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A Palaeoecological approach to understanding the impact of coastal changes in Late Holocene societies using the Isles of Scilly as a case study

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**A Palaeoecological approach to understanding the impact
of coastal changes in Late Holocene societies using the
Isles of Scilly as a case study.**

By

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A thesis submitted to the Plymouth University in partial fulfilment for the degree of

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A Palaeoecological approach to understanding the impact of coastal changes in Late Holocene societies using the Isles of Scilly as a case study.

1 ABSTRACT

The overall aim of this thesis was to explore the impact of environmental changes (relative sea level increase and climate) on coastal communities and to investigate how these environmental factors controlled subsistence economies through the Holocene. The hypothesis tested was that relative sea level rise is a key factor influencing location and subsistence strategies of coastal communities throughout the Holocene and that, due to environmental conditions, these changes will be more evident in islands. The Isles of Scilly, located 27 miles off the south west coast of England, provide a good case study for the response of communities to marine inundations and environmental changes. This project aimed also to obtain a high resolution record of vegetation and storminess during the last 3000 years in Scilly, with a robust chronological setting, and also to offer an accurate shape of the coastline of Scilly since the early Holocene.

Three terrestrial pollen stratigraphic sequences from the Isles of Scilly were obtained, covering the past 3000 years, from the two main wetland areas of Scilly (one in Higher Moors and two in Lower Moors) with the potential to reveal changing patterns of vegetation reflecting intensity and type of land use. Detailed palaeoenvironmental interpretation has been provided by high resolution pollen analysis. These pollen diagrams suggest that the landscape of Scilly has been an open landscape, heavily managed for both pastoral and arable agriculture since the Bronze Age.

There is evidence that the climate during the Holocene period was highly varied. The occurrence of blown sand in the sample cores has been used as an indicator of past storm intensity, by high resolution particle size analysis and Loss-On-Ignition. The three cores show dissimilarities in the storminess indicator during the same periods. It is argued

that this reflects that sand deposition and transport is highly site specific and controlled by topography, sediment availability, wind directions and vegetation cover.

An important part of this thesis was to determine the impact of relative sea level rise in Scilly and the extent of the islands over time. A new sea level curve for Scilly has been generated through GIA (Glacial Isostatic Adjustments) using the Bradley *et al* (2011) method. Palaeogeography maps were produced applying the sea level curve to a new combined bathymetric and topographic model for Scilly. Scilly separated from the mainland around 11500 cal BP, and the islands obtained their modern configuration around 4000 cal BP.

The palaeogeography, palaeoecological and the archaeological records of Scilly show that changes in the coastal configuration and storminess had little apparent influence on society from the 1st millennium AD into medieval times. Both, the archaeological and palaeoenvironmental record, have demonstrated that Scillonian societies had a strong resilience and were able to adapt to environmental changes by diversifying their economic strategies and taking advantage of the new conditions, such as new coastal margins. This adaptability was strong until the development of more complex societies and major land reduction conditions that probably led to a tipping point in resilience. There is no apparent discontinuity in land-use on Scilly during the last 3,000 years, although there have been important social and environmental changes.

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4 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 Graduate Committee.

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During the programme of study work, was presented at international and national conferences. Courses and consultation relevant to the study were pursued. In addition to the presentation detailed below, two departmental seminars were given during the course of study.

Conference presentations

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Signed Marta Pérez-Fernández

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1 INTRODUCTION

1.1 AIMS AND OBJECTIVES

In recent decades there has been considerable interest in the response of past societies to environmental change (e.g. Cooper, 2012), and in particular climatic changes (e.g. Adger *et al*, 2005; Kotova & Makhortykh, 2010). This thesis complements this existing body of research, but it is novel as it explores the relationship between sea-level change and coastal communities rather than only climatic change.

The Isles of Scilly, located 28 miles off the south west coast of England, provide a perfect case study for the response of past populations to marine inundations and environmental changes. Island populations are more sensitive to coastal changes owing to the extent and viability of terrestrial resource bases. These islands have been continuously influenced by relative sea level rise since the Early Holocene. Inundation has resulted in their transformation from one large island to a group of five inhabited islands and around 2000 small islands and rocks. Scilly also has a well preserved archaeological record that indicates that these islands were constantly occupied in spite of this relative sea level rise.

This study aims to assess the extent to which the rising sea level impacted on coastal communities in the past, focussing on the response of these societies to these environmental changes. This thesis tests the hypothesis that relative sea level rise is a key factor influencing location and subsistence strategies of coastal communities throughout the Holocene and those changes due to environmental conditions will be more evident in islands. Whilst it is evident that low-lying coastal wetlands, such as the Somerset levels, the Fenland basin *etc*, are equally sensitive to relative sea level changes, the populations have had greater ability to 'cope' with these changes on the mainland. In addition the thesis aims to obtain a high resolution record of vegetation and storminess

during the last 3000 years underpinned by a robust chronology and to reconstruct the coastlines of the Isles of Scilly since the early Holocene.

The specific objectives of the project are as follows:

- i. Use Glacial Isostatic Adjustment (GIA) model-based predictions to determine the palaeogeography of Scilly through the Holocene.
- ii. Compare GIA model for the Isles of Scilly with known empirical records (SLIPS) of sea-level change in the South West peninsula.
- iii. Undertake palaeogeographic mapping of the coastline from the most appropriate sea level datasets (including estimates of uncertainty) and quantify rates (and directions) of coastal change.
- iv. Reconstruct changes in past land use and characterise periods of land use change through pollen analysis.
- v. Undertake physical analysis of representative cores to assess storm frequency and intensity through the Holocene.
- vi. Obtain a robust chronology for records of storminess and vegetation change through radiocarbon dating and OSL techniques of sampled cores.
- vii. Establish a pattern or relationship between these storms and known periods of climate change
- viii. Examine relationships between storminess and vegetation changes reflecting human reactions during periods of increased storm intensity.
- ix. Test the degree of synchronicity between land cover, coastal, economic and societal changes.

This project developed in tandem with the Lyonesse project (Charman *et al*, forthcoming), which studied the evolution of the coastal and marine environment of the Isles of Scilly.

The data obtained from the intertidal and submerged peats identified through the Lyonesse project require a similar level of temporal analysis for terrestrial pollen analysis.

This thesis offers the opportunity to work with onshore sequences of Scilly and develop them to a high resolution framework.

1.2 THEORETICAL BACKGROUND

Archaeological theory has been heavily researched and a discussion of this would entail another project in itself. For the purpose of this thesis only a brief reference is necessary to explain what the main archaeological theories have to say about environmental archaeology. A brief comment also has to be made about what is understood by the term 'landscape', as this project deals with environmental and past landscapes reconstructions.

After his extensive travels on south west Asia, the American geographer Ellsworth Huntington (1926) promoted the idea that major cultural changes were strongly influenced by climatic change. This concept of climatic determinism was adopted by the geographer Brooks (1926), but it was through the writing of the British archaeologist Gordon Childe (1926) that the idea was fully elaborated in respect of the agricultural revolution in Near Eastern Prehistory. In the development of these ideas none of these writers were constrained by a controlled prehistoric chronology or by independent palaeoclimatic data for the area under consideration (Wright, 1993). Environmental determinism has been subjected to criticism within the environmentalist school (e.g. Whittington, 1988). It has been argued that the relationship between humans and environment should be seen from the standpoint of human adjustment as this is more likely to result in the recognition and proper evaluation of all the contributing factors and is more likely to minimize the danger of assigning to the environment a determining influence which it does not exert (Peet, 1985).

The origins of two of the most important and influential theories in archaeology (processualism and post-processualism) are found in ethno-archaeology. Environmental determinism was still a focus of debate within these theories. The new, or processual archaeology, formulated in the 1960s, generally agreed that cultures were open systems

interacting both positively and negatively with the natural environment and therefore they were part of a large ecosystem (Trigger, 1984). Determinism, system thinking, environment and cross-cultural laws were some of the characteristics of processual archaeology (Peet, 1985). Processual archaeology in its extreme version represents a methodological collectivism (starting with society as a whole from which the individual's behaviour is deduced), whereas its counter-reaction, postprocessual archaeology, in its extreme version represents a methodological individualism (starting with the acting individual from whom society or social units are deduced). There are some hints in post-processual archaeology that the environment is an important part of material culture, but these are rare (Oestigaard, 2004). Another movement in environmental archaeology is the Annalist theory (created by Brundel in 1956), which determined that the landscape is not stable and neither is the environment deterministic, but it is man's influence upon the landscape which is changeable (Skeates, 1990). Another influencing tendency in archaeology and social scientific research is the 'agency theory'. The birth of agency theory reflects a desire to counter deterministic models of human action by acknowledging that people purposely act and alter the external world through their actions. The basic principle of agency theory is that people are not just reacting to changes in the outside world, but instead humans play a role in the creation of the social realities in which they participate (Dornan, 2002). Theoretically this thesis does not agree with environmental determinism. Whilst there is no doubt that the environment influences society there are other factors equally important that must be taken into consideration, such as cultural influences, beliefs and convictions of society, adaptability to changes and the availability of technology. Cultural changes visible in archaeology cannot be ascribed exclusively to climate or environmental changes.

This project deals with landscapes, and in particular, changes within landscapes. Although the term landscape has its origins in geography, there is increasing evidence that landscapes are perceived, interpreted and structured by different cultures and belief systems in many different ways. Studies at site and landscape level often focus on the

symbolic properties of material culture and social systems, whereas at a regional level it is more likely that natural features are assessed since they are important aspects of perception and belief systems. In the study of modern cultural heritage such a perspective is called the 'cultural environment perspective' (Fry *et al.*, 2004). The intellectual foundation of contemporary landscape approaches in archaeology may be traced back to at least the 1920s. Despite their historical presence in the discipline's development, until recently landscape approaches largely provided a backdrop against which material traces (archaeology) were plotted and evaluated (Anschuetz *et al.*, 2001). Historical ecology is another important interdisciplinary research approach, which attempts to understand long-term human-environmental interactions. This concept integrates the social and natural sciences, using data from environmental history, palaeoecology, ethnography, and archaeology, for example, to tease out changes that have occurred to the environment over time by humans (Fitzpatrick, 2007). This project follows these lines, putting together archaeological, palaeoecological (reconstruction of vegetation), climatic (storms, warmer/colder periods) data and sea level changes to deduce the anthropogenic reactions to changes in the environment and to investigate the role of the humans in the environmental changes (e.g. deforestation and intensive cultivation).

Landscape, environment, nature and space designate the physical surroundings of the world that human beings live in, but different meanings are associated with the various terms. 'Space' is in archaeology a neutral category, 'Nature' is untamed and controls human beings, 'Environment' is a contested field of the relationship between man and nature, where human beings are most often the interior part, and 'Landscape' designates the surroundings culturally conquered by man (Oestigaard, 2004). Nowadays the term landscape is used in many archaeological studies as a very important point of research, some authors use a multiplicity of landscape references that emphasise natural (e.g. ecological, geomorphological and hydrological) and cultural (e.g. technological and organizational) aspects of the human environment. In this thesis the term landscape will refer to the 'cultural landscape' created by anthropogenic activities, and it will use the term

vegetation when referring to specific changes in the flora record due to anthropogenic activities and occasionally due to environmental and climatic conditions.

1.3 ISLAND STUDIES

Land masses surrounded by water may be called 'true islands', but academics also speak of 'habitat islands': isolated patches of terrestrial habitat surrounded by completely different habitats (excluding water), such as mountain tops, caves or oases (Whittaker, 1998). Most people would probably identify insularity, a watery surround, as the defining feature, and yet not all water landmasses are considered islands, Australia being the most obvious example. Researchers have tended to adopt a pragmatic approach to the question of what can and what cannot be considered appropriate sizes for a study area. The majority of island studies focus on the smaller islands that may be considered socially and culturally 'insulated' by their geographic isolation (Barrowclough, 2010). Most of the studies about islands have been influenced by research taken in the Pacific Islands and the Mediterranean Islands.

In the 1970s, Evans introduced the concept of 'islands as laboratories' into the archaeological discourse, arguing that islands could function as small scale experiments for cultural processes in general as they are clearly bounded and relatively isolated entities governed by fewer variables (Berg, 2010). Insularity also suggests peripherality, being on the edge, or isolated and bounded by the environment (Baldacchino, 2006). Dissatisfaction with these premises of island biogeography and its archaeological applications arose in the late 1980s. First of all, the insistence of the processualists on physical isolation as the key factor determining prehistoric development in island realms, such as the Pacific and the Mediterranean, came under attack; furthermore the implicit notion of the sea as the main factor of isolation in individual insular societies was seriously questioned (Boomert and Bright, 2007). Most archaeologists working on islands today have, for the most part, dismissed the island laboratory concept and do not see single

islands as ideal units of study; instead new island studies emphasize the ways in which islands societies have interacted with each other through time and see isolation as primarily a sociocultural construct (Fitzpatrick, 2007).

At the core of 'island studies' is the constitution of 'islandness' and its possible influence and impact on ecology, human/species behaviour and any of the areas handled by the traditional uni-disciplines (such as archaeology, economics of literature), multi-disciplines (such as political economy or biogeography) or policy foci/issues (such as governance, social capital or language extinction), not to mention the aspect of small islands as somewhat closed (read manageable) systems, amenable to study (Baldacchino, 2006).

The notion of the edge is central to the construction of islandness and islanders are more aware of, and increasingly confronted by, boundaries than most people – and the smaller the island the more this is so; the key feature of an island is its shoreline (Hay, 2006).

However, coasts cannot any longer be seen as the boundaries of islands. Instead social boundaries are a human creation that, although influenced by environmental factors, are not just determined by them (Barrowclough, 2010). Surveys of individual islands need to integrate studies of the surrounding marine environment. It is vital that projects expand their focus further and go beyond the physical outline of the island itself to incorporate other nearby regions into their design, for example other islands, coastlines or mainland areas (Baldacchino, 2006; Berg, 2010). New studies concerned with islands, propose that, together with the islands themselves, the island researchers should also consider the seascape, the littoral of the close continents and the people who create the remains and perceive the environment rather than the other way around (Rainbird, 2007).

The literature is populated with descriptions of how human populations lived and exploited resources along the coastal environments (e.g. Cunliffe, 2001). As coastlines are very susceptible to natural processes (waves, tsunamis, storms and sea level changes) they offer the opportunity to investigate how people in the past were affected by these events. The Isles of Scilly have been occupied by people since prehistoric times and they have been affected by continuous coastal and environmental changes. The archaeological and

environmental record will assist in the understanding of how those societies adapted and reacted to new environmental challenges and the conclusions of this study can be extended to other islands and coastal settlements. In addition, past solutions to increases in relative sea level could offer new solutions in a modern setting where people remain affected by the same problems.

1.4 USE OF DATES

Throughout this thesis, radiocarbon dates will be presented as calibrated ranges, both in the BP and BC/AD time scale. The rationales for presenting calibrated age ranges in both systems is because of the different traditions of use of these time scales in sea-level and climate research (cal BP) and archaeology (cal BC/AD). Where historical accounts are drawn on, dates will be presented as AD and they will not be converted to the BP scale.

1.5 THESIS OUTLINE

This thesis has first presented the aims, objectives and the theoretical background of the project in this chapter. Chapter 2 provides a literature review of the themes of this research, beginning by setting the geographical location of the studied area, before a summary of the archaeological record, a review of previous environmental studies and sea level models in Scilly and a short revision of general storminess and climate studies.

The methods using during the field work, in the laboratory and during desk assessments are explained in chapter 3, prior to presenting the results in chapter 4. This thesis then discusses the main vegetation changes in Scilly (chapter 5) followed by periods of coastal and climate changes, relative sea level increase, and storminess (chapter 6 and 7), to better understand what the results from this study mean in terms of environmental changes in coastal communities. The interpretations are then discussed in terms of global

patterns in the interaction between environment and humans (chapter 8) and finally conclusion and ideas for future research are presented in the final chapter (chapter 9).

2 LITERATURE REVIEW

This chapter will set the literature background of the themes discussed in this thesis. Prior to any study it is important to set the geographical location of the studied area. The next point will show a summary of the large archaeological record of Scilly. The third section will offer a review of previous environmental studies in the Isles of Scilly. The fourth section will be a succinct introduction to sea-level studies, describing main concepts, theories and the current sea-level models of Scilly. The last section will be a short revision of climate studies and the introduction of the term 'storminess'.

2.1 PHYSICAL GEOGRAPHY AND GEOLOGY OF THE ISLES OF SCILLY

The Isles of Scilly form an archipelago some 27 miles (48km) west-south-west of Land's End, Cornwall (fig. 2.1). At around latitude 49°56'N, longitude 6°18'W, they are the most westerly lands in England and include the most southerly land of the British Isles. Their only official name is the Isles of Scilly, although otherwise 'Sully' is occasionally added to legal documents to cover an ancient spelling, and 'Scilly' is accepted as a shortened form (Lousley, 1971).

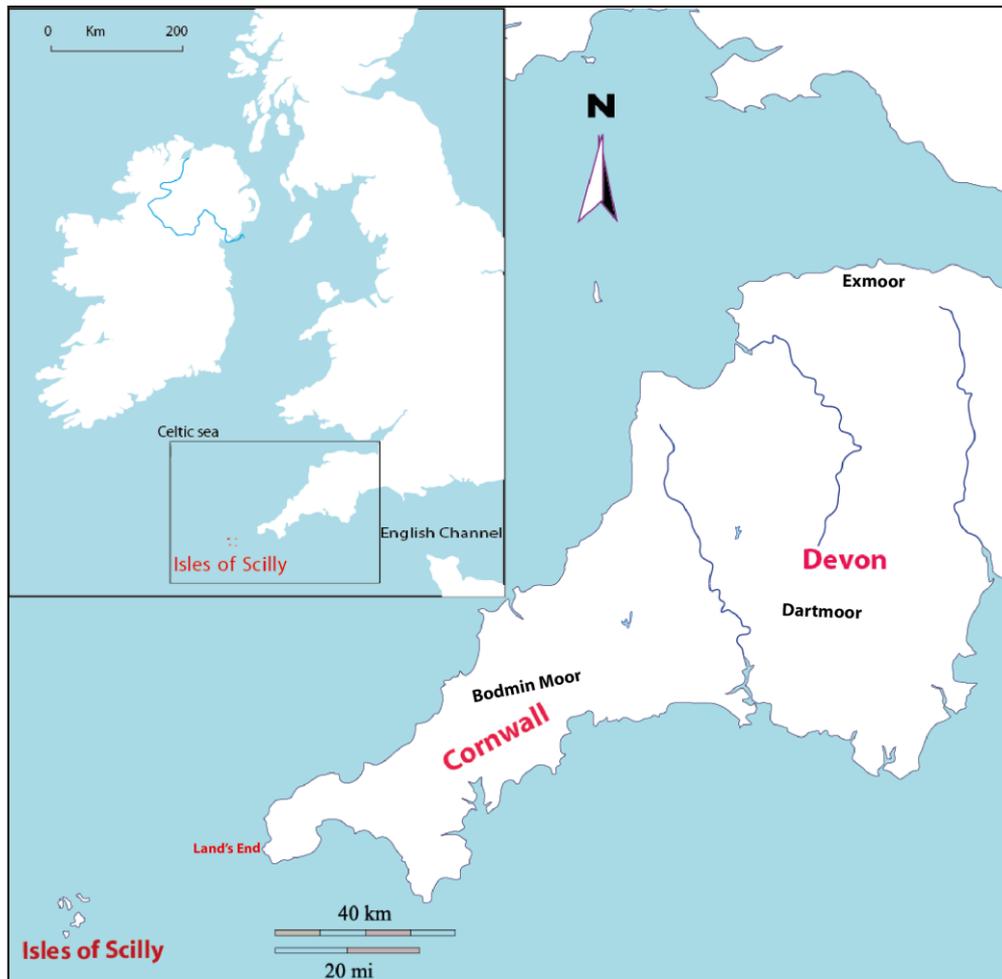


Figure 2.1 Location of the Isles of Scilly in reference to the British Isles and Cornwall and environmental key areas of the South West peninsula.

The Isles of Scilly are composed almost entirely of granite, the products of granite weathering and blown sand. They are part of a single batholith now exposed as five cupolas: four on the mainland (Dartmoor, Bodmin Moor, Carne Menellis and West Penwith) and one that is now largely isolated by submergence and that forms Scilly (Ashbee, 1974). The larger islands of Scilly are a series of flat-topped granite masses separated by shallow sea (Scourse, 1986). Two patches of alluvium were recognised by the Geological Survey: at Higher Moors and Lower Moors, St Mary's (Fig. 2.2).

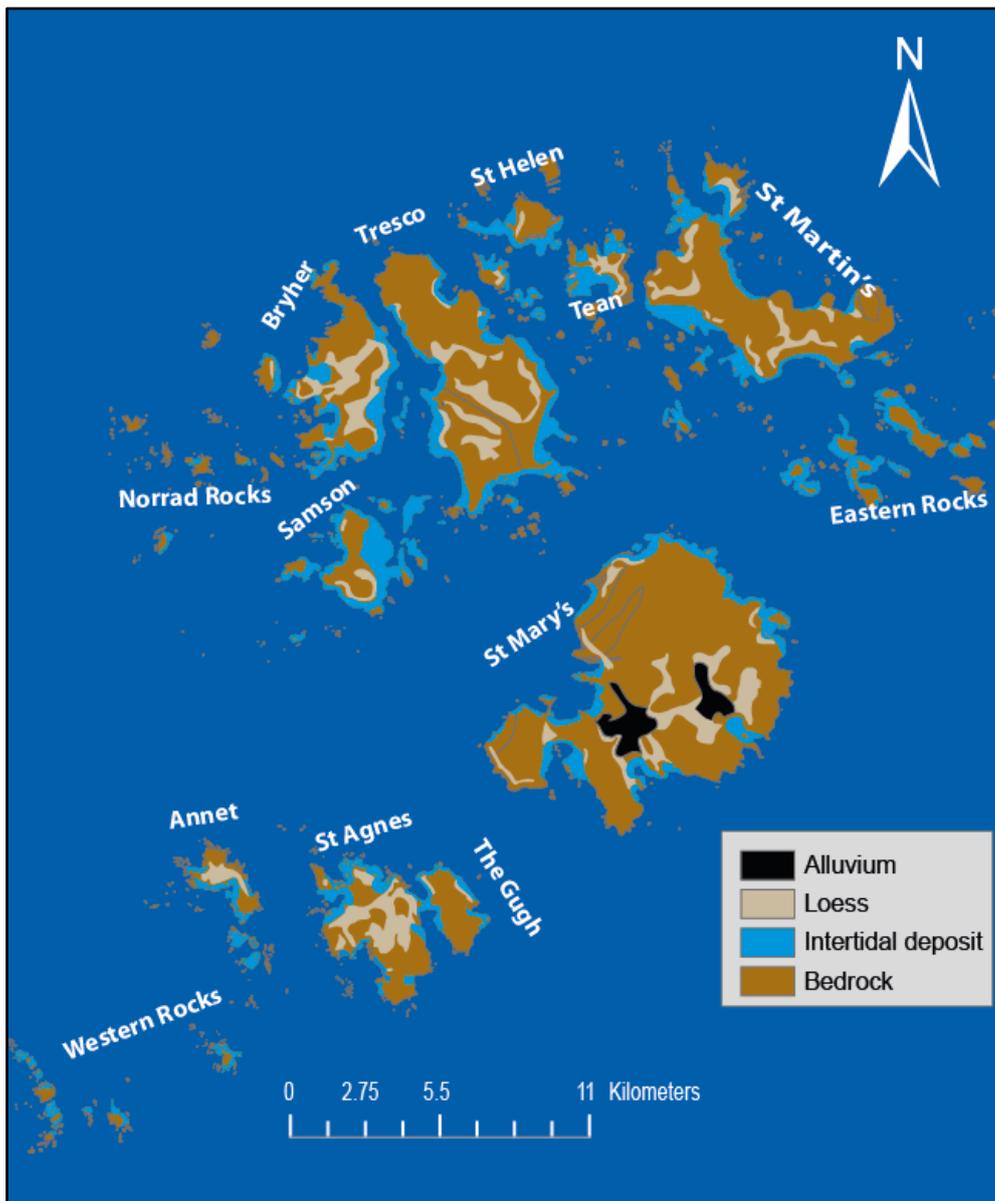


Figure 2.2 Geological map of the Isles of Scilly, Lower and Higher Moors (the studied sites) are shaded in black.

It is widely accepted that most of Devon and Cornwall remained ice free during the glacial period, although recent research suggests the possibility of ice cover on Dartmoor (Evans, *et al*, 2012). There is also evidence from a number of coastal sites that at least one ice sheet extended this far south (Scourse, 1991). The occurrence of erratics on the northern Isles of Scilly is proof of a glacial advance (Whitley, 1982). Evidence for the age of the glaciation comes from the loess which covers much of the islands: on the southern islands of St Agnes and St Mary's (Fig. 2.2), this coarse aeolian silt yielded two

thermoluminescence dates of 18600 years BP. This loess may be associated with an ice advance across the northern Isles of Scilly (Evans, 1990). There is also evidence of an ice invasion from the Irish Sea: Samson's Hill has a fringe of frost-shattered boulders, while the head has the qualities of a glacial scree (Ashbee, 1986). More evidence of this glaciation includes the glacial till (Scilly till) within the Bread and Cheese formation (St Martin's), considered to be in situ and the overlying Tregarthen Gravel and Hell Bay Gravel that are interpreted as glaciofluvial outwash and solifluction deposits respectively, both with erratic assemblages consistent with the till (Evans *et al.*, 2006).

There are no river estuaries in Scilly, large estuarine deposits or lacustrine beds. Except for those on Tresco, the shallow fresh-water pools are modern features. The configuration of Scilly today, with its shallow central tract between St Mary's, Tresco and St Martin's presents a considerable tide-washed area. This tract with the broad low-gradient beaches on the inward sides of Samson, Tresco and St Martin's, is known as the Flats. At low spring tide exposure of so much of the Flats gives access to a wide inter-tidal zone (Thomas, 1985). Contrary to this shallow body of water between the isles, the sea on the Atlantic coast drops sharply to fifty metres. The islands are low-lying with the highest point being Telegraph Hill, St Mary's at just over 50m OD. Although low in altitude, the archipelago reaches out for more than 16km (Robinson, 2007).

The climate of the Isles of Scilly, in common with that of western Scotland and its numerous islands, of western Ireland, of Cornwall and to a lesser degree of the whole of south-west England and western Wales, can be termed extremely oceanic. This means that there is an equable temperature and a lack of variation between day and night temperatures especially in winter. Rainfall is fairly evenly spread throughout the seasons and frost and snow are entirely absent in normal years. The prevailing wind is from the south-west and the air it brings comes from the subtropics around the Azores (Ashbee, 1974).

2.2 ARCHAEOLOGY IN SCILLY

The archaeological database for Scilly is based on over 200 years of archaeological interest in the islands. However, this database is problematic as it comprises mainly of uncoordinated *ad hoc* research and single observations. As part of an archaeological management plan for Scilly a number of intensive surveys have been carried out in order to assess and monitor the archaeological resources of the islands. The Ordnance Survey, Institute of Cornish Studies, Cornwall Archaeological Unit and English Heritage have carried out such surveys that have dramatically increased the number of archaeological site records on the islands to approximately 1500, the majority of which are prehistoric (Robinson, 2007). The number continues to expand due to new excavations, mainly watching briefs conducted during construction developments on the islands. Although large quantities of new data have resulted from survey and excavation on Scilly, little analysis and interpretation have taken place. The published and unpublished work can be consulted freely at the Historic Environment offices in Truro, Cornwall, and all the published data is available on the English Heritage Gateway web page.

The majority of the monuments in Scilly are still extant, although some have been destroyed (by natural and human actions) since their discovery. Scilly represents one of the best-preserved prehistoric landscapes in Britain. The archaeological remains include: houses, field systems, burial monuments, middens and a large range of finds and artefacts. Most of these remains are very well preserved because they were constructed and lie in areas of low agricultural influence or inhabited islands. A very specific characteristic of the Isles of Scilly is the presence of archaeological remains under the tidal range, which gives indication of the existence of a larger mass of land in the past. In Scilly, submerged archaeological sites were identified by William Borlase, who visited the islands in the 1750s and noted field walls running from the North Hill of Samson under the sea towards Tresco. This gave rise to theories about the existence of a drowned landscape between the islands and of another between the Isles of Scilly and mainland Cornwall known as 'Lyonesse' (Tyson *et al.*, 1997). The distinctive 85 foot high rock

'Hanjague' on the east of Scilly is surrounded by relatively deep water; it lacks sufficient vegetation to be considered an island, but myth and folklore suggest that it could once have been a high point in the legendary lost land of Lyonesse (Bowley, 2008).

Scilly is rarely discussed in the archaeological studies of Prehistory in Cornwall and the South West and when mentioned there is special relevance to the Early Prehistory only; it is ignored in other periods such as the Late Bronze Age and Iron Age. Scilly is strategically located in the Atlantic and probably was important in the Western Atlantic Seaways. Nevertheless, it does not get a mention in the most important texts about Atlantic Europe. For example Cunliffe (2001) 'Facing the Ocean, The Atlantic and its peoples', does not even mention the Isles of Scilly when talking about the maritime travels, commercial relations and cultural similarities of the regions in the Atlantic façade. This research will consider the archaeological evidence of Scilly, focussing on its changes in time to deduce the possible social changes that later will be compared to the environmental data.

Developing a chronological framework for the archaeology of Scilly is quite difficult because few of the archaeological sites have been adequately dated. Robinson (2007) provides a comprehensive and critical appraisal of the early archaeology of the Isles of Scilly. This review will draw mainly upon Robinson's account, the synthesis presented in Thomas (1985), Ashbee (1974), Gray (1972) and archaeological reports. Preference will be given to studies with chronological data, but the interpretation of earlier archaeologists and chronology derived from pottery and monument types will also be considered. To aid clarity this section will be divided into subsections according to the standard archaeological periods, although this division also has clear problems such as dating, overlapping of periods *etc.* Although each period has its own representative archaeological evidence, the archaeology in the Isles of Scilly is characterised by its continuity through time and the majority of Scillonian sites extend across various periods. This research has compiled a number of archaeological records: 7 Mesolithic, 47 Neolithic,

748 Bronze Age, 50 Iron Age, 79 Romano British, 81 Early Medieval, 64 Medieval and 313 Post-Medieval.

2.2.1 Mesolithic (10,000-4000BC)

It is generally held that the Isles of Scilly were not occupied until the Neolithic, but the possibility of an earlier human presence should be considered. Mesolithic occupation is not easy to prove because artefactual evidence is likely to have been most abundant on the contemporary coastline, most of which is now submerged (Ratcliffe, 1989). The current artefactual evidence for a Mesolithic presence on the islands (Fig. 2.3) is: a 'chert' retouched piece from Halangy; an obliquely blunted microlith from an unprovenanced collection of the islands; a tranche axe sharpening flake (Berridge and Roberts, 1986); an axe sharpening flake found on Bryher; two unprovenanced pieces in the Alec Gray collection in Truro; a pecked pebble hammer from Porth Cressa, St Mary's; and a small surface collection of debitage such as that from the cliff face at Old Quay, St Martin's (Ashbee, 1986). As Mesolithic artefacts are relatively rare on the islands, the identification of Old Quay as a potential Mesolithic flint-working site is a significant discovery. Apart from Old Quay, no other Mesolithic sites have yet been discovered. A number of substantial prehistoric shell middens occur throughout the islands, the majority remain undated but due to their assemblages they could be part of Mesolithic activity (Robinson, 2007).

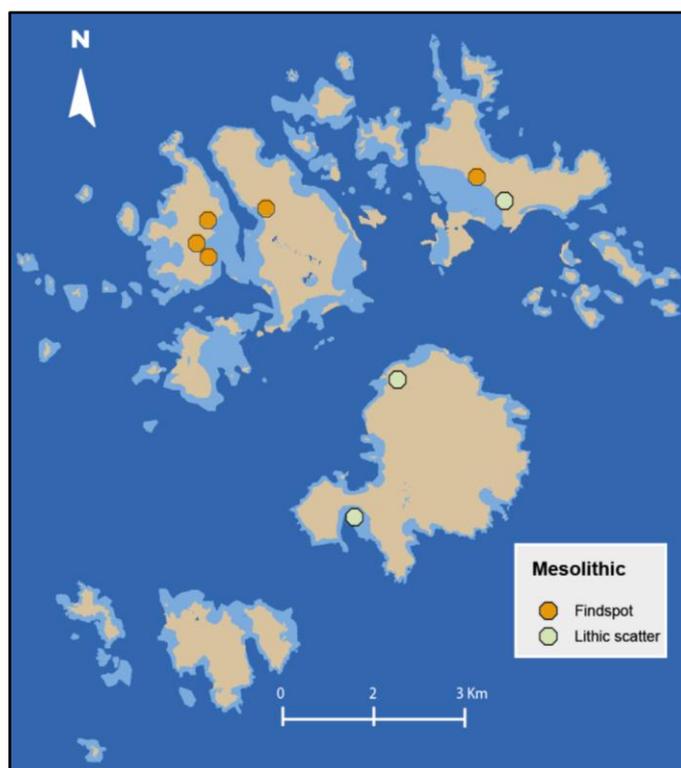


Figure 2.3 Mesolithic Archaeology in Scilly. Archaeological data obtained from the Cornwall and Isles of Scilly HER.

Despite the scarcity of this evidence, it is difficult to imagine that Scilly was not part of the known Mesolithic world along the submerged landscapes (e.g. Doggerland and the Solent) of the North Sea. Mercer (1986) speculated that Scilly could have been 'a seasonal station for the exploitation of specific aspects of the marine resource'. Theoretically Scilly could have been visited by various hunter-gatherer groups, the Isles could have been reached by boat and there is good evidence of the existence of watercraft and sea travel in the Mesolithic in other areas of Britain and Europe (Berridge and Roberts, 1986). The two main maritime routes around the British Isles are the North Sea and the Western Seaway; the Isles of Scilly are conveniently located in the Western Seaway with easy access to Cornwall, Wales, Ireland and the northern British Isles (Fig. 2.1). By the 5th millennium BC there is good evidence for long distance voyages along this route, for example: between the different Channel Islands and the continent, voyages to and from the Isles of Scilly, journeys between the Isle of Man, Scotland, Ireland and between the continental mainland (Garrow and Sturt, 2011). The spread of megalithic monuments from

Brittany, Cornwall, Wales, The Outer Hebrides, Scilly and Orkney indicates considerable seafaring links along this route (Lamb, 1995).

Whether periodically visited or more extensively inhabited it seems likely that traditions of practice (for example seasonal rounds of movement through the landscape, fishing, the collection of flint and other material resources) were established in Scilly from, perhaps, the 6th millennium, in view of the high concentration of later prehistoric monuments in Scilly (Kirk, 2004). Evidence of people occupying islands early in the Holocene can be found in the Hebrides, Scotland (Edwards and Mithen, 1995), where there is evidence of occupation prior to 10,000BP, and Shetland (Melton and Nicholson, 2004), where an oyster midden is evidence of Mesolithic activity. Furthermore the Mesolithic is the period for which we have the first clear evidence of human occupation in Cornwall, however the record is limited to flint scatters and some isolated finds, with few in dated contexts (Caseldine, 1999). One of the best known sites of the Cornish Mesolithic is Dozmary Pool, where about 2500 flints were found and dated to the early 8th millennium due to their style (Simmons *et al.*, 1987). Another important Mesolithic site in Cornwall is Poldowrian, Kerrier, which was fully excavated in 1980, and revealed a dense flint-working area with late Mesolithic microliths and a scatter of charcoal and burnt hazel shells. Interpreted as a seasonally occupied site, a radio-carbon date and the nature of the assemblage suggest occupation in the 5th millennium BC (Smith and Harris, 1982).

2.2.2 Neolithic (4000-2500BC)

There is an on-going debate about continuity and invasion/migration of people from the Mesolithic into the Neolithic period (e.g. Isern, *et al*, 2012; Shennan and Edinborough, 2007); there are questions about whether it is possible to identify the point at which a Mesolithic society becomes a Neolithic one. In the literature there is a tendency to emphasise the role of agriculture as the fundamental core of a Neolithic way of life (Thomas, 2007) and the majority of studies have settled for a date around 4000 cal BC. A

range of different models has been proposed to explain the commencement of the Neolithic. This is not the place to repeat all those models but rather to consider the most compelling arguments for the beginning of the Neolithic in the south west of England. At one end of the spectrum, it has been argued that the onset of the Neolithic was the result of a cultural diffusion of ideas ('indigenism') independent of migration and with little replacement of the original populations (Dennell, 1983). Alternatively, local population increase has been regarded as a causal factor, driving Neolithic migration from the earliest areas of established farming and assimilating or displacing local hunter-gatherers in newly settled lands, termed 'demic diffusion' (Turney and Brown, 2007). It is generally accepted that the Neolithic in Britain could have been introduced by a series of independent arrivals of small migrant groups, embarking from different areas and following different routes; arriving by boat, bringing artefacts, livestock and ideas with them (Sheridan, 2004). Once there, the indigenous Mesolithic populations had a dynamic role in the formation of the British Neolithic. Modern investigation techniques, such as DNA and stable isotopes analysis, have made possible to say that the use of animals by early Neolithic societies of Western Europe was very diverse through time and space and that this diversity mainly resulted from a combination of cultural singularities and interaction between local hunter-gatherers and incoming Neolithic cultures (Tresset and Vigne, 2007).

The evidence for Neolithic occupation (Fig. 2.4) comes from chance finds, excavated possible huts and funerary monuments, and from pottery from cliff face sites such as Porthkillier, Bonfire Carn and Halangy Porth (Johns *et al.*, 2004). Distinctive Earlier Neolithic artefacts from Scilly include two polished stone axes from Bryher and Gugh and Hembury Ware pottery (characteristic of the South West and dating from the early 4th millennium BC). On Scilly, this type of pottery is found at Annet, East Porth, Old Quay, Bonfire Carne, North Hill, Samson and Bant's Carn (Thomas, 1985). Evidence of Neolithic settlements has not been found. Where possible structures can be seen, they normally consist of two or three conjoined circular stone-built huts or homesteads, close to a field

system and, frequently, chambered cairns. Most of these sites are on low-lying ground and have been exposed and largely destroyed by the inroads of the sea (Ashbee, 1986). The absence of houses might result from their destruction or masking beneath later settlements; this interpretation is based upon the consistent occurrence of early artefacts and features such as post-holes and pits below the house floors and walls of later houses (Butcher, 1978; Neal, 1983; Ratcliffe and Straker, 1996). Another explanation for this lack of earlier habitable buildings could be that they were less permanent structures. Pollard and Knight (1999) state that 'proper dwellings' could be the exception for this period, and the tent- or wigwam-style shelters could have been the norm and these would not leave archaeological evidence.

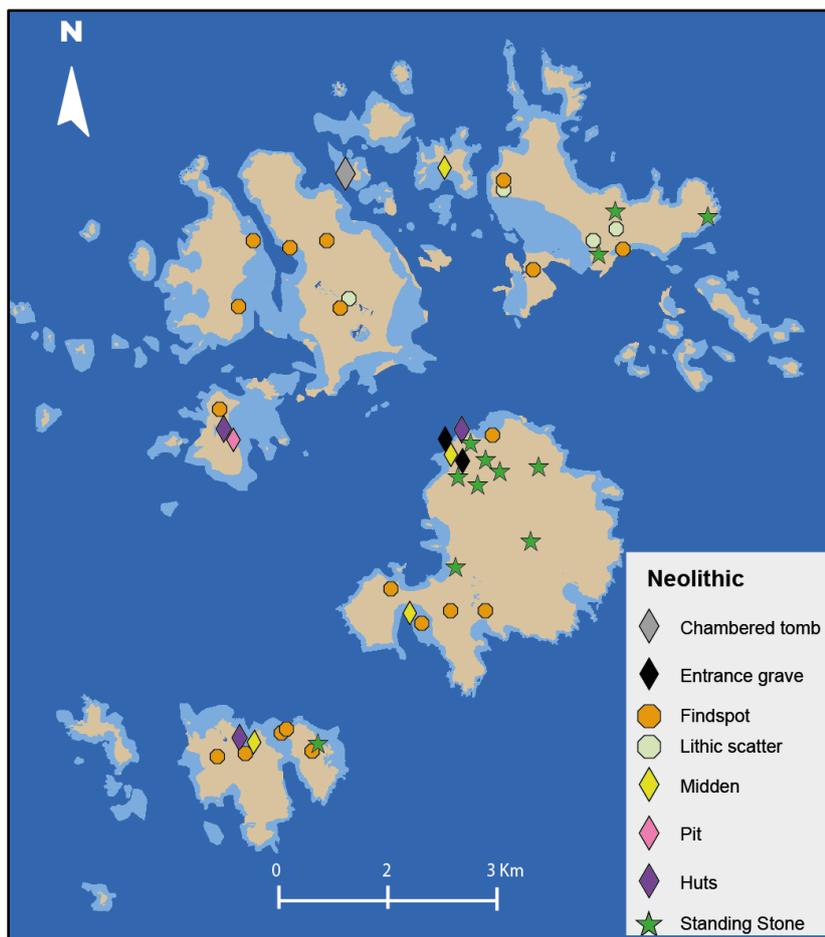


Figure 2.4 Neolithic archaeological remains in the Isles of Scilly. Archaeological data obtained from the Cornwall and Isles of Scilly HER.

The Neolithic Scilly is better represented by large funerary monuments, this parallels mainland Cornwall. Typical features of Scilly are the entrance graves and chambered cairns, some of which could have had Mesolithic origins (Ashbee, 1986). Entrance graves have a very limited distribution within the British Isles, restricted to the Isles of Scilly and West Penwith, in Cornwall. However, similar tombs have been recorded in the Tramore area of south-east Ireland, and lesser numbers of vaguely comparable monuments are known in the Channel Islands and Brittany (Mulville, 2007). Although due to their architecture these monuments could be considered as having originated in the Earlier Neolithic, current data from the islands suggests that the majority of these monuments date to the Late Neolithic and Bronze Age (Robinson, 2007). Due to the number of funerary monuments and the sparse presence of settlements of this period, it has often been suggested that the islands were some kind of necropolis for the Cornish mainland or that their ritual function could have been of a maritime nature, ensuring the continuing fertility of the sea and associated with well-established fishing routes (Ashbee, 1986; Johns et al., 2004).

2.2.3 Bronze Age (2500BC-800BC)

The Early Bronze Age is very difficult to separate chronologically from the Late Neolithic. This is because there are some archaeological problems over the identification and dates of sites and also because there is a continuation of traditions during this era (e.g. Bradley, 1998). The Late Neolithic/Early Bronze Age in Scilly is marked by distinctive burial and ceremonial monuments such as entrance graves, cairns, standing stones (most of them originating in the previous era) and by the use of pottery decorated on their upper halves with comb-impressed and cord-impressed decorations. The adoption of this comb-impressed and cord-impressed pottery and the use of entrance graves set the prehistoric island communities apart from their mainland counterparts and may be suggestive of the creation of a distinctive island identity during this period (Robinson, 2007).

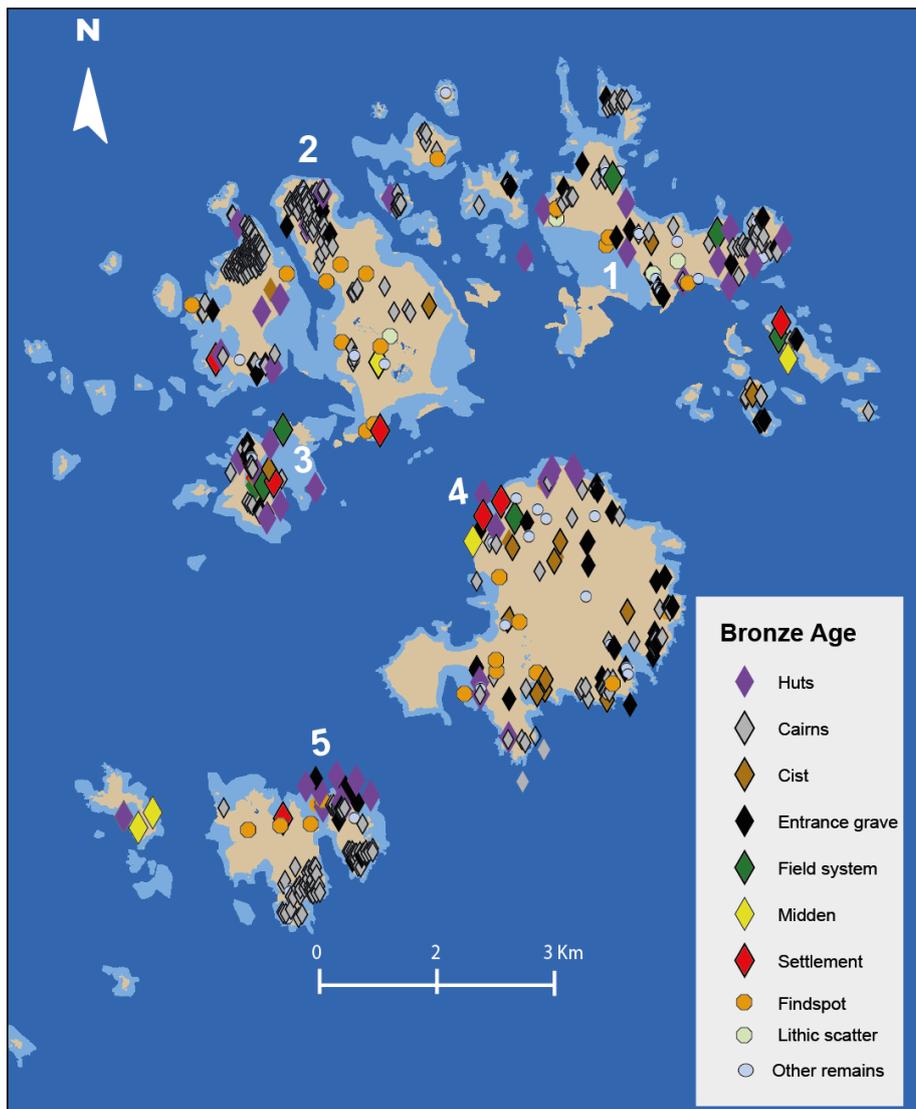


Figure 2.5 Bronze Age archaeological remains on the Isles of Scilly, with the location of the five possible 'founder sites'. Data obtained from the Cornwall and Isles of Scilly HER.

Scilly has a large number of settlements sites dated to the Bronze Age (Fig. 2.5) including villages (Nornour, Halangy Down, Kittern Hill), isolated hut circles (Samson Flats, West Broad Ledge, Little Bay), field systems (Puffin Island, Penninis Head), Cairn cemeteries (Shipman Head Down, Castle Down, North Hill, Salakee Down) and Entrance graves (Knackyboy Cairn, Innisidde Carn) (English Heritage, 2010).

There are remains of some 150 hut circles in the archipelago and, whilst many are probably Bronze Age, only 15 can be securely dated to this period (through pottery and radiocarbon dating). The houses appear in groups of two or three circular stone-built huts

or homesteads, conjoined and thus an entity, close to field system and often chambered cairns. Based upon association with particular substantial chambered cairns, finds, and territories, five founder sites have been suggested (Ashbee, 1984). They are: (1) a cliff-exposed site below the Knackyboy Cairn on St Martin's, (2) hut and fields at Gimble Porth, Tresco, (3) the shore-exposed site with presumably the submerged fields in the East Par of Samson, (4) Halangy Porth on St Mary's and (5) a site below Kittern Hill on Gugh (Fig. 2.5). Such territories would have worked well within the constraints of the early Scillonian environment for each site had access to the sea and to high and low land (Ashbee, 1984; 1986; Thomas, 1985). Entrance graves primarily contain midden debris –dark organic earth, ash, charcoal and abraded sherds. These deposits are reminiscent of the occupation debris deposited at southern English long barrows and causewayed enclosures and of the 'black earth' in some Scottish chambered tombs (Ashbee, 1976). These symbols of life (rich organic soil), of transformation (ash and charcoal) and of decay (broken pottery) have the potential to convey a variety of contextual meanings, perhaps relating to the fluidity and mutability of social identities, perhaps farming relationships between the living and the dead. However, in Scilly the meaning of these deposits may also relate to a specific problem – soil degradation (Kirk, 2004).

Other characteristic features of Scilly from this period are the field systems. A field system is an assembly of parts connected in an organised manner such that each component is linked directly or indirectly to every other element (Yates, 2004). It has long been argued that the appearance of field systems in northwest European prehistory marks a major stage in the socio-economic development of human societies, indicating the intensification of agricultural production and a significant change in human – environment relationships (e.g Stevens and Fuller, 2012); and suggesting the emergence of new forms of land tenure in which patterns of social division were becoming more pronounced (Fyfe *et al.*, 2008). Fragments of the early Neolithic field systems survive in western Ireland (Caulfield, 1978; Caulfield *et al.*, 1998), however, these types of sites are rare and widespread subdivision of the landscape does not appear to have taken place until the Bronze Age,

with the establishment of extensive field systems across both upland and lowland environments (Amesbury *et al.*, 2008). Early field systems in Scilly are defined by walls, stone banks and lynchets, and they have a wide distribution throughout the archipelago. It is difficult to precisely date these field systems; it is possible that they date to the Bronze Age, but they probably continued in use throughout prehistory and in some cases into the Roman and early Medieval period (Johns *et al.*, 2004).

The Bronze Age funerary monuments in Scilly are far more numerous than the habitation sites and the field systems (Fig. 2.5). Over 80 entrance graves have been recorded, about 400 simple cairns and a large number of cists. Quantities of burnt bone, loose or contained in urns, have been found in some of these graves, suggesting that cremation was the burial rite with occasionally some grave goods (Ratcliffe, 1989). One of the most important entrance graves in Scilly, Knackyboy Cairn, appears to have been built late in the second millennium BC, perhaps c. 1200BC (evidence from star bed of faience). These graves continued in use until at least 700BC (O'Neil, 1952). Another important entrance grave is the renowned Barnt's Carn (St Mary's), (Fig. 2.6). Human remains, pig bones and broken pottery have been found there (Ashbee, 1976). Some of these entrance graves are linked by walls or stone rows. For example a long reave on Castle Down, Tresco, acts as the boundary between an area of field and an extensive cairn cemetery to the north-west (Johnson, 1980).



Figure 2.6 Barnt's Carn, St Mary's.

The distribution of Scillonian entrance graves seems, generally, to relate to the original coastline with particular concentrations on Gugh, Samson, the west of Bryher and the eastern side of St Mary's (Fig. 2.5). Most are set along ridges, on relatively level or gently sloping downs, or on hill summits. In some cases they are near to ancient sea cliffs. Low-lying entrance graves are the exception to the rule, only two are known at the bottom of slopes and another one is on the low-lying island Old Man of Teän (Johns *et al.*, 2004).

This preference for coastal locations of these types of monuments can also be seen in the Orkney Islands (Scotland). A recent GIS study that incorporates control samples has shown that the majority of the Orkney monuments are located on the coast overlooking large areas of seascape. On the contrary, in northern mainland Scotland the location of the monuments are related to the land (Phillips, 2003). In Scilly the entrance graves tend to concentrate around the coast, while in mainland Cornwall they are located near or around Tors or prominent rocks, with a more 'land focus' (Tilley and Bennett, 2001).

Other monuments of this period are the standing stones. These are found throughout the archipelago but little evidence for their date is available. Some of them form the central features of cairns or are located close to them. The function of menhirs may encompass way-markers, boundary markers, memorial stones and ritual foci. It is possible that, at some sites, below-ground features survive as a more extensive ritual complex, of which the menhir is merely the surviving above-ground component. Most of them are on high ground, hilltops, ridges or slopes and associated with other contemporary ceremonial monuments and with Bronze Age settlements (Ratcliffe, 1989).

A change in the island's prehistory pottery occurred around 1100 BC with the introduction of a wider range of vessel sizes and forms that included the recognition of a series of Later Bronze Age bowls at Nornour (Butcher, 1978). A change in the archaeological record also occurs at this time. The large monuments ceased to be built. In southern Britain, settlements and field systems became dominant. When large-scale earthwork monuments started to be constructed again (next period) these were typically large enclosures in the shape of hillforts or earthworks (Jones, 2010).

Bronze Age occupation debris from Scillonian settlements reveals that their inhabitants practised a mixed subsistence economy. As well as growing crops and rearing stock (*Bos* sp, sheep and horses), they fished, gathered shellfish and hunted wild animals and birds (Johns *et al.*, 2004). The bones of large and small red deer have been found at Halangy Porth, on St Agnes and on Nornour. It has been proposed that even on the larger island of early times, such a sizeable mammal could hardly have lived wild and been hunted in a random, predatory manner. An insular controlled deer economy seems more likely (Ashbee, 1986).

2.2.4 Iron Age (800BC – AD42)

The term 'Iron Age' is used to describe a period when iron gradually replaced bronze as the main metal for making tools and weapons. However, few iron objects survive in the

acid soils of Cornwall and pottery and the introduction of hillforts have traditionally been used to identify the beginnings of the local Iron Age. These forts are very common in Cornwall and Devon, but a greater number of them can be found on the western extremities. They are seen as sacred sites and/or liminal places at the interface between land and sea, perhaps serving also as a guiding landmark for mariners (Cunliffe, 2002). Initially they were seen as central places and residences of the elite; now it is clear that the majority of these sites might not even have been occupied permanently, since little evidence for occupation or indeed for their elite status has been found (Van Der Veen and Jones, 2006).

Cliff castles are one of the most characteristic Iron Age features of the south west peninsula, they have also been found in Galicia (North West Spain), Brittany (France) and Wales, thus they seem to be typical of this Atlantic area. There are several of these along the Cornish coast: The Rumps (North Cornwall), Trereen Dinas (Penwith), Treelgue Head (Newquay) and so on. In Scilly there are no definitive examples of hillforts but there are Cliff Castles: Giant's Castle on St Mary's, Shipman Head on Bryher and Burnt Hill on St Martin's (Ashbee, 1974; 1986), Fig. 2.7. In Scilly there appears to be broad continuity of settlements and land enclosure across the Bronze Age and Iron Age. Open settlements are commonly found and they seem to be located in the best pasture lands (Forde-Johnston, 1976). Other characteristically south western types of Iron Age settlements are known as rounds. These are sub-circular homesteads, consisting of a simple bank and ditch enclosure with a few huts inside and often associated with fields, which may subsequently develop into 'courtyard houses' consisting of a central paved courtyard surrounded by rooms and enclosed within a massive wall (Cunliffe, 2001). Courtyard houses are found in Nornour in Scilly, the previous Bronze Age group of huts developed during the Iron Age into paved rooms surrounded by a wall (Dudley, 1967).

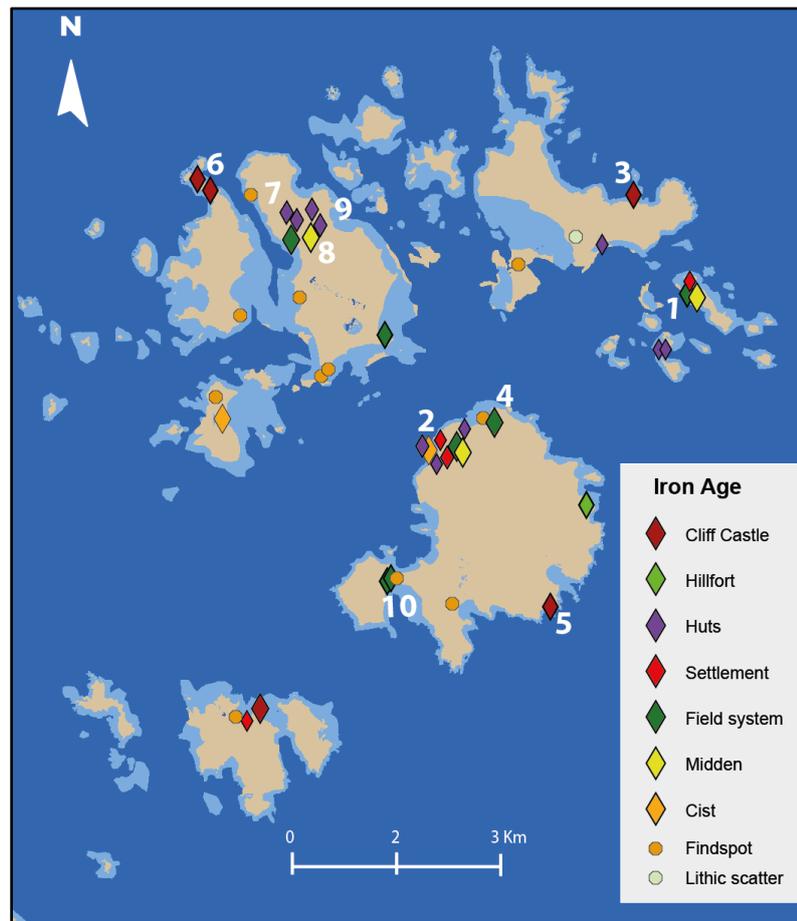


Figure 2.7 Iron Age archaeology in Scilly with the most important sites discussed in this section. (1) Nornour, (2) Halangy Down, (3) Burnt Hill, (4) Bar Point, (5) Giant's Castle, (6) Shipman Head, (7) Castle Down, (8) Dial Rocks), (9) Gimble Bay and (10) Porth Cressa. Archaeological data obtained from the Cornwall and Isles of Scilly HER.

Halangy Down (Fig. 2.7) is the only group of huts from the Iron Age that can be termed a 'village' in Scilly. Ancient fields apparently associated with the settlement were found during fieldwork in 1949. Excavation and clearance has shown that the buildings were set up on cultivation terraces generally retained by massive walls (Ashbee, 1974). It is therefore possible that these terraces were constructed and used before the Halangy Down settlements were built and thus refer to an earlier phase of activity, perhaps the settlement which lies in Halangy Porth (Ashbee, 1984). A precursory settlement in Halangy Porth, now largely destroyed by the sea, was abandoned because of blown sand, resulting in relocation to higher ground at around 400BC (date obtained from charcoal incorporated into the dark loam infill of the circular stone built remnant in Halangy Porth). A clear succession of building construction modification, and dismantling was defined

upon the lower terraces. Eventually a courtyard house was built by alteration and addition higher up on the hillside (Ashbee, 1996).

Iron Age sites can be found in most of the islands, e.g. Burnt Hill (St Martin's), in the Dial Rocks, Pendrathen Quay (St Mary's), Bar Point (St Mary's), Gimble Bay (Tresco) and in Bryher (Evans, 1984; Gray, 1972; Thomas, 1985), Fig. 2.7.

The funerary monuments of this period are the cists, although this type of monument is found also during the Bronze Age. In Scilly there are some 32 known cists, whose current distribution is restricted to a few locations on St Mary's (Toll's Porth, and in the cliff face at Porth Cressa) and the shores of St Martin's (Par Beach), Teãn, Bryher (Green Bay) and Samson. In each case they sit on low-lying ground associated with broadly contemporary settlements and field systems. 22 of the identified cists are now destroyed; others have been reburied or have long been hidden beneath sand. Only three samples of cists of this period are currently visible (Johns et al., 2004). Skeletal remains, where they survive, are very fragmentary and include grave goods, such as pottery and brooches. An exceptional cist grave discovery on Bryher in 1999 contained an iron sword and its bronze scabbard, a mirror, brooch, spiral ring, shield fitting and a crushed tin object. The mirror is the earliest known British decorated bronze mirror (Johns, 2002).

