density and a shift of emphasis to household-scale lifestyles. This then resulted in a shift to unenclosed settlements with perhaps an increased use of smaller-scale arable plots, which may be reflected in the appearance and disappearance of cereal pollen in the pollen diagram of Great Buscombe during the late Bronze Age.

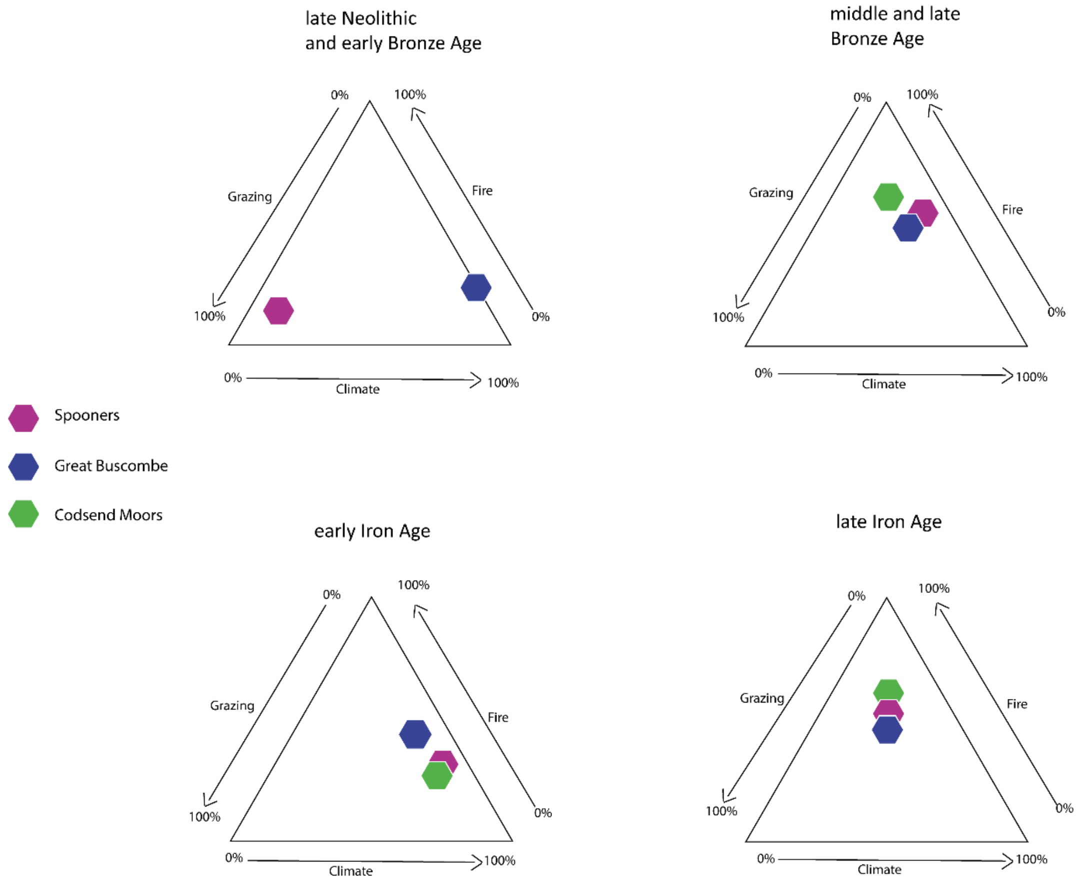


Figure 10.1. *A model attempting to visualize the changing roles of factors that influence the vegetation of Exmoor, divided into four (combinations of) prehistoric time periods.*

