UNIVERSITY OF Southampton

Determining potential: Onshore/Offshore prehistory

Project 6918

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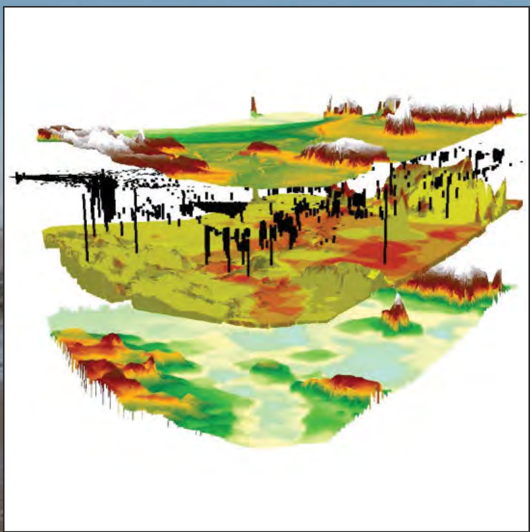

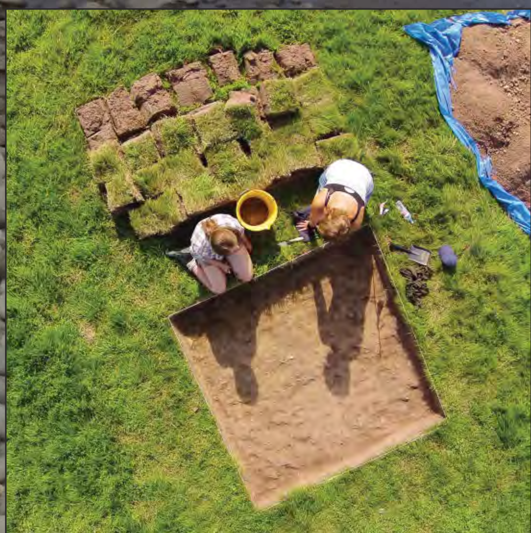

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Executive Summary

Historic England commissioned a team from the University of Southampton to undertake project 6918, 'Determining Potential: onshore/offshore prehistory' between January 2014 and July 2015. The central focus of the research was on evaluating methods that might be used to help move from generic to more specific understandings of archaeological potential within such environs. A region of the Bristol Channel and Somerset Levels was chosen as the study area within which to carry out this work, due to its already noted high potential for contributing to our understanding of prehistory. Three overarching aims were given for the project:

a. Assess the efficacy of predictive modelling for the determination of the potential for submerged prehistoric archaeology in English waters;

b. Evaluate the range of methods open to archaeologists when assessing the potential for submerged prehistoric archaeology offshore, and how best to investigate/mitigate for it; and

c. Extend our knowledge of key inter-tidal and offshore sequences in a region already known for its nationally significant inter-tidal and onshore prehistoric record.

This monograph describes three different approaches to modelling potential: inductive, deductive and geoarchaeological. The conclusion is reached that inductive predictive modelling is currently an inappropriate method for improving our understanding of offshore potential (and in some instances deeply buried onshore locations) in England. This is due to low data density and high degrees of uncertainty with regard to prehistoric activity. Deductive and geoarchaeologically focused methods were found to hold much greater promise for determining potential. However, again the need for high quality input data was highlighted. All of the above approaches should be seen as iterative in nature, and require a commitment to improving data accessibility and joined up approaches to acquisition. It also requires a greater degree of communication with colleagues working in countries whose territorial waters directly abut England's.

The above recognition of the need to improve our baseline understanding of both palaeoenvironmental change and archaeological finds density is one of the most significant and challenging outcomes from this project. In carrying out the review to address point b above, and the fieldwork to address point c, it became clear that we need to sample larger volumes across a wider range of ecological niches. Put simply, without adopting methods that maximise the chance of recovering material culture offshore we will never be able to:

1. Answer key research questions identified in regional and national research agendas that are pertinent to both the onshore and offshore archaeological record.

2. Improve our ability to pinpoint areas likely to produce important finds.

The lack of direct engagement offshore, the limited nature of inter-tidal investigations and the uneven distribution of commercial activity onshore has led to a record that is hard to interpret with regard to the specifics of potential, beyond discussion in the broadest terms.

Rather than being a negative outcome this is seen to be a positive result. The act of creating a deductive model forced detailed analysis of the qualities of input data, and highlighted lacunae in our understanding. In ground-truthing the deductive model new information was generated that contributes to our growing appreciation of the complexities of environmental change across the study region, and areas in need of future research clearly identified. Finally, through accepting that we may not be able to answer questions we have already raised of the offshore record without a change in approach, this research establishes the urgent need for more detailed consideration of how we manage and carry out research into the submerged prehistoric record, as well as compiling and distributing these results.

Acknowledgements

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Tyra, and Emily back after surveying the outer edges of the mud flat

EDF are thanked for their continued interest in the archaeology of the region.

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As ever, archaeology is a collaborative effort and none of the work presented in the following chapters would have been possible without the help and assistance of all of the above.

Photograph of test pits being excavated in Stolford.

Contents

List of Figures

List of Tables

Chapter 1
Determining potential

Introduction

"it might be worthwhile systematically to dredge the Dogger Bank, in order to see whether any implements made by man can be found there"

Reid, C. (1913, 121)

Writing in 1913, the goal of Clement Reid's proposed dredging of the Dogger Bank was to prospect for diagnostic archaeological material, which might be used to relatively date the submerged forests which so fascinated him. In the pre-radiocarbon era, Reid's greatest challenge was to understand the time depth of the environmental archives he had identified, not to determine how they were inhabited. There is no doubt that where such dredging activities have taken place these have often yielded considerable prehistoric assemblages from the marine environment (e.g. Glimmerveen et al. 2006; Bynoe 2014). However for Reid (1913, 113), occupation and use of these now submerged landscapes had been proven beyond doubt, by the infrequent recovery of the lithic artefacts that he used to construct a relative chronology. The plant macrofossils and faunal material extracted from the forests had painted a picture of what these spaces may have been like, but not how quickly they had changed.

Writing in 2015, it is interesting to reflect on how these challenges seem to have been reversed. While dating submerged deposits is a complex operation, the range of methods available to us has expanded beyond anything Reid could have imagined. We have numerous analysed and dated cores from English waters (Hazel 2008) and complex computer models that allow for simulation of changing palaeogeography (Sturt et al. 2013). These, coupled with high-resolution geophysical investigations (Gaffney et al. 2007, Dix and Sturt 2009), have allowed us to map and recreate the submerged worlds that Reid could only hypothesise. Thus over the last hundred years the value of submerged environments for reconstructing past landscapes has become well established, helping us to understand complex stories of environmental change and interaction that are fundamental to resolving archaeological questions (Dix and Sturt 2013, Westley et al. 2013, Bell and Warren 2013). In this light Reid (1913, 10) was prescient in observing that the divides we place between fields of study, such as 'natural' and 'cultural', should be removed if we wish to construct a more meaningful understanding of the past.

However, while considerable advances have been made with regards to understanding the changing landscape, there has not been a corresponding increase in the amount of material culture recovered from English waters, nor development of methods to do so. Thus what Reid viewed as relatively straight forward, and provided the cornerstone to his reasoning, has become a point of archaeological speculation. There is no argument that these spaces were not inhabited at points in the past, nor that sedimentary archives found in submerged and inter-tidal context can transform our understanding of context. It is well understood that the current onshore/offshore divide represents a moment in time rather than a constant archaeological reality. As such, one of archaeology's great challenges lies in overcoming the conceptual and practical challenges this modern change in environment represents.

While consensus has been formed over the fact that the now submerged continental shelf represents a previously habitable landscape, there is considerable discussion as to the potential nature of that occupation (Westley and Bailey 2013), the chances of evidence for it surviving (Salter et al. 2014, 152), and the significance that record may have for our understanding of European prehistory (Coles 1998, Bailey et al. 2007; Engen and Spikins 2007; Benjamin 2010; Sturt et al. 2013; Sturt and Standen 2013, Momber et al. 2013, Bicket and Tizzard 2015). Today these questions are not driven by academic priorities alone. With increasing offshore development, difficult questions are being posed as to the potential impact such work may have on the archaeological record (Ward 2014). Answering these questions is not straightforward as the areas considered are large, and our understanding of histories of occupation limited. It is with this dilemma in mind that the following work was commissioned by Historic England. How best can we determine archaeological potential in submerged and near shore environments?

Understanding Potential

In order to be able to determine potential we first have to establish what this means within an archaeological context. On one level this might appear to be relatively straightforward, with potential relating to the possibility of recovering materials useful for answering archaeological questions. However, as Clarke (1973) made clear in his seminal publication on the 'loss of innocence' in archaeology, such a broad statement hides a series of important issues. Clarke argued that by 1973 archaeology had moved to a state of critical self-consciousness, having moved through phases of consciousness and self-consciousness. In the phase of consciousness the subject of archaeology was defined, and with self-consciousness key methods and techniques were developed. Critical self-consciousness and the loss of innocence, came with an awareness that each of the previous two phases did not solve all the problems associated with improving explanations and interpretations of the past, and that for some issues the theoretical underpinnings of what we are trying to achieve as archaeologists needed to be examined. However, where Clarke thought this might be resolved through the creation of a unified theory of archaeology, we have seen a continued broadening of awareness and acceptance of a variety of ideas and points of engagement. The single theory has not arisen, and as such no one method or approach can address all concerns.

One of the results of this broadening of awareness is that the scope of archaeology today has changed. We now recognise the significance of sedimentary archives and other proxy data as being crucial to our understanding of the past, but so too is a clearly resolved account of what it is we are trying to achieve and why. It is for this reason that rendering of potential today is not straightforward, is unlikely to be universally agreed, and will change through time. As Clarke stated:

> "The loss of disciplinary innocence is the price of expanding consciousness; certainly the price is high but the loss is irreversible and the prize substantial" (1973, 6)

The price in this case appears to be the need to be able to offer more precise accounts of potential with regard to specific questions. This step was taken in the recent *Waterlands* project (Goodwyn et al. 2010) where management indicators for submerged palaeolandscapes were created. Goodwyn et al. (2010, 37) stated that they followed the suggestions of Dix et al. (2008) in arriving at their determination of potential:

> "Waterlands follows a predictive 'potential' model approach recommended by Dix et al. (2008) in the re-assessment of the archaeological potential of the continental shelf study. The 2008 study recommends focusing around areas 'amenable to past human settlement', or areas of 'likely preservation"

The difficulty in this approach revolves around resolving what 'amenable to past human settlement' means for a record of occupation that covers nearly 1 million years. As figure 1.1 makes clear, when pushed to its logical extent, the result is a map of theoretical high potential that covers the majority of English waters that are known to have been above sea level, and beyond the Devensian glacial extent, at some point during the Quaternary. This is not a fault of the Waterlands project, although to deem everything high potential may seem to reduce everything to an equivalency (and thus negate its 'high' status), it can be seen to reflect the variety of archaeological questions we are interested in answering, and our poor ability to resolve what 'amenable to past human settlement' means for different periods. The offshore archaeological record is of inherent high potential due to its ability to contribute to answering key archaeological questions; from those focused on sedimentary sequences, environmental change and taphonomy, to others considering material culture and histories of inhabitation.

As Clarke noted (1973, 10), in order to address this we need to reconsider how we conceive of knowledge and the archaeological record:

> "We must move from the traditional model of archaeological knowledge as a Gruèyre cheese with holes in it to that of a sparse suspension of information particles of varying size, not even randomly distributed in archaeological space and time."

In figure 1.1 Goodwyn et al. (2010) are effectively demonstrating this shift in understanding. There may well be a sparse 'suspension of information' across this whole region, and that information may be of differing significance and relevance to individual researchers. What the Waterlands example indicates is the need for consideration of theories and methods that allow us to move beyond broad based renderings of 'super potential' and towards a consideration of how we can act on and/or refine this understanding.

Aims of this study

This project was commissioned to consider if we might be able to move from generic to more specific understandings of potential, and how these approaches might be evaluated. In this light a study area was chosen that would allow leverage of onshore and offshore data gained over several decades of research; the Bristol Channel, Somerset Levels and Severn Estuary region (figure 1.2). As discussed in chapter four, a long history of research in inter-tidal and terrestrial archaeology, with allied environmental studies, has led to this region being highlighted as of 'high potential' and of national significance. It was thus deemed an appropriate place to start any study seeking to join onshore to offshore, and better understand concepts of potential.

This project had three overarching goals:

a. Assess the efficacy of predictive modelling for the determination of the potential for submerged prehistoric archaeology in English waters;

b. Evaluate the range of methods open to archaeologists when assessing the potential for submerged prehistoric archaeology offshore, and how best to investigate/mitigate for it; and

c. Extend our knowledge of key inter-tidal and offshore sequences in a region already known for its nationally significant inter-tidal and onshore prehistoric record.

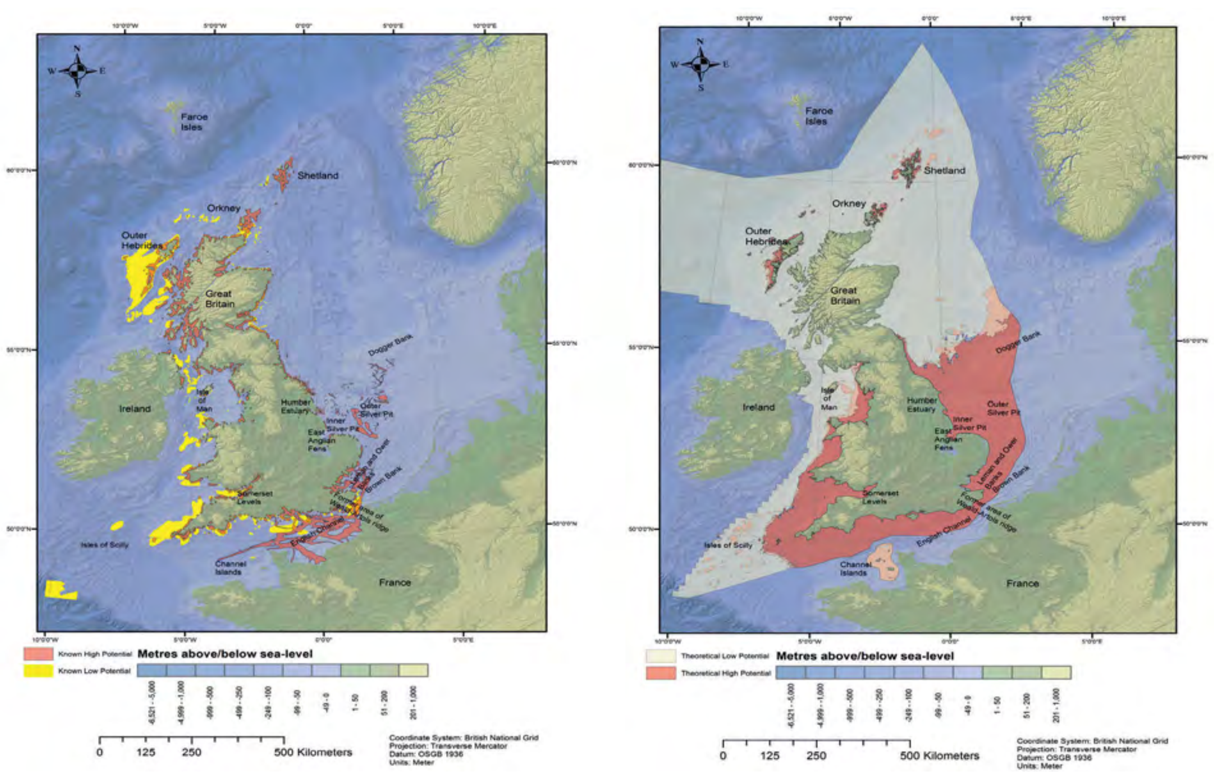


Figure 1.1 Map showing the maps of 'potential' from the Waterlands project (Goodwyn et al. 2010).. © Crown Copyright and Database Right [2015]. Ordnance Survey (Digimap Licence). The bathymetric data products have been derived from the EMODnet Bathymetry portal - http://www.emodnet-bathymetry.eu.

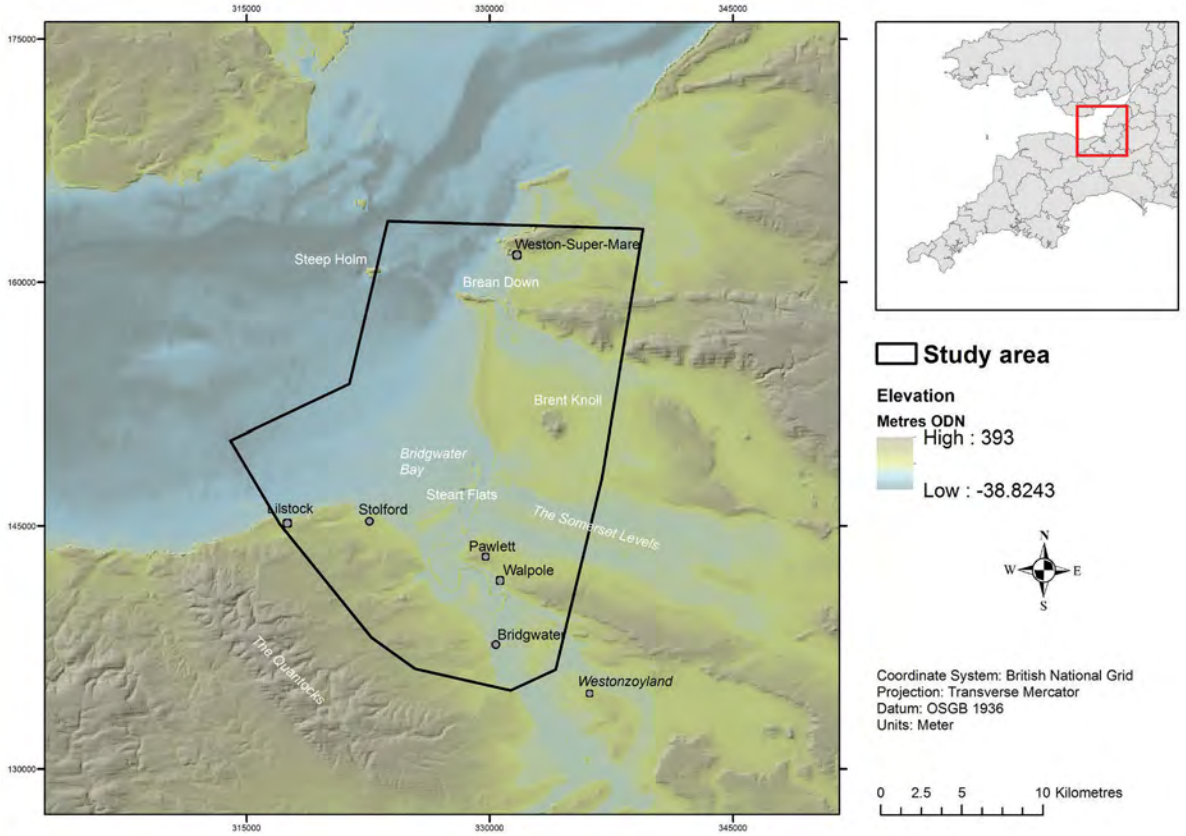


Figure 1.2 Map of the Study area. © Crown Copyright and Database Right [2015]. Ordnance Survey (Digimap Licence). The bathymetric data products have been derived from the EMODnet Bathymetry portal - http://www.emodnet-bathymetry.eu.

Each of the above aims was carefully chosen in order to aid future management and regulatory decisions, while directly improving our understanding of the regional archaeological and palaeoenvironmental record. In order to achieve this, a series of more specific project aims were developed:

Research aims:

- To articulate methods via which we may refine understanding for identification of the potential for submerged prehistoric archaeology in England's territorial waters;
- To quantify the applicability of predictive models of site location and potential for submerged prehistoric environments;
- To document how the results of best practice approaches to modelling relate to the known archaeological record when blind tested; and
- To establish an integrated onshore - offshore account of the prehistoric archaeology within the Bristol Channel region at two resolutions: a baseline account of potential for the Lower (c. 1,000 – 40 ka) to Early Upper Palaeolithic (40 – 13 ka) and higher resolution account of the Upper Palaeolithic archaeology to the Early Bronze Age (13 – 4 ka).

Methodological aims

- Develop exemplar methods for integrated onshore - offshore archaeological modelling of 'potential'; and
- Field test methods through which archaeological potential can be verified onshore and offshore (validation of modelling methods).

Management aims

- To undertake fieldwork to identify areas of submerged prehistoric archaeology within the chosen study area;
- Contribute to the development of effective strategies for managing and mitigating impact on the offshore archaeological resource;
- To produce results from targeted work which will allow archaeologists, regulators and offshore industries to have greater confidence in the predictions made by archaeologists; and
- Demonstrate the development of best practice through learning from international exemplars.

Outreach aims

- To raise the profile of the submerged archaeological resource at a national level;
- To raise awareness in industry of the methods we can adopt and justifications for the measures put in place; and
- To engage the wider international archaeological community in a discussion of how best to understand potential in the offshore zone.

As the following chapters make clear, this project has met the above aims with variable degrees of success. This reflects the challenges in carrying out archaeological research, where multiple factors impact on the trajectory and final outcomes; from physical access to fields, inter-tidal and sub-tidal spaces for ground-truthing, through to more conceptual realignments due to 'loss of innocence'. It is this last point, the loss of innocence, which is perhaps the most significant outcome of this work. As the text in the following sections documents, one of the greatest challenges we face is being clear about the data required to answer the questions we currently pose of the archaeological record. As Clarke (1973, 6) noted, the price required to generate this data may be high, but the prize could be substantial.

Chapter 2
Submerged Landscapes

Introduction

An awareness of the potential of now submerged terrestrial landscapes to inform our understandings of prehistory has long been established. Since Boyd Dawkins (1870) early reporting of lithics from the submerged forests of the West Somerset coast, through Reid's (1913) scholarly work on changing palaeogeography, to Clark's (1932; 1936) recognition of the significance of inundation of vast tracts of land on the nature of Mesolithic Europe, archaeologists working in England have been grappling with how to best engage with this subject. However, whilst consciousness was raised in the 19th century, the nature of the marine environment surrounding England meant that the history of research played out very differently here to that seen in other European countries. In this chapter we consider the implications of this trajectory of development, and compare it to that seen in other countries.

Developing an understanding

Venturing into the water to recover archaeological material is not a recent endeavour. Much of the earliest research we know of focused on shipwrecks and lost cargoes, largely in the clearer waters of the Mediterranean and lacustrine environments. Here we can trace activity from at least the sixteenth century, where rudimentary diving helmets were used to explore Roman wrecks in lake Nemi (Ucelli 1950, 3-4). Spectacular finds such as those made in the early twentieth century at sites such as Antikythera tend to dominate accounts of this early period of discovery, but, significant advances were also made in Britain. For example, the Deane brothers development of underwater breathing apparatus, and their salvage work on sites such as the *Mary Rose* in the early to mid-nineteenth century (Broadwater 2002: 18, 23), raised awareness of cultural material lying below the current waterline. However, it is with the work of Odo Blundell (1910) that we find perhaps the most significant development relevant to this study.

Blundell's contribution to maritime archaeology is now well recognised. What makes him stand out in the early history of the subject is the clarity of his research questions, and, adoption of what were then novel methods to answer them. A Benedictine priest, Blundell became fascinated with the history of the landscapes that surrounded him. In particular he focused on the Crannogs found in local lochs. Unable to answer questions with regard to construction methods from walking over the surface alone, Blundell persuaded the Clyde Navigation Trust to loan him a full set of standard diving dress and "a first-rate man along with it" (1910, 33) to help teach him to use it and pump the system. Blundell personally ventured into the water to record the features he observed, helping him to confirm that these were anthropogenic features. In essence, Blundell did not allow the nature of the working environment to impact on his ability to answer his research questions. However, the standard diving dress that Blundell used was not easily available and thus had a relatively limited impact on archaeological investigations. Blundell's work was an interesting anomaly, a clearly published demonstration of the possible reach of archaeological research, but beyond the means of most practitioners.

This all changed in the late 1940s and early 1950's when Gagnan and Cousteau's refined self-contained underwater breathing apparatus (SCUBA) became an accessible technology for the general public. In areas around Europe benefiting from shallow coastal waters, good visibility and affluent economies, the underwater world suddenly became populated by a host of curious people. This led to a number of interesting archaeological discoveries. So much was this the case that in 1957 the Danish weekly magazine *Hjemmet* launched a competition for divers to find their earliest submerged site. The frenzy of activity that followed resulted in the public recognition of a number of Mesolithic sites, including Tybrind Vig (Andersen 2013, 11), firmly placing the reality of submerged prehistoric archaeology in social consciousness. Interestingly, Andersen (2013, 11) records that although new material was found there was a sense of disappointment, as it all dated to the Ertebølle. As such, the antiquity of inhabitation had not been pushed back by this early example of community archaeology. This led to a twenty year period where little additional research occurred into this remarkable archaeological

resource.

In England, the murkier waters, complex tidal systems, sedimentary sequences and erosion patterns meant that the diving community became better acquainted with the wreck record. As such, the profile of submerged prehistory was not raised. Thus, while in 1979 Søren Andersen was beginning to carefully excavate Tybrind Vig, maritime archaeology in Britain was only just beginning to take shape, with Keith Muckelroy's (1978) foundational text eschewing the study of submerged landscapes in favour of a focus on wrecks and maritime infrastructure.

It is tempting to see such comparatively deep academic history as colourful background and little more. However, it has helped shape our expectations and knowledge of the waters around England. As such, despite Boyd Dawkins (1870), Reid (1913), Crawford (1927) and Clark (1932, 1936) clearly demonstrating the significance of the offshore zone for understanding prehistory, it was not actively pursued as an area of research by the broader archaeological community in England, or public at large, for over one hundred years. It is for this reason that sporadic dredged finds of lithics and faunal material failed to get the broader recognition they may have deserved, resulting in only two high profile cases of direct ground truthing; the Mesolithic site of Bouldnor Cliff from 1999 onwards (Momber et al. 2011) and Palaeolithic finds from Area 240 in 2008 (Firth 2011, Bicket 2011, Tizzard et al. 2014).

While site level investigations did not develop in the same way as on the continent, archaeologists working in England have re-engaged with the broader topic of submerged prehistory. Coles' (1998) seminal 'speculative survey' of the submerged southern North Sea ("Doggerland"), clearly demonstrated the potential of offshore contexts. Importantly this potential was not only seen to lie in the recovery of material, but in relating the broad scale narratives of landscape change and social impact. This played to the strengths of British archaeology in landscape approaches (Johnson 2006) and allowed the broader academic community to realise the significance of what Coles was discussing. The awareness this article generated was timely as it coincided with increased offshore development and acquisition of new data. Pioneering work by Gaffney et al. (2007, 2009) on the submerged landscapes of the North Sea allowed visualisation of these offshore sedimentary sequences, giving a tantalising glimpse of the landscapes Coles (1998, 1999) had discussed. At the same time English Heritage (since 2015 called Historic England) became responsible for the historic environment of England's inshore and offshore waters. Through the Aggregates Levy Sustainability Fund (ALSF) a range of projects were funded between 2002 and 2011 that cast new light on the archaeological potential of the waters surrounding England. The majority of this work again operated at the large regional scale (Bicket 2011, 2013), making best use of the data that the offshore industries supplied.

Despite the impressive amounts of data gathered and analysed, along with limited site specific investigations, significant conceptual and methodological problems have been seen to remain with England's approach to the offshore record (Sturt and Standen 2013). The majority of these hinge on our point of engagement, and a struggle to downscale from generalised large-scale hypothesis to smaller scale archaeological realities. As Lucas (2012) has noted, the way in which we practice archaeology fundamentally shapes how we understand the potential of the resource and the products of our enquiry. Though worthwhile and profitable, the focus on landscape reconstruction has not helped researchers take the next step and fully understand archaeological potential at the site level. Through not ground truthing such hypotheses it has become difficult to establish the voracity of claims made about archaeological potential offshore, and has limited evaluation to very broad statements (Goodwyn et al. 2010). In addition, it has impacted on our ability to evaluate the use of predictive models, such as those used in Denmark (discussed in chapter 3), due to a perceived lack of underlying data. As noted in the recent expert meeting on this topic (Sturt and Standen 2013), to drive any change in approach (a shift from the large scale to small/site level investigation) would require clear articulation of research questions to justify the work. However, these calls are already evident in the Maritime Archaeological Research agenda (Ransley et al. 2013), the Palaeolithic Research Framework (Pettitt et al. 2008), the North Sea Prehistory Research and Management Framework (Peeters et al. 2009) and the Mesolithic Research and Conservation Framework (Blinkhorn and Milner 2013), as well as in the broader academic work of Leary (2009, 2011) and Murphy (2010). As such, it appears that this is a challenge we must now face and fully embrace.

Moving Forward: linking onshore/offshore

Rather than seeing this as a history of missed opportunities, a more positive trajectory can be plotted. The root cause of our current issues offshore have been identified and thus can be addressed. However, in defining a project to do this we stand best able to succeed if we draw on strengths that this variable history brings to light:

1. We have developed world-leading expertise in submerged landscape reconstruction.
2. We can draw on a history of underwater excavation, prospection and predicative modelling strategies developed on the continent (Dencker and Johansen 2011, Weerts et al. 2012) to inform any new research directions.

In addition, a close inspection of the history of submerged prehistory draws attention to additional directly related strengths found in British Archaeology. Clark's (1936) work in the Fenland of East Anglia stemmed from his interests in understanding patterns of inundation, environmental change and the nature of life in the Mesolithic. While he had recognised that now submerged landscapes held great potential, they were inaccessible to him beyond coarse-grained recovery of material via trawler. By moving onshore he could access analogous deposits and carry out exacting archaeological excavation to answer the same research questions. In a similar vein Sturt (2006; 2007) integrated four-dimensional deposit modelling, ground-truthing and environmental analysis to understand prehistoric life and inundation in the Fenland basin. In this example the study area was deliberately chosen as an analogous environment to locations now found offshore, but that were financially beyond the reach of a PhD study.

Thus, while moving beyond landscape level accounts may have been slow offshore, significant advances were made along the current inter-tidal zone and in dry land extensions of former wetland and estuarine environments (Hall and Coles 1994; Bell 2007, 2013, Van de Noort 2004). This history of research now allows for a meaningful onshore/offshore linkup to be posed, where new methods and techniques can be trialled, whilst adding detail to a nationally significant record first picked upon by Boyd Dawkins (1870).

The Bristol Channel and Somerset Levels region thus offers a ready test bed on which to build improved approaches to submerged prehistory, from the Palaeolithic through to the Bronze Age. A combination of detailed onshore studies with well resolved environmental sequences (Kidson and Heyworth 1973, Bell 1990, 2007, 2013), along history of inter-tidal and terrestrial work published in the Archaeology of the Severn Estuary series, matched to an increasing body of offshore data and archaeological analysis (Fitch and Gaffney 2009; Bicket 2013; Sturt et al. 2014; Dix et al. 2014) provide the bounding boxes within which fruitful targeted research can take place. The extant onshore and inter-tidal record allows detailed insights into the nature of prehistoric activity in the study area and associated environmental proxies. This provides a high-resolution understanding at the interface of the onshore/offshore divide, analogous to the knowledge that continental colleagues have gained from decades of underwater test pitting and excavation. The available offshore legacy data provides a baseline directly comparable to the sorts of knowledge generated as part of the current Desk Based Assessment (DBA)/ Environmental Impact Assessment (EIA) processes. As such, when viewed together the onshore and offshore records for the Bristol Channel region ensure that it is a suitable location for testing enhancement strategies and ground truthing techniques. This ensures that the results of this project will do more than address geographical and period specific interests alone, but speak to wider methodological issues with regard to submerged prehistoric archaeology.

In this region we can effectively move from the known to the unknown, providing a safe space within which to answer questions and develop appropriate methodologies. As such, this project seeks to advance our understanding of submerged palaeoenvironments through multi-scale onshore/offshore work in the Bristol Channel and Somerset Levels (figure 1.2). Moreover, the complex tidal characteristics of the Bristol Channel region mean that these methods will be applied in potentially challenging, rather than benign, conditions, ultimately lending greater weight to the assessment of method suitability for broader application.

Conclusions

The work described in the following chapters draws on national excellence in inter-tidal and wetland prehistoric archaeology, expertise in offshore - onshore landscape reconstruction, matched with insights gained from wider experience in the excavation and modelling of submerged prehistoric archaeology. Crucially, through selecting to work in this area the project is able draw on the depth of understanding with regard to prehistoric activity and ecology already gained by the discipline, as well as extensive datasets from previous projects, to create and review the efficacy of different approaches to determining potential.

Through combining these strengths we play to the positive outcomes of variable histories of archaeological management and research across Europe. However, most significantly, it serves to break down arbitrary geographical boundaries, between onshore and offshore, and focuses on engaging with the record as a whole. As Reid (1913) and Clark (1936) understood so clearly, describing something as 'submerged prehistory' conflates two temporal viewpoints into a single position; the contemporary environmental situation with an archaeological evaluation. As archaeologists our primary interest is understanding how this space, and human engagement with it, changed through time. The 'submerged' aspect only relates to how we methodologically have to engage with it. Onshore/offshore, submerged/terrestrial are arbitrary categories forced onto the record by broader environmental changes. As such, we need to work hard to remove the wrinkles created by this difference in engagement. As the above text and following chapters make clear, achieving this may not be easy, but we have little choice if we wish to better understand the archaeological record.

Chapter 3
Predictive Modelling and Evaluation

Introduction

As made clear in chapter one, a central aim of this project was to assess the efficacy of predictive modelling for determining the potential for submerged prehistoric archaeology in English waters. In doing so, the work described here joins a long running archaeological discourse on the production and use of predictive tools that became established with the adoption of processual approaches in the 1960s. Over this fifty-five year period, definitions, expectations and uses of predictive models have changed. Engaging with this history of research is important, as significant questions have been raised as to the value of such approaches, with strong advocates for and against.

Those in favour of predictive approaches have made clear calls for their application to help engage with submerged prehistoric landscapes (e.g. Benjamin 2010, 262). However, any new work in this area needs to be mindful of the debate within the broader literature as the concerns raised are not trivial. In this chapter an account is given of past and present use of predictive modelling in terrestrial and maritime archaeology. This review is used to establish a baseline, and to provide justification for the methodology developed as a part of this project, and reported in chapter five. As will become clear, predictive modelling is a contentious issue, but, not one we should shy away from.

Predictive Modelling: a brief history

As Verhagen and Whitley (2012, 50) note, the origin of predictive modelling can be seen to lie in the large-scale landscape surveys of the late 1950s and early 1960s. Here, researchers such as Willey (1953) sought to understand the relationship between ecology and observed site location, which in turn could give an insight into areas that might reveal additional sites in future. The establishment of these forms of relationships paved the way for statistical approaches for determining likely site locations (Plog and Hill 1971; Green 1973). As Verhagen and Whitley (2012, 51) observe, these early forays are interesting for the fact that they pre-date the widespread use of computer based geographical information systems (GIS); as such GIS and predictive modelling are not synonymous. Predictive modelling should be seen as method in its own right, which has been facilitated by technological and software developments in recent years.

In early instances the models were of two quantitative forms: one based on ecosystem distribution and correlation with known site location (Jochim 1976) and the other, statistical approaches which abstracted the above data in order to predict likelihoods for un-surveyed areas (Kvamme 1983). This style of approach is often described as inductive, working from known distribution/observations to predict likelihoods for unknown areas in a quantitative manner.

These inductive or "data driven" (Wheatley and Gillings, 2002) approaches can be contrasted to the development of deductive and theory driven methods such as those adopted by Dalla Bonna (1994). Here the focus is not on quantification of percentage chance of encountering archaeology, but on providing spatial representation of a hypothesis, to do with relationships between social strategies/human ecology, landforms and environment. These can be produced via simple methods in GIS, through creating a series of overlays to give a clear spatial representation, but not a rendering of 'percentage chance' of encountering archaeology. In this sense the product of the Waterlands project (Goodwyn et al. 2010) can be seen as a simple deductive model.

Given the presence of at least two different approaches to predictive modelling, any definition of the term needs to be sufficiently broad. In light of this Kohler and Parker's (1986, 400) early attempt can still be seen as valid:

> "Predictive modelling is a technique that, at a minimum, tries to predict the location of archaeological sites or materials in a region, based either on a sample of that region or on fundamental notions concerning human behaviour"

Verhagen and Whitley (2012, 52) argue convincingly that the divide between inductive and deductive modelling is more a product of historical development rather than any clear methodological reason as to why the two approaches should not be joined. Leusen (2002, 5-4) puts a slightly different spin on this, explicitly noting that the discourse on predictive models frequently splits these two modes of modelling into dichotomous positions (shown in figure 2.1 below). In this sense the divide between inductive and deductive methods might be seen to be driven by a fundamental epistemological difference between practioners.

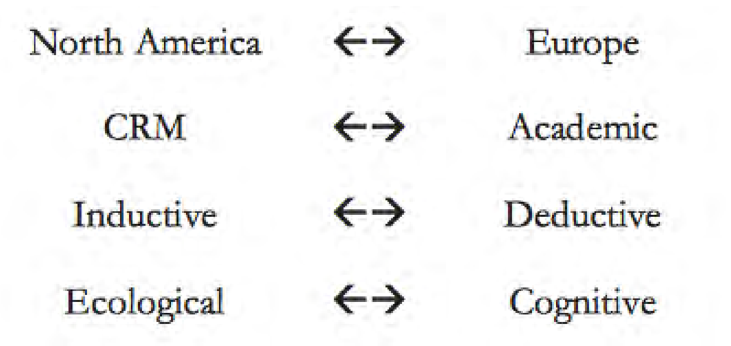


Figure 3.1 Leusen's (2002, 5-4) representation of difference in modelling approach.

Leusen (2002, 5-4) and Verhagen and Whitley (2012, 53) both note the important role of inductive predictive modelling within cultural resource management (CRM) in North America and the Netherlands. Given the history of development of predictive modelling it is perhaps unsurprising that inductive approaches have proven popular (and productive) within North America. As Hegmon (2003, 213) discusses, there is a strong tradition of processual archaeology within North America that aligns itself well with inductive approaches. In addition, commercial archaeologists working in North America are faced with the challenge of evaluating large areas, at times with little preceding survey data to base their evaluations on. Inductive predictive models have thus been used to help constrain areas for targeted survey and sampling.