The Iron Age economy is a continuation of that of the previous periods. The material culture and archaeological remains show a farming society, which still relies on the sea and birds as food resources. Animal hoof prints recorded in the excavations at Bar Point are both cloven and uncloven. The uncloven hoof prints belonged to small horses or ponies, the cloven to cattle, sheep and goats (Evans, 1984). The continued use of enclosed field systems and a large number of querns also indicate arable production. The later Iron Age pottery in Scilly includes a number of distinctive pottery vessel forms that fall within the categories of Glastonbury Ware, which occurs throughout Cornwall and Devon (Quinnell, 1986). They reflect contact with the mainland as they were typically made with gabbroic clay from the Lizard peninsula in Cornwall (Jones, 2006).

2.2.5 Romano-British (AD43-409)

The Roman invasion of Britain did not have a great impact in Cornwall and less so in Scilly. The islands occupied a very remote position in the Roman Empire and, unlike Cornwall they were not a source of streamworked tin (Thomas, 1985). Elements of Romano-British material culture began to appear within existing Iron Age settlements, but generally the excavated hut settlements at Halangy Down, St Mary's and Nornour (Fig. 2.7 and 2.8), indicate continuity between the Iron Age and Romano-British period.

Halangy Down's last phase extends into post-Roman times and the early centuries of Christianity. All in all, it had been occupied for around a millennium (Ashbee, 1996). A large Roman assemblage has been recovered from the Nornour settlement, consisting of: more than 280 brooches, about 25 finger-rings, 10 bracelets, 12 miscellaneous bronze items, 22 glass beads, numerous fragments of vessel-glass, ceramic items, 13 fragments of Central Gaulish clay figurines pseudo-Venus and *Dea Nutrix* type and at least 83 Roman coins from the 3rd and 4th century (Butcher, 1978; Dudley, 1967; Fulford, 1989; Thomas, 1985).

This exceptional collection of brooches, rings, bracelets, coins and beads, not to mention the *Dea Nutrix* Venus figurines and the small archaic vessels were considered to be of votive character, and led some authors (eg Thomas, 1985) and the excavators to consider Nornour as some kind of Romano-British shrine. This could have been dedicated to a maritime goddess intimately involved with the sea passage from Land's End to Scilly. It is possible to link the root of *Silina* with *Sulis Minerva*, a watery deity also associated with beacon fires and used to guide mariners. It is likely then that a beacon or lighthouse existed in the eastern summit of St Martin's, just to the north of Nornour and was associated with the shrine (Ashbee, 1986; Butcher, 1978; Thomas, 1985). Another argument supporting the idea of religious presence in Nornour is the association of plate brooches with temple sites, which has been recognised for some time; some brooch types

can be associated, with varying degrees of confidence, to specific Roman or Romano-Celtic deities (Crummy, 2007).

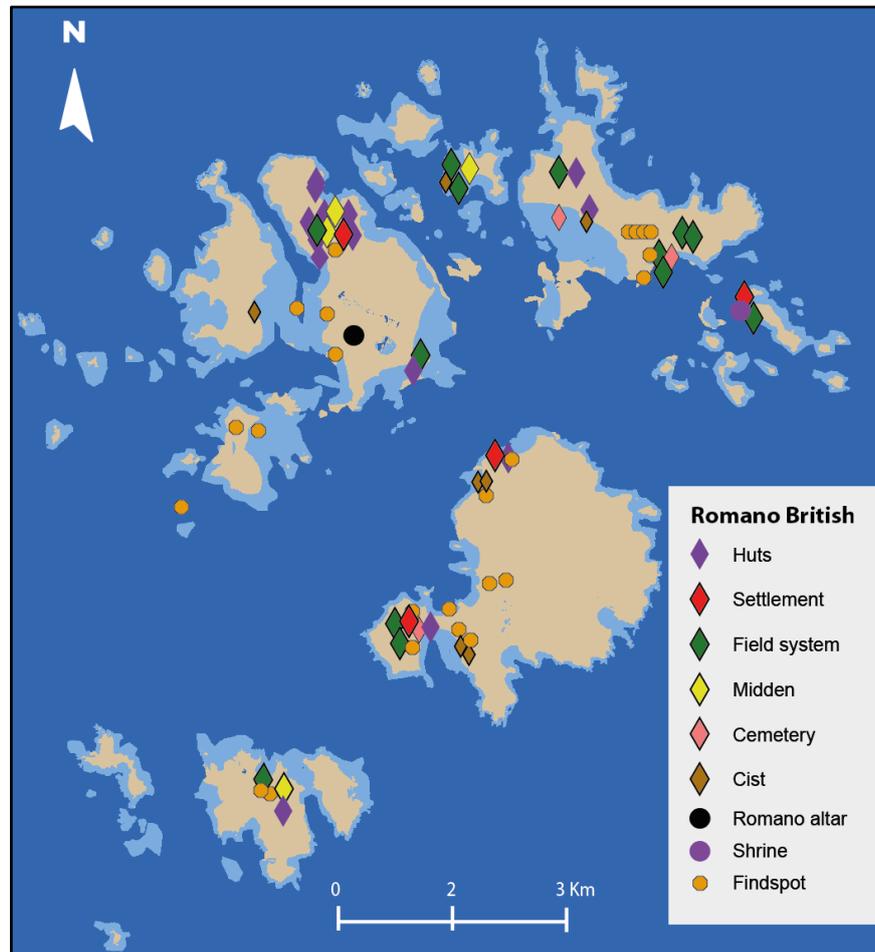


Figure 2.8 Romano-British Archaeology from Scilly. Archaeological data obtained from the Cornwall and Isles of Scilly HER.

However, with the exception of the diminutive pots which were associated with the hearth, all the Roman material derived from secondary context within and around the structure. Indeed, all the brooches and other finds were found on the beach and among the stones of the buildings (Butcher, 1978; Dudley, 1967). This may be used to infer that the structures were long-abandoned before the Roman material arrived. It is necessary to point out that neither of the excavators found evidence of a shrine or any other ceremonial monuments. Another interpretation for this assemblage has been presented by Fulford (1989). Observing the lack of Romano religious monuments nearby, and the lack of stratigraphy of the material, it could be assumed that the material derived from a

shipwreck and was subsequently rescued or washed up, collected and re-deposited over a longer time span. This presupposes that the collection formed part of the stock of a travelling-merchant or itinerant craftsman. Such a collection or hoard would be expected to contain items of diverse origin, as well as some older material in addition to new stock. The pipe-clay figurines might seem to be evidence for a votive interpretation; however they were mass-produced items from workshops in Central Gaul and were widely marketed. Furthermore, although navigational conditions may have been noticeably different in Roman times when the landmass of Scilly was greater than it is today, the island does not offer safe anchorages in bad weather. Why would ships have put into Nornour if their safety was at risk? The absence of Roman material from elsewhere on the islands, suggests that few came to trade. If traders were few, it is harder to explain how so many visits to deposit votive at Nornour, most of which apparently conducted over short periods of times, should have had so little material influence elsewhere on the islands (Fulford, 1989).

During the Romano-British period the tradition of cist-burials continued in Scilly. These were usually built in pits in the loamy soil of selected granite blocks and slabs and were similarly covered. The rite was contracted inhumation with the head to the north, and the body was laid on its right side. Grave goods were a series of provincial Roman brooches and occasional brooches. The cists were usually grouped in cemeteries, surrounded by a stone wall. They are found in St Mary's and St Martin's (Ashbee, 1954; 1979).

The Romano-British economy was not much different to that of earlier periods. A late Roman middle from Tean (Ratcliffe and Straker, 1996) have yielded barley, arable weeds (wild radish, fat hen, knotgrass and vetch), sheep/goat, ox, pig, dog, grey seal, a small range of birds, fish bones, limpets and shells. Evidence from Nornour shows a mixed farming economy, arable and with domestic animals (cattle, sheep and goats.). The field systems are indicative of tenure importance and agriculture. The Romano-British assemblages emphasise the mixture of domesticated and wild resources that continue to be important.

2.2.6 Medieval (AD410-17th century) and Post-Medieval period

The Medieval period can be divided into the Early Medieval (5th to 11th centuries) and Later Medieval (11 to 17th century). Early Medieval society and settlement in Cornwall (and in Scilly) has its roots in the Romano period but the 5th to 7th centuries saw some changes. Firstly, Christianity was adopted. Secondly there appears to have been a change in the form of settlement; the round building went out of use and unenclosed farms and hamlets became the norm. Meanwhile, maritime contact between Cornwall, Wales, Ireland and Brittany intensified with Welsh/Irish immigration from Wales and emigrations to Brittany (Preston-Jones and Rose, 1986).

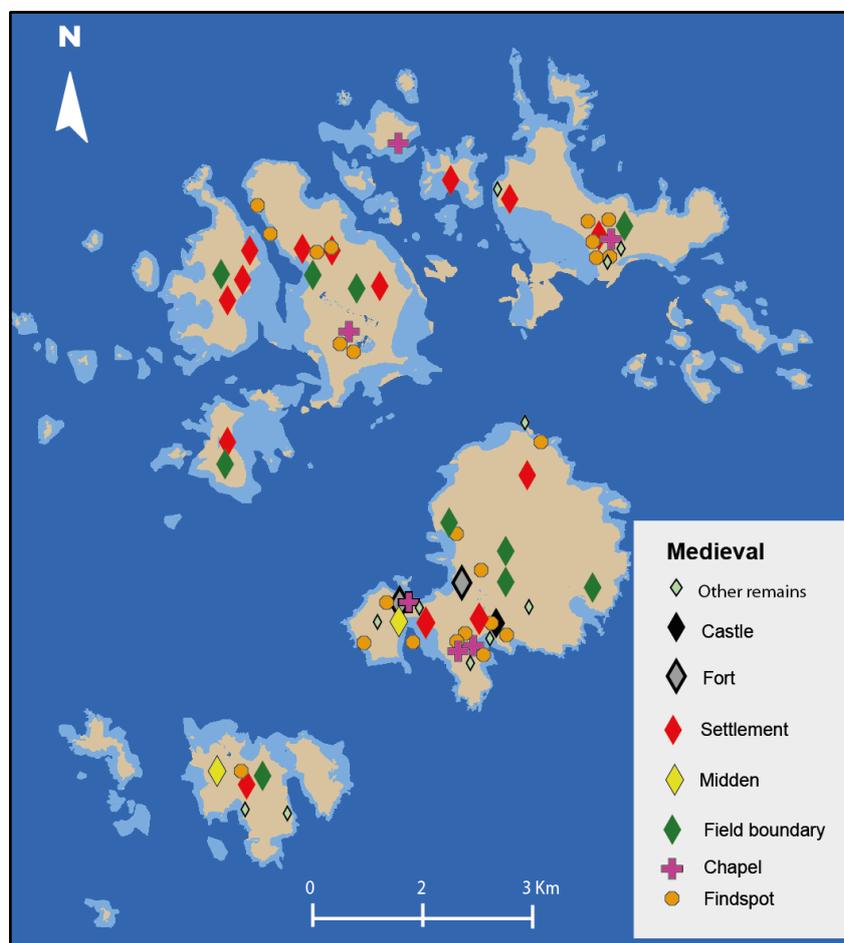


Figure 2.9 Medieval Archaeology in Scilly. Archaeological data obtained from the Cornwall and Isles of Scilly HER.

The Early Medieval settlement pattern in Scilly is reflected by the distribution of locally made grass-marked pottery and sherds of imported wheel-made Gaulish and Mediterranean wares. Some of the identified sites had seen continued occupation since the Romano–British period. In Scilly, a 6th century inscribed tombstone now incorporated into the later priory church on Tresco, represents the earliest evidence of Christianity in Scilly. A number of Early Christian cemeteries have been recorded and cist graves excavated with extended inhumations. Simpler rectangular chapels of the 8th and 10th centuries are also found in Scilly. Later Medieval domestic sites are also extremely underrepresented in the archaeological record and are limited to a number of pottery scatters (Ratcliffe, 1989).

Most of the islands were inhabited at this time, but St Mary's contained the largest settlement and possibly at least two fortifications (Ratcliffe, 1989), Fig. 2.9. St Helen's does not contain any evidence of prehistoric occupation but it was known in the Middle Ages as *Insula Sancti Elidii*, and it contains the remains of a small settlement. This was probably a small Celtic monastic settlement, estimated at only 10 or 12 persons, as greater numbers would have exhausted the capacity of the island (O'Neil, 1964). In Samson, although there is evidence of prehistoric use (mainly tombs and field systems) there is no evidence of any form of settlement until the 17th century (Slade, 1984). Tresco became very important from the 12th century onwards with the building of the Abbey. Before 1648, St Martin's was occupied on a larger scale but by 1952 the island had "only two poore inhabitants" (Thomas, 1985). The tenancies of Agnes and St Mary's were from time to time separated and both could be held apart from the constableness centred on Ennor Castle. Eventually Scilly was acquired in 1547 by Sir Thomas Seymour; after his execution the defence of Scilly was then entrusted by Queen Elizabeth to various Cornish grandees (Thomas, 1985).

The later Medieval economy in Scilly was based on farming (Parslow, 2007). One of the most important crops at that time was potatoes and in good years, the islanders might get two crops annually. The islands also produced barley, rye, oats, pillas, peas, beans,

salads, gooseberries, currants, raspberries, strawberries and garlic. The local horses were small and had to survive off poor fare that included gorse and both the sheep and the small black cattle subsisted on seaweed when there was no hay available. Seaweed was also used to manure the fields, a practice which was in use until the late 20th century. Several of the uninhabited islands were used for summer grazing, as well as places where there were colonies of rabbits and seabirds. From the late 17th to early 19th century the burning of kelp was an important local industry that involved almost every family on Scilly. Scilly had been a base for pirates during the early 12th century. Smuggling has long been associated with the south-western counties of England, and Scilly is very suited to it, with plenty of hidden places around the islands and fleets of gigs capable of sailing to the coast of France (Bowley, 2008; Parslow, 2007).

2.2.7 Summary

There are significant issues when trying to explain the cultural evolution of the Isles of Scilly. The most substantial problem is the lack of a clear chronology for most of the archaeological remains, which is not made any easier by apparent continuity across archaeological periods. The second difficulty is the loss of sites to the sea and erosion: the majority of sites are located close to the coast and suffer erosion; much of the original land mass is likely to be submerged as a consequence of relative sea-level rise (see chapters 4 and 5). There are clear connections between the islands and other places: mainland Cornwall, Wales, Ireland and the continent. Even so, the Scillonians developed a distinctive island identity, especially in the Early Bronze Age, adopting different pottery styles to the Cornish mainland.

The most remarkable archaeological remains in the island are the abundance of funerary monuments. This has produced a record biased towards ceremonial and ritual interpretations of Scilly in prehistoric studies of the South West and the Atlantic façade in general.

The Isles of Scilly are very rich in natural resources. The early inhabitants of Scilly relied on the sea and wild sources, there is ample evidence of burnt hazel shells, and middens (such as Porthkillier, Porth Cressa and Tean) composed mainly of shellfish, fish, birds and mammal bones. Since the Bronze Age (circa 2500BC) people have exploited both domesticated plants (cereals and arable weeds) and animals (goat/sheep, ox, cattle) but also have continued to use wild resources (particularly birds and marine resources eg seals and fish). The fertility of the soils was improved by manure; produced by animals and kitchen waste, and by algae. The importance of the agriculture in Scilly over time is evident in the division of the land (field systems), enclosures and the abundant remains of domestic animals.

2.3 ENVIRONMENT OF THE ISLES OF SCILLY

2.3.1 Previous palaeoenvironmental work in Scilly

Evidence for the past environment of the Isles of Scilly comes primarily from pollen analysis of shallow basins (found onshore and offshore), buried soils, and archaeological sites (Table 2.1 and Fig. 2.10). These sequences are stratigraphically short and without reliable dating, providing a patchy and incomplete account of the character and human impact on the landscape of Scilly over time.

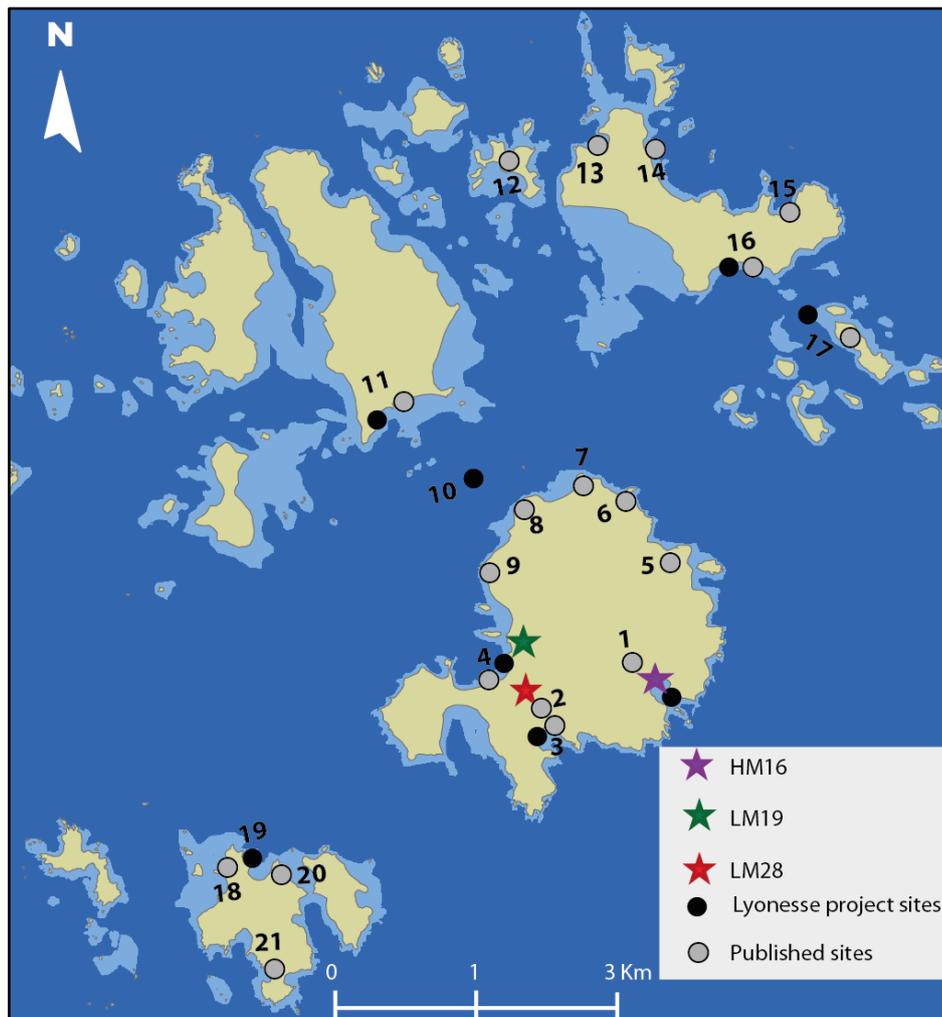


Figure 2.10 Locations of published palaeoenvironmental studies, Lyonesse project sites and cores presented in Chapter 4.

In addition to the existing published body of research concurrent work has been undertaken on subtidal and intertidal peats on Scilly (Charman *et al*, forthcoming). These new palaeoenvironmental sequences will not be reviewed in this project, but their results will be included into the discussion (Chapter 5) where relevant.

Table 2.1 Summary of palaeoenvironmental studies in the Isles of Scilly with reference to the map in Fig. 2.10.

Site number	Island	Site name	Reference	Site type
1	St Mary's	Higher Moors	Scaife 1980,1981 and 1984	Peat sequence
2	St Mary's	Lower Moors	Scaife, 1984	Peat sequence
3	St Mary's	Old Town	Charman, <i>et al</i> , forthcoming	Intertidal peat
4	St Mary's	Porth Mellon	Charman, <i>et al</i> , forthcoming	Intertidal peat
5	St Mary's	Watermill Cove	Scourse, 1991	Organic sequence
6	St Mary's	Innisidgen	Dimbleby, 1977	Palaeosol
7	St Mary's	Bar Point	Evans, 1984	Palaeosol
8	St Mary's	Halangy Down	Dimbleby <i>et al</i> , 1981	Palaeosol
9	St Mary's	Carn Morval	Scourse, 1991	Organic sequence
10	St Mary's	St Mary's Road	Charman, <i>et al</i> , forthcoming	Submerged peat
11	Tresco	Crab's Ledge	Charman, <i>et al</i> , forthcoming. Ratcliffe & Straker, 1996, 1997	Intertidal peat
12	Tean	Tean	Thomas, 1985	Archaeology
13	St Martin's	Porth Seal	Scourse, 1991	Organic sequence
14	St Martin's	Little Bay	Neal, 1983	Archaeology
15	St Martin's	Bread and Cheese Cove	Scourse, 1991	Organic sequence
16	St Martin's	Par Beach	Charman <i>et al</i> , forthcoming. Ratcliffe & Straker, 1996	Intertidal peat
17	Nornour	Nornour	Butcher, 1978. Charman <i>et al</i> , forthcoming.	Palaeosol. Submerged peat
18	St Agnes	Big Pool	Foster <i>et al</i> , 1996	Peat sequence
19	St Agnes	Porth Coose	Charman <i>et al</i> , forthcoming.	Intertidal peat
20	St Agnes	Porth Killier	Ratcliffe & Straker, 1996; 1997	Intertidal peat
21	St Agnes	Porth Askin	Scourse, 1991	Organic sequence

2.3.2 The Early Environment in Scilly

The earliest vegetational record for the Scillies was obtained by Scourse (1991). These are pollen analyses from organic sequences (interpreted as small lakes or ponds) from

Carn Morval, Watermill Cove, Porth Askin, Porth Seal and Bread and Cheese Cove (Fig. 2.10). These produced radiocarbon dates of between 34500 (38101-36420 cal BC) and 25000 years BP (24121-23363 cal BC). All of them contain very similar pollen assemblages: a range of non-obligate aquatic herb taxa, consistent with open temperate grassland. All the herb taxa from Carn Morval are characteristic of open grassland vegetation, with grasses dominating, but with sedge in favourable wetter locations (Scourse, 2006). Bread and Cheese Cove (St Martin's) produced a pollen spectra dominated by herb taxa, in particular Poaceae, *Solidago* type, Rubiaceae and *Ranunculus*, with the tree taxa almost completely absent (Evans *et al.*, 2006).

2.3.3 Mesolithic environment

The pollen sequence from Higher Moors (Scaife, 1981) dates back to the 6th millennium cal BC. At the moment there is no palaeoecological evidence for the character of the vegetation between Scourse's work on the glacial material and the start of this Higher Moors sequences. The predominant pollen recorded was *Quercus*, *Ulmus* and *Corylus*, with *Betula* playing an important role; few herb taxa are noted (Scaife, 1981). The earliest of the intertidal deposits examined by Ratcliffe and Straker (1996), at Par Beach on St Martin's (Fig. 2.10), was dated to the late Mesolithic or early Neolithic (late 5th/4th millennia cal BC). This sequence contained a range of arboreal taxa, including *Quercus*, *Corylus*, *Betula*, *Tilia*, *Ulmus*, *Ilex* and *Alnus*, broadly similar to that identified at Higher Moors for the later Mesolithic. The flora of this period seems to represent extensive tree cover consisting of oak and hazel woodland. Birch was also abundant, probably in the form of a shrub growing in exposed coastal localities. Scaife (1984) argued that the birch scrub could be due to initial human disturbance and subsequent abandonment, hinting at Mesolithic disturbance rather than that of the early farmers, although it is difficult to sustain this interpretation.

2.3.4 Neolithic environment

The Neolithic marked the advent of deliberate cultivation of food-plants, accompanied by increased domestication of animals (Thomas, 1999); however, evidence for Neolithic vegetation disturbance in Scilly is very limited. The pollen assemblage from Higher Moors shows a decline in the arboreal pollen and an increase in herbaceous taxa in a zone radiocarbon dated 3100 ± 70 BP, 1520-1170 cal BC (Scaife, 1980). The decline of *Ulmus* is important, associated with the arrival of cereals and forest clearance, although the date obtained is much younger than similar patterns in other areas of Britain (Scaife, 1988). The chronology for the Higher Moors sequences is problematic because some of the radiocarbon dates are reversed, possibly due to contamination (Scaife, 1981).

Cereal cultivation by the Late Neolithic is implicit in the archaeological evidence. There were a large number of saddle-querns produced in situ from finer-grained granite, occurring at all prehistoric sites on the islands. The prehistoric enclosures also suggest cultivation, and corn-drying ovens have been identified on Teän and at Halangy Down (Fig. 2.10). Direct evidence also comes from impressions of cereal grains caught up in the damp clay and subsequently fired out. Within the environmental evidence pollen samples show the presence of cereal types at Nornour, Innisidgen and Higher Moors (Fig. 2.10), certainly by the Bronze Age (Ashbee, 1974; Thomas, 1985). Soil pollen investigation at Innisidgen revealed an old land surface under a fossil sand dune, which yielded evidence of oak and hazel woodland subsequently replaced by open grass and heather heath, with indications of cereal-growing (Dimbleby, 1977).

By the late Neolithic (3rd millennium BC) at Porth Mellon on St Mary's a mixed deciduous woodland was still a major feature of the local vegetation. It has been suggested that the high percentage of birch pollen in the initial forest phase at Higher Moors represents scrub regeneration resulting from anthropogenic disturbance and abandonment by Mesolithic hunter-gatherers. However, birch was also common in the Neolithic woodland at Par Beach and Porth Mellon and it may have been a major part of the postglacial climax

woodland, which in Cornwall is usually dominated by oak and hazel (Ratcliffe and Straker, 1996; 2000).

The same situation is evident on the mainland. The farther into the Neolithic, the more that woodland clearance became common and more grassland started to appear, maintained by humans for farming or animal grazing purposes. Still there was some woodland and shrub patches in some regions. For example, a detailed study of Bodmin Moor (Fig 2.1) was carried by Gearey *et al* (2000), they evaluated the deposits from Rough Tor and the East moor, showing that prehistoric periods of this area were very complex. The pollen indicated that the settlements and major landscape disturbance took place during the early Neolithic within a forest landscape. Human activity was deduced in both sequences to be contemporary and indicated the creation and maintenance of open areas of the moor. Pollen analysis from under a stone row on Cut Hill, northern Dartmoor, represents a Neolithic landscape with patches of open heath or bog within a generally wooded landscape (Fyfe and Greeves, 2010).

2.3.5 Bronze Age environment

Scaife's (1981, 1984) radiocarbon dating of Higher Moors suggests that woodland clearance occurred during the Bronze Age, followed by a regeneration of *Betula*-dominated woodland. Extensive deforestation probably took place during the Iron Age in the South-West peninsula (Bell, 1984).

Pollen analysis from Nornour (1500BC-AD400) shows an open landscape in later Prehistory. The most abundant pollen is *Plantago* with Poaceae, the tree pollen record is represented by occurrences of *Alnus*, *Quercus* and a scattered presence of *Betula* and *Corylus* (Butcher, 1978). The evidence of clearance found in the buried soil at Innisidgen could also be associated with this phase. This site provides the evidence of the character of late prehistoric woodland (*Quercus* and *Corylus*) followed by clearance which caused soil depletion, podzolisation and development of heath (Dimbleby, 1977). If the evidence

of agriculture at Halangy Down can be attributed to the adjacent Iron Age settlement, then St Mary's was virtually treeless by that time (Dimbleby *et al.*, 1981).

There is currently no pollen evidence from elsewhere in Scilly for the mid to late Bronze Age forest regeneration recorded at Higher Moors. Neither is there any indication of it in the archaeological record. Indeed the two middle to late Bronze Age settlements studied produced evidence for arable and pastoral farming. The Higher Moors evidence may reflect a local vegetational change and not necessarily the situation elsewhere in Scilly (Ratcliffe and Straker, 1997; 2000).

2.3.6 Iron Age

Pollen analysis associated with the excavation of an Iron Age field system and associated features at Bar Point, St Mary's, showed that the site was in use at a time when the islands had long been cleared of woodland and cereals were being grown (Evans, 1984). Soil studies and stratigraphical data indicated that the initial layout of the field system took place in uncultivated land, and that later boundaries were added after a period of cultivation. A soil profile from a marine cliff near the Iron Age settlement of Halangy Down produced a virtual absence of tree pollen (Dimbleby *et al.*, 1981).

Plant remains from middens located on the outer and inner-facing shores of the present coast line produced a range of crops for Scilly during the Bronze and Iron Age, including naked and hulled barley, emmer wheat and celtic bean (Ratcliffe and Straker, 1997).

2.3.7 Historical period

The picture that emerges from the limited archaeological and partial pollen evidence is of an open landscape dedicated to agriculture with a near complete absence of trees from the Iron Age onwards. Evidence of Roman and Medieval crops are sparse. A 3rd to 6th century midden on Teän (Fig. 2.10) produced barley (*Hordeum*) and a range of arable

weeds. The upper layer of this midden, from the Early Medieval era, produced an assemblage of oats (*Avena sativa*) and rye (*Secale cereale*). Late Medieval data came from Lower Town where a small number of wheat (*Triticum* sp.) barley (*Hordeum* sp.) and associated weed seeds were recovered (Scaife, 2006). During the Late Medieval period potatoes were the most abundant crop in the islands (Parslow, 2007).

2.3.8 Summary

The environmental evidence from the Isles of Scilly is very fragmented and poorly dated. Even so, some important changes in the vegetation can be derived from these data. Firstly the Isles of Scilly were wooded during the early Holocene, largely by oak-hazel woodland. By the end of the Bronze Age/Iron Age, the islands became deforested due to anthropogenic activity, mainly agriculture. The landscape of Scilly continued from this period onwards to be largely deforested until modern times, with arable and pastoral activity growing in importance.

2.4 SEA-LEVEL STUDIES

2.4.1 Introduction

This section explains some of the most important concepts used in sea-level studies with a brief introduction to the general patterns in sea-level change across the British Isles and the Isles of Scilly in particular.

The level of the sea relative to the land is produced by two components: sea-surface changes and isostatic changes (Shennan, 2007). The rate and general pattern of relative sea-level during the Holocene was spatially variable and differed according to geographic regions in response to glacio-hydro-isostatic adjustment processes, tectonism and localized climatic changes (Murray-Wallace, 2007). Relative land subsidence and uplift is

the on-going response of the Earth to the last deglaciation and to the coexistent addition of water into the world's oceans, but the adjustment of the land is not restricted to the regions close to the former areas of glaciation (Lambeck and Johnston, 1995).

In the British Isles are highly variable relative sea-level histories within a restricted geographical area. These regional contrasts have been accentuated by the presence of an ice sheet in northern Britain, producing a relative land uplift in Scotland due to glacio-isostatic rebound, and the absence of ice in southern England, with the resultant effect of land subsidence on the coast as a result of shrinkage of the former glacial forebulge (Gehrels, 2010).

This project seeks to consider the impact of relative sea-level (RSL) change on coastal communities of the past. Through history, human societies dependent upon coastal environments have adapted to changes in relative sea-level. For example, drowned peat layers on the North Sea continental shelf contain artefacts from Mesolithic communities that had no alternative than to migrate or drown as sea-level rose (Shennan, 2007). At the same time, those in western Scotland prospered, as illustrated by analysis of Mesolithic shell middens, when the rate of sea-level rise declined to zero at a mid-Holocene highstand (Shennan *et al.*, 2006).

Traditionally, estimations of change in mean sea-level are made relative to a fixed point on land. Consequently, the changes in mean sea-level are a measure of the difference between the vertical movement of the sea surface and of the land itself (Haigh *et al.*, 2009).

2.4.2 Sea-level studies in Southwest England

Geological investigations of the coastlines around the British Isles have provided a large amount of Holocene relative sea-level information, creating extensive datasets for studies of land- and sea- level movements, glacio-isostatic rebound and coastal change (Gehrels,

2010). However, only a few coastal lithostratigraphic studies have been published from southwest England in comparison to the rest of the United Kingdom (Waller and Long, 2003). The British Isles ice sheets stored <1m equivalent global sea-level at the Last Glacial Maximum but postglacial isostatic adjustment processes produced vastly contrasting relative sea-level changes at different locations around the coastlines of the region (Shennan and Horton, 2002; Shennan *et al*, 2006). The southwest coast of England is the fastest subsiding shoreline in Britain (Shennan and Horton, 2002). A common perception of the impact of the relative sea-level rise in the South West is that higher sea-levels will eventually inundate low-lying coastal areas like the Somerset levels. But as is pointed out by Gehrels (2006), it is more likely that extreme events will determine the probability of coastal flooding.

Observations of past changes in sea-level relative to present come from *in situ* sediments and morphological features, whose origin was controlled by paleosea level, where they survive they can be used as sea-level index points (SLIPS) by defining four attributes: location, age, altitude and tendency (Shennan, 2007). High quality sea-level index points are those in which their relationship with former water levels can be accurately determined and whose vertical position within the sediment column has remained stable. Ideal SLIPS are therefore 'basal' (sediments directly overlying a hard substrate, usually sand) samples that are associated with microfossils (Gehrels *et al*, 2011).

Fourteen published index points (10 from the mainland and 4 from the Isles of Scilly) define the trends in Relative Sea-level in the western Channel since 7400 cal BP (6405-6103 cal BC) when Mean Sea-level was at ca. -12m OD (Massey *et al*, 2008). Healy (1995) suggested that the complex local physiography of the coastal zone of Cornwall, coupled with the presence of coastal barriers and variations in tidal range, make the identification of a clear regional trend in relative sea-level difficult. The data are certainly variable, but a slowdown in the rate of rise is apparent at c. 5100 cal BP (3988-3777 cal BC), since then, the Mean Sea-level has risen only c.-4m OD (Waller and Long, 2003). Gehrels (2010) calculated the linear estimate of rate of relative sea-level rise at

1.02±0.14mm/yr in the Isles of Scilly and -1.23±0.18 and -1.12±0.23 for the more eastwards locations of south Devon and west Cornwall respectively.

Gehrels *et al* (2011) offers ten new late Holocene basal sea-level points and 15 early and middle Holocene sea-level index points from previous works to review the Holocene relative sea-level data from southwest England. The data show that at Thurlestone, south Devon, the relative sea-level rose by about 10m between 9000 and 7000 cal yr BP and a further 8m in the last 7000 yr. In the last 2000 years, relative sea-level rose on average by 0.9 mm/yr and that the coast is currently subsiding by 1.1 mm/yr due to on-going glacial isostatic adjustment.

New models of glacial isostatic adjustment (GIA) have shown the necessity of considering various factors when determining the influence of the melting of the great ice sheets and the shape of the Earth when trying to model the sea-level changes of the globe. Studies such as Bradley *et al.* (2009) use continuous global positioning system (CGPS) measurements to refine a model of GIA for the British Isles. The rationale is that CGPS data will provide an important constraint for the Earth component of the GIA model and it aids in reducing the non-uniqueness inherent to the British Isles GIA problem when combined with the sea-level and geomorphological data. The model developed by Bradley *et al* (2009 and 2011) is used in this thesis to infer the palaeogeography of the Isles of Scilly over time. This thesis will compare the existing SLIPS (Sea level index points) from the South West of England and Scilly against the Bradley *et al* model (see sections 3.1 and 4.1.2). These SLIPS are not presented graphically here (but they have been discussed in the text above) as they will be used to constraint the GIA model for Scilly used in this project.

2.4.3 Relative sea-level in the Isles of Scilly

It is possible that approximately 10,000 years ago the melting ice cap led to a significant rise in sea-level, that separated Scilly from what is now mainland Cornwall, although when

the separation occurred has been a subject of speculation for archaeologists (Johns *et al.*, 2004). For Thomas (1985) the last stage at which Scilly could have been reached on foot fell somewhere between the 10th and 8th millennia BC. Other authors, such as Lousley (1971), considered that the separation occurred by the Middle Pleistocene (at least 300,000 years ago). These studies have an archaeological approach and they are not based on detailed sea-level studies. They will be used in this project only as an introduction to the literature about sea-level studies in Scilly.

The Isles of Scilly have undergone submergence during the Holocene, although the coastal evolution and relative sea-level history of this group of islands is still subject to debate (Ashbee, 1974; Johns *et al.*, 2004). The increase of relative sea-level in Scilly is evident in the submerged prehistoric archaeology: huts, houses, field systems and cists, and also in the archaeological remains fringing the inner shallow waters between the principal islands (Ashbee, 1986). The presence of submerged and intertidal prehistoric sites around the inner shoreline of Scilly demonstrates that the landmass of the islands was once larger than today (Robinson, 2007).

There are currently two published models for sea-level change in Scilly (Thomas, 1985; Ratcliffe and Straker, 1996) and a third in progress as part of the Lyonesse project (Charman *et al.*, 2012). The first model published by Thomas (1985) used archaeological and documentary evidence to constrain relative sea-level. Thomas (1985) calculated sea-level changes using the vertical positions of submerged archaeological sites which could be broadly dated from artefactual evidence by analogy with sites elsewhere. Thomas estimated mean sea-level at c. -7.25m OD around 3200 cal BP (1610-1390 cal BC) calculating an average yearly rise in sea-level of 2.1 to 2.6 metres. He maintains that the Isles of Scilly were a single island (with the exception of St Agnes, Gugh and Annet) until at least the Roman times and with the exception of very local marine inroads, this single island was much the same at low water of normal tides until the 11th century AD. By studying the names of the islands, Thomas (1985) attempted to establish their antiquity as independent entities. The main landmass during the Medieval time was restricted to St

Mary's, where most of the inhabitants lived. Early records supply the names *Enor*, *Inor* and *Ennore*, in the 12th century, *Ynner* and *Inoer* in the 13th, and *Enour*, *Enor* and *Inor* in the early 14th. The hypothetical name given to the Islands during the Romano British period might have been *Sindo Diaros*, meaning simply 'The Land'.

Prior to Thomas (1985), other authors reached similar conclusions when looking at the archaeology and geology of Scilly. However, Thomas (1985) was the first to provide a comprehensive model to account for the submerged sections of the Isles of Scilly. Ashbee (1986) speculated that when first occupied Scilly was a substantial island. During the Romano –British times and for a period following, Tresco, St Martin's, the Eastern Isles and St Mary's were joined while Samson and Bryher may have become detached from the main mass. Ashbee (1974) justified this assumption with reference to the archaeological Romano-British features found in the submerged zone and northern cliffs, and also indirectly by the use of the singular term *Siluram Insulam* by Solinus and the even later reference in the singular by *Sulpicius Severus*, in Romano-British times. Bell (1984) interpreted the archaeological evidence of the Isles of Scilly as a suggestion that most of the islands (again with the exception of St Agnes, Annet and Gugh) formed part of a single island until the inundation of the central low-lying area between the 7th and 13th centuries AD, assuming that a great post-Roman sea-level change occurred that separated the islands.

The second published sea-level model for the Isles of Scilly is based on palaeoecological assessment of intertidal peat in the early 1990s, by Ratcliffe and Straker (1996). The considerable potential of the South West for studies of sea-level change has long been recognised due to the large number of coastal peat deposits and submerged forests (Bell, 1984). Three sites with intertidal peat deposits were recorded and sampled: Par Beach, Crab's Ledge and Porth Mellon. These peat samples were assessed for pollen, plant macrofossils, diatoms and foraminifera. The results suggest a mean sea-level some 4.7m higher at 3200 cal BP (1610-1390 cal BC), about 2.55m OD, lower than Thomas (1985) for the same period; and a gradual pattern of submergence (Ratcliffe and Straker, 1997).

The results from the intertidal peat deposits suggested that sea-level rise in Scilly was more gradual than Thomas' (1985) model suggested.

Whichever model is correct, much of Scilly can be considered to be a drowned landscape, with evidence of human occupation and settlement, perhaps dating from the Late Upper Palaeolithic onwards, surviving beneath the sea (Johns *et al.*, 2004).

2.5 STORMS AND STORMINESS

This section will provide a background to the concepts of storms and storminess and a summary of the major climatic changes occurring in Europe during the Holocene. The term 'storm' will be used in this thesis to refer to extreme events, whilst the term 'storminess' refers to the frequency and intensity of storms.

The climate during the Holocene period has been highly varied (Barber *et al.*, 2003; Charman *et al.*, 2001; Hass, 1996; Lamb, 1995). This evidence is based on numerous palaeoclimatic records at annual- to centennial- scale resolution but there are very few that record sub-annual events such as storms (Page *et al.*, 2010). The climatic transition from a relatively warm and dry early and middle Holocene to a colder and wetter late Holocene has been demonstrated by many different proxy responses for example chironomids (Barber and Langdon, 2007), testate amoebae (Charman *et al.*, 2006) and particle size (De Jong *et al.*, 2007; Wilson *et al.*, 2001). However, there are only a few high-resolution palaeoclimatic datasets that represent large geographic areas for the Holocene (Jessen *et al.*, 2005), and no sites or sediments have been found suitable for production of any sort of palaeoclimate record from the Isles of Scilly. A long term proxy-based record of storminess that extends back into the Holocene is desirable, it could provide the basis for the evaluation of trends in past storminess (e.g. Clarke and Rendell, 2009) and it will be suitable for evaluating past societal response to changing conditions.

The Holocene is an era when societal development became dependent on climate to a far greater extent than it had previously, especially following the development of sedentary agriculture and complex civilisations with high population density (Charman, 2010). In marginal areas in particular (e.g. regions with a relatively high ground-water table, small islands with a limited area for crop cultivation) climate change might have had important effects for past societies (Van Geel *et al.*, 1996). However, marginality is often a social construction, particularly in more complex societies and this factor should be taken into consideration when correlating climate and society.

Terrestrial and marine records from around and within the North Atlantic basin have shown that the Holocene has been punctuated by a series of climatic deteriorations, with some evidence suggesting that this has occurred with regular frequency. There is still debate regarding the number, precise timing and magnitude of these Holocene climatic 'events' (Langdon and Barber, 2005). The storminess of the North Sea in historical times is known from the succession of storm flood disasters on its coasts. The partly known history goes back at least to the Cumbrian flood on the coasts of Germany around 120BC, which set off a migration of the Celtic tribes previously settled there. Both Aristotle and the Greek navigator Pytheas, who sailed around Britain *circa* 330 BC had already reported the acquaintance of the Celtic tribes with the storms (Lamb, 1991).

Peat bogs can be used as archives for past climatic fluctuations (De Jong *et al.*, 2009) and aeolian sand found in peat has been used to infer past storminess (De Jong *et al.*, 2007). The rationale behind the use of sand as an indicator of storms is that blown sand is one of the major effects of storms. Sand invasion is driven by an increase in frequency of severe storms, in the North Atlantic associated with cooler periods, and it is also affected by changing sea-levels (Clarke *et al.*, 2002; Szkornik *et al.*, 2008). The movement of sand and sand instability through the Holocene has been aided by fluctuations in climate (Sommerville *et al.*, 2003). Climate change in the Atlantic region has frequently been considered to be an important control of episodes of coastal dune-building because of the coincidence of timing that has been found to exist between dating evidence and periods of

cooling and/or increased storminess (Clemmensen *et al.*, 2001; Wilson *et al.*, 2004). The consequences of such land movement on local society can be profound and there are various examples of land and settlements lost to sand in the United Kingdom. For example: in Orkney there is evidence that the Neolithic village of Skara Brae was abandoned due to sand inundation (Sommerville *et al.*, 2003). In Cornwall, archaeological and historical evidence has been used to reconstruct periods of sand invasion, for example Lewis (1992), who describes historical evidence linking storms to loss of settlements and identified major sand incursions in the Middle Ages, the Norman and early Roman period, and the Bronze Age from Hayle to Gwithian. In the Isles of Scilly the Bronze Age settlement of Halangy Porth (St Mary's) was abandoned due to sand invasion (Ashbee, 1996).

Reconstructions of late Holocene climate variability of the North Atlantic region have been enhanced considerably as a result of Greenland ice-core research. In particular the knowledge of changes in North Atlantic storminess has been enriched as result of the published chronology of Na⁺ (sea salt) concentration changes for the GISP2 drill site (O'Brien *et al.*, 1995). Annual changes in sea salt concentration calculated for the last 1400 years have been interpreted as a regional signal of North Atlantic winter storminess (Dawson *et al.*, 2004). Changes in sea salt and storminess are also related to North Atlantic Oscillation (NAO). The increase of sea salt is associated with a positive NAO index. The NAO refers to a redistribution of atmospheric mass between the Arctic and the subtropical Atlantic and swings from one phase to another producing changes: in the mean wind speed and direction over the Atlantic, in the intensity and moisture transport between continents and in the intensity and number of storms, their paths and their weather (Hurrell *et al.*, 2003). When the NAO is in its positive phase, low-pressure anomalies across the subtropical Atlantic produce stronger than average westerlies across the mid-latitudes. During a positive NAO, conditions are colder and drier than average over the northwestern Atlantic and Mediterranean regions, whereas conditions are warmer and wetter than average in northern Europe (Visbeck *et al.*, 2001). A negative

NAO index corresponds to a winter that is not particularly stormy across the northern Atlantic but with a storminess increase across the areas of the Azores (Clemmensen *et al.*, 2009). Persistence in the spatial location of North Atlantic storm tracks, controlled by the NAO, may result in particular periods of sand mobilisation at a regional level (Clarke and Rendell, 2009).

2.6 SYNOPSIS

Resilience is a very important term used when referring to the responses of societies to environmental change. Resilience is the ability of the coastal systems to absorb incident forcing and return to a pre-forcing state (Betts *et al.*, 2004). Historical accounts from western Europe show that coastal communities have been particularly vulnerable to sand invasion and the burial of settlements and agricultural land due to strong storms (Lamb, 1991). Coastal sensitivity represents a balance between coastal susceptibility and coastal resilience. Susceptibility is a measure of the physical forcing that a coast undergoes as a function of sea-level change over the range of temporal scales. Resilience also involves the capacity for renewal, re-organization and development (Folke, 2006). In short, resilience highlights the ability of systems to withstand change (such as environmental hazards) through both flexibility (innovation and change) and resistance (maintaining essential structures and functions) (Nelson *et al.*, 2012).

The human/ environment relationship is complicated and varies spatially and temporally. The constantly changing dynamic of human-climate-environment relations needs to be understood in terms of flux rather than equilibrium. Therefore hazards (such as storminess and relative sea-level) can only be understood within their individual geographic, temporal and cultural contexts (Cooper, 2012a). Scientific perspectives on the relationship of human societies to the natural environment have ranged from doctrinaire environmental determinism (society heavily influenced by environmental changes) to the contention that the environment has a minimal impact on human societies (Dean, 2000). This thesis

considers that environmental changes in Scilly, mainly climate and relative sea-level rise, have been very important in shaping the culture and lives of the early Scillonians.

However, those environmental changes are only the background against which the societies developed and are not the determinants for cultural change. The cultural changes observed over time in Scilly are likely to also have depended on other factors, equally important as the environment, such as external influences, new technologies (e.g. introduction of metals) and political causes (e.g. civil war).

This chapter has provided a literature review with a brief introduction to the main topics and concepts that will be discussed in the next chapters. This material will provide the framework for the results and interpretation of the new data obtained within this project. In this thesis the climate deterioration (storminess) will be observed through the analysis of particle size that indicates periods of intense sand influx into the peat (Chapter 7). The periods of inferred storminess will then be compared to changes in the vegetation (Chapter 5), palaeogeography (Chapter 6) and the archaeological record of Scilly to discuss the human/environment relationship of the island communities (Chapter 8). The next chapter will describe the methodologies employed in this thesis.

3 METHODOLOGY

This chapter will show the methodologies used to achieve the aims and objectives of this study. The first section will explain the methods used to obtain a detailed bathymetry of the Isles of Scilly and the sea level model used to ultimately create palaeogeography maps of the Scilly through time. Section 3.2 will describe the field and laboratory methods employed to obtain palaeoecological and storminess records of Scilly.

3.1 DEVELOPMENT OF A GIS FOR THE ISLES OF SCILLY

An important part of this thesis is to determine the rise of relative sea-level in Scilly and the changes in extent of the islands over time. A new sea-level curve for Scilly was generated for this project based on a GIA modelling, by Dr. Sarah Bradley, using the Bradley *et al.* (2011) model. Models of the GIA process comprise three components: an Earth model to simulate the isostatic process, a Late Quaternary ice history model and a model to compute the distribution of ocean water associated with mass redistribution (Shennan *et al.*, 2006). The relative sea-level predictions are obtained by comparing estimated of crustal velocities within Great Britain based on continuous global positioning systems (CGPS) measurements. The main advantages of these measurements are that a direct measurement of present-day vertical and horizontal crustal motion is recorded at each site and spatial sampling is not limited to coastal areas (Bradley *et al.*, 2009).

The Scilly relative sea level predictions were created based on a revision of the sea level model developed by Shennan *et al.*, (2006). This study shows evidence that an ice sheet reached the Isles of Scilly during the last glaciation, but there are no empirical constraints of how thick this was or when this occurred. Working on the premise that the BIIS (British and Irish Ice sheet) extended onto/past the Isles of Scilly during or just prior to the LGM (~22-24 kyr) but as a thin and short lived event (duration of 1-2 kyr), rather than a long sustained ice advance, it was found that the inclusion or not of the ice lobe did not impact on the predictions at the nearby sea level sites (Bradley, pers. comm). The short duration

of the possible ice sheet in Scilly has been supported by Scourse *et al.* (2006) and ice sheet models developed by Hubbard *et al.* (2009). As the event has been assumed to be quite short lived, it was introduced as a simple extension of the margin of ice sheet which was previously located at the southern extent of the Irish Sea (as shown in Fig.6 at 21 kyr BP in Shennan *et al.*, 2006), assuming it followed a parabolic shape, meaning thicker at the more northern end of the ice lobe within the Irish sea, thinning towards the margin where it extended past the Isles of Scilly. The model has not been validated for the late-Glacial and early Holocene as there is no empirical data to compare it against (Bradley pers. comm.). The data points for the Isles of Scilly were extracted from Bradley's *et al.* (2011) GIA at 500 years intervals. These points describe difference between present day elevation at a given location, and the elevation of the earth's surface in relation to mean sea-level for the given time slice (Sturt *et al.*, 2013). The Earth model used in the GIA simulations was constrained by GPS data to determine optimum parameters for the Earth model, including a lithospheric thickness of 71km and upper and lower mantle viscosities of 0.5×10^{20} and 3×10^{22} Pas respectively (Bradley *et al.*, 2011). The GIA sea level model for the Isles of Scilly will be compared with known SLIPS from the South West of England to determine its accuracy and how it relates to published data.

Palaeogeography maps of the Isles of Scilly were produced by combining a new bathymetric model (see below), LIDAR data and the new sea level model predictions. A detailed description of the methodology followed to create these maps can be found in figure 3.1.

High resolution topographic datasets (LIDAR) were compiled from the Channel Coast Observatory for the whole of the Isles of Scilly. These LIDAR datasets were mosaicked into a single, seamless topographic model for the islands to provide base mapping for the archaeological distribution maps and provide data for the coastal change modelling. The LIDAR coverage of the Isles of Scilly does not extend below the low water mark and the pre-existing digital bathymetric data for Scilly (available through Marine Digimap) has poor spatial resolution (c. 150m). This project therefore produced a new bathymetric model

better suited to palaeogeographic mapping. Several maritime charts were obtained from the United Kingdom Hydrography Office (UKHO, Taunton) which included detailed sounding data from the Isles of Scilly (Table 3.1).

Table 3.1 Maritime charts used to develop a new bathymetry model for Scilly.

Chart	Location	Scale	Surveyor	Date
K4176	Folio 56, St Mary's Road, Scilly		L ^o N.L. Merrick, R.N. HMS 'Dingley'	April, 1643
K6035	Shelf KL, Isles of Scilly	1:12,500	HMS 'Hecate'	March, 1971
K7408	Shelf Is, Menawethan to Tresco	1:12,500	HMS 'Hecla'	July -Sept., 1975
Chart 34	Isles of Scilly	1:2500	British Admiralty	2001

These charts were scanned, projected in ArcGIS, and all the depth soundings digitised (c. 28,000 points). The soundings were recorded on the charts in metres with the exception of K4176, where they were recorded in imperial units. These were converted into metres to ensure comparability for all the soundings, in below Chart Datum. The depth soundings were interpolated using ordinary Kriging (Burrough and McDonnell, 1998) to produce a continuous bathymetry model (at 5m. resolution) between and around the islands. At the same time, the LIDAR data was also modified and all the tiles were mosaicked into a single tile, producing a 5m LIDAR pseudo-bare earth model.

For the purposes of this thesis it has been assumed that the tidal range in Scilly has been constant over time. The main sea level and tidal range is based in the Admiralty tide tables, volume 1 (2013). Uehara *et al.* (2006) have demonstrated that tides and tidal currents on the western part of Europe were significantly larger than present prior to 10,000 BP while tidal changes have been generally small during the last 8,000 years. The model here presented does not account for sedimentation or erosion of land related to relative sea level rise.

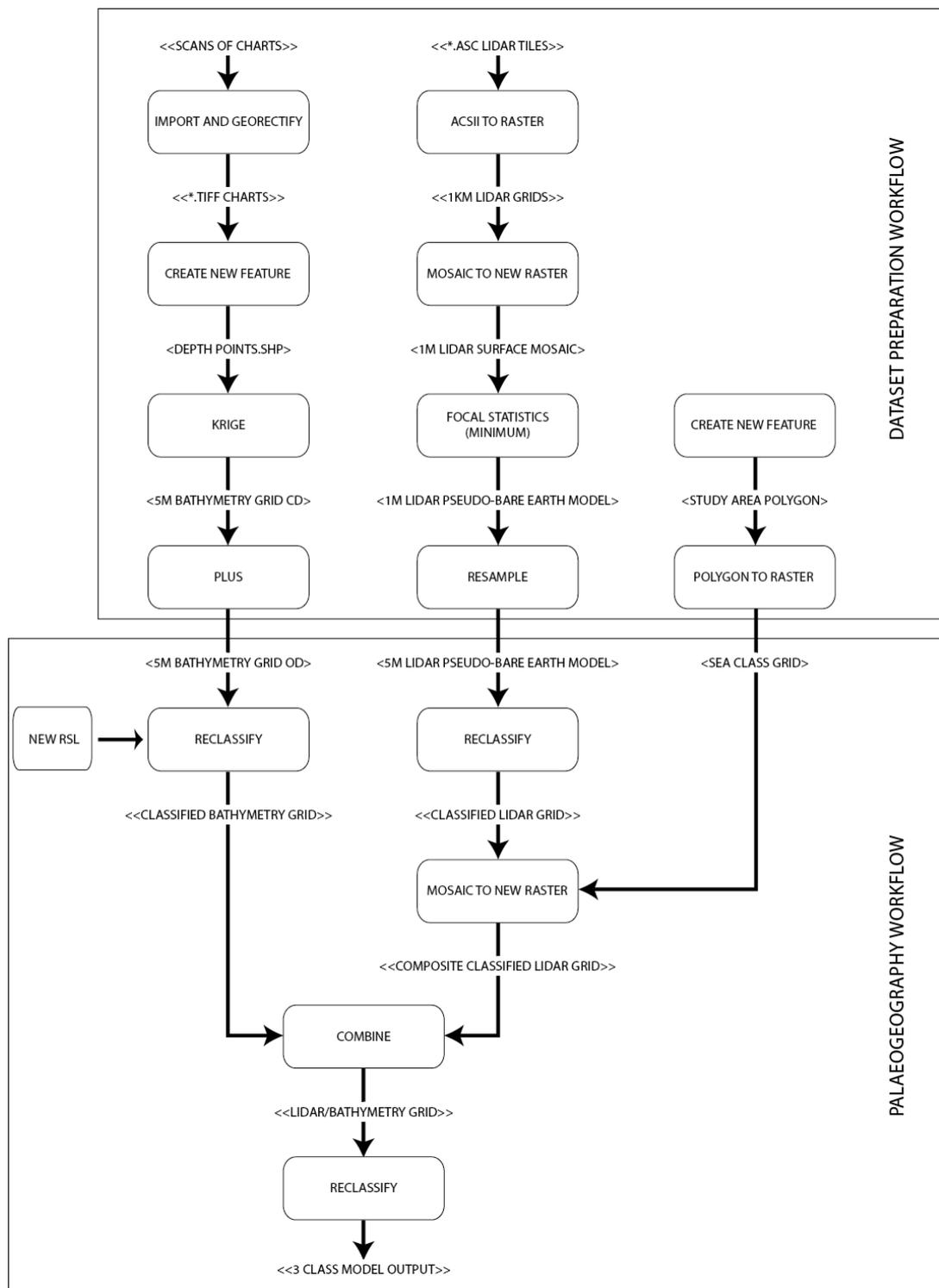


Figure 3.1 Description of methodology. The boxes describe processes/tools in ArcGIS, the text in <brackets> describes the datasets which are used/produced within the model. Where there are <<double brackets>>, it indicates that at this stage the model produced multiple versions of the output, depending on the parameters used.

A collection of published archaeological record from the Isles of Scilly was compiled from the Sites, Monuments and Buildings database housed at Cornwall HER (Historic and

Environmental Record) (English Heritage, 2010) to complete these maps. The archaeological and historical sites were identified, grouped by periods and plotted into GIS. The intention behind the creation of these maps with the relative sea level and archaeology over time was to observe the impact of coastal changes in societies (e.g. changes in settlement location or changes in economic subsistence). For this reason the plotted sites were restricted to: settlements, monuments, field systems, huts, buildings and middens, whilst ignoring other sites such as shipwrecks and war buildings.

3.2 PALAEOECOLOGICAL ANALYSIS

The response of communities to marine inundations was addressed by compiling palaeoecological proxies for past land management and the development of a proxy for storminess from the same cores. Surveys focussed on the known, existing, sites at Higher and Lower Moors (Scaife, 1980; 1981; 1984). These sites were chosen for their potential to deliver long, continuous and datable records.

3.2.1 *Field survey*

Field survey took place in June 2010. The stratigraphy of each site was investigated through coring using a gouge corer. Cores were arranged in transects to allow a detailed understanding of the stratigraphic development of each site. The sediment stratigraphy was described in the field using the Troels-Smith (1955) system. Sample cores were recovered from what were considered to be the most complete and deepest organic deposits. The selected cores were sampled using a Russian-type corer and taking a series of overlapping cores. The cores were placed on plastic guttering, wrapped in cling film and stored in a cold store (constant temperature 3°C) prior to laboratory analysis.

3.2.2 Dating methods

Chronological control for the palaeoecological sequences was established through radiocarbon dating. Initially a sample from each core (from the basal peat) was submitted to BETA Analytic (Florida, USA) to provide a broad chronological framework for the stratigraphic sequences. Further radiocarbon dates were obtained from the NERC Radiocarbon Laboratory. Radiocarbon dating was undertaken at the NERC facility at East Kilbride. All the samples of wet peat weighing a minimum of 2g were carefully extracted from the cores and all obvious rootlet material picked out with tweezers, before analysis. Plant macrofossils were not sufficiently well preserved with the cores. As a consequence the humic peat fraction was dated.

An age-depth model was necessary to establish relevant times-scales for the palaeoecological changes inferred from the sedimentary sequences. CLAM (version 1.0) was used to create an age-depth modelling (Blaauw, 2010). Within this programme cores containing several radiocarbon dates can be processed semi-automatically. The C¹⁴ dates are calibrated and then age-depth curves (based on linear interpolation, linear/polynomial regression, or cubic, smooth or locally weighted splining) are repeatedly drawn through point age estimates sampled from the dates. After this, uncertainty ranges as well as a 'best' age-model are obtained through finding the highest posterior density range of the array of age-depth curves. Modern dates were calibrated using the method CALIBomb, a concatenation of the Levin's Vermunt and Schauisland data set, representative of the European atmosphere (except for highly industrial areas) published by Vermunt and Kromer (2003) (CALIBomb, 2012).