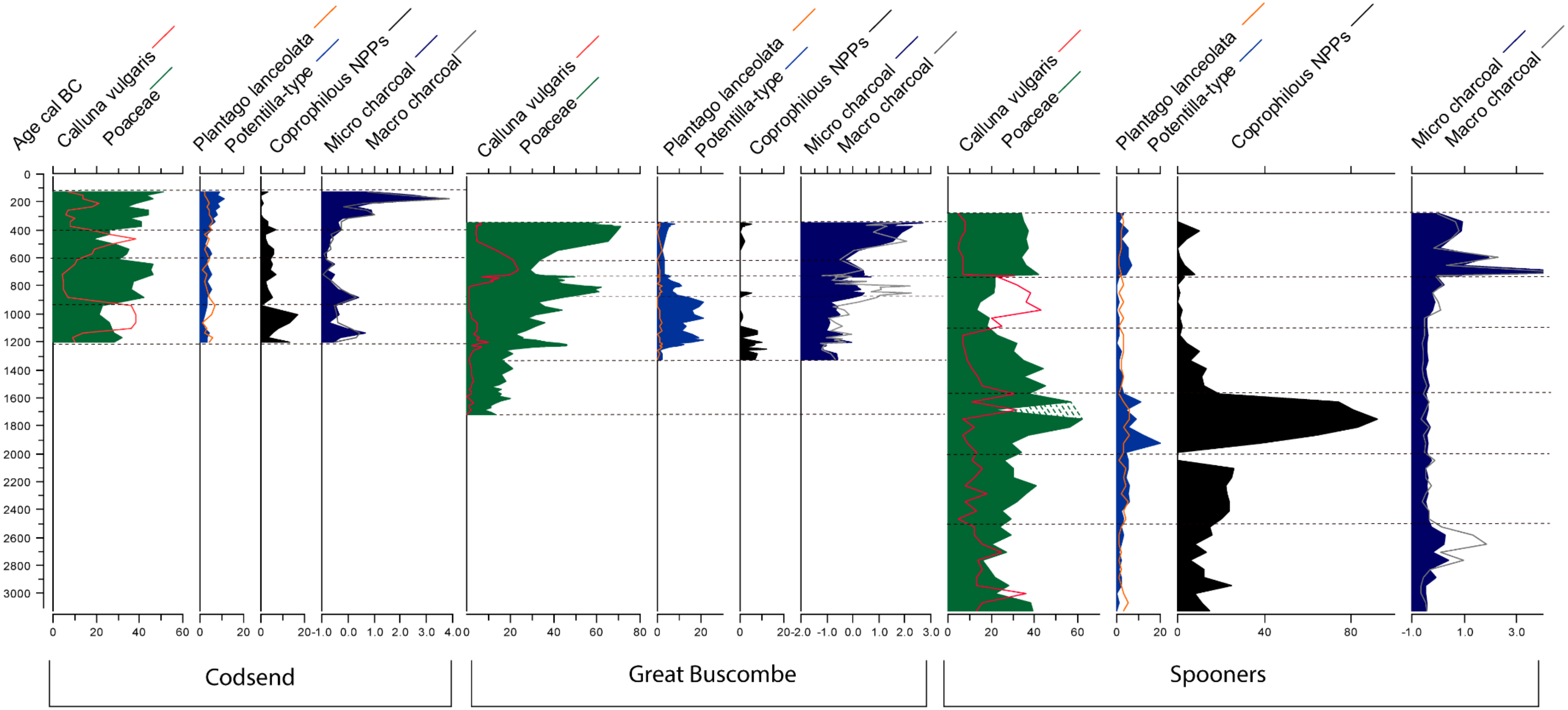


Figure 10.2. *Main indicator pollen taxa, NPP types and charcoal data from all sites, across time*.

The landscape of the early Iron Age remained relatively open, showing an initial mixture of grass- or heather dominance. By 500 cal BC, the majority of Exmoor sites show a strong dominance of *Calluna vulgaris*, which may indicate lower levels of human interference with the vegetation. NPP data has shown that we cannot assume the occurrence of total land abandonment of the uplands due to climatic deterioration (as more traditional papers have suggested), but that a more seasonal or less intense use of the uplands took place during the early Iron Age. Although RDA values of Great Buscombe have indicated that climate, precipitation in particular, may have played a larger role on vegetation changes during the early Iron Age, data from Spooners and Codsend Moors have suggested that the social disruptions that took place during this period in prehistory may affected the local vegetation of Exmoor in different ways.