Over time and through repeated testing these large-scale landscape sampling tools have been developed and refined. As the recent work by Verhagen and Whitley (2012) demonstrates, to state that inductive predictive modelling has been used for nearly three decades does not mean that the models have not changed through time. Nor should an alignment with processual, or what Hegmon (2003) terms 'processual-plus', tenants be seen as reductive in nature or theoretically lacking. Verhagen and Whitley's work (2012) makes clear that the theoretical and deductive can be considered alongside inductive approaches.

Histories of archaeological research and challenges of geography can therefore be used to explain the adoption of inductive predictive modelling in North American contexts. More puzzling in this light though is the use of inductive modelling approaches within the Netherlands. Here the history of research is more aligned with that in Britain in regards to theoretical trends, and the problems of scale and evaluation do not present themselves in the same way as they do in North America. Nevertheless, since 1997 (Deeben et al. 1997) the Dutch have made use of an 'Indicatieve Kaart van Archeologische Waarden' (indicative map of archaeological values (IKAW)) as part of development planning and broader archaeological research.

The IKAW is an interesting case study within the context of this project. The map covers the entire landsurface of the Netherlands (and as discussed below is now being developed for offshore areas). As Deeben et al. (2002, 10) describe, a very clear, data led methodology was established for the production of the map. This required integration of all known archaeological sites and findspots within the Netherlands, along with topographic and geological data. Tests were run to establish relationships between site location, soil type and groundwater level. Significantly, Deeben et al. (2002, 12) clearly state that:

> "Because of the limited number of variables, the way in which the quantitative analysis is carried out and the gaps in the archaeological database, we do not speak of an archaeological predictive map but of an indicative map of archaeological values"

As Verhagen (2007, 19) observers, the first iteration of the indicative map clearly had errors, caused by bias in archaeological datasets. In essence the baseline data was not sufficient for the indicative qualities to be reliably informative. However, through open publication of the map and through widely engaging researchers, the map was updated and revised (Deeben et al. 2002). As such with continued work the map increased in its indicative ability.

There are two factors that are particularly noteworthy in this case study. First, the baseline data entered into the IKAW relies on high-resolution topographic and geological data. Second, the ability of the IKAW to accurately indicate areas of high archaeological value is predicted on the quality/density of the input data. As such, the IKAW's strength lies in its national coverage and ability to be updated. However, in areas of low data density, be it either geological or archaeological in nature, the resulting output is problematic. The above issues should not be confused with indicating that the approach is flawed; rather that there are well known boundary conditions which have to be met in order for the values generated to be operationally useful. The flaw would lie in straightforwardly applying the values generated from the IKAW without consideration of input data density and reliability.

Interestingly Verhagen (2007, 19) states that the shortcomings of the IKAW led commercial archaeologists and researchers to adapt the outputs, adding a more deductive layer to the inductive output in order to help it fit their experience. As Peeters (2007, 296) describes in his work on Hoge Vaart-A27:

> "The 'indicative map of archaeological values' (IKAW) provided a predictive model for the occurrence of prehistoric remains, based on the relief of the Pleistocene land surface and on assumptions about the location of settlements relative to fresh water. As the present study and survey results demonstrate, the archaeological record – which mainly consists of invisible remains of prehistoric forager/early farmer activity and historic shipwrecks – is not only highly variable in terms of the physical occurrence of evidence for past behaviour, but also has a high degree of intrinsic uncertainty regarding location and predictability. Consequently, the use of the existing maps for planning purposes has gradually been abandoned."

Peeters (2007) answer to this problem was to begin to build in additional information on changing landform patterns and ecology, effectively giving greater precision with regard to time-depth to the IKAW. In addition he began to factor in social factors with regard to hunting strategies and preferences for certain ecological niches. In this respect Peeters' (2007) work sits comfortably in the space the Verhagen and Whitley (2012) state should exist, where inductive and deductive methods can be usefully combined. With regard to this project, the significant outcome of Peeters' work is the need to add time-depth to any model, and to be circumspect as to the predictability of prehistoric site locations. This is particularly important within a landscape where the Pleistocene landsurface was subject to considerable change throughout the Holocene, and as such a single surface would make a poor proxy for potential across all periods.

The critique of predictive modelling

As alluded to above, there has been a strong critique of the use of predictive models within archaeology. In the first instance concerns were raised as to their often environmentally deterministic basis (Gaffney and Van Leusen 1995; Kvamme 1997; Wheatley 1999, 2004). This critique was rapidly accepted with scholars such as Verhagen et al. (2004), Van Hove (2004) and Peeters (2007) working hard to integrate a broader range of inputs (and often operating in a less deterministic manner overall). In essence the problem of environmental determinism has been relatively easy to address through querying the indicative weight given to environmental factors within models.

However, Wheatley (2004) has set out a series of fundamental problems with inductive predictive modelling. These are significant in nature and require detailed consideration. Wheatley (2004, 3) establishes two central purposes for predictive models;

- "to explain the observed spatial distribution of archaeological remains, and hence the behaviour of past communities, or

- to inform archaeological management strategies."

These two categories reflect all archaeological work in this area, including the work undertaken in this project (which speaks to both purposes). Wheatley's (2004, 3.2) subsequent critique is then be broken down into three key points:

- it doesn't actually work very well;
- the results are rarely used; and
- that if it did work, and the results were used, then it would be likely to be highly detrimental to the recorded archaeological resource

These points are underlain by three other more theoretical, but still significant, concerns (2004, 3.1):

1. "to explain the past by asserting the primacy of correlations between behaviour and environmental characteristics is reductionist to the extent that it effectively de-humanises the past";
2. "correlative prediction as a form of explanation is profoundly anti-historical. It assumes that the patterns we observe are wholly a product of the immediate surroundings of the individuals and communities responsible for them and can therefore be explained by some link between the two. In reality, the behaviour and activities that structure the spatial patterns in archaeological landscapes are just as much a product of historical as contemporary factors. Spaces may be abstract, geometric and synchronous but places have histories and biographies as well and it is places that are inhabited by meaningful human actors"; and
3. "correlative prediction ignores the critical theoretical space that lies between past people's behaviours and their physical surroundings. It effectively substitutes a mathematical equation for the meaningful bit of human actions."

With regards to this project, Wheatley's first (that it doesn't work) and third (that if it did it would be detrimental) points are particularly concerning. The argument that models don't work very well is predicated on the point that they are often constructed to reduce the area to be investigated as a part of cultural heritage management activities. Wheatley (2004, 3.2.1) argues that this often means that the underlying models are never effectively tested, and thus can't be iterative in nature. Wheatley (2004, 3.2.1) notes that when gain/improvement in model accuracy through time is measured "by any rational estimation [the results are] not very good". Addressing this issue is theoretically straightforward, simply requiring a clear testing of models if they are to be used.

Wheatley's third point (that if models do work, they are detrimental to understanding) is more difficult to address. Wheatley (2004, 3.2.3) argues that use of models can lead to a less representative archaeological record. Figures 2.2 and 2.3 illustrate the process through which this happens. In figure 2.2 a positive feedback loop is represented. Here a biased database leads to a biased model, which shapes archaeological activity, which in turn reinforces the model. Addressing this concern again could be straightforward, but would require testing of areas outside zones of 'high probability'.

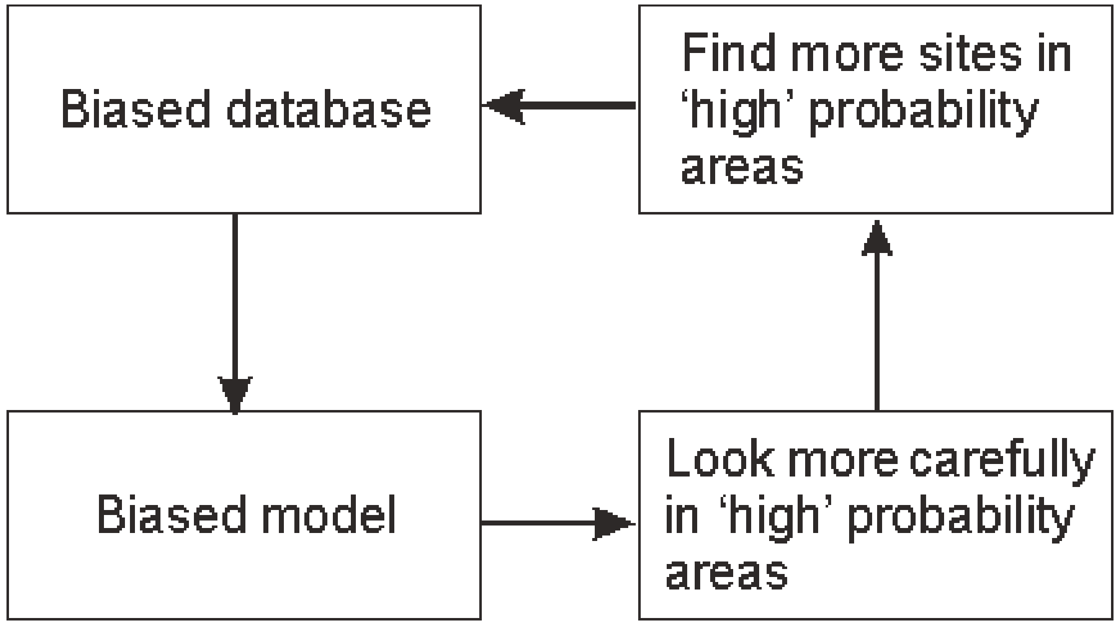


Figure 3.2 A positive feedback loop (after Wheatley 2004, figure 1)

Figure 2.3 shows this positive feedback loop operating through time. The result is that continued use of the model leads to an impoverishment of our understanding as it continually focuses on areas of predetermined potential.

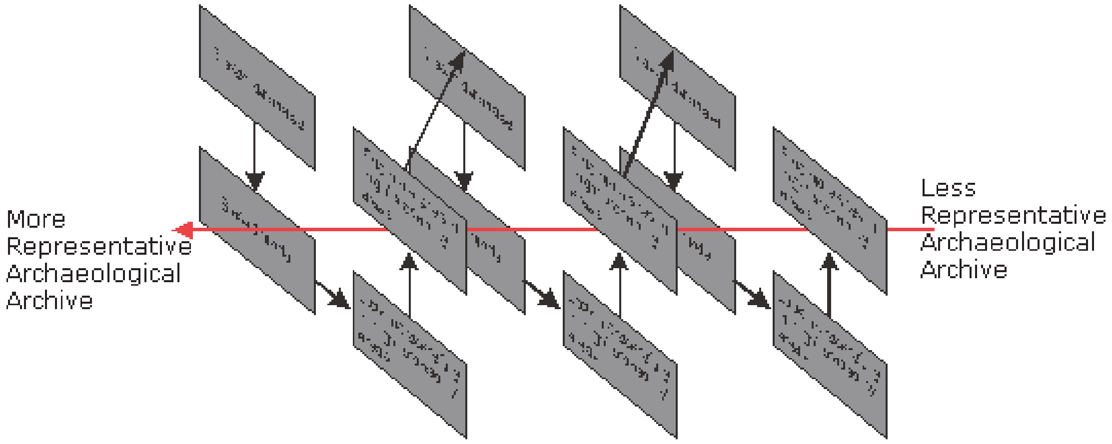


Figure 3.3 a postive feedback loop through time (after Wheately 2004, figure 2)

Wheatley (2004, 3.2.4) concludes by stating that:

> "Archaeology should really face up to the possibility that useful, correlative predictive modelling will never work because archaeological landscapes are too complex or, to put it another way, too interesting. It is obviously unrealistic for financial reasons to expect archaeological investigations to be done everywhere, but generating correlative models that do not work and should not be used is not the answer to the dilemma of how best to deploy scarce archaeological effort.

This is damming indeed. However, others have taken this critique and responded to it through recognising that the problem lies not so much in modelling but how and why models may be used. After considering Wheatley's critique Kamermans (2004, 275) argues:

> "Predictive models should not reach land managing officials and certainly not the planners. Their only role should be in an initial phase, to aid archaeologists to stratify an area in order to plan various forms of archaeological prospection on the basis of a good sampling design."

While seemingly reasonable, as ever the devil lies in the detail. Kamerman's point is well made; the difficult comes in ensuring that the positive feedback loops described by Wheatley aren't allowed to form. In some instances this critique reflects the experiences related by Deeben et al. (2002) and Verhagen (2007) with regards to the IKAW. Taken in a straightforward and static manner the IKAW is problematic, but engaged with in an iterative format, where surprises and changes are to expected, it then gains a more useful position. The significant outcome of this this critique for this project thus appears to be:

1. Considerable caution is required with regard to the use and dissemination of predictive models;
2. If models are used, testing is required;
3. All models should be iterative in nature; and
4. They might best be viewed as aids to sampling.

This last point is perhaps most significant. Wheatley's more theoretical concerns with regards to predictive modelling (that they are reductive, and remove the human element we are looking for in archaeology) are of relevance here. Much of the literature that discusses the value of submerged prehistoric archaeology (Peeters et al. 2009, Bell and Warren 2013, Sturt and Van der Noort 2013) focuses on its potential to provide us with something different and challenging. As such, any method that would threaten this has to be engaged with considerable caution. It would seem unfortunate to develop an approach that was only capable of replicating/reinforcing the record found on land without any consideration of the differences that might exist

Predictive modelling and maritime archaeology

Maritime archaeology, and submerged prehistory in particular, has its own history with regard to predictive modelling. This can be seen to be divided between three approaches: deductive approaches based on the Danish 'fishing site model' (Fischer 1993, 1995, 1997, 2007); those that have a geoarchaeological focus (Ward and Larcombe 2008, Goodwin et al. 2010, Weerts et al. 2012); and more recently attempts to apply an inductive IKAW approach (Erkens et al. 2013, Weerts et al. 2013).

The Danish Approach: Deductive Methods

It is hard to overstate the impact of archaeological research in Scandinavia on our understanding of, and approaches to, submerged prehistory (Benjamin 2010, 256). As made clear in chapter 2, work on sites such as Tybrind Vig (Andersen 2013) have shaped our expectations and helped to establish best practice. Significantly, the impact of the work in Scandinavia has been extended through commercial archaeological investigations. Work by teams such as those led by Jorgen Dencker at the Viking ship Museum in Roskilde have shown how excavation of submerged prehistoric sites can be undertaken as a part of development mitigation. Crucially this work (Dencker and Johansen 2011) involves an integrated approach that makes use of geological and oceanographic data, alongside the deductive 'fishing model', to help target submerged sites for investigation. There is no doubt that this proven to be effective, with commercial projects adding significantly to our understanding of Denmark's submerged prehistoric record.

As noted above, Fischer's (1993, 1995) 'fishing model' is often described as lying at the heart of the method used to determine sampling locations. This model was born out of a series of underwater investigations begun in the 1970s by the Langeland Museum in South Funen (Benjamin 2010, 256). By the mid-1980s it had become clear that there was a pattern to the sites being found, and that these matched locations described by local fisherman with regard to where they might set out to work (Fischer 1993). This produced a loose location/topology based model. Fischer (1993, 66) stated that:

> "Settlements were placed on the shore immediately beside good sites for trap fishery. Such places were at the mouths of streams, at narrows in the fjords, and on small islands and promontories close to sloping bottoms in the fjords"

This gave rise to rendering of land/seascape morphology for where sites were likely to be found, shown in figure 2.4 (below). Interestingly, as Faught (2014, 38) notes, similar deductive approaches were being developed in the United States during the late 1970s (CEI 1977). Here sea-level data were used to model the Northern Gulf of Mexico continental shelf, with archaeological findspot data from current terrestrial regions used a proxy for inhabitation patterns. Sadly this work did not receive the same field testing/evaluation as the Danish model did, and as such has received the same recognition. Following Wheatley's (2004) argument, it becomes an example of a model not being made to work through ground-truthing. It is also interesting to note that when moving offshore a deductive approach was chosen over the inductive methods gaining greater traction in the US at the time.

However, the success of the fishing model within Scandinavian waters over the last twenty years has led to others advocating its use more broadly (Benjamin 2010, Hall 2014). Within the US, contra to the dominance of inductive modelling terrestrially, there has been a continued sporadic engagement with deductive or blended inductive/deductive models offshore (e.g. Watts et al. (2011), Faught (2014)). Benjamin (2010, 258) sees the porting of the Danish model more as a methodological process (linked to deductive reasoning) rather than a direct use of the locations described by Fischer (1995) globally. For Benjamin (2010, 258), the modelling approach equates to:

> "Phase I—Regional familiarization: archaeology, geography, geology, geomorphology, oceanography, and hydrology.
>
> Phase II—Ethnographic component: cultural parallels, historical research, and modern interviews.
>
> Phase III—Map, chart and aerial imagery analysis, and location plotting.
>
> Phase IV—Observation of potential survey locations, physically and with sonar.
>
> Phase V—Marking of theoretical site with GPS and diving to investigate.
>
> Phase VI—Post-fieldwork analysis, interpretation and dissemination."

It is phase II in the above schema that equates most clearly to modelling work. Here, there is a clear attempt to address the social and ecological together in order to create a deductive model. Benjamin (2010, 256) notes that viewing this approach as 'modelling' stretches definition of the term. However, at its heart what Benjamin (2010) describes is a model of sorts, with a clear environmental/resource based focus. Furthermore he is specific in stating that this approach may aid in locating sites in little surveyed areas:

> "Furthermore, predictive models applied to areas where the archaeological record is particularly lacking can be seen as a strategy for beginning the challenging task of locating prehistoric sites underwater."(Benjamin 2010, 262)

The difficulty here is that landscape and environmental change over many thousands of years can mean that any ethnographic or modern parallels can become difficult to justify beyond the most general observations. Perhaps more important is the fact that the size and scale of submerged landscapes in English waters means that just because it is submerged today does not mean it was 'coastal' at the time of occupation. As such, any model of the format proposed by Benjamin needs to include not only fishing practices but also terrestrially activities too. This may be difficult for as noted in recent research frameworks (Ransley et al. 2013, Blinkhorn and Milner 2013), our knowledge of prehistoric lifeways is fragmentary at best and perhaps not well suited to providing the basis of a predictive model. This is particularly the case if submerged landscapes offer the potential for non-analogous environments to those represented in the current archaeological record.

As noted below, as part of this project an expert meeting on predictive modelling was held. This saw participants from the Netherlands, Denmark and Britain discuss different approaches. In these exchanges it was Jorgen Dencker who noted that the fishing model was a broad heuristic device that was effectively constantly updated, and that the more work they did, the more sites they found, in a greater variety of contexts. This points to the importance of Wheatley's observation that no model should remain static if it is to be at all useful, and that all models need to be tested.

In essence the Danish fishing model is a good example of deductive reasoning and integration of archaeologi-

cal experience with survey planning. Benjamin (2010) extends this further by considering how different factors can be built into project design, to ensure that social and the spatial are considered side by side. However, the challenge lies in understanding how representative either the extant archaeological record is, or how relevant any historical or ethnographic parallels are.

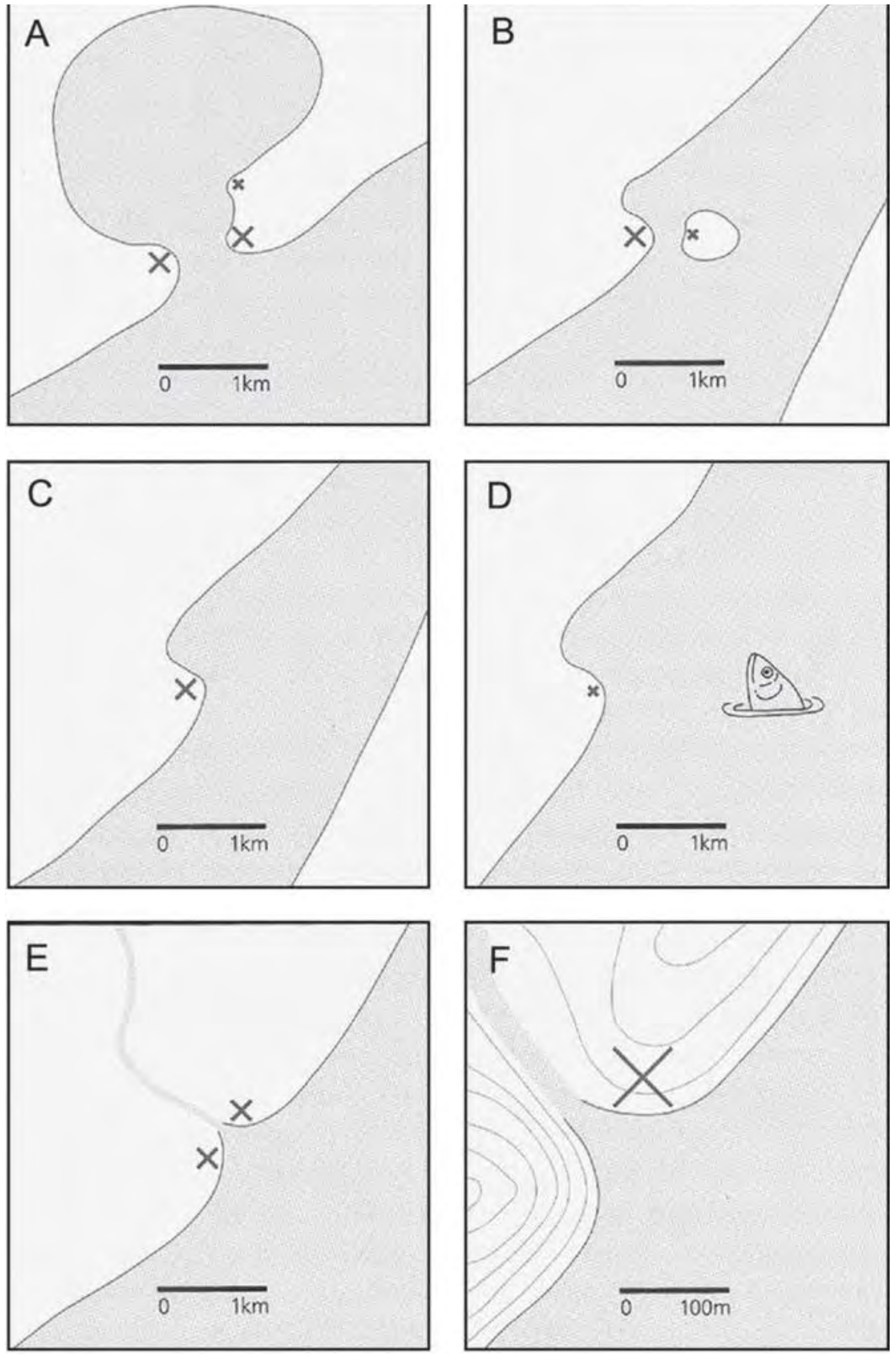


Figure3.4 The Danish fishing model (after Fischer 1995)

Georchaeological Approaches

Since Coles (1998) 'speculative survey' of the Southern North Sea ('Doggerland') there have been a range of studies that have attempted to refine our understanding of the potential for submerged prehistoric archaeology in the North Sea and further afield (Ward 2006, 2014; Ward and Larcombe 2008; Ward et al. 2013). These studies have drawn strongly on broader research within geoarchaeology. Ward and Larcombe (2008, 61) note that:

> “Geoarchaeological research on land has shown an association between certain landform elements and known types of archaeological and palaeoenvironmental remains (Rapp and Hill 1998; Howard and Macklin 1999; Passmore et al. 2002) that can be used to provide a first-order geomorphological estimation of the unknown archaeological and palaeoenvironmental potential (e.g. Waddington and Passmore 2006).”

More broadly Ward et al. (2014, 218) have reiterated Ward and Larcombe’s (2009) argument that “potential is best considered as the combined probability of contemporary occurrence and subsequent long-term preservation”. This form of modelling potential clearly adheres to elements of the inductive modelling described above, but with a more pronounced focus on the significance of deposit/stratigraphic modelling. Ward (2014, 228) argues that with a lack of direct evidence of human activity, the best we can do is model the location of deposits which may preserve in-situ deposits. In essence Ward’s (2014) work on the North Sea is a more focused and geologically refined rendering of Goodwin et al’s (2010) broad scale ‘high potential zone’ (discussed in chapter 1). However, the outputs of these models and resultant determinations of potential are still heavily skewed by the quality of the input data, and our understanding of histories of human occupation and activity across the region. This is problematic for submerged prehistory in the UK, as it is the area we have the least amount of information for, but feel an increased pressure to model in order to help understand it. It is at this point that Wheatley’s (2004) critique becomes particularly poignant; modelling based on low quality data may negatively impact on our understanding of the past. As such, both Goodwin et al. (2010) and Ward’s (2014) work becomes commendable for its generalizing qualities and calls for further work to improve interpretation. Here interpretation is not stretched, the qualities of the input data are made clear and the output resolution and confidence is commensurate with the inputs.

Inductive Approaches

Given the success of Fischer’s approach in Denmark, and the widespread practice of inductive predictive modelling in North America and the Netherlands, it is perhaps unsurprising that a number of studies have begun to experiment with these methods offshore. Mackie et al. (2013) document the development of a predictive model for submerged Pleistocene sites on the North West coast of America. Again, Mackie et al’s (2013) approach might best be described as a blend of inductive and deductive modelling. They advocate the use of known terrestrial site distribution patterns to predict offshore location, but mediated through an understanding of landscape change and human response. Again, this points to the merging of a theoretically sensitive approach and data led models advocated by Verhagen and Whitley (2012). Interestingly Mackie et al. (2013, 144) suggest for their study region that models could be bracketed into 5m vertical contour bands, within which different certainties/understanding of archaeological activity could be mapped based on current inter-tidal site distribution. The difficulty with this is that it again focuses on current shorelines and does not engage with large areas that may have been inland but that are now submerged. This plays to the strengths of inductive modelling, when the relationship between the source dataset used to infer patterning is as close to the modeled area as possible.

The challenge of engaging with wider areas that have undergone more dramatic landscape changes has recently been taken up by Dutch researchers. Erkens et al. (2013) have attempted to extend the IKAW offshore. This was a brave and academically challenging endeavour given that the quality of the output map is known to be strongly correlated to the quality of the input data. Where there is a small amount of site location information the indicative map has already been shown to be problematic in terrestrial contexts, and thus faces a daunting job when moving offshore (given the reduced amount of fieldwork and finds reporting that has occurred offshore). Reporting on the results of this project Weerts et al. (2013) concluded:

> “The picture that emerged was that (1) very many data are available, (2) but of often unknown quality and (3) not evenly distributed over the sector. (4) Therefore, making a detailed predictive map that covers the entire sector is still far off. (5) Making such a map for the areas with enough good data would be very expensive. So the picture we now have is that we are going to have to look for alternative solutions.“

This last study is salutary when considering options for English waters. Dutch colleagues have considerable experience in the construction and use of indicative maps, but have still struggled with implementation.

Predictive Modelling: integrating experience and perspectives

Given the complex histories of the use of predictive modelling, theoretical concerns and lack of practical experience of its application in the UK, an expert meeting was held in Southampton on the 26th March 2014. The idea of this meeting was to draw together practitioners from across Europe with experience in different areas of modelling. The speakers were:

Kieran Westley and Ruth Pletts (Centre for Maritime Archaeology, University of Ulster)

Louise Tizzard & Cathie Barnett (Wessex Archaeology)

Hans Peeters (University of Groningen)

Jørgen Dencker (Viking Ship Museum)

Fraser Sturt, Michael Grant & Tyra Standen (University of Southampton)

Additional attendees were present from the University of Southampton and Historic England. Furthermore, as space at the meeting was limited, the session was advertised and webcast to an audience of over 200 people. The PowerPoint slides, audio and video files from this meeting have been archived at the University of Southampton and remain available for viewing at the following web links.

Part 1:

https://coursecast.soton.ac.uk/Panopto/Pages/Viewer.aspx?id=77556729-8914-48e7-a1ef-93aa58835fde

Part 2:

http://coursecast.soton.ac.uk/Panopto/Pages/Viewer/Default.aspx?id=e1a3a5df-1d6c-4be3-8315-4c138411e88d

The meeting was productive in that it allowed archaeologists who work with inductive, deductive and geoarchaeological approaches to compare experiences. As might be imagined, there was more concordance between speakers than the polarised positions taken in the literature might suggest. In fact, agreement as to best practice with regard to how to get the most out of modelling submerged landscapes rapidly emerge. This focused on:

1. Ensuring input data is of a high quality and density. This must include geological as well as archaeological data.
2. Inductive modelling of site location in areas of low data density/high uncertainty with regard to human activity is highly problematic.
3. All models need to be ground truthed.
4. All models need to account for landscape change through time.

Dencker’s account of current practice in commercial archaeology in Denmark was particularly enlightening with regard to selection of areas for ground truthing. Although the fishing model was seen to provide a starting point, areas were chosen based on exposure/accessibility and after detailed analysis of high resolution geophysical data. As such, the Danish model and the geoarchaeological model appear much closer together, with the major difference being the impact that ground truthing has had on Danish understanding of site density.

This, when taken with Weerts et al.’s (2013) account of moving the IKAW offshore, firmly established that inductive modelling of submerged archaeological potential for English waters would be problematic and unsatisfactory. As such, a combined geoarchaeological and deductive approach was favoured.

Both the literature review of predictive modelling and the expert meeting placed a significant emphasis on the need for ground-truthing. Without some form of field engagement the models produced would be worthless.

As Wheatley (2004) argued, unless tested they have no merit.

Evaluation methods

As Faught (2014, 44) notes:

> "It is arguable that more work has gone into creating models for determining submerged archaeological site's potential occurrences and preservation potentials than on actual in-field testing of submerged landforms by diving, coring or, dredging."

Whilst perhaps not the case in Scandinavia, the above comment holds true for much of the world and certainly England. This presents a possible problem with regard to meeting Wheatley's (2004) required field-testing of model outputs. England has a single excavated submerged prehistoric site, Bouldnor Cliff (Momber et al. 2011). The result of this is that there is dearth of experience when comes to fieldwork and lack of research into effective methods for UK waters.

In recognition of the need to assess methods for sampling large offshore prehistoric landscapes, Wessex Archaeology was commissioned to carry out a review in the Area 240 site environs (Russell and Tizzard 2010). Russell and Tizzard (2010, 6) assessed the efficacy of three different methods; clamshell grab, video survey and beam trawl. The grab samplers were hydraulic clamshell systems capable of capturing c. 280 l per grab with stratigraphy relatively in-tact (Russell and Tizzard 2010, 10). The beam trawls were 2 metres in width and trawl length was determined by understanding of underlying geology. Building on benthic mapping methods, the video systems were deployed on sledges towed behind a survey vessel (Russell and Tizzard 2010, 9) with a USBL positioning system attached.

The results of this study are interesting for what they indicate as to viable methods for recovering archaeological material from submerged landscapes. Russell and Tizzard (2010, 20) note that the video sled was of little value, largely due to poor visibility. However, the authors note that if conditions were better on site and surface exposures expected, video systems could play a valuable role in site evaluation. The beam trawl proved difficult to manage, but did produce representative samples of surface sediment. Thus if the task were to locate peat outcrops it would be a viable method. However, as means of targeting and understanding stratified sequences it would unsatisfactory. The grab sampler (as might be expected) was found to do a better job at providing an insight into point specific conditions. However, Russell and Tizzard (2010, 21) point out that even with their comparatively large sample the volume of material recovered is small and the depth of penetration limited.

None of the above observations should come as surprise to practicing archaeologists with experience of terrestrial evaluation and excavation. Here, if we wish to evaluate an area, large scale sampling procedures are followed. Gurney et al. (2003, 12) note that in terrestrial contexts "Evaluation trial-trenching will normally examine an appropriate sample (often expressed as a percentage of the area of the proposed development site)". Russell and Tizzard (2010, 21) are thus making the valid point that even within their study, widely spaced clam shell grabs would not achieve an appropriate level of sampling interval if it were transferred to a terrestrial context. We are thus actively supporting differing levels of engagement between terrestrial and submerged contexts. As returned to later in this volume, this has significant implications for our ability to gain credible data and answer archaeological questions.

There are alternatives to this. As reported in Dencker and Johansen (2011) and explained at the expert meeting, the Danish approach is to adopt a programme of targeted excavation more akin to that seen on terrestrial research projects. Test pits of variable size (but frequently 1m wide) are dug on locations identified via the geophysical, diver and camera surveys. These often occur at points where sediments are shallow and eroding material is visible. This system has the advantage that archaeologists are present on the seafloor and detailed attention can be paid to stratigraphic sequences. Within English waters it is this sort of hands on approach which has allowed Momber et al. (2011) to excavate the complex Mesolithic site of Bouldnor Cliff. A more ambitious landscape sampling approach via test pitting has recently proven successful in a terrestrial context with the work by Oxford Archaeology on the Bexhill-Hasting link road. This project transformed our understanding of Mesolithic activity in the area by exploring a variety of locations, and sampling rather than stripping buried soils (Oxford Archaeology 2015, NHPP 7043).

This approach also has important implications for how the archaeological record is understood and related to. As Lucas (2012) has argued, the practice of archaeology (how we create our knowledge base) fundamentally impacts on our interpretations and valuing of it. By moving away from a remote system of extraction the archaeological record gains immediacy and intelligibility. This translates into a more nuanced form of writing and a greater expectation and understanding of that record. However, it should be noted that Danish waters are often more convivial to this approach than those that surround England, particularly those within the study area of this project. However, the Danish model of evaluation certainly seems to be a gold standard worthy of pursuing where possible, and in many respects maps on well to the methods used on the Bexhill-Hastings link road project.

More recently Dutch researchers (Weerts et al, 2010; Moree and Sier 2015) have tackled the problem of representative sampling raised by Russell and Tizzard (2010) in a marine context. When the Yangtze Harbour development was first proposed there was a known background of Mesolithic archaeological finds from the area, discovered as part of the initial Maasvlakte 1 works. With this knowledge in mind a desk based assessment was carried out, followed by a detailed geoarchaeological investigation. This enabled high resolution modelling of the submerged land surfaces, and from this planning of targeted extraction work to search for archaeological material culture. Three trenches were 'dug' and sample areas dredged. A 2x5m flat bottomed clam shell grab recovered material in 20cm deep units, with material bagged and labelled with coordinates on board the vessel (Schiltmans and Vos 2015, 46). These samples were then sieved onshore.

This working method allowed for targeted extraction of large volumes of material from areas known to contain in-situ Holocene deposits. The quantity of material recovered was startling; over 46,000 archaeological and ecological artefacts. In this case there was a clear adoption of a geoarchaeological (or what Groenendijk and Vos (2002) term a 'geogenetic') approach, followed by a 'strip, map and sample' invasive phase. The result has to be one of the most significant investigations of a submerged prehistoric landscape outside of Scandinavia. Although the approach is very different to the high resolution diver based work in Denmark, it has still afforded a transformation in understanding. Significantly, it enables a move away from discussions of potential and rendering of landscapes alone, to capture of artefactual material which allows engagement with broader, more traditional, archaeological questions.

It is this last point about categories of data that is particularly important. Work in Scandinavia, and now in the Netherlands, has contributed to broader archaeological understanding by being able to produce the full suite of data types required to engage in archaeological debate. As is clear from the discussion above, this should not devalue the need for palaeoenvironmental data. Improving our understanding of context is crucial for any engagement with submerged prehistoric archaeology. However, if we wish to do something with this knowledge we need to enable generation of commensurate data to that produced by traditional archaeological practices. To return to Clark's (1973) loss of innocence, there will be a price to pay for this, but the prize is clearly visible.

Conclusions

It would appear clear that an inductive modelling approach is inappropriate for English waters at this point in time. We have insufficient terrestrial evidence to create a viable starting point for accurate prediction. Deductive models offer some potential, as these allow for integration of broader archaeological experience at a regional level. Most promising however are geoarchaeological approaches, with a focus on deposit and palaeogeographic modelling to render an understanding of 'spaces of opportunity'. While the Waterlands project (Goodwin et al. 2010) did this at a very large and coarse scale, it is now clear that we can begin to provide higher resolution outputs that may be of greater benefit to researchers and regulators alike.

The need for ground-truthing is also apparent. As Wheatley (2004) argues, any modelling of potential without ground-truthing is a partial and ineffective job. In the context of this project large-scale strip, map and sample is not financially feasible. As such, a Danish approach of small scale test pitting will be adopted. It is recognised that this has its limitations, and these are discussed in detail at the end of this report.

Chapter 4
Prehistoric Archaeology in the Severn Estuary and Bristol Channel region

Introduction

The potential for the existence of prehistoric material and features within the Severn Estuary and Bristol Channel coastlines has long been alluded to, with submerged forest-beds and flint finds being identified within the intertidal zone since the nineteenth century (e.g. Boyd Dawkings 1870). However, it was the numerous discoveries made by the late 'amateur' archaeologist Derek Upton (Bell 2005), during the latter half of the twentieth century, which helped spark a greater academic interest in the region. Additionally, Allen's work on the estuary-wide Holocene sedimentary sequence allowed such findings to be contextualised within the broader environmental changes of the Holocene, confirming their age, and thus significance, to our understanding of British prehistory (Bell 2013: 6).

Since then, a number of organisations have conducted multi-disciplinary projects within the region, producing some of the country's most impressive prehistoric discoveries as well as a well-studied environmental archive in the form of Holocene sedimentary sequences. One of the most extensive intertidal and wetland studies undertaken has been conducted in the Gwent Levels on the northern side of the estuary (e.g. Bell 1994; 1995; Bell and Neumann 1997; 1998; Neumann and Bell 1997; Bell et al. 2000). Here, several prehistoric features and structures dating from the Mesolithic to the Iron Age have been identified including some of the country's more unusual discoveries, such as the preserved Mesolithic human and animal footprint-tracks at Goldcliff East (Scales 2007). Some of these footprint-tracks represent the presence and movements of children as well as adults; thus highlighting how the impressive preservation in this region has helped provide glimpses into different aspects of prehistoric lifeways, normally invisible within the British archaeological record.