Sand layers that offered potential for OSL dating were observed between the organic layers of one of the sampled core (LM28). Thus, in addition to conventional carbon dating, optical dating was used for sandy sediments, and the results compared with carbon dating analysis. Optical dating can determine the time which has elapsed since minerals in the sediment were last exposed to daylight. This is achieved by measuring the optically

stimulated luminescence (OSL) signal. The OSL signal is light given out by crystals on the exposure to a standard light source, due to the release of stored energy resulting from prior exposure to ionizing radiation. The OSL signal must be measured at a different wavelength from that of the stimulation source and is proportional to the radiation dose received since the signal was last zeroed by exposure to light, thus enabling it to be used for dating sedimentary deposits ranging from a few hundred years to several thousand years old (Clemmensen *et al.*, 2001; De Jong *et al.*, 2006; Szkornik *et al.*, 2008).

Dating Holocene aeolian sand units can provide a record of past aeolian sand movement and windiness. Largely unaltered aeolian sediments interleaved with peaty palaeosols have provided Luminescence-based dating of sand movement in Thy, Denmark (Murray and Clemmensen, 2001) and in Aberffraw, Anglesey, North Wales (Bailey *et al.*, 2001). Optically stimulated luminescence was also used by Sommerville *et al.* (2003) to date large storm events in Northern Scotland. The results presented demonstrate that OSL dating can assist in the identification stormy periods, thereby helping to understand past climate change and its impact on local communities. Three samples were collected from one of the sample cores (LM28) for OSL dating close to the depth of equivalent radiocarbon samples. The samples were taken in a dark room at University of Exeter and dated in Aberystwyth University.

The size or intensity of the OSL signal observed in the laboratory is related to the time elapsed since the mineral grains were last exposed to sunlight. In this study, the D_e (how much radiation the sample was exposed to during burial) was obtained using the Single Aliquot Regenerative dose (SAR) measurement protocol (Murray and Wintle 2000), applied to coarse-grained quartz (i.e. grains $>63\mu\text{m}$ diameter). Working with quartz offers the advantage that it is not subject to anomalous fading, unlike some feldspars (e.g. Spooner 1994; Huntley and Lamothe 2001). The SAR protocol uses the response to a fixed test dose to correct for any change in luminescence sensitivity occurring in the sample during laboratory measurements (eg as a result of thermal pre-treatments), with all of the measurements necessary for the determination of D_e being made on a single

aliquot. By measuring several aliquots, many independent determinations of D_e can therefore be obtained. Following measurement of the natural luminescence intensity the response (L_x) to a series of artificial radiation doses is measured, and normalised to the response (T_x) to a fixed test dose. A normalised dose-response or 'growth' curve can then be constructed by plotting the ratio L_x/T_x as a function of radiation dose. This enables the natural luminescence intensity to be calibrated to these responses to a given laboratory radiation dose, thereby determining the laboratory equivalent dose, D_e (Charman *et al*, 2012)

3.2.3 Particle size and Loss-on-ignition

The presence of interleaved organic and higher energy, sandy deposits, coupled with the exposed natures of the sites, would suggest that deposition was controlled by sudden inputs of energy from an external source such as the passage of storms (Delaney and Devoy, 1995). There is growing evidence that periods of sand drift provide proxy records of the impacts of storms in coastal areas (e.g. Clemmensen *et al.*, 2001; Clarke *et al.*, 2002; Szornik *et al*, 2008). The methods followed to establish a storminess record in the Isles of Scilly are a modification of De Jong *et al.* (2006) and De Jong *et al.* (2009). These methods are based on contiguous measurements of the physical properties of each core, established through particle size analysis and loss-on-ignition. Prior to any assumption it is necessary to test whether the sand found within the peat has an aeolian origin. This was undertaken through statistical analysis of the particle size data.

The measurement of particle size is one of the most important and useful techniques of sediment analysis. It helps in the understanding of processes of transport and deposition of sediments, both at present and in the past, and it is therefore important in studies of contemporary processes and of palaeo-environments (Briggs, 1981). Around 3ml of sediment was taken at 1cm or 2cm intervals from each core, with sampling intervals determined by availability of sediment. Five replicas of each subsample were taken. The

sediment was passed through a 1mm sieve and all quartz particles >1mm were counted. A solution of 3% peroxide was added to the sieved sediment and left overnight to remove Carbon and Nitrogen. In the morning the sediment was left for two hours in a water bath at 95° -100° C. When it was cooled a solution of 6% peroxide was added and left overnight. The next day, the samples were put in a water bath for two hours at 95° - 100°C. When cooled a solution of 30% peroxide was added and the whole process repeated. This method assures the destruction of any organic content that could affect the particle size readings.

Particle size analysis was carried out by sieving and by laser analysis using a Mastersizer 2000 (version 5.6) laser particle-size analyser over a range from 0.1-2000µm. Samples were dispersed in fresh water with the aid of 20g of sodium carbonate/ 132g of sodium hexametaphosphate per 2litres of water, in accordance with standard laboratory practice. Graphic measure of sediment distribution characterisation was calculated using the computer programme Gradistat, commonly used for the analysis of grain size statistics. Mean, mode, sorting, skewness and size are calculated arithmetically and geometrically (in metric units) and logarithmically (in phi units) using moment and Folk and Ward graphical methods (Blott and Pye, 2001), and the data was plotted in graphs using C2 and Illustrator. It has been demonstrated that the laser diffraction granulometry method underestimates the proportion of the clay fraction in a sample. It has been suggested that a solution to this problem is to change the upper limit of clay to 8 µm, applying a transfer function to calibrate this data. However, experiments carried out by Scott-Jackson and Walkington (2005) have proved that the standard cut off point for the sand-silt boundary does not give and underestimation of the sand fraction only of the clay fraction. This study was particularly interested in the coarse fraction of the sediments; therefore the clay percentages were not especially relevant.

Sequential loss on ignition (LOI) is a common and widely used method to estimate the organic and carbonate content of sediments. Organic matter oxidises at 500-550°C to carbon dioxide and ash. The weight loss during the reaction is easily measured by

weighing the samples before and after heating and is closely correlated to the organic matter content of the sediment (Heiri *et al.*, 2001). Subsamples from the cores were taken at 1 cm intervals and then dried overnight at 105° and weighed to determine water loss. The dried sample was then ignited in a muffle furnace for four hours at 550°, then reweighed to provide the percentage of non-organic matter and the ash weight. Loss on ignition was calculated as the percentage difference between those two weights.

3.2.4 Pollen analysis

The analysis of fossil pollen assemblages from appropriate sedimentary environments provides data about the vegetational history, climatic change, changing hydrological relationships, the influence of man on the vegetation and even the development of farming types (Tooley, 1981). Pollen is the most ubiquitous proxy available for reconstructing past changes in land cover and has the ability to display vegetation changes at a variety of temporal and spatial scales (Fyfe *et al.*, 2010). Although there are some exceptions, it seems to be generally true that once incorporated within the deposit the pollen moves neither upwards nor downwards so serial samples in the pollen spectra through a deposit would show changes that should represent a chronosequence (Dimbleby, 1985).

Pollen grains are carried to the sampling point via a range of transport mechanisms. Tauber (1965, 1967) first proposed a conceptual classification of the different routes of this transfer, later modified by Jacobson and Bradshaw (1981). These considered that only airborne and water-borne pollen would make a significant contribution to the assemblage, since the accidental shedding of insect-borne pollen was a relatively rare event. When dealing with palaeoecological data processes such as reworking and occasional exposure to bacterial and animal activity can also affect the assemblage (Bunting, 2008).

The studied sites are very close to the coast and in consequence their sediment and pollen supply would have certain characteristics different to other sites. There are many

factors influencing the dispersal and deposition of pollen in near-shore marine environments. These factors include: the vicinity of the plant to the sedimentation site; the size, specific gravity and strength of the pollen grain; air and water transport pathways; and the preservation potential of the final depositional environment (Long *et al.*, 1999).

Cores were subsampled for pollen analysis in the laboratory and intensively treated to extract microfossils by physical and chemical treatments using KOH, HCL, acetolysis and HF techniques (Faegri *et al.*, 1989; Moore *et al.*, 1991). Known numbers of *Lycopodium* spores were added to subsamples at the earliest stage to assess pollen concentrations. The prepared samples were mounted in silicone oil and counted; both conventional pollen counts and pollen preservation analyses were completed. A minimum of 500 total land pollen (TLP) grains were counted and this was used as the basis of the pollen sum for calculation of pollen percentages. The aquatic taxa were included in the pollen diagrams but these percentages were not used to determine the total land pollen.

The pollen, spore and microscopic charcoal (10-50µm and >50µm long axis) content of each subsample was recorded using an Olympus binocular microscope at x400 and x1000 magnification. Pollen and spore types were identified using the key in Moore *et al.* (1991), Bennet (1994) nomenclature and the reference collection at the University of Plymouth. Microscopic charcoal was counted to identify the presence of fire and the possible subsequent changes in vegetation. High frequencies of micro-charcoal have been interpreted as being indicative of repeated burning, and lower frequencies of the absence of charcoal as periods of reduced or ceased burning (Blackford *et al.*, 2006). Microscopic charcoal is an essential tool in palaeoenvironmental reconstructions, informing on fire histories and cycles, vegetative response to fire, climate change and human manipulation of the environment through the use of fire (Moore, 2000).

Further identification of large grasses for classification into the *Hordeum*-group, *Avena-Triticum*-group or *Secale cereale* involved consideration of pollen size, annulus diameter and surface sculpturing (Andersen, 1979). The grains of *Secale cereale* are usually

characterised by their prolate shape and are the only cereal pollen that can be identified by shape alone (Dickson, 1988). In this research, only those grains greater than 37 μ m with an annulus diameter greater than 8 μ m were classified as cereal type. Grains of *Secale cereale* were identified as a separate category because of their overall diagnostic morphology.

In terms of pollen diagram format, two types of diagram have been constructed. The full pollen diagrams from each site with the total percentage of land pollen plus the aquatic taxa. These diagrams are presented with the radiocarbon dates, followed by the stratigraphic depth, and pollen frequency curves. For the diagrams that feature in the interpretation section, the relevant species have been categorise into ecological groups, according to Rodwell *et al* (2003) and Gaillard (2007) and, to obtain a human impact pollen diagrams, in order to facilitate interpretation of human impact and land use change.

3.2.5 Numerical zonation of data

Sequences of stratigraphical data are difficult to describe and interpret without some reduction of the data set to manageable units. This reduction is normally termed 'zonation'. In the case of pollen data, the aims of zonation are to ease description and to identify zones of uniform pollen content (local pollen assemblage zones: lpaz) which can then be compared with other such zones from other sites by means of a time-scale (Bennett, 1996). In the case of the particle size date, the zonations are described as local sedimentary assemblage zones (lsaz). Zonation of the biostratigraphic sequences was undertaken using the PSIMPOLL programme (Bennett, 2008) with the statistical method CONISS. CONISS is a model developed by Grimm (1987) and based on cluster analysis, with the constraint that clusters are formed by hierarchical agglomeration of stratigraphically-adjacent samples.

4 RESULTS

4.1 PALAEOGEOGRAPHIC MAPPING OF THE ISLES OF SCILLY

The first section of this chapter shows the new palaeogeography of Scilly obtained when combining the new bathymetry, LIDAR data and the new GIA-based relative sea-level predictions. The second subsection shows the new relative sea-level curve with the inferred loss of land over time for Scilly. It also offers a visual representation of the extent of land and intertidal area during period of important changes due to increase relative sea-level.

4.1.1 *New Bathymetry model of the Isles of Scilly*

Figure 4.1 shows more than 28,000 sounding points obtained from different maritime charts (table 3.1) and the LIDAR data for the Isles of Scilly. Chart K7408 (light green) covered the area between eastern St Mary's, the Eastern Islands, St Martin's and part of Tresco, 11,182 sounding points were obtained from this maritime chart. Chart K4176 (light purple) also covers part of the Eastern side of St Mary's but the main study area is the Western side of St Mary's and the sea between this island and Tresco, Bryher and Samson. This chart produced 3,101 sounding points. Chart K6035 (light green) provided 14,283 sounding points and covered the area to the west of Scilly, from Samson to St Agnes and to the South of St Agnes. There were important areas that were not covered by these maritime charts so to fill the gaps 2,337 points were obtained from Chart 34 (dark blue). This last chart covered the area between the islands of St Martin's, Tresco and Samson, the area between St Mary's and St Agnes, and the area outside Scilly. There are fewer points between Gugh and St Mary's, so there is likely to be more uncertainty in any model here that where sounding points are more dense.

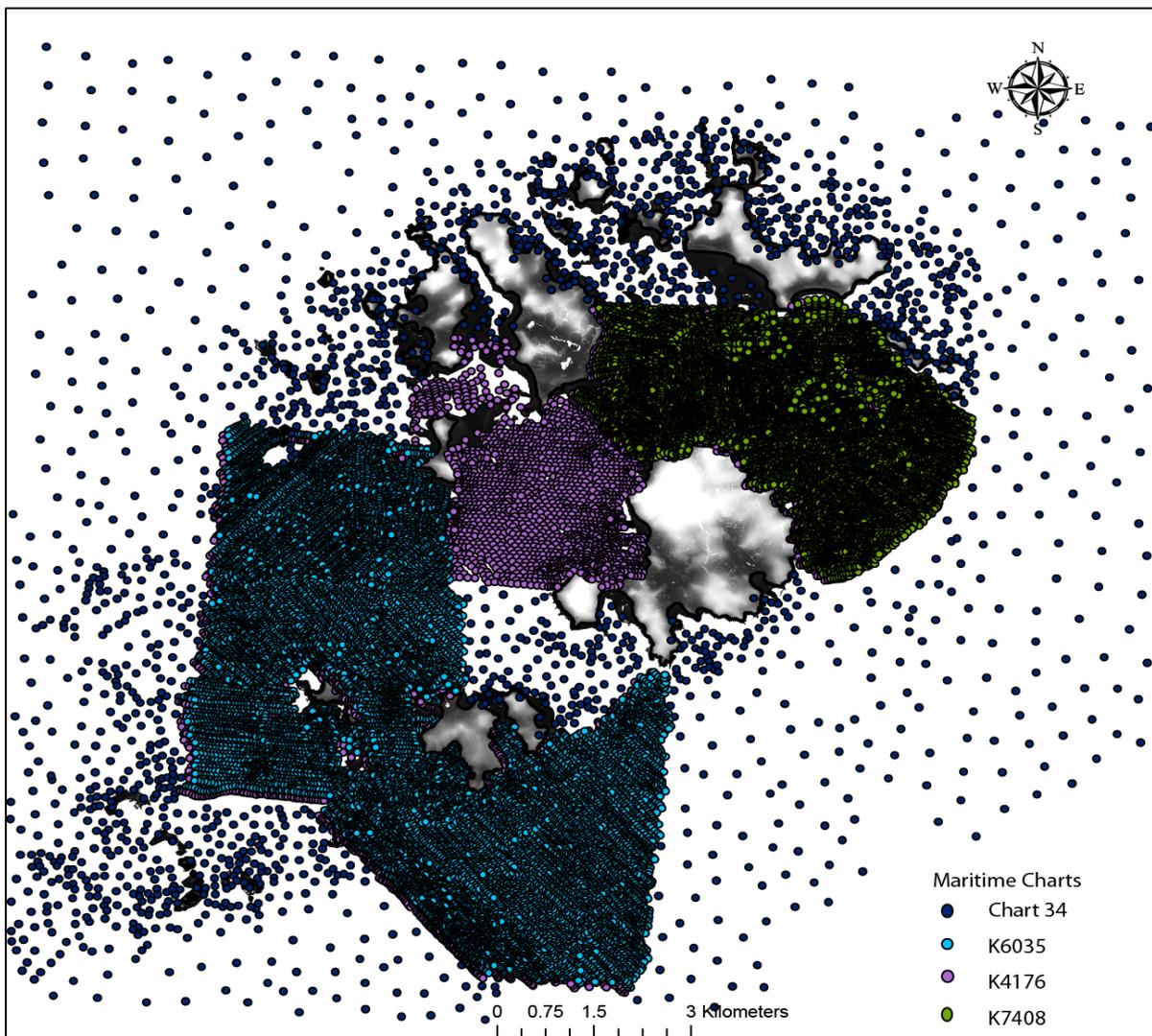


Figure 4.1 Digitised sounding points and LIDAR data from Scilly

4.1.2 Palaeogeographic maps with new sea-level curves and rates of island area change

The new sea-level predictions for the Isles of Scilly are based on the improved Glacial Isostatic Adjustment (GIA) model for the British Isles developed by Bradley *et al* (updated). This model closely mirrors for match known SLIPS from the mainland South West and the Isles of Scilly (Fig. 4.2). To date there are no data from Scilly and Cornwall to constrain the older part of the curve. Although, early Holocene SLIPS are found in Devon; the differences within Bradley's model for the Isles of Scilly and these SLIPS could

be due to different effects of the glaciation and relative sea-level changes between these locations. The early Holocene Devon SLIPS are from basal peats and their lack of relationship with RSL is likely to be due to peat initiation occurring above RSL (a common problem in sea-level research). The Isles of Scilly published SLIPS (Waller and Long, 2003; Massey *et al*, 2008; Ratcliffe and Straker, 1996) are in accordance with the new GIA model here presented and more importantly this model is within the error bars of the new SLIPS obtained for Scilly (Charman *et al*, forthcoming). This model is also within the error bars of the SLIPS for Cornwall and Devon (Waller and Long, 2003, Massey *et al*, 2008, Gehrels *et al*, 2011). These points validate the use of the model here.

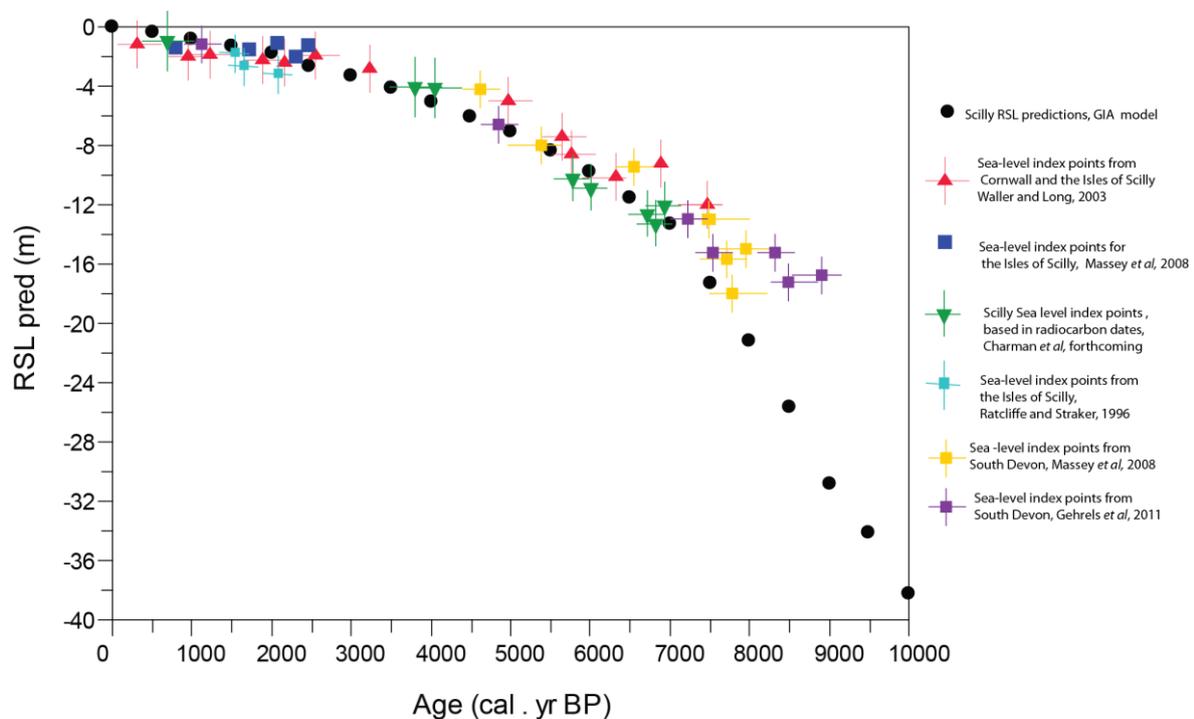


Figure 4.2 Graph showing GIA-based sea-level curve for the Isles of Scilly constrained by known SLIPS from the Isles of Scilly, Cornwall and Devon

Table 4.1 and Fig. 4.4 show the relative sea-level predictions for the last 10,000 years. This table contains the predictions of the Mean High and Mean Low Water level based on those predictions and the land surface of the Isles of Scilly (above Mean High water level) in km² with the land loss (also in km²). Relative sea-level, land cover and loss of land

through time are illustrated in Fig 4.4. By assuming that modern tidal ranges are similar to those in the past, it has been possible to map on the baseline topography three distinct zones from each of the selected time frames: (1) dry land, catchment above Mean High Water, (2) intertidal, catchment between Mean High Water and Mean Low Water and (3) marine.

Table 4.1 Relative sea-level predictions for the Holocene in Scilly, according to Bradley *et al*, (updated), with the calculated Mean High Water and Mean Low Water level, land cover, intertidal area and percentages of land lost over time.

Isles of Scilly		Datum M.S.L : 3.19m MHWS: 2.79m above MSL; MLWS: 0.7m					
yr BP	cal BC/AD	RSL_preds	MHWS	MLWS	Land area km ²	Intertidal km ²	% land lost
10000	-8050	-38.26	-35.75	-40.75	111.66	6.91	
9500	-7550	-34.1	-31.6	-36.6	105.69	7.14	5.35
9000	-7050	-30.88	-27.47	-32.48	99.17	7.86	6.17
8500	-6550	-25.59	-23.07	-28.07	89.88	10.29	9.37
8000	-6050	-21.22	-18.71	-23.71	78.02	13.53	13.20
7500	-5550	-17.34	-14.83	-19.83	67.75	13.70	13.16
7000	-5050	-13.31	-10.8	-15.8	57.02	13.44	15.84
6500	-4550	-11.52	-9.01	-14.01	51.62	14.05	9.46
6000	-4050	-9.74	-7.23	-12.23	46.71	14.38	9.52
5500	-3550	-8.36	-5.86	-10.86	42.77	14.44	8.44
5000	-3050	-7.01	-4.5	-9.5	38.36	14.61	10.30
4500	-2550	-6.47	-3.48	-8.5	34.40	15.84	10.33
4000	-2050	-5.01	-2.5	-7.5	29.37	18.11	14.63
3500	-1550	-4.11	-1.6	-6.6	24.58	20.33	16.29
3000	-1050	-3.24	-0.74	-5.73	20.37	22.00	17.14
2500	-550	-2.5	0.001	-5	19.19	20.79	5.78
2000	-50	-1.81	0.7	-4.3	18.21	19.45	5.13
1500	450	-1.29	1.22	-3.79	17.52	18.26	3.80
1000	950	-0.79	1.72	-3.28	16.89	16.45	3.60
5000	1450	-0.37	2.13	-2.86	16.33	14.74	3.29
0	1950	MSL	2.51	-2.49	15.94	13.39	2.41

Fig 4.3 shows the new sea-level curves for Scilly based in the points from Fig. 4.1 and the sea-level predictions from Table 4.1. Only maps from the key periods of significant change are shown. Map 4.2A shows the land extension of Scilly by 10000BP. At this time the main islands (St Mary's, St Martin's, Tresco and Bryher) were a single land mass. The Eastern Isles, St Agnes, a large land track to the north west of St Agnes and the Western

Rocks were also part of this one island. The intertidal zone was very minor at this time. At 8000BP (Map 4.2B) the main islands, including St Agnes were still joined but there has been a considerable loss of land. The large main island was separated from the western rocks, although they were joined at low tide. The great loss of land was due to the inundation of the land north west of St Agnes and the territory west and east of St Mary's. The intertidal zone was increasing at this time. Map 4.2C (6500BP) shows an important reduction in dry land cover from the previous map, the main loss of land was to the west and north east of St Mary's. The western islands had lost most of their area and St Agnes is only joined to the main island by a thin track of intertidal land. The intertidal zone was increasing around the zones of land loss, especially the area known as St Mary's Road (Fig. 2.10). The greatest loss of land at this time occurred between 8000 and 7000 BP (Table 4.1). At 4500 BP St Mary's was separated from the other islands but still joined to them at low tide. There was also inundation of land to the north of St Martin's and to the west of Bryher and Samson and the Norrad Rocks became a separated entity from the main island. St Agnes was totally separated from the main islands. The intertidal zone was quite substantial at this time. By 3000 BP (Map 4.3D) Scilly has separated totally and the archipelago obtained its present configuration. The loss of land was more evident between Trecco and St Martin's, Samson and Bryher. Most of this area was inundated between 4000 and 3000 BP (Table 4.1). All the previous dry land between these islands became intertidal by 3000BP. The palaeogeography at 2000 BP (Map 4.3F) and 1000 BP (Map 4.3G), with the exception of the gradual reduction in intertidal area over time, is very similar to the modern geography of Scilly (Map 4.3H).

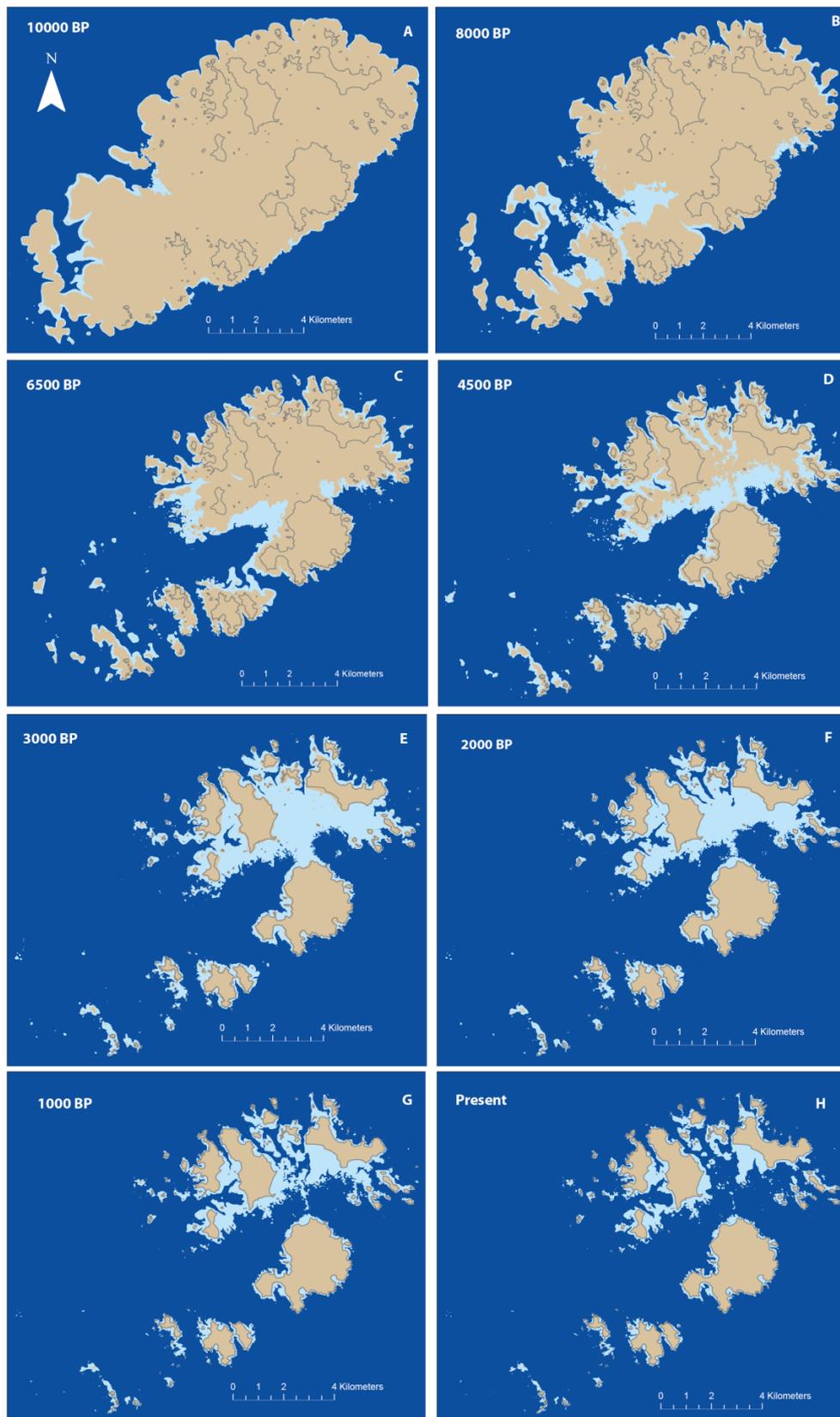


Figure 4.3 Palaeogeography of Scilly based on the new bathymetric model and Bradley et al (2011) GIA-based relative e sea-level predictions. Dates are cal BP, dry land is coloured light brown and intertidal area is light blue.

Table 4.1 and Figure 4.4 show that the sea-level has been rising for the last 10,000 years, increasing between 4 and 5m every 500 years until 7000 BP (5050 cal BC), and slowing down thereafter between 1 and 3m every 500 years. During the last thousand years relative sea-level has risen less than a metre. Figure 4.4 also shows that the loss of land has not been parallel to the degree of increase relative sea-level. Until 8000 BP (6050 cal BC) the loss of land is very similar (between 6 and 9 km²), between 8000 and 7000BP (6050-5050 cal BC) the amount of land inundated by the sea increased substantially (between 13 and 15% of the total land, every 500 years). Between 7000 and 4500 BP (5050 - 2550 cal BC) the total of loss of land is decreasing steadily (average of 9%, every 500 years). The largest percentage of land lost occurred between 4000 and 3000 BP (2050 – 1050 cal BC) with an average of 15% of land covered lost every 500 years. After 3000 BP (1050 cal BC) both the rise in relative sea level and the percentage of land loss have been gradual, slow and low. The intertidal area has been expanding steadily until 3000 BP (1050 cal BC), when it reached its maximum extent. And it has been decreasing constantly from that period until present.

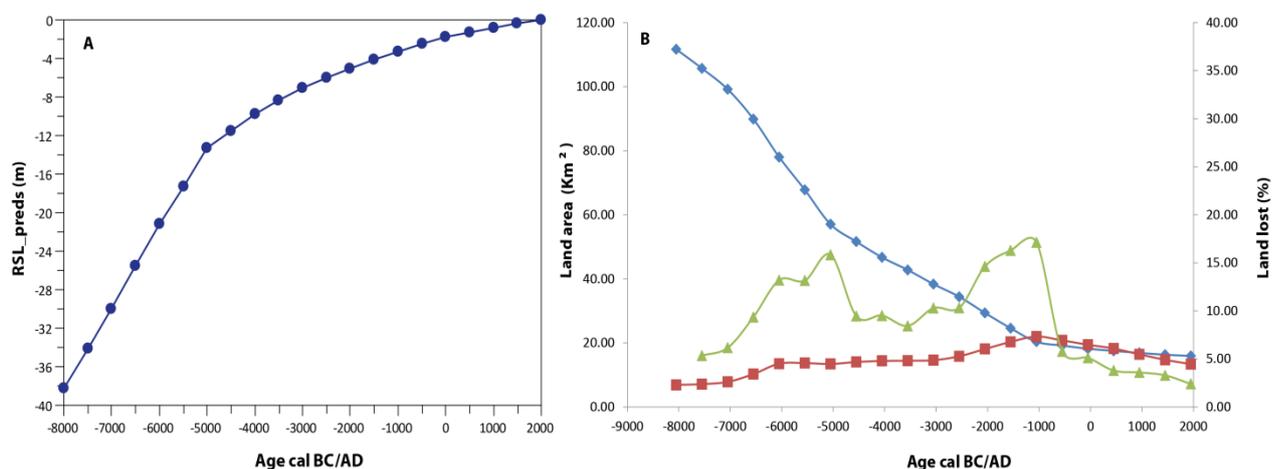


Figure 4.4 Graph A shows GIA-based sea-level curve for the Isles of Scilly taken Bradley *et al*, updated. Graph B shows land area (blue), intertidal area (red) and percentage of land loss (green) as a consequence of RSL changes through the Holocene.

4.2 PALAEOECOLOGICAL ANALYSIS

This section describes the stratigraphy of each of the studied sites obtained during the fieldwork season, followed by the results from the laboratory analysis of each core (age, pollen and particle size analysis).

4.2.1 Higher Moors

Higher Moors is a SSSI (Site of Special Scientific interest) which lies within the Isles of Scilly Area of Outstanding Natural Beauty (AONB) and Heritage Coast (Fig. 4.5). This peat mire contains the largest area of open water on St Mary's. It extends from Porth Hellick Bay (SV925107) to the centre of the island at Holy Vale (SV921115). It is separated from the sea by a vegetated sand dune and a shingle bar. Higher Moors is fed by a stream from Holy Vale and flows along the Holy Vale nature trail.

The shingle and sand bar at the back of Porth Hellick are dominated by Sea sandwort (*Honkenya peploides*) and sea kale (*Crambe maritima*). The narrow band of maritime grassland behind the bar has abundant red fescue (*Festuca rubra*) and thrift (*Armeria maritima*). The pool is freshwater but occasional salt intrusion occurs which allows some salt-enduring species to survive at the seaward end, including sea club-rush (*Scirpus maritimus*), saltmarsh rush (*Juncus gerardii*), water-crowfoot (*Ranunculus baudotii*) and sea-milkwort (*Glaux maritima*). The pool is surrounded by common reed (*Phragmites australis*), grey willow (*Salix cinerea*) and bulrush (*Typha latifolia*). The wetland habitats include reedbeds and marsh areas, soft rush (*Juncus effuses*), yellow iris (*Iris pseudacorus*), lesser spearwort (*Ranunculus flamula*), gypsywort (*Lycopus europaeus*), water mint (*Mentha aquatic*), hemlock water-dropwort (*Oenanthe crocata*) and ragged robin (*Lychnis flos-cuculi*) with populations of royal fern (*Osmunda regalis*), greater tussock-sedge (*Carex paniculata*) and southern marsh orchid (*Dactylorhiza praetermissa*).

More acidic bog conditions are indicated by small populations of bog pimpernel (*Anagallis tenella*), star sedge (*Carex echinata*), marsh St John's-wort (*Hypericum elodes*), marsh willowherb (*Epilobium palustre*), bog stitchwort (*Stellaria alsine*) and bog pondweed (*Potamogeton polygonifolius*). The stream flowing from Holy Vale into the pool is the only running water habitat of any size on Scilly. There is a dense growth of hemlock water-dropwort in the lower reaches whilst further upstream there is a narrow band of fringing woodland with English elm (*Ulmus procera*) and grey willow (Isles of Scilly Wildlife trust, 2012).

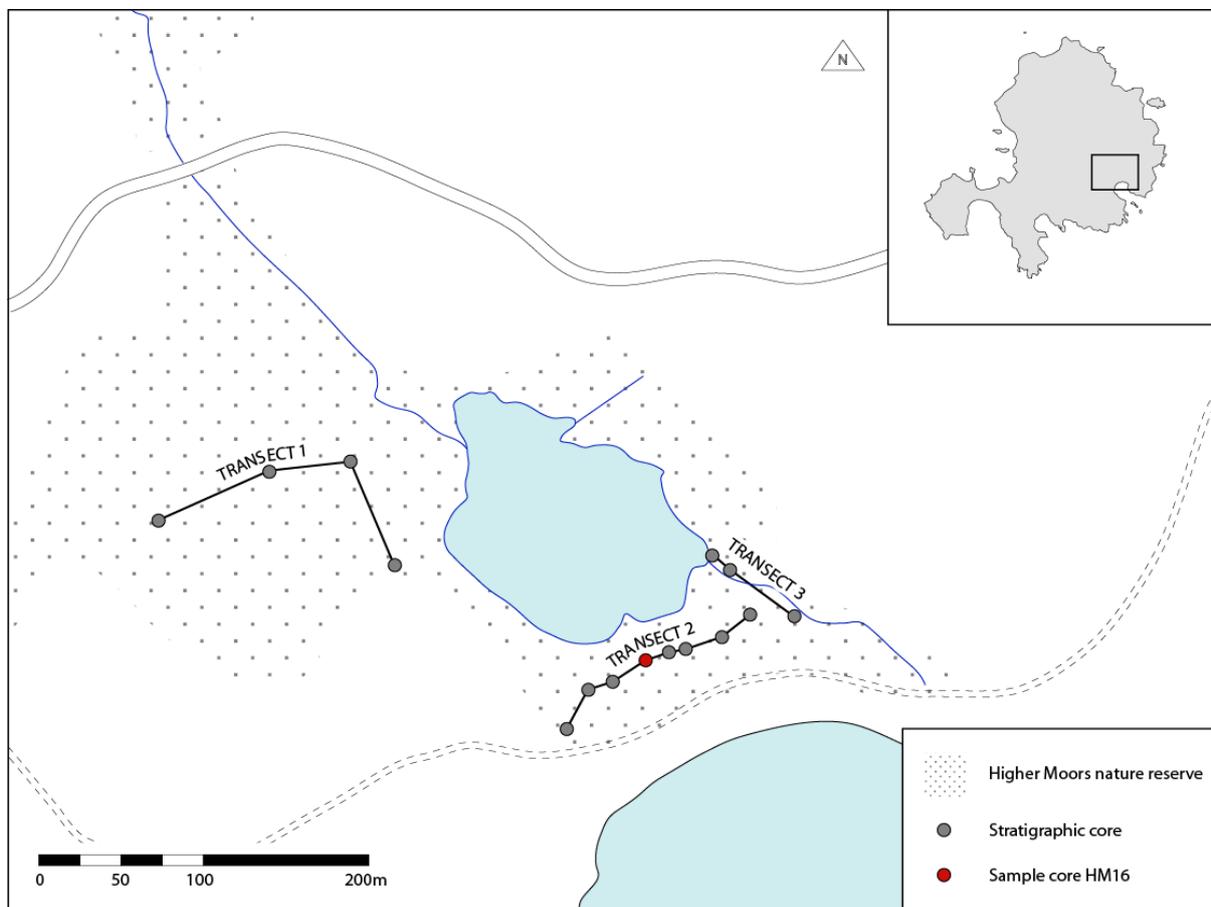


Figure 4.5 Map showing St Mary's and a detailed map of Higher Moors (dotted area) where transect were taken. The location of sampled core HM16 is shown by a red dot.

4.2.1.1 Stratigraphy and sample core.

Transect 1 (Fig. 4.5 and Fig. 4.6) crossed the north area of Higher Moors. Few cores could be taken due to restricted access. All cores produced very degraded humified material and with abundant sand. Two distinctive sedimentary divisions can be distinguished. The lower stratigraphic unit is stiff grey clay silt with occasional pebbles, with thickness varying between 15 and 20cm. The top layer is a dark brown well humified peat with some traces of fine sand and silt.

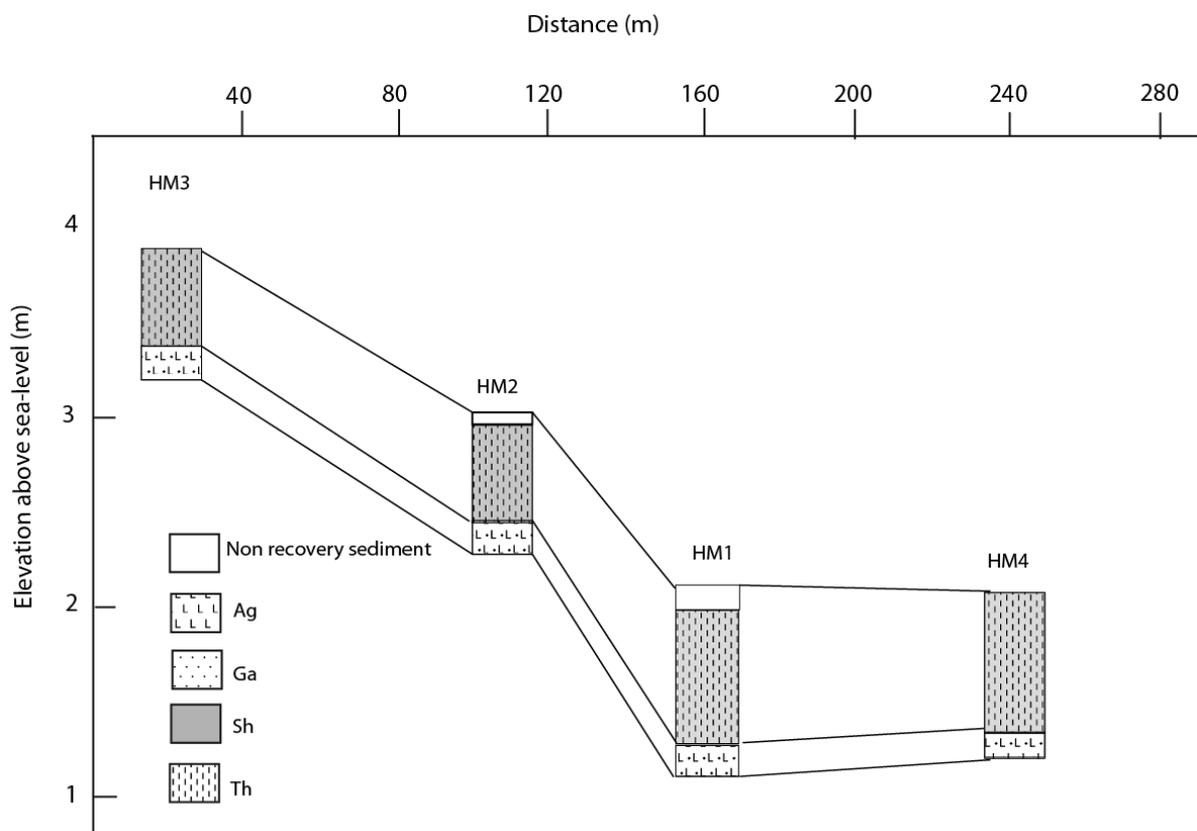


Figure 4.6 Stratigraphy of Transect 1, Higher Moors.

Two more transects (T2 and T3 in Fig. 4.6) were taken across the south end of Higher Moors (Fig. 4.5), behind the sand dunes. Transect 2 was taken parallel to the coast and Transect 3 was taken from the sand dune to the edge of the shallow lake. In this area of Higher Moors five sedimentary units are observed. The first sedimentary unit is a very stiff

grey silt. Unit 2 is a layer of organic silt with some sand contents and occasional organic bands. This deposit is found in the majority of the cores and it ranges in thickness from 10 to 60cm. Unit 3 is a well humified peat varying in thickness (between 20 and 100cm). This unit is wetter and darker towards the bottom. Unit 4 also varies between cores. It is a grey sand with some organic inclusions and sand layers, occasionally with thin layers of yellow very fine sand. It ranges in depth from 10 to 20cm and it is absent in some cores. The top unit is top soil, formed by brown ell humified peat with sand and roots.

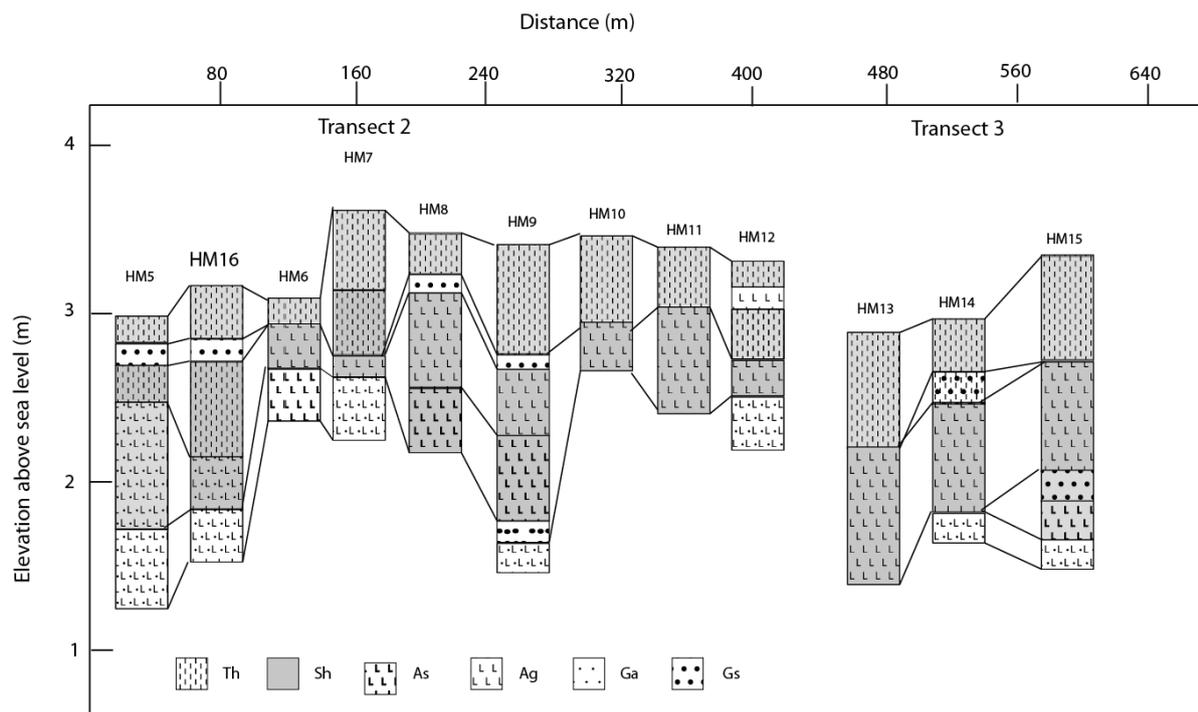


Figure 4.7 Stratigraphy of Transect 2 and 3, Higher Moors.

A sample core 1.58 m long was recovered for laboratory analysis (core hm16) and is described in detail in table 4.2. the grid reference of the core is E92435 N10748 and elevation 2.74m.

Table 4.2 Stratigraphic description of core HM16, Higher Moors

Core Higher Moors, HM16		
Depth (cm). Troels-Smith (1955) description.		
1-5	Sh2, Th2	Brown humified peat
5-10	Gs2, Ga2	Light grey sand, different size pebbles, brownish as the top.
10-15	Th1, Sh3, Ag+	Brown humified peat
15-26	Gs2, Ga2	Light grey sand, different size pebbles, brownish as the top.
26-41	Th1, Sh3	Brown humified peat
41-43		Light grey band of very stiff clay within the peat
42-50	Th2, Sh2	Very dark peat
50-100	Th2, Sh2	Dark brown peat
68-69		Band of light grey silt
100-147	Th2, Sh2	Very dark peat
116	Gs2, Ga2	Sandy layer
121	Gs2, Ga2	Sandy layer
147-158	Gs1, Ga1, Th1, Sh1	Bands of sand with brown and black peat

4.2.1.2 Chronological control

Table 4.3 shows the results of the radiocarbon samples obtained from the core HM16 from higher moors. the basal date (at 144-145cm) was obtained from the BETA labs in Miami (USA) on decayed plant remains. The other dates were obtained from the NERC labs in East Kilbride (Scotland), in this instance the humic fraction was used for dating.

Table 4.3 Radiocarbon dates from HM16, Higher Moors

Depth	Lab code	Date (Radiocarbon yr BP)	$\Delta^{13}C$	cal BC/AD	cal BP
HM10/16- 25-26cm	SUERC-39442	modern	-27	AD 1950-1960	-10
HM10/16- 62-63cm	SUERC-39443	996 \pm 35	-29.1	AD 980-1060	890-970
HM10/16-83-84cm	SUERC-39444	1437 \pm 38	-8.3	AD 560-660	1290-1400
HM10/16- 107-108cm	SUERC-39444	1762 \pm 38	-28.9	AD 130-340	1600-1740
HM10/16- 144-145cm	BETA-301601	2050 \pm 30	-27.4	160BC- AD10	1930-2070

This core covers the last 2100 years. The oldest date at a depth of 144-145cm calibrates to cal 1930-2070 cal BP (160BC- cal AD10). The sequence of dates is in its correct stratigraphic order up to the present.

The age-depth model is based on the 5 calibrated ^{14}C ages. The programme Clam provides various types of age depth models. Each of them were tested and the most suitable age depth models were the Linear Interpolation and Smooth Spline (Figure 4.7) because this sequence does not have hiatuses and there are no reverse dates (Blaauw, 2010). Linear interpolation proved to be the most appropriate model, the confidence range was 95% and the goodness-of-fit was 4.55, in comparison with the smooth spline model where the goodness-of-fit was 50.95.

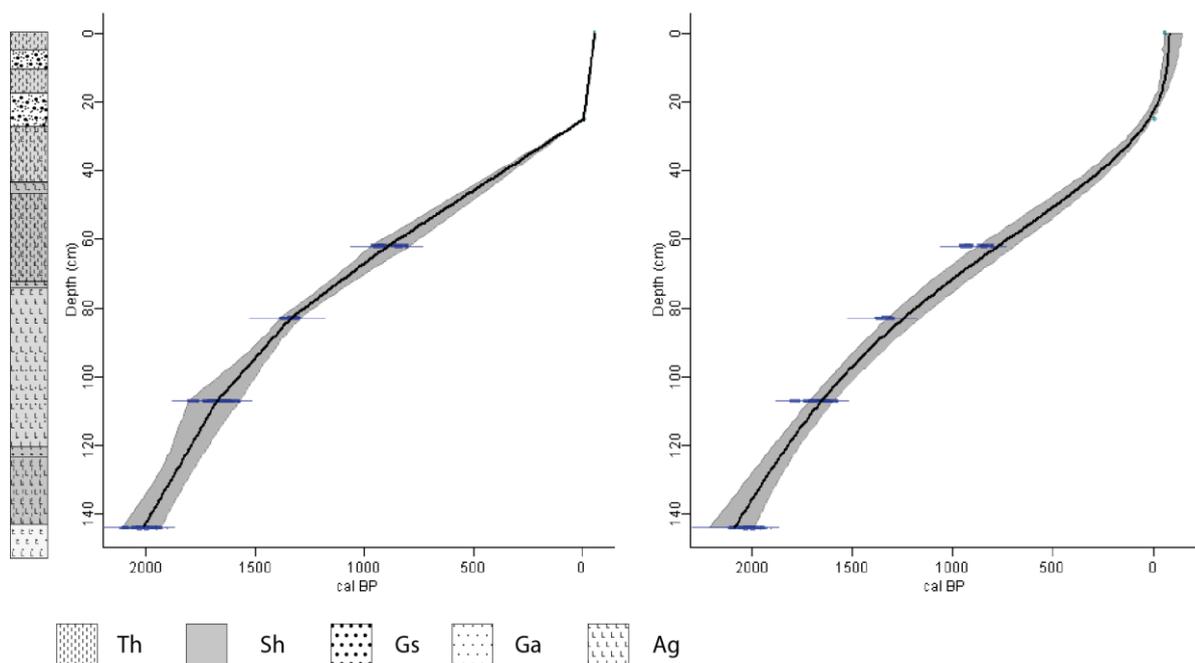


Figure 4.8 Core HM16 stratigraphy and the two age-depth models discussed: linear interpolation (left) and smooth spline (right). Linear interpolation includes all the radiocarbon dates.

4.2.1.3 Particle size and Loss on Ignition

One hundred and fifty-five contiguous 1cm samples were processed for particle size and LOI from core HM16 (Fig 4.9). CONISS identified eight local sediment assemblage zones and these are described below, dates (best fit dates) are taken from the linear interpolation age depth model.

HM16 Isaz1: 155.5 -150.5cm

160 – 120 cal BC

This zone is characterised by high percentages of very fine sand (average 26%), followed by coarse and medium silt (average 22%). There are important percentages of organic matter (20 and 30%). There is a considerable amount of very coarse, coarse and medium sand (10%) and only a small presence of fine silt and clay.

HM16 Isaz2: 150.5-107.5cm

120 cal BC- cal AD 270

The organic matter starts to increase slowly reaching up to 80% and decline again slowly, ending at the top of the sequence at 64%. All the other components decrease constantly with some important fluctuations. There is a short increase in silt and sand with a decrease in organic matter between 130 and 132cm. From 122.5cm upwards there are considerable fluctuations in all the units, decreases in organic matter and mirrored by increases in the other factors and *vice versa*. The clay levels are low and stable

HM16 Isaz3: 107.5-83.5cm

cal AD 270-610

This zone is characterised by a general decrease in organic matter that keeps a constant presence (between 22 -26%) and an increase in very coarse, coarse, medium, fine and very fine sand. There is some localised presence of >1mm sand, mainly quartz grains. It is a very stable zone with just minor fluctuations.

HM16 Isaz4: 83.5-25.5cm**cal AD 610-1960**

The organic matter increases with respect to the previous zone, the percentages are more or less stable (average 45%) with some fluctuations. There is considerable reduction in the amount of very coarse, coarse, medium and fine sand, while there is an increase in the amount of very fine sand, silt (coarse, fine and very fine) and clay (although, still small percentages). There are some important variations: at 61.5cm there is an increase in the amount of coarse and medium silt (36%), at 42.5cm the coarse, medium and fine sand disappears. Clay keeps constant increasing slightly at the top of the section but still very low percentages.

HM16 Isaz5: 25.5-17.5cm**cal AD 1960-1980**

The start of this zone is marked by a very distinctive decline in percentages of organic matter (falling down to less than 1%). On the contrary, the percentages of sand (>1mm, very coarse, coarse, medium and fine) increase noticeable, coarse and medium sand reaches c.79%. Sediments in other size fractions fall to minimum percentages and clay disappear totally.

HM16 Isaz6: 17.5-11.5cm**cal AD 1980-2000**

In this zone the percentages of organic matter rise steadily up to 20%. This is mirrored by the decrease in coarse and medium sand (fluctuating between 27 and 40%). The rest of the sediments keep their low and constant percentages with a small presence of clay.

HM16 Isaz7: 11.5-4.5cm**cal AD 2000**

This zone is very similar to HM16 Isaz5. Decline of the percentages of organic matter (down to 2%) and all the sediment fractions with the exception of the increase in coarse and medium sand (up to 75%) and the highest percentages of >1mm sand in the whole core.

HM16 Isaz8: 4.5-0.5cm

cal AD 2000 -2008

This zone is the opposite to the previous one: the percentages of organic matter increase up to 70%, also the percentages of silt (coarse, medium, fine and very fine) increase slightly while the percentages of sand decrease considerably.

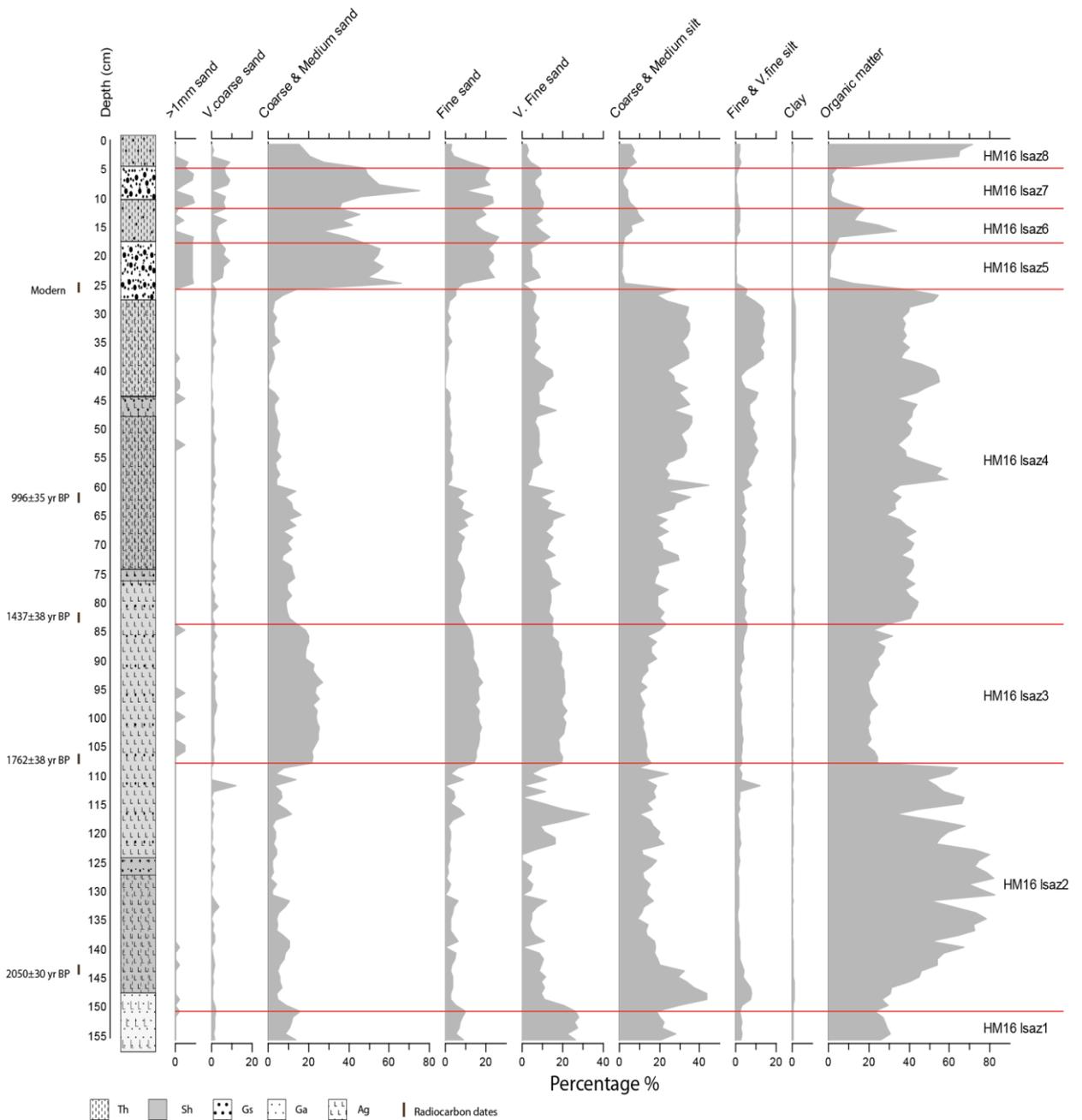


Figure 4.9 HM16 stratigraphy, particle size and Loss On Ignition results.

4.2.1.4 Pollen data

Core HM16 was subsampled at 2cm intervals and 74 samples were obtained for pollen analysis. CONISS recognised six distinctive local pollen assemblage zones (Ipaz; Fig. 4.10), which are described below. Dates are taken from the linear interpolation age depth model (section 4.2.1.2).

HM16 Ipaz1: 155.5-137.5cm, Poaceae – *Plantago lanceolata* – *Calluna vulgaris*

160 cal BC- cal AD 10

Poaceae is the dominant species, between 55% and 60% of the taxa represented. *Plantago lanceolata* fluctuates along the zone. Cyperaceae are present at low levels and steadily decrease. *Calluna* is present through the whole sequence, increasing considerably at the top (reaching 33%). Tree taxa are only represented by a small amount of *Fraxinus* and low levels of *Quercus* pollen. There is an increase in *Corylus avellana* (up to 33% of the total taxa presented) with *Polypodium* and Pteropsida spores between 150-145cm, at the same time that Poaceae decrease drastically (from 31% to 2%). At 145cm Poaceae recover their percentages (up to 57%) to decrease again at the top of the sequence, *Corylus avellana* also decreases leaving very low percentages of trees and shrubs pollen, only represented by small amounts of *Prunus*, *Carpinus*, *Alnus* and Ericaceae. There is a constant presence on charcoal with important amounts of particles <50µm, although its importance declines at the top of this zone.

HM16 Ipaz2: 137.5-111.5cm, Poaceae- *Plantago media* – *Calluna vulgaris*

cal AD 10 - 240

Poaceae increase and it is the dominant taxa along this section. *Calluna* decreases but it maintains a constant presence (average of 7%). The three types of *Plantago* (*lanceolata*, *media* and *maritime*) are increasing with some minor fluctuations. Other herbs also increase such as: Lactuceae, *Rumex* and *Potentilla* type. Trees and shrubs are

represented by *Prunus*, *Corylus avellana* and some *Alnus* (mainly at the bottom of the zone). The microscopic charcoal presence is steady and constant, similar to the previous section, but there is an important peak at 125.5cm which declines immediately, this peak is mirrored by *Pteropsida*.