A larger trend of woodland clearance is evident from numerous sites on Exmoor during the late Iron Age, but patches of trees remained on steeper slopes. These may have been kept here for resource purposes, as steep valley slopes would not have been very suitable for any form of agricultural activity, but could be valuable sources for timber and fuel. This shows an overall agreement with upland areas across Britain from the Bronze Age onwards, where besides land use, soil and topography have played a key role in land use related to woodland clearance (Bartley, Jones & Smith, 1990; Ellis & Tallis, 2001; Mighall & Chambers, 1995).

10.7.2 Pastoralism

NPP and pollen data indicated that pastoralism was the dominant lifestyle that shaped the vegetation during the late Neolithic with an increased dominance during the early Bronze Age, at Spooners in particular. This increase of pastoralism was visible in the coprophilous peak in the Spooners NPP diagram (figure **10.2**) and can perhaps be linked with a measured peak in the population of Britain and Ireland during the early Bronze Age (Bevan *et al.*, 2017). In contrast to the early Bronze Age, grazing activities during the late Bronze Age appear to be lower, although different intensity levels simultaneously appeared across both Exmoor and Dartmoor. Lower levels of grazing activity are suggested to have carried on into the late Bronze Age, and may have indirectly been the result of a climatic downturn at 850 cal BC, or associated with the population decline mentioned earlier in this summary. During the late Iron Age, grazing activities are believed to have increased, preceded by low levels during the early Iron Age, but had been replaced by burning as the dominant factor in vegetation changes on Exmoor.

10.7.3 Upland land use and climate changes across Britain

Phases of intensified land use across the three sites studied, varied significantly in both length and date ranges. This may suggest that upland land use was not systematically occupied and abandoned as a whole. Although climate data analysis was limited in this study, due to a lack of region-appropriate data, there is no direct evidence in the palaeoecological data that climate (indirectly) drove a synchronous phase of land abandonment across the uplands of Exmoor. NPP data shows some possible links between the degree of wetness and the presence of certain types, although the presence of fire may play a large role in this finding and needs further testing before comparing this to climate data. This supports work of e.g. Tipping (2008), suggesting that land use and occupation of uplands was not directly affected by climatic conditions only, but that more social aspects should be taken into account (Bevan *et al.*, 2017). It further supports more recent research of the occupation of other upland areas, which were initially believed to only exist during phases of increased population pressure (e.g. Cootes & Quinn, 2018). Palaeoecological data in this study cannot exclude that occupation of the site areas may have been seasonal or temporary, but does not support the idea of a synchronous period of complete land abandonment. Several types of archaeological features lie in close proximity with the upland sites used in this study and may partially explain the different lengths and timing of intensified land use. For instance, the clear episode of pastoralism found at Spooners (visible in the NPP data in figure **10.2**), may have had direct associations with the construction of the burnt mound, considering both are dated to the early Bronze Age. Gillings *et al.* (2013) suggested that the chronology of cairns found in the Lanacombe region, where Great Buscombe is located, showed episodes of revisiting. The combination of several phases of intensified land use, evident from the palaeoecological data, and that of archaeological data may suggest a link between the two. Furthermore, the complex field systems near the sequence location of Codsend Moors, suggests that this area was occupied to different extents and may explain why field systems on uplands elsewhere in the UK may result in chronologies that are initially difficult to interpret (e.g. Saunders, 2017; Vervust *et al.*, 2019). Although a lack of evidence of cereal production within or near the field systems of Codsend Moors do not exclude this possibility, the continuous presence of evidence of grazing activities may suggest that the field systems were predominantly associated with pastoral activities. This supports the idea that the construction of field systems is not linked to one particular reason across Britain and Northwest Europe (e.g. Brück, 2000) and is supported by upland palaeoecological studies elsewhere (e.g. (Mosler & Hobson, 2018; Saunders, 2017).