On the southern side of the channel investigations have also targeted numerous locations including: Oldbury in South Gloucestershire (Druce 2000; Brown and Allen 2008), Gravel Banks, Bristol (Druce 2000), Brean Down (Bell 1990), Burnham-on Sea (Druce 1999; 2000), Stolford (Heyworth 1985), Minehead (Jones et al. 2005), Porlock (Canti et al. 1995; Jennings et al. 1998; Straker et al. 2004) and Westward Ho! (Jacobi 1979; Balaam et al. 1987). In addition, Cameron et al. (2004) carried out a detailed study on the inland coastal clay belt in Somerset, allowing a better understanding of the development of saltmarsh communities during the late Mesolithic (Hosfield et al. 2007: 40). These have demonstrated that deposits on both sides of the estuary have the potential to greatly improve our understanding of Holocene environmental change within this area, as well as producing additional material that can provide new insights into the land-use and occupation patterns of prehistoric communities.

The current study area

The current study area forms part of this impressive archaeological landscape, encompassing part of the Somerset Levels and Moors area, a section of the inner Bristol Channel coastline and the Bridgwater Bay Mudpatch. Despite the relative wealth of the archaeological material found within Somerset, a comparatively low number of sites pertaining to the chronological focus of the project (Lower Palaeolithic – Early Bronze Age) has been identified within the study area. Few finds have been recorded from the local foreshore either, with the exception of a small number of flint finds purportedly recovered from near the submerged forest-beds on Stolford Beach (Gray 1908; PRN 34078; 34893). This is slightly surprising given the preservation of land surface and peat deposits at numerous coastal locations, including Stolford (Heyworth 1985) and Burnham-on- Sea (Druce 1998; 1999), along with the remarkable discoveries found along the Welsh side of the estuary (e.g. at Goldcliff and Uskmouth: Bell 2007; Aldhouse-Green et al. 1992).

The majority of the more impressive prehistoric sites in Somerset therefore lie further east, in central Somerset, such as on the Burtle Formation at Shapwick and Greylake (Bell et al. 2015), or on the surrounding upland areas such as the Mendip Hills to the north. This bias in the distribution of archaeological investigations appears to have resulted from the difficulties encountered when attempting to access the deeply buried early Holocene deposits, known to exist in parts of Somerset. Past investigations have therefore tended to focus

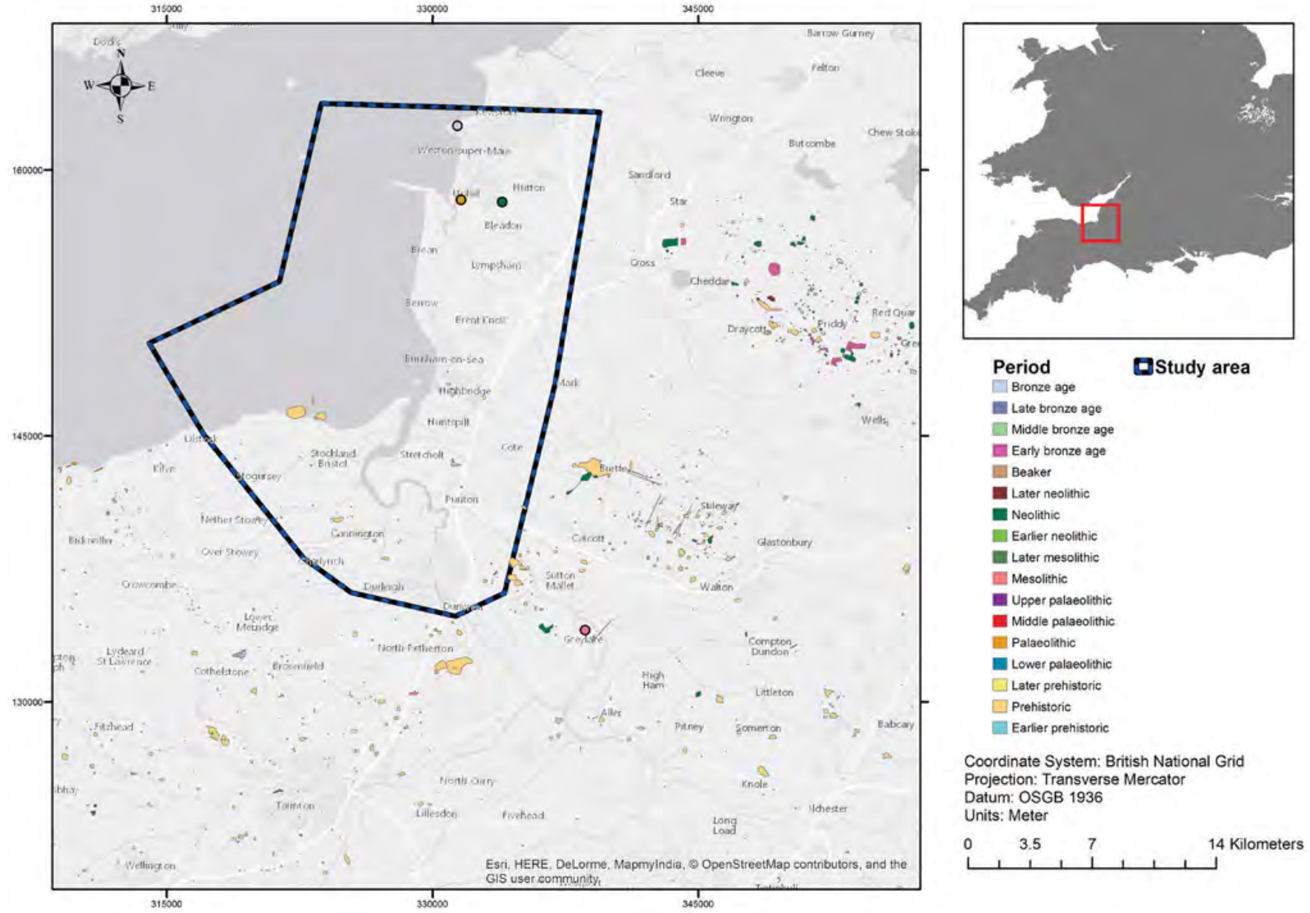


Figure 4.1: Distribution of prehistoric sites for study region. © Crown Copyright and Database Right [2015]. Ordnance Survey (Digimap Licence).

on areas of hard geology, where onlapping deposits are easier to access. Alternatively, when possible, the exploitation of larger industrial interventions within the landscape has also exposed deeper deposits and associated archaeological material at certain locations (e.g. Somerset Level project; Volumes 1-15: Coles *et al.* 1973-1989; Coles and Coles 1986). Whilst such investigations have often been successful in producing prehistoric archaeological material, this variable history of research has meant that there are areas within Somerset that seem to be conspicuously lacking in earlier archaeological material, when actuality it may simply be due to a lack of sampling at depth.

It has also been highlighted that despite the numerous intertidal and wetland studies conducted in this part of Britain (eg McDonnell 1980, Chadwick and Catchpole 2013), comparatively little work has been carried out below the mean low water mark (MLWM; Webster 2007: 273) - something that recent work offshore of Hinkley Point (Sturt et al. 2014) and the current study has begun to address. This bias greatly hinders our knowledge regarding the nature of any Holocene deposits preserved offshore; thus limiting how we may incorporate these submerged areas into our broader discussions of past environmental and cultural changes. It is therefore clear that more targeted investigations are still required in this area, both onshore and offshore, in order to facilitate new understandings of postglacial human-environment interactions within this part of the British Isles.

Existing radiocarbon dates and dendrochronological sequences

As part of this project a database of existing radiocarbon dates and dendrochronological sequences was compiled for the study area. This was derived from a literature search of both published and unpublished works. The main fields included within the database were as follows: Site name, sample ID, lab code, method, material, material identification, locational data, radiocarbon date, source of information and audit status. The full database is included in Appendix 3.

Each entry was audited for precision, accuracy and confidence, with particularly close examination of sample type and positional data and, wherever possible, checked against original radiocarbon laboratory reports (including the journals *Radiocarbon* and *Archaeometry*). The resultant dataset was used to help with verification of the palaeogeographic outputs created during the modelling work discussed in chapter seven, and with the review provided below.

Archaeological Background

Lower Palaeolithic – Middle Palaeolithic

The Lower Palaeolithic and Middle Palaeolithic (c. 700,000- 40,000 BP) archaeological record for the South West of England is noted as being diverse, with some areas producing rich deposits and concentrations of findspots, whereas other areas appear to have very little material representing this period (Hosfield et al. 2007). However, lithic findspots, rather than sites, generally dominate the region's archaeological record, limiting our understanding of the nature of occupation patterns within the region, as well as affecting the chronological resolution of the existing datasets. In regards to this research, fourteen sites associated with 'Lower Palaeolithic' material are noted within Somerset's Historic Environment Record (HER). Only one of these is located within the current study area though, representing an Achuelean hand axe recovered near Fiddington (PRN 10526). Sites not recorded within the HER include Cave 8 at Uphill Quarry (NRHE 192504), where a Mousterian assemblage was recovered.

The more impressive sites of Lower Palaeolithic-Middle Palaeolithic date, within Somerset, therefore lie beyond the geographical focus of the project. This includes the Medip Hills caves which has produced both lithics and rich faunal records. The Mousterian artefacts and distinctive Devensian faunas from Rhinoceros Hole and the Hyaena Den at Wookey Hole (Wymer 1999: 91; Jacobi 2000: 45-6) stand as a good example of this. Another notable site is Westbury-sub-Mendip, which has produced distinctive Cromerian fauna, associated with a sparse assemblage of artefacts (Andrews et al. 1999). Other parts of Somerset have also produced a rich Lower Palaeolithic record, including several hundred Lower Palaeolithic artefacts made from greensand Chert from Cothill (Norman 2000: 56-7), and c. 200 artefacts (including 1 Levallois flake, 24 handaxes and 29 cores) from the beach and foreshore at Watchet (Wymer 1999: 186-7). Additional, single handaxes have also been recovered from the Doniford gravels inshore at Watchet and Willton (Hosfield et al. 2007). All of this points to Lower-Middle Palaeolthic activity across the region more broadly, but lacking within the study area specifically.

Upper/ Terminal Palaeolithic

The British Upper Palaeolithic can be split into two periods: the Early Upper Palaeolithic phase (c. 40,000 – 21,000 BP) and the Late Upper Palaeolithic (c. 21,000 -12,000 BP) (Hosfield et al. 2007). The Early Upper Palaeolithic is associated with three artefact based sub-divisions, although detailed information regarding the dating and sequences of these divisions is generally lacking. These include bifacial and unifacial leaf points, Aurignacian technologies (e.g. nosed and shouldered scapers, and beaked burins (*burins busqués*) and the Gravettian (represented by stray finds of stemmed points (Font Roberts points) (Hosfield et al. 2007)). After the Last Glacial Maximum (LGM, c. 19,000 BC), the occupation of Britain can be divided into three periods: The Late Upper Palaeolithic (Creswellian (Magdalenian), the Final Upper Palaeolithic and the Terminal Upper Palaeolithic (also known as Long Blade or Bruised Blade) (Barton and Roberts 1996; Conneller 2007: 17). The Terminal Upper Palaeolithic relates to the final centuries of the Pleistocene and the very beginning of the Holocene, where human populations returned to Britain, after a brief period of abandonment due to the cold conditions of the Younger Dryas (Loch Lomond) Stadial (c. 12,500 BP). The lithic industries associated with this time are characterised by the production of long straight blades (frequently over 12cm in length) knapped from alternately worked opposed platform cores, which are also often abandoned when still relatively large (Barton 1997). The 'bruised blades' *(lames mâchurées)* recovered from Terminal Palaeolithic knapping scatters commonly have battered margins, with it thought that such bruising possibly results from flint-on-flint contact, perhaps occurring when the blades were used to adjust the edges of a striking platforms of cores (Froom 1965; Hosfield et al. 2007).

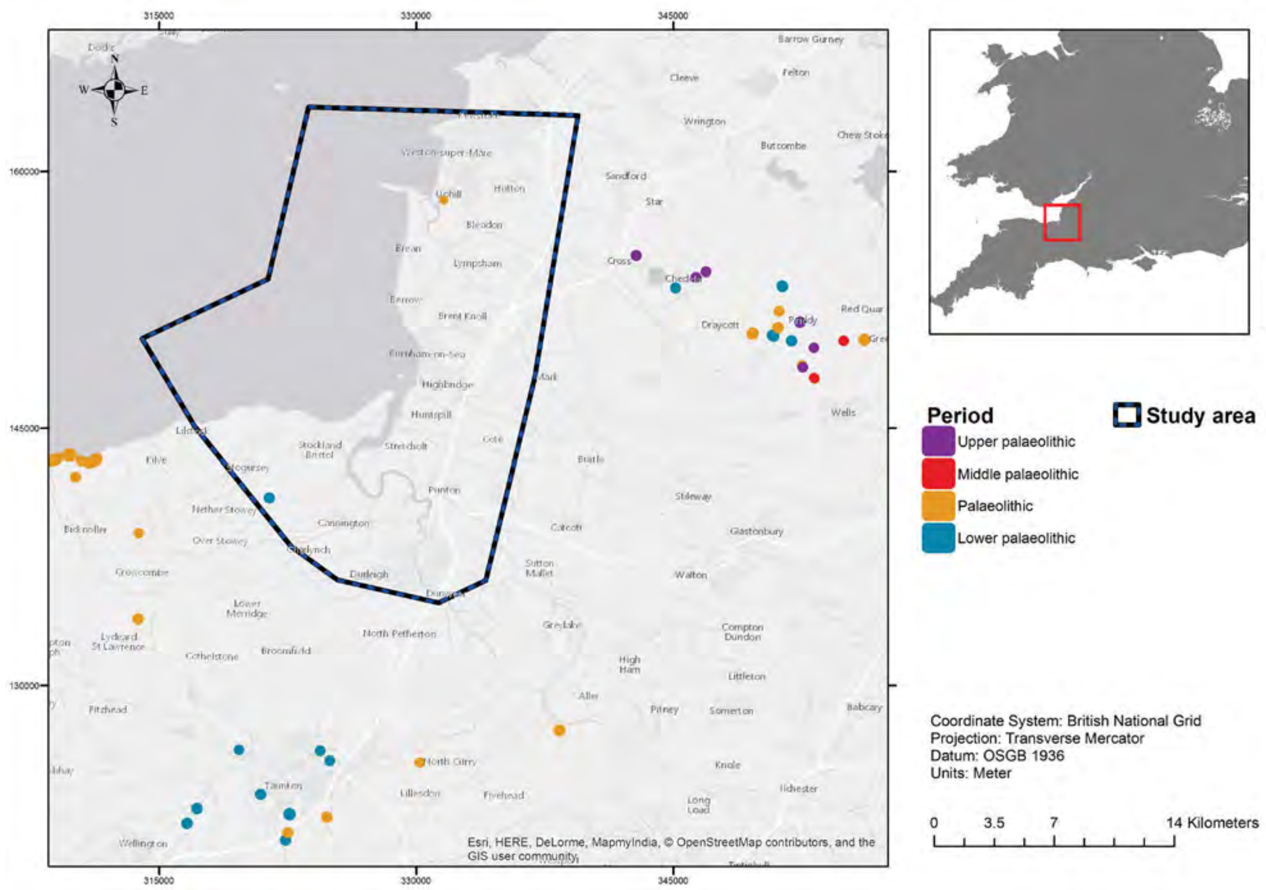


Figure 4.2 Distribution of Palaeolithic sites. © Crown Copyright and Database Right [2015]. Ordnance Survey (Digimap Licence).

Although the Somerset HER suggests an absence of sites dating to the Upper Palaeolithic, a number are recorded by Hawkins and Tratman (1977). Cave 8 at Uphill Quarry (NRHE 192504) contained early Upper Palaeolithic leaf points, which Jacobi and Pettit (2000) have suggested as being the latest Neanderthal artefacts in Britain, as well as the presence of a bone point of Aurignacian type. The latter was radiocarbon dated, following ultrafiltration pre-treatment, to 36,183-35,055 cal BP (OxA-13716; 31730±250 BP; Jacobi et al. 2006). The point is typologically similar to points from continental Aurignacian II assemblages with similar ages, with the age further supported by a date derived from a typologically undiagnostic bone/antler point from the Mendips site of Hyaena Den, Wookey Hole, of 36,164-34,784 cal BP (OxA-13803; 31550±340 BP; Jacobi et al. 2006). These provide the earliest demonstrable age for the Aurignacian presence of Homo sapiens in Britain, with both dates considerably older than previous radiocarbon measurements on the same implements of 32,970-31,230 cal BP (OxA-8408; 28080±360BP; Jacobi and Pettitt 2000) at Uphill and 29,197-27,886 cal BP (OxA-3451, 24500±300 BP; Hedges et al. 1996) at Hyaena Den. The Hutton Cave site, know for yielding considerable deposits of Pleistocene animal remains during the early 19th century, is also purported to have yielded a number of Aurignacian flint implements (Davies 1926), now held in Weston-super-Mare Museum, though the collections from Banwell and Hutton caves are not differentiated.

To the east of the study area are some of Britain's best-known Upper Palaeolithic sites. These include Gough's Cave in Cheddar Gorge (PRN 10398) which has produced lithic industries of Creswellian and *Federmessergruppen* typologies and human skeletal remains (e.g. Jacobi 1991; 2000; 2004). An earlier AMS radiocarbon dating programme on the artefacts and human bones have indicated that Late Upper Palaeolithic human use of the cave occurred during the first half of the Late Glacial Interstadial, equivalent to the Bølling and Older Dryas Chronozones (Greenland Interstadial 1e, 1d and the beginning of 1c). More recent application of ultrafiltration radiocarbon dating has provided a tigher dating for occupation, suggesting that Creswellian activity, covering two or three generations only, dates to 15,238-14,462 cal BP (12,600 ±80 BP, OxA-18035). The subsequent occupation phase, attributed to *Federmesser* industry, is dated to 14,436-13,973 cal BP (12,245±55 BP, OxA-18067) (Jacobi and Higham 2011). Other nearby Upper Palaeolithic cave sites, such as Sun Hole and Soldier Hole, are also associated with Creswellian material (Hosfield et al. 2007: 26). In addition, human bone from Sun

Hole has been dated by ultrafiltration radiocarbon dating producing a date of 15,271-14,533 cal BP (12,620±80 BP, OxA-19557) (Gowlett et al. 1986; Housley 1991; Jacobi 1991; Housley et al. 1997, Jacobi and Higham 2011). The studies have focused upon excavated sequences in sealed contexts from cave sites but human activity within the wider landscape, including open air sites, is still largely under recorded for the area (Bond 2013).

In regards to the Later Pleistocene – Holocene transition, there is currently no evidence known to exist within the whole of the South West region, with evidence of human occupation during this time generally coming from sites in the south east and east of England (Hosfield et al. 2007: 36-7). However, a few 'long-blade-like' lithics have been identified during a re-assessment of local museum collections in Somerset (Bond 2013), pointing to the need for closer scrutiny of archived collections. The finds discussed by Bond (2013) include a flint blade, found north of Priddy Farm, Priddy, and a single long, flint scraper, found in the same area, and believed to be "typologically comparable to scrapers in long flake/ blade assemblages, attributed to the Later Upper Palaeolithic" (Bond 2013: 183). In the Worlebury area there are reports of possible Final Upper Palaeolithic / Early Mesolithic patinated flints (Somerset County Museum Acc. No. A.2554, Leivers 2014). It is therefore possible, if not likely, that archaeological material dating to the Late Upper Palaeolithic may in fact exist within this part of Britain but is yet to be recovered, or recognised within existing collections.

The Mesolithic period

The British Mesolithic is generally recognised as the period beginning during the start of the Holocene c. 11700 BP (Pettitt and White 2012) and ending with the introduction of agriculture c. 6000 BP (Bell and Warren 2013); although the nature of the cultural transitions at either end are still not fully understood (Blinkhorn and Milner 2013). This period has traditionally been divided into two broad chronological phases based primarily on typological differences within archaeological assemblages, with a change occurring across the late 11th and 10th millennia cal BP (ibid). The Early Mesolithic is characterised by "broad blade assemblages" (featuring obliquely blunted points) although it has been recently emphasised (e.g. Barton and Roberts 2004, Reynier 2005) that archaeological assemblages dating to this time are not uniform in character and so should not be thought to be represented by a single, lithic type. In contrast, the Late Mesolithic is typically associated with 'narrow blade assemblages' (relatively small microlith forms such as needle points and scalene triangles (Hosfield et al. 2007: 48)). A 'Middle' facies has also been suggested for the southern and central England. However, the scarcity of substantial archaeological material and associated radiocarbon dates still tends to result in this period being conflated, and thus seen as a fairly 'timeless' period in British Prehistory, lacking in history and change until the beginning of the Neolithic (Blinkhorn and Milner 2013: 7).

Within the study area, only three entries are categorised as 'Mesolithic' within the HER for Somerset (2015). These include: four Mesolithic flint flakes, two with secondary working, found during a small excavation at Long Field Champion's Farm, Puriton (ST 316 421) in 1971 (PRN 30225, Fowler 1971: 7; Dawson 2001), some 'possibly residual' Mesolithic flints recovered from features thought to date to the Middle Bronze Age during an archaeological evaluation to the south east of Cannington (PRN 10296) and an alleged flint find site at Brymore House, Cannington (PRN 10206). It should be noted though that the finds reported in the latter entry may in fact have been recovered from Cleeve Hill, Watchet (see HER entry for further details). Additional possible Mesolithic sites from the Cannington area were recorded by Roger Jacobi (Leivers 2014). Mesolithic flint scatters were also reported in 1992 during field walking, for Nuclear Energy, along the coast just west of Hinkley Point Power Station (ST 200 456) (PRN 15722; Bromhead 1992; Croft 1992: 66). Two of the cave sites in the north of the study area also contain Mesolithic flints including the Hay Wood Cave rock shelter (NRHE 192543) and Shiplett Hill (Leivers 2014), while the main Mendip cave complexes to the east contain more extensive evidence of Mesolithic activity (see below).

This small number of find spots highlights how the distribution of material dating to this period varies greatly across the Severn Estuary and Somerset Levels, with most work conducted within the study area producing only peat or organic deposits dating to the later Mesolithic, rather than anthropogenic material. It also shows how generally the dating for such areas of activity is simply driven by lithic typologies, thus limiting how well we can relate human occupation patterns to changes within the local environment during this period.

Looking at the wider region, the county of Somerset is noted as having a relatively rich Mesolithic record - par-

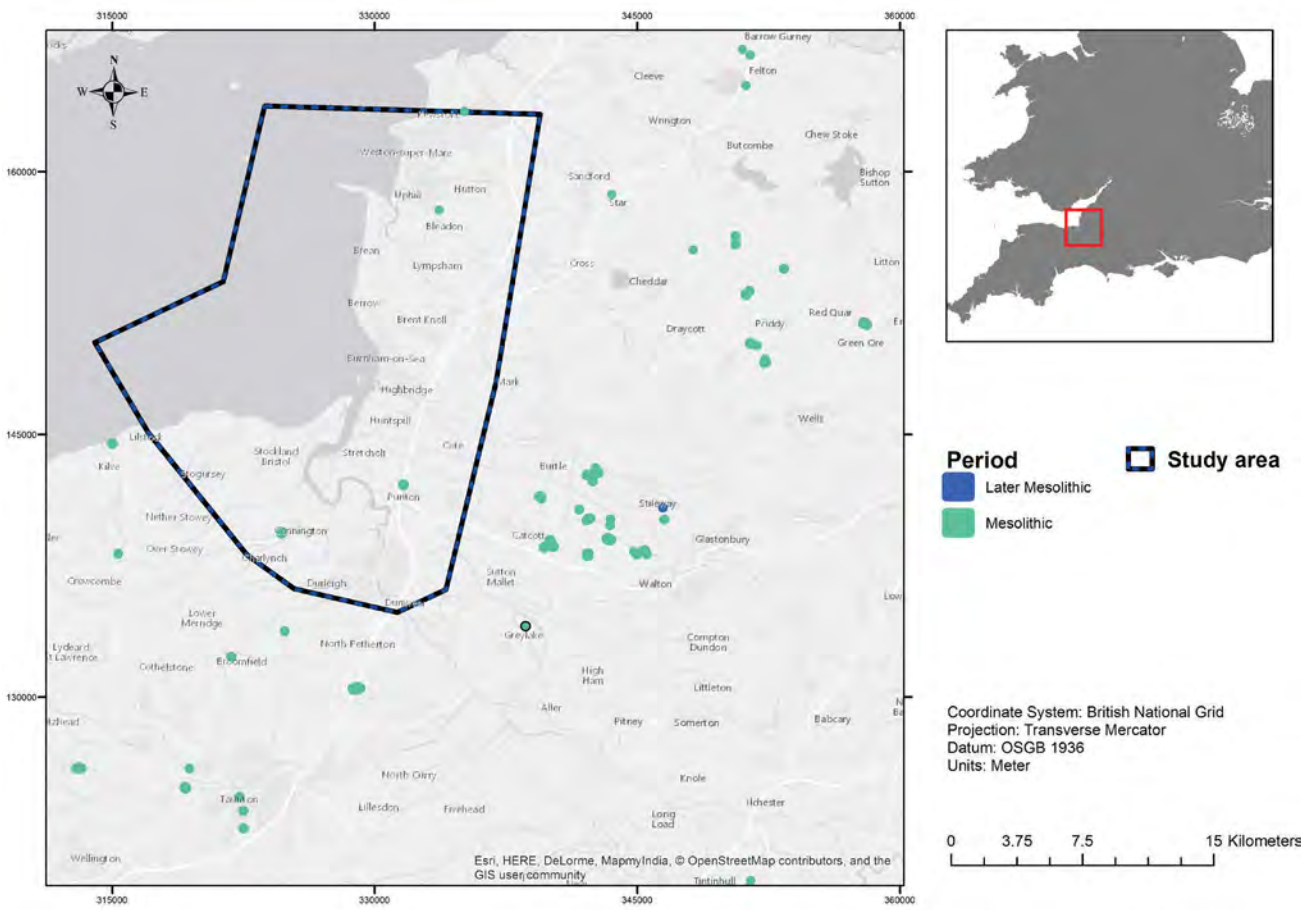


Figure 4.3 Distribution of Mesolithic sites. © Crown Copyright and Database Right [2015]. Ordnance Survey (Digimap Licence).

ticularly when compared to other parts of the South West of England, such as Cornwall and Devon (Hosfield et al. 2007: 23). Some important discoveries include a relatively high number of human skeletal remains recovered from cave sites in the Mendips. The largest collection of human remains comes from Aveline's Hole, Burrington combe, where at least 50 individuals were recovered from the cave floor (Davies 1921) although unfortunately much of the collection was destroyed during the Second World War. Bayesian analysis of radiocarbon dates from some of the remaining specimens produced burials dates of between c. 10350 to 10150 cal BP (Tratman 1977; Jacobi 1982; Schulting 2005; Marshall *et al.* 2005; Hosfield 2007: 50), and a re-assessment by Schulting and Wysocki (2002) also identified infants as well as adults within the assemblage; thus providing a contrast to burial patterns seen in cemeteries elsewhere in Europe (Hosfield et al. 2007). Given that children's footprint-tracks are also recorded on the Welsh side of the channel at Goldcliff (Scale 2007) these findings help remind us that within this region the rare possibility exists to discuss certain aspects of Mesolithic lifeways, such as group demographics, life-course and environmental interaction.

Other significant burials within the region include the 'Cheddar Man' from Gough's Cave which has been dated to 10650-9740 cal BP (9080±150 BP, BM-525; Davies 1904; Stringer 1986). This skeleton represents a young adult male and is the most complete human skeleton from this period in Britain. It is rumoured that other remains were also discovered at the site which could make it a comparable site to Aveline's Hole, but sadly no additional human remains were retained (Hosfield et al. 2007: 51). The remains of one adult from the swallet Hole at Totty Pot, Cheddar, excavated during the 1960s, has yielded radiocarbon dates which provided a combined calibrated date of 9305-9031 cal BP (8180±70 BP BM-2973 and 8245±45 BP, OxA-16457; combined date 8226±38 BP), though dating of the remaining five skeletons indicated they were all Neolithic (Schulting 2005; Schulting et al. 2010). To the south of the study area at the Greylake sand quarry up to five individual have been reported to have been recovered, with radiocarbon dating on the two remaining skulls providing dates of 1030450- 10210 cal BP (9118±37 BP, Wk-30930) and 10402-10226 cal BP (9134±37 BP, Wk-30931) (Brunning and Firth 2012, Brunning 2013). These finds are of particular interest as they are thought to potentially represent the only Mesolithic 'open air cemetery' in Britain. These dates are indistinguishable from those derived from some of the cave sites suggesting deposition of human remain in both open air and cave burial sites at the same time (Brunning 2013, 70). Taken together, these finds help provide new insights into the types of mortuary practices that people were practising during this period, as well as helping to begin to humanise a period in prehistory where societies are often represented by lithic scatters alone.

True to this trend, and despite these more impressive discoveries, the local region's archaeological record is dominated by lithic findspots, many lacking in detailed chronological resolution. A synthesis of the known Mesolithic record for Somerset was conducted recently (see Brunning and Grove 2015) and so will not be replicated in detail here. However, a few points relevant to this project were highlighted in this work which are worth reflecting on. Firstly (as mentioned above) there is a bias in the history of lithic collection in Somerset, with prior research focussing on specific areas such as the Burtle Formation in the central Somerset Levels. Thus the distribution maps for this area must be viewed cautiously, and taken to be representative of past research locations rather than an accurate reflection of past occupation patterns. This obviously has implications when attempting to resolve the relationships between the changing environment and past human activities.

Another issue raised was the lack of modern excavations of Mesolithic sites, with previous studies tending to focus on sites dating from the Neolithic onwards – something the recent project conducted by Bell et al. (2015) in central Somerset has sought to address. This work proved that stratified Mesolithic archaeological material and palaeoenvironmental sequences are preserved at certain locations, already known to have produced lithic material (such as sites associated with Burtle Formation outcrops at Shapwick and Greylake). The additional evidence recovered can consequently help provide useful additional information, helping to refine the chronology of the site as well as provide new information regarding changes within the local landscape which can enhance our understanding of human influence on the local evidence. It has therefore been argued that more specific research fieldwork needs to be conducted in the region, targeting sites with known lithic collections (Brunning and Grove 2015: 36). This would not only help refine the chronological resolution of known material but also potentially highlight the presence of additional Mesolithic material in areas that have previously been neglected by archaeological research. Arguably, it would also be useful to target areas where no activity is recorded (when possible) in order to help move our current understanding of local Mesolithic land-use patterns forward – something this project looks to achieve.

Finally, it was noted that the number of past studies in the region have produced a good palaeoenvironmental record for the region. However, there is still a relative lack in the number of samples obtained and dated from the earlier Mesolithic period, due to the depth at which they are buried, or due to the lack of organic material suitable for radiocarbon dating. The proven existence of more deeply stratified deposits in the intertidal and offshore zones (e.g. Heyworth and Kidson 1973, and Sturt et al. 2014) also indicates that additional work in these zones can help address this issue, whilst also providing additional information regarding the changing coastline during the early Holocene (Brunning and Grove 2015).

Neolithic – Earlier Bronze Age

The latter part of the project's chronological focus starts at the beginning of the 6th Millennia BP and ends at c. 4200 BP. This timescale broadly corresponds with the British Neolithic and the start of the Earlier Bronze Age. The transition from the Late Mesolithic to the Neolithic is traditionally associated with the adoption of agriculture and a time when human societies began to adopt a more sedentary lifestyle than seen during the preceding periods. The Earlier Bronze age (c. 4300-3500 BP) saw the introduction of metalwork in Britain, as well as the appearance of certain styles of pots, houses, lithic assemblages, burials types and stone monuments (Parker-Pearson 1999: 77).

Within the study area, Walpole Landfill site (PRN 28495, 26106; Hollinrake and Hollinrake 2002; 2007; 2010) has produced some of the most impressive evidence for Neolithic activity. Excavations within a thick sequence of Holocene estuarine clays have produced a number of Neolithic structures associated with a series of palae-

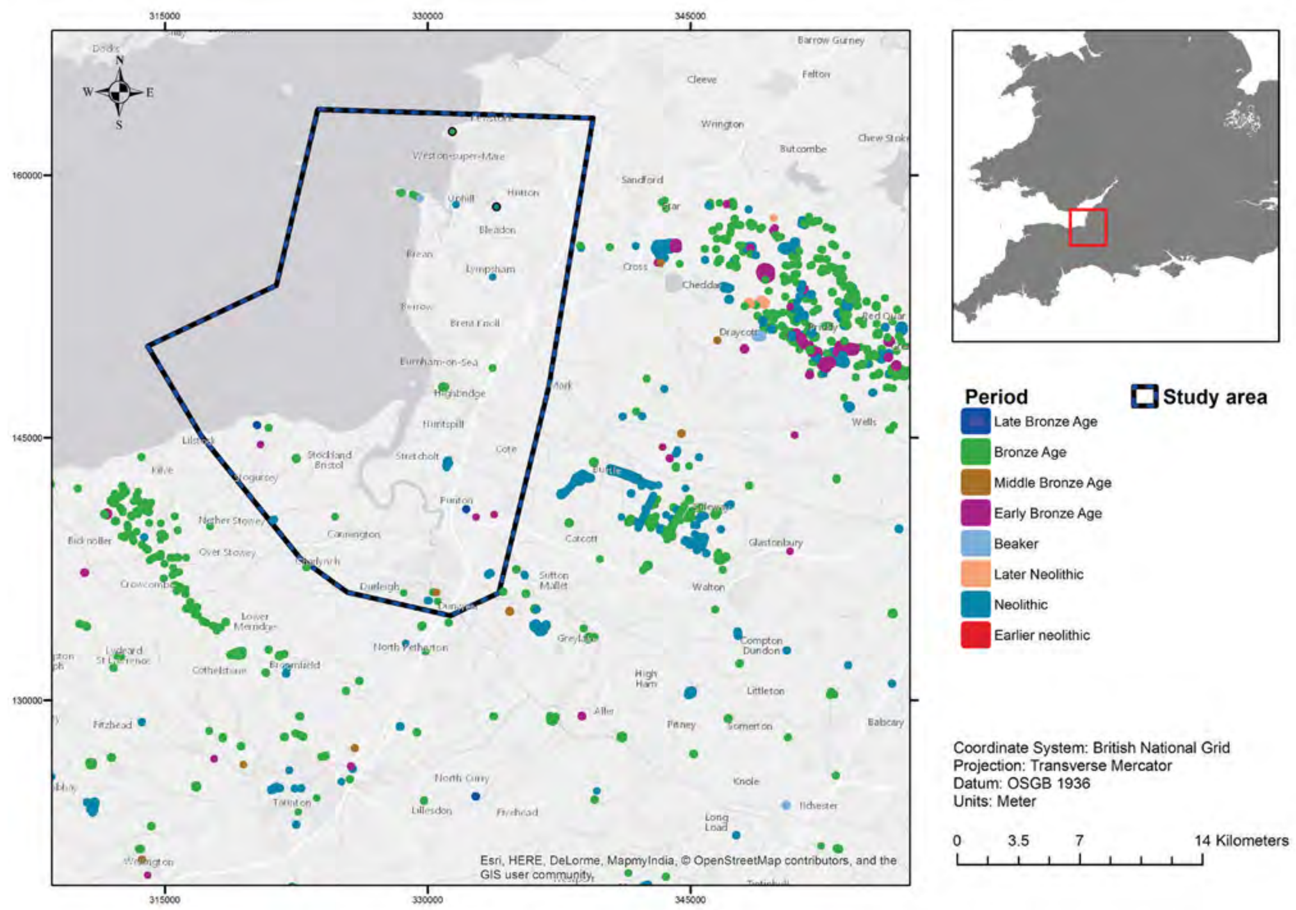


Figure 4.4 Distribution of Neolithic and Bronze Age sites. © Crown Copyright and Database Right [2015]. Ordnance Survey (Digimap Licence).

ochannels located near the submerged Lias bedrock outcrop known as Walpole 'island'. These include early 6th millennium BP timber structures, a series of mid 6th millennium BP stake alignments, and late 6th millennium BP brushwood structures (Hollinrake and Hollinrake 2007, 2013). Additional finds from the area have included a number of auroch bones scattered along one of the channels, prehistoric flint flakes, fragments of animal bone, and, upon the island, some occasional pottery sherds dated to the late Bronze Age through to the Roman period (Hollinrake and Hollinrake 2007). A possible Late Mesolithic post alignment (structure 8) has also been uncovered, based upon a single radiocarbon date of 6304-6001 cal BP (5405±66 BP, Wk-25817), though no additional Mesolithic features have been found at the site (Brunning and Grove 2015: 30).

Additional 'Neolithic' entries within the local HER include a potential cursus moment running across Pawlett Hill (ST 294 433) (PRN 10700), which was identified from an aerial photograph, a Neolithic or Bronze age scraper found SE of Marlpits Farm at Fiddington (PRN 10527) and a 'possible long barrow' crop mark at Burton (PRN 35252). A polished stone axe has also been found at Lympsham (PRN 15169) and some possible Neolithic flint was also recovered south-east of Cannington (PRN 28287). A human skull find (PRN 31673) from a brick pit on the Burnham – Highbridge road is also noted as being of possible Neolithic date. One of the most important Neolithic sites in the area is the Hay Wood Cave (NRHE 192543, Everton and Everton 1972). Excavations between 1957 and 1971 yielded a large assemblage of human remains, though the age was uncertain due to a mixed artefact assemblage ranging from Mesolithic microliths to Romano-British pottery. A subsequent AMS dating programme on 10 individuals demonstrated that much of this assemblage of human remains dates to the earlier Neolithic period. Schulting et al. (2013) argued that the use of the cave for burial could be modelled as commencing in the period 5880-5665 cal BP and ending 5530-5300 cal BP. While the majority of individuals centred on 5500-5450 cal BP, similar to nearby sites such as Picken's Hole (Blockley 2005). Two indiviudals were found to be significantly earlier, representing the earliest directly dated Neolithic remains from the Mendips. Furthermore, isotope analysis demonstrated that the diet of these individuals was predomainantly terrestiral ,despite the coast being only 3km from the site. This interpretation was also recognised at Walpole where there were no indications of exploitation of the nearby marine and coastal resources (Hollinrake and Hollinrake 2013: 30). These observations are consistent with results from other Mendip sites, and Britain overall, and provide support for a rapid and relatively complete dietary transition between the Mesolithic and Neolithic (Schulting et al. 2013).

With the exception of these key sites, however, the majority of the more extensive areas of Neolithic activity in Somerset are located in other parts of the county. This, once again, may be a product of the history of archaeological research in the region rather than a reflection of prehistoric human activities.