HM16 Ipaz3: 111.5-67.5cm, Poaceae – *Calluna vulgaris* – Cyperaceae

cal AD 240 - 950

Poaceae are once more the most represented taxa, with minor fluctuations and a slight decline towards the top of this section. *Calluna* increases steadily (up to 12%).

Cyperaceae start to be more significant, constant but shifting, these variations paralleled the fluctuations in Poaceae. The presence of the three types of *Plantago* is still constant, although they decrease at the top of this zone. The aquatic taxa start to increase specially *Myriophyllum* (average 20%). Microscopic charcoal is abundant with peaks between 84 and 72cm.

HM16Ipaz4: 67.5cm-39.5cm, Poaceae – Cyperaceae – *Calluna* – *Pteropsida*

cal AD950 - 1620

Poaceae decreases steadily from 56% to 29%, Cyperaceae increases up to 32% but it falls to 11% at the top of this section. The amount of *Calluna* is still constant (average 11%). The presence of the three *Plantago* taxa is constant, with an increase of Chenopodiaceae. Trees and shrubs taxa are recorded at very low levels principally: *Corylus avellana*, *Alnus*, *Quercus* and *Betula*. Microscopic charcoal is continuous with peaks at 56 and 40cms.

HM16lpaz5: 39.5cm-19.5cm, Cyperaceae – Poaceae – Chenopodiaceae**cal AD 1620-1970**

Cyperaceae increase at the start of the zone (from 15% to 32%), Poaceae decrease (from 40% to 14%). *Plantago media*, *P. lanceolata* and *P. maritima* pollen keep a continuous presence. Chenopodiaceae increase along the sequence up to 28%. There is a noticeable increase in the amount of *Ranunculus acris* type, *Rumex* and Lactuceae pollen. *Calluna* decreases until it practically disappears at the top of the sequence and the trees and shrubs taxa are just represented by small percentages of *Corylus avellana*, *Prunus* and insignificant amounts of *Quercus* and *Alnus*. Microscopic charcoal diminishes considerably in this section.

HM16lpaz6: 19.5.5-0.5cm, Poaceae- Cyperaceae – Chenopodiaceae – Pinus**cal AD 1970-2010**

Herbs are still the dominant group, mainly with Poaceae (average 75%) and small percentages of Cyperaceae, *Plantago*, *Sanguisorba* type, *Potentilla* type, Apiaceae and Chenopodiaceae. The shrubs taxa have reduced considerably and there is only a small percentage (less 5%) of *Calluna*. Tree pollen percentages are also very low, small percentage of *Quercus* at the bottom of the section but it disappears immediately and some *Pinus* increasing towards the top of the pollen diagram. Charcoal levels have been reduced but there are still important amounts.

4.2.1.5 Summary

Core HM16 provides a continuous stratigraphic sequence of pollen and particle size that will be used as proxies for vegetation and sand influx (storminess) for the last 2100 years. The particle size results show changes in the amount of sand and organic matter in the core. Although along the sequence there are some important fluctuations in the amount of

organic and sand, the most drastic change occurs in zone HM6 Isaz5, where the percentages of coarse and medium sand rise up to 89%, while the presence of organic matter reduced to 1%. There are some changes in the vegetation through time that may be related to land management. There is an increase of the Cyperaceae and Chenopodiaceae pollen from the HM16 Ipaz4. Also it is remarkable the relation between some of the herbaceous taxa. There is a see-saw effect between Poaceae and Cyperaceae, when one increases the other decreases and *vice versa*. Evidence of tree communities in the past in the Isles of Scilly is very clear in HM16 Ipaz1 where they are a noticeable part of the pollen assemblage.

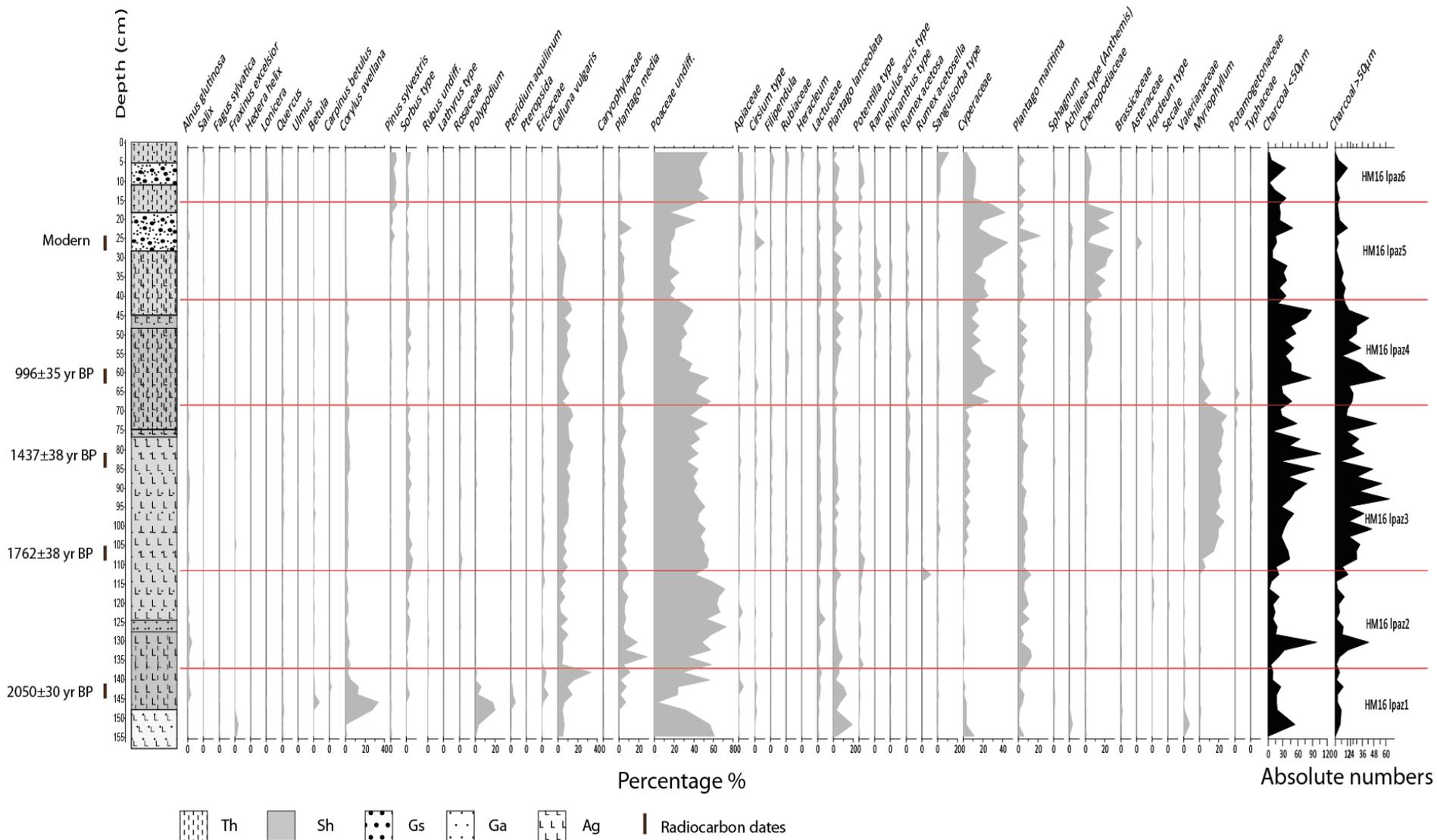


Figure 4.10 HM16 stratigraphy, pollen and charcoal results..

4.2.2 Lower Moors

Lower Moors is a SSSI and lies within the Isles of Scilly Areas of Outstanding Natural Beauty. This site is protected from the sea by the sand bar at Porthloo (SV909112) and Porth Mellon (SV909108) and it is located south of Old Town Bay (Scaife, 2006). Drainage ditches flow through the site and into the sea at Old Town.

Lower Moors is a mire developed on peat overlying granite bed rock. Part of this site is reed bed, dominated by common reed (*Phragmites australis*) with a fringe of grey willow (*Salix cinera*). The acidic waterlogged soils have abundant populations of hemlock water-dropwort (*Oenanthe crocata*), lesser spearwort (*Ranunculus flammula*), water mint (*Mentha aquatic*), common marsh-bedstraw (*Galium palustre*), and marsh pennywort (*Hydrocotyle vulgaris*). There are also small populations of rare species such as the royal fern (*Osmunda regalis*) and southern marsh orchid (*Dactylorhiza praetermissa*). The wet meadows have abundant doft rush (*Juncus effus*) and yellow iris (*Irish seudacorus*) together with ragged-robin (*Lychnis flos-cuculi*) and greater bird's-foot trefoil (*Lotus uliginosus*). The slightly higher and drier areas are dominated by bracken (*Pteridium aquilinum*) and bramble (*Rubus fruticosus*) (Isles of Scilly Wildlife Trust, 2012).

Owing to access constraints, Lower Moors has been divided into three main areas for survey: The 'Duck's Pond', the 'Nature Trail' and 'Lower - lower Moors'.

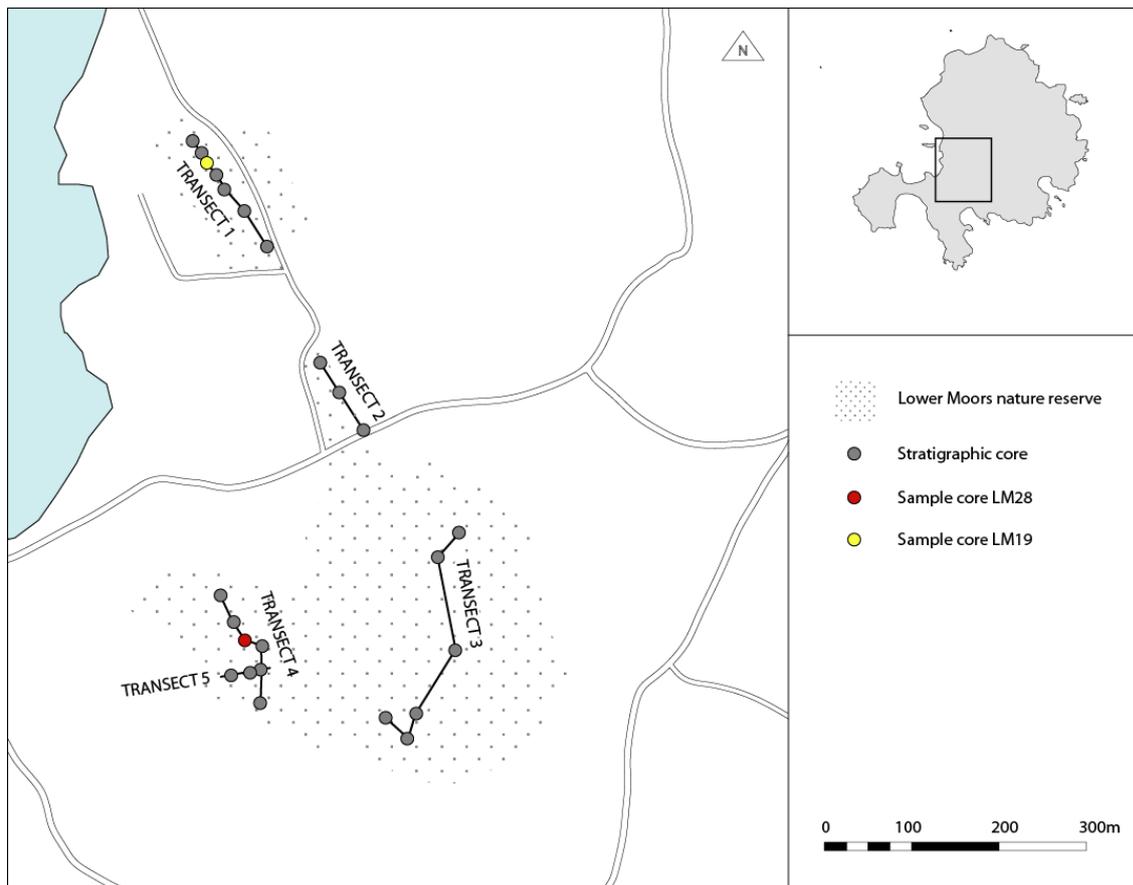


Figure 4.11 Transects taken along Lower Moors. The location of core LM19 (Duck's Pond) is represented with a yellow dot. Core LM28 (Lower-lower Moors) is represented by a red dot.

4.2.2.1 Stratigraphy and sample core (Duck's pond)

At the northern end of Lower Moors is a shallow freshwater pool, known as the 'Duck's Pond' (Fig. 4.11). It is located beside the road from Porthloo to Rose Hill, with two fields on the west and Well Field on the east and is managed by the Isles of Scilly Wildlife Trust as a nature reserve. These fields are composed of a mixture of wetland plants and open grassland. It is separated from the sea by a road and some houses and divided by a wooden track. Four distinctive sedimentary layers were recognised (Fig. 4.12).

The lowest sedimentary unit is a stiff grey silty clay found in all the cores except core LM04. Unit 2 is a deposit of dark brown, well humified peat, sometimes formed by

alternative bands of darker and lighter brown peat. Its degree of humification varied across the transect, with depths varying between 10 and 40 cm and with varying degrees of sand content. The third stratigraphic unit is a organic clay with a range in depth from ranged from 20 to 135cm. The last sedimentary unit is made of brown well humified turfa peat with traces of sand (top soil).

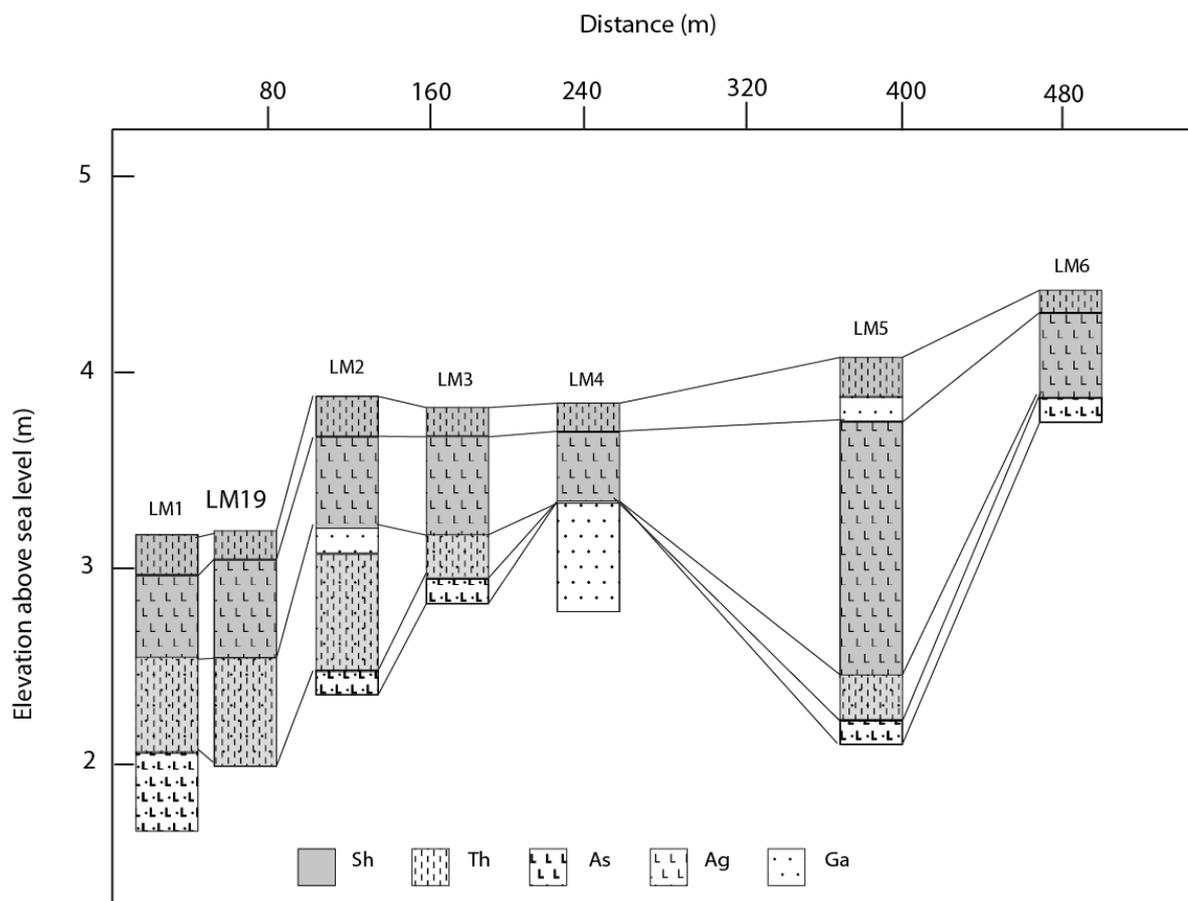


Figure 4.12 Transect 1 from Lower Moors, Duck's Pond, with the sampled core LM19.

A sample core 91cm long was recovered for laboratory analysis (core LM19) and is described in detail in table 4.3. The grid reference is E90988 N11147 and elevation 3.49m.

Table 4.4 Sediment description of core LM19, Duck's Pond, Lower Moors, St Mary's

Lower Moors , LM 10/19		
Depth (cm). Troels-Smith (1955) description.		
0-19	Th1, Sh3, Ga+	Brown well humified turfa peat with traces of sand
20-55	Ga2, Sh1, As1, Gg+	Dark brown clay sand with humid substance and occasional pebbles. Some sandier band of lighter colour, about 102cm thick, located along the sediment
55-91	Th+, Dh1, Sh3	Dark brown well humified peat with detritus organics. Variable in colour, black bands with very dark brown bands

4.2.2 Chronological control (Duck's pond)

Table 4.5 shows the results of the radiocarbon samples obtained from the core LM19 from Lower Moors. The basal date (at 85-86) was obtained from the BETA labs in Miami (USA), coarse humin was dated. The rest of the dates were obtained from the NERC labs in East Kilbride (Scotland) where the humic fraction was used for dating.

Table 4.5 Dating results from LM19.

Depth	Lab code	Date (Radiocarbon yr BP)	$\Delta^{13}C$	cal BC/AD	cal BP
LM10/19- 12-13cm	SUERC-39446	modern	-30	AD 1960	-10
LM10/19- 54-55cm	SUERC-39447	1378 \pm 36	-30.5	AD 600-690	1260-1350
LM10/19- 76-77cm	SUERC-39448	1953 \pm 38	-30.5	AD 1-90	1860-1950
LM10/19- 85-86cm	BETA-301602	2000 \pm 30	-28.8	50 BC-AD60	1880-2000

The core covers the last 2000 years; the oldest date at a depth of 85-86cm calibrates to cal 1880-2000 cal BP (50BC-AD60). The sequences of dates are in their correct stratigraphic order up to the present.

The age-depth model is based upon the 4 calibrated radiocarbon dates. The most suitable age depth models were Linear Interpolation and Smooth Spline (Fig. 4.13) because this sequence does not have hiatuses and there are no reverse dates (Blaauw, 2010). Linear

interpolation proved to be the most appropriate model, the confidence range was 95% and the goodness-of-fit was 3.38, in comparison with the smooth spline model where the goodness-of-fit was 45.46.

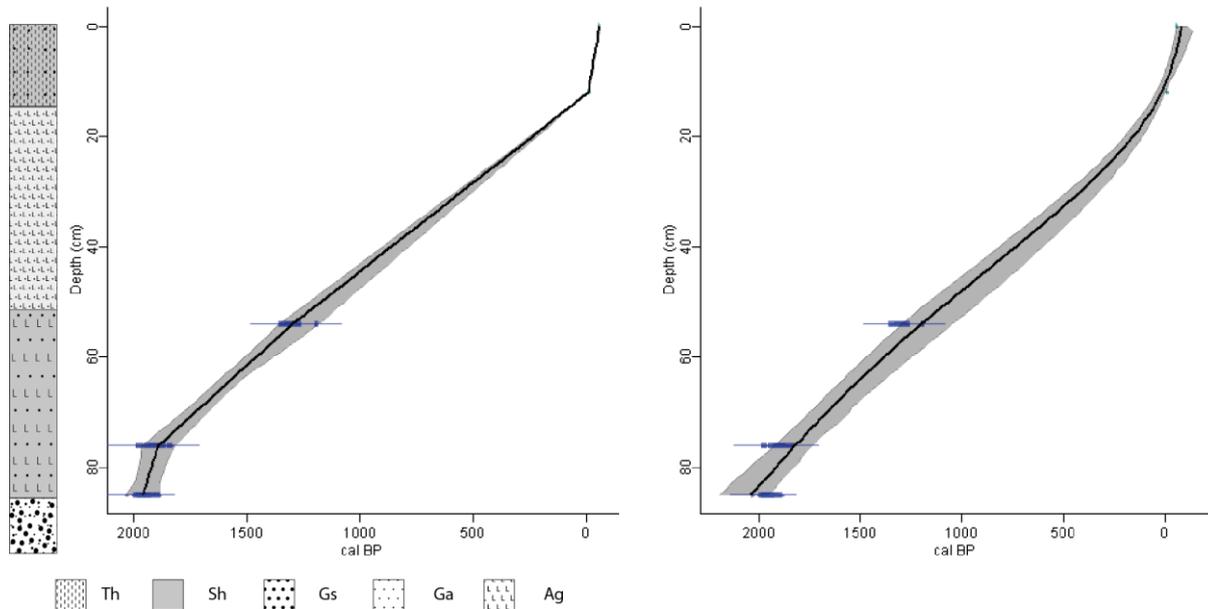


Figure 4.13 Stratigraphy of the core LM19 with the two age-depth models discussed: Linear Interpolation (left) and Smooth spline (right).

4.2.2.3 Particle size and Loss on Ignition (Duck's pond)

Eighty contiguous 1cm samples were processed for particle size and LOI (Fig. 4.14).

CONISS identified three local sedimentary assemblage zones (Isaz), which are described below. Dates (best fit) are taken from the age depth model (Linear interpolation) previously discussed.

LM19 Isaz1: 90.5-54.5cm

60 cal BC- cal AD 650

This zone is characterised by the high presence of organic matter with some localise percentage reductions. The average of organic matter in this zone is 65% but it falls to less than 40% at 80.5cm 71.5 and 65.5. These falls and increases are echoed by the increases and falls of the rest of the sediment fractions. When organic matter decreases,

sand (coarse, medium and fine) increases whilst fine sand and silt (coarse, medium, fine and very fine) decrease. Clay percentages are very low but constant through the whole zone. This zone coincides with the stratigraphy unit described in the field as dark brown well humified peat with detritus organics (Table 4.4).

LM19 Isaz2: 54.5-12.5cm

cal AD 650-1940

The organic matter reduces constantly from 25% at the bottom down to 14% at the top of this zone; however there is a peak in organic matter (55%) at 48.5cm. Coarse and medium size sand percentages increases reaching percentages up to 70% but keeping an average of 55%. This zone also has the highest percentages of >1mm sand (top) and very coarse sand (bottom). The rest of the sediment fractions also increase slightly in comparison with the previous zone, and they keep a low but stable presence. This zone coincides nearly totally with the stratigraphy unit described in the field as dark brown clay sand with humid substance.

LM19 Isaz3: 12.5-1.5cm

cal AD 1650-2005

Organic matter becomes the predominant sediment in this zone, increasing from 49% to 69% with some small fluctuations. Coarse & medium sand decreases from 20% to 4%. Fine & very fine sand also decreases whilst silt (coarse, medium and fine) increase constantly along the section with minor fluctuations. This zone corresponds with the top soil of the area.

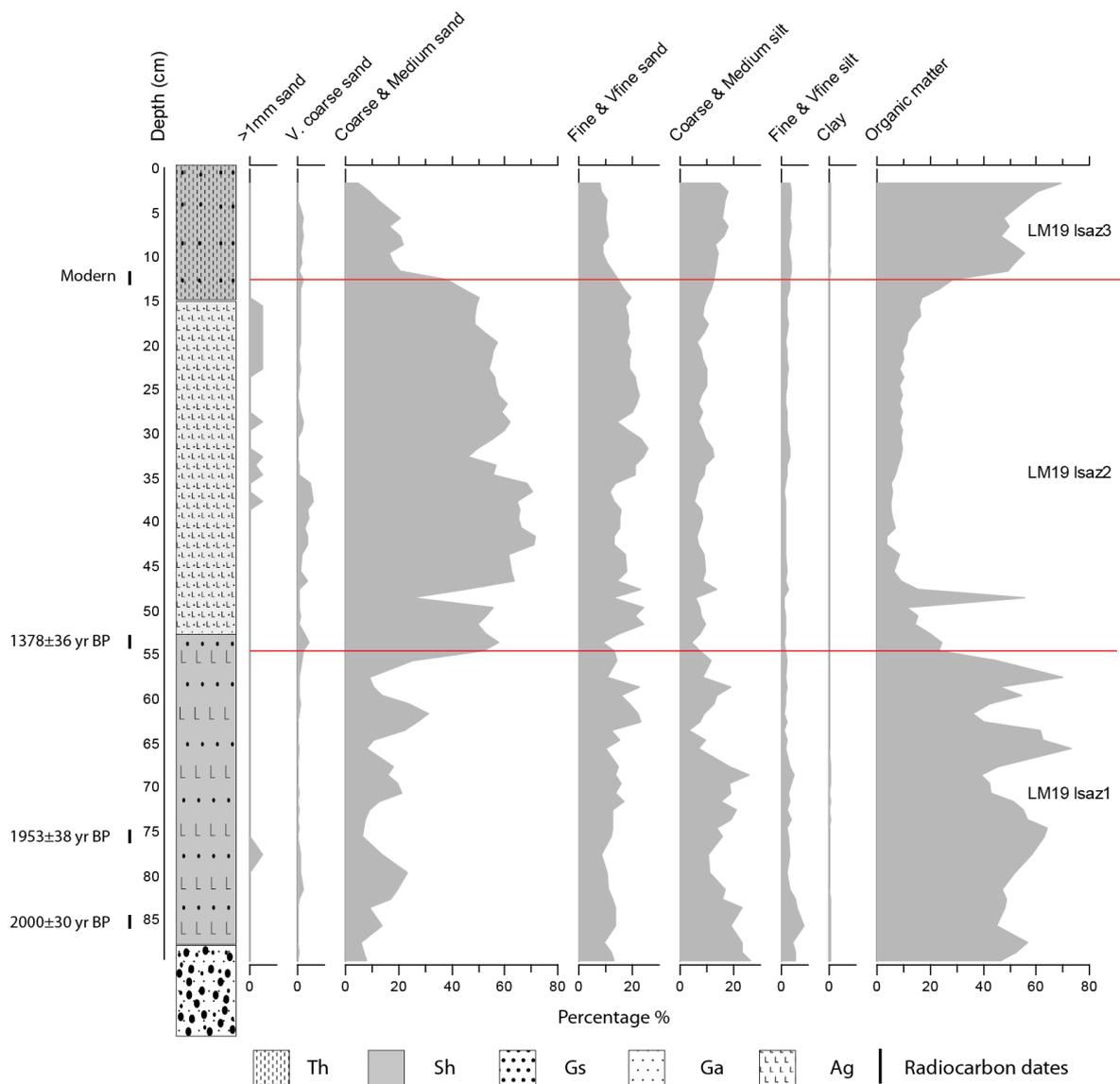


Figure 4.14 Stratigraphy, particle size and Loss On Ignition results from LM19.

4.2.2.4 Pollen data (Duck's pond)

Core LM19 was subsampled at 4cm and 2cm intervals (from 48.5cm downwards), 34 samples were obtained for pollen analysis. CONISS distinguished five different local pollen assemblage zones (Ipaz; Fig. 4.15), they are described below. Dates (best fit) are taken from the linear interpolation age depth model previously discussed.

LM19Ipaz1: 92.5-67.5cm, Poaceae – *Plantago lanceolata* – *Sphagnum*

60 cal BC – cal AD 300

Poaceae are the most abundant taxa; keeping an average of 45% with some localise changes (up to 76% at 86.5cm and 84.5cm, and down to 26% at 88.5cm). *Plantago lanceolata* is the other most common taxa however it fluctuates constantly, ranging from 1% to 30%. Its presence is affected by Poaceae, it decreases when the Poaceae increases and increases when Poaceae decrease, there is a see-saw effect within these two taxa. The *Calluna vulgaris* presence is constant (between 7 and 10%), decreasing towards the top of this zone. There are other herb pollen present such as *Plantago media*, Lactuceae, *Rumex*, *Potentilla*, Apiaceae and Asteraceae, most of them disappearing at 88cm before slowly starting to increase again. There is range of tree taxa constantly present but in small quantities: *Corylus avellana*, *Quercus* and *Alnus*. *Sphagnum* increases considerably up to 31% (at 78.5cm) but it decreases considerably at the top of the zone (less than 1%).

Charcoal is present in very small amounts, just a short peak of charcoal<50 at the bottom of the sequence and a shorter peak at 88.5cm.

LM19 Ipaz2: 67.5-59.5cm, Poaceae – *Rumex* – *Plantago lanceolata* – *Corylus*

avellana

cal AD

300- 520

This zone is dominated by the presence of herb taxa: Poaceae (average 49%), *Rumex* (reaching 24% at 72.5cm but fluctuating constantly), *Plantago lanceolata* (reaching 30% at 76.5cm but then reduce to an average of 10% during the rest of this zone). Other herbs with a significant presence are: Apiaceae (reaching a peak of 26% at 62.5cm), Asteraceae, *Plantago media* and Lactuceae. Shrubs taxa are represented by *Calluna* fluctuating constantly from 0.5% to 5%. There are some tree taxa, the highest presence is *Corylus avellana* (varying from 2% to 10% and reducing towards the top). There are a few *Quercus* and *Alnus* pollen grains with a insignificant presence of *Betula* and *Fagus*. There

is still not significant presence the charcoal, except for a short peak of <50µm particles at 64.5cm.

LM19 Ipaz3: 59.5-22.5cm, Poaceae – *Plantago lanceolata* – *Calluna* - *Galium*

cal AD 520 - 1650

This zone is again dominated by herbaceous taxa: Poaceae fluctuating constantly between c.30% and 60%. Other herb taxa such as *Galium* (average of 6% but reaching a peak of c.30%), *Sanguisorba* type (average 4% although reaching a peak of c.40%), *Plantago lanceolata* (average 10%) Asteraceae, *Cirsium* type and Chenopodiaceae dominate this zone assemblage. Cyperaceae maintains a low (average 2%) but constant presence in this zone with an important peak at 54.5cm, reaching 24%. The percentages of tree pollen has reduced considerably from the previous zones, there is a low but constant presence of *Corylus avellana*, *Quercus*, *Alnus*, *Salix* and *Prunus*. Shrubs taxa are well represented by *Calluna*, increasing from c.1% at the bottom of the zone up to c. 10% at the top, with some peaks in between (e.g. 24% at 52.5cm). Aquatic type pollen appears with *Myriophyllum* and *Typha* reaching percentages up to 4%. Microscopic charcoal increases within this zone.

LM19 Ipaz4: 22.5-10.5cm, Poaceae –*Plantago lanceolata* – Lactuceae

cal AD 1650 - 1970

This zone is characterised by the dominance of the herb taxa. Poaceae increase from 38% to 51%. Other pollen taxa with important presence are: *Plantago lanceolata*, *P. media*, Lactuceae, Asteraceae, Apiaceae and *Potentilla* type, however, all of them start to decline towards the top of this zone. The low shrubs and tree pollen percentages from previous zones are even lower now. Levels of microscopic charcoal remain high, but start to diminish towards the top of the zone.

LM19lpaz5: 10.5-4.5cm, Poaceae — *Plantago lanceolata* – *Rumex* – *Pinus***cal AD 1970 - 1990**

This zone is characterised by an increase in *Pinus* (4%), for the first time in the pollen diagram. Herbs are still the dominant taxa, mainly with Poaceae (between 59 and 76%), *Plantago lanceolata*, *P. media*, *Rumex*, Lactuceae, *Potentilla* type and Asteraceae. The microscopic charcoal levels have reduced in comparison to the previous zone.

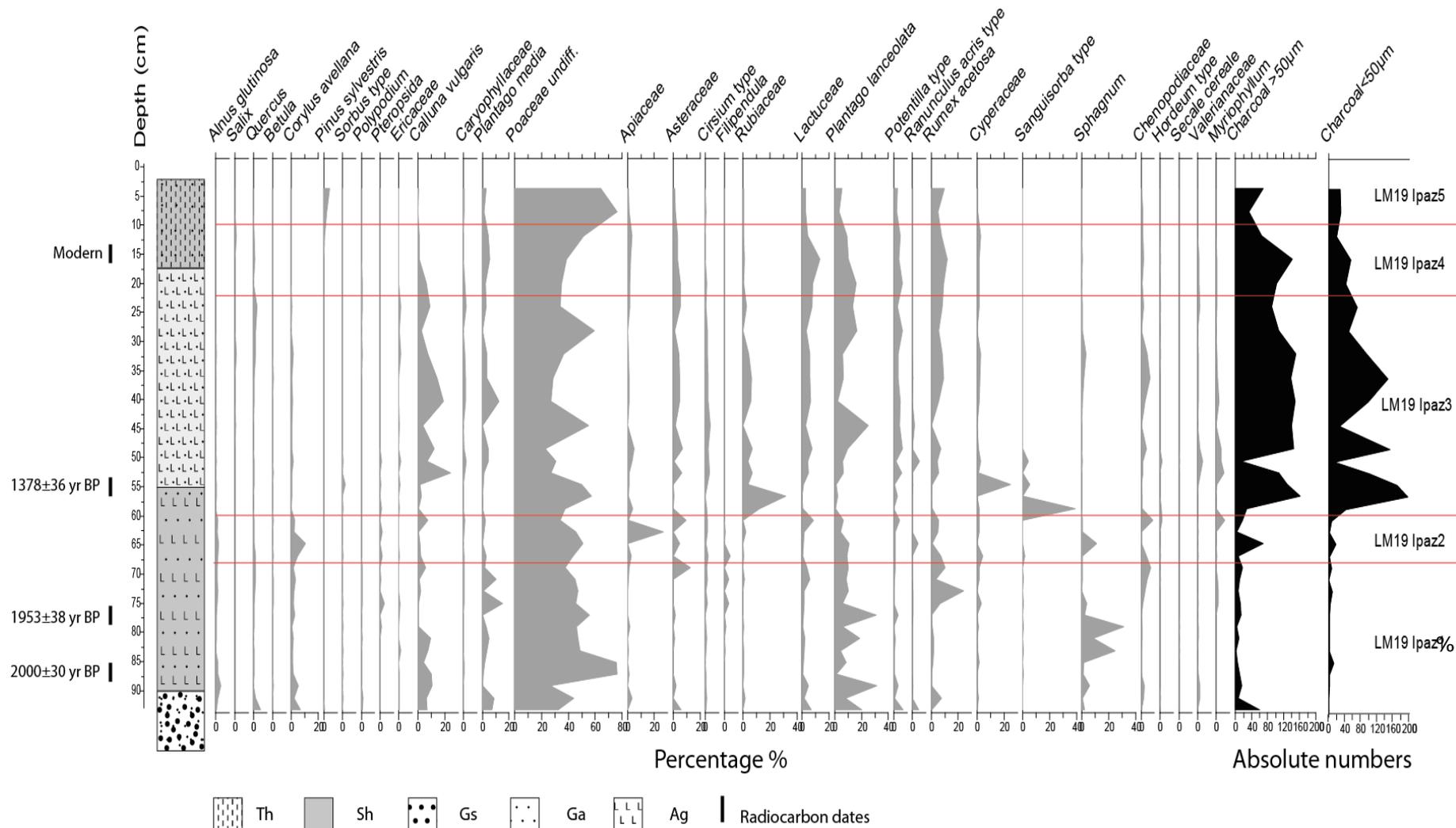


Figure 4.15 LM19, stratigraphy, pollen and charcoal results.

4.2.2.5 Summary

The stratigraphy varied greatly across the Duck's pond section of Lower Moors (Fig. 4.12). The sampled section was short, but appears to preserve a continuous record of vegetation and particle size for the last 2000 years. The particle size and LOI diagram shows some fluctuations in the amount of sand and organic matter. These two parameters (coarse and medium sand, and organic matter) show a see-saw effect constantly, when one increases the other decreases. This is particularly obvious in LM19 Isaz2, where the coarse and medium sand increases up to 60% while the organic matter reduces down to 9%. The opposite occurs in LM19 lasz3, where the coarse and medium sand falls down to 4%, while organic matter reaches up to 69%. The pollen diagram shows some fluctuations in the flora assemblage probably related to land management and/or climatic factors. There is evidence of *Secale cereale* in most of the diagram zones, but its presence decreases considerably when Cyperaceae increases, especially in LM19 lpaz3. Where *Secale cereale* and *Hordeum* increase, there is a slight decrease in the percentages of Poaceae, for example in LM19 lpaz3 and 4.

4.2.3 *Lower Moors: Nature trail section*

4.2.3.1 Stratigraphy

Two more transects (Fig. 4.11) were cored along the Nature Trail, part of Lower Moors. The dominated vegetation along this area were grasses, *Rumex*, *Ranunculus*, Filipendula and Bracken, all meadow type grasses with some ivy and willow scrub. A great part of this area was inaccessible and very wet. This section of Lower Moors was not sampled as the peat was in poor condition, probably truncated and disturbed as result of peat cutting. All the cores contained great amounts of sand and silt and little organic sediment. Three

different sedimentary stratigraphic units could be distinguished (Fig. 4.16). The lowest sedimentary unit was a band of stiff grey silty clay. The second stratigraphic unit varied along the site, most of the cores had a layer of dark brown peat, while others had a layer of dark brown organic clay. The thickness of this layer varied between the cores from 25 to 50cm and sometimes it had layers of sand at the top and bottom and plant fragments. This organic layer was absent in transect 2. The uppermost unit was formed by dark brown sandy silt with some turfa and some unsorted pebbles.

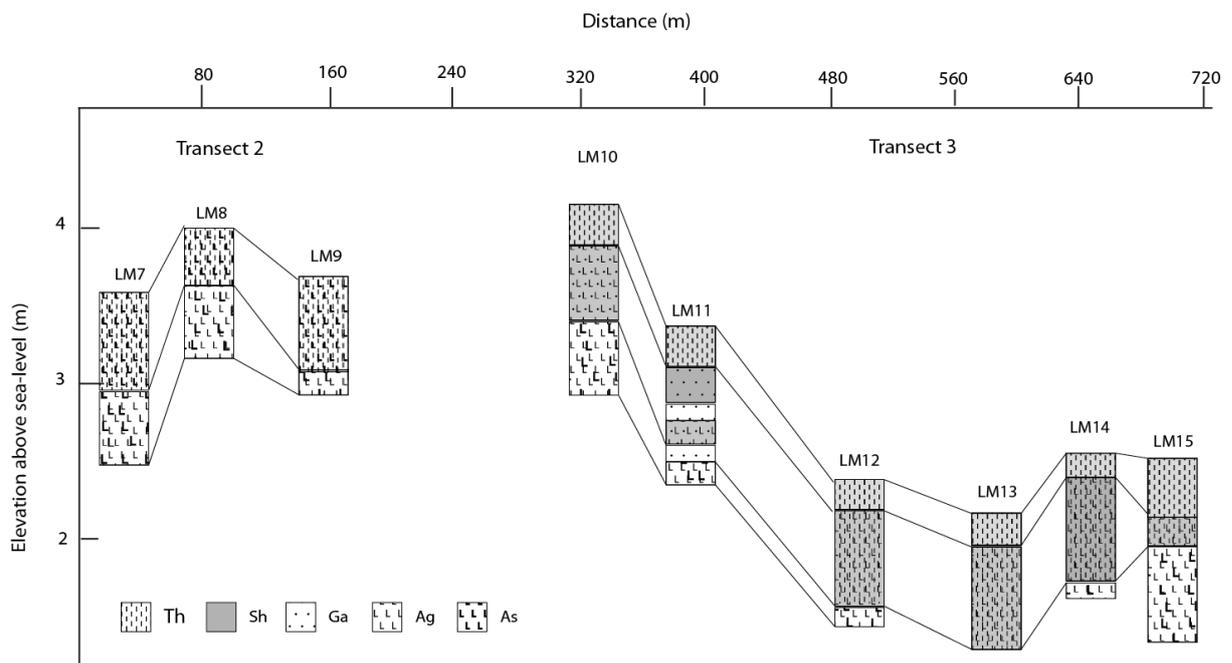


Figure 4.16 Stratigraphic sequence from Upper Lower Moors, Transect 2 and 3.

4.2.4 Lower Moors: Lower section

4.2.4.1 Stratigraphy and sample core

The stratigraphy of the Lower section of Lower Moors is shown in Fig. 4.17. This wetland is separated by the ones above by a road and an Industrial estate, it is next to the Incinerator of the islands. The dominant vegetation here is tall grasses *Osmunda Regalis*

(Royal Fern), rushes, reeds, phragmites and juncus. Two transects were cored here because the area is divided in two by a small water channel. These transects proved to have good peat preservation, with long sequences and organic clays. Five sedimentary units are distinguished. The lowest unit is a layer of sand, with coarser material towards the bottom. Above this is a layer of grey stiff silty sand found in all the cores, this unit contains few pebbles and it is sandier towards the bottom. The third sedimentary unit is a light grey/brown organic silt and organic clay, sometimes both together alternatively or just one of them (either organic silt or organic clay). This unit varies in depth along the transect, ranging from 30cm to 188cm. The fourth sedimentary unit is composed mainly by dark brown/black organic peat, very often with sandier and siltier bands and organic clays. It ranges in depth from 24 to 163cm. The top sedimentary sequence is the top soil formed by dark brown humified peat, ranging in depth from 26 to 50cm.

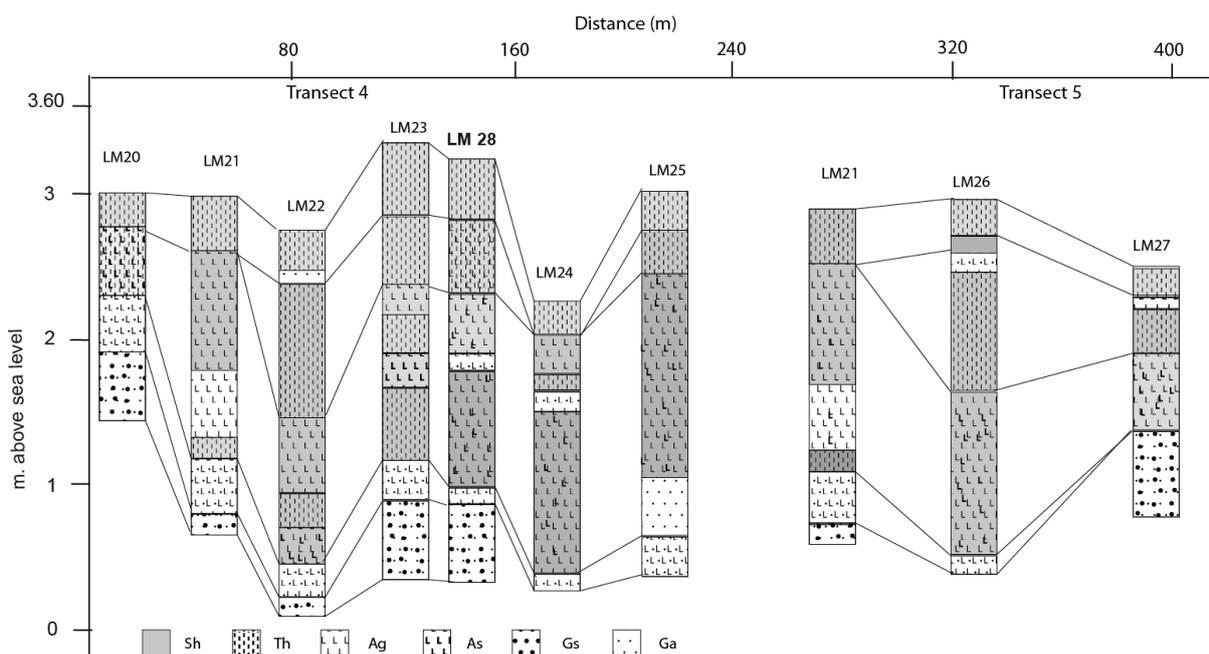


Figure 4.17 Stratigraphic sequence of Lower-lower Moors, with the sampled core LM28

A 275cm long sample core was recovered for laboratory analysis (LM28) and is described in detail in table 4.6. The grid reference of the core is E991033 N10957 and elevation 2.15m.

Table 4.6 Sediment description of LM28

Lower Moors LM10/28		
Depth (cm). Troels-Smith (1955) description.		
0-40	Sh2, Th2, As+	Dark brown humified peat. Phragmite fragments
40-100	Th1, Sh2, Ag1	Grey brown silty peat
100-143	Sh2, Ag2, Th+	Brown organic silt with silt inclusions
121-129	Sh2, Ag2, Th+	Brown organic silt. Scattered silt layers (light grey-brown) along the sediment
150-216	Sh2, Ag2, Th+	Brown organic silt
216-242	Ag3, Sh1	Light grey brown organic silt. Silt layer banding
242-244	Ga2, Ag2	Pale grey silt layer
244-275	Ag4, Ga+, Th+	Dark grey silt with fine sand, sandier at the bottom

4.2.4.2 Chronological control

Table 4.7 shows the results of the radiocarbon and OSL samples obtained from LM28. The basal date (at 257-259cm) was obtained from the BETA labs in Miami (USA), a further date at 120-121 cm was obtained from BETA labs. The rest of the radiocarbon dates were obtained from the NERC labs in East Kilbride (Scotland). The OSL dates were obtained from Aberystwyth (Wales). The resulting chronology gives a range of dates between 2761cal BP- -58cal BP (920 cal BC-AD2008).

The radiocarbon ages all lie in their correct stratigraphic order. The OSL, however, are all slightly older than the corresponding radiocarbon determinations, these OSL dates are broadly of a similar age (between 3000 and 3130 years before 2010). This implies rapid sediment accumulation, which is supported by the three lower radiocarbon dates (2720±30, 2560±38 and 2481±38, over a 1m depth of core). The large error ranges on the

OSL dates (around 10% of the age of the samples) means that there is overlap with the radiocarbon determinations.

Table 4.7 Radiocarbon and OSL dates from LM28

Depth	Lab code	Date (Radiocarbon yr BP)	$\Delta 13C$	cal BC/AD	cal BP
LM10/28- 25-26cm	SUERC-39449	modern	-29.6	AD 1950-1960	-10
LM10/28- 39-40cm	SUERC-39452	689 \pm 38	-28.3	AD 1290-1320	630-690
LM10/28- 120-121 cm	BETA- 351909	730 \pm 30	-26.1	AD 1260-1290	690-650
LM10/28- 162-163cm	SUERC-39453	2481 \pm 38	-28.3	769-48BC	2430-42720
LM10/28- 218-219cm	SUERC-39454	2560 \pm 38		806-735BC	2690-2750
LM10/28- 257-259cm	BETA-301603	2720 \pm 30	-25.1	920-810 BC	2760-2870
Depth	Lab code	OSL Age	cal BC/AD	cal BP	
LM10/28- 161-165cm	184/lm10-28-161	3000 \pm 370	990BC	2340-4090	
LM10/28- 217-221cm	184/LN10-28-217	3050 \pm 280	1040 BC	2700-3970	
LM10/28- 271-277cm	184/LM10-28-277	3130 \pm 410	1120 BC	2430-4410	
OSL Ages are expressed as years before AD2010, rounded to the nearest 10 years.					

The age-depth models were produced using CLAM. The first model is based only on the radiocarbon determinations and the second used both the radiocarbon and the OSL results. Using the OSL dates and radiocarbon dates resulted in age-reversals and poor goodness-of-fit (Fig. 4.18). The best fit for the model based only in radiocarbon dates was linear interpolation which is used in the discussion and interpretation.

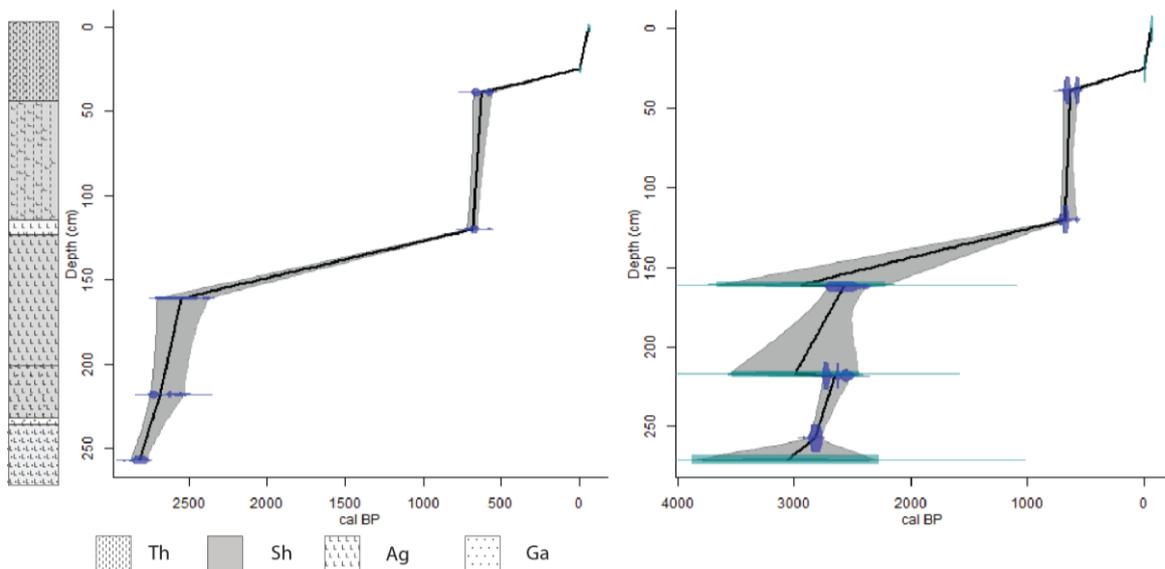


Figure 4.18 Stratigraphy of the core LM28 with the two age-depth models discussed: linear interpolation with only the radiocarbon dates (left) and Smooth spline with the radiocarbon and OSL dates (right). Observe the large error bars when using both types of dates

The dates obtained between 150 cm and 120 cm are very different (2481 ± 38 and 730 ± 30 respectively) but only a few centimetres apart (Table 4.7). This raised the possibility of a hiatus in this sequence. Figure 4.19 shows the lithology of core LM28, the total land pollen concentration, the percentages of organic matter and coarse sand and the age-depth model. According to Middelorp (1984, 1986) there is a relationship between the increase of accumulated regional pollen on the site and time. Figure 4.19 shows a constant influx of pollen from the base of the sequence, until a slight increase between 145-110 cm. This increase could be an indication of slower sedimentation and in consequence could explain the large period of time constrain within a short sequence. The increase in accumulation rate in the upper part of the core (around 40 cm) may reflect a change sedimentation processes or a hiatus. This change occurs also after a change in lithology and sediment type, there is an increase in coarse sand and a sudden increase and drop in organic matter. The six radiocarbon dates are all in sequence, but they represent a marked change in sedimentation rate. The core was rich in detrital plant material, and although great care was taken when taken the samples for radiocarbon date, there could have

been some downward penetration of root material and percolation of organic matter. Since these ages form a coherent sequences, there is no evidence of abrupt pollen concentration changes (other than at the top of the core), no brusque changes in the lithology of the sampled core and no evidence of root contamination, for the purposes of this thesis the linear interpolation age model has been used and assumed to be correct (Fig. 4.18 and Fig. 4.19).

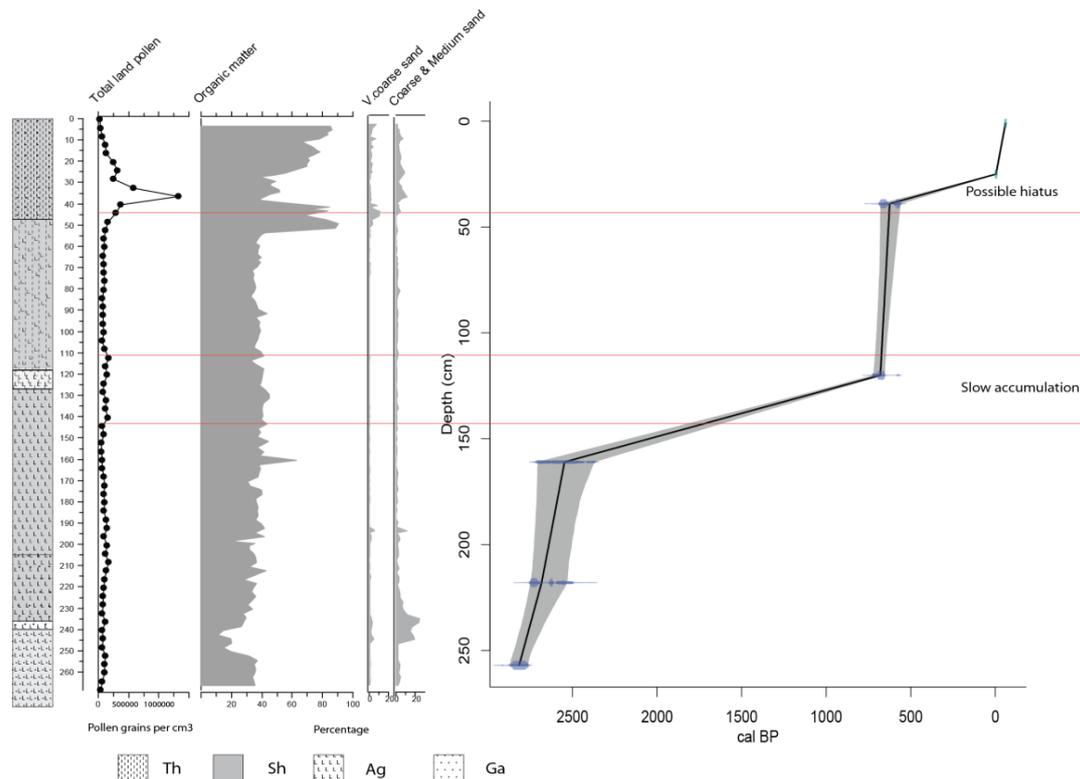


Figure 4.19 Core LM2: lithology, total pollen concentration, percentage of organic matter and coarse sand and age depth model

4.2.4.3 Particle size and Loss on Ignition

Two hundred and seventy three samples, taken each 2cms, were analysed for Particle Size (PS) and Loss On Ignition. CONISS recognised four different local sedimentary assemblage zones (Isaz. Fig. 4.20). The dates are based in the age-depth model from section 4.5.2.

LM28 Isaz1: 272.5-251.5cm**910 - 840 cal BC**

This zone is characterised by high and constant percentages of organic matter (average 33%) with also high percentages of coarse and medium silt (average 30%) and very fine sand (average 15%). The other sediment fractions are very low and decreasing towards the top of the zone. This zone coincides with the sedimentary unit described in the field as dark grey silt with fine sand, sandier at the bottom.

LM28 Isaz2: 251.5-51.5cm**840 cal BC – cal AD 1320**

The most remarkable aspect of this section is its stability with minor fluctuations. The most dominant sediment fractions are the coarse and medium silt (average 45%) and organic matter (average 36%). Sand (>1mm, coarse, medium and fine) is well represented at the bottom of this zone (coarse sand up to 24%) but they are considerably reduced at the top. This zone has the highest presence of >1mm sand. It is noticeable that when the sand fractions increase, the organic matter and silt fractions decrease. Clay keeps a very low but constant presence.

LM28 Isaz3: 51.5-28.5cm**cal AD 1320 - 1820**

This zone starts with a great increase in organic matter percentage (up to 83%) and a considerable decrease of silt (down to 2%) in comparison with the previous zone. The percentages of sand (very coarse, coarse, medium and fine) also increase slightly. At the top this pattern reverses. Organic matter percentages (down to 45%) and sand percentages diminish, whilst very fine sand and silt (up to 30%) increases. Clay still keeps a very low but constant presence.

LM28 Isaz4: 28.5-4.5cm**cal AD 1820 - 2000**

Organic matter percentages increase again and become the dominant fraction, reaching 88% at the top. All the other sedimentary fractions reduce considerably, sand fractions fall down to 1%, silt fractions drop down to 3% and clay percentages are still less than 1%.

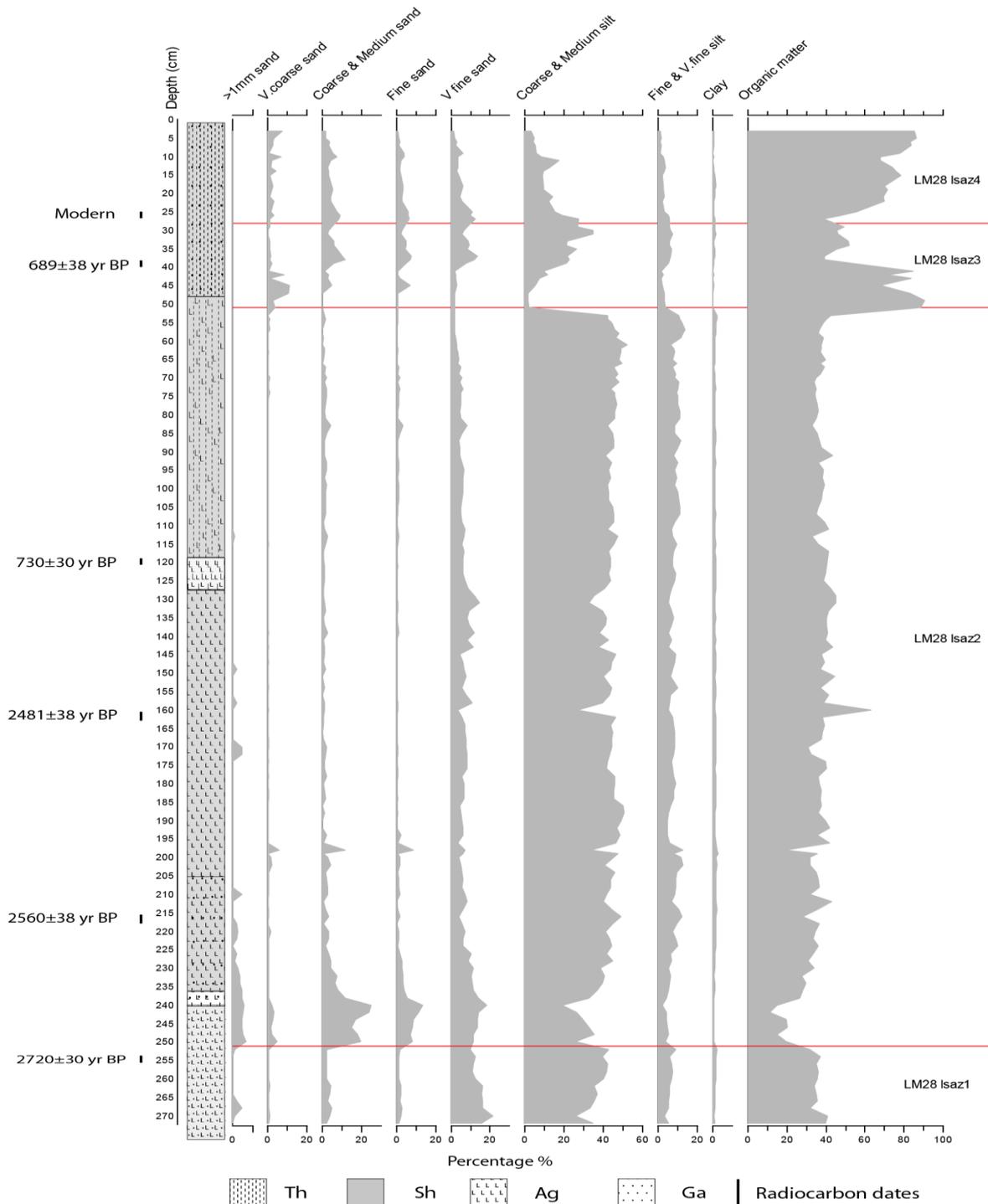


Figure 4.20 Stratigraphy, particle size and Loss On Ignition results from LM28.