10.7.4 Burning

Fire during the late Neolithic and early Bronze Age has mainly been linked with the control of heather growth. It furthermore did not show to be strongly influential on all vegetation on Exmoor, but that rather a mixture of land use and/or management practices at different locations took place. This resulted in a variety of changes in the vegetation across Exmoor on local scales, which contributed to the development of a mosaic-like (heterogenous) landscape. During the middle Bronze Age, burning became a more important management tool and was associated with a further increase of woodland clearance across Exmoor. Higher levels of burning took place during the late Bronze Age and have been linked to both heather control and tree reduction. During the late Iron Age, burning activities increased at Spooners, Codsend Moors and Great Buscombe, as charcoal values reach their highest recorded values in the sequences.

This is similar to other known sites across northern and western Britain, and may reflect the presumed increase in population with associated economic pressure on the landscape at around 250 cal BC.

Conclusion

11.1 Introduction

This palaeoecological research has shown the identified changes in vegetation and land use on Exmoor during late prehistoric times, alongside the role that climate and human land use may have played in these changes. The two main research questions are stated in chapter **1** and will be briefly discussed in section **11.3**. With the use of four aims, also stated in chapter **1**, these two research questions were answered. These aims are repeated and elaborated on where necessary in section **11.2**.

11.2 Reflecting on the research objectives

In chapter **1**, two research aims were stated to be answered with the use of four key objectives. These objectives are reintroduced and reflected on below.

a) To review the current state of knowledge of long-term vegetation change and land management, in particular the role of fire and grazing.

Chapter **2** and **3** are dedicated to this objective. Chapter **2** focusses on the wider literature and discusses several aspects, including: the known patterns and changes of subsistence strategies, settlements and land use changes during late prehistoric times of northwest Europe and the UK, as well as how these may have been influenced by periods of climatic deteriorations. Chapter **3** is focussed on the previous knowledge of Exmoor's past vegetation and land use changes before this research took place. A comprehensive list of recorded vegetation changes from the literature are shown in this chapter, alongside measured changes of land use through previous palaeoecological research. Whilst there is a significant existing body of knowledge from Exmoor and the wider southwest uplands of Dartmoor and Bodmin Moor, the role of grazing on the uplands has only previously been speculative, and the impact of climatic changes largely conjecture.

b) To develop high-resolution vegetation reconstructions for multiple sequences, using pollen analysis.

Based on pollen data collected from the sites of Great Buscombe, Spooners and Codsend Moors, three high-resolution vegetation reconstructions on a decadal time scale were produced and are presented in chapters **5**, **6** and **7**. Due to different depths, these reconstructions have different start dates, but cover large or all parts of late prehistory, from at least the late Neolithic onwards. The results illustrate contrasting vegetation histories, indicating the importance of considering local-scale vegetation patterns. Furthermore, distinct phases of land cover and land cover change occur at sub-centennial time-scales, illustrating the importance of such high-resolution analysis to understand patterns of human-environment relationships.

c) **To establish new proxy-based archives of past grazing intensity and fire histories from the same core material used for the vegetation reconstructions.**

With the use of NPP and charcoal data gathered from the same material used to achieve objective b, three high-resolution reconstructions of grazing intensity and fire histories were produced for the sites Great Buscombe, Spooners and Codsend Moors. Alongside the use of coprophilous NPPs, a variety of other NPP types have been identified and recorded in order to aim a higher and more local scale reconstruction of vegetation changes. Analysis of the NPP data (presented in chapter **9**) confirmed the use of key NPP types as coprophilous indicators, and the data were used to demonstrate that relationships between different proxies (NPPs, pollen, charcoal) are non-stationary through time.

d) **To generate the first long-term climate reconstructions for Exmoor, with the use of peat humification analysis.**

A long-term climate reconstruction was produced with peat humification data from The Chains and is presented in chapter **8**. Due to the age of the material, this reconstruction could not be used for any further analysis for this research. Instead, climate proxy data from Crag Cave and Greenland Ice Cores were processed and partially presented, in order to gain insights as to how climate may have played a role on Exmoor’s past vegetation changes.