The most fully investigated Bronze Age sequence in the Somerset Levels is at Brean Down, located at the western end of Mendip and in the north of the study area. Here, a series of past studies (e.g. ApSimon 2000; ApSimon et al. 1961; Bell 1990) have identified a multi-period occupation site which includes five distinct phases of Bronze Age activity, separated by blown sands and colluvial sediments. At the base of this sequence, a buried soil has produced evidence of beaker activity dating to c. 4000-3800 cal BP (Bell 2014: 309). Additional evidence recovered from this palaeosol (Unit 8a) included some leaf shaped flint arrowheads, Beaker pottery and charcoal which has been radiocarbon dated to 5742-5038 cal BP (4720±140 BP, HAR-7023), suggesting this horizon is either disturbed or a palimpsest. However, based in the low number of finds associated with the palaeosol, activity at the site does not appear to have been intensive during the Neolithic and Beaker period (Bell 1990).

Other finds recorded as 'Bronze Age' within the local area include a Bronze hoard found near Wick Park covert, Stogursey (PRN 34093), a bronze knife at Cannington hillfort (PRN16250), some arrowheads at Edithmead (PRN 10285) as well as some evidence of middle Bronze Age activity recovered during excavations near Cannington (PRN 28287). Excavations at Wick Barrow, North Moor, Stogursey (PRN 34063, 30237) also discovered three secondary crouched inhumations accompanied by bell-beaker, a necked-beaker and a necked-beaker and flint knife-dagger (Gray 1908).

Looking beyond the study area, along with dense concentrations of lithic scatters on some of the Burtle Formation outcrops and western parts of the Mendips (Pollard and Healy 2007), there are at least thirty-eight Neolithic and Bronze Age timber structures (some with associated platforms) within the Somerset Moors area (Coles and Coles 1986; Somerset HER). The most famous trackway is the Sweet Track, which has been dated by dendrochronology to c. 5820/ 5756 BP (Hillam et al. 1990), with some trees being felled for presumed repairs at c. 5750 BP. Three paddles, a dish, hazel arrow shafts, parts of three hazel bows, a small bow and "tomahawk", yew pins, digging sticks, a mattock, a comb, toggles, a spoon fragment and wedges were also found in association with the track (Coles et al. 1973; Pollard and Healy 2007). These impressive finds not only demonstrate that different prehistoric communities were utilising the local wetlands at various times but also hint of the locations of other occupation areas, likely to have been present on the neighbouring Burtle Formation outcrops (Coles and Coles 1986; Brunning 1993). In regards to the current study, the high levels of preservation at these locations also suggests other parts of the Somerset region, where comparable stratigraphic sequences exist, have a high potential for producing additional stratified prehistoric material and palaeoenvironmental evidence.

Summary

The Severn Estuary and Bristol Channel region has produced some remarkable prehistoric material and associated stratigraphic sequences, which have provided invaluable information to our current understanding of British prehistory. However within the current area of interest there are comparatively few finds or sites recorded, particularly relating to the earlier periods of prehistory. Whilst this is not an uncommon issue within the British archaeological record, given the well-documented existence of preserved early Holocene stratigraphic sequences, it initially seems a little surprising that not more prehistoric material has been recovered.

After considering the history of research within the wider region, though, it becomes clear that the issues associated with accessing these earlier Holocene deposits (whether onshore or offshore) are likely to have played a key role in the production of the current archaeological record. As noted above, the majority of the key archaeological investigations within the Somerset region have tended to focus on areas further east within Central Somerset or targeted the surrounding upland areas. These locations have generally been targeted after they produced archaeological material (e.g. through fieldwalking) or as a result of industry driven works, which have allowed larger areas of the local stratigraphic sequences to be exposed. Thus the current distribution of prehistoric material in this area is probably more reflective on where work has been possible, rather than prehistoric human activities.

The lack of detailed excavations within the study area also creates difficulties in relating our understanding of environmental changes to prehistoric behaviour, with few finds recovered from stratified contexts. It is therefore clear that more targeted research across this area has the potential to greatly improve our understanding of the preserved archaeological record. This would not only allow us to gain a better appreciation of the archaeological potential of particular parts of this important archaeological landscape but also, ultimately, enhance our ability to relate the well-studied broader environmental changes of the region with those experienced by prehistoric communities.

Chapter 5
Geology, Topography and Bathymetry

Introduction

The Somerset Levels covers an area of c. 650 km^2 and is located between the Mendips in the north, Blackdown Hills in the south, and the Quantock Hills and Bristol Channel in the west. The Mendips form the northern boundary and separate the Somerset Levels from the North Somerset Levels, while through the centre of the Somerset Levels the Polden Hills separate the drainage catchments of the River Parrett, to their south, and the Rivers Brue and Axe to their north. The rivers Parrett and Brue enter Bridgwater Bay at Burnham-on-Sea, whereas the River Axe runs parallel to the Mendip Hills, along the northern edge of the Levels separated from the rest of the Levels by the Isle of Wedmore, and enters Weston Bay through the gap at Uphill between Brean Down and Bleadon Hill.

On the western boundary of the Somerset Levels lies Bridgwater Bay, which itself lies at the eastern end of the Bristol Channel, downstream of the lower Severn Estuary. The Bay comprises an extensive area of coastal lowland bounded in the north by Brean Down and the south by Hinkley Point. The coast of today varies; south of Brean a set of coastal dunes overlie Holocene estuarine deposits and freshwater peats whilst between the River Parrett and Hinkley Point, Holocene deposits are overlain by storm shingle ridges which reach elevations of 6m ODN.

Bridgwater Bay and the Bristol Channel

The Severn Estuary / Bristol Channel is a flood dominated macrotidal or hypertidal rock bound system. At

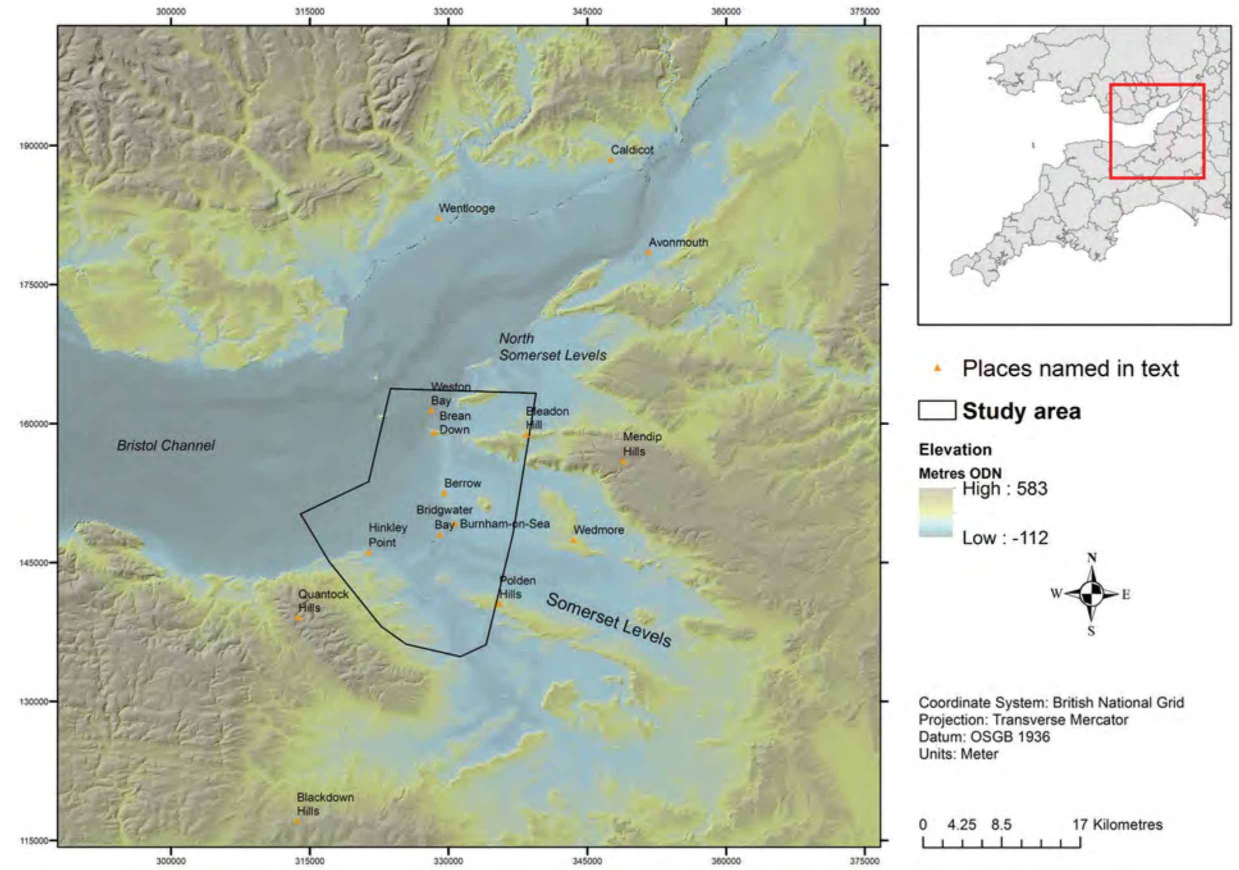


Figure 5.1 Key locations mentioned in text. © Crown Copyright and Database Right [2015]. Ordnance Survey (Digimap Licence). The bathymetric data products have been derived from the EMODnet Bathymetry portal - http://www.emodnet-bathymetry.eu.

Avonmouth the extreme astronomical tidal range is 14.8 m, although this fluctuates over the 18.6 yr lunar tidal nodal cycle (Allen 1990b) with the predicted annual extreme range of Highest Astronomical Tide (HAT) varying from 13.9 m to 14.6 m (Allen 1990b). Tidal currents exceed 1m s^{-1} over much of the system and these factors, coupled with the exposed westerly aspect, means that the water body is well mixed. Estuarine alluvium covers 840 km^2 concealing approximately 8 km^3 of Holocene sediments (Allen 1990a, Allen and Duffy 1998). During the late Holocene the pattern of sedimentation in this system has been dominated by minerogenic saltmarsh and mudflat accretion. In addition, since Roman times many of the former saltmarshes have been embanked (Allen and Fulford 1990a; b). Sediment is supplied to the system from rivers, bedrock erosion, as well as cliff erosion including relict Pleistocene deposits (Allen 1991; Williams and Davies 1987). Fluvial supplies of sediment are the most significant of these, contributing between 1.0 and 1.6 x 10^6 tonnes a^{-1}, mostly from the Severn, Wye, Usk and Avon (Kirby and Parker 1980; Collins 1987). During the late Holocene these rivers have been important sources of pollutants into the estuary, which provide valuable chronological markers in mudflat and saltmarsh deposits throughout the estuary (Allen and Rae 1987; Long et al. 2002). Estimates of inputs from cliff erosion vary between 5.5 x 10^5 tonnes (Allen 1990a) and 2 x 5^{10} tonnes a^{-1} (Kirby 1994).

During the late Holocene the Severn Estuary has retreated landwards by up to 20 km, driven by rising RSL (Allen 1990b). Evidence for this retreat includes erosion of cliffs in the outer coastal areas, former peat deposits which testify to a once considerably narrower estuary, and the occurrence of archaeological material in intertidal settings. Large areas of the present intertidal and subtidal zone is experiencing erosion and are only covered in a thin veneer of sediment. Indeed, the estuary has a larger proportion of exposed bedrock on its bed than any other estuary in northwest Europe (Evans 1982), and what sediment does exist is highly mobile (Kirby and Parker 1980) with over 30 x 10^9 tonnes of sediment in suspension on spring tides (Kirby 1994). The landwards and upwards transgression of the estuary during the late Holocene is associated with a process of 'stratigraphical roll-over' with erosion in the outer parts of the system and accretion in the middle and inner parts (Allen 1990b).

Several significant sinks for fine-grained sediment occur within the estuary. These include Newport Deep, parts of Bridgwater Bay and possibly in shallow subtidal/low intertidal areas at Peterstone-Wentlooge and off Caldicott (Kirby 1994; McLaren et al. 1993). Whilst there is some evidence for a landward movement of sediment from the Celtic Sea into the estuary (Murray and Hawkins 1976), there is no evidence for a net loss of sediment in the opposite direction. The largest and most significant of these mudpatches is in Bridgwater Bay and extends over an area exceeding 140 km^2 (including Berrow and Stert Flats). This deposit has been subject to intense study for several decades (e.g. Kirby and Parker 1980; Mantz and Wakeling 1981, Long et al. 2002) and, although parts are experiencing erosion and others accretion, it appears to have continued to be a net sink of sediment for at least the last few centuries or millennium (Kirby and Parker 1980; Kirby 1994, 40).

The long-term erosive nature of the Severn Estuary has also been directly observed in recent decades. Kirby (1994) compares a repeat survey profile of the tidal flat at Catsford Common near Stolford in Bridgwater Bay. This line, surveyed in 1954 and 1974, shows a loss of sediment across the full width of the surveyed profile. By comparison, other areas of Bridgwater Bay receiving intense study for several decades (e.g. Kirby and Parker 1980; Mantz and Wakeling 1981, Long et al. 2002; Kirby and Kirby 2008) appear to show a continued net sink of sediment for at least the last few centuries or millennium (Kirby and Parker 1980; Kirby 1994, 40). Kirby (1994) argues that the accumulation of sediment in the Bridgwater Bay mud patch may be related to the estuary wide changes in sediment budget. An upwards decrease in sand content recorded in cores from the mud patch may record the progressive loss of sand from the system at a time when increased erosion of fine-grained sediment derived from outcrops of Holocene sediment is occurring, with the Severn system having become muddier over the last few centuries.

Historic changes in the shoreline for the past c. 200 years have been outlined by Kirby (1996). Between Brean and Barrow the shoreline has fluctuated with periods of both advance and retreat, though overall there has been shoreline retreat here of between 80 m and 275m during the last 50 to 100 years. At the mouth of the River Parrett significant changes in the shoreline position have been documented. McDonnell (1996) used cartographic, hydrographic and documentary evidence to construct the evolution of islands in the mouth of the Parrett (Slab Island, Dunball Island, Fenning Island and Stag Island), which have changed considerably over the last several hundred years. Kidson (1960) showed that between AD 1802 and 1886, Stert Point retreated by c. 550m at an average rate of 6.45m a^{-1}. The rate of retreat then slowed and between AD 1886 and 1956 a further 36.5m of retreat took place. Most of this erosion occurred between AD 1886 and 1928 when *Spartina* was introduced by the Somerset River Authority in an effort to curb this long term trend in erosion, which was initially successful and led to sediment accretion (Ranwell 1964). However, from the mid to late 1960s onwards this trend has been reversed, and today only a few hundred meters of saltmarsh remain in some areas. Most recently some of the defences upon the Steart Penninsula along the River Parrett have been breached in order to create a 500 hectares managed realignment flood defence and wildlife habitat known as Steart Marshes.

Geology

Palaeozoic geologies represent the oldest geologies in the area and are typified by the higher topographies bounding the Somerset Levels. The Middle Devonian Hangman Grits and Upper Devonian Ilfracombe Series and Morte Slates Formation form the Quantock Hills (and outcrops in their hinterland) along the south western boundary of the study area. Along the northern boundary of the Somerset Levels, and forming the internal divisions of the North Somerset Levels, are a discontinuous series of hills or elongate east-west ridges of Lower Carboniferous Limestone, surrounded by Mesozoic or younger rocks, which progressively lower westwards and, within the current study area, terminate onshore as Brean Down and Worlebury Hill. The islands of Flat Holm and Steep Holm represent the offshore continuation of two of these ridges, which themselves are surrounded by Mesozoic geologies exposed on the seafloor. In the south of the study area an isolated outcrop of Lower Carboniferous Limestone is also found in the vicinity of Cannington Park. Bleadon Hill represents the highest point on the Mendips within the study area, peaking at 168m ODN, and is only exceeded on the south-western edge of the study area where the northern part of the Quantock Hills attains a height of c. 240m ODN.

Mesozoic rocks are found within the main basins separated by the outcrops. Within the Somerset Levels the thickness of Triassic rocks is in excess of 695 m, while the smaller basin between the Mendips and West-on-Worle ridge contains thicknesses in excess of 260 m. Towards the margins of these basins successively younger strata progressively overlap onto the Palaeozoic basement and locally within the Mendips overlap the whole succession by Jurrasic Lower Lias strata. The oldest Mesozoic rocks found in the area belong to the Permo-Triassic Sherwood Sandstone Group which outcrops in the south of the study area west of Bridgwater as the Otter Sandstone Formation. A continuation of the Sherwood Sandstone Group beneath the Somerset Levels was demonstrated in the Burton Row Borehole, northern side of Brent Knoll, where it was identified below c. -900m ODN. The most extensive Triassic rock across the basins is the Mercia Mudstone Group, consisting mainly of the Blue Anchor Formation, which have a recorded thickness of 424m in the Burton Row Borehole. This is overlain locally by Triassic Penarth Group rocks, including the Lilstock and Westbury Formations, visible as outcrops around Uphill and Locking in the Weston district and forms the Isle of Wedmore, a southeast-northwest ridge on the eastern side of the study area running between Bagworth and Theale and separating the River Brue and Axe drainage basins. These formations were also visible in the Burton Row Borehole as a c. 12m thick layer. Surveys of the Inner Bristol Channel (e.g. Lloyd et al. 1973; Evans 1981) and Weston Bay have demonstrated that the Triassic geologies are exposed on the seabed beyond the inshore mud / sand patch of Weston Bay, with seabed exposures of both the Mercian Mudstone and Penarth Group extending westwards to surround Steep Holm.

The Lower Jurassic Lower Lias underlies much of the centre of the Somerset Levels as an east-west strip between Huntspill and Dunball, outcropping above the Levels upon the Polden Hills and Pawlett Hill. Extensive outcrops of Lower Lias are found west of Combwich, with their best exposure as the north-facing cliffs and wave-cut platforms along the coastline west of Stolford and Hinkley Point. Offshore the Lower Lias is visible exposed on the seabed (see Lloyd et al. 1973; Evans and Thompson 1979) beyond the limits of the Bridgwater Bay mud patch and other superficial gravel / sand patches (e.g. Culver Sands), most notably in the Steep Holm area abutting the Triassic rock exposures. The Lower Lias strata exposed at the surface belong mainly to the Blue Lias and comprise alternating limestone and shale / mudstone. Within the Weston area the Lower Lias is restricted to outcrops on the edge of the Carboniferous Limestone around Uphill, with additional outcrops in the east of the study area around Locking and Hutton. Later Jurassic geologies are found onshore at Brent Knoll, which rises from the Somerset Levels to an altitude of 140m OD, containing an outcrop of Jurassic Middle and Upper Lias limestones / mudstones overlain by Middle Jurassic Inferior Oolite limestone at its summit. Offshore exposures of Middle Lias have been mapped adjacent to the Culver Sands.

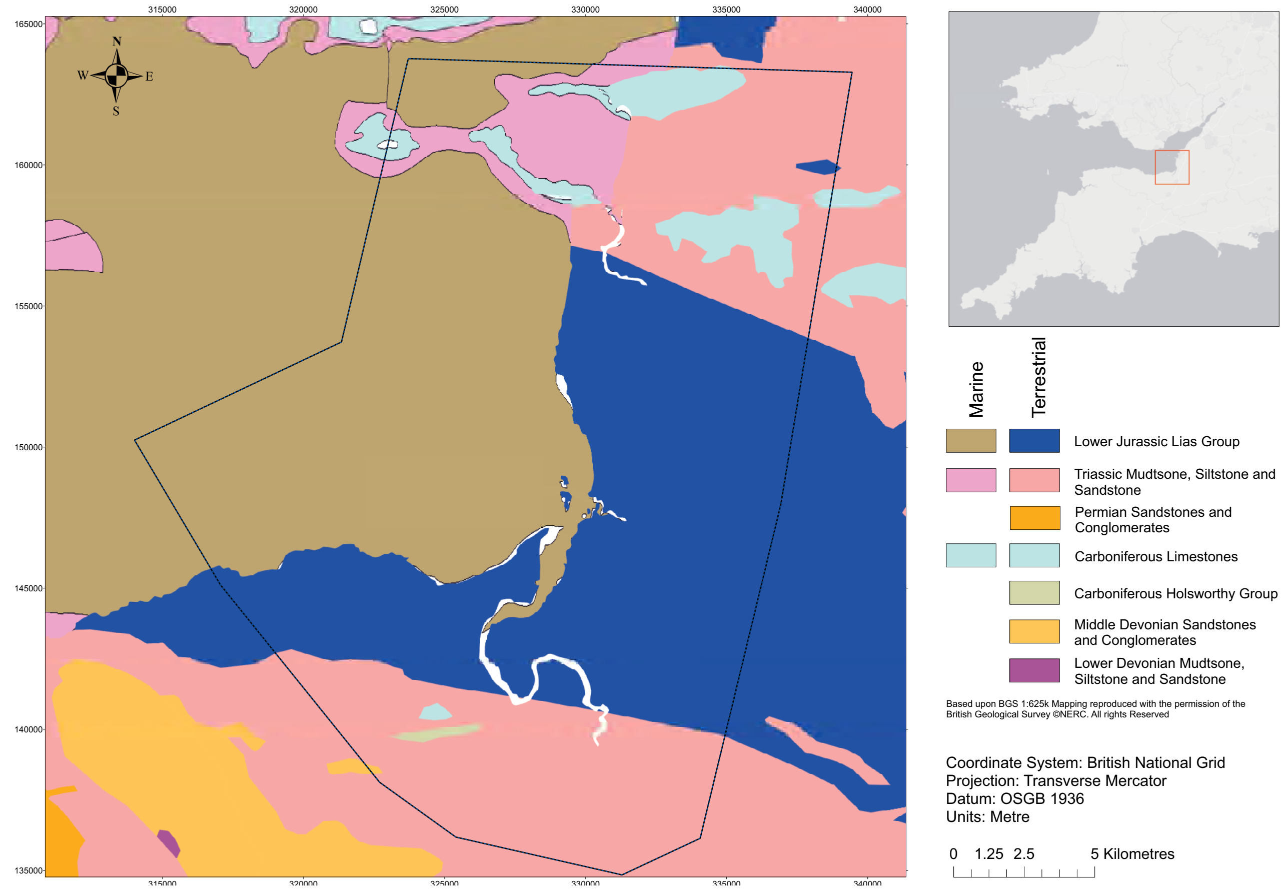


Figure 5.2 Geological map of the study region. © Crown Copyright and Database Right [2015]. Ordnance Survey (Digimap Licence).

Quaternary deposits.

The Somerset and North Somerset Levels is an extensive coastal lowland which has been infilled during the Holocene epoch by extensive estuarine deposits and peat beds. However a number of pre-Holocene Quaternary deposits are known to exist within the wider area.

Pleistocene deposits

The few deposits interpreted as glacigenic found in Somerset have all be assigned to the pre-Devensian (Bowen 1973a; Campbell 1998a; Evans et al. 2005). Originally these were thought to be Wolstonian (Saalian; c. OIS 6) (Gilbertson 1974; Gilbertson and Hawkins 1978) or earlier (Gilbertson and Hawkins 1978; Andrews et al. 1984), though have been largely reassigned to either OIS 10 or 12 (Anglian) glaciation (Bowen et al. 1986; Jones and Keen 1993; Kellaway and Welch 1993; Keen 2001; Harrison and Keen 2005) with some having since been considered to be OIS 14 or 16 (Bowen 1991; Campbell 1998a). Deposits interpreted as till, possibly pre-OIS 15, are recorded at Kenn (Kenn Formation) and may extend as far south as Greylake Quarry where similar deposits are found underlying the Burtle Formation (Gilbertson and Hawkins 1978; Hunt 2006). At Kenn, gravel interpreted as till is overlain by younger interglacial deposits (Kenn Church Member). The current suggestion is that the Kenn Church Member is likely to be OIS 11 or 9 (though often listed as OIS 7), which would place the glacial Kenn Formation deposits in OIS 10 or 12 (Keen 2001; Harrison and Keen 2005; Westaway 2010; Birdle 2012).

During the Middle Pleistocene it has widely accepted that the Anglian glaciation (OIS 12) ice sheet reached the northern coast of Devon and Somerset (Bowen et al. 1986; Gibbard and Clark 2011, 81-82). Such an ice sheet would have blocked the local drainage, leading to proglacial lake formation. The idea of a proglacial lake in south west England was first postulated by Maw (1864) [for the Taw Estuary, Barnstable – see overview in Campbell et al. 1998, 203-210] and considered in more detail by Mitchell (1960; 1972) and Stephens (1970; 1973). Woodcock (2012, Fig. 21.8) maps such a lake centred over the Somerset Levels, which is commonly referred to as Lake Maw. Originally it was speculated that Lake Maw was created by damming of the Bristol Channel by a Wolstonian Ice Sheet (e.g. Edmonds 1972), with the lake having a southern-flowing outlet through the Chard Gap, which stands at 85-90m ODN. However there is no supporting evidence within the gravels at the Chard Gap for such an outflow (Green 1974; 2013; Campbell et al. 1998a; b) and current estimates for the maximum glacial limit for the Wolstonian stage glaciations (covering OIS 10 to 6) (Gibbard and Clark 2011) not indicating that the Bristol Channel was dammed by an ice sheet at this time, making an Anglian date for such a lake forming most likely.

One of the most intriguing deposits in the area is a patch of sand and gravel on the south side of Bleadon Hill at 82m ODN (the type site for the Bleadon Member). The origin of the deposits is uncertain, possibly relating to a Mesozoic sea beach deposits, or Pleistocene shoreline materials, proglacial lake-shore sediments or a glacio-fluvial gravel (Findlay et al. 1972). The deposit is understudied and often thought that the high altitude of the deposits is too high to represent a Pleistocene shoreline deposit. However these deposits also lack the cementation that would be expected with a Jurassic age deposit. To the west of the study area, around Weacombe, a series of thin pebbly drift deposits have also been mapped lying at 85-100m ODN, which Edmonds and Williams (1985, 49) tentatively list as possible beach deposits and speculate might be related to Lake Maw. In the south east of the study area a series of river gravel terrace deposits of uncertain age are found on the lower lying Mercian Mudstone Group, at lower altitudes, associated with the rivers draining the Quantock Hills.

The most notable Pleistocene deposits in the area is the Burtle Formation (Burtle Beds). This comprises a series of low relief mounds of often laminated shelly sand / sand and gravel deposits, commonly calcreted and indurated, that rise above the surrounding alluvial surface reaching c. 5-10m ODN. Spreads are known to occur in at least 20 distinct locations within the Somerset Levels, including (within the study area) exposures between Huntspill and Alstone, Stretchott, Wembdon and around Chedzoy (see Bulleid and Jackson 1937), and more extensive spreads around Westonzoyland (which includes the Greylake quarry sites), east of Bridgwater, and Burtle itself.

The name 'Burtle Beds' was first coined by Buckland and Conybeare (1824, 309) to describe the shelly sands and sandy gravels which formed 'batches', the local name for areas raised above the alluvial deposits of the Somerset Levels, and were interpreted as being of marine origin. These deposits were also noted by Ussher (1908) but detailed descriptions were first provided by Bulleid and Jackson (1937; 1941) and have been repeatedly reinvestigated since (Kidson 1970; Kidson and Haynes 1972; Kidson et al. 1974; 1978; 1981; Gilbertson 1979; Andrews et al. 1979; 1984; Hughes 1980; Hunt and Clark 1983; Hunt et al. 2006). At the site of Greylake the Burtle Formation can be sub-divided into two distinct members (Kidson et al., 1978; Campbell et al., 1999):

- Greylake Member: body of silts, clays, fine silty sands, fine gravels and shelly sands likely to be associated with an estuarine environment, showing a shift from formation near high water to later formation near the low water mark. This is capped by a cemented palaeosol which has been partially reworked; overlain by

- Middlezoy Member: sands and gravels typical of the classic Burtle Beds sequence, associated with a higher energy marine environment, and locally includes a basal lag deposit containing reworked molluscs from the Greylake Member, *including Corbicula*.

Vertebrate remains include elephant (Elephantidae sp. indet.), narrow-nosed rhinoceros (*Stephanorhinus hemitoechus*), auroch (*Bos primigenius*), red deer (*Cervus elaphus*), fallow deer (*Dama dama*) and Roe Deer (cf. *Capreolus capreolus*), spotted hyaena (*Crocuta crocuta*) and wolf (*Canis lupus*) and clearly represents temperate conditions. Specimens of horse (*Equus* sp.) reported in Bulleid and Jackson (1937, 190) are thought to be of a much later date than the rest of the fauna assemblage (Currant 2000, 42). The vertebrate fossils appear to have been concentrated in the basal lag deposits of the Middlezoy Member. Hippopotamus and fallow deer are major elements of the British mammal fauna of the earlier part of OIS 5 with the absence of horse also suggestive of a Last Interglacial (OIS 5e) age. The marine shells indicate both cold and warm water climates and sandy, muddy and rocky habitats. The assemblage included a number of finds of the freshwater bivalve genus *Corbicula* (identified as *Corbicula fluminalis*) which commonly occurs in Pleistocene interglacial deposits, notably OIS 11, 9 and 7, but is unknown from the last interglacial (OIS 5e). Bulleid and Jackson (1937, 188) noted that the few shells present were associated with the marine shell assemblage and clearly derived specimens,

which matches accounts from elsewhere in North-West Europe when found in OIS 5e deposits, especially as it has been noted over the last few decades that *Corbicula* never occurs in Britain in sediments containing Hippopotamus (Meijer and Preece 2000, 246).

Dating of the Burtle Formation has proven difficult with several attempts to radiocarbon date material either indicating reworking of the deposits in the Holocene (Kidson et al. 1974, 212; Kidson and Haynes 1972, 392; Kidson et al. 1981, 41) or are rejected as unreliable (Kidson 1970, 190), particularly as some of samples provided date results close to the limit of radiocarbon dating. Amino Acid Racemisation (AAR) ratios, produced by Andrews et al. (1979), on shells from the Middlezoy Member were closely comparable with other AAR ratios, associated with U/Th dates, correlated to OIS 5e. However there was considerable scatter in their data with some ratios able to correlate with sequences from OIS 7. Hunt et al. (1984) obtained AAR ratios directly on *Corbicula* which has suggested that these shells are likely to be from OIS 7/9. Campbell et al. (1999) surmised, based upon the available geochronological, biostratigraphic and sedimentological evidence, that the Greylake Member can probably be referred to OIS 7 and the Middlezoy Member was laid down by the OIS 5e marine transgression. This has been supported by recent investigations of the Greylake sequences by Tony Brown (Southampton) and Kirsty Penkman (York) (pers. comm.) where new AAR dates for OIS 5e have been derived from the Burtle Formation.

During site investigations at Stert Point, in advance of the development of the Steart Marches wetland reserve, boreholes were drilled through the marsh sequence in the vicinity of Marsh Farm (Russell 2011; 2012). Beneath the estuarine alluvium a dark grey clay deposit was found overlying the Lower Lias, with a maximum altitude close to Ordnance Datum. Although the sediments did not yield any palaeoenvironmental remains, it was possible to Optically Stimulated Luminescence (OSL) date the sediments from two boreholes. Both sequences resulted in comparable OSL dates of 169±31 ka (GL11023) and 149±22 ka (GL10081). Caution was issued over the dates, with D_e exceeding functional range in the former and over-dispersion of repeat regenerative-dose data in the latter, so these dates should be considered a minimum value. The OSL dating results suggests that

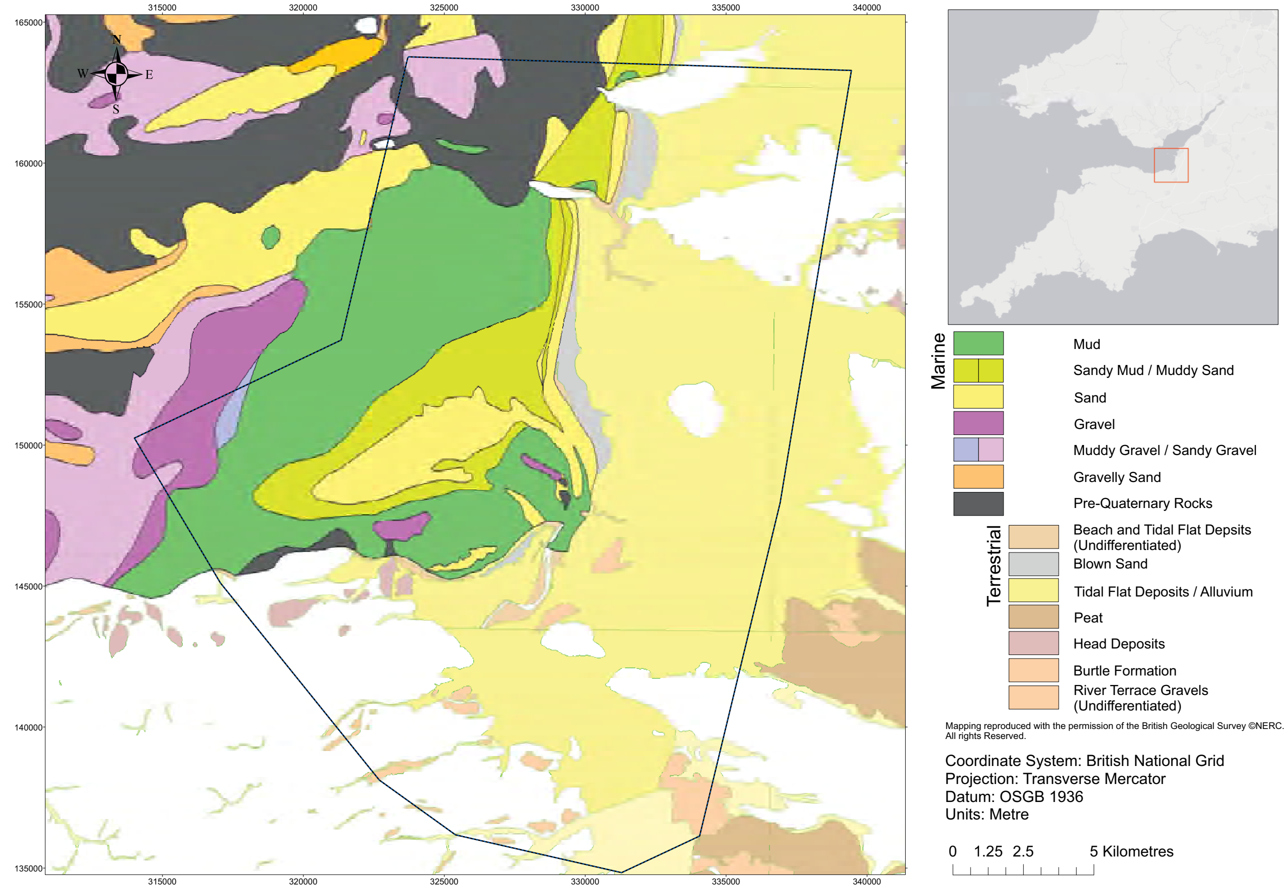


Figure 5.3 Superficial Deposits. © Crown Copyright and Database Right [2015]. Ordnance Survey (Digimap Licence).

this clay deposit was deposited by OIS 7/6.

Raised beaches have also been recorded in the area, including that at Spring Cove (Birnbeck Cove), on the western edge of Worlebury Hill, estimated to lie at c. 13.5 m ODN (first described by Day 1866). The study area also includes a number of cave sites (see Hawkins and Tratman 1977) in the Mendips including the Hutton Bone Cave (NRHE 192377) and Uphill Quarry caves (NRHE 192504; Wilson and Reynolds 1901; Harrison 1977). Typically these contained Devensian mammalian fauna and/or Middle/Upper Palaeolithic flints. In a number of instances interglacial fauna remains were also encountered, including the Worlebury Hill Cave (Milton Quarry), which yielded teeth from two individual Merck's Rhinoceros (*Stephanorhinus kirchbergensis*) (Savage and Richards 1980) attributed to MIS 11, and the important Banwell Bone Cave (NRHE 192377; Currant 2004). The latter produced a distinctive mammalian assemblage attributable to MIS 4 (Currant and Jacobi 1997) and is the type locality for the *Banwell Bone Cave Mammal Assemblage Zone* (MAZ), a formal unit within a Late Pleistocene biostratigraphic framwork applicable to the whole of southern Britain (Currant and Jacobi 2001), though does not contain evidence for hominin activity.

One of the most significant Devensian deposits in the area is found at Sand Cliff, Brean Down, where a thick late Pleistocene sequence of sands, silts and breccias rests upon a shore platform, lying between -6 and 0m ODN, and against an ancient cliff. The first account was provided by Ravis (1869) with subsequent description of the deposits by Ussher (1914), though the first detailed account was provided by ApSimon et al. (1961; 2000). The basal sediments are dated to the early Devensian and comprise limestone weathered from the cliff and a significant proportion of blown sand. The bone bed has an arctic vertebrate faunal assemblage, including woolly mammoth (*Mammuthus primigenius*) and reindeer (*Rangifer tarandus*), and has been OSL dated 64.87±4.26 ka (X1468; Current et al. 2006). The overlying main aeolian sediment, up to 18m thick of largely stone-free coversand, has been OSL dated in the range 60.71±5.5 ka (X1468) to 47.81±4.47 ka (X1467) (Currant et al. 2006). This aeolian sequence is the type site for the Brean Down Member which is also represented at a number of sites in the area (Campbell 1998a), including Greylake, potentially within caves 2 and 13 from Uphill Quarry, and may also be expected to underlie parts of the Somerset Levels stratigraphy. Towards the top of the aeolian sequence was a late glacial (Windermere) interstadial buried soil horizon.

On the south side of Purn Hill, Bleadon, breccias with marine shell and a cold mammalian fauna are recorded at about the same level as the marine beaches to the north. This deposit appears to be an earlier beach deposit that may have been incorporated into later (Devensian) solifluction scree (Whittaker and Green 1983).