4.2.4.4 Pollen data

Core LM28 was subsampled at 4cm intervals and 68 samples were obtained for pollen analysis. CONISS recognised six distinctive local pollen assemblage units (fig 4.21).

Dates (best fit) are taken from the age depth (linear interpolation) previously discussed.

LM28 Ipaz1: 268.5 -258.5cm, *Plantago lanceolata* – Poaceae – *Corylus avellana*

900 – 870 cal

BC

This zone is dominated by the presence of herb taxa, with *Plantago lanceolata* pollen (between 30 and 40%) dominating. Poaceae have very stable levels (average 22%) through the zone. Other herb taxa present are: *Potentilla*, *Rumex*, *Chenopodium* and Cyperaceae. Shrub taxa are represented by *Calluna*, maintaining the same level through the zone (3%). Tree taxa include *Corylus avellana* (increasing at the top, from 9 to 19%) *Quercus* and *Alnus*, those last two decreasing at the top of the zone. There is a small amount of microscopic charcoal reducing towards the top of the zone.

LM28 Ipaz2: 258.5-94.5, Poaceae – *Calluna vulgaris*– *Corylus avellana*

870cal BC –

cal AD 1290

Herb taxa continue to dominate the pollen assemblage with Poaceae increasing and keeping stable levels through this zone (average 39%). *Plantago lanceolata* percentages are smaller than in the previous zone but it maintains a presence of around 6% whilst *P. media* and *maritima* taxa increase their presence. *Littorella uniflora* reaches c.10% at the bottom of the zone but it reduces after that, reaching less than 1% at the top. Cyperaceae and the aquatic taxa follow the same pattern. *Hordeum* and *Secale cereale* have a low but constant presence along the zone, increasing slightly towards the top. The shrub taxa are numerous, *Calluna* (average 5%), Ericaceae (average 2%) and low but constant presence

of *Viburnum* and *Empetrum*. Tree percentages are low but a varied range of taxa can be found. *Corylus avellana* has the highest values (average 5%, but fluctuating) followed by *Quercus*, *Alnus*, *Betula*, *Pinus* and *Salix*. The microscopic charcoal levels are low but with localised peaks at 160.5cm and 124.5cm

LM28 Ipaz3: 94.5-46.5cm, Poaceae - *Myriophyllum* -Pteropsida

cal AD 1290 - 1320

The pollen assemblage here is very similar to previous zones; the zone is distinguished by the high presence of aquatic pollen taxa. *Myriophyllum* reaches high levels (25%). The shrub and tree taxa maintain similar levels than before with no important changes. The herb taxa are also very similar with small changes, *Hordeum* and *Secale cereale* have higher levels than before, *Hordeum* reaches 4% and *Secale* 2%. The charcoal presence is low but there is an important peak at 64.5cm

LM28 Ipaz4: 46.5-38.5cm, Poaceae – *Rubiaceae*

cal AD 1320- 1370

In this zone Poaceae reaches 95% of the identified taxa, followed by an increase in *Rubiaceae* (*Galium* type) (7%). The shrub and tree presence has fallen considerably, and there are only traces of *Corylus avellana*, *Quercus* and *Calluna* pollen. The aquatic plants have diminished greatly to only small percentages of *Typha*. There is a high amount of microscopic charcoal.

LM28 Ipaz5: 38.5-6.5cm, *Plantago lanceolata* – Poaceae – *Potentilla*

cal AD 1370 - 2000

Plantago lanceolata is the dominant taxon at the base of the zone (57%) but it falls very quickly (4% at the top of the zone), Poaceae increases (from 20% to 60%) and becomes the dominant taxon again. There are percentage increases in some herb taxa such as

Potentilla type (up to 24%) and *Rumex* (13%) and a constant presence of *Chenopodiaceae* (average 3%). Cyperaceae is present at high values at the bottom of the zone (c.31%) but it reduces drastically down to less than 3%. The shrub pollen is still very low, there is an increase of *Calluna* at the bottom which diminishes immediately. Tree taxa are virtually absent although *Pinus* pollen starts to appear at the top of the sequence. Microscopic charcoal levels are low with only a peak at the beginning of the zone.

LM28lpaz6: 6.5-0.5cm, Poaceae – Cyperaceae– *Pinus*

cal AD 2000 - 2010

This zone is similar to the previous zone with some important changes. Poaceae is still the main herb (56%), with some increase in Cyperaceae, *Plantago maritima*, *Hordeum* and *Secale cereale*. The shrubs and tree percentages are still low but *Pinus* increases (up to 5%) in this zone. Charcoal levels are very low.

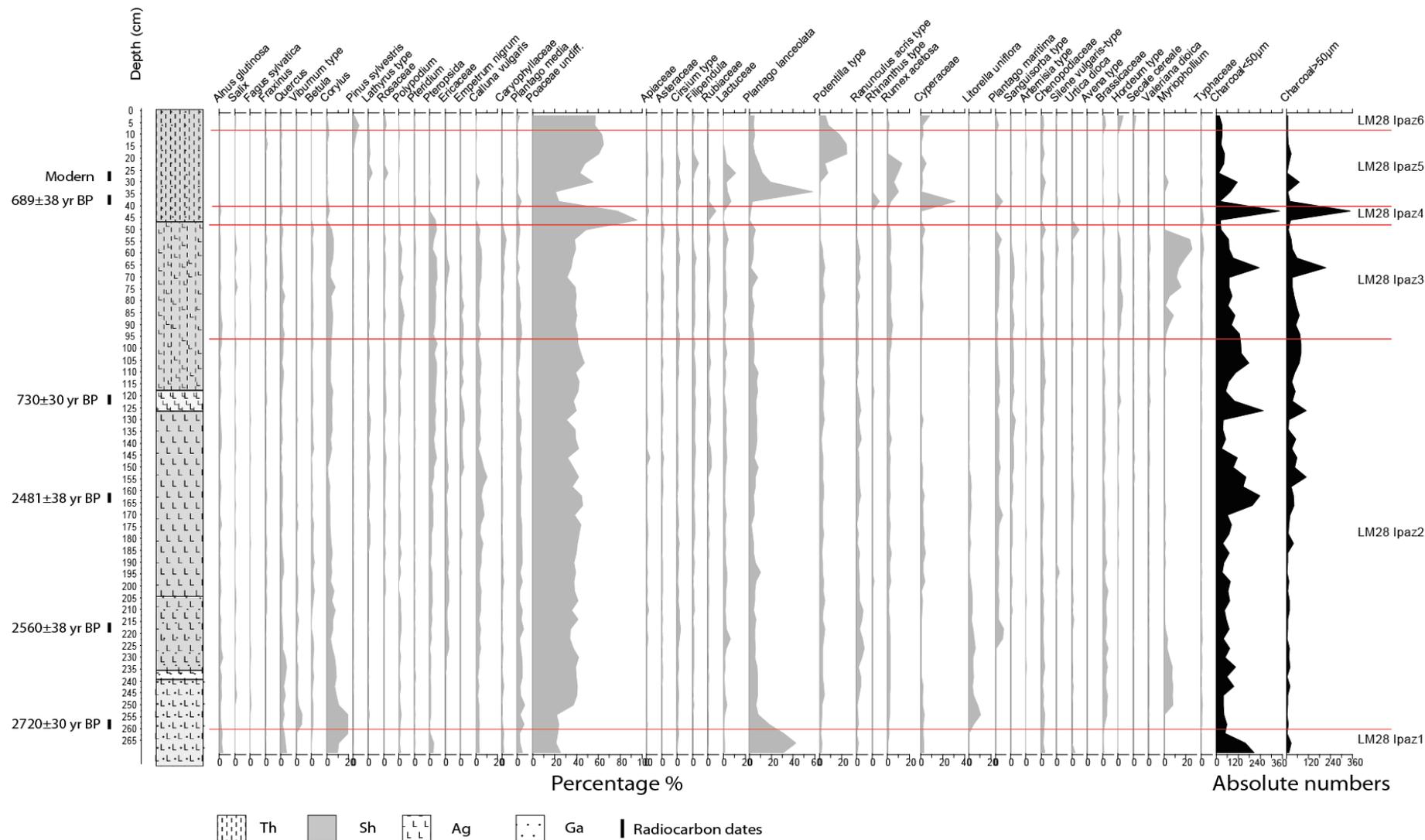


Figure 4.21 Stratigraphy and pollen diagram from LM28, Lower-lower Moors.

4.2.4.5 Summary

The sampling in the lower part of Lower Moors was determined by access to the site and sediment availability. The sample core (LM 28) is the longest continuous stratigraphic (2.75m) sequence, so far, found in Scilly. The chronological model demonstrates that this core provides information about the vegetation and particle size record of Scilly for the last 3000 years. The particle size and LOI diagram shows a stable and continuous sediment input, until more recent periods when clear fluctuations are evident; these may be related to storminess or proximity to the coast. This is very obvious in LM28 Isaz3, 4 and 5, where the organic matter percentages increase drastically whilst all the other sediment fractions reduce considerably, especially coarse and medium silt. The presence of coarse and medium sand is very localised along the core with high peaks in LM28 Isaz2, 3 and 4, these peaks are accompanied by a reduction in organic matter.

The pollen diagram is also very stable with herb-dominated assemblages until recent periods with a marked increase in aquatics between AD 1290-1320 (LM28 Ipaz3). Poaceae is the dominant taxa, but it reduces considerably when *Plantago lanceolata* increase (LM28 Ipaz1 and 5). Tree and shrub taxa are low but constant along the diagram.

4.3 SYNOPSIS

This chapter has shown the results of the application of the GIA-based relative sea-level model of Bradley *et al* (updated), a new GIS-based bathymetric model to create a new paleogeography of the Isles of Scilly. These results show that the Isles of Scilly were a large single mass where important changes were occurring due to increase of relative

sea-level. The palaeogeography model shows that Scilly obtained its present configuration between 1000 and 500 BP.

The stratigraphic results from the survey of Higher and Lower Moors have been presented. A continuous sedimentary sequence spanning the last 2070 years was obtained. Two Lower Moors sequences were recovered spanning the last 3000 years (LM28) and the last 2000 years (LM19).

The results from the laboratory techniques employed in this project: particle size, Loss on Ignition and pollen analysis. These results provide a record of mineral composition, organic matter and vegetation history for the last 3000 years.

The results will be discussed in the following chapters. Chapter 5 will discuss the palaeoecology of Scilly (pollen analysis). Chapter 6 will discuss the palaeogeography of Scilly (results from new sea model and Bathymetry). Chapter 7 will discuss the evidence of storminess in the records (particle size analysis)

5 VEGETATION HISTORY AND CHANGES IN LAND USE IN SCILLY DURING THE LAST 3,000 YEARS

5.1 GENERAL INTRODUCTION

An important aim of this thesis is the reconstructions of the land management and land use of Scilly during the late Holocene: for this reason this section will undertake a critical analysis of the results of the pollen diagrams described in chapter 4. A variety of methodological approaches to transforming pollen count data to estimate past-vegetation changes have been developed over the past 40 years (Fyfe *et al*, 2010a). These approaches varied and some of them include statistical methods (Webb and Bryson, 1972), indicator-species approaches (Behre, 1986; Gaillard *et al.*, 1992) and model-based corrections approaches (Sugita, 2007). The approach used in this thesis is the second option; this approach was widely discussed and developed by Berglund (1991). The vegetation is described by taking the ecological requirements of the individual species as a starting point so the species groups that are ecologically defined can be used to identify specific ecotopes (Cappers and Neef, 2012). It relies on the modern ecology of species; that is the indicator values of species in terms of environmental characteristics such as soil properties, climate temperature, humidity and human induced factors including deforestation, cultivation, grazing and mowing (Birks, 2007; Gaillard, 2007).

The indicator species approach allows the division of the vegetation in groups where anthropogenic activities can be inferred. In this study, the pollen indicators are grouped into categories of human induced vegetation as a basis for percentage calculation of groups of pollen types that can be displayed in a so-called 'human impact pollen diagram' (Berglund, 1991; Gaillard, 2007). In this project the taxa were grouped following Gaillard (2007) and adapting the groups and taxa to the environment of Scilly using Rodwell *et al*

(2003) NVC. Table 5.1 shows the vegetation groups found today in Scilly and the equivalent pollen taxa found in this study.

Table 5.1 National Vegetation communities from Scilly according to Rodwell, *et al.* (2003) with the constant and associated taxa and the equivalent pollen taxa found in this study.

Rodwell NVC from Scilly	Rodwell constant taxa	Rodwell other taxa associated	Equivalent pollen taxa (found in this study)
M23 Mires	<i>Galium palustre, Holcus lanatus, Juncus effusus/acutiflorus, Lotus uliginosus</i>	<i>Cirsium palustre, Rumex acetosa, Angelica sylvestris, Ranunculus acris, R. repens, Hydrocotyle vulgaris, Viola palustris</i>	Rubiaceae, Lotus, Rumex acetosa, Ranunculus acris-type, Hydrocotyle.
H8/11 Heaths	<i>Calluna vulgaris, Erica cinerae, Ulex gallii, Carex arenaria</i>	<i>Potentilla erecta, Galium saxatile, Polygala, Rumex acetosella, Jasione montana, Plantago maritima</i>	<i>Calluna vulgaris, Empetrum</i> , Ericaceae undiff, Cyperaceae, <i>Potentilla</i> type, Rubiaceae, <i>Polygala, Rumex acetosella, Plantago maritima</i> .
U1/4 Grassland communities	<i>Agrostis capillaris, Festuca ovina, Rumex acetosella, Anthoxanthum odoratum, Festuca ovina, Galium saxatile, Potentilla erecta</i>	<i>Astragalus danicus, Dianthus deltoide, Lychnis viscaria, Scleranthus perennis, Silene conica, Plantago lanceolata, P. coronopus, P. media, Taraxacum, Galium verum, G. saxatile, Rumex acetosa, Ranunculus acris, Cirsium vulgare, C. arvense, Sanguisorba minor, Trifolium repens, Cerastium fontanum, Campanula rotundifolia, Lotus, Succisa pratensis, Lathyrus montanus.</i>	Poaceae, Rumex acetosella, Rubiaceae, <i>Potentilla</i> -type, Caryophyllaceae, <i>Plantago lanceolata, P. media</i> , Asteraceae, Rumex acetosa, Ranunculus acris type, Cirsium type, Sanguisorba type, Trifolium type, Campanula type, Lotus, Succisa pratensis, Lathyrus type
SD1/4/6/8 Shingle, Strandline and sand-dune communities	<i>Glaucium flavum, Rumex crispus, Elymus farctus spp boreali-atlanticus, Ammophila arenaria, Festuca rubra, Galium verum, Lotus corniculatus, Plantago lanceolata, Trifolium repens</i>	<i>Silene vulgaris, Beta vulgaris, Cirsium arvense, C. vulgare, Sonchus, Geranium, Sedum, Potentilla anserina, Rumex crispus, Taraxacum, Cerastium, Arteminis maritima, Polygonum, Ranunculus repens, Heracleum sphondylium, Rubus fruticosus, Calystegia soldanella, Astragalus, Dianthus deltoides, Primula scotica, Plantago maritima, Primula vulgaris, Prunella vulgaris, Trifolium Rhinanthus minor, Gentianella, Cerastium, Rumex acetosella, Polygala vulgaris, Vicia cracca, Salix repens, Rosa pimpinellifolia</i>	Caryophyllaceae, Chenopodiaceae, Cirsium, Asteraceae, Lactuceae, <i>Potentilla</i> -type, <i>Artemisia</i> type, Apiaceae, Rubus indeff., Rosaceae, <i>Plantago maritima</i> , Gentianaceae, Rumex acetosella
M5/10 Maritime cliff communities	<i>Armeria maritima, Plantago coronopus, Festuca rubra, Cerastium diffusum, Sedum spp, Festuca rubra, Plantago lanceolata, P. maritima, Agrostis stolonifera.</i>	<i>Allium, Astragalus, Brassica olearaceae, Centaurea capitatum, Lotus, Trifolium, Sagina apetalata, Primula scotica, Gentianella, Rumex acetosa, Empetrum nigrum.</i>	Poaceae, Caryophyllaceae, Brassicaceae, <i>Plantago lanceolata, P. maritima, Lotus, Trifolium, Sagina, Primula veris</i> -type, <i>Gentianella campestris</i> -type, Rumex acetosa, <i>Empetrum nigrum</i> .
OV2/6 Arable weeds and track-side communities	<i>Anagallis arvensis, Briza minor, Rumex acetosella, Silene gallica, Trifolium dubium, Cerastium glomeratum, Fumaria muralis, Juncus bufonius, Senecio vulgaris, Sonchus asper.</i>	<i>Briza minor, Trifolium, Vicia sativa, Rumex acetosella, Geranium molle, Allium, Veronica arvensis, Sagina apetalata, Fumaria bastardii, Convolvulus arvensis, Papaver dubium, Heracleum sphondylium, Chenopodium album, Trifolium repens, Sagina procumbens, Urtica urens.</i>	Poaceae, Rumex acetosella, Caryophyllaceae, Asteraceae, <i>Sagina</i> , Apiaceae, Chenopodiaceae.
S12 Swamps and tall-herb Ferns	<i>Typha latifolia</i>	<i>Cicuta virosa, Lemna minor, Solanum dulcamara, Galium palustre, Juncus effusus, Urtica dioica, Callitriche stagnalis, Apium nodiflorum, Carex rostrata, Hydrocotyle vulgaris, Caltha palustris, Potamogeton.</i>	Thyphaceae, Potamogetonaceae, <i>Urtica dioica</i> , Cyperaceae, <i>Hydrocotyle, Caltha palustris</i> -type.

It is important to establish that the some pollen taxa can be attributed to different environments, for example many herb pollen types regarded as anthropogenic indicators such as *Rumex*, Brassicaceae, Asteraceae, Apiaceae, *Ranunculus* and *Urtica*, can also

be found in wetland vegetation (Waller, 1993) and as part of grassland communities, sand dunes communities and arable weeds (Rodwell *et al*, 2003). To avoid these problems, the vegetation groups are interpreted together in order to find associations between them to make sure that the changes in vegetation are interpreted correctly. For example, it can be assumed that a pastoral-type episode would be indicated by pollen spectra displaying high Poaceae and *Plantago lanceolata* values with an absence of cereals, and reduced values for arable weeds and woodland taxa (Buckland and Edwards, 1984). Also the taxa will be grouped combining Gaillard (2007) and the modern ecological conditions (Rodwell, *et al*, 2003). It is difficult to ascribe taxa that can be found in various ecosystems to one specific group. For example Chenopodiaceae is commonly used as a salt-marsh indicator but in Scilly there are no extant salt marshes and it is included in the sand dune communities and arable weeds (Rodwell, 2003). Gaillard (2007) includes Chenopodiaceae also within the ruderal communities, so in this project it is included with the arable communities (see Appendix I). The major issue occurs with herbs and grass that can be found in various environments (such as *Potentilla*, Asteraceae, Lataceae, Brassicaceae *etc.*). In this case these herbs are assigned to the groups where they are part of the dominant species. The groups have been named according to their ecological characteristics and paying special attention to the ecology around the sampled sites and the possible origin of the pollen. The trees and forest herbs and ferns have been grouped according to Gaillard (2007). The group Heaths and Sand dunes communities include pollen taxa from shrubs and plants that can be found in the dunes in Scilly close to the sampled sites and shrubs from heaths. The group Pastures and grassland includes the pollen taxa from plants found in fresh meadows, rush pastures and communities of open habitats in general. Ruderal communities group includes arable weeds and track side communities. Cultivated land group, as it names indicates, includes cereals and cultivated plants. The Maritime communities include pollen taxa from plants that are salt-tolerant and influence by marine conditions, as the sampled sites are close to the coast. The last group include the pollen taxa of plants that can be found in aquatic environments.

A list detailing which taxa has been ascribed to each group in this thesis can be found in Appendix I.

It is important to determine the origin of the pollen and charcoal of the studied sites. As previously determined these sites (Higher and Lower Moors) are small basins located closer to the coast. These were also fresh water lakes at some point in time in consequence the pollen received was predominantly wind-transported and well-mixed from the air, representing the regional vegetation (Jacobson and Bradshaw, 1981). A major advantage of focusing in small scale studies is that it is possible to relate reliably past changes in species composition and structure to external factors causing the changes such as fire, human disturbance and storms in vegetation dynamics (Seppä, 2007).

5.2 HIGHER MOORS

The age depth model for HM16 provides a basal age for the palaeoecological record of *circa* 2110 cal BP (160 cal BC), around the end of the Iron Age. At this time the pollen data (HM16 lpaz1: Fig. 5.1) indicate a predominantly pastoral landscape (dominated by *Poaceae* and *Plantago lanceolata*) with very low percentages of trees, forest herbs and ruderal communities. HM16 lpaz1 shows a change in the landscape beginning around 2030-2020 cal BP (80 - 70 cal BC). The pasture land reduces greatly whilst the presence of trees notably increases, with an increase in forest herbs and ferns. These changes occur after a slight peak in microscopic charcoal and a change in sedimentology (from a sandy peat to a more organic peat). Whilst this episode may imply some woodland expansion, the percentages are still very low. This indicates that the landscape was still mainly an open area with some trees in the vicinity.

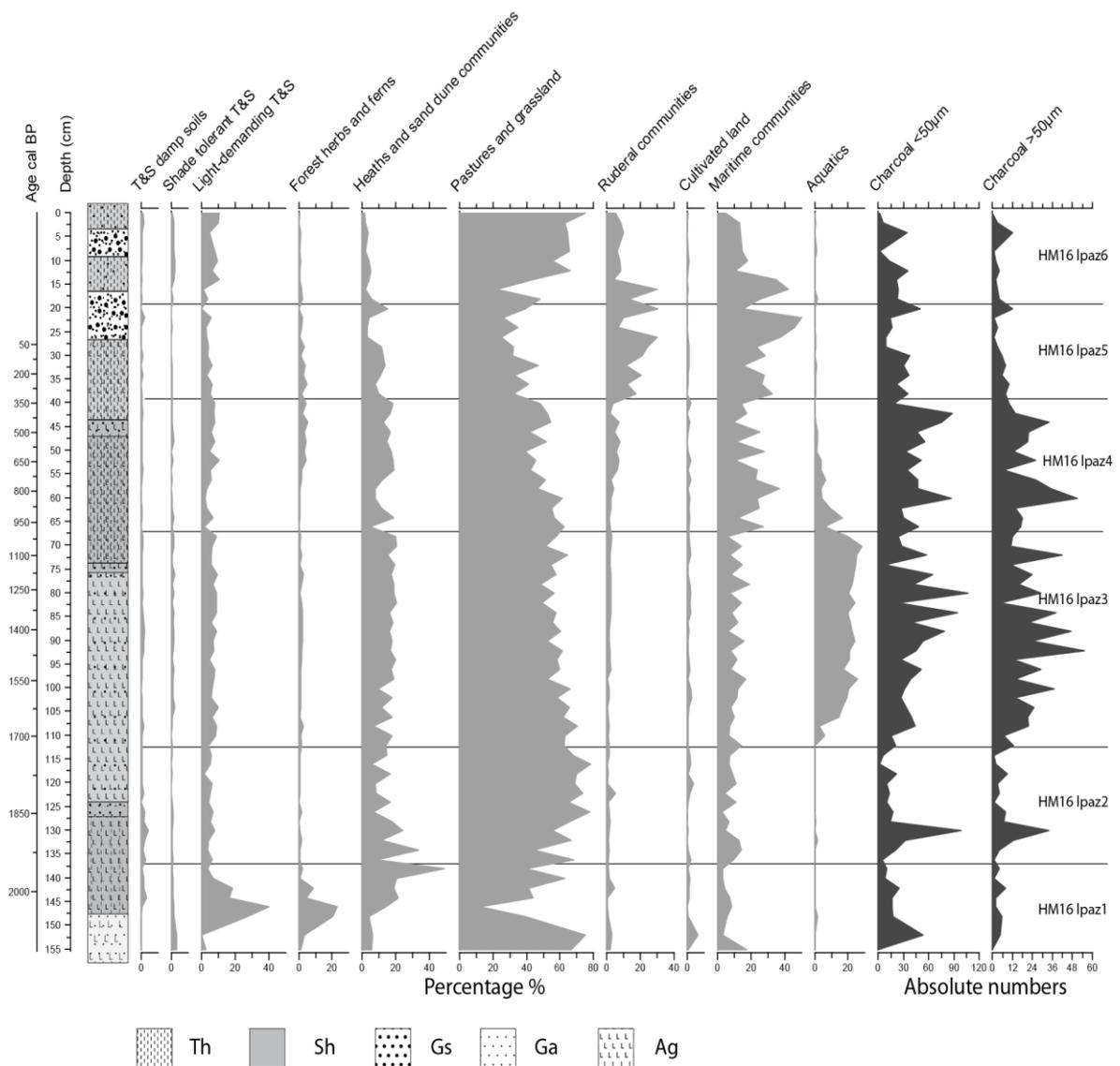


Figure 5.1 HM16 Human impact pollen diagram, charcoal and lithology. Pollen taxa are allocated to groups following Gaillard (2007) and Rodwell (*et al*, 2003).

The pollen record does not directly reflect plant abundance because some taxa are overrepresented and others underrepresented in pollen assemblages (Seppa, 2007).

Trees and some shrubs, such as *Calluna*, are overrepresented in pollen diagrams whilst herbs (such as *Apium* and *Prunella*) and cereals may be present in the vegetation but recorded in low frequencies or even absent in diagrams (Bröstrom *et al.*, 2008; Hjelle, 1999; Randall *et al.*, 1986). At Higher Moors the forest herbs and ferns are represented mainly by *Polypodium* and Pteropsida (HM16 lpaz1: Fig. 4.9). High values of Pteropsida could suggest that ferns were abundant (Gearey *et al.*, 2000). Although *Polypodium* has

been used to indicate the former presence of oak (Bradshaw, 1981) this fern also occurs in open habitat conditions, and its presence can be alternatively interpreted as indicative of open land with only limited grazing (Caseldine and Maguire, 1981). Reduced grazing pressure may result in the expansion of heath taxa and some shrub colonisation, including high pollen producers such as *Calluna* and *Corylus avellana* (Bröstrom *et al.*, 2008). This would alter absolute pollen loadings, which in turn impacts significantly on pollen proportions (Fyfe, 2006). It seems reasonable to suggest that the decrease in pasture, cultivation and ruderal taxa, at the middle of HM16 Ipaz1, reflects a reduction in farming activity, decreased grazing pressure and development of heathland and shrubs during this period.

At around 2020 cal BP (70 cal BC) the landscape around Higher Moors appears to change again. The fresh meadow and pasture assemblage recovers. Increases of *Plantago lanceolata*, Poaceae and other herbs may point to an expansion of pastures (Berglund, 1991). The decline in tree taxa around this time coincides with a peak in micro charcoal; it is possible that fire may have been used to assist in the process of re-opening for grazing areas of hazel and shrub in the more marginal parts of the landscape (Dark, 2005).

Around 1960-1950 cal BP (10BC and AD1), another vegetation change is noticeable in HM16 Ipaz1 (Fig. 5.1). The heaths and sand dune communities increase whilst the other groups reduce considerably. The pollen record shows an increase in heather pollen with still high values in the pastures and grassland, these features would be consistent with pastoral land use and also suggest some impoverished soil conditions (Edwards *et al.*, 2005a). The soils of Scilly are eroded granite (Scourse *et al.*, 2006) and are already quite poor so grazing or cultivation pressure will have had a negative effect on them. The intensification of pasture, deduced from the previous pollen assemblage, may have reduced the quality of the soils, favouring the expansion of heather.

In HM16 Ipaz2 (Fig. 5.1) from 1950 cal BP (cal AD1) there is an increase in the pastures and grassland group which may indicate that locally grasslands expanded at the expense of the previous heath cover (Hjelle *et al.*, 2012). There is also an increase in taxa associated with grazing (Fig. 4.9), including: *Galium*, *Succisa*, *Cirsium* and *Cyperaceae* (Hjelle, 1999). These changes started at the end of the Iron Age and extended into the Romano-British period and Early Medieval period. This core shows that from the early Romano-British period the landscape in Scilly around this area was mainly grassland with important variations through the period in the presence of heaths, with a significant increase in the aquatic taxa, and maritime communities by the end of this period. The aquatic plant taxa are more numerous between 1710 and 1000 cal BP (cal AD240 – 950), HM16 Ipaz3 (Fig. 4.10). The high presence of *Myriophyllum* is indicative of a body of fresh water with floating-leaved and submerged macrophytes (Gaillard & Göranson, 1991). There is cartographic evidence dated to 1585 showing Higher Moors and Lower Moors with areas of fresh water and marsh (Scaife, 1984). This core provides evidence that Higher Moor had previously been a lagoon or lake. After 1000 cal BP (cal AD950), HM16 Ipaz 4 (Fig. 5.1), the aquatic taxa reduced considerably while the salt meadows taxa increased. The significant occurrence of *Cyperaceae* and *Poaceae* after the reduction of aquatic pollen, could suggest the presence of marsh/fern vegetation communities (Bunting and Tipping, 2004), perhaps encroaching into the previous water body. The *Cyperaceae* and *Poaceae* pollen taxa include many species whose members occur in a wide range of environments including wetlands. The coastal location of the core makes it difficult to determine if taxa are responding to changes in the height of the water-table (due to relative sea rising) or due to anthropogenic activities (Waller, 1993; 1998; Waller and Hamilton, 2000). Continued land use is clear from archaeological and documentary sources from this period.

A number of changes occurred in the Higher Moors landscape from 340 cal BP (cal AD1610), HM16 Ipaz 5 (Fig 5.1). Maritime communities are still increasing and becoming dominant but the most important change is the noticeable increase in ruderal taxa

(Chenopodiaceae and *Anthemis*). High frequencies of Poaceae, Cyperaceae and typical salt marsh species, including *Plantago maritima* and Chenopodiaceae (Fig 4.10) imply a regularly inundated surface or gully close to the tidal flat and the development of saltmarsh conditions close to the site (Long *et al.*, 1996). There is no other evidence in this core for salt-marsh conditions (no foraminifera have been found), so it is possible that these plants were growing here due to the proximity of the site to the sea (Hirons and Edwards, 1990; Lespez *et al.*, 2010). There is a third alternative explanation for the presence of Chenopodiaceae. Chenopodiaceae are a large family and some of its members are indicative of arable agriculture (Edwards, 1985). This interpretation may be supported by the slight increase in cultivated pollen taxa at this time. From -20 cal BP (cal AD 1970), HM16 Ipaz6 (Fig. 5.1) the vegetation is dominated by pastures and grassland, with a slight increase in light-demanding trees, mainly *Pinus*. Historical evidence indicates that these were planted in Scilly around the 1950s (Lousley, 1971).

Overall HM16 shows an open grassland landscape since the Late Iron Age until modern times, with some changes in the vegetation probably caused by relative sea-level changes and changes in the intensity of land management.

5.3 DUCK'S POND (LOWER MOORS)

The age depth model for LM19 provides a basal date for the palaeoecological record of around 2010 cal BP (60 cal BC), close to the end of the Iron Age and the beginning of the Romano-British period in Scilly. LM19 Ipaz1 (Fig. 5.2) shows a landscape highly dominated by fresh meadows and pastures taxa with some heathland and an increasing presence of ruderal and cultivated taxa.

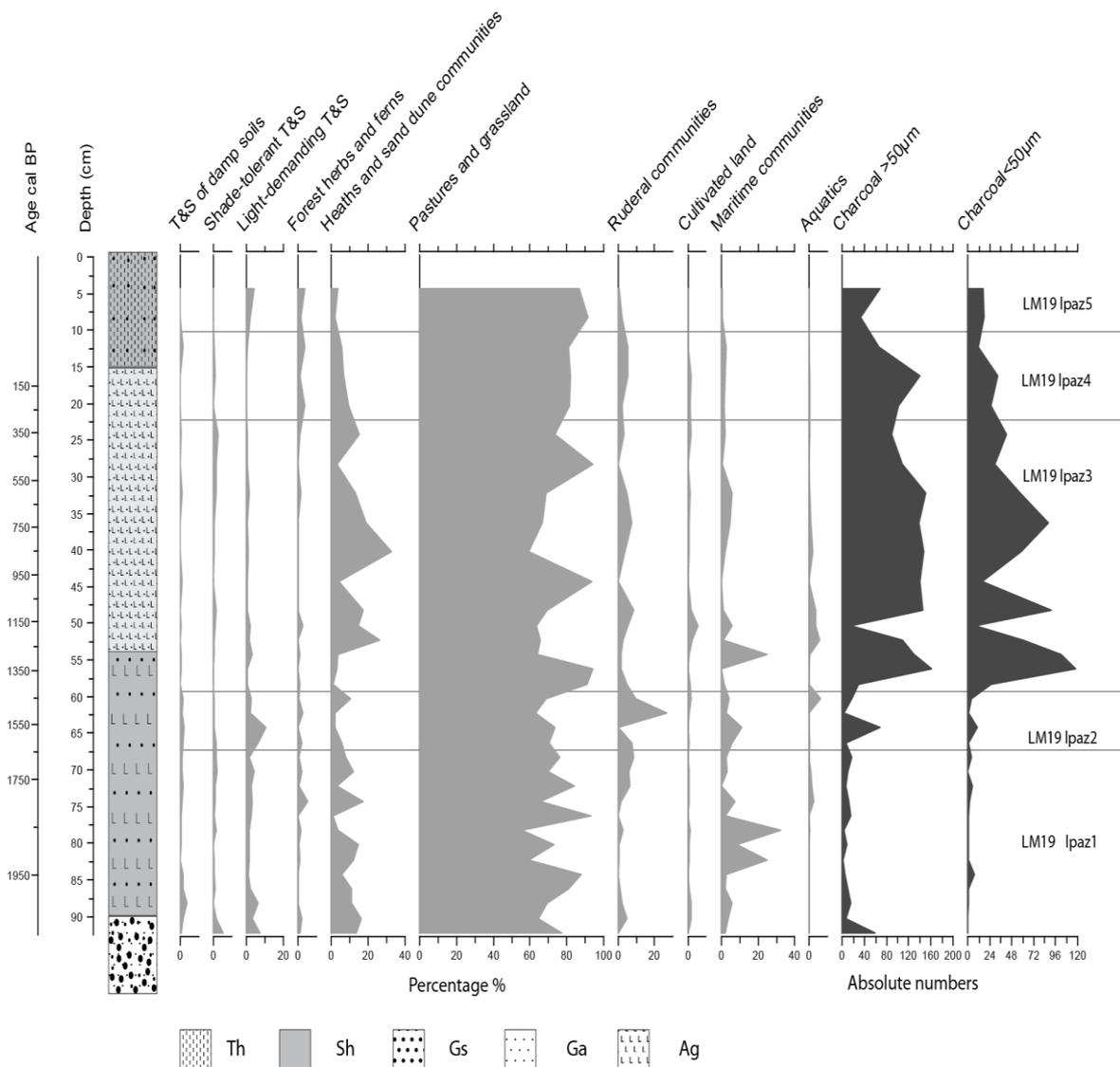


Figure 5.2 LM19 Human impact pollen diagram, charcoal and lithology. Pollen taxa are allocated to groups following Gaillard (2007) and Rodwell (*et al.*, 2003).

Evidence points to the prevalence of pastoralism in this area, with some cultivation in the environs of the site. Some of the herb taxa identified such as Apiaceae, Brassicaceae, Caryophyllaceae, *Ranunculus* type and *Rumex* (LM19 lpaz1: Fig 4.15) are derived from open habitats. In Late Holocene sequences they are regarded as being associated with human activity (Waller *et al.*, 2005). In line with Gaillard (2007) and Rodwell (*et al.*, 2003) some of these herbs are included in the ruderal communities; in this case this is reinforced by the presence of cultivated taxa. To aid in the interpretation of vegetational changes as a consequence of human activities a distinction is made between primary and secondary

anthropogenic pollen indicators. Primary anthropogenic pollen indicators are economic plants, including crops; secondary anthropogenic indicators are plants associated with cultivation, typically weeds (e.g. *Chenopodiaceae*, *Apiaceae* etc.) which seem to increase in number with the development of agriculture (Cappers and Neef, 2012). The presence of these weeds is significant when their representation increases in the pollen diagram at the same time as cereal taxa, particularly as cereals are self-pollinating and poorly represented in pollen diagrams (Vuorela, 1973). Caution must be taken in the identification and interpretation of cereal pollen as large Poaceae grains allocated to cereal categories could include wild grasses, especially in coastal wetland (Waller and Grant, 2012). In this case the presence of other taxa attributed to anthropogenic activities (such as *Plantago lanceolata* and *Rumex*) reinforces the interpretation of large grasses as cereals. From the late Iron Age until the Early Medieval period, this area was predominantly pastures and grassland with some heathland and almost no woodland cover (LM19 Ipaz1 and 2: Fig. 5.2).

At around 1430 cal BP (cal AD520) there is a change in the vegetation (LM19 Ipaz3: Fig. 5.2). There is an increase in the presence of maritime communities and, although there is a slight reduction in the presence of pastures and grassland, their continued dominance suggests that animal grazing conditions were maintained at a high level. Pastoral use of the land is also indicated by the presence of *Potentilla* (LM19 Ipaz3: Fig. 4.15) whose growth can be encouraged by grazing (Blackford *et al.*, 2006); and by the noticeable expansion of *Galium*, commonly present in hay meadows but a taxa that reaches its highest pollen percentages in grazed sites (Hjelle, 1999). At *circa* 1200 cal BP (cal AD 750), LM19 Ipaz3 (Fig 5.2), pastures taxa became dominant again whilst the maritime communities reduced considerably. At this time there is also an increase in heathland, sand dune communities, ruderal communities, and cultivated land, all accompanied by a rise in microscopic charcoal, implying that fire becomes part of land management practices. Fire and heath have a positive relationship, in this case the burning of the landscape, probably to improve the palatability of the vegetation for stock, will encourage

the spread of heathland (Dodson and Bradshaw, 1987). These observations (increase of grassland, heath, ruderal and cultivated taxa) are consistent with pastoral land use and with cultivation. Such features in Shetland have been interpreted as an economy where much land would have been used for grazing, and where grazing and access to the sea would have been more important than arable cultivation (Edwards *et al.*, 2005a).

The landscape around this area of Lower Moors continued to be dedicated to grassland and pasture until modern times. The only change occurs around cal AD1650 (300 cal BP), LM19 Ipaz4 (Fig 5.5), when there is an important decline in heath but a slight increase in ruderal and cultivated taxa. Increases in herbs such as *Rumex*, *Succisa* and *Potentilla* type (LM19 Ipaz4: Fig 4.15) suggest some disturbance pressure and may indicate relatively intensive grazing of wet grassland pastures (Innes and Blackford, 2003).

Nowadays, this area of the Lower Moors is a protected zone and it is managed by the Scilly Wildlife Trust. Grazing is used as a tool to control the vegetation. It is assumed that this is what is reflected at the top of this pollen diagram. In conclusion, this area around Lower Moors has been pasture land at least since the Late Iron Age, with evidence of constant cultivation around the environs of the site.

5.4 LOWER-LOWER MOORS

The age-depth model for LM28 (Fig. 5.3) provides a basal age for the palaeoecological record *circa* 2860 cal BP (910 cal BC), around the end of the Bronze Age in Scilly. This landscape is characterised by open grassland, with grassland and pastures dominating the pollen assemblage and little evidence of ruderal and cultivated land (Fig. 5.3, LM28 Ipaz1). This pollen diagram (Fig 4.20, LM28 Ipaz1) also shows some limited woodland cover, largely *Corylus avellana* (hazel) and some *Quercus* (oak), with *Corylus avellana* increasing *circa* 2820cal BP (870 cal BC). This increase in tree pollen may be misleading and it cannot necessarily be interpreted as woodland regeneration or even expansion of woodland. Modern studies using pollen reconstruction modelling have proved that tree

pollen production would obscure herb taxa presence in palaeoecological diagrams (Nielsen *et al.*, 2012) presenting a larger wood cover than potentially existed. In consequence the landscape here remains largely open with some trees in the area and it continues without major changes until *circa* 400 cal BP (cal AD1550), Fig 5.3, LM28 lpaz1, 2, 3 and 4.

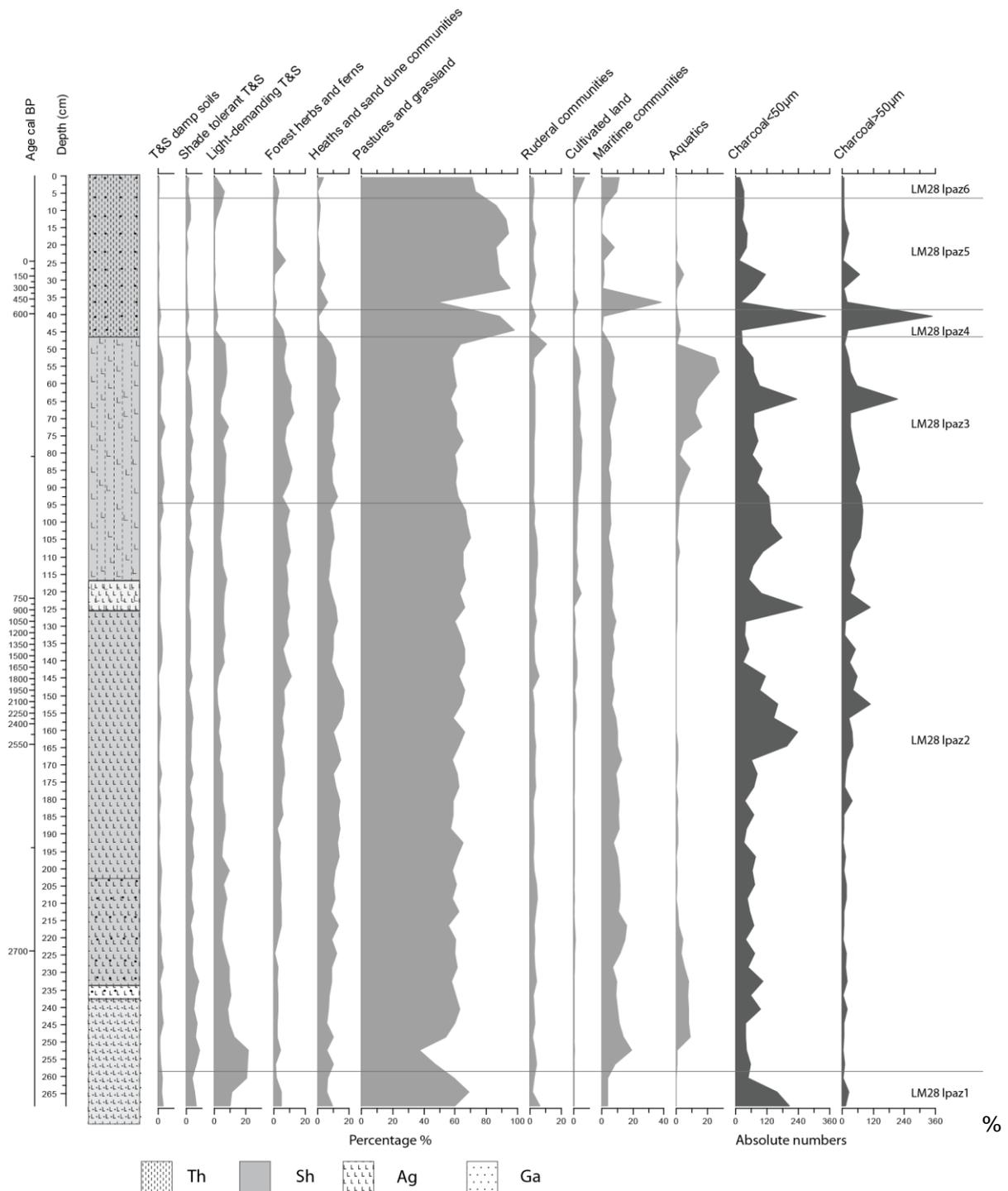


Figure 5.3 LM28 Human impact pollen diagram, charcoal and lithology. Pollen taxa are allocated to groups following Gaillard (2007) and Rodwell (*et al*, 2003).

There is continuous dominance of pastures and grassland with a constant presence of ruderal communities, cultivated plants and heathland, indicating an intensively managed landscape. As previously discussed, cultivation taxa are always underrepresented in the pollen diagrams and there are some issues with in the distinction between wild grasses and cereals. In the Lower Moors diagram *Hordeum* is indicative of cultivation, along with other taxa such as *Avena* type, *Secale cereale* and *Valeriana* (following Gaillard, 2007; Appendix I). These taxa together with *Plantago lanceolata* (commonly associated with pasture land) and other herbs such as Lactuceae, *Ranunculus*, *Artemisia* and *Rumex* (Fig 4.21), can be indicative of pastoral and arable cultivation close to the site (Dark, 2006; Gearey *et al.*, 2009). Although the landscape appears to be stable until the Medieval period there are some subtle changes. Around 2710 cal BP (760 cal BC) there is a noticeable decrease in the presence of tree and forest herbs, whilst the other groups increase, specifically ruderal and cultivated taxa (*Avena- Triticum*, *Hordeum* and *Secale cereale*; LM28 lpaz2: Fig. 5.3). The presence of *Avena- Triticum* pollen, given the poor dispersion of cereal pollen, verifies the presence of arable agriculture, at least nearby (Waller and Grant, 2012). There is evidence that England, and of course Scilly, have been densely cultivated from the Bronze Age onwards and the cereals grown included both glume wheat (*emmer* and *spelt*) and free-threshing cereals such as bread wheat and barley (Van Der Veen and Jones, 2006). Not only are cereals evidence of cultivation, it is also very likely that some Poaceae and Brassicaceae pollen grains originated from cultivated plants (Lespez *et al.*, 2010). A constant curve of *Hordeum* may not necessarily reflect arable cultivation because it could indicate on-site wet grass communities (Fyfe *et al.*, 2004). However, when considering the whole assemblage (in this case accompanied by *Secale cereale* and *Avena- Triticum*, whilst wet communities decrease) it seems more likely that they are part of the cultivated taxa. Plant remains from archaeological sites have proved that a range of crops (e.g. barley, emmer wheat and celtic bean) were grown

during the Bronze and Iron Age in Scilly (Ratcliffe and Straker, 1997). There is another noticeable increase in cultivation taxa around 2000 cal BP (50 cal BC) and a small increase in heathland whilst the pastures and grassland decrease slightly (LM28 lpaz2: Fig 5.3).

LM28 shows little change in the landscape between 1890 and 660cal BP (60cal BC to cal AD 1290) suggesting continuity and stability in the land use (pastoral and arable) of this area of the Lower Moors (LM28 lpaz2: Fig 5.3). This supports the general concept of stability in rural southwest England from the Late Iron Age to the Medieval period, as reflected in the cultural record there is little evidence of domestic Roman presence or any impact of Roman culture on land management through Devon and Cornwall (Fyfe *et al.*, 2003a). The predominance of fresh meadows and pastures was still evident until modern times, with a lapse around 500 cal BP (cal AD1450), LM28 lpaz5: Fig 5.3, when maritime communities became dominant for a short time. After a period without evidence of agricultural taxa since 630 cal BP (AD1320) LM28 4: Fig 5.3, there is an increase in cultivated pollen at the end of the twentieth century (LM28 lpaz6: Fig 5.3). Trees were nearly absent until the twentieth century, when *Pinus* is planted. This area is managed by the Scilly National Wild Trust and the vegetation is controlled by seasonal grazing. This is probably reflected in the pollen diagram by the increase in *Potentilla* (LM28 lpaz 5 and 6: Fig. 4.20). This taxon has been associated with grazed sites and is indicative of traditional management (grazing) of hay meadows today (Hjelle, 1999).

The high values of *Myriophyllum* (LM28 lpaz2 and lpaz3: Fig. 4.21) imply a lake or body of fresh water on Lower Moors between 2780 – 2690 cal BP (830 and 730 cal BC) and between 660 - 630 cal BP (cal AD1290 -1320) This is further supported by Lousley (1971), who maintains that Lower Moor has been a lagoon at times. Overall, LM28 presents an open and largely managed landscape since the Late Bronze Age until the modern era. The landscape was mainly pastoral and arable, with some localised changes over time due to anthropogenic management and environmental changes.

5.5 SYNTHESIS

Palynological data has been used to infer both local vegetation changes and changes in the major vegetation patterns from each of the three new sites used in this thesis. By combining pollen diagrams from several sites within a region, as has been done here, it is possible to reconstruct a detailed local vegetation history and identify the human impact on the vegetation on different spatial scales (Fyfe *et al.*, 2003a; Hjelle *et al.*, 2012). The three pollen diagrams overlap for the period from the 1st century AD to modern times with LM28 going back even further to the 1st millennium BC; together they offer a picture of the landscape in the area for the last 3000 years. These pollen diagrams suggest that the landscape of Scilly has been an open one, managed for both pastoral and arable agriculture since the Bronze Age. Summaries of the changes in vegetation observed in the cores under discussion from Scilly can be seen in table 5.2.

It appears that in all three pollen sequences (Higher and Lower Moors) the herbaceous vegetation responded in various ways, probably depending on grazing pressure, intensification in the agriculture and climate. Variable evidence for pastoral farming was obtained from the three pollen profiles. From the Late Bronze Age and through the Medieval and Post-Medieval period the agricultural system around Higher and Lower Moors appears to be pastoral, with continuity in the landscape of very open conditions and without phases of scrub or woodland regeneration indicating any reduction in the intensity of land management.

This environmental evidence from Scilly shows similarities to the landscape of Cornwall and Devon during the last 3000 years. The same tree clearance and management landscape that occurs in Scilly can be observed in mainland Cornwall and Devon. Here

the evidence is quite fragmentary but in general there is a steady decrease in mixed oak woodland from the beginning of the first millennium BC, and indeed earlier. Whilst open country conditions with hazel-dominated woodland became established, particularly in the coastal areas, some parts of Cornwall were still heavily wooded but with open grassland spreading (Christie, 1986). An example of early clearance on Cornwall can be seen in Stannon Down, St Breward. Archaeological and environmental investigations showed evidence of human impact on the vegetation during the Neolithic with extensive clearance during the Bronze Age, widespread of grassland (Jones, 2004). More evidence of clearance in Cornwall is visible in the palynological record from Rough Tor, Bodmin Moor, with the tree taxa start to fall during the Neolithic period and evidence of grassland and pastoral use of the land from the Bronze Age onwards (Gearey *et al*, 2000b). An example of clearance in Devon can be seen in Shovel Down, on northeast Dartmoor, which shows that around 1480 cal BC the landscape was already being transformed into a rich grassland (Fyfe *et al.*, 2008). Equally, pollen assemblages from four sites in lowland Devon have evidenced an open pastoral Bronze/Iron Age landscape (Fyfe *et al.*, 2004). Similarly to Scilly, by the Iron Age this landscape became very stable and was without major changes until at least the medieval period.

Table 5.2 Summary of the main vegetation zones on the Scillies including results from this study (LM28, LM19 and HM16) and from other dated sequences: HM and LM (Scaife 1980, 1981 and 1984), Porth Mellon (LPOT1) and St Agnes (LPSA1) (Charman *et al*, forthcoming).

Periods	LM28	LM19	HM16	Scaife HM	Scaife LM	LPOT1	LPSA1
Post Medieval/Modern: 17th-21st century	Pastures and grassland	Pastures and grassland	Pastures and grassland				Pastures and grassland with maritime communities
Medieval: 1485-17th C.			Maritime and ruderal communities				
Middle Ages: 1066-1485	Maritime communities	Pastures, grasslands and maritime communities	Pastures and grassland	Pastures and grassland with important presence of forest herbs, ferns and maritime communities		Pastures and grassland landscape	
Early Medieval: 410-1066							
Romano-British: AD43-409	Pastures and grassland	Pastures and grassland	Heath with pastures and grassland.		Pastures and grassland, important maritime communities		
Iron Age: 800BC- AD43			Pastures and grassland landscape with heaths and sand dune communities				
			Increasing amounts of forest herbs and ferns, heaths and sand dunes communities. Slight increase of shrubs (<i>Corylus</i>)				
			Pastures and grassland				
Bronze Age: 2500BC-800BC	Maritime communities		Pastures and grassland with important maritime communities				
	Pastures and grassland		Forest herbs and ferns dominated the landscape, with important presence of pastures and grassland				
Neolithic: 4000BC-2500BC			Woodland dominated with forest herbs and ferns and maritime communities nearby.				

5.5.1 From woodland to open landscape in Scilly

The three cores studied here cover the last 3000 years of vegetational change in Scilly, showing an open, managed landscape. However there is evidence from previous records that Scilly could have been heavily wooded at some time in the past prior to these records. The presence of prehistoric woodland in Scilly is demonstrated by pollen samples for various areas (Fig 2.10): Higher and Lower Moors (Scaife, 1984), Innisidgen (Dimbleby, 1977), Nornour (Butcher, 1978) and Par Beach and Porth Mellon (Ratcliffe and Straker, 1996). Furthermore evidence of early woodland in Scilly can be found in two pollen diagrams from St Mary's Road and a pollen diagram from Porth Hellick (Charman *et al.*, forthcoming). All of them show a wooded landscape, mainly dominated by *Quercus*, *Corylus avellana* and *Betula* from the early Holocene up to *circa* 4000 cal BC. Scaife (1981) pollen assemblage from Higher Moors (Fig. 5.4) provides environmental information about the periods before the Bronze Age in one of the studied areas. Scaife's diagram shows that *circa* 4310 cal BC the vegetation in Higher Moors was primarily a deciduous forest, dominated mainly by *Corylus avellana*, *Ulmus* and *Quercus* with *Betula* playing an important role, very few herb taxa and no evidence of cultivation or ruderal communities. The same pollen diagram shows that by 1520-1170 cal BC the tree taxa start to decrease (slightly) but still are dominant in the pollen assemblage, particularly *Corylus avellana*. At this time herb taxa indicative of pastures and grassland start to increase but there is little evidence of cultivation or ruderal species.

It is worth mentioning that these taxa (*Corylus avellana*, *Ulmus*, *Quercus* and *Betula*) are high pollen producers (Bröstrom *et al.*, 2008). Highly pollen producing trees would suppress non arboreal pollen, affecting the way in which openness of the landscape is reflected (Nielsen *et al.*, 2012). Modelling approaches of pollen reconstruction have concluded that the human impact and openness of the landscape is usually much larger than could be concluded from pollen percentages (Soepboer *et al.*, 2010). Even so, there is evidence of woodland in the islands during the early Holocene and it is very likely that the degree of openness in the landscape is under-represented in the pollen record.

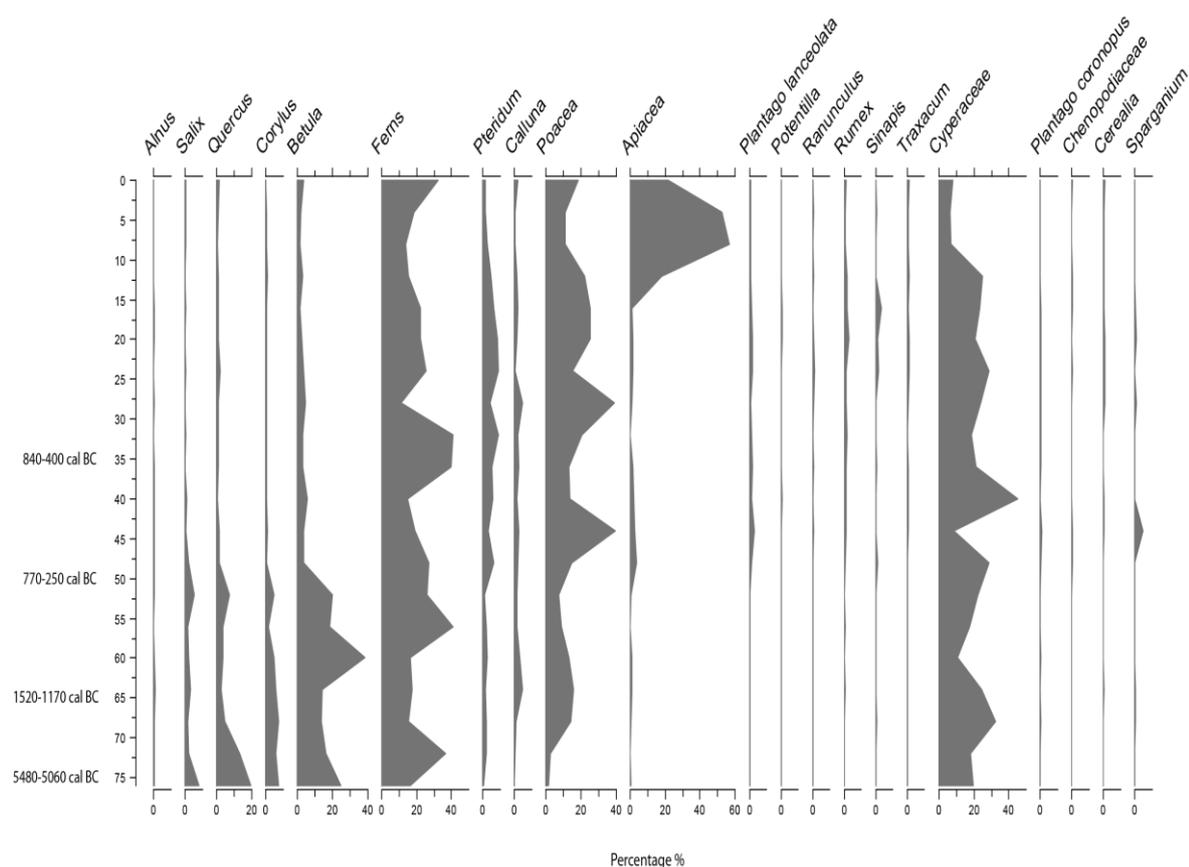


Figure 5.4 Summary of Scaife's (1981, 1984) Higher Moor pollen diagram. Taxonomy follows Scaife's original publication.

In comparison, LM28 (Fig. 4.20 and 5.3) shows very little evidence of woodland or even any tree cover by 2860 cal BP (910 cal BC). This could mean several things: (1) the records are highly localised and the vegetation was heterogeneous, with woodland around Higher Moors and openness around Lower Moors, (2) there are some problems with the chronologies at Scaife's Higher Moors and (3) there were rapid and dramatic changes between the middle of the 2nd millennium BC and the start of the 1st millennium BC.

Scaife's Higher Moors diagram (Fig. 5.4) also suggests that there might have been a hiatus in peat formation until the Bronze Age, when clearance occurred followed by a regeneration of *Betula* dominated woodland. There is currently no pollen evidence from elsewhere in Scilly for the mid to late Bronze Age forest regeneration recorded at Higher Moors, and although LM28 (LM28 Ipaz2: Fig 4.20) shows a slight increase in *Corylus avellana* and *Betula* pollen circa 2790 cal BP (840 cal BC), this cannot be considered as

extensive woodland regeneration as the dominant landscape, at that time, is fresh meadows and pasture.

The main phase of woodland clearance from Scaife's Higher Moors sequence is radiocarbon dated to the late Bronze Age/Early Iron Age (840-400 cal BC) (Ratcliffe and Straker, 2000; Scaife, 1984), but given the emerging picture of fairly intensive occupation throughout the Bronze Age in Scilly (cairns, tombs, settlements and field systems) this could have occurred earlier in other parts of the Isles. For example, two cores from Par Beach, St Martin's (Charman *et al.*, forthcoming) show a largely wooded landscape, dominated by *Betula* but also with *Corylus avellana*, *Quercus* and *Calluna* circa 3000 cal BC. However, by 2000 cal BC both show very low tree pollen with tree taxa replaced by Poaceae pollen and abundant disturbed ground indicators (such as *Plantago*). The same can be observed from two pollen diagrams from Porth Mellon, St Mary's (Charman *et al.*, forthcoming), taken from an area very close to Lower Moors (LM28 and LM19). At Porth Mellon the pollen assemblage shows an open disturbed grassland with some woodland nearby composed of *Betula*, *Corylus avellana* and *Quercus* by the 2nd millennium BC.