The reconstructions mentioned at objective b, c and d were used in statistical analyses, in order to gain a further understanding of the relative roles of land use change and climate change on Exmoor's past vegetation changes. A brief summary of the main findings (discussed in chapter 10) will be provided in section **11.3**.

11.3 Answering the research questions

Two main research aims were presented in chapter 1 and are repeated below. Considering a more detailed outline is provided in chapter 10.7, only a brief summary of the key findings in this research will be presented here in order to answer the two research questions.

1. **To define the past vegetation of Exmoor, where the time period of focus covers the late Neolithic, Bronze Age and Iron Age. The selection of key time periods of focus for this study is based on previously carried out research, where specific time periods of transition have been demonstrated.**

2. **To test the relative importance of land management and climatic change in vegetation patterns.**

From the late Neolithic onwards, periods of declined and recurring woodland were visible in the pollen data from all known Exmoor sites. Woodland clearance was largely completed by the late Iron Age, although patches of trees still remained on steeper sloped valleys. During this period, NPP data in particular has shown that pastoralism was the dominant lifestyle across Exmoor, with several asynchronous burning events, resulting in a mosaic landscape of either grass- or heather dominated vegetation. During the middle Bronze Age, evidence for pastoralism declined, and tree clearance became more associated with the use of fire. Archaeological evidence, alongside palaeoecological data, previously suggested that the middle Bronze Age represents a time of a more sedentary lifestyle, but NPP data shows pastoralist activities continued. This may have resulted in the decline of evidence in pastoralism during the middle Bronze Age, as grazing animals could have been contained within the field systems, rather than free-roam, like during the early Bronze Age. The transition between the Bronze- and Iron Age shows to have been influenced by a widely acknowledged climatic deterioration. Statistical analyses in this research has however shown that only at Great Buscombe this may have had a significantly direct impact on vegetation patterns, whereas at Spooners and Codsend Moors do not show this trend. Climate change could have indirectly impacted vegetation changes by causing social disruptions during the Iron Age, and may be partially the cause of a measured decrease in land use across Exmoor. From the late Iron Age onwards, heather dominance increased and burning became more evident in the palaeoecological data. Although the direct reason for the increase of charcoal particle could be due to a higher intensity of burning in an attempt to control heather, it also could be associated with an increase in population in the final stage of late prehistory.

11.4 Future research suggestions

A variety of possible future research work could expand further on this study, or improve the resolution and higher understanding of the records presented in this study.