Head and alluvial fan gravels are an important component of Pleistocene deposits in the region with a Devensian (OIS 2) age is usually assumed for head deposits, although evidence of earlier cold stage (possibly OIS 6) slope deposits are found in Somerset (Hunt and Haslett 2006). To the west of the study area extensive spreads of gravel occur opposite the gorges of Burrington, Churchill, Cheddar, Winscombe, Draycott, Wookey and Wells (Findlay 1965) and spread out fanwise across the floodplain beneath alluvium (Palmer 1931; 1934). Only the gravels of Burrington Combe and Wookey have been attributed to alluvial fan deposition; the remainder are considered to be head (Pounder and Macklin 1985; Macklin and Hunt 1988; Green 1992; Kellaway and Welch 1993), although Farrant and Smart (1997) have suggested that many of the Mendip 'head' deposits are also probably alluvial fans. Findlay and Catt (2006) identified two distinct periods of alluvial fan deposition at Burrington Combe; one correlated with OIS 6 (Campbell et al. 1999) pre-dating the interglacial Burrington palaeosol; the younger attributed to the late Devensian (OIS 2). In the south of the study area head deposits are mapped in the Stolford and Burton area and, although not specifically defined, are probably Devensian Late Glaical periglacial solifluction deposits. These deposits consist of rounded Devonian sandstone pebbles within a loam and sandy loam matric, known locally as 'stonerush' due to the abundance of stone within them. In the Burton head deposits inclusions of Blue Lias limestone and chalk have also been observed (Whittaker and Green 1983, 86). Additional Late Devensian periglacial solifluction deposits have also been suggested by Hughes (1980) in the Pawlett and Dunball area around the base of the Ponden Hills.

Bristol Channel Quaternary Drainage Patterns

A simplified interpretation of the palaeochannels in the Severn Estuary and Inner Bristol Channel, based on hydrographic charts, has been presented by Bell (2007) in order to provide a landscape context to the Meso-

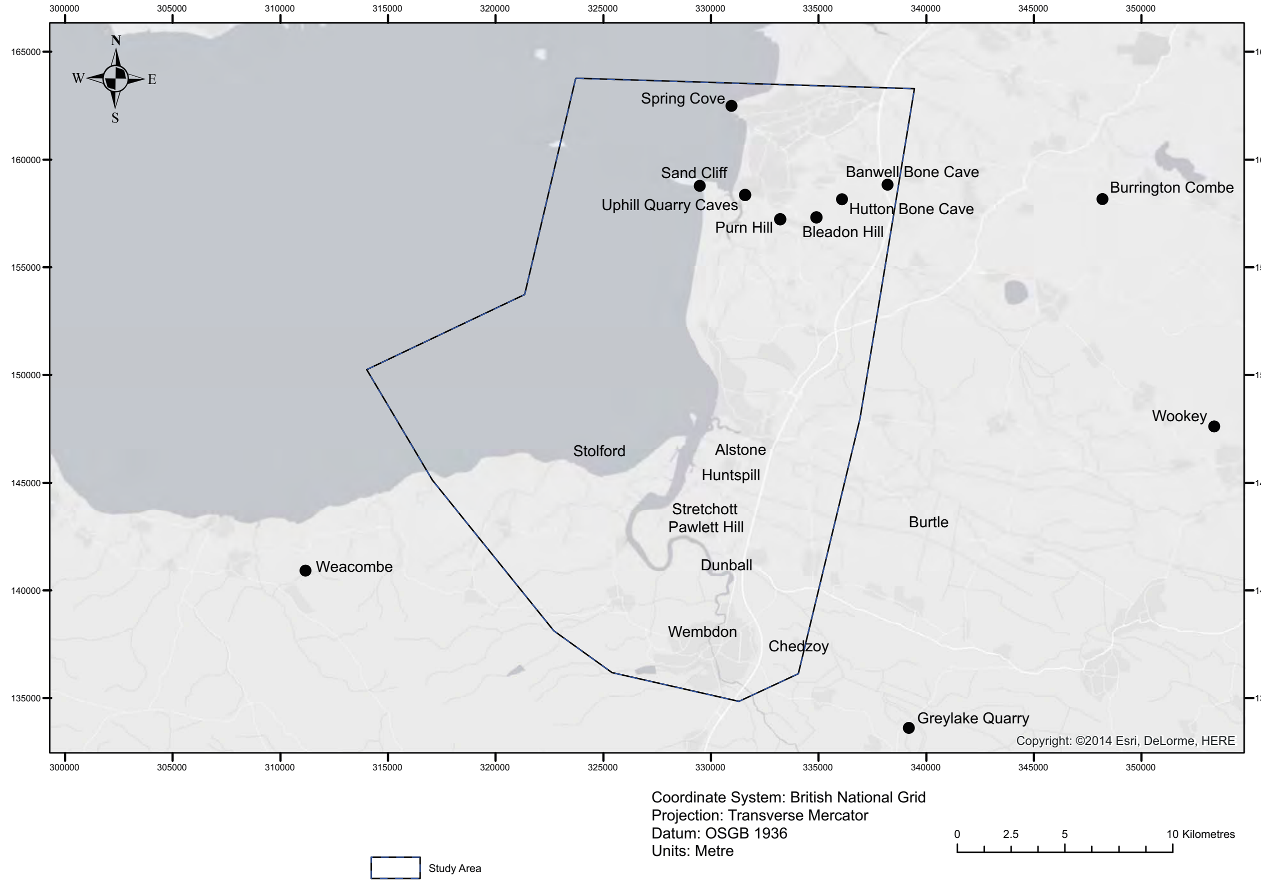


Figure 5.4 Pleistocene sites mentioned in text. © Crown Copyright and Database Right [2015]. Ordnance Survey (Digimap Licence).

lithic site at Goldcliff. Fitch and Gaffney (2011) have produced a palaeolandscape reconstruction of the Outer Bristol Channel based on re-interpretation of the BGS seismic data, enhanced with 2D seismic data from the oil industry. This latter work identified a series of east to west flowing large, meandering, river systems and associated lakes on a low-lying valley floor bounded to the north and south by the higher ground of the present day Somerset and South Wales uplands. One of these lake deposits coincides with the location of a core studied by Brown (1977) which revealed, at -36m ODN, an assemblage deposited in a freshwater pond and reedswamp, possibly attributable to the Windermere Interstadial (Greenland Interstadial I), c. 12,700-10,600 BC. However, recent re-analysis of seismic data for the Atlantic Array windfarm (RWE 2013) has cast doubt on the existence of large lakes in the area.

Most recently Dix et al. (2015) has revived the palaeochannels within the Bristol Channel using higher resolution bathymetry datasets. This shows the area dominated by a prominent palaeochannel system (the "palaeo-Severn") that can clearly be identified at Sharpness, towards the landward limit of the Severn Estuary, and traced to a location due south of Swansea in the outer part of the Bristol Channel, a total distance of c. 130 km. Within the Severn Estuary, the current bathymetric expression of the "palaeo-Severn" represents an open meandering system. From Avonmouth south-westwards, the "palaeo-Severn" system appears to take a central position between Cardiff and Sand Point. Westwards of the Isles of Flat Holm and Steep Holm sedimentary cover on the seabed reduces significantly and bedrock outcrops over large tracts of the Bristol Channel floor helping exemplify, and control, the "palaeo-Severn" incision within the underlying mudstones and interbedded limestones of the Lower Lias (after Lloyd et al. 1973; Evans and Thompson 1979). This results in the "palaeo-Severn" following an open meandering course due west from the Isles to offshore St Donat's Bay (at a consistent distance of c. 3.5 km offshore from the current coastline) where it turns abruptly due south as it exploits the structural weakness of the main Bristol Channel syncline (after Lloyd et al. 1973).

The "palaeo-Severn" in this area has a typical width of 1-2 km, 20 m deep, and thalweg depths ranging west-

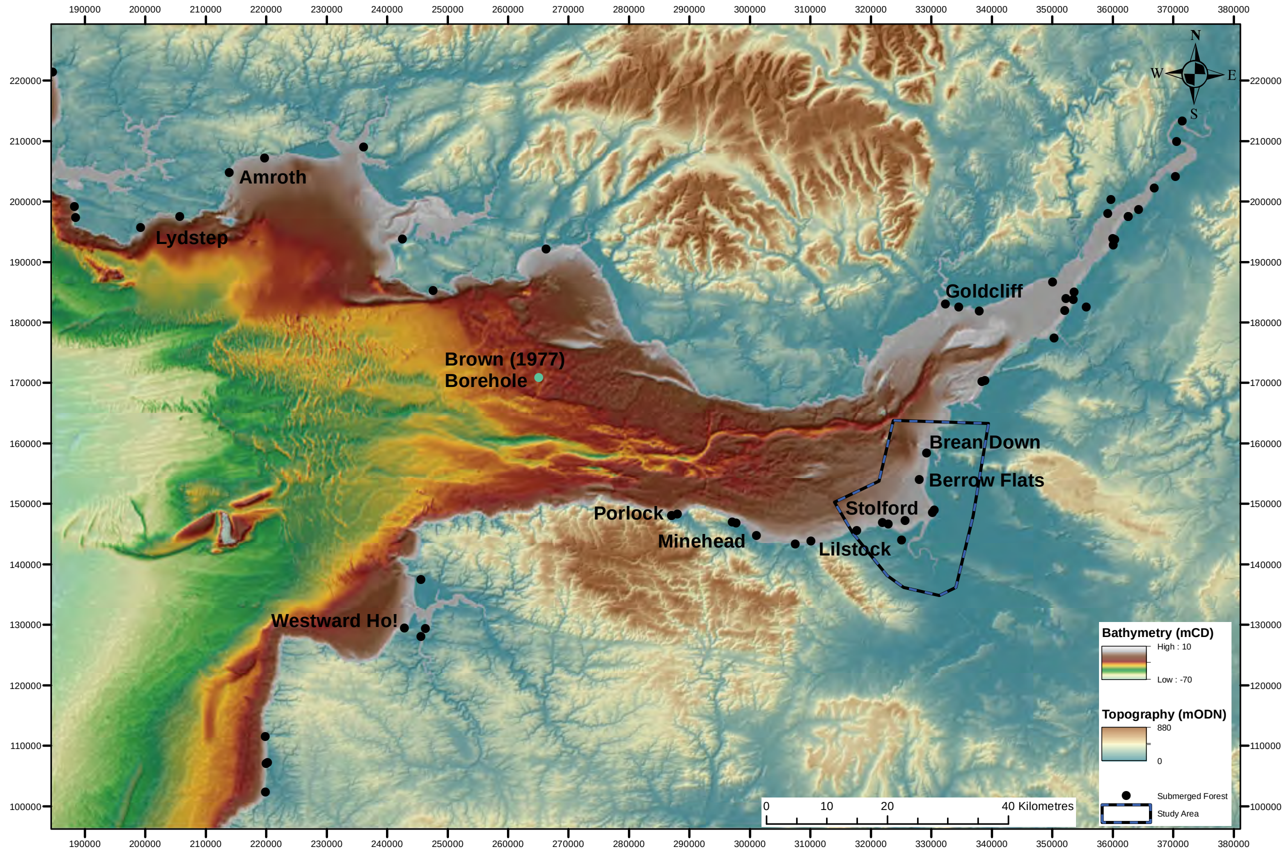


Figure 5.5 Bathymetric map of Bridgwater Bay and wider Bristol Channel, including location of submerged forests. © Crown Copyright and Database Right [2015]. Ordnance Survey (Digimap Licence). The bathymetric data products have been derived from the EMODnet Bathymetry portal - http://www.emodnet-bathymetry.eu. and UKHO INSPIRE Open Government Licence

wards from -32 to -42m ODN over a distance of c. 40km (Dix et al. 2015). On the northern flank of the "palaeo-Severn", in the Inner Bristol Channel, there are at least seven, meandering, dendritic, tributary channels which intersect at almost 90º to the main channel. On the southern margin of the "palaeo-Severn", the bathymetry is distinctly different and few tributaries clearly identifiable from the innate irregular topography of the folded and eroded Lower Lias bedrock platform. To the west of Bridgwater Bay the next main southern tributary valley system entering the palaeo-Severn is found north of Minehead. The centre of this southerly platform is covered by the Culver Sands, which is part of a major sand deposit that has accumulated in the wake of the Isle of Steep Holm.

Holocene Stratigraphy of Bridgwater Bay

Within Bridgwater Bay water depths across the main part of the mud patch are relatively shallow (-6 to 0m ODN), with large patches of Berrow and Stert Flats exposed at low tide. Exposures of the underlying Lower Lias platform occur at c. -12-14m ODN on the edge of the mud patch, while the area between Brean Down and Steep Holm contains deeps of up to -21m ODN.

The surface of the mud patch is dominated by sandy silts (coarse enough to be able to maintain small-scale, flow perpendicular, bedforms with amplitudes of 0.05m and wavelengths of 4m) and silty and sandy clays, which exhibit shore and flow parallel linear tidal flute marks immediately offshore of Hinkley Point. Surveys of the mud patch in Bridgwater Bay by Kirby and Parker (1980) have shown the thickness of settled mud to range from a few decimetres to >7m in places.

In some locations coarser grained sediments are found. Offshore at Stolford and Hinkley Point is a thick, eroded, patches of clayey, gravelly, fine sand have a linear shore-parallel morphology, resting on a bedrock surface

(-13 to -14m ODN), which could potentially represent overtopped barrier systems. Coarser, gravel barrier deposits have certainly been described along the margin of the Bristol Channel (Heyworth and Kidson, 1982; Jennings et al., 1998) behind which marsh or fen habitats developed. However, seismic data and borehole logs through these deposits shows no internal structure typical of such barrier systems and subsequently the currently available data is equivocal over the origin of these thin linear patches of sand (Dix et al. 2015). Bell (1990) made a similar suggestion for the Brean Down area where a recovered peat, dated 6660-6210 cal. BP (HAR-8546; 5620±100 BP), may have formed in the lee of a sand or gravel barrier which lay between 0.5 km and 1 km seawards at this time during this time.

Exposures of peat within the intertidal area are well known from the Bridgwater Bay area, including those dated at Brean Down (Bell 1990), Burnham-on-Sea (Druce 1999) and Stolford (Heyworth and Kidson 1982; Kidson and Heyworth 1976; Heyworth, 1985; Hillam et al. 1990). An additional series of sinuous intertidal peat deposits, probably representing a peat-filled palaeochannel, were identified on Berrow Flats west of Brean (centred on ST 2895 5557 and ST 2893 5576) during the Rapid Coastal Zone Assessment Survey (RCZAS; Chadwick and Catchpole 2013, 63-64). These peats were found at c. -2m ODN and, where measured, were up to 0.22 m thick. From the edge of one eroding face a stained bovid bone was found on the marine clay surface. The interpretation provided was that these peat deposits represented infilled sinuous salt marsh channels, though the peats themselves were not radiocarbon dated. During one of the Severn Barage feasibility studies (Evans 1981; 1982) a geophysical survey was run parallel to coastline c. 1.5 km offshore. Within one of the survey lines available (Evans 1982, Fig. 2e) a palaeochannel is clearly visible beneath the mud patch surface measuring c. 100 m wide and 7 m deep. This channel is c. 1.5 km WSW of the pre-mentioned foreshore Berrow Flat palaeochannels and could, conceivably, represent part the main channel associated with this salt marsh channel system.

In both the Stolford and Burnham-on-Sea area the exposed peat beds (and onshore continuations at Stolford identified through borehole transects; Kidson and Heyworth (1973; 1976)) show the presence of intercalated peat beds, which incorporate the Stolford submerged forest. Correlation between these peat exposures, based upon age and altitude, is complicated by factors including sediment compaction, the integrity of the material dated (often undefined bulk sediments), and the beach / foreshore gradient where some laterally consistent peat beds can be seen to decrease several metres altitude as they progress from the current shoreline (Kidson

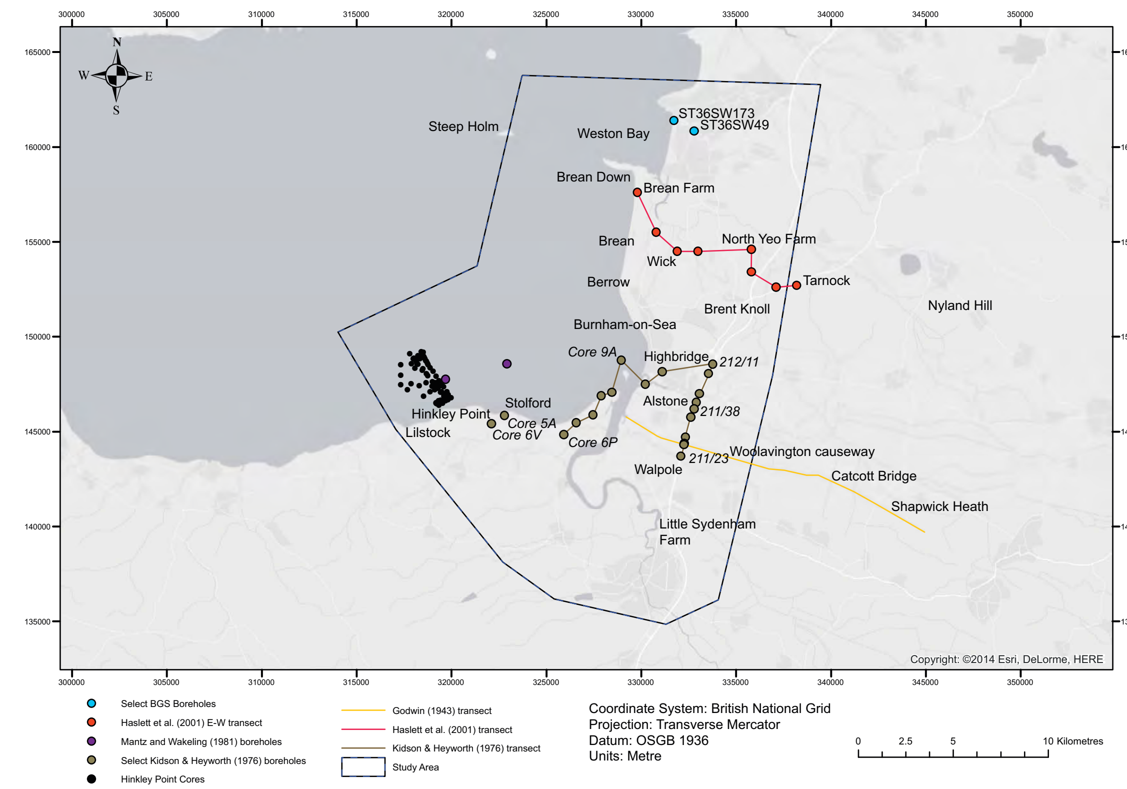


Figure 5.6 Distribution map showing location of Holocene sites and named boreholes mentioned in the text. © Crown Copyright and Database Right [2015]. Ordnance Survey (Digimap Licence).

and Heyworth 1976, Figure 4). However some broad correlations are possible. The lower peat identified by Druce (1999) at Burnham-on-Sea (BU2), found at c. -3m ODN, has a date range of c. 7250-6350 cal BP (Wk-5297; 5590±70 BP and Wk-5298; 6340±70 BP). This is broadly chronologically comparable with a dated peat recovered on the Stolford foreshore within borehole 5c, at -2.0m ODN, dated 7420-7130 cal BP (NPL-148; 6230±95 BP), and the offshore peat bed at Brean Down, found at -0.15m ODN, dated 6660-6210 cal BP (HAR-8546; 5620±100 BP). The upper thin peat from Burnham-on-Sea (BU1), located just below Ordnance Datum, has a date range of c. 6150-5500 cal BP (Wk-5299; 5370±70 BP and Wk-5300; 4790±70 BP), broadly chronologically comparable to a 1.3m thick basal peat in core 6F at Stolford, dated between 6110 and 6030 cal. BP, also bridging Ordnance Datum (I-3397 and I-3396), which is laterally equivalent (Kidson and Heyworth 1973, Fig. 2) to the basal peat dated in core 6V at Stolford, albeit that this is formed over a stratigraphic high at 2.2m ODN, dated 5890-5080 cal. BP (I-3395; 4790±120 BP). Later phases of the peat formation are currently only dated from the submerged forest record at Stolford from which some of the Stolford oak sequence were extensively radiocarbon dated as part of an inter-laboratory radiocarbon calibration study (Heyworth 1985; Hillam et al. 1990), all located above Ordnance Datum on the foreshore. The latest radiocarbon date available from the Stolford area is from core 5a at 0.6m ODN, providing a date of 3970-3730 cal BP (NPL-146; 3460±90 BP). This post-dates the submerged forest (and all other dated intertidal peats along Bridgwater Bay) but there is no published stratigraphical data available to assess the reliability of this date.

Submerged forests and intercalated peats are also found further west along the Somerset coast within embayments at Minehead (Jones et al. 2005) and Porlock (Jennings et al. 1998; Godwin-Austen 1866), the latter also containing deeply buried Early Holocene peat beds. To the west of Hinkley Point, c. 400m from the high water mark at Lilstock (nee Little Stoke), Horner (1816, 382) reports the presence of another submerged forest. Although Ussher (1908, 83) reports the presence of tree stumps under 4m of silt in the bed of the River Parrett near its mouth, citing Horner (1816), it is possible that these trees may be actually those from the Stolford submerged forest. Kidson (1977, 282) also reports the presence of a submerged forest near the mouth of the River Axe within Weston Bay.

Offshore extensive peat deposits have recently been found north of Hinkley Point (Sturt et al. 2014). During this study a total of 24 boreholes and 63 vibrocores were collected which revealed a broadly consistent stratigraphic sequence consisting of nine key stratigraphic units recognised. These included a thin compacted basal peat / basal organic rich silt, lying between -14 and -11m ODN, including some intact regressive contacts that graded into overlying estuarine and marine silts. A number of intercalated peats were also found in the sequence, which was subsequently overlain by several meters of more recent silts, sands and / or gravels. The peats have been extensively dated (see Griffiths et al. 2015) indicating that the basal peat formation occurred c. 9500 cal. BP and lasting c. 650-1130 years. Within the peats themselves, charred plant remains suggested the possibility of deliberate Early Mesolithic human activity which predated similar evidence from peats along the coastal fringe by c. 1500 years (Sturt et al. 2014).

Cores reported within Mantz and Wakeling (1981) suggest that these organic offshore deposits are likely to be laterally extensive north of Stolford and Hinkley Point and may possibly form a continuation of the intercalated peats found nearshore at Stolford and reported from Lilstock. However the large areas of partly mobile sand, mud and shingle make definitive identification and mapping of such sediments in this area difficult, with difficulties in surveying the area using sub-bottom geophysical profilers due to shallow gas blankets within the mud flats (see Sturt et al. 2014; Kirby and Parker 1980), resulting in the need for extensive offshore coring to identify the stratigraphy of the area.

Coastal Plain

Immediately inland of the coast is a belt of surface minerogenic sediments which comprise the coastal plain, or 'coastal clay belt'. Rippon (1997) notes that the elevation of this plain is significantly higher than the levels, lying typically between 6-7m ODN close to the coast and decreasing in elevation inland to c. 4 m OD at the inland limit of the clay belt. The surface peats of the inner levels are lower still, with surface elevations of between c. 2-4m OD. Much of this height difference is due to the history of post Roman flooding, which was restricted to the coastal plain (see below) and to the compaction of the waterlogged peats of the inner levels.

Along the foreshore at Weston Bay and a 10km stretch between Brean Down and the mouth of the River Parrett a dune barrier exists that separates the levels from Bridgwater and Weston Bay's. At Brean Down Holocene aeolian deposits were found to contain four separate Bronze Age occupations between Beaker and Late Bronze Age (Bell 1990). Investigations of the sands in this area demonstrate some interleaving of colluvium, blown sand and marsh deposits implying that a sand bar has existed in this area from at least c. 4000 cal BP. Bell and Brown (2009) suggest that the barrier may have become established c 6000 cal BP as sea level rise reduced and subsequently migrated landwards with continuing sea level rise and erosion. At Berrow the sand dunes contain stratified medieval and post-medieval occupation horizons.

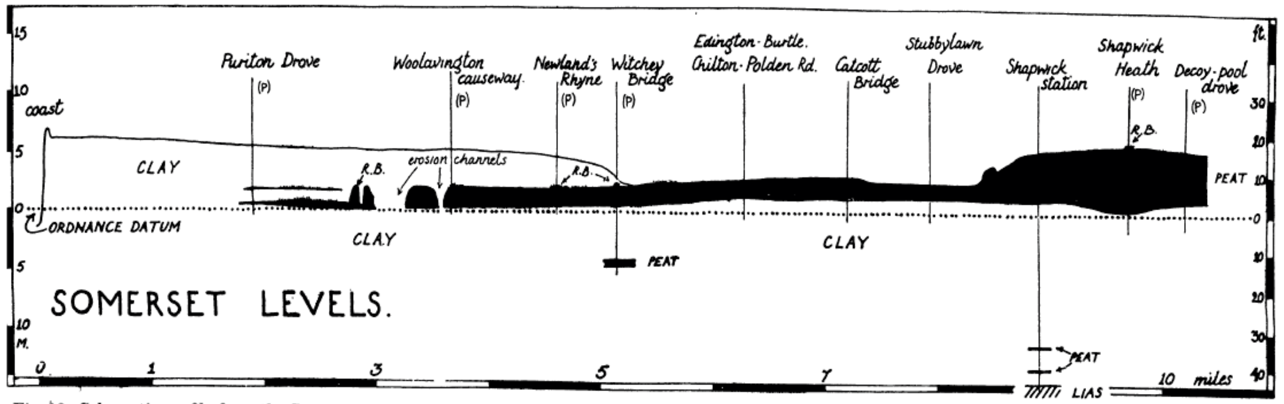


Fig. 12. Schematic profile from the Somerset coast, inland to the region of relict raised bogs. Thick ombrogenous peat extends seawards below the coastal clay belt for about 2 miles, and has Romano-British remains on its surface. The raised-bog system lies on an estuarine clay surface now a few feet above mean sea-level. Based on borings by the Somerset Rivers Catchment Board, by the author and Dr A. R. Clapham, and on field observations by W. Abery.

Figure 5.7 Godwin's (1943) Hunspill transect

Brue Valley and central Somerset Levels

During the early 1940s the Somerset Rivers Catchment Board begun to cut the deep Huntspill Cut drainage channel from the peat beds of the inner levels at Witchey Bridge directly to the sea (Godwin 1943 - see figure 5.7 above). While this process was being undertaken it was possible to examine the freshly exposed sections (recorded by W. Abery). This transect was extended eastwards into the inner levels by Roy Clapham and Harry Godwin through a series of borings up to the Shapwick area, resulting in a 16km long transect across the coastal and inner levels. This section demonstrated that the lower marine clay, sometimes including isolated peat beds at depth, was overlain by persistent raised bog peats in the inner levels. The raised bog peats of the inner levels area best known for their associated archaeology which includes numerous Neolithic and Bronze Age trackways and the Iron Age Glastonbury and Meare Lake Villages. These peats can be followed seaward, below an upper clay, for about 3km where they ended in what was interpreted as an erosional channel probably the result of later marine transgression. Although undated in the 1940 investigations, some of the peat surfaces below the upper clay could be assigned a *terminus post quem* age of the Romano-British period as there were a series of Romano-British sites upon the peat surface including those at Newland's Rhyne and Witchey Bridge. This observation was also made in the wider area where Romano-British material was found upon the peat surface at Shapwich Heath in the east, while around the Highbridge area (Nash 1973; Rippon 1995) and at Combwich (Godwin 1941) Romano-British occupation surfaces were contained within the upper clay. More recently a Romano-British saltern near Woolavington Bridge has been found with salt making activity taking place upon the top of the peat layer, at 3.37m ODN, with the upper peat surface dated 2060-1820 cal BP (Wk11546; 1991±45 BP, cf. Brunning and Farr-Cox 2005, 13). The presence of Roman activity on and above the peat surface led to the belief that the second transgression associated with the upper peat begun and ended within the restricted period of the Roman occupation (Godwin 1943, 219).

This area was reinvestigated by Kidson and Heyworth (1976) during the construction of the M5 motorway, with the borehole transect running perpendicular to the Huntspill Cut transect, between Loxton and the Lox Yeo River valley in the Mendips to the north, and Bridgwater in the south. A subsequent parallel transect of boreholes has recently been completed by Wilkinson and Watson (2013). Several of these boreholes were able to penetrate the full thickness of the Somerset Levels Holocene infill demonstrating the presence of basal peats

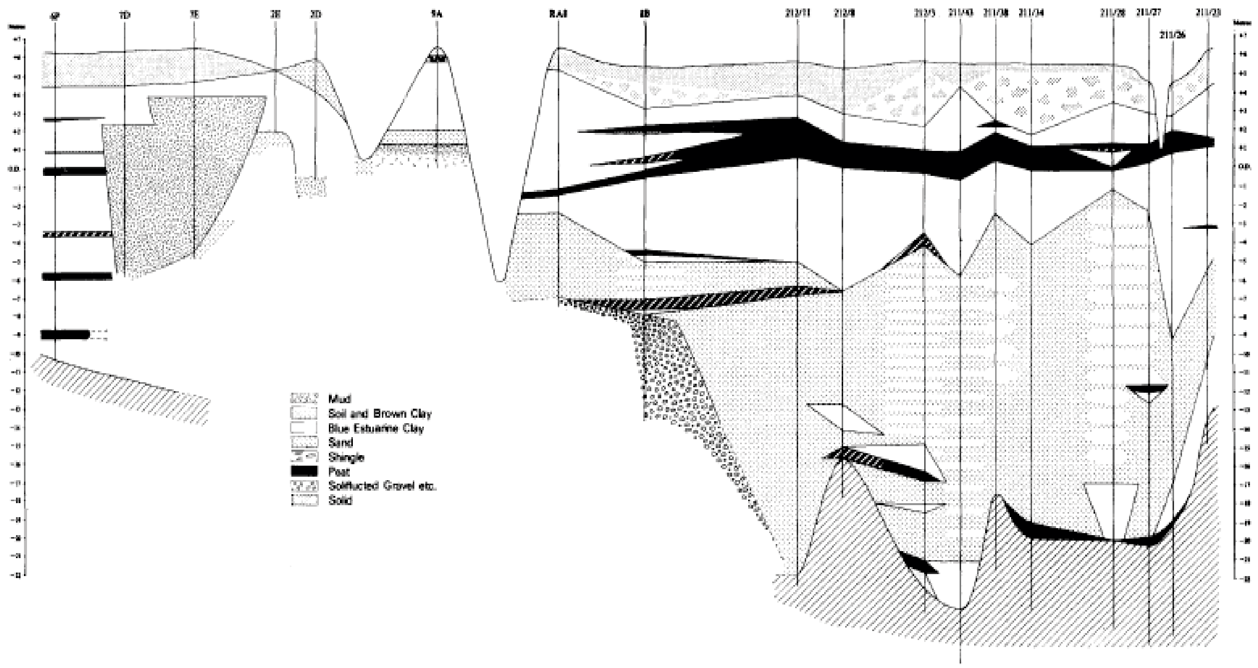


FIG. 6. Section across the mouth of the Parrett to the M5 boreholes.

Figure 5.8: Kidson and Heyworth's (1976) stratigraphic cross section

between c. -18 and -21 m ODN (though locally some were found up to -13m ODN). Radiocarbon dates from peats to the east of Highbridge (I-4315, I-4402, I-4403 and ST3407) suggest peat formation c. 9400 cal BP. Further peat beds are found between c. -9 and -6m ODN (though locally some were found up to -3m ODN), with those from the Highbridge, Burnham and East Brent area (I-2688, I-2690 and St3281 respectively), between -9 and -8.5m ODN, radiocarbon dated c. 8010 cal. BP. These peats were within the thick minerogenic Holocene infill dominated by sands towards the base of the cores which fine up into blue/grey silts and clays. Between c. -1 and 3m ODN a laterally extensive peat can be traced over ≥10 km across the Somerset Levels, correlated with the coastal plain peat reported by Godwin (1943). The peats are subsequently overlain by the marine transgressive blue/grey silts.

In addition to the broad tripartite sedimentary sequence, this area of the Somerset Levels also contains evidence of a number of notable palaeochannels and embayments that are no longer existent. Samuel Nash (1973; Rippon 1995) identified the presence of a substantial deep water inlet lying between Highbridge and the submerged northern exposure of the Burtle Formation at Alstone, visible during the excavation of the 1806 New Cut. The presence of this feature is supported by deeply buried Roman material in the area, the pattern of field-boundaries, the lower elevation of the area, and the medieval name 'Broad Wharf' for the area south of Bristol Bridge (Rippon 1995, 102) on the east side of Highbridge. This has been termed the 'proto-Brue' as it predates the modern River Brue position which is a medieval canal that cut into the naturally meandering course of the Westhill Rhyne.

The second substantial palaeochannel in the area lies between Brent Knoll and Berrow in the north and Burnham and Highbridge in the south, which is referred to as the River Siger which is known to have marked the southern edge of the 7th century Brent estate granted to Glastonbury Abbey. The palaeochannel is visible as a topographic low prone to flooding and is readily identifiable in aerial photography. However it was the more recent study of LiDAR data (Brunning and Farr-Cox 2005) that revealed how extensive the palaeochannel system is, joining Bridgwater Bay close to the Burnham-on-Sea low lighthouse, though notably with no connection to the postulated deep water inlet around Highbridge. The interpretation provided by Brunning and Farr-Cox (2005) is that this was a salt marsh channel which the authors suggested might have come into existence during the Roman period and lasted into the early medieval period. The basis for the Roman origin was in part based upon the Huntspill Cut section recorded by Godwin (1943) showing erosion of the peats by a series of channels between Withy and Woolavington Bridges with the neighbouring peat surfaces supporting

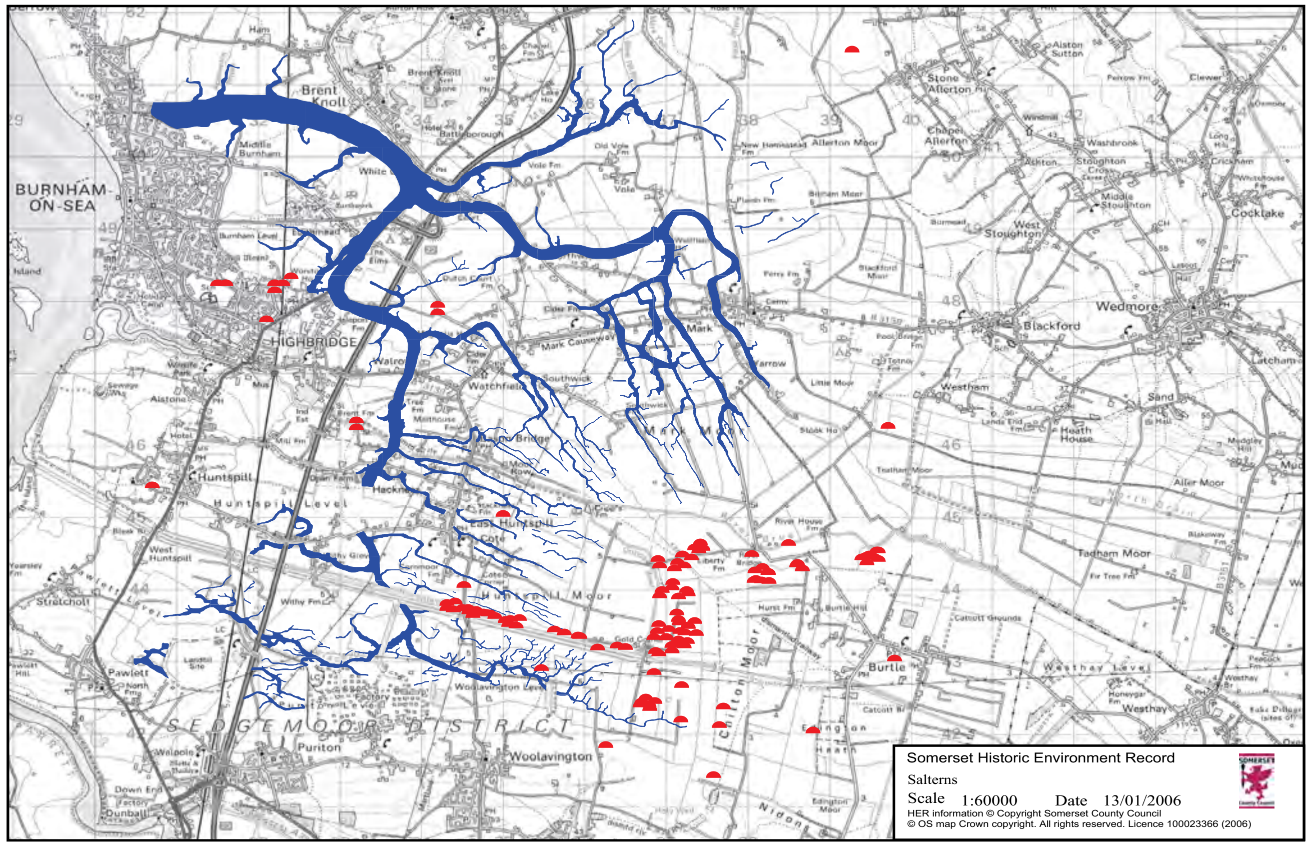


Figure 5.9 interpretation of river Siger from LiDAR data (after Brown and Brunning 2014) Image provided by R. Brunning.

Romano-British saltern industries. On the eastern edge of the River Siger a series of relatively straight channels are visible which Brunning and Farr-Cox (2006, 13) suggest may be the result of Roman peat cutting, particularly as peat is known to have been the main fuel used in the salterns (Leech et al. 1983). More recently Brown and Brunning (2014) have investigated part of the River Siger stratigraphic sequence close to the slopes of Brent Knoll. The two boreholes revealed 5 m of green-grey silty clay overlying 10m of olive green silty-clay with micaceous clay laminations. Within this unit a thin organic-rich band was encountered at c. -2.5 m ODN, dated (using bulk sediment) to 5590-5320 cal. BP (UBA-18118; 4728±36 BP), leading Brown and Brunning (2014) to postulate an Early Holocene initiation for the River Siger. Brown and Brunning (2014, 290-291) suggest that the previous assertion of a Romano-British age for the River Siger can be dismissed as the channels cutting through the peats referred to by Brunning and Farr-Cox (2005) and are likely to be later tidal creek extension into the southern claylands or activation and extension of the salt marsh creek system from a re-activated channel system. However the authors do state that with the limited evidence available such an Early Holocene initiation is purely speculative. However what is certain is that the River Siger main palaeochannel, close to Brent Knoll, does reach considerable depths within the Somerset Levels resulting in a unique stratigraphic sequence truncating the tripartite sedimentary sequence of the area.