The new pollen sequences presented in this thesis place the woodland clearance long before the end of the Bronze Age, showing an intensively managed open landscape at this time. A similar conclusion can be drawn from Scaife's (1980, 1981 and 1984) Lower Moors pollen diagram (Fig. 5.5). In this core, the arboreal pollen has reduced considerably by the Middle Bronze Age and agricultural activity is indicated by the presence of small amounts of cereal pollen and ruderal taxa. There are high values of Poaceae and Cyperaceae pollen, suggesting a grassland environment and possibly pastoral economy. By the Late Bronze Age there is a higher presence of cereal pollen and possibly weed or arable land, with a landscape dominated by fresh meadows and pastures. The same open landscape can be observed in other areas of Scilly. Pollen samples, from a soil section associated with the Iron Age settlement site Nornour (Butcher, 1978), are indicative of grassland (dominated by *Plantago* and Poaceae) with some occurrence of tree pollen. There is also evidence of clearance and development of heathland from Innisidgen,

another Iron Age occupation site, Fig 2.10 (Dimbleby, 1977). Pollen profiles from Old Town, St Mary's, further suggest a largely open landscape with very little woodland cover and some heathland from the Late Iron Age onwards (Charman *et al.*, forthcoming).

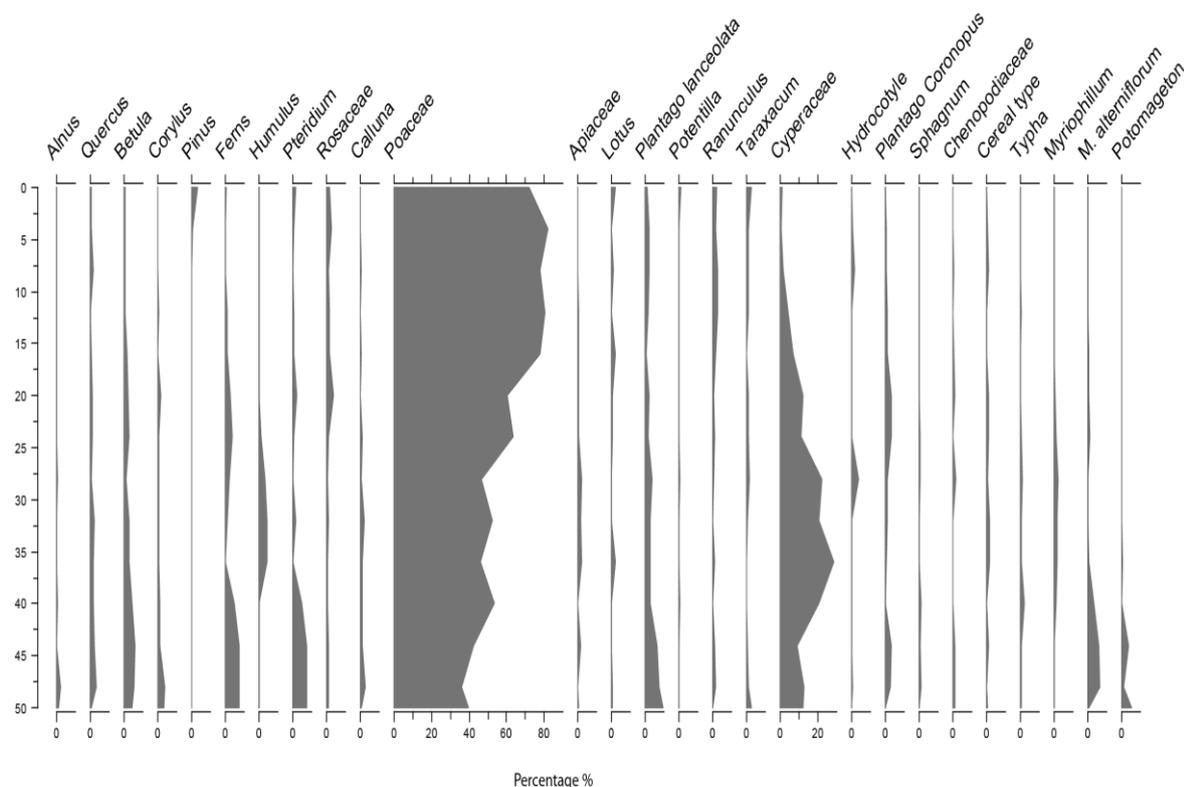


Figure 5.5 Summary of Scaife's (1981, 1984) Lower Moors pollen diagram. Taxonomy follows Scaife's original publication.

The same tree clearance and management landscape that occur in Scilly can be observed in the mainland. There is evidence of woodland clearance from the Neolithic onwards, with palynological records showing a largely open landscape by the Bronze Age, and a dominance pastoral use of the land (e.g. Gearey *et al* 2000b; Jones, 2004; Fyfe *et al.*, 2008).

In the absence of wood, peat may have been used as fuel. It can be speculated that ponds such as Porth Hellick Pool and others may be ancient workings, abandoned and flooded. A source might also have been the now submerged central area of *Insula Sillina* and such digging may have promoted marine transgression (Ashbee, 1984). Any

assessment of the ancient Scillonian woodlands must take into consideration the processes which would have demanded wood, either as fuel or as construction material for boats and other apparatus. The manufacture of pottery would have demanded wood fuel over and above domestic needs. Periodically, it would also have been needed to cremate those individuals interred in cists and incorporated into chambered cairns. Where peat, a fuel of lower calorific value, would have been available, there would also have been a continuing demand for wood (Ashbee, 1986)

In conclusion the early Holocene landscape of Scilly was heavily wooded. By the Late Bronze Age the majority of this woodland had been replaced by large areas of open grassland, with some arable cultivation. It is likely that closed woodland was still present in some areas of mainland of the South West but in Scilly this is very unlikely; here, the evidence points to a largely open landscape. Whilst there is evidence of some trees on the Isles of Scilly after the Bronze Age, these are most likely to be integrated into the fabric of the cultural landscape, in managed copses or possibly on field-banks or as hedges. Field systems and division of the land is a common feature during the Bronze Age in Britain and in Scilly. It is possible that these divisions were created by ditches, banks, stone walls and also hedges to create a formal distinction between different zones in the landscape (Barrett, 1999).

5.5.2 Continuity of land management in the Late Holocene

The three studied cores show a continuation of the use of Higher Moors and Lower Moors as pastoral and arable land from the Late Iron Age until the modern era (Fig. 5.6). The evidence presented here shows a constant presence of ruderal and cultivated taxa with some differences between the three cores. Ruderal communities have a stronger presence in LM19 from the Late Iron Age until recent times, whilst they are not so well represented in LM28. In HM16, the ruderal and cultivation communities are present in

small quantities since the Late Iron Age but they increase greatly at the end of the Middle Ages, losing importance again in the 20th century.

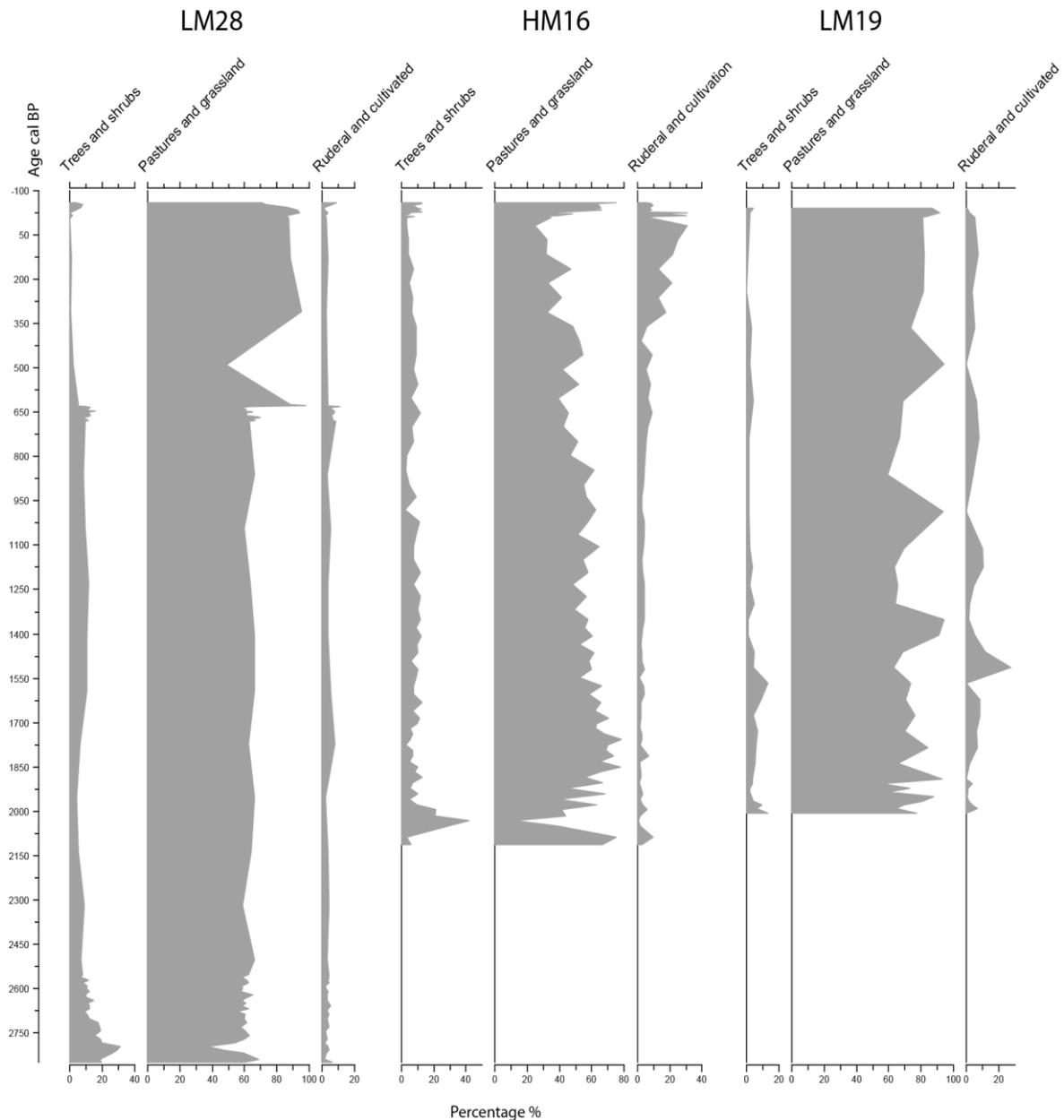


Figure 5.6 Discussed groups from the three studied cores presented on a timescale. Observe the dominance of open conditions (pasture and grassland) in the landscape during the late Holocene.

Even considering these changes, this palaeoecological material does not point to any striking changes in cultivation or land management in these areas throughout history. The importance and permanence of pastoral and arable land in Scilly can also be deduced from other pollen sequences. Scaife's (1984) pollen diagrams show the predominance of

pastures and grassland, with a constant presence of cultivated taxa from the Iron Age forward, as well as evidence of cereal cultivation from the Iron Age onwards at Bar Point, St Mary's (Evans, 1984). The interpretation of the pollen diagrams is supported by the plant remains from the nine archaeological sites located on the outer and inner-facing shores of the current Scillian coast line, demonstrating that a range of crops were grown during the Bronze and Iron Age. These included naked and hulled barley, emmer wheat and celtic bean (Ratcliffe and Straker, 2000).

Continuation and extension of the pastoral/arable economy in Scilly over time, deduced from the studied cores, is also supported by new evidence in Scilly obtained during the Lyonesse project (Charman *et al.*, forthcoming). A pollen diagram from Old Town in St Mary's shows that by cal AD 540-650 the predominant landscape in this area was fresh meadows and pastures, with an important presence of ruderal communities until the Medieval period. The same situation is seen in a pollen diagram from St Agnes, while pollen data from Crab's Ledge (Tresco) indicates that Chenopodiaceae and Brassicaceae dominated the pollen assemblage from cal AD 400-550. In conclusion Scilly vegetation was continually intensively managed by people, who divided the land to be used for different purposes: pastoral and/or arable. This agricultural economy has been in Scilly since at least the later Bronze Age and into the modern era.

5.5.3 Use of fire for landscape management

The three pollen sequences presented in this thesis show microscopic charcoal particles. The microscopic charcoal found in these cores has not been identified to species level, so its source is unclear. The archaeological record, however, does provide insights into species that were selected for use. Charcoal from a range of woodland trees including: oak, elm, hazel, ash, willow and alder (present only in prehistoric to Romano British settlements) is accompanied by taxa which are not represented in the pollen diagrams, such as: *Ulex* (gorse), *Cytisus* (broom), *Hedera* (ivy), *Sambucus nigra* (elder), *Acer* (field

maple) and *Larix* (larch/spruce) (Ratcliffe and Straker, 1996). Gorse has been found in other settlements such as in Halangy Porth (dated to the second millennium BC) (Ashbee, 1984), Porth Cressa (gorse and rose/blackberry) and at Bonfire Carne (gorse and heather/ling) (Ratcliffe and Straker, 2000). Charcoal from Iron Age/Romano-British contexts is also very varied. Halangy Down yielded charcoal identified as: *Alnus* (alder), *Corylus avellana* (hazel), *Quercus* (oak), *Salix* (willow), *Populus* (poplar), *Sambucus* (elder), *Ulex* (gorse), *Cytisus* (broom), *Larix* (larch), *Picea* (spruce) and *Pseudotsuga* (douglas fir) (Ashbee, 1996). The main groups of charcoal identified from Bar Point were *Ulex*, *Cytisus*, *Sambucus*, *Quercus* and *Arrhenatherum* (false oat-grass) (Evans, 1984).

The charcoal identified from the Romano-British period onwards contains fewer species. The charcoal from the Romano-British period from Halangy Down consisted mainly of ash and gorse (Ashbee, 1955). Meanwhile the charcoal from Nornour, from hearths and occupation levels, mostly derived from Leguminosae, probably gorse (Butcher, 1978). Medieval and post-medieval charcoal continuous to be associated with occupation debris in Scilly and contains a mainly heathland assemblage of charred plant remains with bracken, gorse and heather (Ratcliffe and Straker, 1996). That the main source of fuel at least after the Romano-British period, was gorse and heath/ling further supports the interpretation of the pollen data of a largely open landscape with little timber. Scilly would have had heavy demand for wood, not just for fuel but also for boat construction, pottery making and to make home implements (spoons, forks, plates). It seems that the early Scillonians also used drift wood. Some of the charcoal found in early settlements has been identified as *Larix* (larch) and *Picea* (spruce), neither native to the British Isles (Ratcliffe and Straker, 1996). The first began to be cultivated in Britain in c. 1620 and the second in 1500 AD. Their presence in an ancient context can only be explained as products of drift-wood. The Isles of Scilly are dangerous areas for shipping and both *Larix* and *Picea* have been used for ship-building (Ashbee, 1996).

The three pollen sequences presented in this thesis show a noticeable increase in charcoal after the Romano-British period (with some localised peaks in the previous

periods), lessening in modern times. This charcoal did not seem to have a strong impact on the vegetation, only slightly affecting the proportion of dry pastures and heath. On the Scillies, elevated values of microscopic charcoal may reflect fertilization of meadows and fields, or regular burning of heather (Hjelle *et al.*, 2010). Historically there is evidence of the burning of seaweed to produce kelp (Thomas, 1985), it is very likely that seaweed was also burnt in the past and it could have been also a source of charcoal. Fire could also have been used as a land management tool, heather has traditionally been burned to encourage the growth of young heather shoots for winter fodder and to make the sedge and grasses more palatable for domestic animals (Holden *et al.*, 2007). This could also explain why there is a slight increase in *Calluna* (heather) pollen taxa after peaks of microscopic charcoal in the pollen diagrams. It is also possible that a portion of this charcoal was part of the kitchen waste used as fertilizer to improve the fertility of the soils. This would account for the reduction in charcoal during modern times, where chemical fertilizers are preferred.

People from the Isles of Scilly would have used peat as fuel too. In all references to Scilly from the seventeenth century onwards, it is common to read that the Isles were notably and totally tree-less. In the 1690-95 account, the cut and stacked peat, (known locally as *beat* or *turf*), was reckoned to be: 'the only Fewell they have, there being no Coal, nor any Trees, nor not so much as a Shrubb, except Brambles, Furzes, Broom and Holly, and these never grew above 4 foot high' (Thomas, 1985). Historically, peat has been used as fuel in various areas. For example in the Western and Northern Isles of Scotland, where well-humified peat was the dominant fuel source over thousands of years in addition to other types including: dung, seaweed, straw/hay and organic turf (Church *et al.*, 2007).

In conclusion, the microscopic charcoal found in the three studied cores could be incorporated into the sediments as fertilizer (from kitchen waste) and/or be a product of land management (burnt off shrub). The species included in this microscopic charcoal could vary from grass, to shrub, to seaweed and to wood charcoal. Without a proper

charcoal identification it is impossible to determine which type of vegetation is included in the charcoal of these cores.

5.6 SYNOPSIS

This chapter has presented a critical discussion of the three sampled cores taken in Scilly, and compared them with other pollen sequences from Scilly and mainland Britain, in order to achieve the second aim of this project. In conclusion, the evidence indicates that the Isles of Scilly became an open, managed landscape from the Late Bronze Age onwards, with the predominant use of the land pastoral and arable. The next chapter will discuss the rates of sea-level rise in the Isles of Scilly, using GIA models, Bathymetry and LIDAR data. It will focus on periods of the greatest coastal change, such as the separation of mainland and Scilly, inundation episodes of large areas of land and the conversion of the Isles of Scilly from one land mass to various islands.

6 PALAEOGEOGRAPHY OF THE ISLES OF SCILLY

6.1 INTRODUCTION

This chapter will discuss the results of combining the new model of relative sea-level rise and bathymetry presented in Chapter 4, focussing particularly on periods of important coastal change, and will relate the palaeogeography to the archaeology of Scilly. This will aid in the achievement of the principal aim of this thesis: to investigate the response of past communities to marine inundation and the change in the availability of marine resources. Relative sea-level has been rising in the Isles of Scilly constantly during the Holocene (Fig. 4.1). The first section of this chapter will focus on the time when the islands became separated from the mainland and will speculate on the consequences of this for communities visiting or utilizing this area at the time. The following three sections will discuss the periods of major coastal changes on Scilly due to relative sea-level rise (Fig. 4.3). These three relevant periods fall within the Early Holocene: 11,500 BP (total separation of the Isles of Scilly from the mainland), 8000 to 7000 BP (important loss of land) and 5000 – 3000BP (separation of the main islands on Scilly).

6.2 SEPARATION OF SCILLY AND CORNWALL

The Isles of Scilly were joined to the mainland (Cornwall). The exact time when the separation from Cornwall took place has been subject for speculation by archaeologists. Some authors (e.g. Johns *et al*, 2004) consider it to be possible that the separation took place about 10,000 years ago. For Thomas (1985) the last stage at which Scilly could have been reached on foot fell somewhere between the 10th and 8th millennia BC. Other authors, such as Lousley (1971), consider that the separation had occurred by the Middle Pleistocene (at least 300,000 years ago).

According to bathymetry and hydrography data from the maritime chart 1148, at its deepest point the water between Cornwall and Scilly is less than 60 m. A drop in the relative sea-level of about 50m would join the islands and mainland again.

The new relative sea-level predictions in the GIA model (Bradley *et al.*, updated) indicate that the Isles of Scilly were still joined to Cornwall at around 14,000 BP (c.12,000 BC), when the relative sea-level was at least 75m lower than today. It is likely that the separation started to take place around 13,000 BP (c. 11,000 BC), with the complete separation by 11,500 BP (c.9500 BC), when the relative sea-level was only 41m lower than today (Table 6.1). This separation took place broadly around the start of the Holocene and also the start of the Mesolithic. Thus it is unlikely that early Mesolithic communities were able to walk to the Isles of Scilly; any pre-separation archaeology must therefore be late Palaeolithic.

Table 6.1 Relative sea-level predictions for Scilly from 14000 to 10000 BP as in the new GIA model (Bradley *et al.*, 2011).

Time kyr BP	cal BC/AD	RSL_preds
10	-8050	-38.27
10.5	-8550	-44.83
11	-9050	-51.33
11.5	-9550	-54.03
12	-10050	-56.55
13	-11050	-61.06
13.5	-11550	-63.38
14	-12050	-75.48

The only archaeological evidence of Scilly that can possibly be dated to the period when the islands were part of Cornwall is a potential Palaeolithic curved back point, possibly a 'penknife point' from the Upper Palaeolithic (Berridge and Roberts, 1986). However there is plenty of evidence of human presence in the South West of England at this time. There is no reason to believe that the Isles of Scilly, being part of this large area, were not inhabited too. It is possible that this track of land between Cornwall and Scilly could be one of the 'submerged prehistoric landscapes in Britain' together with Doggerland (Coles, 1998) and the Solent area (Momber *et al.*, 2011). These are tracks of land that were

exposed in the past but have been inundated as a result of relative sea-level rise and they are very rich in archaeological remains.

Sporadic incursions into northern Europe appear to have taken place between 23,000 and 14,000 years ago and the relationship between population demographics and climate change appears increasingly complex (Conneller, 2007). However, the Late Pleistocene history of human activity in Britain has many gaps. For many years it has been apparent that a gap in settlement occurred at the same time as an ice advance that reached its maximum extent about 18,000 radiocarbon years ago. This gap seems to have lasted at least 7,000 years, with the earliest resettlement taking place 13,000 years ago at the same time as a sudden rise in both summer and winter temperatures (Jacobi, 2000). New radiocarbon data at Gough's Cave (Fig. 6.1), located on the southern side of the entrance to Cheddar Gorge in southwest England, has established that the start of the occupation of the cave was around 14,840-14,680 cal BP (Jacobi, 2004). Human remains of at least 5 individuals were found from this period of occupation. These bones show cut-marks made by stone tools during excarnation and disarticulation and have been significantly smashed. They were found mixed with cut and smashed animal bones, flints, ivory and antlers, leading the excavators to conclude that humans were the one form of food for the cave's occupants (Jacobi, 2000; Jacobi and Higham, 2009). Gough's Cave has yielded a high number of projectile points and cut-marked animal bone, indicating that the site was used as a hunting camp. The site continued to be primarily used as a hunting and butchery site for several centuries; however from around 12,500 BP more activities seem to have taken place. Butchery marks suggest that tendons were removed from horse metapodials for use as sinew and an awl made from the tibia of an arctic hare may suggest clothing manufacture. This wider range of activities could be interpreted as the work of a broader social group (Conneller, 2007).

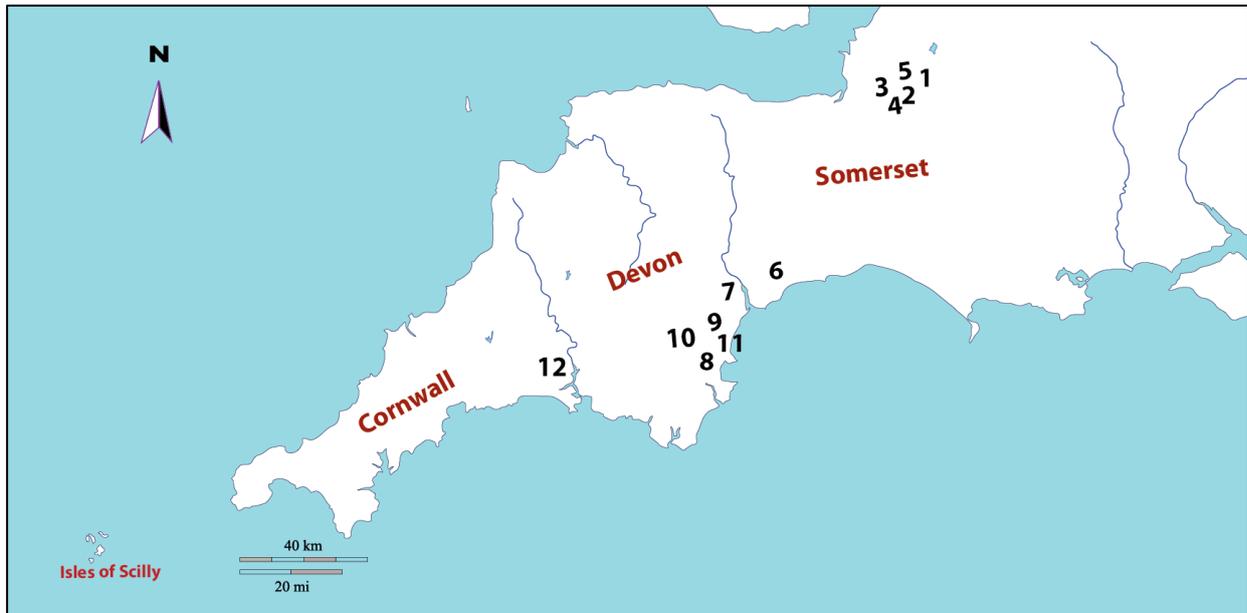


Figure 6.1 Map of the southwest of Britain with the main sites discussed: (1) Gough's Cave, (2) Aveline's Hole, (3) Sun Hole cave, (4) Pickens's Hole, (5) Hay Wood cave, (6) The Axe valley, (7) Exe, (7) Teign, (9) Kent's Cavern, (10) Kettleby Bob's cave, (11) Tornewton cave and (12) Plymouth.

Other caves in the South West have evidence of human occupation. For example the lithic collection from Aveline's Hole (Fig. 6.1), in Somerset, documents human activity at the cave during the Late Upper Palaeolithic and the earlier part of the Mesolithic (Jacobi, 2005). The Palaeolithic caves represent only a fraction of the evidence for earlier Palaeolithic occupation in the southwest of England. Findspots confirm the importance of the relatively rich Palaeolithic landscapes within the South-West. At least 61 Lower and Middle Palaeolithic find-spots were distributed throughout the South West region area. The majority are found in areas of well documented Palaeolithic heritage such as the Axe Valley and Broom, the Exe and the Teign (Fig. 6.1), but there are others in less studied areas such as the south-west of Cornwall and Plymouth (Hosfield *et al.*, 2006).

With the south western area of Britain populated prior to the Mesolithic it is very likely that the Isles of Scilly were also occupied, or at least visited occasionally if not permanently. It is possible that the evidence now lies underwater. Isotope analysis of the human remains from Gough's Cave, Sun Hole, Kent's Cavern and Aveline's Hole indicate that their main protein sources were consistent with those of red deer and bovines (Stevens *et al.*, 2010).

This indicates a society of hunters and they would have travelled around the South West following their prey, making it possible for these hunters to have reached Scilly. The Isles of Scilly were habitable during this period. Pollen evidence from St Mary's Road (Charman *et al.*, 2012) shows that around 11300 cal BC the landscape was open and dominated by grasses and sedges with a rich herb flora and many taxa suggesting disturbed conditions (probably due to anthropogenic presence on the islands). When Scilly got separated from Cornwall it is possible that these societies lost some of their known hunting routes. However, new coastal areas then became available to them with new marine resources.

6.3 SEA-LEVEL RISE FROM 11,500 TO 5000 BP

The beginning of the Holocene has been placed at *circa* 11650 BP (Walker *et al.*, 2009) or around 9700 cal BC. Map A (Fig. 6.2) offers an idea of how Scilly could have been at the beginning of the Holocene, later Holocene palaeogeographic maps are shown on figure 4.3. At the start of the Holocene the sea would have been nearly 51m lower than today (Table 6.1) and the land area would have covered more than 140km². According to Bradley *et al.* (updated) before 11000 cal BP (9050 cal BC) the rate of relative sea-level rise was 4m per 500 years (0.8cm yr⁻¹). However, between 11000 and 10000 cal BP (9050-8050 cal BC) the rate of RSL rise increased to around 1.2cm yr⁻¹ due to deglaciation during the early Holocene. After 10000 cal BP (8050 cal BC) the rate of relative sea-level returned to between 0.8 – 1 cm yr⁻¹ until 4000 cal BP (2050 cal BC), at which time the rate decreased to less than 0.2 cm yr⁻¹ (Table 4.1). The loss of land in Scilly, through this time period, has been relatively steady, at the 500 years resolution used here, and parallel to the increase in RSL (Table 4.1 and Fig. 4.4), except for a hiatus between 8000 and 7000 cal BP (Map 6.2 E and F), during which time the loss of land surface in Scilly was very significant. A large area to the south west of the Scillies was then lost to the sea, St Agnes and Gugh separated from the main island. These coastal changes are dependent on RSL increase and Scilly's coastal shape and topography.

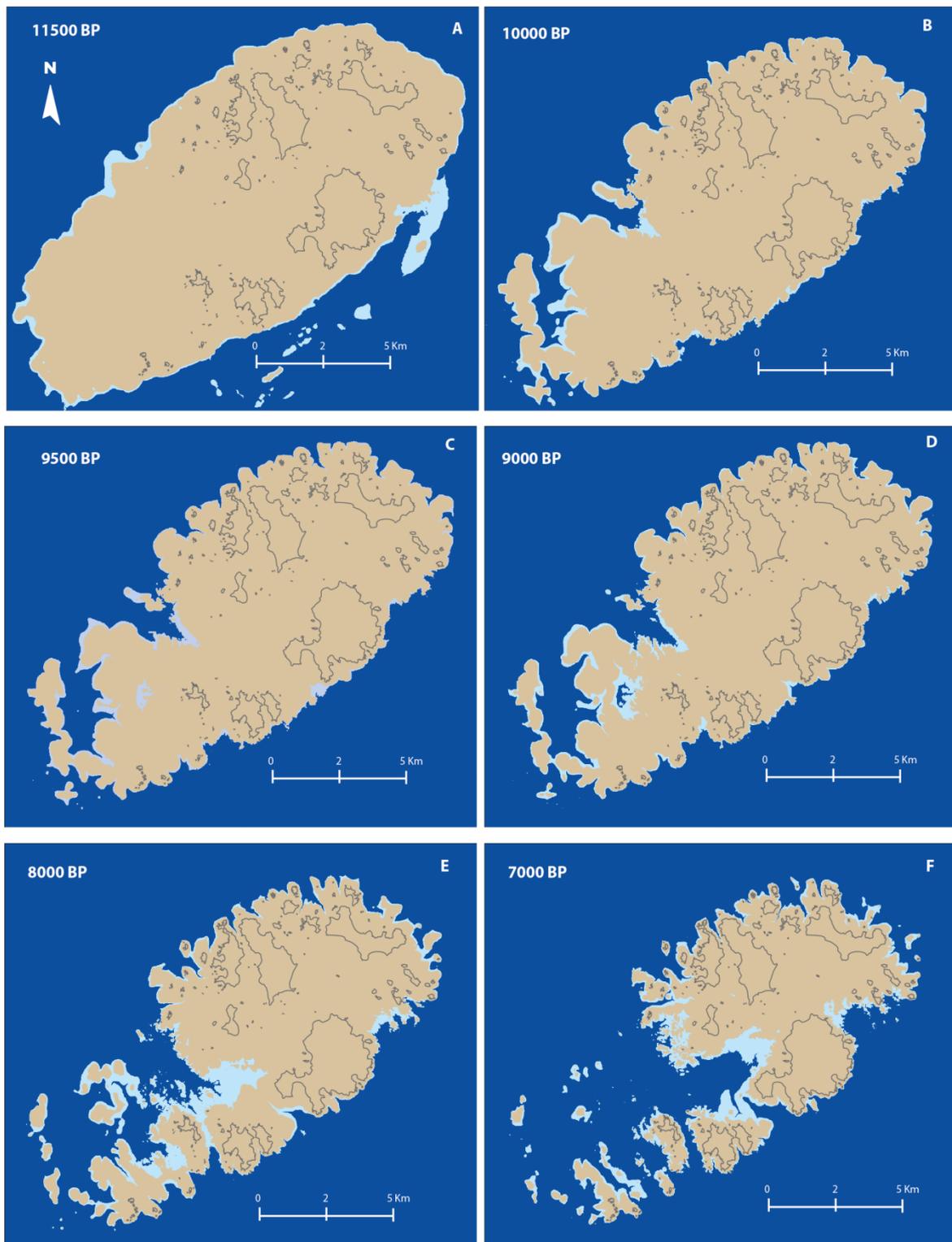


Figure 6.2 Palaeogeographic maps of the Isles of Scilly during the early Holocene.

It has long been accepted that knowledge of early and mid-Holocene subsistence and patterns across southern Britain is incomplete due to the loss of the coastline by inundation. Unfortunately, ethnographic and archaeological evidence suggests that the

greatest potential for fisher-hunter-gatherer socioeconomics (typical of the early Prehistory) can usually be found among coastal groups (Schulting and Richards, 2002). These now submerged areas were potentially important landscape for prehistoric humans as they offered a range of coastal marine and terrestrial resources as well as access to transportation and migration routes along coastlines (Westley *et al.*, 2010). Coastlines typically offer numerous attractions: a wide range of plant and animal resources, more abundant water supplies and quite often easy pathways to move along the shore edge and between the coast and hinterland. There is no reason why these advantages should not have been realised from the very earliest periods of prehistory (Bailey, 2004).

The archaeological record of Scilly does not start until the Mesolithic (Map 6.3C) with the exception of a possible Palaeolithic find (as previously discussed). Mesolithic finds in Scilly are found along the modern coastline of Scilly. Very likely the early inhabitants of Scilly would have been coastal people who crossed the sea between the mainland and Scilly and who, once established, continued to make use of the coastal and marine resources, permanently or seasonally. It is also possible that some of those inhabitants were already in Scilly by the time that the land bridge between Cornwall and the islands became inundated. There has been much discussion of the role of marine resources, including shellfish in Mesolithic subsistence strategies in north-western Europe. On a broader geographic scale, stable isotope evidence from the late Mesolithic remains of a range of sites along the Atlantic coast of Europe suggests that marine foods were a significant part of the diet. Evidence from the Culverwell midden (Portland, Dorset) suggests that intertidal species of shellfish were intensively exploited for food by earlier Mesolithic populations. Very likely this was seasonal and part of an annual cycle where coastal environments were not the only ones exploited (Mannino and Thomas, 2001). Isotopic values from individuals in the Caldey Islands (Wales) imply a high reliance on marine protein and also a specialized coastal economy at an early stage in the Mesolithic. In contrast to Palaeolithic human remains from sites in southwest England, sites including Hay Wood Cave and Picken's Hole in the Mendips, and Kitley Bob's Cave, Broken Cavern

and Tornewton Cave in Devon (Fig. 6.1), show no significant use of marine foods (Schulting and Richards, 2002).

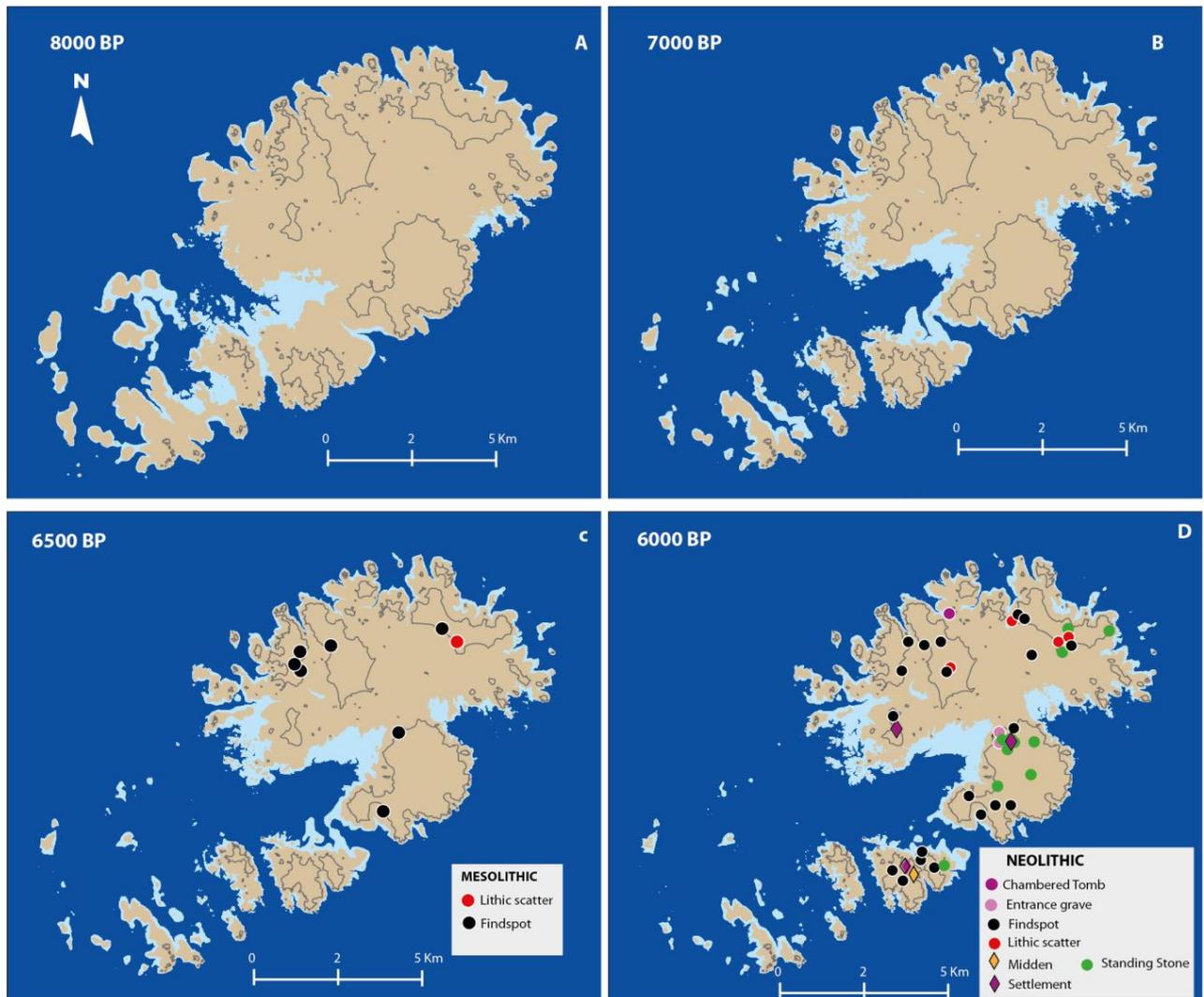


Figure 6.3 Palaeogeographic maps of the Isles of Scilly during the Palaeolithic, Mesolithic and Neolithic. Archaeological find spots are mapped based on the data obtained from the Cornwall and of Scilly HER.

Mesolithic artefacts are relatively rare on Scilly but a number of substantial prehistoric shell middens occur throughout the islands, the majority of which remain undated but which could be part of Mesolithic activity (Robinson, 2007). Changes in the coast would have affected the Mesolithic and Neolithic communities in Scilly but not all those changes would have been negative. The maps in Fig. 6.3 show that the most noticeable relative sea-level rise can be observed in the area north of St Agnes and, although some land is

lost, a nice protected bay is also forming with a large intertidal zone. Foraminifera evidence from St Mary's Road (Charman *et al.*, forthcoming) indicates that this area was a saltmarsh *circa* 7000 cal BP (5050-4830 cal BC). This would have provided the Scillonian communities with a valuable source of food, such as molluscs from the intertidal zone and new plants and birds, making those areas closer to the coast the most logical places for habitation during this period. New lithic techniques during the Mesolithic were centred on the bow and reaping knife and equipment for tree felling, woodworking and mollusc collecting, these enabled successful adaptation to the new coastal environments of Europe (Straus, 1995). In Scilly there is evidence of this new coastal culture in the archaeological and palaeoenvironmental record. Archaeologically Mesolithic middens (not dated but assumed to have a Mesolithic origin due to their composition) show a great variety of fish, shellfish and seabird being exploited (Robinson, 2007) and the palaeoecological record shows human disturbance in the landscape, evidence of charcoal and tree cover reduction (Charman *et al.*, forthcoming).

By 6500 cal BP (4550 cal BC) Scilly had lost a considerable track of land (Map 6.3C) but was still a substantial island and the archaeological evidence grew noticeably in relation to the previous period. As discussed in Chapter 2, in Scilly it is very difficult to separate the Neolithic (4000-2500BC) from the Mesolithic and even from the Bronze Age (2500-800BC) as a consequence of poor chronological control. During these periods Scilly was a large island that could have been easily spotted from mainland Cornwall and by people travelling to and from Wales, Ireland and the British west coast. Evidence of these contacts is supported by the cultural similarities (e.g. Entrance graves and funerary monuments) found in all the regions around this western fringe. Work on stable isotopes has demonstrated a major shift from marine-based to a terrestrial based diet in many coastal regions of north west Europe at the Mesolithic-Neolithic transition (Phillips, 2003). Although available isotope records consistently indicate a more dominant terrestrial diet for Neolithic individuals compared to their Mesolithic predecessors, the evidence cannot exclude the consumption of marine or terrestrial foods by Neolithic individuals, let alone

whole populations, especially on the coasts of north west Europe, with an abundance of fish, sea mammals and shellfish (Milner *et al.*, 2004). In Scilly there is evidence that an important marine economy functioned during the Neolithic. Limpet middens occur frequently on the islands (for example: Porthkillier, Porth Cressa and Teän) and they produce not only mammal bone and birds but also fish and shell (Ratcliffe and Straker, 1996). This, and the fact that most of the known Neolithic sites are located inland, could indicate that even though maritime resources were exploited, the terrestrial sources were more important. The same situation can be seen in Neolithic Orkney, where although a Neolithic midden in the Knap of Howar settlement has produced bones of domesticated (cattle, sheep and pig) as well as remains of cultivars (wheat and barley), it also included a wide range of fish and sea birds (Garnham, 2004). Coastal zones, and in particular salt marshes, are areas of significant food resources so it is possible that Neolithic shell middens were accumulating along the shoreline where the coast and salt marshes were being exploited. On Scilly these locations are now largely underwater. In other places in the UK, Neolithic middens have been found along the coastline, for example, in Scotland's Forth lowland, where middens show that Neolithic people were exploiting the marshes and intertidal areas for over 2000 years when the RSL was rising (Smith *et al.*, 2010). More evidence of coastal resources being used in Scilly can be deduced by concentrations of finds, lithic scatters and monuments (Map 6.3D) in zones that are relatively close to where saltmarshes may have been during the Neolithic as suggested by the new palaeoecological studies in Charman *et al* (forthcoming), particularly St Mary's Road and Nornour (Fig 2.10).

According to the Bradley *et al.* (updated) GIA model, the loss of land due to sea rising after 7000BP (Table. 4.1) was only a few square kilometres per 500 years (an average of 3 to 4km²: 0.6 – 0.8 ha yr⁻¹). The resolution of the Bradley model is coarse and so it is possible and likely that abrupt coastal changes could have happened during the period. For the present purpose it is sufficient to note that these changes may have been gradual as hence beyond the scope of human perception of change. The periods after the

Neolithic and the human response to environmental changes have been discussed previously (e.g. vegetation changes: Chapter 5) and will be discussed in more detail in Chapter 8.

6.4 SEA-LEVEL RISE AND PALAEOGEOGRAPHY: 5000 TO 3000 BP

As has been previously established, in terms of land loss, the period between 7000BP and 5000BP (5050 – 3050 cal BC) was relatively stable and gradual (table 4.1, Fig. 4.3). It can be argued that the most significant change since separation from the mainland occurred between 5000 and 3000 cal BP (3050 – 1050 cal BC; Fig. 6.4). In spite of the RSL rise of about a metre (every 500 years) the loss of land was substantial and led to the break-up of the islands. All the low lands were inundated between St Martin's and Tresco, and between Tresco, Bryher and Samson. Nowadays those areas are the famous sand bars of Scilly. This palaeogeographic change is an important event in the Scillies coastal history, as it signifies the emergence of the major separate islands from a single mass. The changes in land cover were very important and noticeable during the Bronze Age, and it is very likely that some of these changes occurred abruptly and were perceptible during a human life span. From an anthropogenic perspective the loss of land would have been important, especially considering that during this period the society was agrarian and as a consequence highly dependent on land access and availability.

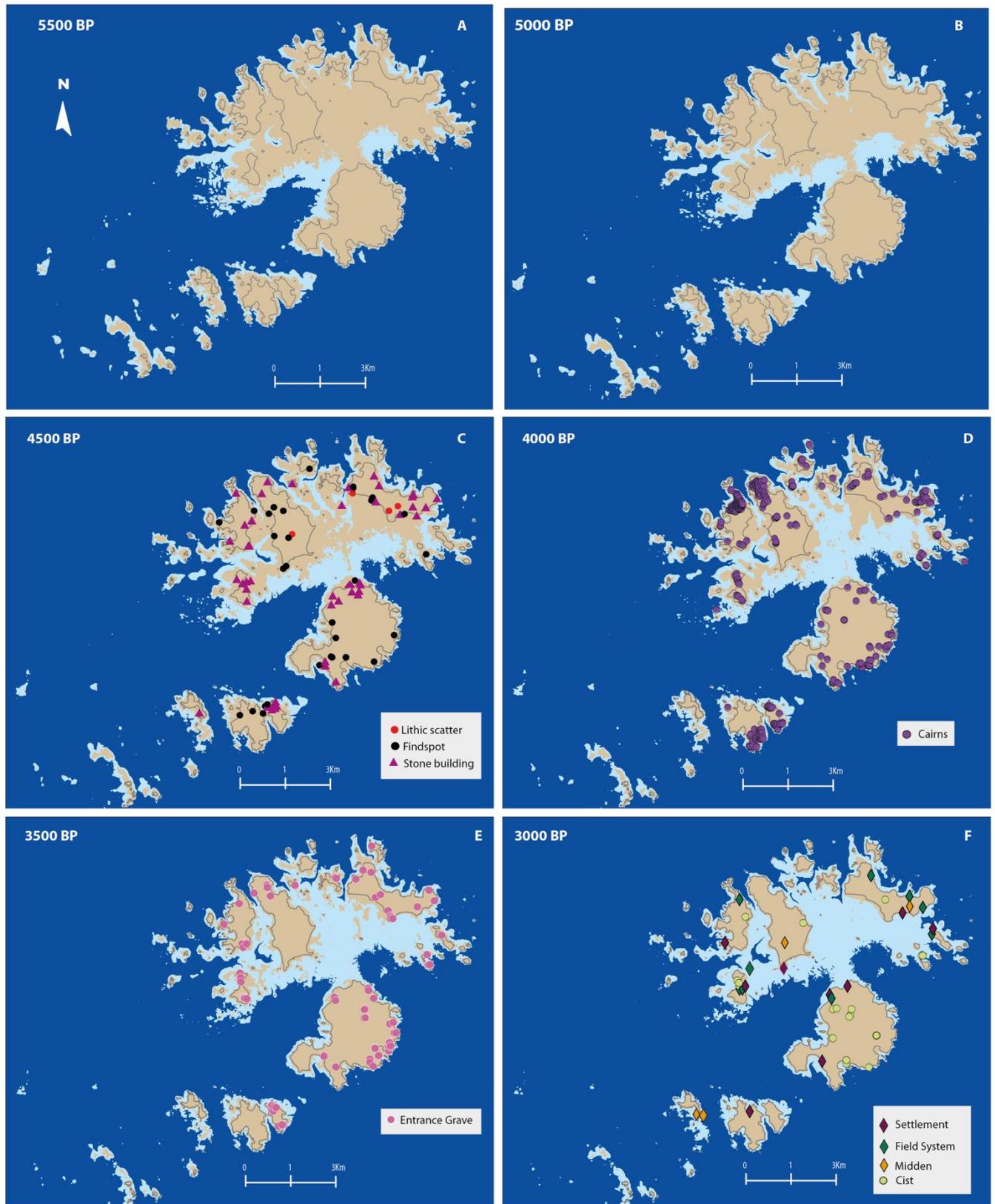


Figure 6.4 Palaeogeographic maps of the Isles of Scilly during the Bronze Age. The Archaeology was mapped according to the data from the Cornwall and Isles of Scilly HER. The Bronze Age archaeological remains are numerous so they are divided in different maps (Maps C, D, E and F belonging to the same period) to see them clearer.

At 5500 BP (3550 cal BC), during the Neolithic period the main islands were still joined (Map 6.4A), by 4000 cal BP (2050 cal BC; Map 6.4D; the start of the Bronze Age) all the islands are separated and only joined at intertidal level, and by 3000 cal BP (1050 cal BC; Map 6.4F) the islands obtained their modern configuration. It is during this period that the most iconic archaeological remains of Scilly started to appear, these are the Chambered tombs and Entrance graves (Maps 6.4D and F). The first radiocarbon determinations from an entrance grave have just been obtained (Mulville and Sawyer forthcoming), a sequence 10 dates from Knackyboy Cairn on St Martin's all fall within the period 1742 to 1266 cal BC. Although these monuments are classified as funerary, the majority of them do not contain any human remains so it is possible that they had other ritual meanings (discussed in Chapter 2). In Scilly they are predominantly located on the outer coast (Maps 6.4D and E). The location of cairns and entrance graves along the coast is shared by the other areas of the Atlantic fringe such as Ireland and Scotland with its various islands (Gordon, 2006).

The occupation sites tended to be concentrated in the interior of the archipelago, close to the new intertidal areas (Maps 6.4C and F). There were more field systems than before, mostly located outside the settlements and in the intertidal areas (Map 6.4F). In contrast to the dry land reduction the intertidal area increased considerably (Fig. 6.4). This area stretched across St Mary's Roads and covered the region between the Eastern Isles, St Martin's, Tresco, Bryher and Samson. Most of this intertidal land was probably only covered during high tides in consequence this would have been a useful part of the land, especially used for grazing (Charman *et al*, forthcoming). New pollen diagrams obtained from St Martin's (core LPSM1, Charman *et al*, forthcoming) show abundant disturbed ground indicators consistent with pastoral land use and maritime influence during the period c. 4980 - 4300 cal BP (3030- 2350 cal BC). There is no other palaeoecological evidence for this period, but this study (Chapter 5) has shown that by the end of the Bronze Age pastoral use of the land was the main agricultural activity in Scilly. Also environmental analysis carried by Ratcliffe and Straker (1996) at Crab's Ledge, Tresco (Fig. 2.10) showed a

predominance in pollen of coastal and saltmarsh plants in the pollen record by the Late Iron Age.

Wetlands are among the most productive environments, very rich in natural resources (Allen, 2000). There are numerous archaeological, ethnographic and historical references to the anthropogenic exploitation of salt marshes (for example Bell & Neumann, 1997). Coastal marshes were a large exploited resource in many areas Britain and northwest Europe and were considered to be prime land for the grazing of animal stock (Britton *et al*, 2008). The importance of the pastoral economy during this period can be deduced from the archaeological record. Bronze Age occupation debris from Scillonian settlements and middens have yielded a large number of domestic animal bones, for example, ox, sheep/goat and pig from Little Bay (Neal, 1983), Halangy Down (Gray, 1972) and Nornour (Butcher, 1978). The pastoral use of the intertidal land could also explain the location of the monuments in Scilly. These were located mainly on the outer coast of the archipelago, whilst the occupation sites and field systems are inland, where the best pastoral land would have been available. It is possible that the cairns and entrance graves were built in areas not very agricultural productive and most of them were erected when the fields were being clear of stones.

The palaeogeographic maps presented are only estimates of the past changes in sea-level based on the Bradley *et al.* (updated) GIA model and bathymetry, and as such there are a range of limitations to the analysis. The lack of an existing detailed topography of the submerged land of Scilly and absence of high resolution bathymetry or mapping of the sea bed meant that a new bathymetric model had to be constructed based in available soundings. The bathymetry data obtained for the Isles of Scilly was unevenly distributed (Fig. 4.1) and values between soundings had to be interpolated (Chapter 3). There were some problems matching the soundings where survey charts overlapped, due to differences in the measurements (taken at different times and using different scales). Second, there are likely to have been changes over time in bathymetry caused by changing sand movement, channels and bars, as well as coastal erosion around the

present and past coast, altering the shape of the submerged and contemporary coast.

Third, and finally, the GIA-based sea-level curve is temporally crude, with data points only every 500 years. Thus the apparently gradual changes in coastal form, and loss of land, may hide more abrupt changes in palaeogeography caused by rapid relative sea-level jumps as those suggested by Gregoire *et al* (2012).

6.5 SYNOPSIS

The Isles of Scilly have gone through important palaeogeographic changes over time due to relative sea-level rise, resulting in major land reduction. One of the most critical changes was the separation of Scilly from the mainland, around 11500 cal BP (c. 9550 cal BC). There is very limited evidence (a possible Palaeolithic find) of the Island having been occupied at this time but there is plenty of evidence that the south west of Britain was occupied. Consequently it is possible that the Island were at least seasonally occupied or visited by nomadic or semi-nomadic hunter-gatherers. The separation from the mainland would have disturbed these communities, in the sense that they lost land and hunting ground, but it would have provided them with new maritime resources.

Sea-level rose more rapidly from 11000 to 10000 cal BP (9050 - 8050 cal BC), when a large area of Scilly, located to the West of St Agnes, was inundated. However, the most noticeable change was the large loss of land to the sea between 8000 and 7000 cal BP (6050 - 5050 cal BC). Again, there is no archaeological evidence of permanent settlers during this period but, as previously discussed the presence of humans in Scilly cannot be dismissed. There is more evidence of permanent settlements after 7000 cal BP (5050 cal BC). The islands were fit for human habitation from the early Holocene and offered a large range of resources that could be very attractive, such as an extensive coastal zone, a large range of plants and most likely animals (terrestrial and marine) judging by finds from later periods. According to the GIA model, RSL continued to rise but slowed down. The rate of land loss was steady, at the scale of analysis, and more noticeable in the north

side of the islands and the west and east coast of St Mary's. This change was drastic between 5000 and 3000 cal BP (3050 – 1050 cal BC), when the land surface of Scilly decreased significantly. All the lowland between Tresco, St Martins, Samson, Bryher and St. Marys became intertidal by 3500 cal BP (1550 cal BC) and the islands were completely separated. This important coastal change coincides with the appearance in Scilly of permanent settlements. It is possible that at that time people were economically reliant on the land and the loss of potential agrarian area could have had important social effects. The building of megalithic monuments started at this time, the construction of numerous Entrance graves and cairns could be a consequence of the rapid loss of land in a relative short period of time. On the other hand, this lost track of land was occupied by marshland which offered new resources and a rich grassland area instead. More likely this was used as pastoral land while the marine resources were still being exploited.

From 3000 cal BP (1050 cal BC) onwards the relative sea level and the percentage of loss land is gradual and low (Fig. 4.3). This relative stability can be deduced also from the palaeoecological and archaeological record of Scilly. The archaeology (Chapter 2) shows that the Isles continued to be permanently inhabited and there is a continuation of tradition reflected in the location of the settlements and occupation sites. Even so, there are some changes such as the adoption of fortified settlements and adoption of different types of monuments over time. The palaeoecological record (Chapter 5) also shows a continuation in traditions. The environmental evidence points to an agrarian society and a continuously managed landscape.

The next chapter will discuss the results obtained from the particle size analysis to obtain a storminess record for Scilly, covering the last 3000 years.

7 STORMINESS DURING THE LATE HOLOCENE IN SCILLY

7.1 INTRODUCTION

The preceding chapters (5 and 6) have discussed the physical evolution of Scilly and the key aspects of Holocene, and in particular late Holocene, land management and human impact. As described in Chapter 2, this thesis recognised the potential disruptive nature of storms to vulnerable coastal communities. This chapter therefore discusses the evidence of storminess in the three analysed cores and their possible correlation with major climatic changes highlighted in the literature. These results will contribute to the achievement of the principal aim of this thesis: to investigate the response of early people to marine inundation and environmental changes. The physical properties of the sample cores are described in Chapter 4, in particular P-size distributions and LOI. This chapter will first discuss the origin of the inorganic sediments, in particular to determine whether any of the material is indeed aeolian.

A growing number of studies (Clarke and Rendell, 2009; Clemmensen *et al.*, 2001; De Jong *et al.*, 2006) have used particle size, and specifically sand from sedimentary sequences, as a proxy for past storminess. The hypothesis tested in this thesis is that stormy periods will be represented in the studied cores by coarse sediments (sand) interbedded within the peat. It is necessary to consider the different sedimentary processes which both transport and deposit sand sediments. In coastal areas the distribution and deposition of sand can be due not only to winds but also to the action of water (i.e. over-wash and/or floods).

One of the most obvious differences between aeolian and fluvial sediment transport is spatial, i.e. the direction and dimensions of transport characteristics. Aeolian transport is two dimensional, with transport occurring in both vertical and horizontal directions and with material potentially being transported in any wind direction. Fluvial transport is

primarily one-dimensional, with flow occurring horizontal to slope and unidirectional and the direction of the transport being downslope (Field *et al.*, 2009). During aeolian transport and deposition there will be sand in layers extending through the whole area, although subsequent irregular erosion of these deposits may result in only pockets of sand remaining within the landscape (Sommerville *et al.*, 2003). In a fluvial environment, overwash deposits typically result in a 'wedge shape' in the sediment stratigraphy (e.g. Szkornik *et al.*, 2008). The differences between the two types of sand deposition (aeolian and fluvial) will be evident in the stratigraphy obtained through the coring of the studied areas (Lower and Higher Moors).

Statistical parameters (mean-particle size, modes, sorting and skewness) based on grain size distribution are also used to infer depositional processes. Mean particle size is related to current velocity or to the overall energy. Coarser mean sizes in aqueous and aeolian contexts are indicative of high energy, while finer mean sizes are related to lower energy settings. The most common size fraction within a particle distribution is its mode. A single mode is indicative of a single agent of transportation and deposition. Bimodality of size frequency generally indicates mixing of sediment from two sources or processes that do not 'sort' sediments, e.g. mass movement. Sorting is an indication of entrainment and transport by water and air currents (Briggs, 1981; Field *et al.*, 2009; Houser and Greenwood, 2005; Masselink and Hughes, 2003).

Relations between kurtosis (peakedness of the distribution curve) and skewness provide an expression of sediment energy response which may be applied to different environments (Rapp and Hill, 2006). Plots of skewness (indicator of the symmetry of the grain size distribution) against kurtosis (peakedness of the size distribution) are used in environmental studies to identify the depositional environment of sedimentary deposits. These plots are based on the fact that each process of transport and deposition tends to produce sediments with a characteristic range of particle size distribution (Briggs, 1981). Skewness and kurtosis values seem to be the result of the mixing of two normal populations in various proportions in the resulting sediment (Shackley, 1975). In coastal

sediment extreme kurtosis values are common because the sand mode achieves good sorting in the high-energy environment on the beach and then is transported en masse by storms where it becomes mixed with other sediment and is finally deposited in a medium or low sorting efficiency environment. If the sediments are near the surface of the sand, they are characteristically leptokurtic and positive skewed because the sand is in excess. The more extreme the kurtosis values, the more extreme is the sorting of the mode in their previous environment and the less effective is the sorting in the present environment (Folk and Ward, 1957).