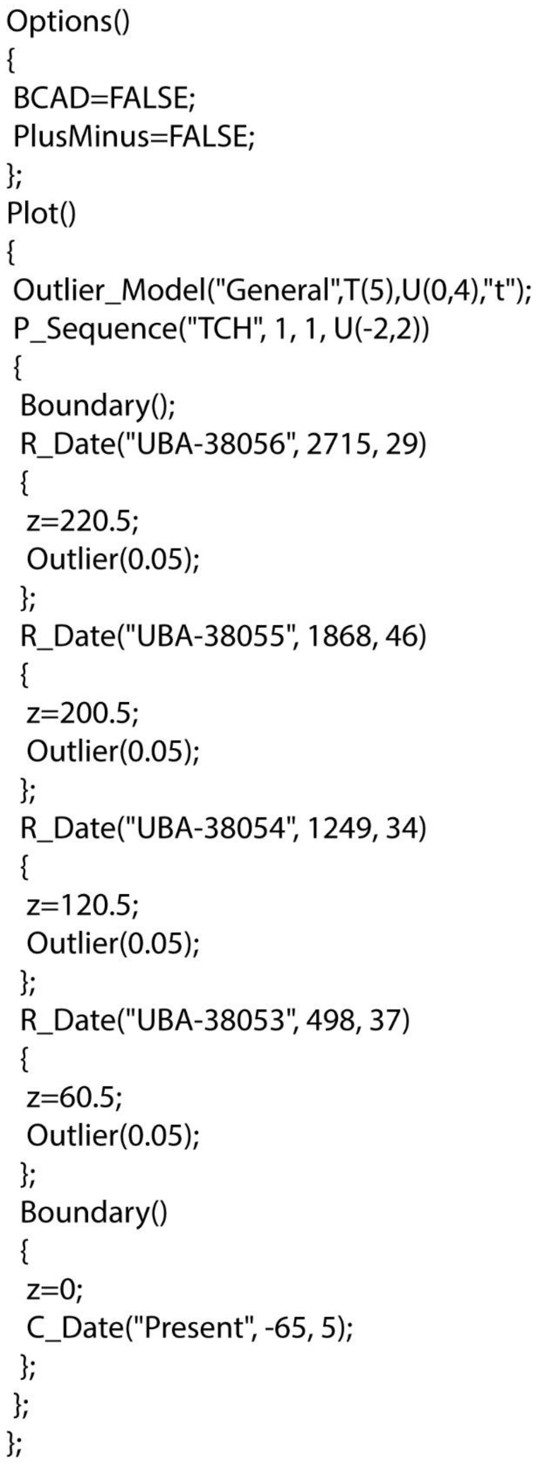
A larger time scale of research focus can be of significant value for a further understanding of how prehistoric and historic people may have altered vegetation patterns on Exmoor. By extending the focus of study further back in time, such as the early and middle Neolithic, a possible new study could focus on grazing pressure and the extent of woodland clearance, compared to the late Neolithic and Bronze Age. With an expansion of this study into historic periods, such as the medieval period, the long-term climate proxy from The Chains that is presented in this thesis, could be used to analyse the relative roles of climatic events, such as the little Ice Age or the Medieval Warm Period, and land use, such as grazing pressure, during historic periods. This can further be a valuable addition to a comparison study between prehistoric and historic land use changes, but can also be a helpful tool in future moorland management.

A second suggestion includes the integration of several unpublished pollen and NPP sequences from Dartmoor. This material could be used to extend the analysis of NPPs in general and how they relate to vegetation patterns, but can also increase the understanding of the role of grazing in prehistoric times and provide material for a comparison study between Exmoor and Dartmoor.

A third suggestion is that to analyse material from Codsend Moors in the search of tephra layers, to increase comparability with the other two sequences. All sequences would also benefit from geochemically identified tephra layers in material from The Chains, which will allow for a more precise correlation of climate data with palaeoecological records.

A fourth and final suggestion is to use this data to compare it with nearby located mires of lower lying areas in order to compare grazing pressure from upland and lowland sites during time periods of climatic downturns. This could then also be compared to palaeodemographic data in order to further understand the relationships between population pressure on upland areas during time periods of known climatic events.

Appendix



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};
Plot()
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   Outlier(0.05);
  };
  R_Date("UBA-38055", 1868, 46)
  {
   z=200.5;
   Outlier(0.05);
  };
  R_Date("UBA-38054", 1249, 34)
  {
   z=120.5;
   Outlier(0.05);
  };
  R_Date("UBA-38053", 498, 37)
  {
   z=60.5;
   Outlier(0.05);
  };
  Boundary()
  {
   z=0;
   C_Date("Present", -65, 5);
  };
 };
};
```

Figure **AX1**. *Code used in OxCal to produce the age-depth models. This particular example is from The Chains. See section 4.3.2 for details.*

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