Parrett Valley

Extensive work in the Stert and Stolford area was undertaken by Kidson and Heyworth (1976). Similar to the work of Godwin they demonstrate that much of the area is underlain broadly by a tripartite sediment sequence comprising a lower minerogenic deposit, a deposit of peat which thickens in a landwards direction to reach in excess of 2 m to 3 m thickness, and a capping minerogenic deposit which extends to present day surface. The lowermost deposit comprises Holocene estuarine sands, muds and clays, with the occasional brackish water peat, and extends from bedrock at c. -18m to 0m ODN. The main deposit of peat accumulated during the mid-Holocene, commencing after c. 7000 cal BP with peat accumulation continuing until 4000 cal. BP, after which a return of estuarine sedimentation occurred.

The area around Bridgwater has been subject to extensive development and site investigations. The stratigraphic sequence north of Bridgwater has been extensively investigated in recent years in relation to develop-

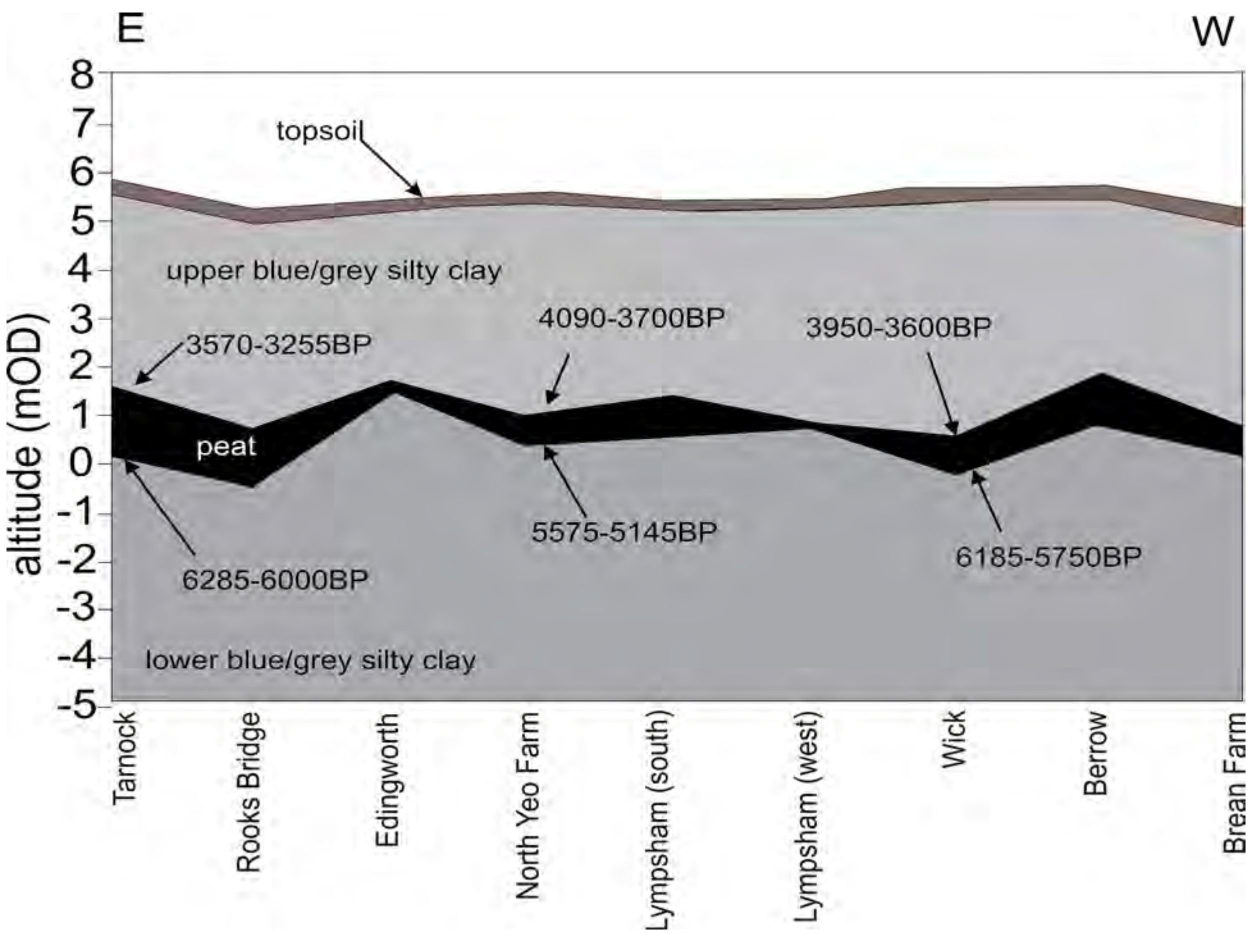


Figure 5.10 Cross section of the Axe Valley, after Haslett et al. (2001, figure 2)

ments between the eastern bank of the River Parrett and the M5 in the vicinity of Little Sydenham Farm. LiDAR coverage of the area shows extensive palaeochannel meanders associated with a previous eastern course of the River Parrett, with borehole and geophysical investigations of the area (OA 2008) revealing tidal channels and channel margin environments. The underlying geological rockhead was present between -18 and -15m ODN, though significant thicknesses of gravels were found across this surface extending up to c. -10m ODN. These in turn are overlain by substantial thicknesses of silts and sands with occasional intercalated organic silts / peats between -3.6 and 2.5m ODN. These organics were not laterally extensive across the study area and probably eroded by later channel migration. The sequence was overlain by a silty clay. The stratigraphic sequence at Little Sydenham Farm provides a useful comparison for the largely under investigated River Siger stratigraphic sequence to the north and demonstrates how the often discussed laterally extensive peats found around Ordnance Datum are laterally constrained away from the main drainage channel networks on the Somerset Levels.

One of the most unique archaeological sites in the coastal plain is to be found at Walpole on the Pawlett Level. During site investigation associated with a landfill site an outcrop of Lower Lias bedrock was found below the alluvial deposits, forming an island outcropping at c. 1m (c. 4m ODN) below the modern surface, which drops off to c. -19m ODN at its northern end. The site has revealed a series of Neolithic structures and channel systems around the island, with occupation horizons focused upon the island itself including Bronze Age and Iron Age pottery (Hollinrake and Hollinrake 2002; 2007). Final inundation of the island had occurred by the Romano-British period. Boreholes to the edge of the island have revealed a series of intercalated organic layers between c. 0.6 and 3.5 m ODN which yielded a date range for organics formation between c. 6500 and 3400 cal BP

Axe Valley

In the north of the coastal plain, the Axe valley has generally experienced few investigations, especially in its

lower reaches, aside from some single boreholes (see Whittaker and Green 1983; Ussher 1908; Woodward 1876), such as those associated with the Brean Sea defences (Allen and Ritchie 2000; Kirby 1994) and where the M5 crosses the valley. Godwin (1981, 141) notes that a series of borings were undertaken within the Axe Levels (probably in the east) where the peat beds were more deeply buried by the upper clay that they assumed was also of Romano-British age. More recently Haslett et al. (1998; 2001) undertook investigations comprising two lengthy stratigraphic transects extending west-east from Uphill to the northern tip of the Isle of Wedmore, with an additional north-south transect to Brent Knoll and coring around Nyland Hill to the east of the study area. Further unpublished work around Brent Knoll has been undertaken by Emma Vowles (outlined in Haslett et al. 2006). These results confirmed the previous findings of a tripartite stratigraphic sequence which has close similarities with the sequences reported from further south on the coastal plain by Kidson and Heyworth (1976) and Godwin (1943). However the full stratigraphic sequence in the Axe valley (including maximum thickness of Holocene deposits) was not established as, with the exception of cores on the margin of Brent Knoll, the underlying rockhead surface was not reached, with coring typically only reaching -5m ODN. By contrast two boreholes at the north of the Brean sea defences (Kirby 1994) established that the local bedrock surface was between -16 and -24m ODN. Haslett et al. (2001) formally separates the 'Somerset Levels Formation' as:

- Lower Somerset Levels Formation: Consists of ≥6m of marine minerogenic blue/grey silty clay, commonly with fine sand laminations and occasional plant macrofossuls such as *Phragmites*. Kirby (1994) identified in the Brean sea defences BH41 a thin probable basal peat at -22m ODN implying that freshwater deposits exist below the marine minerogenic deposits identified by Haslett (2001).

- Middle Somerset Levels Formation: Characterised by 0.5-2m thick organic peat facies, either as a single bed or thinner intercalated lenses, mostly of freshwater origin.

- Upper Somerset Levels Formation: Up to 5m thick marine minerogenic silty clay, occasionally sandy.

Radiocarbon dates from the peats of the Middle Somerset Levels show peat initiation between c. 6200-5400 cal BP (Figure 5.10). Haslett et al. (2001, 85) suggest that the variability in timing of peat accumulation is caused by 'accumulation over a surface exhumed by regression, so that dates from attitudinally low sites are closest to the time of regression while dates from attitudinally higher sites record vertical peat growth over the exhumed surface'. The end of peat formation is also diachronous, with earliest inundation at the seaward sites after c. 3900 cal. BP. The Upper Somerset Levels Formation accumulated as sea-level rose once more during the late Holocene, outstripping the rate of vertical peat accumulation. Foraminifera suggest that the peat-clay contact separating the Middle from Upper Somerset levels Formations accumulated at approximately MHWST. These minerogenic sediments continued to accumulate until land claim took place by Roman settlers, dated using pollutant data in the Axe Valley to c. AD 130-221 (Haslett et al. 1998).

Weston Valley

The basin between the Mendips and Weston-Worle ridge has not been subject to the same level of study as many areas of the Somerset Levels. However it has been subject to much more intense borehole investigation as a result of the density of urban development, as well as sea defence and road construction. Similar to the Holocene deposits in the south, a broad tripartite sequence can be identified. Overlying the basal Mercian Mudstone Group geology are a series of silty sand and / or thick clay deposits with frequent organic inclusions. A number of thin peat horizons are also recorded at depth within boreholes from this area, such as a 0.2 m thick silty peat with wood fragments between -9.94 to -10.14m ODN in borehole ST36SW173, or a basal peat at c. -17.8 m ODN in borehole ST36SW49. A persistent peat is found across much of the area away from the seafront, with altitudes for the base and top of the peat varying between 0.5 and 2.5 m ODN. David Gilbertson (see Welin et al. 1972) collected material for radiocarbon dating from an exposure of this peat in a sewer trench at Milton, Weston-super-Mare (ST 3457 6194). These provided a date for peat initiation at 0.5m ODN of 5470-4870 cal BP (St-3297; 4530±105 BP), and the end of peat formation at 1.6 m ODN of 4350-3710 cal BP (St-3296; 3675±100 BP). While this peat is persistent within the centre of the Weston basin, it is not observed along the shoreline where thick sand deposits, occasionally interbedded with silty clays, are found. This pattern matches that to the south of Brean Down where it is suggested that a sand / gravel bar barrier may have formed with the protected marsh developing in its lee to the east. Within the main Weston basin, east of the dune sand deposits, the peat surface is overlain by an upper silty clay (where not truncated by made ground).

Review of the tripartite stratigraphic sequence

Holocene deposits within the Severn Estuary and Inner Bristol Channel has long been recognised to have such a broad tripartite lithostratigraphic division (Sollas 1883), most prominently defined in the Gwent Levels as the Wentlooge Formation (Allen and Rae 1987). In addition, along the coastal fringe three actively accreting salt-marsh terraces can be found, in ascending sequence, the Rumney Formation (begun accumulation at times between the early medieval and early modern periods), the Awre formation (probably begun accumulating in the 19th century) and the Northwick Formation (from the early 20th century) (Allen and Rae 1987).

Haslett et al. (1998, 2001) suggested that their Somerset Levels Formation, derived from the Axe Valely, may be lithologically correlated with the Wentlooge Formation. However they do observe that the Middle Somerset Level formation is variable with the widely recorded single peat-bed in some places seen to split into thin peaty-clay intercalations or be absent altogether. Although the Wentlooge Formation is widely used to assign sequences to broad chronological periods and stratigraphy types, it is recognised that there is significant geographical variation in the nature of the intertidal and terrestrial Holocene deposits, and therefore this is not universally applicable. For the Bridgwater Bay area Allen (2001, 23-24) states that the sequence "differs from that in the Gwent Levels (where there are more and longer-lasting peats) possibly because in Somerset peat-formation (on the foreshore) was suppressed in favour of mineral sedimentation, perhaps due to high compaction rates favoured by the deep rockhead present beneath much of the area".

As outlined above, the use of a tripartite stratigraphic system can be broadly applicable over large areas of the coastal plain, though within the wider area a highly spatially heterogeneous sedimentary exists, notably within the offshore (Bridgwater Bay) Holocene sedimentary sequence (where a staircase of peat sequences have been identified that would chronologically correlate with the minerogenic-dominated Lower Wentlooge Formation), blown sand dune barrier complex along the coastline, and the thick raised bog peats to the east of the coastal plain, which themselves are also diachronous. Similarly in areas where palaeochannels have been most active, notable along the margins of the River Parrett and Siger, much of this stratigraphic sequence is obscured and a clearly definable Middle Somerset Levels organic horizon largely absent. The disparity over the age, and thickness, of the Middle Somerset Levels peat, particularly in relation to the peat surfaces encountered by Godwin (1943), can be accounted by the type of peat formations present. Peat surfaces which yielded Romano-British occupation surfaces were associated with the thicker peat beds shown to contain an ombrotrophic mire peat stratigraphy, particularly within the Inner Levels. These mires would have continued to grow during initial marine transgression, as an atmospheric fed raised bog, able to keep pace with initial estuarine expansion, with some continuing to grow up until the historic period when human activity (notably peat cutting and drainage) stopped peat accumulation (Aalbersberg 1999). By comparison the peats associated with much of the coastal plain are non-ombrotrophic and would have been rapidly inundated as marine transgression occurred. As a consequence the date of the end of peat formation varies across the Somerset Levels, with the latest dates in the east, and earliest dates along the coastal fringe and within the offshore record. For these reasons although the use of the tripartite Somerset Levels Formations is useful and applicable in many instances, considerable caution should be exercised where attempts to directly correlate deposits are based upon the Somerset Levels / Wentlooge Formations schemes, particularly along the margins of Bridgwater Bay and wider Bristol Channel.

Relative sea-level change

Many of the stratigraphic changes discussed above have been caused directly or, in the perimarine zone, indirectly by changes in Holocene RSL. The proliferation in the number of radiocarbon dated Sea-Level Index Points (SLIPs) over the past 60 years has enabled the development of a series of RSL time/altitude graphs depicting changes in regional sea-level change in the South West of England (e.g. Hawkins 1971; Kidson and Heyworth 1973; 1976; Heyworth and Kidson 1982; Lambeck 1995; Haslett et al. 1998; Long et al. 2002). The early regional sea-level curves identify the salient features of time/altitude changes in RSL in southwest England which remain largely unchanged to the present day, despite a significant increase in the number of radiocarbon dates available. Thus, Hawkins (1971) depicts MHWST rising rapidly from c. -45 m ODN at c. 10000 cal. BP to

c. -15 m ODN by 7800 cal. BP, at a rate of c. 20 mm a^{-1}. After this period the rate of RSL rise began to fall, with a pronounced slow down between 7800 to 5800 cal. BP. This was followed by a period of more gradual RSL rise between c. -8 m ODN and present. Kidson and Heyworth (1973; 1976) employed a correction factor for sediment compaction to generate a revised RSL curve for the Bristol Channel which suggested a slower rate of rise than the analysis of Hawkins (1971), but with the same tripartite division of rates of change. This interpretation suggested a net rise in RSL of 24 m since c. 9500 cal BP. Haslett et al. (1998) and Aalbersberg (1999), who largely relied on the same data presented by Heyworth and Kidson (1982), defined a similar pattern although the same correction factor for sediment compaction is not applied. An alternative approach to time/altitude reconstruction was provided by Lambeck (1993; 1995) who utilised a mathematical model, accounting for glacio and hydro-isostatic rebound, to predict RSL change. More recently Glacial Isostatic Adjustment (GIA) Models (see Shennan et al. 2002; 2012; Peltier et al. 2002) have been used to model RSL change.

With each of these subsequent studies, however, the basic form of Holocene RSL change in the Bristol Channel area has remained largely unchanged, yet significant uncertainties in these reconstructions remain, especially with regard to the varied nature of material included in analysis (much from archaeological sources and possessing a poorly defined height relationship to a former sea-level), uncertainties regarding changes in tidal range (within the Seven Estuary / Bristol Channel area and more locally within each sedimentary basin), as well as the effects of compaction which tend to lead to over-estimates of RSL rise. Edwards (2006) reviewed RSL change in SW Britain, including new SLIPs, The results indicate that decompaction based on the stratigraphic position of sea-level index points, could eliminate much of the misfit between reconstructions and predictions, and substantially reduce vertical scatter in geological data. He also suggested that the influence of compaction on sea-level data from this region may be larger than previously thought. Finally, Elliott (2015) has established a local sea-level record from the Steart Peninsula using a transfer function approach for the period between c. 7500-4000 cal BP which implies that local factors influencing the intertidal environment were superimposed onto the regional drivers throughout the early to mid-Holocene.

The distribution of data is also uneven in time, with many dates derived from the Early Holocene prior to initial marine inundation of freshwater landsurfaces, the mid Holocene when the rate of RSL was relatively low permitting organic fen deposits to expand laterally, and no index points available from the last 2000 years. Recent work offshore at Hinkley Point (Sturt et al. 2014; 2015) has demonstrated that datable deposits suitable for sea level index points covering areas of the sea level curve devoid of SLIPs can be found which is helping to refine our understanding of Early Holocene sea level change.

It is, however, clear that the tripartite RSL history has strong links to the stratigraphic sequences of the Somerset Levels (Long et al. 2002). Thus, during the early Holocene period, rapid RSL rise was associated with the widespread accumulation of the Lower Somerset Formation comprising minerogenic silts, clays and sands of marine and estuarine origin. As the rate of RSL fell during the mid-Holocene, so peat initiation occurred and there followed a protracted period of freshwater organic accumulation in the much of Bridgwater Bay. Finally, during the late Holocene, a period of renewed RSL rise (poorly defined in age altitude graphs due to the effects of sediment compaction) is correlated with the widespread flooding of these freshwater peats in the coastal plain, and possible episodes of freshwater flooding in more inland areas.

Rates of Holocene RSL change suggest that during the last 2000 years, MSL has risen at a rate of between 1 mm and 2mm a^{-1}. However, archaeological, some sedimentary and recent tide gauge data, suggest that rates of increase in HAT have been higher. HAT is of more importance to coastal managers than MSL and these findings therefore demand attention. Allen (1991) suggests a rate of raise in HAT of 2.23 mm a^{-1} averaged over the last 200 years, and a rate of 4.65 mm a^{-1} since 1945. These estimates are close to the 3.3 mm a^{-1} rise in HAT estimated for the area by Allen and Duffy (1998), who combine crustal subsidence (0.24 ± 0.19 mm a^{-1}, a global eustatic rise of c. 1.7 mm a^{-1}, and a rise in high tide levels of about 1.3 mm a^{-1}). This has implications with regard to the tidal range of the river, and with that erosion and sedimentation rates.

Holocene palaeogeographic change in the Bristol Channel, Severn Estuary and Bridgwater Bay area

Together, the above data have been used by a variety of scholars to address the changing palaeogeography of the region. Key to these studies has been keen interest in how how this has impacted upon, and been influenced by, both prehistoric and historic communities interacting with the wetlands, leading to their eventual drainage and adoption for widespread farming.

Hawkins (1971) generated a series of maps, based upon a limited number of radiocarbon dates, showing shoreline retreat during the early Holocene for southwest England. These demonstrated c. 13,500 cal BP the entire Bristol Channel and Severn Estuary area was above contemporary sea-level, with subsequent rapid shoreline advance along the Bristol Channel during the early Holocene, though by c. 9000 cal BP it was predicted that Bridgwater Bay was still dryland. Lambeck (1995) and Shennan et al. (2000) provided more sophisticated maps of this region, based upon an expanded RSL database corrected for changes in tidal amplitude (e.g. Austin 1991) and crustal subsidence (Shennan 1989), as well as for variations in glaciohydroisostatic load. The resulting diagrams show large scale changes during the early Holocene, but are limited by low resolution during the period from c. 8000 cal. BP onwards. Both these models were useful for understanding broad regional-scale change but limited by a number of significant simplifications such as ongoing tidal activity within deep palaeovalleys (including those subsequently infilled by later Holocene sediment accumulation, including beneath the Somerset Levels) and provide little information beyond the point where coastal change begins to coincide with the current coastline boundary.

To understand the more local palaeogeography change associated with the Bridgwater Bay and Somerset Levels area Kidson and Heyworth (1973) combined information regarding the pre Holocene buried land surface of Bridgwater Bay with RSL data to develop a series of five maps depicting shoreline changes starting at c. 10,000 cal. BP. While these have provided the best first indication of palaeogeographic change in the area, they are still constrained by a limited number of radiocarbon dates and it is not possible to easily discern the location of their chronolological tie-points used in map construction. As a result, several of their maps depict shoreline advance or retreat which is contradicted by the lithological data and enlarged radiocarbon database of later studies, notably by Haslett et al. (2001) in the Axe Valley, and Housely (1998) and Aalbersberg (1999) in the inner reaches of the Brue valley. Long et al. (2002) provided a revision of the palaeogeographic evolution of Bridgwater Bay as a series of six time slices (represented here in figure 5.11).

Map 1: c. 10,000 to 8750 cal. BP

Kidson and Heyworth (1976) suggest an early Holocene marine influence into the western part of Bridgwater Bay. There are, in fact, only a small number of index points from this period, clustered geographically around Stolford and dating from between 9500 and 9300 cal. BP. These dates are each from basal peats and record freshwater peat formation over bedrock as a consequence of rising freshwater table ahead of MSL (see figure 5.12). Stratigraphic data from this area demonstrate that these peats are thin and short-lived (see Griffiths et al. 2015), succumbing to rapid sea-level rise at this time. Control on the remaining areas inundated by the sea are lacking and the Kidson and Heyworth (1976) map closely follows the -90 foot (c. -27m) ODN contour.

Map 2: c. 8750 to 6700 cal. BP

Marine influence has extended inland by this time, though radiocarbon dates covering this period provide contradictory information regarding trends in shoreline position, with a mixture of surfaces recording both negative and positive sea-level tendencies. The stratigraphy at many of these sites is not well constrained, with the dated peat beds often very thin and developing within the minerogenic-dominated Lower Somerset Levels Formation. Direct correlation between these sites is not possible, although the altitudes of the dates are broadly comparable (c. -6 to -4m ODN). The dates do indicate that the spatial extent of marine conditions mapped by Kidson and Heyworth (1976) at this time is misleading and a more varied pattern of coastal change, including short lived periods of advance and retreat, took place. The last index point from this period is from close to Glastonbury where stratigraphic data presented by Aalbersberg (1999) show the replacement of estuarine by saltmarsh conditions dated to 6970-6730 cal BP (UtC-7083; 6004±46 BP). This also requires a minor revision to the Kidson and Heyworth (1973) palaeogeographic map which does not show marine conditions extending this far landwards at this time. The change in sedimentation recorded here heralds the onset of a wider expansion of peat formation associated with the Middle Somerset Levels Formation. Haslett et al. (2000) suggest that during the rapid rate of RSL rise would have outstripped the available sediment, with the result that the intertidal mudflats and saltmarshes developed relatively low in the tidal frame. They argue that

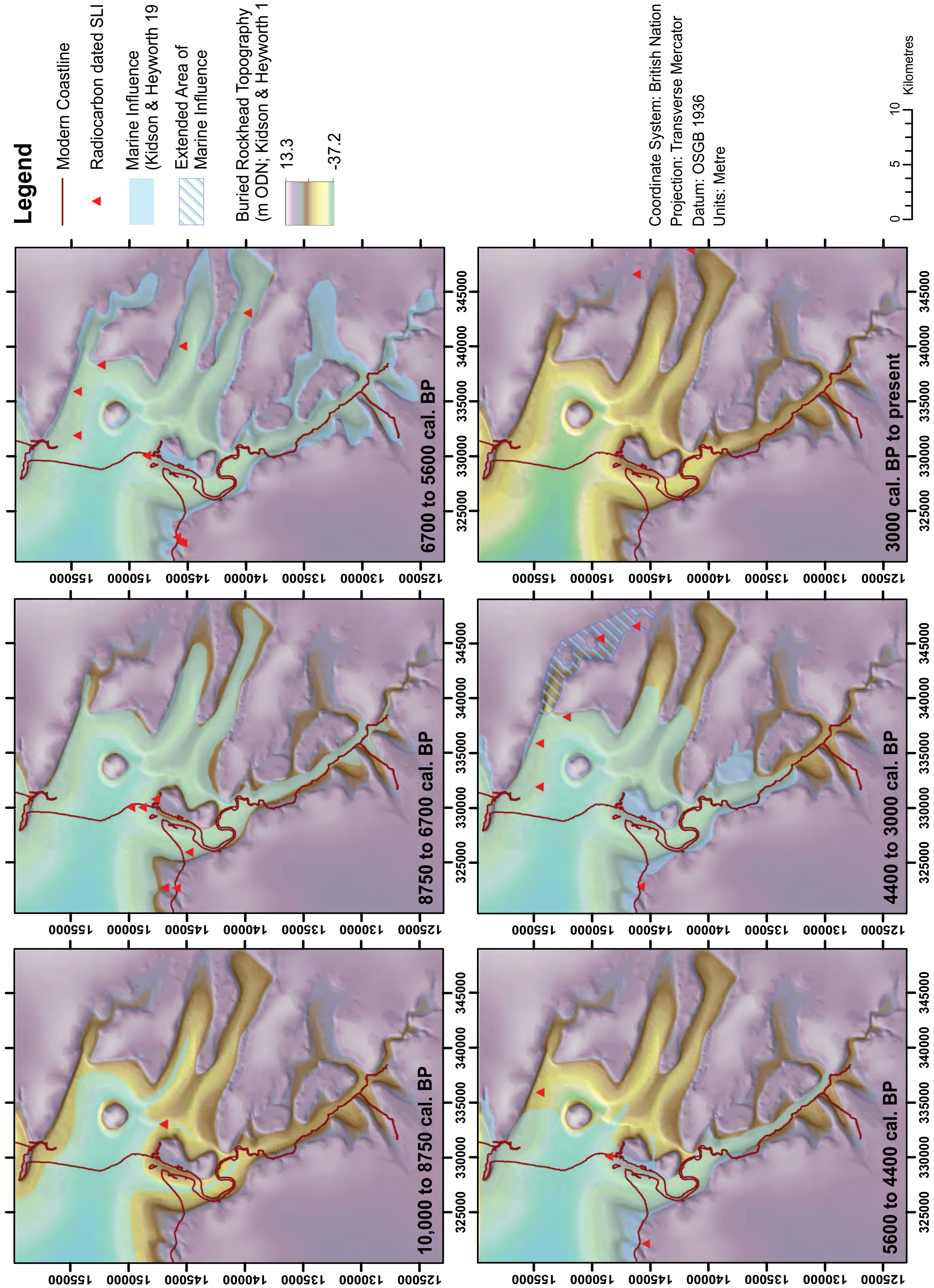


Figure 5.11 Palaeogeographic maps of the study area (after Long et al. 2002)

Bridgewater Bay would have supported minerogenic rich saltmarshes with soft mud and sparse vegetation cover subjected to frequent tidal inundation. The intertidal area at this time would have supported a relatively small number of large, deeply incised tidal channels/creeks, developing in response to the high hydraulic duty (the amount of tidal water accommodated by the intertidal surface).

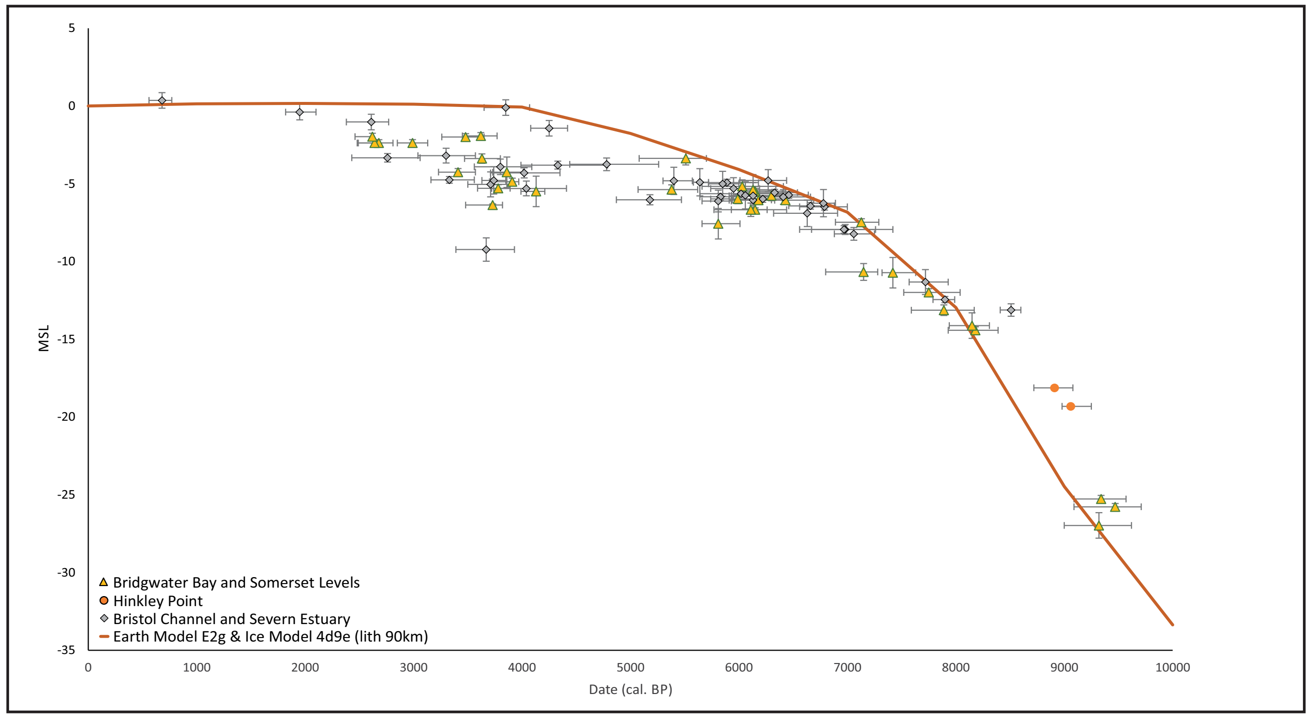


Figure 5.12 Sea-level curve and Sea-level index points for the Severn Estuary and Somerset Levels

Map 3: c. 6700 – 5000 cal. BC

This map depicts the marine influence in Bridgwater Bay at its maximum extent. Research since the Kidson and Heyworth (1976) analysis has increased the number and spatial distribution of dates from this period significantly, in particular those focused on deriving new dates on the age of peat initiation associated with the Middle Somerset Levels Formation. RSL during this period was still upwards and by the continuing formation of basal peats. Although RSL was still rising, nevertheless this interval saw a massive expansion of peat forming communities across much of the Central Somerset Levels. Dates from a range of coastal and inland sites date the onset of a protracted period of peat formation to between 6400 and 6000 cal. BP. Haslett el at. (2001) demonstrated that the maximum transgression of Kidson and Heyworth (1976) in the Axe Valley, dated c. 6700 cal. BP, is incorrect as their dates for the onset of peat accumulation date from at least 6700 cal. BP, whilst freshwater conditions extended to the [north] west of Brent Knoll by 5600 cal. BP. Their analysis can be extended across much of the Central Somerset Levels and to portray this interval as a period of maximum marine expansion is misleading, since the majority of dates show that the marine influence was rapidly declining at this time. Haslett et al. (2001) suggest that the transition to peat accumulation reflects sedimentation higher within the tidal frame, in response to the reduction in rate of RSL rise with respect to sediment accretion. This change allowed the intertidal surface to increase in elevation and become vegetated due to the reduced frequency of tidal flooding. An associated fall in hydraulic duty is likely to have promoted the development of smaller channels/creeks.

Map 4: c. 5600 to 4400 cal. BP

During this period the marine influence is excluded from much of the Central Somerset Levels, though the available dates are somewhat contradictory. Regressive contacts are found in a number of locations, though at Burnham-on-Sea local transgression is recorded in the thin forshore peat dated 5650-5320 cal. BP (Wk-5300; 4790±70 BP; Druce 1999). This inundation is generally contrary to the regional trend in shoreline movement at

this time and probably indicates local processes, possibly even related to the nearby River Siger postulated by Brown and Brunning (2014) to be active at this time, with a dated organic layer providing an age of 5590-5320 cal. BP (UBA-18118; 4728±36 BP).

Map 5: c. 4400 to 3000 cal. BP

The marine influence was returning to the Central Somerset Levels and in several places dates' record the end of the Middle Somerset Levels Formation as organic sedimentation was replaced by marine deposition. Haslett et al. (2001) argue that during this time the return of marine conditions is likely to have been associated with the lowering of the intertidal surface, an increase in hydraulic duty and palaeochannel enlargement prior to land claim during the Roman period. Data from the coastal plain and inner levels suggest that the inundation was diachronous, with inundation first in the west and progressively later in the east.

The last 3000 years

Archaeological and historical data from this period are reviewed comprehensively by Rippon (1997) and are not repeated here. However, in summary, several major changes in shoreline position occurred in the late Holocene, with two transgressive episodes (during the late Iron Age and the post Roman period) and two regressive phases characterised by land claim and occupation (the Roman period and the late Saxon - early medieval periods) (Rippon 1997). The configuration of the coast 3000 years ago is uncertain. Archaeological investigations at Brean (Bell 1990) suggest that the dunes were established at this time (although Brown and Brunning (2014, 291) have suggested establishment earlier around Burnham) and it appears that they have played a prominent role in the natural defences of the Central Somerset Levels ever since this period.

Oscillations in shoreline position were progressively limited; during the Iron Age marine water penetrated deep into the inner levels of the Brue valley (see Housley et al. 2000), during the post Roman period they were restricted to the coastal plain, whilst the storms of the late medieval period resulted in no permanent flooding or major sediment deposition.

Conclusions

While chapter 4 detailed the comparatively sparse nature of previous archaeological research within the study area, this chapter has demonstrated the value of regional geological and geoarchaeolgoical investigations for our understanding of context and potential. The sedimentary archive of the Bridgwater Bay mud patch and Somerset Levels has attracted a range of researchers with diverse interests, principally focused on changes occurring over the Holocene. While this incorporates a series of site specific high resolution accounts, attempts to move to broader scale reconstructions have always had to note the impact that spacing of dated cores and well recorded sequences has on interpretation. Although chapter five adopts a glacio isostatic modelling technique in an attempt to overcome this problem, the issue still stands that a higher frequency of dated cores would dramatically improve our understanding of palaeogeographic change, and archaeological potential, across the region.

Chapter 6
Modelling the western Somerset Levels and Bridgwater Bay pre-Holocene surface

Archaeological evaluation of deeply stratified sedimentary sequences from lowland river valleys and estuaries are problematic due to the often excessive depth of deposits encountered, high water table levels and ground instability. Consequently alternative strategies are required for understanding the nature of the buried landscape and determining the likely location of both archaeology and the subsequent placement of any archaeological excavations. Within the marine environment the determination of the sub-surface stratigraphy can often be readily identified through sub-bottom geophysical surveys, coupled with ground-truthing with geotechnical investigations. Onshore the deployment of geophysical equipment is logistically more complex and time consuming to obtain similar data coverage to that which can be acquired offshore upon a survey vessel. Geotechnical site investigations, utilising a range of coring methods, provide the ability to visually inspect the stratigraphic sequence but are again costly and time consuming to obtain coverage over a large area in order to understand the nature of submerged landscapes.

With greater access to open datasets, coupled with increased availability of computer software and processing power, it is now becoming increasingly possible to access and model large archive datasets, providing greater geographical coverage. Within the UK such data is being deployed to create 3D geological models covering large geographical areas (e.g. Mathers et al. 2014; Gow et al. 2014). This has been paralleled by similar advances in the use of deposit modelling for understanding Pleistocene and Holocene sedimentary sequences, submerged landscapes, and associated archaeological sites, notably within river valleys (e.g. Corcoran et al. 2011; Stevens et al. 2014; Harding et al. 2012; 2014; Grant in press). Modelling Early Holocene drainage basins, imprinted into the pre-Holocene surface topography, also permits palaeogeographic reconstructions to take place and predictive models of where, within this landscape, human activity might have been most prominent. For understanding coastal evolution and mapping palaeocoastlines the ability to define the pre-Holocene surface is important because it is against this surface that the surface indicating relative sea level at any particular time is intersected, so giving the form of any embayment, and possible limits of marine transgression and estuarine development, at a given time period (Brew 2006; Sturt et al. 2013).

Such models also permit volume calculations of marine accommodation space along the coastline. If there is zero accommodation space available, sediments will be transported to an area of (positive) accommodation space where they can be deposited. Thus, areas of zero accommodation space are sites of sediment by-pass. If there is a negative amount of accommodation space, the previously deposited sediments will be eroded and transported to an area of (positive) accommodation space. This pattern is visible today in the Bridgwater Bay area with areas of both sediment accumulation and erosion in a constant flux (Kirby and Parker 1980; Kirby and Kirby 2008). This is because all sedimentary systems are trying to achieve and then preserve an equilibrium profile (or depositional profile) where the available accommodation space is balanced by the amount of sediment supplied. Modelling of the pre-Holocene surface enables an estimation of the total available accommodation space to be made, as well as determining the nature of the submerged basin. Such an approach, shown by Sturt et al. (2013), permits a greater understanding of geomorphological processes and how to model the extent, and rate, of inundation and palaeogeography change.

Somerset Levels and Bridgwater Bay.