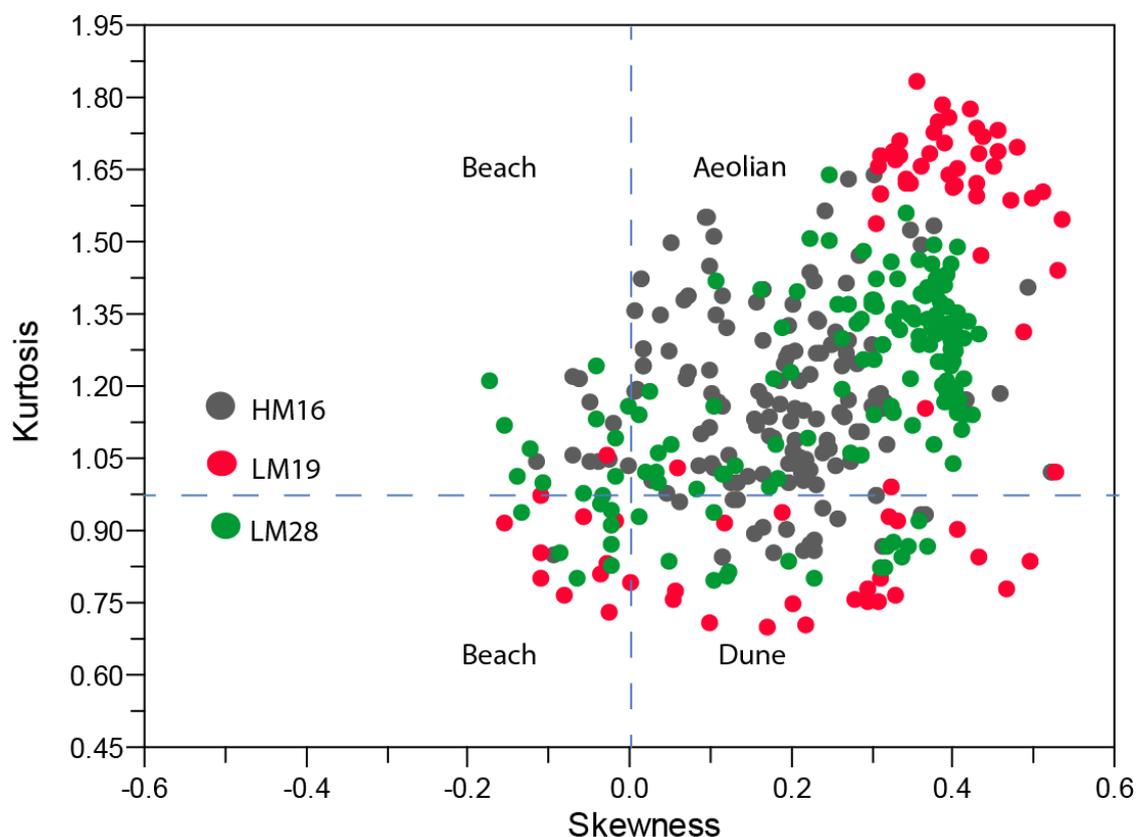


Figure 7.1 Skewness of particle size plotted against Kurtosis for the three studied cores. This bivariate scattergram shows the possible origin of the sand found in the samples, according to Briggs, 1981.

Figure 7.1 shows the skewness of the particle size of each sample in the three studied cores plotted against the Kurtosis. This shows generally a positive skewness with high kurtosis. This plot is consistent with aeolian sand deposition according to Briggs (1981) and Folk and Ward (1957). The particle size distribution of the three studied cores varied

between bimodal (mainly silt and very fine sand, poorly sorted) and unimodal (coarse and medium sand, moderately sorted). This bimodality characteristic of the studied cores also implies that part of the sediment reaching the peat achieved its sorting elsewhere in a high-energy environment (dune or beach), and that it was transported essentially with its size characteristics unmodified into another environment (peat) where it was mixed with another type of material (Folk and Ward, 1957). Rapidly deposited sediments from a single transport event (such as storms) are often poorly sorted, whereas frequently reworked and redeposited sediments tend to be well sorted (Masselink and Hughes, 2003). The mineral particles (sand, silt and clay) found in the three studied cores are mostly from moderately to very poorly sorted, indicative of rapid deposition into the peat, interpreted here as stormy deposition.

The sand reaching these mires was carried by the wind from the sand dunes close to the sites; strong winds (associated with storms) are necessary for the transport of sand-sized grains which form the coastal dunes (Clarke and Rendell, 2009). Even so, the movement of sand and mineral particles is not straight forward; and particularly in coastal environments is very complicated and other factors such as topography of the site, sediment availability, relative sea-level and wind direction have been taken into account with discussing the inferred storminess record. There is no doubt that some of the sand found in the cores could be due to erosion from land. However in these case there would be a gradational process from peat to a sandier peat, meanwhile the deposition of sand by storms will be represented by peat combined with sand deposition in thin laminated or lenses of sand (Delaney and Devoy, 1995). The stratigraphy of the studied sites (Chapter 4), the presence of sandy layers within the peat and the fact that after peaks in sand the values remain low also support the idea of this influx as a localised climatic signal (De Jong *et al*, 2006).

The next section aims to determine the most likely wind direction, through time, in Scilly and draw them together with the palaeogeography (changes in relative sea-level, coastal and intertidal zone), the location of the cores and the tidal currents. All these parameters

will be used together with the particle size analysis to interpret the particle size record and create a record of storminess for the Isles of Scilly.

7.2 RELATIVE SEA-LEVEL AND PREDOMINANT WIND DIRECTION IN SCILLY

Understanding the local coastal configuration of the study sites (Higher and Lower Moors) is important in the interpretation of their particle size records and/or storminess signal. Lower Moors is on the west side of the islands (Fig. 4.11) whilst Higher Moors is on the South facing the open sea (Fig. 4.5). An attempt has been made to deduce the prevailing wind direction and storm tracks in Scilly during periods of known climate change, such as the end of the Bronze Age (Maps 7.4 A and B), the Romano Optimum Climate (Map 7.4C), the Medieval Warm Anomaly (Map 7.4E) and the Little Ice Age (Map 7.4F) Time slice maps have been drawn to graphically represent the location of the analysed cores through time, to observe their distance from the coast and intertidal area (important for sediment availability) and the increases in relative sea-level. Tidal currents are also important for sediment transport so it has been assumed that the tidal regime in the past was the same as at present (Maritime chart 34 was used for this purpose). Palaeotidal simulations conducted for the North-West European shelf seas have demonstrated that tidal changes have been generally small during the last 8000 years (Uehara *et al.*, 2006).

The frequency of storms in the Atlantic region, and the predominant wind direction, is controlled by the NAO (De Jong *et al.*, 2006). The North Atlantic Oscillation (NAO) is defined by the pressure gradient between the Arctic and Subtropical Atlantic in winter. Changes in the mean circulation patterns over the north Atlantic associated with the NAO are accompanied by changes in the intensity and number of storms and their paths (Fig 7.2). Generally, positive NAO index winters are associated with a north eastward shift in the Atlantic storm activity, with enhanced activity from Newfoundland into northern Europe and a modest decrease in activity to the south (Hurrell and Deser, 2009). During positive

NAO phases, conditions are colder and drier than average over the north-western Atlantic and Mediterranean regions, whereas conditions are warmer and wetter than average in northern Europe (Visbeck *et al.*, 2001). These periods are characterised by mild, wet and windy weather in North Europe (Clarke and Rendell, 2006). During positive NAO phases the axis of the westerly winds orients southwest-northeast and shifts to the north. In the negative phases the axis of the westerlies lies further south (Wanner *et al.*, 2001). However, this pattern has changed in recent times. For example the Little Ice Age, a period of well-known climatic deterioration, coincided with a negative NAO phase dominated by easterly wind patterns around the UK (Dawson *et al.*, 2003; Dawson *et al.*, 2007; Lamb, 1991), rather than westerly winds. This has been interpreted as a possible shift or a large atmospheric scale circulation pattern change (Alexander and Tett, 2005). Dawson *et al.* (2002) argued that the increased storminess during negative NAO phases in the late Holocene was due to the formation of high pressure over Iceland and the build-up of sea ice in the Iceland/Greenland Sea causing a southward deflection of storm tracks. Trouet *et al.* (2012), using a combination of high-resolution proxy records and model simulation of positive and negative NAO models, reached the conclusion that while an increase in storm frequency implies positive NAO, negative NAO phases will be marked by increased storm intensity.

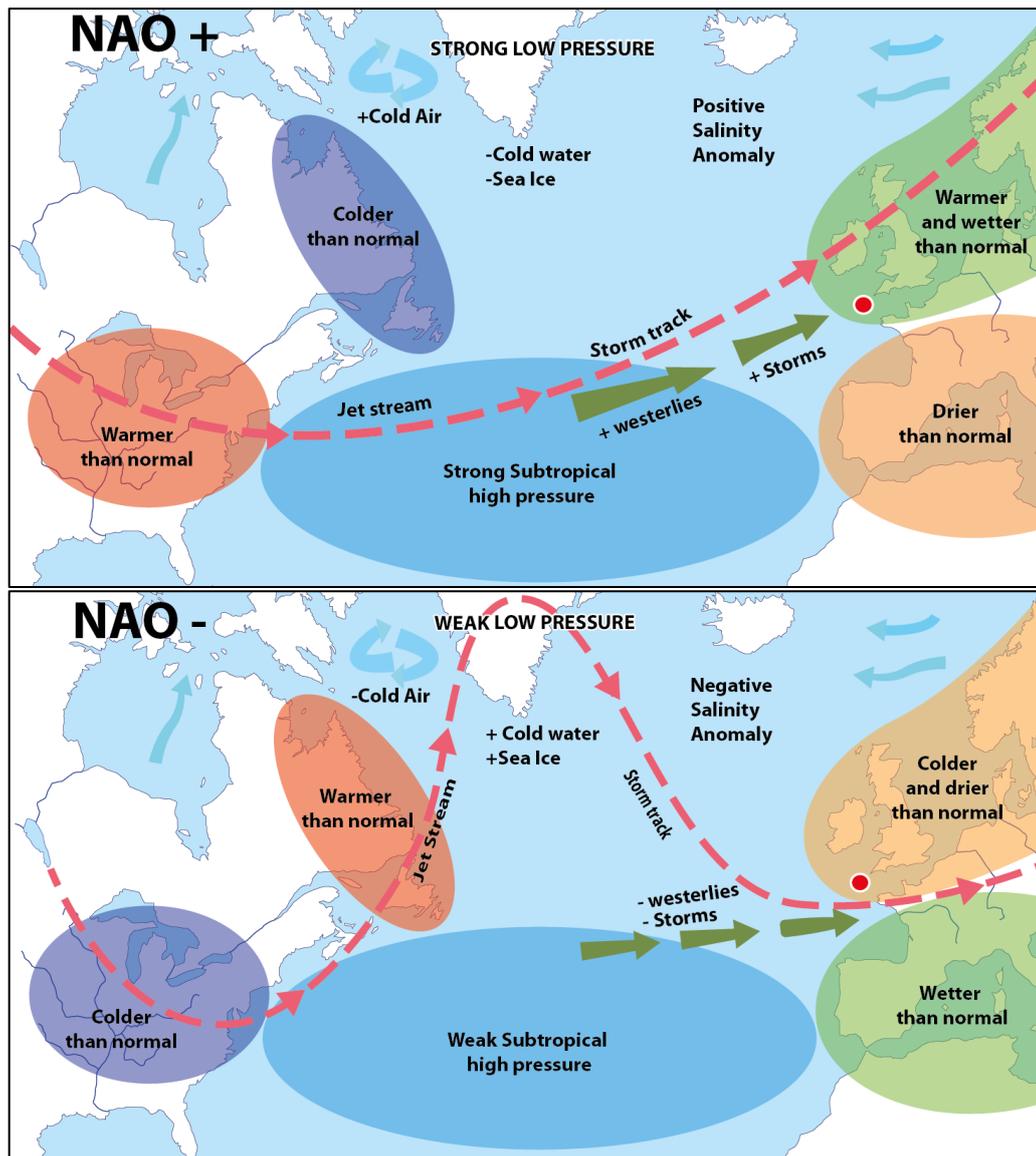


Figure 7.2. Graphical representation of the two modes of the NAO, showing the predominant wind direction and the main environmental characteristics for the North Atlantic zone. The Isles of Scilly are marked by a red circle. Adapted from: Clarke and Rendell (2006), Fischer and Mieding (2005), NC State University (accessed 2013) and Olsen *et al.*, (2012)

The approximated wind direction for Scilly has been deduced by correlating Na^+ (salt) from Greenland cores with North Atlantic Oscillation (NAO) indexes. The increase of Na^+ ion concentration has been interpreted in previous studies as an indicator of North Atlantic storminess, although it is recognised that this relationship is not straight forward (Fischer and Mieding, 2005; Mayewski *et al.*, 2004). Even so, this proxy is still valid to create a record of storm frequency because it provides a record of sea salt deposition (Fischer, 2001) and northern coastal European records are very similar to those reported of sea-

salt sodium (Na^+) from Greenland ice cores (Sorrell *et al.*, 2012). It has been hypothesized that winter with low temperatures and NA precipitation high (in the GISP2) may have been characterized by exceptional storminess across the North Atlantic region (Dawson *et al.*, 2003). Higher sea salt deposition onto the northeaster Greenland ice sheet is connected to the positive NAO phase, whilst a decrease in sea salt is related to a negative period of NAO (Fishcher and Mieding, 2005). A finer and higher resolution NAO index for the last 5200 years (Fig. 7.3 shows the indexes for the last 3000 years) has been developed by Olsen *et al.* (2012) using a high-resolution multi-proxy geochemical record from a small lake near Kangerlussuaqu (Greenland) and linking these results (a palaeo-redox proxy Mn/Fe ratio) to a reconstruction of the NAO index based on tree rings and speleothems.

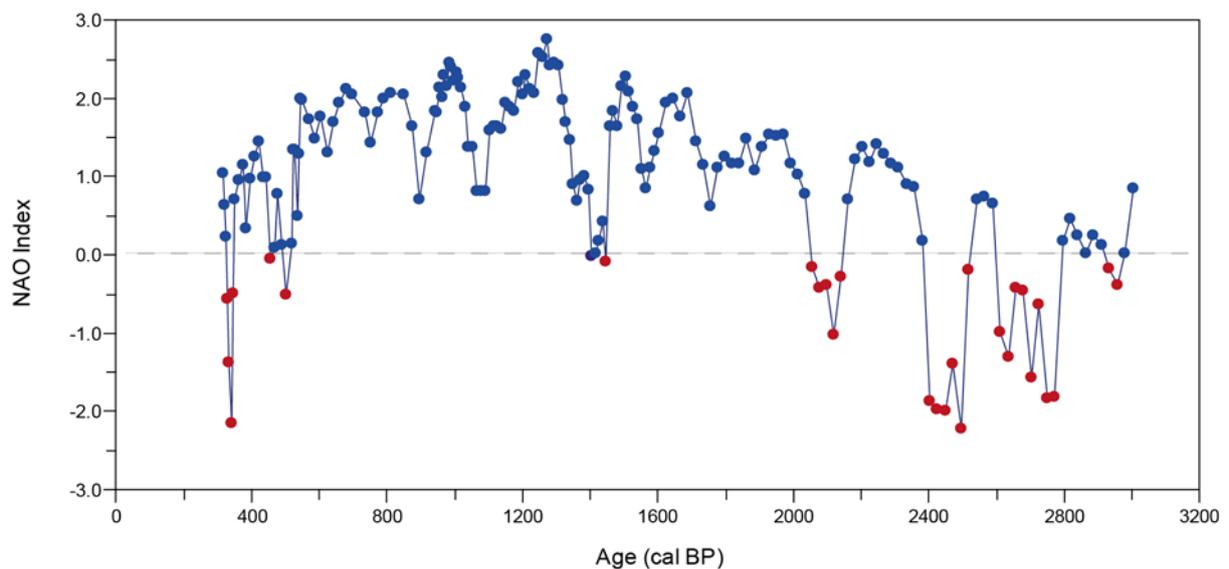


Figure 7.3. Graphic representation of the North Atlantic Oscillation indexes for the last 3000 years. The blue dots represent positive NAO indexes while the red dots show negative NAO indexes. Data obtained from Olsen *et al.*, 2012.

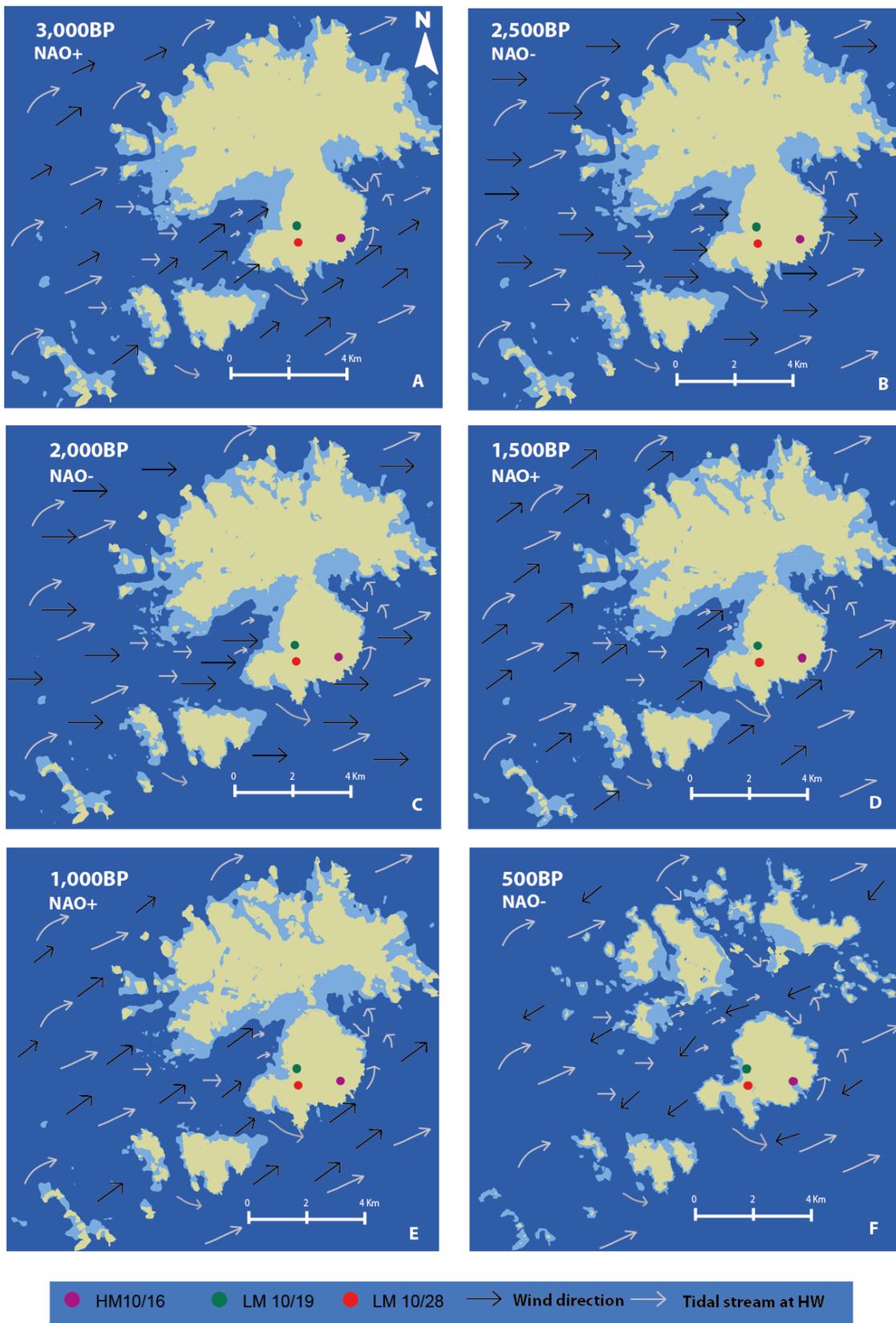


Figure 7.4. Palaeogeography of the Isles of Scilly through time and schematic representation of the tidal currents (based on Chart 34) with possible wind direction (based on Na+ chronologies and NAO indexes).

The inferred direction of prevailing winds through time in Scilly (Fig 7.4) is based on Na⁺ index chronology (O'Brien *et al.*, 1995) and the high resolution NAO indexes (Olsen *et al.*, 2012). The periods 2400 - 3100 cal BP and 600 cal BP are characterised by an increase in the Na⁺ (sea salt) of the Greenland ice cores (O'Brien *et al.*, 1995). This signifies periods of positive NAO, with strong westerly winds with a north orientation and a higher number of storms (Fig. 7.2). The rest of the Greenland record has low Na⁺, signifying negative NAO phases resulting in weaker westerly winds and a reduced number of storms (Fig. 7.2). The higher resolution NAO indexes from Greenland (Olsen *et al.*, 2012) show the same results with the difference that there is a short period of negative NAO index around 3000 cal BP (Fig. 7.3). Overall, these two records indicate that the periods between 4500 and 2500 cal BP (with a positive spell around 3000 cal BP) and 500 cal BP are characterised by negative NAO indexes while the period between 2500 and 550 cal BP is represented by more positive NAO indexes.

7.3 STORMINESS AND CLIMATE CHANGES IN SCILLY DURING THE LAST 3000 YEARS

It has been argued (section 7.1) that the high resolution particle size analysis of the three cores and the robust chronology obtained provide records of sand movement associated with storms on Scilly for the last 3000 years. This section of the thesis will develop an understanding of past storm conditions on the Scilly Isles by interpreting the three particle size records. The next step will be to compare these results with climate changes occurring during those 3000 years. These records have been plotted on a composite diagram to aid the comparison between the sequences, showing the coarser grain sizes, degree of sorting, position of the dating control and periods of positive and negative NAO indexes (Fig. 7.5). From the 17th century onwards the NAO indexes have been deduced from Cook and D'Arrigo (2002).

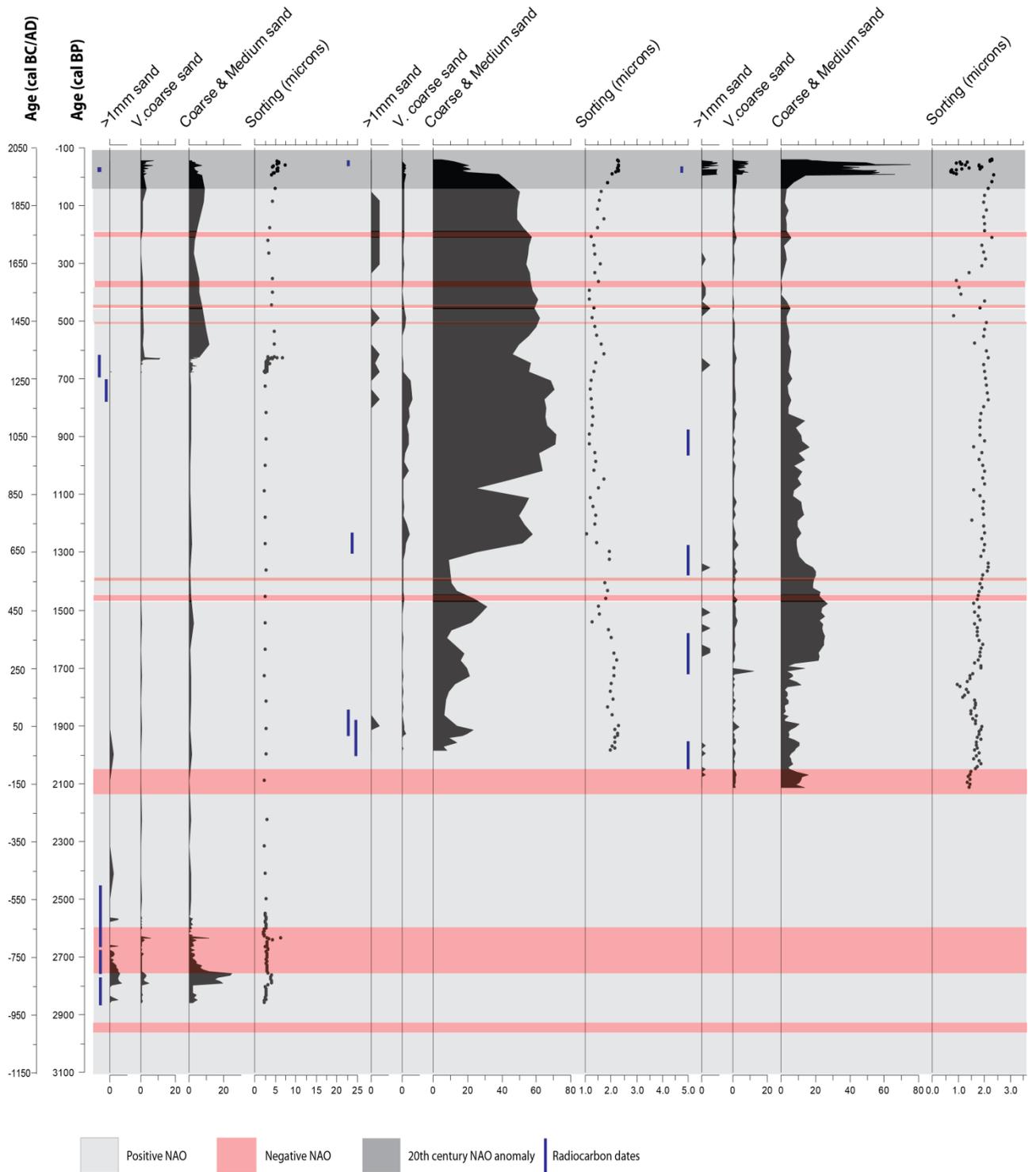


Figure 7.5 Summary of particle size data showing the coarser sand fraction (percentage), sorting mode, radiocarbon dates (in blue), Negative periods of NAO (in red) and positive NAO (in grey) periods.

7.3.1 Scilly storminess record for the late 3,000 years

It has been established that the origin of the sand found in the sample cores has an aeolian origin. The peak values in very coarse, coarse and medium sand (1mm-200µm) are thus indicative of periods of storminess. The most striking feature in figure 7.6 is that the storminess records are not synchronised between cores. Core HM16 particularly shows a seesaw effect to cores LM28 and LM19, when the storminess record is more pronounced in these last two, HM16 shows a reduction in the amount of sand and vice versa. This could be explained by the topography and location of the sites and wind direction and sediment availability. Due to their location it is very likely that Lower Moors is more sensitive to westerly winds, while Higher Moors (located on the opposite side of the island) is more affected by easterly winds.

The first evidence of a strong influx of sand (inferred storminess) in core LM28 (Fig.7.5) occurs between 2860-2700 cal BP (910-750 cal BC). A second period of storminess is marked in LM 28 starting around 700 cal BP (1250 cal AD) and finishing at the beginning of the 20th century. These storminess periods have higher percentages of sand when these occur simultaneously with positive NAO indexes. During those positive periods the offshore winds would have been running in a direction nearly parallel to the coast (Map 7.4A). Relative sea-level and wind direction are important factors for sand transport. When the wind blows parallel to the beach, the fetch and sand source are practically infinite, the wind is saturated with sand but not much sediment is transported inland (Arens, 1996b).

It is possible that although the wind was blowing towards the area where the core was taken, the sand was travelling further away so only a small fraction was deposited within the peat. Aeolian transport of sand is sensitive to disturbances in vegetation cover, soil surfaces and other disturbances such as livestock grazing (Field *et al.*, 2009). Sand transport increases if vegetation density is low (Arens, 1996a) because the sand can be carried freely by the wind and it is not trapped by the vegetation. As shown by pollen analysis of LM28 (Fig. 5.3) this area was mainly a very open landscape dedicated to

grazing. This open landscape would have allowed the transportation of aeolian sand as far as possible leaving only small amounts of sand deposited in the peat. Topographically, the area where LM28 was taken is nowadays quite protected by embankments, and it can be speculated that this was the case in the past, as this area is a bit lower than the surrounding areas. The wind would have been particularly strong in order for the sand to reach this area.

Core LM28 shows some storminess (but to a lesser degree) between 2750 and 2500 cal BP (800 – 550 cal BC). Within this period, the higher storminess rate coincides with a negative NAO period (Fig 7.5). This phase is characterised by weaker westerly winds and fewer but more intense storms (Fig. 7.2). It is possible that this period the wind would have blown nearly perpendicular to the beach (Map 7.4B). During perpendicular winds the sand is taken up and transported further inland (Arens, 1996a). These offshore winds are also running in the same direction as the tidal current and due to relative sea-level increase the intertidal area is substantial. The location of core LM28 is in the path of these winds so the sand transported by these winds could have reached this area relatively easily during storms.

Core LM28 shows a period of reduced sand movement, or storminess from *circa* 2500 cal BP to 700 cal BP (550 cal BC to 1250 cal AD). During this lengthy period the core shows only small amounts of sand reaching this area of Lower Moors. On the contrary, the other two cores show evidence of storminess during this period but at different times. The palaeogeography of Scilly (Fig 4.2) shows that the intertidal area close to LM28 was stable during this period, so this reduction of sand into the bog cannot be explained due to reduction in sediment availability.

LM19 was also taken in another basin of Lower Moors, located on the same geographic side and orientation of St Mary's. Replication of the general patterns seen at LM28 will support the interpretation of storminess. LM19 shows a constant influx of sand in the core with three markedly different periods. The first period was between 1990 and 1450 cal BP

(40 cal BC and 500 cal AD) with high but fluctuating amounts of coarse and medium sand (Fig. 7.5). A second period, from 1300 cal BP (650 cal AD) to the 20th century, shows constant and important percentages of aeolian sand inclusions. During the third period, the 20th century, the influx sand reduces drastically. Similarly to LM28, the highest percentages of sand inclusion in LM19 are present when the NAO has a positive index. During periods of negative NAO, the sand percentages diminished slightly.

The differences between the storminess record between LM28 and LM19 may be due to sediment availability (De Jong *et al*, 2006). This is a very important factor in aeolian sand transport. As can be observed in the maps of figure 7.4, LM19 is located closer to the coast than LM28 and the intertidal zone increases over time; increasing sediment availability from exposed intertidal sand and flats. Pollen analysis from LM19 (Fig 5.2) also shows an open landscape dominated by grasses through time. This open vegetation, the closeness to the coast and the increasing sediment availability would have allowed sand to be transported and deposited at LM19 more readily than at LM28 (Maps 7.4 D and E).

The storminess record shown by HM16 (Fig. 7.5) is different to LM28 and LM19. HM16 shows a constant influx of sand in the sedimentary record but in smaller amounts than LM19. Changes in the sedimentary record seem to occur simultaneously in LM19 and HM16, but they are opposite, resulting in a see-saw effect. For example the period of inferred higher storminess in HM16 1670-1340 cal BP (cal AD 280 – 610) coincides with the period of inferred lower storminess action in LM19. The main periods of storminess in HM16 are found between 1670 and 1340 cal BP (280-610 cal AD) and during the 20th century. Other periods of importance (but with lower percentages of sand influx) are found *circa* 2110 to 1670 cal BP (160 cal BC – 280 cal AD), and 1340 to 400 cal BP (610-1550 cal AD).

Due to its location Higher Moors is more sensitive to easterly winds than westerlies.

During negative and positive NAO phases (Maps 7.4C, D and E) the westerly winds would have been running parallel to this site probably resulting in less sand transport to the site,

in spite of the fact that this site is very close to the coast. The palaeoecology of HM16 (Fig. 5.1) also shows a largely open landscape, so the vegetation would not have impeded sand movement. Another important consideration is the sediment availability of this area. Figure 7.4 shows that this area had a very small intertidal catchment. So even under the right conditions (storms and the right wind directions) there would have been much less sand available to be transported into the site, compared to the Lower Moors core locations.

Important changes in the sedimentary record of the three cores occur during the 20th century (Fig. 5.7). Cores LM28 and LM19 show a considerable reduction in the influx of sand into the sediment whilst core HM16 shows a dramatic increase in the amount of sand in the sediment. This period is characterised by drastic fluctuations in the NAO indexes with the prevailing easterly wind direction during phases of negative NAO (Alexander and Tett, 2005; Dawson *et al.*, 2002). HM16 is more sensitive to easterly winds (e.g. Map 7.4F) and it is an exposed coastal area, only separated from the sea by sand dunes. At this time, the intertidal area close to Higher Moors is slightly larger than before so the sediment availability is also higher (Fig. 7.4). The opposite pattern occurs in Lower Moors. The two cores show a large reduction in the amount of storminess. Due to their location they are well protected from the westerly and easterly winds. The area where LM28 was taken is now surrounded by trees and separated from the sea by an industrial estate and higher ground, which would make it difficult for the aeolian sand to reach this area. LM19 was also taken from an area separated from the coast by houses and trees and was therefore well-protected. Very strong winds will be necessary for aeolian sand to reach this area.

Once the storminess evidence in the particle size record of the three studied cores is analysed it is possible to explore if changes in the storm signals are also related to overall climate change during the Holocene.

7.3.2 Correlating the Scilly storminess record with other known periods of sand movement

The time span covered by the three studied cores (Fig 7.5) allows for the correlation of the records with other, published, accounts of sand movement around the North Atlantic and known past and recent climatic changes, such as the 'Medieval Warm period, the Little Ice Age and the late 20th century global warming. These climatic periods are well-documented so it was possible to try to compare them with the storminess records obtained from the three cores. First it is necessary to establish a very schematic and brief summary of the major climate changes occurring in Europe during the last 3,000 years prior to commencing this comparison. Around 1300-1200BC the warm Subboreal Optimum ended and a cool and wet phase began, which lasted roughly until 300BC. The following period until c. 400AD was characterized by a generally warm climate and it is sometimes called the Roman Climate Optimum; subsequently until c. 900AD the climate was very unstable and severe. The following 500 years included the mildest period in Europe (1080-1300AD) since the Holocene climate optimum, however noticeable oscillations have been reported. From the 14th century until the 19th century AD there was a period of extreme climatic conditions known as the Little Ice Age. In the middle of the 20th century AD another warm phase (Modern Climate Optimum) can be inferred from instrumental records. In the following years a moderate natural cooling trend appears to have been anthropogenically reversed from the 1970s into a slight warming trend (Hass, 1996).

The first inferred stormy period deduced from LM28 (Fig. 7.5) coincides archaeologically with the end of the Bronze Age (c. 800BC) and the early Iron Age (800BC-42AD). Climatically this was a changing period from a continental climate to an oceanic, which led to raised lake levels, expanding bogs, lowered tree limit and increased glacial activity (Anderson *et al.*, 1998). This period has also been identified as an era of widespread stormy intervals in Europe (Sorrell *et al.*, 2012). In Scilly there is also archaeological evidence, from this time, of accumulation of blown sand forming considerable dunes along

the islands' south facing and south-westerly inner shores. A good example is the sand which made the earlier lower part of the Halangy village uninhabitable at the end of the Bronze Age (Ashbee, 1974). The same situation was observed by the excavators in Little Bay (St Martin's), this was occupied during the second half of the second millennium BC and abandoned during the Iron Age due to blown sand incursions (Ashbee, 1986). In mainland Cornwall, there is also evidence of sand invasion of Late Bronze Age settlements from Hayle to Gwithin Thomas (Lewis, 1992).

The earliest important influx of sand in HM16 occurs around 1670 lasting up to 1340 cal BP (280-610 cal AD), although this period is interpreted as a time of fewer storms in Lower Moors (Fig. 7.5). This contradiction has been explained before so here the focus will be on comparing these records with the overall climate at that time. Climatically this period is known in the literature as the 'Roman Climate Optimum' (McDermott *et al.*, 2001) due to its relative rise in temperatures. However this period is associated in England with wet winters and floods, for example there are several 'sea incursions' in the southern North Sea, implying storm surges in around AD 270-300 (Lamb, 1995). This period coincides with a dominant positive NAO index and prevalent westerly storm tracks, which bring more storms. However these westerly airflows also increase the precipitation in the western area of the UK (Charman *et al.*, 2006). During very wet conditions (prolonged rainfall) and especially during gales and surges, transport of sand declines to zero, regardless of wind speed, although high rates of sand transport are observed during heavy showers (Arens, 1996a). It is possible nevertheless that the conditions during this period were good for sand movement in the Isles of Scilly (wind direction and abundant storms). These coastal areas (Map 7.4D) were more affected by gales and surges rather than only by strong winds, especially in the areas close to LM19 and HM16, as they were closer to the coast and more exposed. The Isles of Scilly are very exposed to wave energy with storm wave heights attaining 14m. Directional data shows that the biggest waves approach from between the south-west and north-west, but large waves can also approach from the east (Munro and Nunny, 1998). During this period, both cores, LM19

and HM16 show a strong bimodality in the sorting indexes (Fig. 7.5), where the sorting mode varied from a low index (moderately sorted, aeolian sand) to a less sorted (possible fluvial sand transport).

The next period of inferred storminess is represented by LM19, starting around 1300 cal BP (cal AD 650) until the 20th century. This stormy period is also indicated by periods of sand influx in HM16 with much lower percentages of sand and in LM28, from c. 750 cal BP (1200 cal AD). This longer period (from the 7th to the 20th century) includes two very different climatical periods: 'The Medieval Climate Anomaly' (AD 800-1300) (Trouet *et al.*, 2009) and the 'Little Ice Age' (AD1250-1850) (Sommerville *et al.*, 2003).

There is no consensus about the start and duration of the Medieval Warm period; most authors restrict it to the era between AD900 to 1300, while others set the beginning of this period around AD700 (Bjorck and Clemmensen, 2004). This warm period was manifested in the British Isles by temperatures comparable to the present day under relatively dry conditions (Turney *et al.*, 2006). Although there are doubts about the existence of the Medieval Warm Period at a global level, a reconstruction of winter air temperature variations in western Europe for the period AD750 to 1300 by Pfister *et al.* (1998) has produced evidence of colder intervals between AD 1066-1086 and AD 1110-1180, with relatively warm stable winters especially from AD1180 to 1299. This warm period coincides with a period of extremely high positive NAO indexes (Fig. 7.3).

LM19 would have been right on the path of the prevailing westerly winds during the Medieval Climate Anomaly (Map 7.4 E), with an increasingly large intertidal zone and an exposed zone close to the coast. In this case not even strong winds would have been necessary to transport the sand into the site. LM28 would also have been in the way of the westerly winds but this area is protected by the isthmus and higher ground. The winds would have been running parallel to Higher Moors, in consequence transporting limited amounts of sand. The area close to HM16 also had a very small intertidal area, producing a very limited quantity of sediment. Overall the three storminess records inferred from the

three cores do not show a change or reduction in the intensity of storms between this warm period and the previous era.

Climatically the Little Ice Age is completely different to the previous period; however, the inferred storminess record of Scilly only shows very subtle changes. This period is associated with movements of sand, sand instability, stormy weather and direct observations of glaciers and sea ice (Sommerville *et al.*, 2003). Evidence of this enhanced storminess during the Little Ice Age has been deduced from the Greenland cores, from historical data and proxy datasets from North West Europe (Clarke and Rendell, 2009). Sand records from Europe show synchronicity with increased sand mobilisation in south-west France, north-east England, south-west Ireland and the Outer Hebrides during the cool phases of the colder periods of the Medieval Warm period and the Little Ice Age (Dawson *et al.*, 2004). In Western Europe the last major phase of sand drift which took place circa 500-200 cal BP (AD1450-1750) has been linked to storminess in the North Sea region (Szkornik *et al.*, 2008). Not only was this period marked by an increase in storm activity but the coldest phase of the Little Ice Age was characterized by an intensification of gales and sand mobilization (Trouet *et al.*, 2012).

As previously discussed (section 7.2) the Little Ice Age (LIA) coincided with a positive NAO, but due to changes in atmospheric circulations the winds were not only westerly orientated but the easterly winds became dominant during this period. During the Little Ice Age there is an increase in the amount of negative NAO indexes, especially towards the end of the period (Fig. 7.3). The easterly winds are the ones responsible for bringing storminess and precipitation to Europe (Dawson *et al.*, 2007). For example, in Northumberland, northeast England, most dune building occurred during the LIA, principally during a period of easterly circulation wind (Wilson *et al.*, 2001). This period is represented differently in the three studied cores (Fig 7.5), due to their location, relative sea-level, wind direction and sediment availability. The storminess record inferred from LM19 does not show any difference when compared with the Medieval Anomaly period. The only difference is that the aeolian sand has increased its size from 770 cal BP (1180

cal AD), maybe indicating more extreme storms and stronger winds. There are differences in the storminess record visible in LM28. This core shows an increase in storminess from 760 cal BP (1190 cal BC). The location of these cores (Map 7.4 F) during this period, indicate that they were closer to the coast, but the intertidal area was not larger than before. Contrary to the two previous records HM16 (Fig. 7.5) shows a slight reduction in the percentages of sand influx from c. 800 cal BP (1150 cal AD). This is quite surprising as the prevailing easterly wind direction in Scilly during this time (Map 7.4 F) would have been straight into Higher Moors. The lack of sand is probably due to the increase in gales and surges accompanying the storms. As previously discussed when there is an increase in the amount of gales the transportation of sand is minimal even if the winds are strong.

Not only was the Little Ice Age as a whole marked by an increase in storm activity but the coldest phases, notably the Maunder Minimum (MM), were characterized by an intensification of gales and surges (Trouet *et al.*, 2012). The inundation by the sea of the studied areas and the presence of surges could also explain the increase in >1mm sand found during this period in LM19 and HM16, the cores closer to the coast. Water flows are able to transport clasts as large as a boulder but even at the very high wind strengths of storms the largest rock and mineral particles carried are likely to be around a millimetre in size (Nichols, 1999). In Scilly there is historical evidence of surges at this time, inundating Lower and Higher Moors. There is a historical record of a big storm taking place on 26 September 1744. Robert Heath described how “...*it being a very high Tide, the Sea rolled in vast Mountains, driven by the Winds*”. Models of this episode postulated a flood-level that may have reached 7 metres when plotting the areas of Lower and Higher Moors that would be subject to marine flooding (Thomas, 1985). It is very likely that similar episodes to this one were occurring in the past and more frequently under deteriorating climate conditions.

The next period of increasing storminess in Scilly is observed in HM16 and starts in the 20th century (Fig. 7.5). Once more the cores from Lower Moors show the opposite situation to Higher Moors. These two cores show a period of reduced storm intensity. The

20th century started with a warm phase (Modern Climate Optimum) (Hass, 1996). The NAO indexes varied constantly (Cook and D'Arrigo, 2002) so it is difficult to determine the wind directions and why the storminess record for the three cores is very different at this time. As previously mentioned, the explanation could be due to the location of the sites. LM19 and LM28 are protected from the coast whilst HM16 was taken in a very exposed coastal area close to sand dunes. The UK regions have tended towards larger magnitude events in recent decades, particularly in the more southerly regions, and there has been a significant increase in the number of severe storms over the UK as a whole since the 1950s (Alexander and Tett, 2005). Furthermore coastal meteorological data from Ireland to Spain have shown an increase in the occurrence of storms since the 1940s (Lozano *et al.*, 2004). These storms' effects (sand deposition) are more evident in Higher Moor because of the exposure of the site and the closeness to the coastal dunes.

It has proved difficult to correlate inferred storminess records from a site to general climate changes. Global patterns in climate are not always represented by individual climate signals (e.g. storms). This is even more obvious when trying to connect climatic changes occurring at a global scale with climate signals from specific and smaller areas. Several records within the same area will show different climatic events depending on location, topography, wind direction, sea-level and more factors.

7.4 SYNOPSIS

Historical accounts from western Europe show that coastal communities have been particularly vulnerable to sand invasion and the burial of settlements and agricultural land (Lamb, 1991) due to storms. In coastal environments there are a variety of processes that can trigger sand movement, including overwash, aeolian and fluvial transport. The influx of sand in these cores has been interpreted as aeolian sand (due to size, skewness, kurtosis and mode). Furthermore these periods of mineral changes seemed to coincide

with climate change and storm events across Europe, suggesting that they represent, at a regional level at least, storminess.

The effect of a storm action on a coastline may involve a complex pattern of sediment redistribution and may be controlled by numerous factors in addition to storm intensity, including: changes in relative sea-level, the volume of sediment available, tidal regime, coastal and offshore morphologies and anthropogenic influences (Delaney and Devoy, 1995). The understanding of these factors has been essential in order to interpret the meaning of the sand records in the three studied cores. Relative sea-level has been rising constantly in Scilly (sometimes abruptly, sometimes moderately) and this would affect the amount of sediment available for transport during storms (Masselink and Hughes, 2003). Careful analysis and understanding of coastal changes through time were necessary when correlating the particle size records to specific climate signals (e.g. storms).

There is some evidence that persistence in the spatial location of North Atlantic storm tracks (controlled by NAO phases) may result in particular periods of sand mobilisation at a regional level (Clarke and Rendell, 2009). The NAO indexes and prevailing wind direction in Scilly through time have been speculatively calculated using Na⁺ chronologies based on O'Brien *et al.* (1995), Olsen *et al.* (2012) and Cook and D'Arrigo (2002). These results have been used as guidance when determining a storminess record for Scilly.

The three cores show dissimilarities during the same periods (Fig 7.5). This is because sand deposition and transport are highly site specific, controlled by local topography, sediment availability, wind direction and vegetation cover. For the late prehistoric period of Scilly, LM28 provides evidence of widespread sand movement, although the clearest evidence of drastic sand invasion continues to be the layer of sand that inundated the Bronze Age settlement of Halangy Porth St Mary's. The next stormy period represented by LM28 does not start until the beginning of the 12th century AD, with reduced storm intensity between these two stormy phases. LM19 offers a different picture to this calm period. The first stormy period spans 1990 and 1450 cal BP (40 cal BC – 500 cal AD), and

a very intense storm period starts in the 7th century AD. The differences between these two records from Lower Moors, when both of these zones shared the same geographical location and are affected by the same wind direction and increase in relative sea-level, have been explained due to differences in the sediment availability and topography. LM19 is closer to a larger intertidal zone and closer to the coast, whilst LM28 was taken from an area further from the coast and well protected by higher ground. Both cores show an increase in the storminess level from the 12th to the 20th century AD.

HM16 also shows differences in the storminess record and the differences are even more evident when comparing the result with LM19. These two cores have been taken from opposite sides of the same island, and in consequence they are affected by different wind directions. At LM19 aeolian sand influx is likely to be due to the action of westerly winds, whilst HM19 aeolian sand influx with the easterly winds.

The inferred storminess record of the three studied cores shows drastic changes during the 20th century. The two cores from Lower Moors show a notable decrease in the amount of sand influx while the core from Higher Moors shows a period of intense storminess. This difference between the three cores has been explained due to fluctuating changes in the NAO indexes, wind direction (more easterly), topography and sediment availability. The areas where LM19 and LM28 were taken are well protected areas and separated from the sea by roads, houses and buildings making the aeolian sand transport difficult. On the contrary, HM16 was taken from an exposed area, very close to sand dunes and with a large intertidal zone. In addition, due to its geographical location this area is more susceptible to easterly winds.

Europe, and of course the Isles of Scilly, has had important climate changes through the Holocene. Climate variations that have been widely recognised and well-explored but despite the new dating evidence from these cores, it is not yet possible to link with confidence these climatic periods and the sedimentary records. Furthermore, due to the error margins that are inherent in age models, a direct correlation between peak events

recorded at different sites cannot be established with certainty (De Jong et al., 2006). Climate events are not uniform and do not happen at the same time and with the same intensity everywhere. Spatial and temporal differences are the common denominator. It was not expected that a uniform response to the same climate signal would be found in different areas (or even in the same area). Instrumental and documentary records of storminess along the Atlantic coast of western Europe have shown that storm activity exhibits strong spatial and temporal variability (Clarke and Rendell, 2009).

8 DISCUSSION

8.1 INTRODUCTION

This chapter investigates the response of people in Scilly to coastal changes, drawing together: (1) the changes in vegetation and land use deduced from the pollen diagrams (Chapter 5); (2) the new palaeogeography mapping of the coastline (Chapter 6); and (3) the storminess record (Chapter 7). These parameters are used to test the existence of a pattern or relationship between environmental changes and the archaeological record of Scilly during the late Holocene. In this project the adoption of a palaeoecological approach, with a robust chronology, has the potential to uncover natural environmental and landscape changes as well as anthropogenic landscape changes. As pointed out by Mitchell (2011) a palaeoecological dataset with a temporal component will identify the extent and severity of human induced impact on the landscape. Furthermore, interdisciplinary research on selected key studies that combines palaeoecology and archaeology is a useful strategy aiming at a more profound knowledge of the interaction between environment and society. The combination of data from both sources provides a solid framework for understanding palaeoclimate as a driving agent along with other factors in prompting cultural change (Moreno *et al.*, 2009).

How people reacted to alterations in the environment would have been imprinted in changes in the landscape, changes in agricultural production, consumption and subsistence (Bürgi and Russell, 2001). In this thesis the combination of bathymetry and a relative sea-level GIA model for Scilly allows the construction of time-slice models relating to the changing environment. An accurate representation of the extent of the Isles of Scilly during the Holocene, with the mapped archaeology and the vegetation changes, will contribute to the interpretation of the impact of coastal changes in Scillonian societies.

Prior to any analysis it is important to re-emphasise that the environment alone does not determine the social organisation of human societies, but it sets the frame to which they must adapt, establishing boundaries for the range of social strategies that can be selected and applied (Dearing and Battarbee, 2007).

This chapter starts by discussing the impact of coastal changes in the Scillonian societies during the Early Holocene and the last 3,000 years, before going on to integrate this data within a wider context, making comparisons to similar studies. Finally, it undertakes a brief analysis of the consequences of future coastal changes for Scilly.

8.2 COASTAL, ENVIRONMENTAL CHANGES AND SCILLONIAN SOCIETY

Throughout the Holocene, coastal processes and the human use of coastal areas have been directly influenced by relative sea-level fluctuations and climatic changes (Sommerville *et al.*, 2003) and the vulnerability of people in these coastal areas is best exemplified in islands (Berglund, 2003). Scilly seems ideally suited to this type of study. It is an archipelago that has experienced relative sea-level rise since the early Holocene, with very limited land surface and an archaeological record that goes far back in time. For the purpose of detecting the impact of coastal and environmental changes in Scillonian society over time, it is important to document natural changes in past climate and relative sea-level rise and relate those changes to the archaeological record.

It is important to make a distinction between climate and weather concepts. Climate may be simply defined as average weather, whilst weather is the day-to-day occurrence of atmospheric phenomena which impact in perceptible ways on people's lives (Bell, 2012). Disjuncture between weather and climate, and people and society, shows the importance of understanding the scaled temporalities within which people experience weather (Cooper, 2012a). Weather is the first and most immediate environmental experience; extreme weather situations often leave evidence in the environment and it may then be explored in connection to archaeological records to determine the possible effects of such

extreme weather events on societies (Gronenborn, 2012). Whereas climate and weather are indeed important to the interpretation of past ways of life, when trying to recognize a direct correlation between a climate proxy record and any specific human behaviour it is common to discover that any neighbouring proxy record will show a different set of relationships (Wilkinson, 2012). It is expected that changing weather conditions will impact farms and farming practices most significantly (Pillat, 2012). Consequently, this will be reflected in a change in the palaeoecological record. This thesis aims to discover the impact of storms (weather) in coastal communities through the vegetational record and relate these to broader climate impacts and archaeology.

The data presented in this project (vegetation changes and storminess record) cover only the last 3000 years, however the paleogeography presented goes back to the Early Holocene. As a consequence, it is possible when comparing this palaeogeographic data with the archaeology of the Early Holocene to discuss the human impact of coastal changes in these early societies. This section thus examines two themes. The first deals with coastal and social changes on hunter-gatherer and early agricultural societies during the early Holocene (Palaeolithic, Mesolithic and Neolithic) and the second on social and environmental changes to agrarian communities during the last 3000 years.

8.2.1 Early Holocene

The reaction to climate and environmental change is exemplified by the way that communities have dealt with the loss of land due to rising sea-levels (Adger *et al.*, 2005) and the Scillonian communities have been affected by relative sea-level increase since they first arrived on the islands. Relative sea-level rise results in the alteration of the landscape and it could cause major economic damage such as loss of land and disruption in subsistence patterns. For the purpose of detecting the impact of coastal and environmental changes on Scilly in the earlier Holocene, it is important to document natural changes in the relative sea rise and correlate them with the archaeological record.

The physical impacts of sea-level rise are well known. The immediate effect is submergence and increased flooding of coastal land, as well as saltwater intrusion into coastal aquifers. For the populations of small islands, reduction or disappearance of potable water may be the greatest impact on their survival (FitzGerald *et al.*, 2008). Longer term effects also occur as the coast adjusts to the new conditions, including increased erosion and ecological changes; and those impacts in turn have both direct and indirect socioeconomic consequences, which appear to be mostly negative (Nicholls and Cazenave, 2010).

The Isles of Scilly were joined to mainland Cornwall until *circa* 11,500 cal BP (c. 9550 cal BC) but it is possible that since 13,000 cal BP (c. 11500 cal BC) the track of land between Scilly and Cornwall was submerging periodically and progressively. As previously discussed (Chapter 6.1) there is plenty of evidence of human presence in the South West of England at this time although very limited in Scilly. Socially this period is characterized by highly mobile groups that moved around Europe hunting, fishing and gathering plants, exploiting a wide range of territories (Hotl, 2003). Early groups could have wandered freely across northern Europe, locating and establishing territories, subsisting by fishing, hunting and gathering. Despite the reduction in land mass due to inundation by the North Sea, the increase in the coastal zone with its high levels of food productivity probably favoured an expansion of Early Mesolithic (c. 10000 cal BP) in this region (Momber, 2000). Evidence of this coastal culture, now underwater, can be found elsewhere in Britain. For example a submerged forest in the eastern Solent, has revealed a Mesolithic settlement at a depth of 11m, while in the southern section of the English Channel, the Cotentin peninsula has shown submerged Palaeolithic evidence at a depth of 20m (Bailey and Fleming, 2008).

It is very likely that the first settlers of Scilly were nomads that lived by hunting, fishing and gathering, so it is possible to assume that early Scillonian settlers tended to cluster along the coast. In all probability most of this evidence now lies underwater, hence the limited presence of early activity in the archaeological record of Scilly (Fig. 6.3). Part of this

record is located near the new 'inundated area' where the increase of relative sea-level is creating a protected bay. New palaeoenvironmental records (Charman *et al*, forthcoming) have identified this area as marshland during this period, with evidence of human activity nearby, including large peaks of charcoal associated with a decline in *Quercus* (oak) and an increase of *Betula* (birch), indicative of anthropogenic woodland disturbance. In this case the impact of the relative sea-level and separation from the mainland, in the society did not have a totally negative effect. The societies were able to adapt and exploit new environments and the increase in relative sea-level led to the creation of a larger intertidal zone providing these early groups with important coastal resources. The permanent occupation of the islands during the Mesolithic, based on the present artefactual evidence, seems unlikely. It is more probable that the islands were occupied seasonally to fish, collect shellfish and hunt sea mammals; it would also have provided welcome landfall for mainland Mesolithic offshore fishing forays (Robinson, 2007). Evidence of Mesolithic communities using fire to manipulate the vegetation and exploiting a growing intertidal zone was also observed at Goldcliff on the Welsh site of the Severn estuary (Bell, 2007).

A major effect due to relative sea-level rise could have happened in Scilly after 7000 cal BP (c. 5000 cal BC), when the rise in relative sea-level stabilised and the increase slowed down (Table 4.1 and Fig. 4.4). It is only after this time that evidence of occupation starts to appear in Scilly (Map 6.3 C) and 1000 years later there is evidence of a permanent occupation (settlements) together with the building of the first megalithic monuments. Day *et al.* (2007) tie the emergence and rapid expansion of the first complex societies to a slowing rate of sea rising. These authors suggest that prior to that time the sea-level rose too quickly to permit communities to become permanently established, but once the sea stabilized the societies started to move slowly from a nomadic to a more sedentary subsistence. A higher degree of Sedentism (a significant factor in the progress of societies) could develop in groups along the Atlantic coastline, moreover these groups could have attained a larger size before needing to disperse, and/or resort to less preferable food items, due to the higher capacity of the habitat (Fa, 2008). This is very clear in the

Scillonian record; once the relative sea-level rise was more stable, evidence for human activity became evident in the archaeological record. About a millennium later permanent settlements and megalithic monuments start to appear around the Scilly landscape, implying a highly organised society. This is part of a wider pattern of social development that it was occurring at this moment also in the mainland. According to the GIA model (500 year intervals) the relative sea-level has continually risen on Scilly (Table 4.1). Meanwhile, the archaeological evidence suggests continuous occupation of the islands throughout the later Holocene (Chapter 2). The detailed palaeoenvironmental records presented here allow for discussion of the impact of coastal changes in Scillonian society for the last 3,000 years.

8.2.2 Scilly and environmental changes during the last 3,000 years

Establishing a causal relationship between environment and culture is always problematic. There are two different types of environmental changes that can affect human populations. Short-term abrupt changes, such as floods or droughts, can be repeatedly observed in the span of a few human generations and cultural responses to them would be hard to reconstruct. Meanwhile long term events, such as climatic changes or sea-level rise, can modify substantially the landscape and can be linked to long-term trends in human evolution (Hudson *et al.*, 2012; Morales *et al.*, 2009). Minor cultural adjustments to environmental shifts, especially if they are short lived, are less likely to be manifest in the archaeological record. On the other hand, long-term sustained changes in the environment, particularly if they affect critical resources detrimentally (most likely in extreme environments) are more easily identified in the archaeology (Lepofsky *et al.*, 2005).

It is very challenging to identify through archaeological data alone the intentionality behind human decision-making processes because it is difficult to differentiate between deliberately planned disaster management strategies that have been intentionally adopted

and cultural practices that have the benefit of mitigating potential hazards (Cooper, 2012). The chances to discuss such relationships are improved when palaeoecological and climate records are considered alongside archaeological changes. Bringing together the palaeovegetational records, storminess records, new palaeogeography, a robust chronology and the archaeological record allow for the reconstruction of the impact of environmental changes in the societies in Scilly.

The palaeoenvironmental record shows a heavily exploited landscape since prehistoric times. This is supported by the archaeology that shows a society highly dependent on agriculture (field systems, enclosures, midden remains). The main problem of an agricultural society is that it is highly reliant on climate and weather (Pillat, 2012). Climate change is often suggested as a cause of Holocene vegetation change (Giesecke *et al*, 2011); however this relationship is more complex, especially when humans are active in the landscape. Even under constant climatic conditions, vegetation will not remain stable; for example: soil leaching, podsolization and peat development may occur in response to a constant excess of rainfall and/or incomplete nutrient cycling by plants (Bunting, 1994). Changes in vegetation cannot be ascribed totally to climate, is an influencing factor but people are the main drivers of vegetation throughout the later Holocene (Woodbridge *et al.*, 2012). The three studied core were taken from areas where past and present human activities are evident. The vegetational changes deduced from these cores can be associated with anthropogenic uses of the landscape (e.g. cultivation, grazing, and deforestation) and with certain climatic influences (e.g. increase and decrease of wet tolerant species).

The three studied cores (Fig. 7.5) show great variation in the intensity and amount of inferred storms over time, as well as differences within the sampled areas. The contrary effect is visible in the palaeoecological record (Fig. 5.6). This shows an open landscape, managed for both pastoral and arable agriculture since the Bronze Age in Higher and Lower Moors. For example, LM28 shows a period of inferred storminess around 2870 cal BP (920 cal BC) and a period of relative calm from 2500 cal BP (550 cal BC) onwards. In

both cases the vegetation record (Fig. 5.3) shows a continuation in the pastoral use of the land. It is possible that due to its location (Fig. 4.11) this area of the Lower Moors has always been sheltered from the storms. However, the same situation is observed from the other two cores, taken in more exposed areas.

LM19 shows a constant period of storminess (Fig. 7.5) especially intense from around 1300 cal BP (650 cal AD) until the 20th century, whilst the only change in the vegetational record between this period and the preceding centuries is the increase in heath and dry pastures. Pastoral land use remains dominant (Fig. 5.2). The same is observed in HM16. The changes in the storminess record are not followed or accompanied by changes in the vegetational record (Fig. 5.1). In the three cores the vegetational record is more affected by the anthropogenic use of the land rather than climatic or weather conditions. Through time a managed landscape dominated by pastoral use is visible, which kept the areas open.