The Somerset Levels are known to have very thick Holocene deposits which cover the underlying valleys within which the rivers Parrett, Brue and Axe flow towards the Bristol Channel. While this has been long acknowledged (e.g. Smith 1815; Buckland and Conybeare 1824; Ussher 1908; Poole 1864; Woodward 1876) the first attempt to reconstruct the pre-Holocene (rockhead) surface was provided by Kidson and Heyworth (1976). They used borehole evidence from the coastline between Stolford and Stert, a long north-south borehole transect associated with the construction of the M5 and an unspecified number of other boreholes from the wider area. This model showed four main valleys draining into Bridgwater Bay, with valley bases in excess of -30m ODN around Brent Knoll. The model clearly identified an island between Stretcholt and Alstone, capped by the Burtle Formation, at the mouth of the valleys, with the palaeo-Parrett cutting across the present Stert

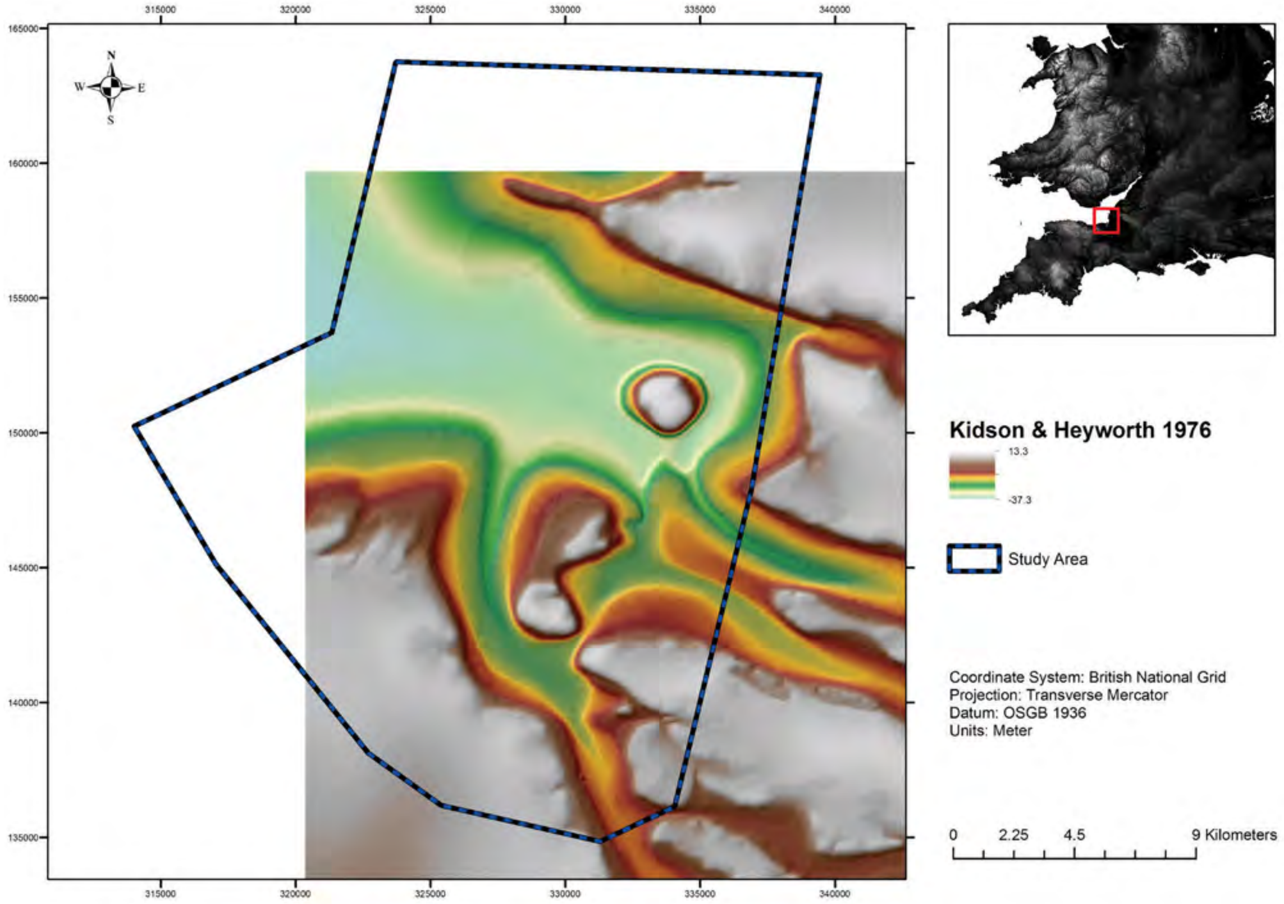


Figure 6.1 Kidson and Heyworth Modelled pre-Holocene Surface (ArcGIS Raster)

Peninsula to the south and entering Bridgwater Channel to the west of present-day Stert village. It is probable that this model contains extensive extrapolation between borehole locations and although it provides a representation of what the pre-Holocene surface may be, it should be utilised cautiously.

An alternative model for the, covering the area between the Mendips and Polden Hills, was provided by Whittaker and Green (1983, 88). This model predicted that the area under East Huntspill was significantly (30m) deeper than that predicted by Kidson and Heyworth and also indicated that the River Brue entered Bridgwater Bay through a narrow channel in the Highbridge area. This narrow channel was determined by two lines of evidence:

- Woodward (1876, 164) quotes W.A.E. Ussher as stating that under the sand of the beach at Burnham, blue Lias Clay may be seen with beds of Limestone.
- Two wells c. 91m north of the Burnham-on-Sea parish Church. These wells, excavated by the Rev. David Davies prior to 1836, and known as the Saline (ST34NW70) and Sulphur (ST34NW71) Springs. Sections recorded in Cameron (1891) and Richardson (1928), revealed a Clay Marl at c. -0.3m ODN in both wells which they interpreted as being Lower Lias.

The stratigraphy of the two wells can be reviewed at nearby (c. 80m SW) borehole ST34NW44. This revealed a similar stratigraphic sequence though, in this case, organic peaty inclusions were found within the lower clay with the underlying Mercian Mudstone Formation encountered at -9.81m ODN. This suggests that the shallower Lower Lias encountered in the Sulphur and Saline Springs was actually the lower marine clays commonly correlated with the Lower Somerset Levels Formation. The observation made by W.A.E. Ussher is more difficult to appraise as the location for this observation is unknown. It is possible that this account might relate to features such as the Chisel Rocks, located c. 3km west of Burnham-on-Sea within Bridgwater Bay, with additional rock exposures, mapped by the BGS as Mercian Mudstone Formation, along the northern edge of the River

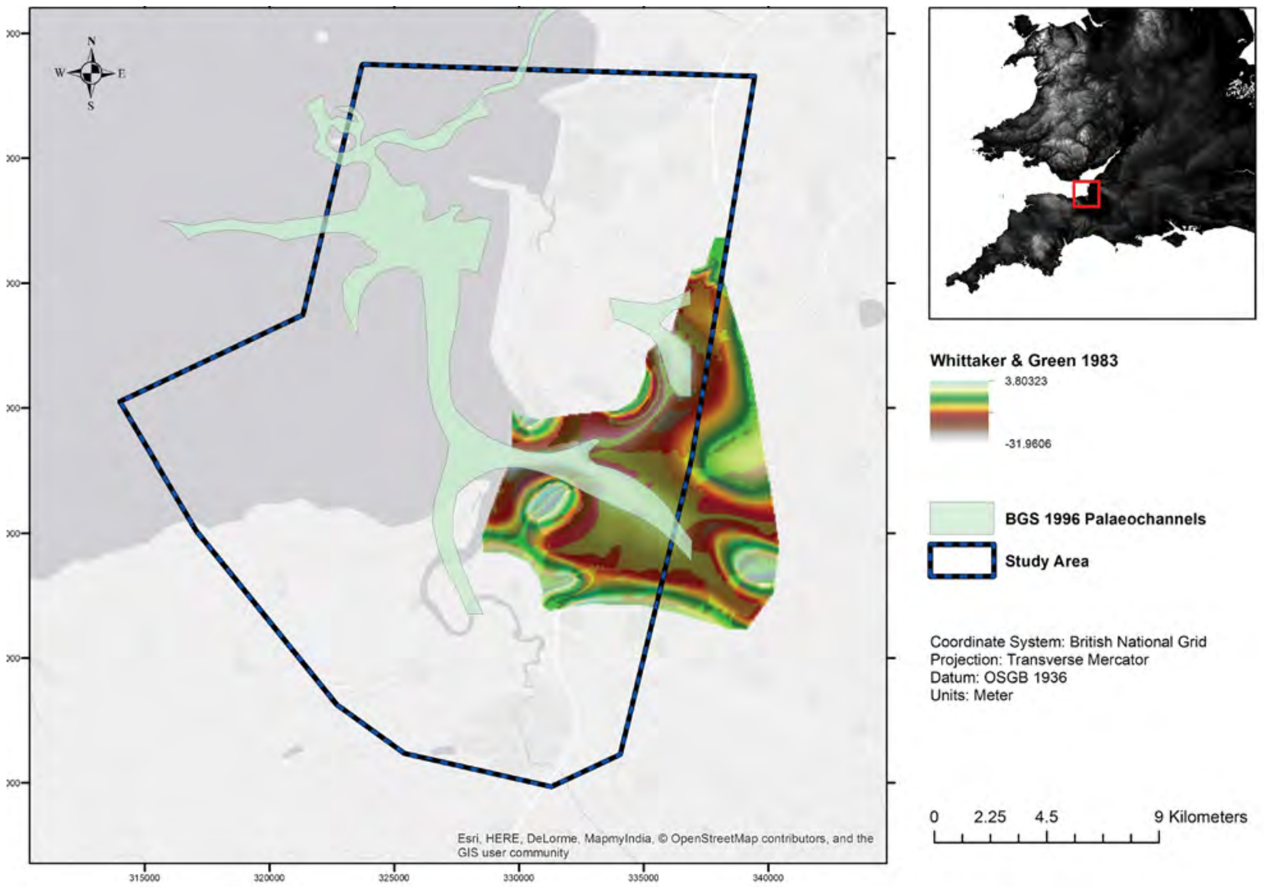


Figure 6.2 Whittaker and Green (1983) Modelled Surface (ArcGIS Raster) and BGS (1996) PreHolocene Surface (onshore) and Late Pleistocene Channels

Parrett approach channel on the south side of Gore Sands.

While the model of Whittaker and Green (1983, 88) overcompensates for the rockhead elevation, it is true that the Mercian Mudstone Formation is found at shallower depths in this area than was suggested by Kidson and Heyworth (1973). This has the implication that draining of the palaeo-Brue would either have been north of Burnham-on-Sea or through a narrow channel along the current course of the River Brue, as postulated by Nash (1973) and Rippon (1995), where a deep tidal inlet is thought to have been present during the Romano-British period. Subsequent mapping by the BGS (1996) included postulated Late Pleistocene drainage routes for both the onshore and offshore area of the inner Bristol Channel. Similar to the previous model by Whittaker and Green (1983, 88) the palaeo-Brue enters Bridgwater Bay along its modern channel course to join the palaeo-Parrett. The channel then turns north and runs parallel to the modern coastline approaching Brean Down before turning northwest towards Steep Holm where it subsequently joins the main palaeo-Severn channel. The pattern of drainage of the palaeo-Axe between Brent Knoll and Brean Down was not postulated, but the most likely route was through a palaeochannel that was recognised just south of Brean Down connecting with the combined drainage from the palaeo-Brue and Parrett. This model also suggested that drainage from the modern River Banwell, which enters the Severn Estuary east of Middle Hope, also flowed south to join the main channel at Steep Holm, encapsulating the drainage of the basins entering both Weston and Sand Bay.

More recently the BGS (Gow et al. 2014) have revised their deposit modelling of the Somerset Levels. This was initially produced as a superficial deposit model under the Landscape Evolution team, part of the Climate Change programme during 2009/2010, but was 2014 as part of the Geology and Regional Geophysics Programme to provide a basic, low-resolution, geological framework model in response to the flooding crisis in the region. The model is based upon the BGS boreholes within the area and therefore is constrained by available coverage which, for the western Somerset Levels, is limited to clusters of data at Burnham-on-Sea,

along the M5 corridor and around Bridgwater, with good coverage around Weston-Super-Mare. The modelling did interpolate the buried Holocene deposits, notably demonstrating previous assertions of a laterally persistent peat found close to Ordnance Datum. The model was extended to a maximum depth of -30 m ODN and demonstrated that Holocene deposits did not reach, nor exceed, this depth, questioning previous suggestions by both Kidson and Heyworth (1976) and Whittaker and Green (1983) for much deeper valley incision in the Brent Knoll area. However much of the model was driven by existent BGS geological and superficial deposit mapping of the area and did not extend to cover much of Bridgwater Bay.

Current Study

For the purposes of the modelling of the pre-Holocene surface, three stratigraphic units were defined:

- Pre-Holocene, to include all Palaeozoic and Mesozoic geology and Pleistocene deposits including the Burtle Formation
- Holocene alluvium, including all deposits within the Bridgwater Bay mud patch, coastal Aeolian and gravel beach deposits, Lower, Middle and Upper Somerset Levels Formations (Haslett et al. 2001; and corresponding deposits in the Weston area) and peat and alluvial deposits exposed along the foreshore.
- Made Ground: areas where the Holocene / pre-Holocene sediments have been truncated by later development, or built upon.

While a gross simplification of the stratigraphy of the study area (as outlined in Chapter five), this simplification was deemed sufficient to reconstruct the pre-Holocene surface to inform the modelling process and test the reliability of pre-existing models (Kidson and Heyworth 1976; Whittaker and Green 1983; Gow et al. 2014). The use of more detailed stratigraphic categories would have been unworkable across the large dataset due to considerable variation in the level, and precision, of sediment description between different studies and practitioners, with variations in the precision of recording organic deposits observed by Hawkins et al. (1989, 285). Most notably the offshore surveys rely upon geophysical sub-bottom profiling and / or depth probing with little / no accompanying stratigraphic data available. Conversely onshore there are large gaps within the data distribution and, in many instances, data is only available in broadly defined classifications (e.g. drift, alluvium, clay, etc) which do not permit direct correlation between neighbouring sample locations. While dominant features such as the extensive peats separating the Lower and Upper Somerset Levels Formations are widely recorded, the poor spatial distribution of data across areas such as the palaeochannel network of the River Siger (Brunning and Farr-Cox 2014; Brown and Brunning 2014) would have resulted in extrapolation of such deposits across wide areas where they are likely to be absent. Mapping of key geoarchaeological features, such as palaeosols, would also have led to bias in the distribution of these deposits to areas where specific types of site investigations (such as archaeological excavation or geoarchaeological coring) had already taken place, particularly where shallow buried deposits along the margins of the Somerset Levels can be easily accessed through trenches.

Consequently it was preferred to use the simplified stratigraphic units stated above to ensure that all data could be utilised within the modelling and to achieve the aim of generating a pre-Holocene surface across the large study area.

Data sources

For the Bridgwater Bay area data coverage is uneven. While this area has been subject to investigations in relation to a proposed Severn Barrage scheme (e.g. Evans 1981) it has not been possible to source much of the original survey data, with the exception of those published independently (e.g. Evans 1982). However the interpretative report (Evans 1981) does outline the thickness of deposits overlying the Mesozoic geology and, consequently, the topography of the pre-Holocene surface across a wide area. Elevations for the topography of the pre-Holocene surface was extracted to provide 535 point estimates.

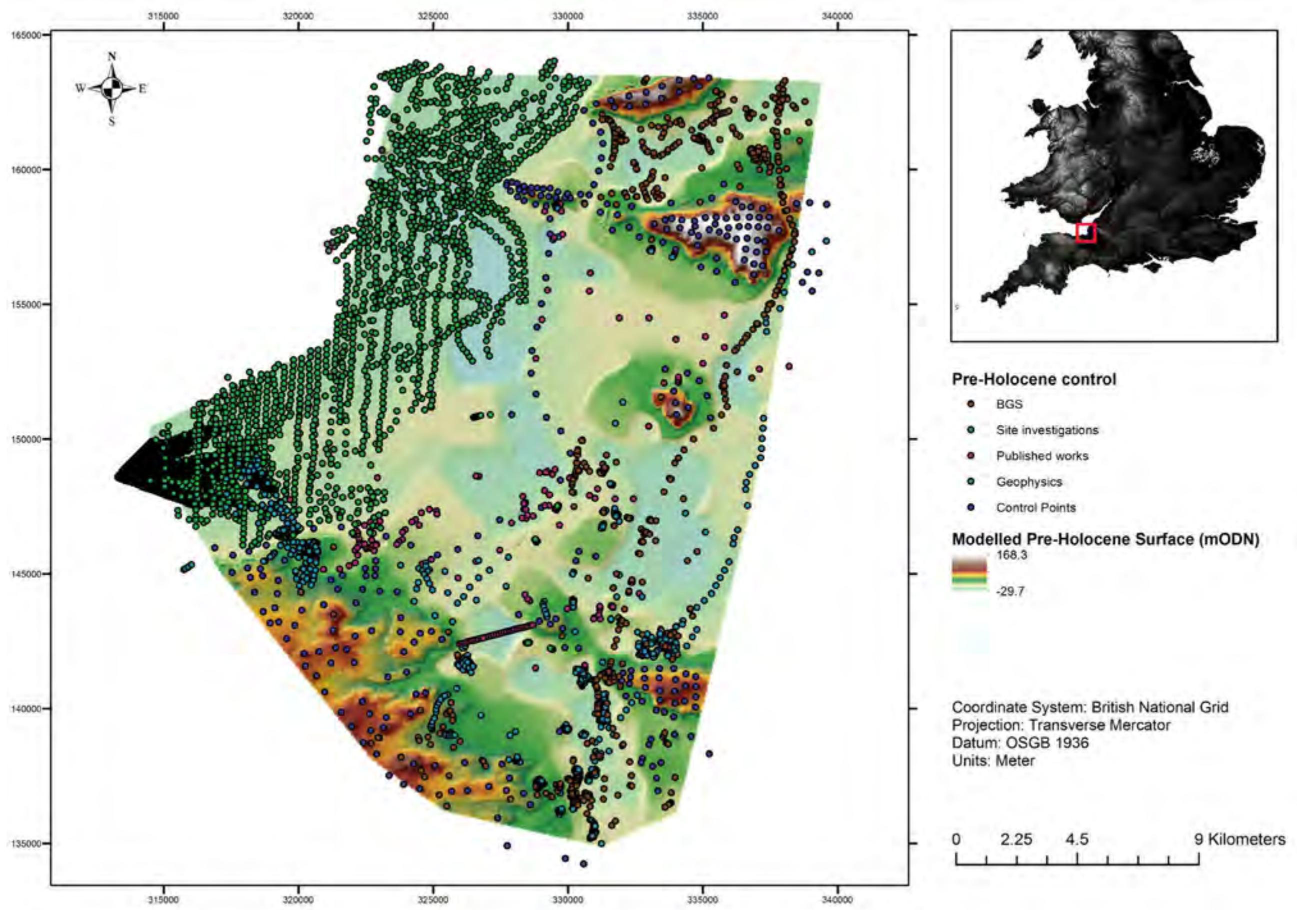


Figure 6.3: Data distribution – filtered by type: Geophysical pick, BGS, Site Investigation, Published Data, Ctrl Points

Between 1972 and 1976 the Institute of Oceanographic Sciences undertook an extensive study of the Bridgwater Bay area (Kirby and Parker 1980) seawards of the Berrow and Stert Flats. The purpose of this study was to understand sediment mobility within the Bay and to quantify the thickness of the settled mud areas. Results from the three surveys, depicting sediment thickness, were collated into a single point dataset and the results smoothed to take account of annual variations in accumulation / erosion of the Bridgwater Bay mud patch. To estimate the underlying topography of the area the thickness point data was subtracted from VORF corrected modern bathymetry to produce estimates of the pre-Holocene surface and a total of 1035 data points. An additional survey by Mantz and Wakeling (1981) around Hinkley Point, covering c. 21 km^2, provided an additional 59 data points, though this survey (like most others in the area) suffered from large areas of shallow gas inhibiting sub-bottom profiling of the pre-Holocene surface across large areas (c. 40% of survey area providing no penetration of the mud patch sediments). Recent sub-bottom surveys around Hinkley Point (reported in Dix et al. 2015), covering 17km^2, provide a more detailed interpretation of the buried pre-Holocene surface (beyond areas of shallow gas). Sampling of this surface has provided an additional 3395 data points. Further data from geophysical surveys was derived from bathymetric surveys of the River Parrett where Lower Lias and Middle Mudstone Formation bedrock is visible in some areas of the main channel and its approaches. The Bridgwater Bay geophysical datasets were ground-truthed by borehole data from the Hinkley Point C investigations (Sturt et al. 2014; 2015) with additional offshore borehole data from Mantz and Wakeling (1981), Kirby and Parker (1980), Long et al. (2002) and data recently released within the BGS Offshore GeoIndex.

The onshore deposit modelling is derived solely from boreholes unevenly distributed across the study area. The data used includes 702 boreholes derived from the BGS Onshore GeoIndex, 66 locations published by Kidson and Heyworth (1973; 1976), 14 cores along the Axe Valley by Haslett et al. (2001), a further 152 data points from other published studies (including Bell 1990; Hughes 1980; Hollinrake and Hollinrake 2002; 2007) and 911 investigations (boreholes and trenches) from unpublished site investigation reports. Many of the

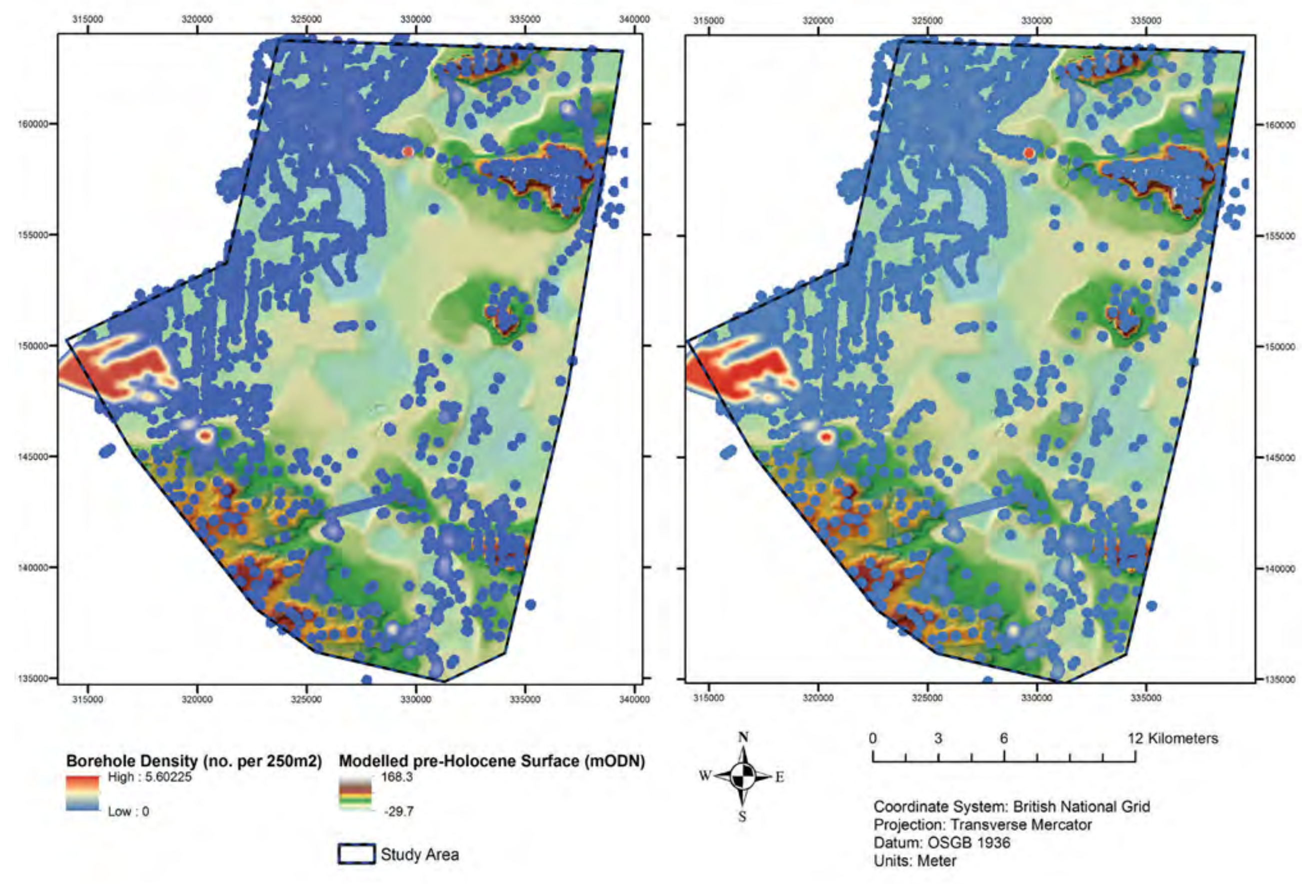


Figure 6.4 Data density of existing boreholes. Left: Boreholes that contact pre-Holocene surface. Right: All boreholes used to produce the deposit model.

coring locations indicated in the work of Kidson and Heyworth (1973; 1976) are unpublished and attempts to locate Prof. Clarence Kidson's field notes, or any other archive material, were unsuccessful. Similarly it was not possible to source the additional borehole data around Brent Knoll, reported in Haslett et al. (2006), for inclusion in the deposit model.

Away from the Levels data coverage was spatially uneven so it was necessary to introduce control points to limit the effects of interpolation over large areas within the deposit model. A total of 281 control points were introduced into the dataset to constrain the margins of the Holocene infill within the Levels. These were determined using the BGS 1:50000 geological and superficial deposit mapping and assigned an arbitrary sequence depth of 0.3m. Altitudes for each of these locations was extracted in ArcGIS 10.2 from OS Terrain 50 data.

The full dataset consists of 1907 boreholes, 5055 geophysical survey data points and 281 control points, providing a total of 7243 data points with which to model the pre-Holocene surface of the area.

Modelling

The data was stored within an Access (MDB) database. All elevation data is related to Ordnance Datum (mOD) with locations stated using a British National Grid numeric 12 digit reference. For all historic boreholes the quoted well head elevations, if provided, were cross-referenced to modern topography (using OS Terrain 50 data) to identify any outliers. Where borehole locations were reasonable constrained (to within 10m or 100m in areas with very poor data concentrations) but altitudes were absent, these were derived from the OS Terrain 50 dataset.

Deposit modelling was run within RockWorks 15, using the interpolation method of Inverse Distance Weight-

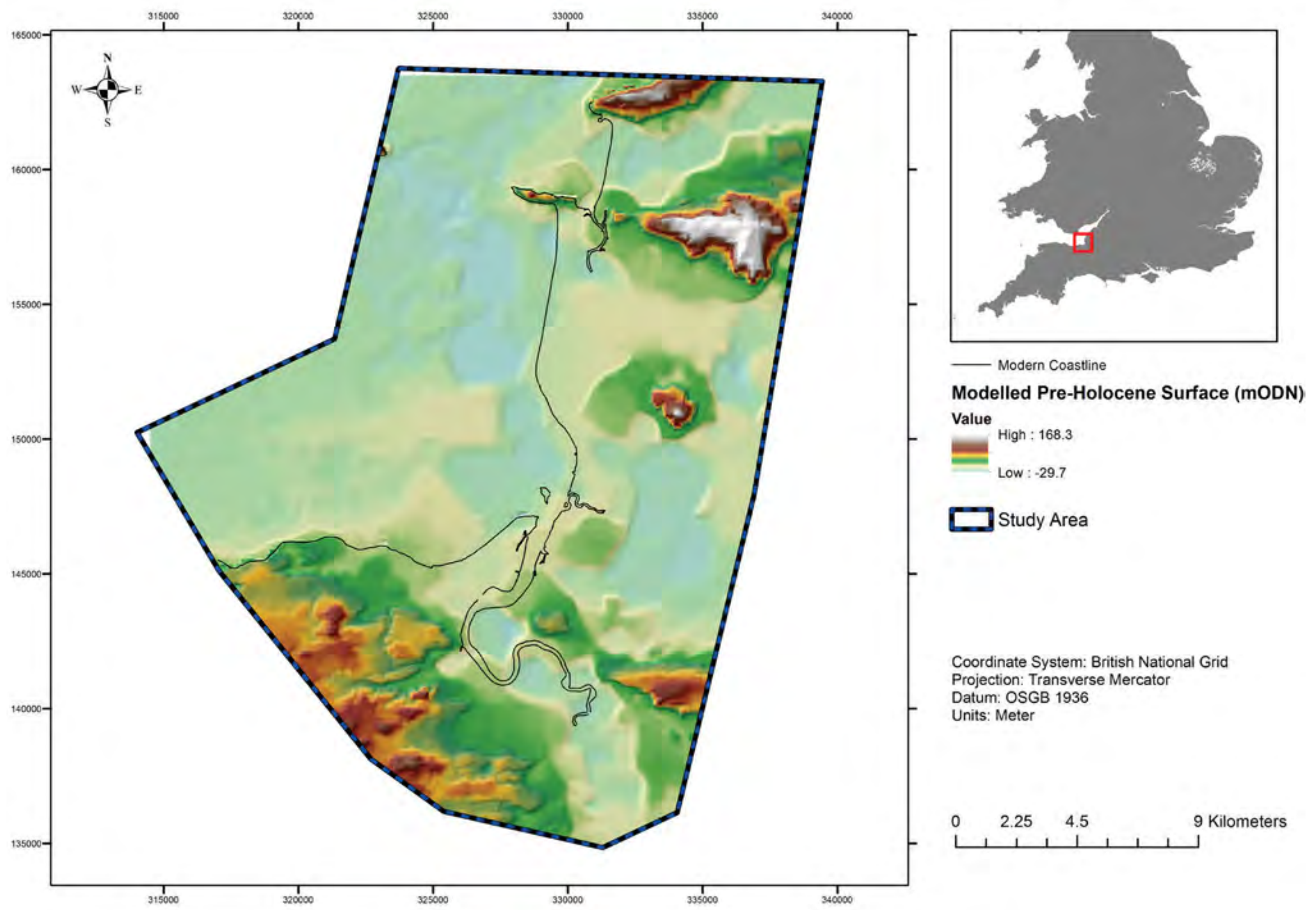


Figure 6.5 Model of Pre-Holocene surface

ing, and a node spacing of 50m. The surface of the model was constrained using the OS Terrain 50 dataset for onshore and assimilated bathymetry for the offshore area (see Dix et al. 2015), VORF corrected to Ordnance Datum (see Iliffe et al. 2006; 2007). Both surfaces were integrated into a single surface within ArcGIS 10.2 and incorporated into RockWorks 15 as an ASCII XYZ dataset. An isochore map, to calculate true vertical thickness of the Holocene alluvial infill, was also calculated (Figure 7.1). Appendix 5 includes cross sections of the model outputs.

Results

The resultant dataset, whilst providing greater coverage than the previous models for the area, does show spatial unevenness, most notably across the Berrow and Stert Mud Patches and the area west of Brent Knoll between Burnham-on-Sea and Brean (Figures 6.3 and 6.5).

Palaeo-Pawlett

The modelled position of the palaeo-Parrett largely matches that defined by Kidson and Heyworth (1976), though the valley base is wider than previously envisaged. Data density west of Chilton Trinity is low with few coring locations through the centre of the palaeochannel reaching underlying geology. The previous model of the palaeo-Pawlett dissecting the Stert Peninsula is supported, running c. 1 km west of the modern channel. The modelled pre-Holocene surface indicates a submerged ridge running between the Polden Hills and Pawlett Hill, indicating that the rivers Parrett and Brue were separate basins during the Late Devensian.

Palaeo-Brue

The modelled pre-Holocene surface suggests that the palaeo-Brue did not flow through the gap between the Burtle Formations at Stretcholt and Alstone. While data from this area is limited, the concentration of investigations undertaken by Kidson and Heyworth (1973; 1976), coupled with investigations associated with the

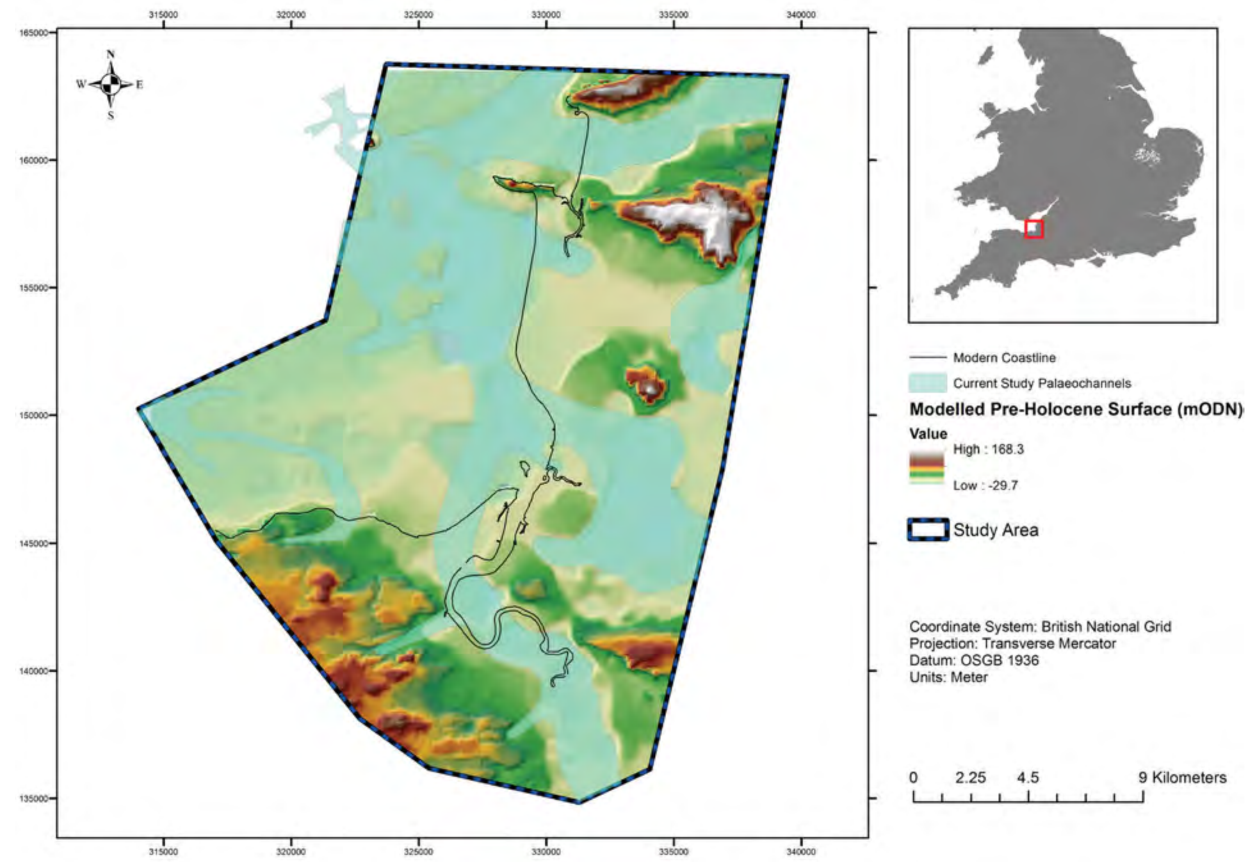


Figure 6.6 Palaeochannel vs Modelled Pre-Holocene surface

development of the Stert wetland reserve, do seem to support the suggestion that there was no connection at the beginning of the Holocene. However two boreholes north of Pawlett Hill (ST34NW24 and ST34SW44) do show a deepening of surface to c. –12 m ODN.

Along the northern edge of the Polden Hills a submerged Lower Lias islands is known at Walpole (Hollinrake and Hollinrake 2002; 2007) that appears to have been a focus of prehistoric activity, similar to some of the Burtle Formation islands to the south and east. The deposit modelling suggests that the island at Walpole is not an isolated occurrence with further islands possible to the east beneath Puriton Level.

To the east lies the main basin of the palaeo-Brue. Kidson and Heyworth (1976) suggested two separate channels, separated by a ridge passing beneath East Huntspill then turning north towards Edithmead. However two boreholes at East Huntspill (ST34NW23 and ST34NW25) show the underlying geology between -21 and -24m ODN (compared to c. -12m ODN suggested by Kidson and Heyworth 1976). By comparison the model of Whittaker and Green (1983) places their channel beneath East Huntspill between the two channels identified by Kidson and Heyworth (1976). However this doesn't take into account boreholes associated with the M5 investigations to the south of their channel which show similar depths of the pre-Holocene surface (below c. -20 m ODN) east of Alstone. The spread of BGS boreholes that reach the underlying geology surface does indicate problems with both previous models and seems to suggest a large depression within the valley bounded by the Polden Hills in the south, Burtle Formation outcrop at Burtle and Isle of Wedmore in the east, Brent Knoll in the north, and Burtle Formation and elevated geology surface between Huntspill and Highbridge in the west. Any extension of this basin northwards around the eastern edge of Brent Knoll towards the palaeo-Axe, as postulated by Kidson and Heyworth (1976), cannot be determined from the current data, though is likely. The deepest borehole in this area, ST35SE11, reaches c. -11 m ODN at its base where it was terminated within a very sandy silt.

The course of the palaeo-Brue into the Bridgwater Bay area is likely to be located around Burnham-on-Sea, similar to the River Siger (Brunning and Farr-Cox 2006), as postulated by Kidson and Heyworth (1976), rather than the more southerly route proposed by Whittaker and Green (1983). It is postulated that this channel met with the palaeo-Parrett west of Burnham-on-Sea possibly in the Gore Sands area at the south of Berrow Flats. A deep borehole (ST34NW49) at the mouth of the modern River Brue does suggest a deep channel present, c. -13m ODN, which might relate to the later deep inlet postulated by Nash (1973).

Palaeo-Axe

A deep basin is visible east of Brent Knoll that can be traced northwards into the Lox Yeo River Valley which flows south from the Mendips. However this pattern is determined by the north-south distribution of boreholes along the M5 corridor. The modern River Axe in this area is canalised south of Loxton with the Old River Axe flowing south at Crab Hole, then west to join the Mark Yeo just north of Rooks Bridge before travelling northwards to rejoin the River Axe southwest of Loxton near White House Farm. Whether the palaeo-Axe (and Lox Yeo) originally flowed west similar to the current course of the River Axe, or south around the edge of Brent Knoll to join the palaeo-Brue, cannot be determined based upon the available data. Certainly the latter course is a strong possibility and likely to have been formed as a result of high energy discharge from the Mendip hills during the Late Devensian.