Nevertheless, sometimes it is possible to observe subtle changes in the vegetational record after periods of increased inferred storminess. For example, LM19 (Fig. 5.2) shows an increase in maritime communities after stormy periods and the opposite during stable periods. LM28 (Fig. 5.3) shows a drop in the presence of cultivation taxa during and after periods of inferred storminess. For example from 650 cal BP (1300 cal AD), LM28 shows a period of intense storminess and the palaeoecological record (Fig. 5.3) shows a drastic reduction in ruderal communities, cultivated land and pastures, whilst the maritime communities increase considerably. HM16 shows a slight increase in the presence of heather and sand dune communities (Fig 5.1) during stormy periods and the same is visible in LM19. Storms (with the consequent input of sand into the soils) influence on site-flora and they impact on local vegetation. These storms are not only carrying and depositing sand but they also bring water and when accompanied by a relative increase in sea-level and surges they also bring salt. This will also allow the growth of wet and salt-tolerant plants to the detriment of other flora. If the nearby dunes are stable enough to support flora, these pollen will also be carried with the sand. The increase in sand on the

soils will also affect the cultivation. Sandy soils are particularly vulnerable to erosion, they tend to have low organic matter content and poor structural stability (Quinton and Catt, 2004). In Scilly the soils are mainly weathered granite (Chapter 2) and not very fertile; an increase in sand would have negatively influenced the possibility of using them for cultivation.

8.2.3 Environment and settlement patterns

There is evidence of important climatic changes during the last 3000 years in Europe (Hass, 1996; Wanner *et al.*, 2001) and there is no doubt that these would have been perceptible in Scilly too. Regardless of these climatic changes, the vegetational record presented in this thesis and other palaeoecological studies show that the agricultural economy (pastoral and arable) has been permanent since at least the end of the Bronze Age (2500-800 BC) and into the modern era. However there are important changes in the archaeological record that hint at disruptions in the society, occasionally happening at the same time as major environmental changes (climate and relative sea-level rise).

The first storminess record showed by LM28 (Fig. 7.5) is dated to around 2800 cal BP (850 cal BC). Archaeologically this period encompasses the end of the Bronze Age (c. 800BC) and the beginning of the Iron Age (800BC – 42AD). Environmentally this is a period of climate deterioration (Amesbury *et al.*, 2008; Dark, 2006), but a relatively slow increase in sea-level (less than one metre every 500 years, Table 4.1). Culturally there are political, economic, and social transformations (Cunliffe, 2001). The most remarkable innovation in architecture in Scilly after 800 BC is the construction of defensive monuments. In Scilly there are no definitive examples of hillforts, although the Civil War Battery on Mount Todden in St Mary's may represent the reused remains of such a monument (Thomas, 1985). The Cliff Castles (common in Cornwall and along the Atlantic Façade) are represented by Giant's Castle on St Mary's, Shipman Head on Bryher, Burnt Hill on St Martin's and possibly another one in St Agnes (Ashbee, 1986), Fig. 8.1. It has

been assumed in the literature that these monuments have a defensive nature, constructed in periods of adverse climatic conditions, to protect the limited resources. For example in Ireland there is an extensive construction of forts in periods of increased wetness (Turney *et al.*, 2006). The presence of fortified habitation indicates a desire to maintain some form of land tenure and protect the groups' members and store resources from the raids of rivals (Field and Lape, 2010). In Scilly there is no evidence of societal collapse or abandonment during this period and the most common habitation sites after 800BC are still the open settlements (Fig. 8.1). The palaeoecological record also shows a continuation in the use of land as pastoral and in LM28 (Fig. 5.3) there is evidence of uninterrupted cultivation from this period onward.

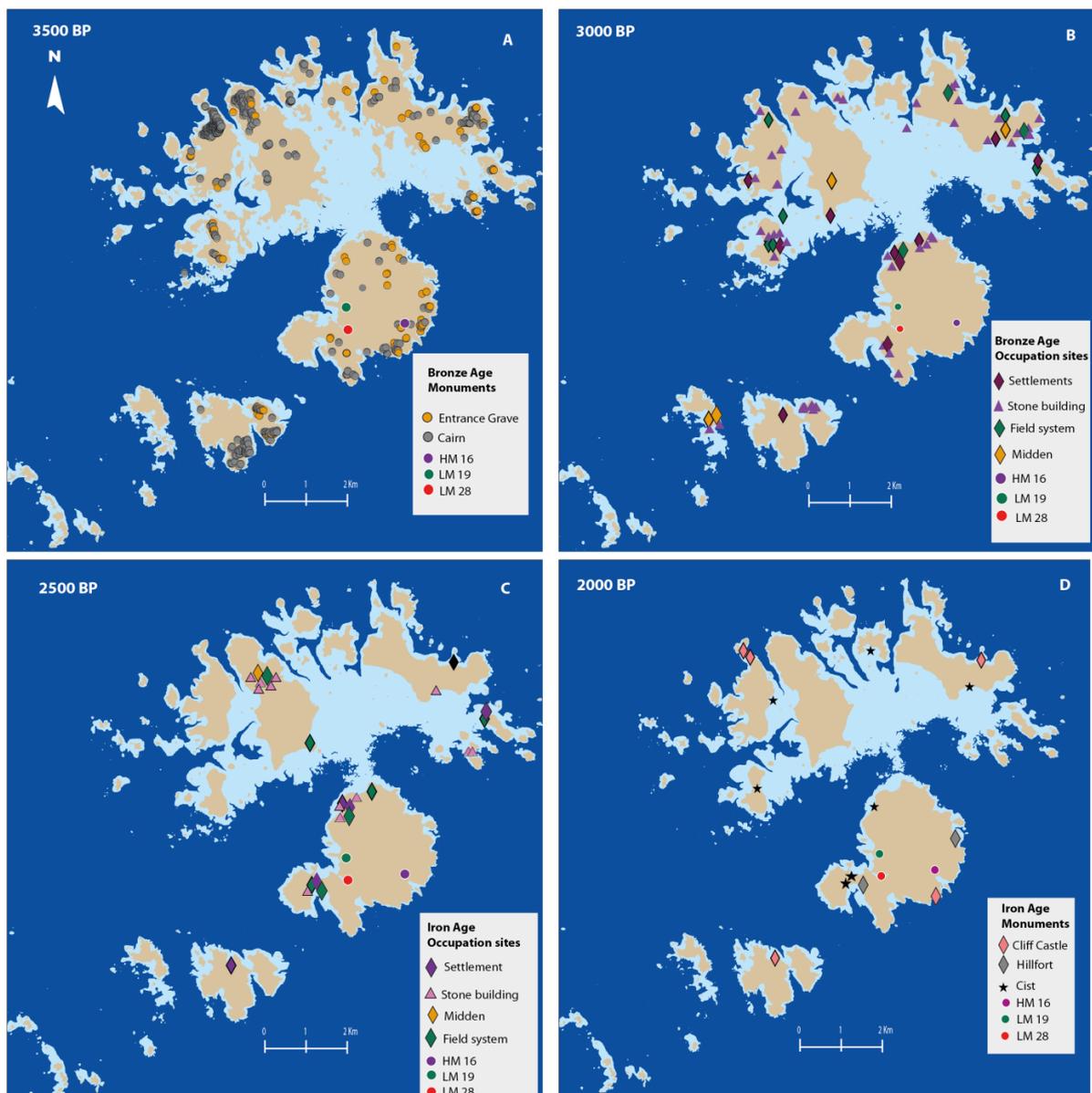


Figure 8.1 Palaeogeographic map of the Isles of Scilly during the Bronze (maps A and B) and Iron Age (maps C and D). Archaeology is mapped from the Cornwall and Isles of Scilly HER. Archaeological evidence from the same period is separated in two different maps to show a clearer distribution of the remains.

While the consensus seems to be that climate change has the potential to influence human settlement, it is difficult (1) to provide a chronology to determine the climatic change and its parameters that affect human societies, (2) to provide a direct link between the phenomena and (3) to estimate the impact of climate change on settlements (Faust and Ashkenazy, 2007). A causal link cannot be inferred merely by observing correlations between environmental and cultural variables because such associations may be purely

coincidental (Coombes and Barber, 2005). The cultural changes observed in Scilly cannot be related to climatic changes only; there is no evidence of drastic changes either in the landscape or in the use of land. It is very likely that the abandonment of previous traditions and the appearance of new cultural trends could be due to external influences and more contact with other cultures. Cliff castles are found along the entire Atlantic Façade, physically these sites show a remarkable similarity and it seems that the choice of location was to a large extent conditioned by a desire to control the interface between land and sea. In all probability these promontories were conceived of as liminal places endowed with particular power, if so it is possible to see in the distribution of 'cliff castles' the physical manifestation of a belief system shared along the Atlantic interface (Cunliffe, 1999), not just a consequence of deteriorating climatic conditions.

In terms of the Isles of Scilly, the comparison of the maps from figure 8.1 shows that the location of the Cliff Castles is the site previously used as a concentration of cairns and Entrance Graves. It can be hypothesised that the cliff castles in Scilly were built to protect these 'old' monuments' from the advance of the sea. It is very unlikely that they were used as storage or as protection for animals; in these cases it would have been easier to build such defensive monuments inland where they would have been sheltered from the wind and mostly from surges and storms. The Cliff Castle building and the protection of 'ancient' monuments could be interpreted as the protection of a social identity at a time when ancient and important monuments were being destroyed by the advance of the sea (Van de Noort, 2011). It can also be theorised that the Iron Age people of Scilly established their connection to the land through previous 'ancient monuments'. Examples of the 're-use' of early monuments by late prehistoric societies have been observed in Atlantic Scotland where Neolithic chambered cairns have produced Iron Age finds (Hingley, 1996). Early Anglo-Saxon burials are also found in prehistoric (mainly Bronze Age) barrows and Roman monuments and it has been speculated that this was their way of connecting to the newly conquered land (Williams, 1997).

8.2.4 The environment and the economy

The palaeogeography, palaeoecological and the archaeological records of Scilly show continuation in traditions from the 1st millennium AD into medieval times, with some cultural and technological changes and some changes in the landscape due to anthropogenic activities. The evidence shows a mixed farming economy, pastoral and agricultural with constant contact with the mainland and the continent. The storminess record still shows evidence that storms occurred during this period but they should be expected occasionally even in favourable climate periods.

Debris from middens (Neolithic, Bronze Age, Iron Age and Romano-British) and Scillonian settlements (from the Bronze Age onwards) reveal that their inhabitants practised a mixed subsistence economy. As well as growing crops and raising stock, they fished, gathered shellfish and hunted wild animals and birds. Cereals such as naked barley and emmer wheat were cultivated with pulses. The remains of domestic animals found include: cattle, sheep/goat (often the most plentiful species), horse and pig, and wild animals, such as seals, red deer and small deer. Some of the fish bones identified were of a varied range of species: conger, cod, gadoid, Pollack, saithe, black and red sea bream, gillthead, wrasse and a substantial amount of limpet shells and other molluscs (Butcher, 1978; Gray, 1972; Johns *et al.*, 2004; Neal, 1983). These observations suggest a large presence of domestic animals in Scilly so grassland will be a significant feature in the landscape. Evidence of the importance of pastures and cultivation over time in Scilly can be observed in the three studied cores (table. 5.1). As shown by the archaeology, the people from Scilly were exploiting both the sea and land resources, so it is possible that those areas not vulnerable to coastal flooding, those located inland and further from the coast, were the ones used for animal rearing and probably cultivation. The coastal area could have been used mainly for grazing. Coastal marshlands are particularly suited to pastoral farming with their high grass yields and rich meadows (Rippon, 2001).

Important changes start to appear during Medieval times (410-1600 AD) in Scilly, culturally and climatically. Culturally this period saw an increase in the construction of defensive structures (forts) and there are historical accounts of great social turmoil and poverty during these centuries in Scilly and lasting until the beginning of the 20th century (Parslow, 2007). This was a period of great climatic extremes (Medieval Warming and Little Ice Age); on the other hand, the palaeogeography shows that the configuration of Scilly has been similar since 3000 BP (1050 cal BC) with only the intertidal zone losing area (Fig. 4.2). The three cores show evidence of storminess during both periods (Fig. 7.5), to different degrees. The three cores show an important reduction in the presence of cultivated taxa, especially during the Little Ice Age. Medieval agriculture in Europe, and in Scilly, relied mainly on drought-adapted cereals from the Near East, hence warm and dry summers were essential for successful cereal production (Bonsall *et al.*, 2002). The consequences of cold-humid years were famines and increased death rates (Tinner *et al.*, 2003) and during the 14th century most regions of Britain were experiencing severe economic and subsistence crises from the unseasonably wet weather (Jordan, 1996). Historical accounts show that Scilly faced famine and poverty during this period (Parslow, 2007; Thomas, 1985). In contrast to previous periods, this Medieval Society did not exploit all of the sea resources as had been done previously. Medieval middens are composed almost entirely of limpet shells, with a very limited amount of land mammal bones (Ashbee, 1954) and remarkable in the lack of fish bones and cereals. This point will be discussed at length in section 8.3.3. when comparing different social choices taken under similar environmental changes and circumstances.

The climate changes occurring during the modern era have still affected Scilly; however, the main economical source in Scilly is no longer agriculture. Nowadays, Scilly is well known for its tourism industry. The most important environmental challenge that the Isles of Scilly are now facing is the increase in relative sea-level.

In conclusion, there is no apparent discontinuity in the inhabitation of Scilly. Social changes typical of British and European archaeology (e.g. from a nomadic to a sedentary

society, construction of fortifications, *etc.*) are evident within the Scillonian archaeological records and there are clearly important environmental changes (climatic oscillations and relative sea-level increase). However, this thesis has found no clear relationship between sea-level rise, storminess and either the archaeological record or land management practices on Scilly. The next section will expand on the mechanisms adopted by Scilly, both in the past and during modern times, to handle the alterations in the landscape and environment.

8.3 RESILIENCE AND SOCIETY

8.3.1 Concepts

It is useful to introduce and summarize some of the principal concepts employed in the literature when referring to the relationship between culture/society and environment.

Resilience is an important and widely used term in these studies (Wilson, 2012). Social resilience is defined as the ability of groups or communities to cope with external stresses and disturbances as a result of social, political and environmental change (Adger, 2000).

The mechanisms for enhancing social and ecological resilience are often inherent in the communities and those societies that are vulnerable to climate change, such as Scilly, have in the past adapted to change through strengthening their spaces of dependence to spread the risk (Tompkins and Adger, 2004).

Adaptation and coping are also important notions in cultural and environmental studies. Adaptation to climate change is defined as an adjustment in ecological, social, or economic systems in response to observed or expected change in climatic stimuli and their effects and impacts, in order to alleviate the adverse impact of change or to take advantage of new opportunities (Adger *et al.*, 2005). More often adaptation to environmental changes is limited by the values, perceptions, processes and power structures within a society. What may be a limit in one society may not be in another,

depending on the ethical standpoint, the risk perceptions of the society and the extent to which places and cultures are valued (Adger *et al.*, 2009). Coping mechanisms are the bundle of short-term responses to situations that threaten livelihood systems and they often take the form of emergency responses in abnormal seasons or years (Berkes and Jolly, 2001).

A term used when describing the relationship between environment and society is collapse. This means a drastic decrease in human population size and/or political/economic/social complexity, over a considerable area and for an extended period of time (Diamond, 2005). The archaeological and historical record is replete with evidence for prehistoric, ancient and pre-modern social collapse (e.g the Mayan culture, Haugh *et al.*, 2003). These collapses occurred quite suddenly and frequently involved regional abandonment, replacement of one subsistence base by another (such as agriculture by pastoralism) or conversion to a lower energy socio-political organization (Weiss and Bradley, 2001). Although the term collapse implies a downward change from something more complex and larger to something else less complex and smaller, it is possible to also consider collapse as a movement from a relatively more stable condition to one that is less stable (Yoffee, 2006). Collapse is not limited to any type of society or level of complexity; it can manifest itself in a transformation from a larger to smaller state, from more to less complex chiefdoms or in the abandonment of settled village life for mobile foraging (Tainter, 1988).

8.3.2 *Adaptation, collapse and coping mechanisms in Scilly*

The data presented here suggests that the early societies in Scilly adapted to continuous relative sea-level increase and climate variability. This constant adaptation left imprints in the landscape and in the archaeological record. In Scilly the major social changes such as adoption of agriculture, permanent settlements and construction of fortifications could have been connected to changes in relative sea-level increase, climate and cultural

influences, whilst the changes in the vegetation could be considered coping mechanisms related to changes in the soil conditions, climate and anthropogenic use of the land.

Adaptation to climate change is exemplified by the way communities have dealt with the loss of land due to rising sea-levels. Sea-level rise could result in major economic damage (it could produce social upheaval, migration, innovation and conflict), and equally it could result in the alteration of characteristic regional landscapes and the loss of ancient and important monuments, affecting people's sense of place and social identity. How people reacted to these alterations would be imprinted in changes to landscapes (the disappearance of established flora and fauna and arrival of new species), as well as changes in agricultural production, consumption, and subsistence (Van de Noort, 2011). In addition to inundating low-lying coastal areas, rising sea-level increases the vulnerability of coastal regions to flooding caused by storm surges, tsunamis and extreme astronomical tides (McInnes *et al*, 2003). As sea-levels rise, storms of a given magnitude reach higher elevations and produce more extensive areas of inundation. However, relative sea-level increase also offers benefits, such as the creation of larger coastal margins that provide a range of food and resources through the year (FitzGerald *et al.*, 2008). Periods of unpredictability in both resource-rich and resource-poor environments tend to intensify competitive and cooperative strategies. Archaeological studies suggest that human groups resort to conflict during longer or extremely severe periods of resource unpredictability, yet also invest in buffering strategies (such as diversified diets, mobility and exchange) in order to alleviate shortfalls. Archaeological studies of environmental disruptions have documented a variety of human responses such as: relocation, increased diet breadth, physical stress, trauma, population aggregation and increased reciprocal exchange (e.g. Allard and Erdenabaatar, 2005; Cooper, 2012; Field, 2004; Rosen, 2007).

As discussed in Chapter 6, the increase in relative sea-level in Scilly during the Early Holocene brought important environmental and coastal changes, such as the separation of Scilly from the mainland, and more importantly the separation of the main islands. This

last and important change took place during the Bronze Age. A large track of dry land became submerged by the increase in relative sea level, although, as a consequence a large area of intertidal land and possible marshland became available. People took these changes as an opportunity to increase their food resources and the coastal and marshland ecosystems were exploited, as shown by the archaeological record (middens and settlements debris). An important social change occurring at this period of coastal changes can be inferred from the archaeology. Numerous funerary monuments (Cairns, Entrance graves and cists) started to appear and although these are found in other places (such as Cornwall, Ireland and Brittany), their concentration is higher in Scilly than anywhere else. The success or failure of a community's ability to environmental changes is related to internal factors such as social organization, technology and the perception of environmental change and its causes (Adger, 2000; Adger *et al*, 2009). There are some examples where episodes of severe environmental changes have been perceived as related to religion. For example in the case of the Greenland Norse population the causes of environmental changes were attributed to the sins of the community and the relief of such situation would come from intensified religious activity and increased investment in religion institutions (Rosen, 2007). It can be speculated that similar situation could be an explanation for the amount of monuments (Maps 6.4 D and E). Other explanation has been offered in Chapter 6. These monuments are mostly found on the outer coast of the Isles of Scilly, so it is also possible that some of them were the product of stone clearance of the fields; without losing their ceremonial used or purpose. The reduction in land would have forced the Scillonian communities to use every area in the islands for agriculture. Logically they could have used the new intertidal area as pastoral but they would still needed areas dedicated to arable.

Human adaptations to environmental changes are also visible in how people react to extreme climatic changes. One of the most significant climatic excursions in later prehistory was at the end of the Bronze Age, when the climate of north west Europe and possibly all the northern hemisphere worsened through weakening of the ocean 'heat

pump' of the north Atlantic current (Bond *et al*, 1997). This period of climatic stress has been considered to have generated economic and population collapse in parts of northern Britain (Tipping *et al.*, 2008), whilst in the South the Dartmoor reaves are also argued to have been abandoned in this period (Fleming, 2007). Although the relative sea-level rose at a slow rate (less than a metre every 500 years, table 4.1), the area of land loss in Scilly was considerable. During the Bronze Age Scilly reduced its area to half its size, and the islands obtained their actual configuration. This rise combined with occasional storms will have had more repercussions in coastal settlements, where large areas could be inundated due to these storms. The sudden advance of the sea as a result of a storm surge would have meant that during a major storm the sea would have devastated land several kilometres inland (McRobie *et al*, 2005). During the Bronze Age, land was probably the most important commodity and some of the worst storms occurring in coastal areas will have produced loss of land for the people (Lamb, 1991). Core LM28 (Fig. 4.19) shows a period with a considerable influx of coarse sand, during the Late Bronze Age, the highest levels until modern times, interpreted as evidence of a very stormy period.

There is evidence that these environmental changes (loss of land due to relative sea level rise and climatic deterioration) had a negative influence on Scillonian societies and that there may have been some disruption in the social structures. As previously stated the term collapse should not only be applicable when referred to large scale events (for example the complete disappearance of a society in the archaeological record), it can refer also to small and complex disruptions and abrupt changes in societies.

Based on the archaeological evidence and taking a totally deterministic approach, Scilly shows a region where there is a drastic reduction in the amount of occupation sites and monuments at the end of the Bronze period (Fig. 8.2) indicative of a 'societal collapse'; after major environmental changes. Large monuments were no longer constructed after the Bronze Age and the number of later prehistoric huts and settlements diminished considerably. All these were accompanied by a considerable amount of land loss due to relative sea level rise and an increase in storminess (as shown by LM28 particle size

record). In contrast, the pollen record shows a continuation in the land management, with a continuous presence of ruderal and cultivated taxa.

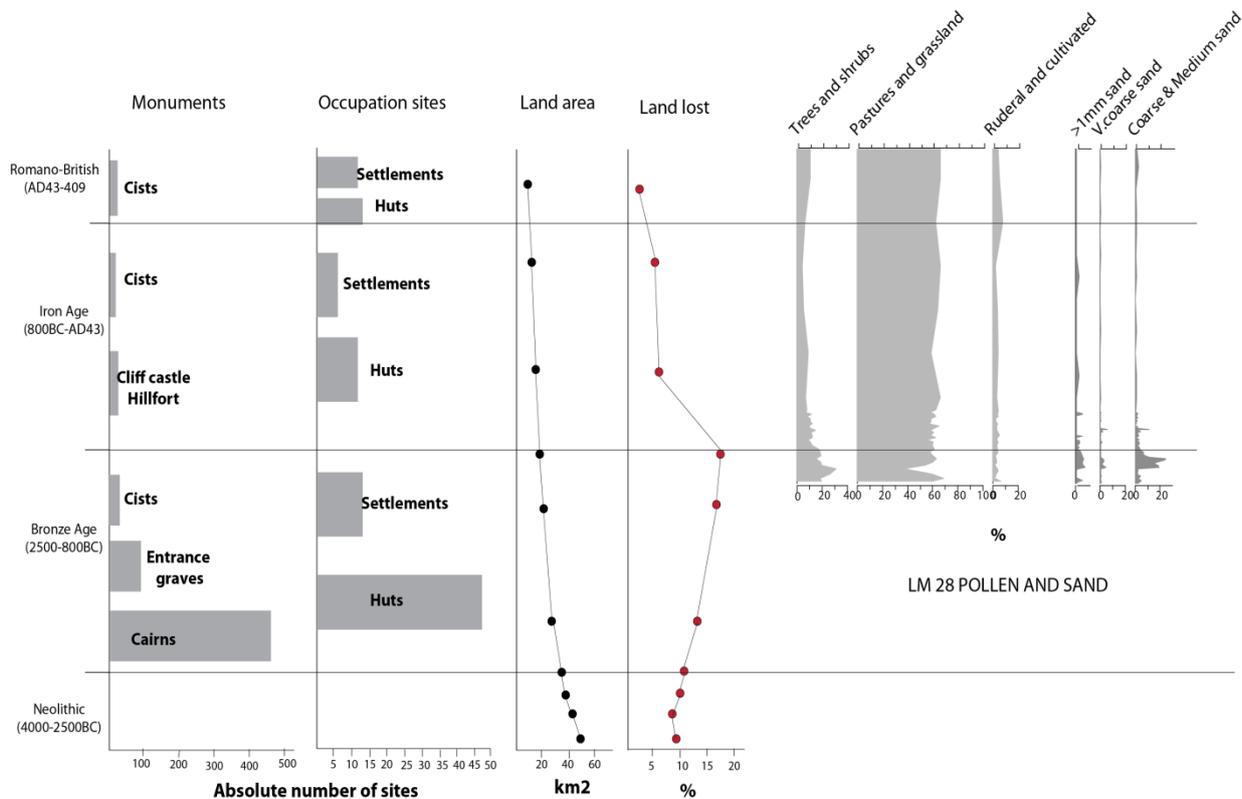


Figure 8.2 Comparative Graph of the absolute number of sites tentatively dated to the Bronze Age, Iron Age and Romano-British period in Scilly, the land area (km²) of the Islands during this periods and the Neolithic, together with the percentage of land lost due to increase in relative sea level, and LM28 pollen diagram and particle size also for these periods.

This proposition of Late Bronze Age societal collapse in Scilly is only conjecture at this point. It is limited by the absence of secure and comprehensive chronology for the majority of archaeological sites on Scilly. For it to be verified further archaeological investigations and a deep chronological study of the sites in Scilly are necessary. As discussed before (Chapter 2), the Scilly archaeological record is highly bias towards the Bronze Age, due to the presence of (highly visible) large monuments, and most of the huts and settlements lack dating control. Furthermore, the archaeological evidence suggests that the Scillonian sites are characterized by a continuous and unbroken sequence of occupational phases indicating continuity of settlement across periods (eg

Nornour, Halangy Down). Thus while some settlements could have been abandoned or contracted in size, the region did not collapse altogether. On the contrary the palaeoecological record (in this thesis) and the archaeology (architecture styles, pottery, and middens) indicate a continuous develop of the Scillonian society with social and political structures across time. Another point to consider is that the erection of funerary monuments occurs at the same time that the major environmental changes are occurring (discussed in Chapter 6). The monuments stop being building and the occupation sites seemed to diminished when the environmental conditions improved, probably indicating that these changes were more due to social factors than environmental circumstances.

The palaeoecological records show that rather than the Scillies being abandoned during this period of climate deterioration, it is very likely that land that became unsuitable for crops was converted to pasture. Similar examples have been found in Orkney where, during the Bronze Age, a pastoral specialism developed in the more marginal parts while elsewhere arable cultivation intensified; at that there time were indications of a slight climatic deterioration and the spread of heathland at some sites (Farrell, 2009). Another example is Dartmoor, where pollen and fungal spore data suggested that following a period of intensive pastoralism in the middle Bronze Age, there was a shift to low intensity land-use in the Late Bronze Age and Iron Age (Fyfe *et al.*, 2008).

The evidence of marine features disappearing into or buried in the sand on Scilly, and the sand-buried sections still to be seen at certain cliff-exposed sites, show that fields and dwelling sites were abandoned in the face of blown sand during this period (Ashbee, 1974). The earlier lower part of Halangy Porth was filled with sand and made uninhabitable at the end of the Bronze Age (Ashbee, 1974). This settlement was abandoned around 2260 ± 90 cal BP (400-200 cal BC) (radiocarbon dating obtained from a charcoal fragment incorporated into the dark loam infill of the circular stone built remnant in Halangy Porth). However, the inhabitants relocated to the higher terrace fields (Halangy Down) where the buildings were progressively occupied and modified for around a

millennium before they were abandoned (Ashbee, 1996). This is a clear example of resilience and adaptation to extreme environmental conditions.

The deterministic perception of climate/culture relationship has been fuelled in recent times by contemporary concerns over global climate change, putting climate back at the front of archaeological interpretations (Pillat, 2012). As a result, this leads to a rather simplistic understanding of environment and people, establishing direct links between evidence for environmental changes (mainly climate) and archaeological changes (eg: Van Geel *et al*, 2004). This simplistic chain of events are heavily criticised by scholars arguing for a new forms of determinism (McIntosh *et al*, 2000; Pillat, 2012). This thesis follows the view that although the environment (specially the increase of relative sea-level in Scilly) influences and sometimes constrains the social systems at the end the cultural and social changes are caused by other factors such as: external influence, political and cultural ideas.

An example of a coping mechanism used in Scilly could be the artificial fertilization of soils. The transition from woodland to open land in Scilly has been discussed in Chapter 5: by the Iron Age pastoral land dominated, supporting a combination of grazing and cultivation. The deforestation is very likely to have accelerated the processes of erosion of the already impoverished soils of Scilly. In the short term, forest clearance would have provided people with easily settled farm-sites and also increased the amount of available field and pasture, but in the long run soil erosion would have decreased the productivity of the soils and the erosion will gradually have reduced the areas available for agriculture and settlement (Smith, 1995). Intensive arable production will exhaust the soil nutrients, unless fertility is maintained by crop rotation, intercropping or manuring. Before the advent of chemical fertilizers, hearth ash and kitchen waste were commonly composted and spread onto agricultural lands, ash continues to be widely used as a fertilizer in Scotland and Ireland today (Guttmann, 2005). In Scilly it is also possible that algae were used as fuel to take the role of a combustible in a land with limited wood resources. Worked flint associated with boundary walls on the flats (especially on Samson) may be the only

durable residue of household waste spread on fields, while sea-shells and beach pebbles associated with early boundaries may indicate the use of seaweed as manure (Kirk, 2004; Thomas, 1985).

The evidence of coastal changes/climate and cultural interactions presented here suggests not only an environmental component but also social and human decisions. A range of interrelated factors, for example population growth, expanding exchange networks and technological developments, would also have been implicated in social changes (Haberle and Lusty, 2000). The next section will discuss how important the cultural aspects of a society are when taking decisions to deal with environmental changes.

8.3.3 Social choices and environmental changes

How societies respond to environmental changes is varied and depends on multiple factors. Human perceptions of nature, environment and climate change are key to how societies adjust to the impact of these changes. This impact is highly variable according to technological development, social organization and perception of this change (Rosen, 2007). Reactions can occur at many levels in the same society and may differ considerably (Cleuziou, 2009). The limits to adaptation are endogenous and emerge from 'inside' society; it all depends on goals, values, risk and social choice. These limits to adaptation are mutable and subjective, the decisions are made regularly at individual and societal levels and have implications for current and future adaptation (Adger *et al.*, 2009).

An example of how societies react differently to the same environmental changes is visible in Scilly. Prehistoric and Medieval societies (10th to 17th century AD) react differently when confronted with similar situations, such as loss of land, relative sea-level rise and deteriorating climatic conditions. As previously discussed (Chapter 6) the larger loss of land in Scilly occurring between 5000 and 3000 BP (2050 -1050 cal BC) coincided with the development of a highly organised society, the appearance of large monuments

and permanent settlements (Fig. 6.4). There is no evidence in the archaeological or environmental record of Scilly being abandoned during this time, very much the evidence indicate the opposite. Archaeological remains (middens and settlement debris) from the Bronze Age societies (c. 4000BC) until the Medieval period (c. 400AD) show evidence of societies that use as many natural resources as possible, they hunted wild animals and birds, fished (deep and shallow fishing), gathered shellfish and adopted and practised both arable and pastoral agriculture. The prehistoric middens are rich in remains and varied, contrary to Medieval middens. These produced large amounts of limpet shells, very few mammalian bones (all smashed into small fragments, probably to obtain marrow, some burnt and all of them with cuts indicating defleshing, even the horses' bones) and a very limited presence of cereals (Ashbee, 1954). The assemblage of these middens is thus totally different. Although both societies (Prehistoric and Medieval) turn to the sea for food, during the Medieval period they are only exploiting the intertidal resources (no evidence of deep sea fishing) and there is no evidence of diversification in their agricultural economy. It seems likely that during later periods the social structures and changes in subsistence base resulted in more rigid responses and the decisions were more dependent on the society as an entity rather than on the individual.

There are historical records confirming the impact of the climate in Scilly at that time, for example there are records indicating that magistrates were sent over to Scilly from Penzance to enquire about the causes of poverty in Scilly (Thomas, 1985). The deduced causes were the insufficiency of corn grown on the island in addition to bad harvest, the failure during the previous years of the making kelp (burning seaweed to make soap), the partial failure of the fishery and the suppression of smuggling into the islands by the Preventive boats (Vyvyan, 1953). The making of Kelp was introduced in the islands in 1684; this is made during the months of June and July and it requires dry weather to allow algae to dry before it is burnt in pits to be transported and transformed into soaps (Borlasse, 1756). Attempts to relieve the poverty and distress of the islanders by establishing pilchard and mackerel fisheries was not very successful and famine

conditions continued for some years, especially on the small islands (Parslow, 2007). Matters were made worst by the existence of so many over-large families and by the fact that most of Scilly's domestic economy was on a non-monetary footing. Boiled limpets were the only freely available foodstuff and they were consumed in their thousands; smuggling with pilotage and kelp-burning were a major component of the Islands' non-agricultural economy (Thomas, 1985). In a highly specialised economy like Medieval Scilly, depending totally on agriculture, the reduction in land availability (losing the intertidal area available for pastures) and the adverse climate will have more repercussions on the society than any other factors. However, social regulations such as the constant division of the land into smaller and smaller parcels due to hereditary regulations (Thomas, 1985), and the constant growing of families due to religious convictions (adoption of Christianity) could have also had a negative effect on a very limited land cover. During previous periods (Prehistory) of adverse environmental conditions, Scilly societies were able to adjust and modify their cultural options, for example: from a sedentary to a more mobile economy and exploitation of a wider range of resources. Late Scillonian societies have had much more complex pathways to effecting change in the face of environmental changes, including needs from external (mainland) communities. It is very likely that the limitations to coping with adverse environmental changes (reduction of land due to increase in relative sea-level) and bad climatic conditions, Little Ice Age) were influenced by the social turmoil happening not only in Scilly but in England more generally. Wars such as the English Civil War and the Napoleonic wars and constant political changes (Thomas, 1985; Parslow, 2007; Vyvyan, 1953) were adding more distress to a society already in trouble. The evidence from Scilly thus supports the notion that complex societies are more vulnerable to environmental impacts than simple ones. As the culture develops, individuals will be dependent upon a wider and wider network of subsystems. The growth in sophistication also creates a society that is far more specialized and the cost of maintaining the social infrastructure could lead to an increase of social ossification.

This will leave the community less flexible in its ability to respond to environmental changes (Brunk, 2002; Coombes and Barber, 2005; Messerli *et al*, 2000).

8.4 SYNOPSIS

Based on a multidisciplinary approach and taking into account archaeology, changes in storm conditions, relative sea-level rise and vegetational variations, this study offers valuable evidence of anthropogenic use of the landscape over time and helps to draw reliable inferences on the late Holocene environmental changes in Scilly. Placing the archaeological record within the contexts of detailed and well-dated Holocene palaeoclimate records has presented the opportunity to examine how societies responded to environmental changes. This chapter has summarised and synthesised the various strands of evidence, including: (1) landscape modifications (palaeoenvironmental reconstructions), (2) physical remains and material objects (archaeology), (3) residues resulting directly or indirectly from human activities (for example middens) and (4) oral or written traditions (Hassan, 2000).

One of the major environmental 'threats' in Scilly has been the increase of relative sea-level. The main consequence of this is principally the loss of already limited land. Prehistoric Scillonian societies demonstrated a particularly strong resilience and they were able to adapt to this land loss by diversifying their economic strategies and taking advantage of the new coastal margins. There is archaeological evidence of Bronze Age Scillonian societies being affected by increasing storminess conditions and an increase in relative sea-level. Fields and dwelling sites were abandoned in the face of blown sand during periods of increased storminess. The solution found by the inhabitants to these adverse conditions, was to move the settlements to higher ground and into more protected areas.

It is difficult to relate past cultural changes to environmental variations, however, several studies of climate-culture interactions in various regions of the globe suggest a significant

environmental component in human behaviour. Moreover, there are numerous examples in the deep past of conflict over resources, episodes of environmental degradation, deforestation, soil erosion and extinctions (Haberle and Lusty, 2000). In Scilly there is no evidence of societal collapse or abandonment of the islands, but there are changes in the structure of the society during times of major relative sea-level rise or changes in the climatic conditions. However, those social changes also coincide with changes in society all around Europe. For example the building of cairns and entrance graves is shared by other areas of the Atlantic fringe such as Ireland, Scotland and various Atlantic islands, indicating a cultural spread and influence all around this area (Cunliffe, 2001). The building of cliff castles and hillforts (during a period of deteriorating climatic conditions) coincides with the 'invasion' or 'influence' of new cultures from the North of Europe (falling of the Beaker culture and beginning of more 'Celtic' influences and the substitution of bronze for iron). The social changes in medieval times can be related not only to environmental changes but also to important social changes, such as the adoption of Christianity and the practice of an economic feudal system. It is worth emphasising that although the environmental circumstances were capable of enhancing the cultural transformations in Scilly they were not the only causes of these changes.

Adaptation and coping techniques are not only observable in the archaeology, the impact of social, climate and environmental changes in Scilly were also reflected in the vegetation records. Landscapes are dynamic social constructions, part of the order and structure of societies and they are designed to interact with the physical environment (Adger *et al.*, 2009). Given that most pre-industrial landscapes were ecologically complex, climatic shifts likely resulted in diverse ecological responses that were stratified over the landscape mosaic (Lepofsky *et al.*, 2005). It is also expected that changing weather conditions will have a more significant impact on farming practices (Pillat, 2012). In Scilly this is manifest in the different changes in landscapes deduced from the palaeoenvironmental record. Some of these changes were climatic and anthropogenically enforced, for example the

transition from cultivation to a pastoralist economy during the Bronze Age and the reduction of cultivation and arable land during the Little Ice Age.

Human societies respond to environmental signals through multiple pathways, including collapse or failure, migration and creative invention through discovery. This response to change may in turn alter feedbacks between climate, ecological and social systems, producing a complex web of multidirectional connections in time and space (Constanza *et al.*, 2007). The human response to variation of the environment is also conditioned by the way individuals as members of a community comprehend variability; their response, ability to adapt to changes, and ability to access the society's past experiences with similar variations will differ widely around the world (McIntosh *et al.*, 2000). In Scilly the responses to similar environmental situations change through time. The early societies, due to their flexibility and probably less rigid social constructions, were able to overcome extreme climatic changes more easily than the modern societies. This somehow contradicts the traditional view that changing environmental conditions will have had a larger impact in earlier societies than now (e.g. DeMenocal, 2001). It is true that rural societies such as Medieval Scilly depended more on favourable climatic conditions than modern Scilly. Although the same can be said about prehistoric Scilly, the reactions to similar adverse environmental conditions were completely different. This is evidence that not only is the environment important but so too are social constrictions as important markers when relating the cultural and environmental changes.

Islands tend to experience exacerbated environmental and social vulnerabilities, particularly due to island characteristics of isolation, insularity, small size and a small resource base, yet, those same island characteristics can also lead to strong and successful coping mechanisms (Kelman, 2006). This statement is totally applicable to the Isles of Scilly. Scilly's past (and modern) societies have proved to be adaptable to environmental changes, the continuous success of their resilience will depend on how flexible they are when facing new environmental threats.

8.5 SCILLY FUTURE

The impact of climate and environmental shifts on societies is highly variable according to technological development, social organization and perception of these changes (Rosen, 2007). It is tempting to affirm that the changes in the environment would have a lesser impact on modern societies; however this impact is still relevant to rural communities and to not well-developed societies. Furthermore, the influences of coastal changes on societies are not only visible in islands; they are also recognisable in coastal settlements all around the world. Modern societies, threatened by these changes, have the opportunity to learn from the past through studies like the one here. The past is not a direct analogue for the future; however, it can be a guide of how past coastal behaviour responded to environmental changes (Woodroffe and Murray-Wallace, 2012).

Scilly is still under the menace of relative sea-level increase and the subsequent loss of land and inundation. Even Hugh Town, the largest town in Scilly, is located on a low-lying bar and potentially vulnerable to inundation. Eventually a decision will have to be made about the population. This will not be an easy decision, and with continuous relative sea-level rise it may be that the only long term option will be permanent evacuation of the islands. This evacuation (and the same will be applicable to coastal settlements that are threatened by sea rise, as well as other islands) could have strong consequences for the societies in question. Various problems will arise such as the cost and preparation of such an event, where to relocate the inhabitants, how to maintain their identity *etc.* (Kelman, 2006). This could bring unwanted conflicts that will damage societies that are already losing their land and their historical and cultural heritage too.

According to individuals affected by it, the desirable strategy of adapting to rising sea-levels is clear: invest in hard defence structures. However, for central government the priority will be centred on fairness, cost-effectiveness and long-term planning (Adger *et al.*, 2009). There are other possibilities, for example new islands can be created. The Spratly Island of Layang was artificially created by Malaysia through filling in the shallow sea

between two reefs and it now serves as a resort. The Palm Islands off the shore of Dubai were built to create residential, leisure and entertainment areas. Islands could be built which are high and wide enough to prosper despite climate change exacerbated extreme events (Kelman, 2006). In Europe there are also successful examples of land reclamation to the sea such as in Holland. These new constructions are very costly and it has to be decided by government if it is worthwhile and who will cover the costs.

Archaeology, History and Psychology have proved that adaptation decisions depend on the perceptions of risk held by a society, and this could act as a limiting factor if the society does not believe that the risk is great enough to justify action (Adger *et al.*, 2009). This is an important point to take into consideration when decisions about the future of the inhabitants of coastal areas will be made. The final decision will depend on those societies and what they believe to be the right solution. So far Scillonian society has demonstrated a large capability for adaptation and transformation and lessons from the past should be applied in the future. Only when the societies were more flexible and could diversify their behaviour (Mesolithic, Neolithic and Bronze Age societies), were they able to adapt to environmental changes. When they had a very rigid and specialised economic system and depended on outside institutions (e.g. Medieval Scilly) the adaptation was more difficult and dependent on political decisions taken outside Scillonian society. Technologically more advanced societies may be more susceptible to disruption because of their scale and complexity but may also prove more innovative and able to respond to change (Mitchell, 2008).

9 CONCLUSIONS AND FUTURE RESEARCH

9.1 CONCLUDING REMARKS

The overall aim of this thesis was to explore the impact of environmental changes (relative sea-level increase and climate) on coastal communities and to investigate how these environmental factors controlled subsistence economies through the Holocene. The hypothesis tested was that relative sea-level rise is a key factor influencing location and subsistence strategies of coastal communities throughout the Holocene and that, due to environmental conditions, these changes will be more evident in islands. The Isles of Scilly, located 27 miles off the south west coast of England, provide a good case study for the response of communities to marine inundations and environmental changes. This project aimed also to obtain a high resolution record of vegetation and storminess during the last 3000 years in Scilly, with a robust chronological setting, and also to offer improved palaeogeographic maps of Scilly since the early Holocene. This thesis assumed that the environment has an important influence on a society, but recognised that cultural changes are not dependent on the environment. Other factors are equally important and must be taken into consideration when relating culture and environment, including cultural influences, beliefs and convictions of the society, adaptability to change, and technology availability.

This thesis presented a summary of the large archaeological record of Scilly, a review of previous environmental studies, sea-level models in Scilly, and a short revision of general storminess and climate studies. Scilly represents one of the best preserved prehistoric landscapes in Britain, with a remarkable variety of archaeological remains representing over 6000 years of occupation. However, the vast majority of these remains do not have a reliable chronology. A very specific characteristic of the Isles of Scilly is the presence of archaeological remains under the tidal range, which gives an indication of the existence of a larger mass of land in the past. New sea-level curves for Scilly have been generated

through GIA (Glacial Isostatic Adjustments) developed by Bradley *et al* (2011). The palaeogeographic maps of the Isles of Scilly were produced by application of the new RSL curves to bathymetric and mapping. The Isles of Scilly have gone through important changes through time, due to relative sea-level rise and major land reductions. One of the most critical changes would have been when Scilly separated from the mainland around 11500 cal BP (c. 9550 cal BC), when the relative sea-level was only 41m than today, and when the islands separated completely around 4500 cal BP (2550 cal AD). The rate of RSL rise in Scilly during the Holocene has been an average of 0.8cm yr^{-1} , reducing to less than 0.2cm yr^{-1} during the last 4000 years. The loss of land in Scilly due to relative sea rising has been an average of $0.6 - 0.8\text{ha yr}^{-1}$. The resolution of this new sea-level model is coarse so it is possible that abrupt coastal changes could have happened during the Holocene. New palaeogeographic maps of the coastline of Scilly over time have been generated to determine the coastal changes of Scilly and to offer a background to the archaeological and environmental changes.

The response of communities to marine inundations was addressed by compiling palaeoecological proxies for past land management and the development of a storminess record from the same cores. Higher Moors and Lower Moors, the two wetlands on St Mary's, were chosen as areas of study for having the greatest potential to provide datable environmental material. Three sample cores were recovered from what was considered to be the most complete and deep organic deposits as revealed by the augering of various transects along Higher and Lower Moors. Chronological control for the palaeoecological sequences was established through radiocarbon dating and OSL dating. The earliest date obtained for the records was 2870 cal BP, and the three cores overlap from the first century AD; together they offer a picture of the landscape and storminess record in the area for the last 3000 years.

Detailed palaeoenvironmental interpretation has been provided by high resolution pollen analysis. By combining the pollen diagrams it has been possible to reconstruct a detailed local vegetation history and to identify the human impact on the vegetation on different

spatial scales. The results of high resolution pollen analysis, supported by radiocarbon dates, suggest that the landscape of Scilly has been an open landscape, managed for both pastoral and arable agriculture continuously since the Bronze Age. In the three pollen sequences the vegetation responded in various ways, probably depending on grazing pressure and intensification in the agriculture. There is evidence from previous records that Scilly could have been very heavily wooded in the past. The new pollen sequences presented in this thesis placed the woodland clearance before the end of the Bronze Age, showing an intensively managed open landscape and no indications of woodland regeneration from this period forward.

The presence of interleaved organic and higher energy sandy deposits in the sample cores suggested that the sequences recorded sudden inputs of energy from an external source, such as the passage of storms. The measurement of particle size and loss on ignition were used to develop a proxy-based record of past storminess, peak values in very coarse, coarse and medium sand. The understanding of the local coastal configuration of the study areas was important in the interpretation of the storminess signal. Palaeogeographic maps were used to observe the distance of sites from the coast and intertidal area through time, to assess possible changes in sediment availability, the increase in relative sea-level and wind direction. The three records showed a high variability in the evidence of storminess and dissimilarities during the same time period. It is argued that sand deposition and transport are highly site specific; controlled by topography, sediment availability, wind direction and vegetation cover) and these factors were taken into consideration when deducing a storminess record for Scilly. Instrumental records of storminess along the Atlantic coast of Europe confirm that storm activity exhibits strong spatial and temporal variability. The time span covered by the three studied cores allowed for the correlation of these records with other, published accounts of sand movement around the North Atlantic and known past and recent climatic changes. For example: these new records provided evidence of widespread sand movement during the late Bronze Age in Scilly and this could be correlated with the archaeological record

(abandonment of settlements due to sand inundation), and the 'Little Ice Age' is represented in the cores also by an increase in sand influx.

This thesis has shown that the primary control of the record of environmental change in the Isles of Scilly during the last 3000 years has been anthropogenic activity, influenced by relative sea-level changes. This conclusion has been reached through the use of three different proxy techniques (GIS, pollen and particle size analyses) and their comparison with archaeological records, facilitated by a robust dating control provided by ^{14}C and OSL dates. In particular these techniques have been successful in identifying social and cultural developments related to changes in the environment, such as permanent settlement after a stabilisation in relative sea-level increase, changes in settlement structure (fortified buildings) sometimes coincident with climatic changes. It should be remembered that those cultural changes were also influenced by internal factors (e.g. social beliefs) and external influences. The evidence here shows a dynamic pattern of vegetation and social changes in Scilly through time. When analysing the pollen and particle size results in this study, it was recognised that each one reflects the vegetation and environment of the source area, and these vary between sites and over time at each particular site. It has been recognised that each core offers a different climate signal during the same period, but it has also been discussed that these differences are due to important factors besides climate, such as wind direction, topography and geographical location of the areas. The cultural changes observed in the archaeological record have been set against a background of climate and environmental change. The pollen and archaeological record provides no reason to believe that there was a major crisis such as social collapse at any time during prehistory. Instead evolution and adaptation have been suggested. These records, along with radiocarbon dates and climate data, show minimal effect on the vegetation during periods of relative environmental stability. The changes appear when societies have to face extreme environmental changes and their actions are even more evident in adverse climatic circumstances.

Ultimately, this study has provided an opportunity to explore the various aspects of environmental changes and the impact of these changes on the society, and consequently the human reactions and their impacts on the landscape. It has been demonstrated that Scillonian societies, in the past, had a strong resilience and were able to adapt to environmental changes by diversifying their economic strategies and taking advantage of the new coastal margins. This adaptability was strong until the development of complex societies and mayor land reduction conditions that probably led to a tipping point in resilience. The continuous success of the Isles of Scilly resilience will depend on how flexible they are when facing new environmental threats. The findings of this study can be extended to other islands and coastal settlements with a similar history to Scilly, where these methods can be used.

9.2 IMPLICATIONS AND PROPOSALS FOR FUTURE RESEARCH

The Isles of Scilly have been seen to be an excellent area to study the impact of environmental changes in a society. There are numerous ways in which the palaeorecord obtained by the present research could be improved and expanded. First of all it would be necessary to do a more detailed and precise chronological investigation of the archaeological record of Scilly. This should include: reassessment, new dates and targeted excavations and more palaeoecological and survey investigations of the intertidal and sub-tidal zone.

New pollen records from intertidal and sub-tidal peat are currently being produced (Charman *et al.* forthcoming). Compiled of these together with the data generated here (pollen and sea-level curves) should allow detailed palaeogeographic mapping integrated with vegetation histories for Scilly through time and offer a longer perspective on anthropogenic use of the landscape in Scilly over time. A more focussed programme of environmental sampling needs to be developed of terrestrial pollen sequences closer to or from archaeological sites. Where good pollen preservation is not an option, other

environmental techniques could be applied. Insect, plant and mollusca remains could provide an alternative to pollen or complement it.

It would be very interesting to carry out an investigation specifically targeted at reconstructing the palaeoclimate in Scilly. Particle size and/or chemical analysis from cores taken from various sites (ideally as far from the coast as possible) will complement the storminess record of Scilly started here. This study has demonstrated that cores from the same area will vary in their records, so detailed multi-core analyses of as many cores as possible would be optimal, to avoid spurious interpretations of climate oscillations from single cores.

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3 APPENDIX I

List of types of pollen indicators of human impacts according to Gaillard 2007, vegetation communities according to Rodwell *et al*, 2003, and pollen groups used in this thesis with their correspondent taxa.

Gaillard, 2007	Pollen types	Rodwell <i>et al.</i> , 2003	Pollen types	Pérez, 2013	Pollen types
Trees and shrubs of damp soils	<i>Alnus, Salix, Myrica gale</i>	-	-	Trees and shrubs of damp soils	<i>Alnus, Salix, Myrica</i>
Shade-tolerant trees	<i>Fraxinus, Ulmus, Tilia, Quercus, Acer, Hedera helix, Viburnum, Sambucus nigra, Cornus sanguinea, Lonicera, Fagus, Carpinus, Picea abies</i>	-	-	Shade-tolerant trees	<i>Fraxinus, Tilia, Quercus, Hedera helix, Viburnum type, Lonicera, Fagus sylvatica, Carpinus betulus, Ulmus.</i>

<p>Light-demanding trees and shrubs</p>	<p><i>Corylus, Betula, Populus, Pinus, Prunus spp., Rosa, Rubus spp.</i></p>	<p>-</p>	<p>-</p>	<p>Light-demanding trees and shrubs</p>	<p><i>Corylus avellana, Betula, Pinus sylvestris, Prunus, Rubus undiff., Sorbus type</i></p>
<p>Forest herbs and ferns</p>	<p><i>Rosaceae undiff., Lathyrus sylvestrics, Vicia type, Polypodiaceae undiff. Dryopteris, Polypodium vulgare, Pteridium aquilinum</i></p>	<p>-</p>	<p>-</p>	<p>Forest herbs and ferns</p>	<p><i>Rosaceae undiff., Lathyrus type, Polypodium vulgare, Pteridium aquilinum</i></p>

<p>Dry Patures and heath</p>	<p><i>Juniperus,</i> <i>Calluna,</i> <i>Empetrum,</i> <i>Ericaceae undiff.,</i> <i>Centaurea nigra type,</i> <i>Dianthus type,</i> <i>Gentianella campestry type,</i> <i>Helianthemum,</i> <i>Plantago media,</i> <i>Potentilla,</i> <i>Sagina, Sedum</i></p>	<p>Heaths developed in sand dunes</p>	<p><i>H8 and H11:</i> <i>Calluna vulgaris ,</i> <i>Carex arenaria,</i> <i>Euphorbia portlandica,</i> <i>Trifolium suffocatum, Usnea flammea,</i> <i>Potentilla erecta,</i> <i>Galium saxatile,</i> <i>Polygala, Rumex acetosella,</i> <i>Plantago maritima.</i></p>	<p>Heaths and sand dune communities</p>	<p><i>Calluna vulgaris,</i> <i>Empetrum,</i> <i>Caryophyllaceae,</i> <i>Ericaceae undiff.,</i> <i>Gentianella type,</i> <i>Plantago media,</i> <i>Sagina type.</i></p>
<p>–</p>	<p>–</p>	<p>Shingle strandline</p>	<p><i>SD1, SD4 and SD8: Glaucium flavum, Silene vulgaris, Beta vulgaris, Cirsium, Sonchus, Rumex crispus, Festuca ruba, Galium verum, Lotus, Plantago lanceolata, P. maritima, P. coronopus,</i></p>		

		and sand-dune communities	<i>Tripfolium repens, Taraxacum, Cerastium, Artemisia, Primula vulgaris, Prunella vulgaris, Trifolium, Rhinanthus minor, Rumex acetosella, Gentianella,.</i>		
Fresh	<i>Apiaceae undiff., Aster type, Campanula type, Cerastium type, Cirsium, Filipendula, Galium type, Heracleum, Hypericum, Lathyrus pratensis, Lotus type, Plantago lanceolata, Poaceae undiff., Polygala vulgaris,</i>	Rush	<i>M23 (rush pastures): Gallium palustre, Holcus lanatus, Juncus effusus, Lotus, Cirsium palustre, Rumex acetosa, Epilobium Ranunculus acris type, Hydrocotyle</i>	Pastures	

<p>meadows and pastures</p>	<p><i>Potentilla</i>, <i>Prunella</i> type, <i>Primula</i> type, <i>Ranunculus acris</i> type, <i>Rhinanthus type</i>, <i>Rumex acetosa/acetos ella</i>, <i>Saxifraga</i>, <i>Succisa pratensis</i>, <i>Trifolium</i> type, <i>Vicia</i> type, <i>Viola</i></p>	<p>pastures (Mire)</p>	<p><i>vulgaris</i>, <i>Viola palustris</i>, <i>Trifolium repens</i>, <i>Cerastium fontanum</i>, <i>Plantago lanceolata</i>, <i>Prunella vulgaris</i></p>	<p>and grassland</p>	<p><i>Poaceae undiff.</i>, <i>Anthiscus</i>, <i>Asteroideae</i>, <i>Caryophyllaceae</i>, <i>Cirsium</i> type, <i>Filipendula</i>, <i>Rubiaceae</i>, <i>Heracleum</i>, <i>Hypericum</i>, <i>Lactuceae</i>, <i>Lotus</i>, <i>Plantago lanceolata</i>, <i>Polygala</i>, <i>Potentilla type</i>, <i>Primula</i> type, <i>Ranunculus acris- type</i>, <i>Lactuceae</i>, <i>Rhinanthus</i> type, <i>Rumex acetosa</i>, <i>Rumex acetosella</i>, <i>Sanguisorba</i> type, <i>Succisa pratensis</i>,</p>
<p>-</p>	<p>-</p>	<p>Grasslands</p>	<p>U1 and U4: <i>Festuca ovina</i>, <i>Rumex acetosella</i>, <i>Dianthus deltoides</i>, <i>Silene conica</i>, <i>Plango lanceolata</i>, <i>P. coronopus</i>, <i>P. maritima</i>, <i>Taraxacum</i>, <i>Galium verum</i>, <i>Potentilla erecta</i>, <i>Ranunculus acris</i>, <i>Cirsium vulgare</i>,</p>		

			<i>Sanguisorba minor, Succisa pratensis, Lathurus montanus.</i>		<i>Trifolium type.</i>
Ruderal communities	<i>Apiaceae, Artemisia, Anthemis type, Chenopodiaceae, Euphorbia, Plantago major, Rumex obtusifolius type, Silene dioica, Solanum, Urtica.</i>	Arable weeds and track side communities	<i>OV2 and OV6: Anagallis arvensis, Rumex acetosella, Silene gallica, Trifolium, Vicia sativa, Allium, Geranium, Sonchus asper, Convolvulus arvensis, Papaver, Heracleus sphondylium, Chenopodium album, Trifolium repens, Sagina procumbens, Urtica urens.</i>	Ruderal communities	<i>Anthemis, Artemisia type, Apiaceae, Chenopodiaceae, Rumex obtusifolium type, Urtica dioica.</i>

<p>Cultivated land</p>	<p><i>Cerealia unidff.</i>, <i>Avena type</i>, <i>Hordeum type</i>, <i>Secale cereale</i>, <i>Cannabis type</i>, <i>Ranunculus arvensis</i>, <i>Trifolium type</i>, <i>Valeriana locusta type</i></p>	<p>-</p>	<p>-</p>	<p>Cultivate d land</p>	<p><i>Avena type</i>, <i>Hordeum type</i>, <i>Secale cereale</i>, <i>Valeriana dioica</i>.</p>
<p>Wet meadows and salt meadows</p>	<p><i>Cyperaceae</i>, <i>Armeria maritima</i>, <i>Caltha palustris</i>, <i>Epilobium Hydrocotyle vulgaris</i>, <i>Mentha type</i>, <i>Menyanthes</i>, <i>Plantago coronopus</i>, <i>Ranunculus ficaria group</i>, <i>Thalictrum</i>, <i>Sphagnum</i>.</p>	<p>Maritime communities</p>	<p>M5 and M10: <i>Armeria maritima</i>, <i>Plantago coronopus</i>, <i>Festuca rubra</i>, <i>Cerastium diffusum</i>, <i>Sedum</i>, <i>Festuca rubra</i>, <i>P. maritima</i>, <i>Brassica olearaceae</i>, <i>Lotus</i>, <i>Trifolium</i>, <i>Rumex acetosa</i>, <i>Primula scotica</i>.</p>	<p>Maritime communities</p>	<p><i>Caltha type</i>, <i>Cyperaceae</i>, <i>Litorella uniflora</i>, <i>Brassicaceae</i>, <i>Menyanthes type</i>, <i>Plantago maritima</i>, <i>Sanguisorba type</i>, <i>Thalictrum</i>, <i>Sphagnum</i>.</p>

-	-	<p>Swamp and tall herbs</p>	<p><i>Typha latifolia,</i> <i>Lemna minor,</i> <i>Solanum dulcamara,</i> <i>Galium palustre,</i> <i>Urtica dioica,</i> <i>Callitriche stagnalis,</i> <i>Apium nodiflorum,</i> <i>Carex rostrata,</i> <i>Hydrocotyle vulgaris,</i> <i>Caltha palustris,</i> <i>Potamogeton.</i></p>	<p>Aquatics</p>	<p><i>Typhaceae,</i> <i>Myriophyllum</i> <i>Potamogetonaceae.</i></p>
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