Haslett et al. (2001) undertook coring along the Axe Valley but never cored deeper than -5m ODN. Therefore it is not possible to postulate the pre-Holocene surface topography in this area. However two borehole investigations close to the coastline do define the depth of this pre-Holocene surface. During construction of the Brean sea defences R. Kirby (see Long et al. 2002) reports deep alluvial deposits. In BH41, c. 300m south of Brean Down, Holocene alluvium was recorded down to a depth of -30m ODN. In BH42, close to Brean Farm, Holocene alluvium was recorded down to -21m ODN. A further borehole on the bank of the River Axe, close to the Brean Cross Pill (c. 330830 156170), encountered the underlying geology at c. -20m ODN, with Hawkins et al. (1989) noting that a previous borehole, taken by the Somerset River Authority in 1967, c. 100m away encountered bedrock at a depth of 22.5m (c. -16m ODN based upon estimated modern surface). While this

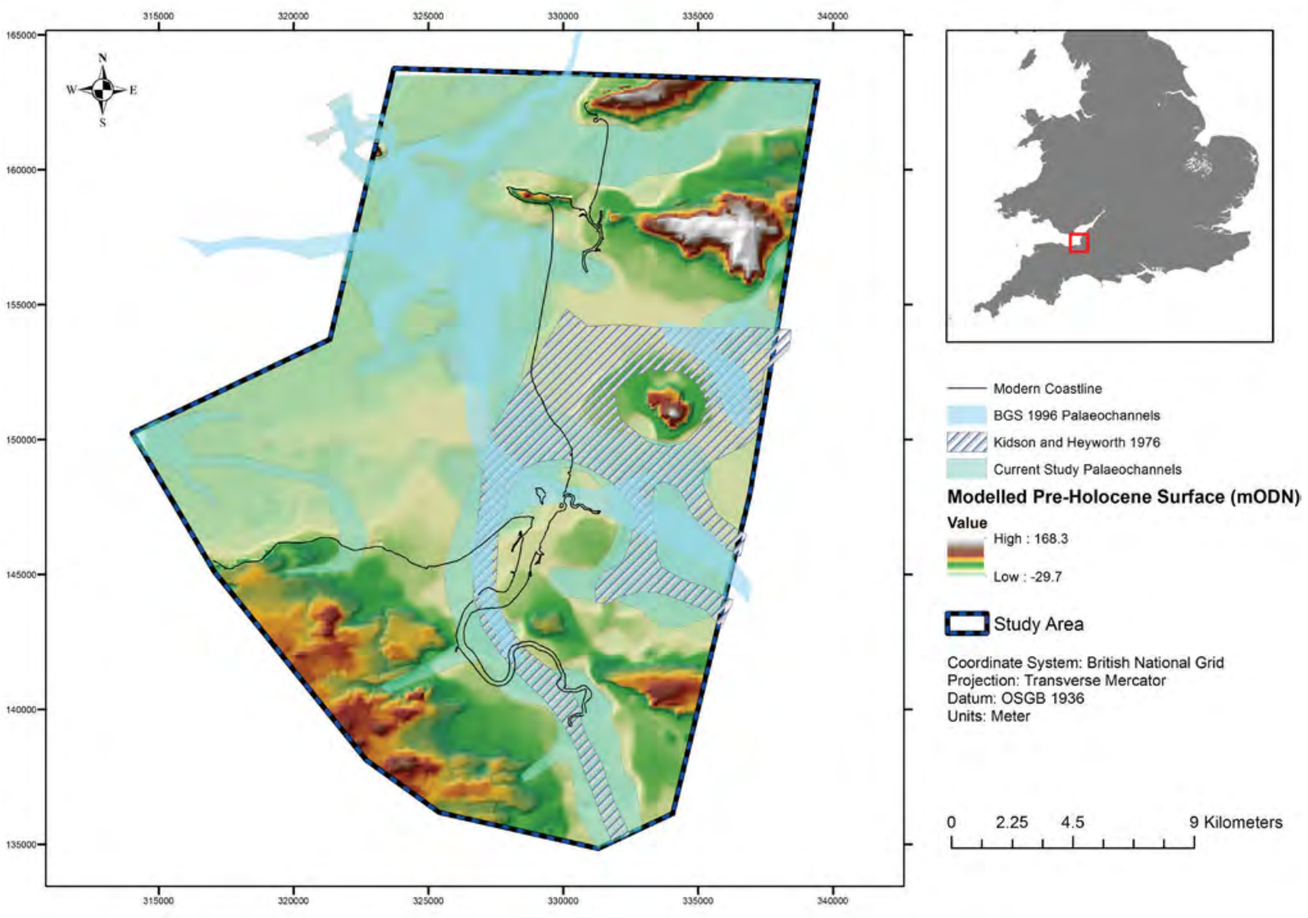


Figure 6.7 Comparison of modelled palaeochannels

only represents a small number of data points close to the coast, it does indicate that a topographic deep does extend at least 1.3km into the Somerset Levels in this area to the edge of Bleadon Levels and the modern course of the River Axe.

The current course of the River Axe enters Weston Bay at Uphill through the gap between Brean Down and Bleadon Hill. However this connection is likely a response to the development of the windblown dune system along the Brean coastline impeding drainage. A borehole from the mouth of the modern River Axe (ST35NW7) shows that Mercian Mudstone Formation was encountered at c. -10m ODN, overlain by Holocene alluvial deposits. This would suggest that a ridge, running between Brean Down and Bleadon Hill, exists below the modern River Axe but, at the beginning of the Holocene, would have stood c. 10-20m above the base of the adjacent basins.

Weston Basin

The Weston Basin of the North Somerset Levels has been largely overlooked with regard to the Holocene valley infills in previous studies. The current study demonstrates that similar thicknesses of Holocene deposits exist within this basin as they do in the main channel areas of the Somerset Levels to the south.

Drainage across Bridgwater Bay

Palaeochannels crossing the Bridgwater Bay area closely resembles that mapped by the BGS (1996). Both studies showa northward flowing palaeo-Parrett channel, parallel to the modern coastline, heading towards the western tip of Brean Down before turning northwest towards Steep Holm and the palaeo-Severn. The underlying Lower Lias and Mercian Mudstone Formation topography shows a series of islands within the main channel area. Between Brean Down and Steep Holm the drainage of the Weston Basin meets that from the Somerset Levels.

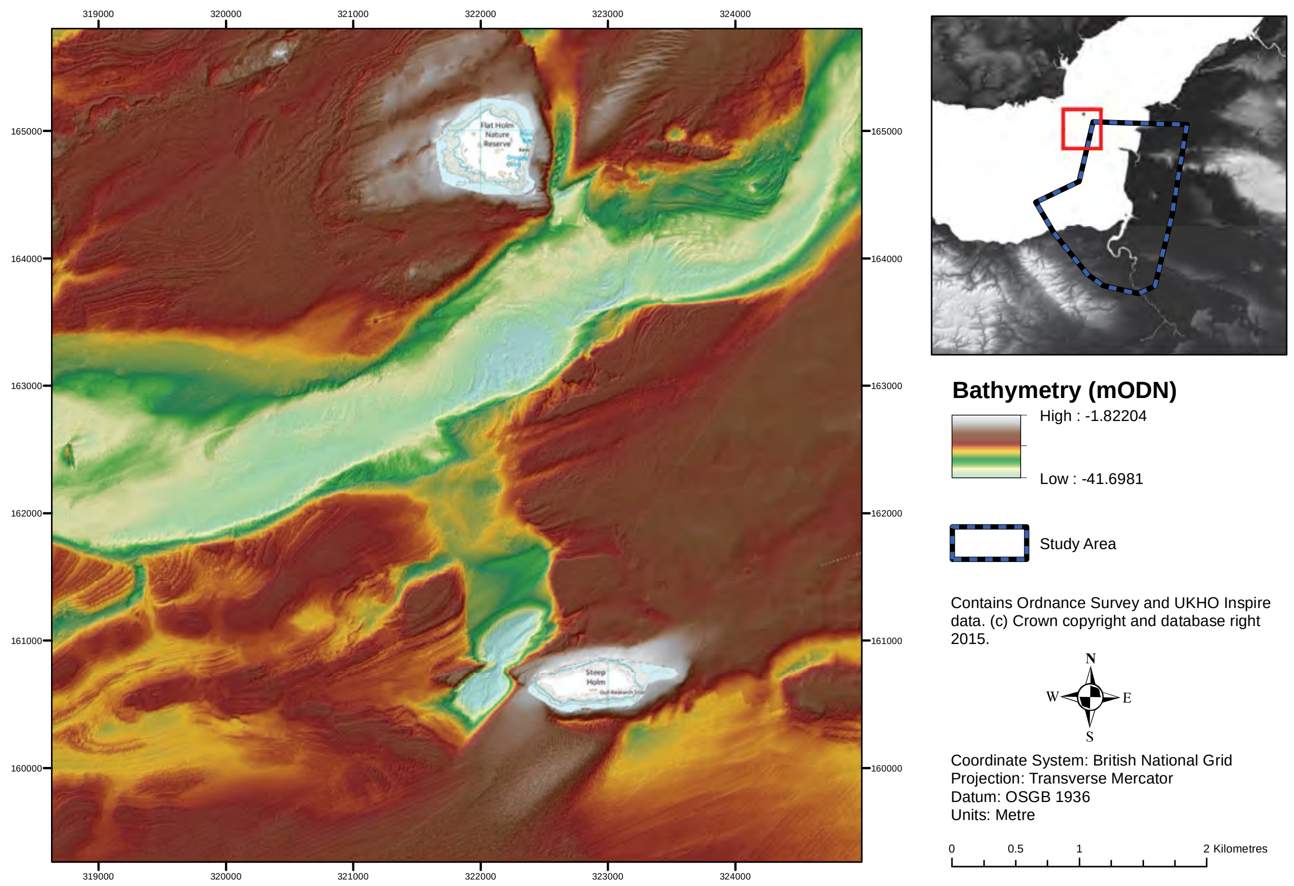


Figure 6.8 Palaeo-Severn Channel

Dix et al. (2015) recently provided an overview of the submerged drainage pattern within the Bristol Channel. From the Isles of Flat Holm and Steep Holm westwards, bedrock outcrops over large tracts of the Bristol Channel floor with the palaeo-Severn channel clearly defined. The palaeo-Severn in this area has a typical width of 1-2 km, 20 m deep, and thalweg depths ranging westwards from -32 to -42 m ODN. The channel margins are steep with gradients up to 13^{o} in some localities (c. 1:5), with narrow benches < 600m wide, at altitudes of -28 to -32 m ODN, flanking the channel on both north and south margins before entering a flat valley floor.

On the northern flank of the palaeo-Severn a series of meandering, dendritic, tributary channels, are present intersecting the palaeo-Severn at almost 90^{o}. By contrast, the bathymetry of the southern margin of the palaeo-Severn is distinctly different with few tributaries clearly identifiable from the innate irregular topography of the folded and eroded Lower Lias bedrock platform. West of Steep Holm a clearly defined channel is present running north towards the palaeo-Severn. At its narrowest point, this channel measures c. 200m across immediately west of Steep Holm, with a thalweg of -36m ODN, where it passes between outcrops of Carboniferous Limestone protruding from the seabed. Northwards the channel widens to c. 1km for the final 2.8 km stretch to meet the palaeo-Severn.

The bathymetry suggests that the channel draining the North Somerset Levels passes east of Steep Holm to meet the main drainage from the Somerset levels on the island's southern margin. However drainage around the eastern side of Steep Holm is obscured in the bathymetry by gravel deposits, though channels entering the main channel are visible in two locations north of Steep Holm. This implies, certainly for the Late Pleistocene and Early Holocene, that the drainage of the Somerset Levels and North Somerset Levels were both part of the same river catchment entering the palaeo-Severn channel near Steep Holm. This general pattern matches that predicted by the BGS (1996).

A possible tributary draining into the palaeo-Severn from the southern edge is located c. 3.7km west of the main channel by Steep Holm, measures c. 80m wide, and has formed along the natural folds in the Lower Lias. However there can be little doubt that the majority of the Somerset Levels drained into the palaeo-Severn through the main channel beside Steep Holm, with the pre-Holocene surface modelled for the Bridgwater Bay area aligned on the channel visible in the bathymetry data.

For the area north of Hinkley Point, possibly including Stolford, a drainage catchment separate from that of the Somerset Levels might be present. Possible east-west oriented palaeochannels, with widths of <250 m and depths of <1.5 m, were revealed incised into the Lower Lias Lithology. These palaeochannels flow westwards towards the undulating relief of the bedrock plain that dominates the area to the south of the palaeo-Severn channel. These channels extend beyond the study area but it is possible that these channels might continue westward to join a series of palaeochannels visible in the bathymetry 5km north of Blue Anchor Bay. This links with a clearly defined drainage network c. 6.5km north of Selworthy Beacon which incorporates the drainage between Porlock and Minehead. Recently acquired bathymetric survey data of this area by the UKHO in 2014 does not clearly demonstrate the presence of a westward flowing channel from the Stolford area and, due to the low density of data from Stert Flats, north of Stolford, it is not possible to dismiss the likelihood that there is a connection with the palaeo-Pawlett north of the Stert peninsula.

Future data requirements

While the deposit model presented in this study provides the most detailed representation of the pre-Holocene surface for the western Somerset Levels and Bridgwater Bay area to date, it still contains a number of areas where interpolation is required over large areas where data is absent. To enable future testing of the current pre-Holocene surface model, and most notably the position and age of the drainage basin, the following areas are identified as priority areas where targeted investigations could be of great benefit.

Relationship of Stolford to the palaeo-Parrett

There is an absence of data points for the area of Stert Flats. While this area was investigated by Kidson and Heyworth (1973; 1976) it was not possible to locate where this data may reside after enquiries with the Aberystwyth University. However Kidson and Heyworth (1976) do show that a pair of looping borehole transects, extending north to c. 324830 147400, coincide with a northward extension of the proto-Stert peninsula. While

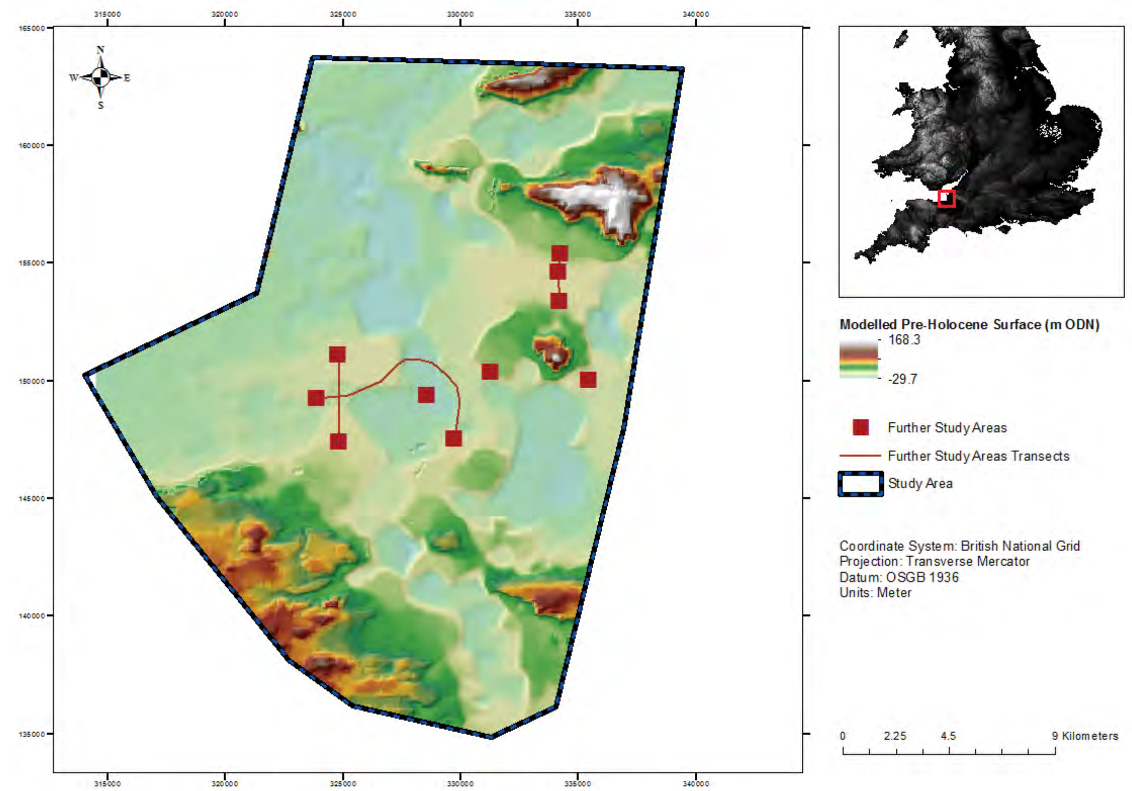


Figure 6.9 Areas of future investigation

this doesn't provide conclusive proof of a promontory, in this location, separating the River Parrett from the Stolford valley, it does suggest that the latter continued northwards out to this point. Beyond these nearshore coring locations there is a c. 3km gap across Stert Flat until the datasets of Evans (1981) and Kirby and Parker (1980) are encountered. It is therefore possible that an eastward draining channel into the palaeo-Parrett was located within this gap. Therefore an alignment of boreholes / sub-bottom geophysical surveys (if problems associated with the shallow gas blanket can be overcome) between c. ST 24830 47400 and ST 24800 51100 would help to establish whether there was a drainage connection or peninsula within this area.

Similarly, site investigations by Kidson and Heyworth (1973; 1976) between the tip of the Stert peninsula and course of the River Parrett along the edge of Gore Sand can also not be located. Again Kidson and Heyworth (1976) suggest the course of the palaeo-Parrett passes west of their coring locations in this area, including Stert Island, which may suggest a northward extension of the Stretcholt - Pawlett Hill peninsula. A single core reaching the pre-Holocene surface, centred on c. ST 28600 49400, would help the test the interpretation of Kidson and Heyworth (1976) and establish the eastern edge of the palaeo-Parrett Channel. Similarly there is a need to establish the extent of the palaeochannel, and connection with the palaeo-Brue / Siger, in the Burnham-on-Sea area. A sub-bottom geophysical survey along the present River Parrett channel approach should avoid the issue of the shallow gas blanket and would help clarify both the presence, and extent, of shallow geology in the base of the channel and the location, and dimensions, of the northward flowing palaeo-Parrett. Such a survey might also identify the inflowing channel of the palaeo-Brue / River Siger. A survey, on favourable tides, starting at c. 323880 149280 and continuing to the mouth of the River Brue, c. ST 29750 47560, would help clarify the pre-Holocene topography of this area of Bridgwater Bay.

Origin of the River Siger

Brown and Brunning (2014) postulated that the origin of the River Siger might be in the Early Holocene, with the alignment of the River Siger within LiDAR resembling the location of the course of the palaeo-Brue within the pre-Holocene surface. There is therefore a requirement to obtain a pair of boreholes in the area to identify both the full thickness of the Holocene deposits in this area, as well as establish the thickness of the River Siger deposits encountered by Brown and Brunning (2014). Coring north of Stodden's Road, Burnham-on-Sea, centred on c. ST 31290 50400, targeting the deepest part of the River Siger, may also reveal organic deposits at depth suitable for dating.

Course of the River Axe

It is probable that the palaeo-Axe flowed westward into Bridgwater Bay where it joined the channels from the palaeo-Parrett and Brue. However there is a need to establish where this channel lay - either north close to the edge of Bleadon Hill, or further south close to Brent Knoll. Coring of the full Holocene sequence in three location, aligned north-south across this area, would help to establish the most likely route of this channel: ST 34220 53370; ST 34180 54630; ST 34280 55400. This could be coupled with, or substituted by Cone Penetration Test (CPT) or Resistivity Tomography geophysical survey if sediment sample recovery is not required (e.g. date deeper organic layers). A second channel course, east of Brent Knoll, can also be envisaged and could be evaluated by a single borehole to establish the depth of bedrock north of Rookery Farm Cottage, centred on c. 335460 150040. This location is also centred over the northern tributary feeding the River Siger, which would permit an evaluation of both the age, and thickness, of the river deposits that drain the northern part of the Somerset Levels into the River Siger system.

Chapter 7
Predictive Modelling: Method and Results

Introduction

As discussed in chapter three, following a detailed literature review and expert panel meeting, the decision was made to adopt a geoarchaeologically focused deductive approach for the study area. The reason for this was the relatively sparse nature of archaeological information/interventions within the project boundaries, and for offshore regions in general. As the indicative map of archaeological value (IKAW)case study in chapter three made clear, this indicated that any inductive model would be highly problematic, and, following Wheatley (2004), potentially detrimental to archaeological understanding. More positively chapters three, four, five and six, have clearly established that a geoarchaeologically focused deductive model does have a demonstrable value. Through charting depths of deposit and landscape change through time it is possible to better appreciate where deposits may survive intact, and facilitate sampling of them.

This chapter provides an account of the approach developed as a part of this project and the results gained. It emphasizes the importance of acquiring high quality geotechnical, geophysical, palaeoenvironmental and chronometric data. These data directly impact on the quality of any modelling work undertaken, be it inductive or deductive in nature. Furthermore, as Westley and Bailey (2013, 14), Bell and Warren (2013, 43) and Sturt and Van der Noort (2013, 51) have made clear, archaeological potential extends beyond location of sites and recovery of artefacts, to include all lines of data that help us to understand the changing contexts of human life. As such, there is no contradiction in calling for an improved understanding of environmental sequences in order to better understand the archaeological record. Through developing core datasets such as these we improve our ability to link onshore to offshore sequences, and to account for regional variation in depositional sequence which may impact on the survival of artefacts.

The model described below is not intended as a template to be adopted more widely. There are elements of this model which were trialled and tailored to local conditions and histories of research (to include the 'deductive' element). This being said, there are steps taken within the modelling process which are seen as more widely applicable. Where appropriate these have been highlighted in the text.

Methodology and Outputs

The models for this project were produced within ESRI's ArcGIS 10.2.2 and Rockware's Rockworks 15 software packages. The method for the model's creation was relatively straightforward and deliberately modular in nature. This allows for different elements of the model to be included or excluded depending on preference. This was done to ensure that no matter what the outcome, parts of the modelling element of this project could be used to inform later work. It effectively allows for increasing or decreasing use of deductive elements within the model. Additional Cartesian outputs from each step are given in appendix 5.

Step 1: Creation of a combined topographic and bathymetric model of the current Earth's surface

Fifty metre raster resolution topographic data (Terrain50) was downloaded from the Ordnance Survey for the terrestrial part of the study area. This was then merged with Civil Hydrography Programme (CHP) and United Kingdom Hydrographic Office (UKHO) bathymetric data, converted from Chart Datum (CD) depths to Ordnance Datum depths via the vertical offshore Reference Frame (VORF; Liffe 2007). This gave a seamless 50x50m resolution grid of the current topography and bathymetry of the study area and wider environs.

This mid-to-coarse grained resolution of topographic data was selected in preference to merging smaller areas of higher resolution lidar and swath bathymetry with the 5m resolution (Terrain5) data. Whilst this would have produced a more aesthetically pleasing output, and a more accurate representation of the modern terrain, it would have exceeded the output resolution achieved by the deposit model, and significantly increased processing time.

Step 2: Isochore creation

As noted in chapter three, deposit modelling was determined to be the essential basis for any model of potential. Furthermore, it allowed a secure method through which to link onshore and offshore records (discussed in chapters five and six).

The isochore (total sediment thickness, discussed in chapter six) generated within Rockworks was imported into ArcGIS 10.2 as a raster grid at 50m resolution. Point data for each sample location (boreholes, cores etc.) were also imported along with their attribute data (ID elevation, depth, lithology, stratigraphy).

Step 3: Generation of Pre-Holocene Surface Model

In order to model change through time, the isochore data was used to backstrip sediments from the model of the current topographic surface. As discussed by Sturt et al. (2013, 3969) and Westley et al. (2014, 426) due to the fact the thickness represented by the Isochore relates to Holocene sedimentary infill, by subtracting the isochore values from current topographic surface you can generate an approximation of the pre-Holocene land surface (shown in figure 7.1 below). This surface in turn permits the subsequent steps in the modelling process.

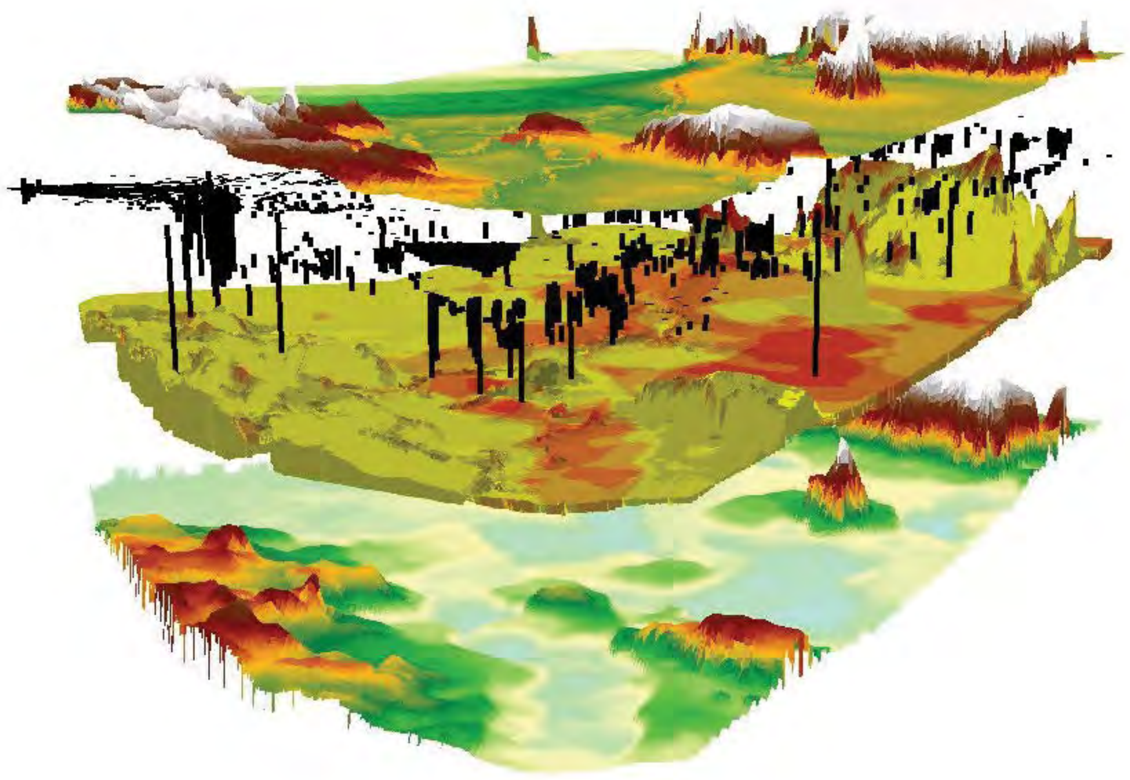


Figure 7.1 Image showing the current topography and bathymetry of the study area, overlying the borehole records, isochore (indicated by red surface) and modelled pre-Holocene land surface created in ArcScene 10.2.2, with a vertical exaggeration of 10. © Crown Copyright and Database Right [2015]. Ordnance Survey (Digimap Licence). The bathymetric data products have been derived from the EMODnet Bathymetry portal - http://www.emodnet-bathymetry.eu. and UKHO INSPIRE Open Government Licence

Step 4: Glacio isostaic adjustment (GIA) modelling of inundation history

With the back-stripped pre-Holocene surface created it is possible to generate high resolution palaeogeographic models of the study area. Following the method described by Sturt et al. (2013) data points were extracted from Bradley et al's (2011) GIA model at 500 year intervals. These points were used to generate raster elevation surfaces indicative of the 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. Using the raster maths tools within ArcGIS, these surfaces were then batch processed to adjust the elevations of the pre-Holocene land surface model. The result was palaeogeographic renderings from 20 kya through to present day at 500 year intervals, a selection of which are shown in figure 7.3 below.

While an improvement in our understanding of changing palaeogeography and the context of human activity for the study area discussed in chapter five, a number of caveats still need to be borne in mind when looking at the outputs. As discussed by Sturt et al. (2013) and Westley et al. (2014), while the back-stripped models allow for a better understanding of initial transgression, they do not account for aggradation rates. Thus the 'blue' areas representing water in actuality reflect a complex mosaic of wetland environments and alluvial silts that would have created a complex reality. This would also have generated a more subtle variation in topography. In particular these models fail to account for the complex impact of anthropogenic activity and its impact on local stratigraphy. As such, they provide a good starting point, but need to be queried against the local record and radiocarbon dated core material (discussed in step 11 below). The location of dates relevant to each time slice is shown in figure 7.3. This helps demonstrate the comparative dearth of data for the Late Pleistocene and early Holocene, and the uneven distribution of dated cores from the Mid-Holocene onwards. As noted in chapter five, improving the frequency of dated cores across the study area would significantly aid in evaluating the validity of the palaeogeographic models. Finally, figure 7.3 does not account for variation in tidal range over this period. Palaeotidal modelling of the broader study area would be a valuable next step in terms of resolving the shifting nature of environments represented in the models. This, and additional potential improvements are discussed in the conclusion to this chapter, and in chapter eleven.

Step 5: Hydrological Analysis

As noted in chapter three, distance/relationship to water sources is a frequently used variable within deductive models (e.g. Dalla Bonna 1994, Deeban et al. 2002, Peeters 2007). To investigate the impact of considering distance from water source ArcGIS's hydrological tool set was used to reconstruct drainage patterns across the pre-Holocene surface model. This required running the slope analysis, follow direction, flow accumulation and stream order tools. The end result was a theoretical hydrological network which could be directly compared to observations made during the deposit modelling process. The outputs showed a high level of conformity (as shown in figure 7.2 below).

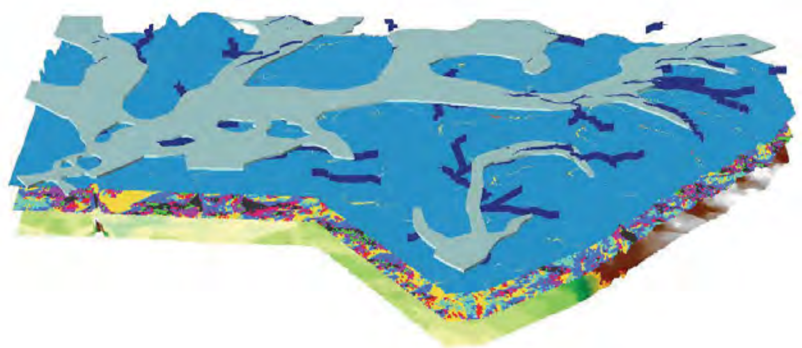


Figure 7.2 image showing the pre-Holocene surface overlain by flow direction, flow accumulation, stream order and digitised channels from the deposit modelling work. © Crown Copyright and Database Right [2015]. Ordnance Survey (Digimap Licence). The bathymetric data products have been derived from the EMODnet Bathymetry portal - http://www.emodnet-bathymetry.eu. and UKHO INSPIRE Open Government Licence

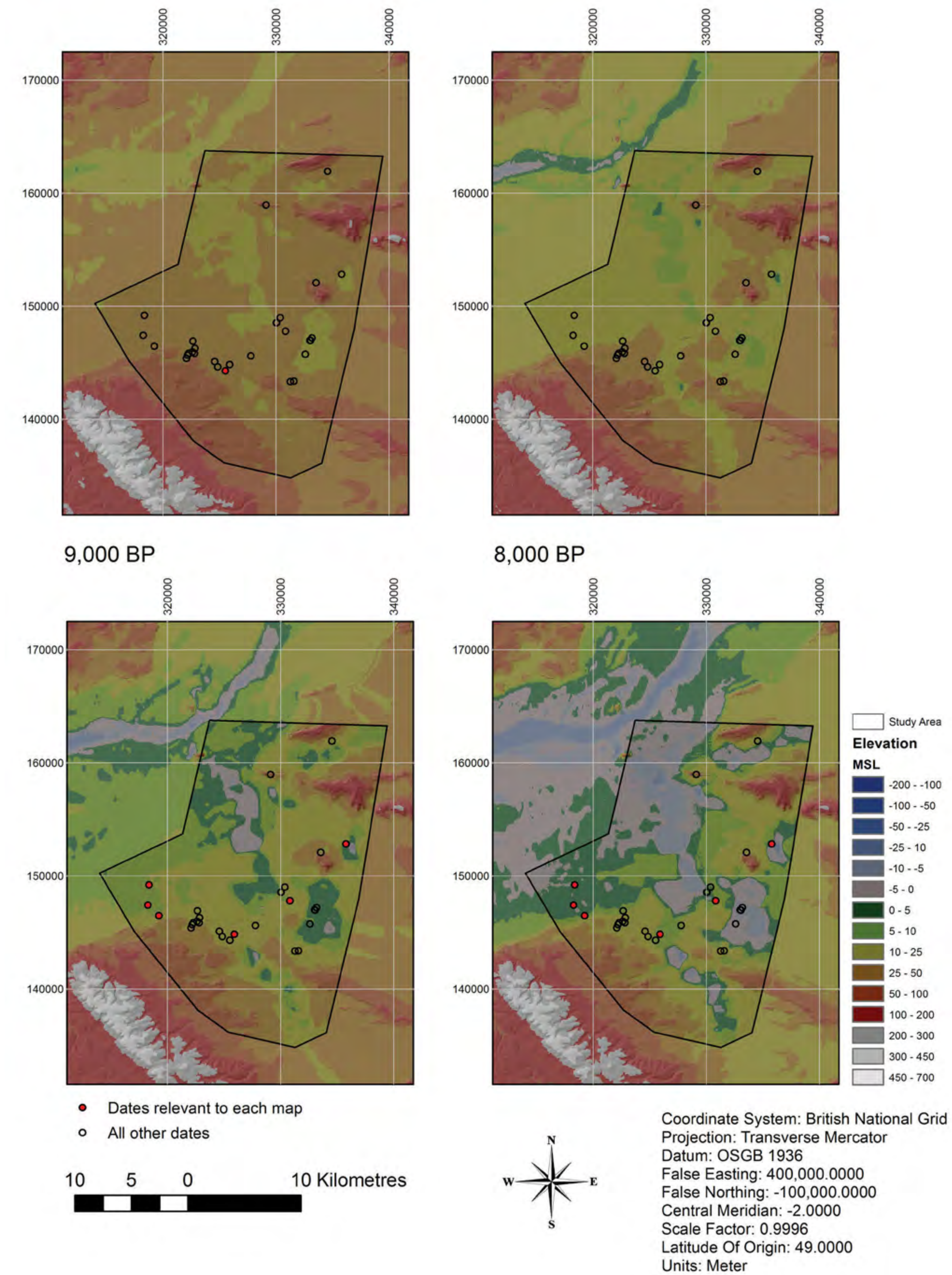


Figure 7.3a Backstripped palaeogeographic models with relevant radiocarbon dates showing. © Crown Copyright and Database Right [2015]. Ordnance Survey (Digimap Licence). The bathymetric data products have been derived from the EMODnet Bathymetry portal - http://www.emodnet-bathymetry.eu. and UKHO INSPIRE Open Government Licence

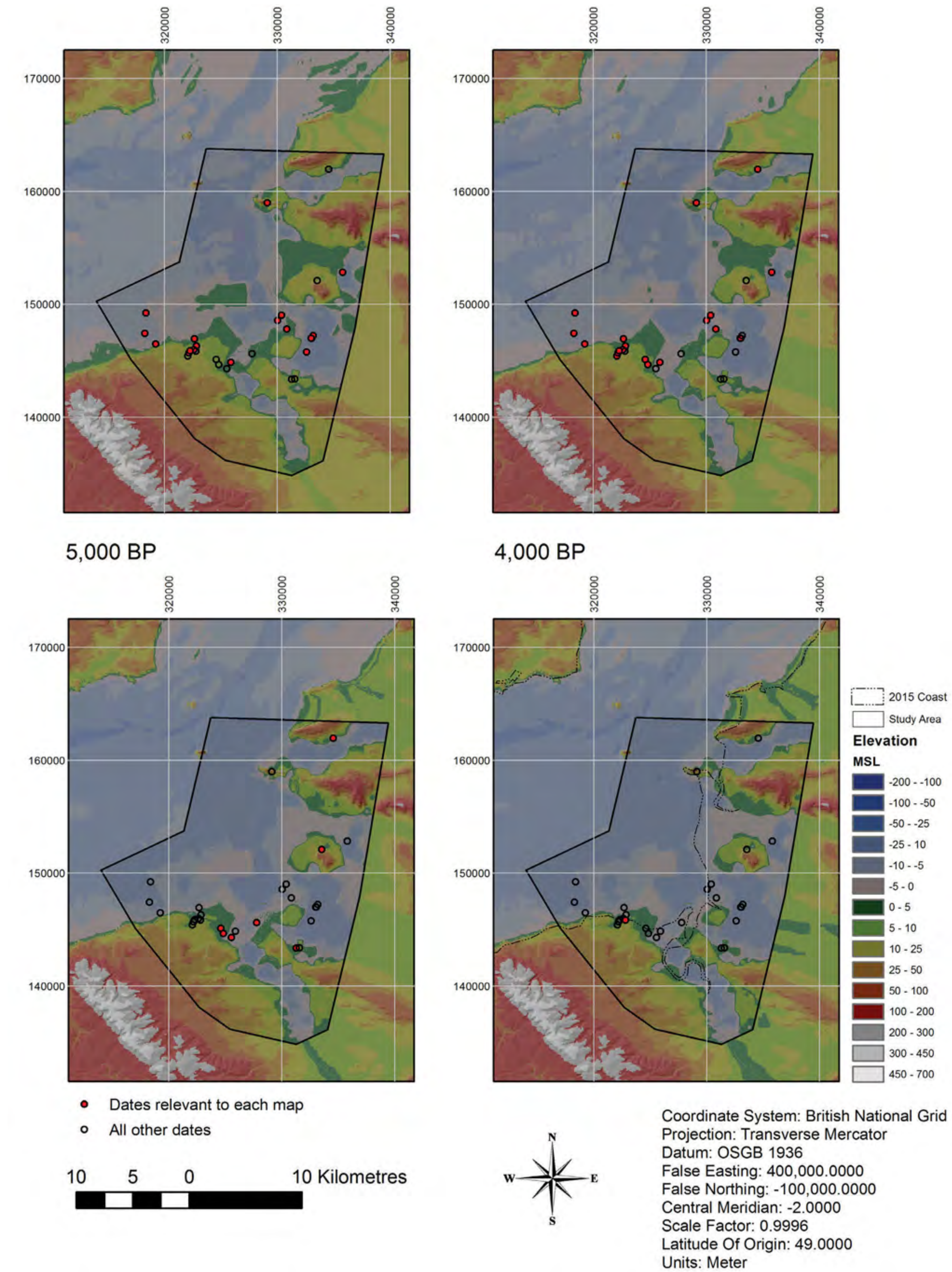


Figure 7.3b Backstripped palaeogeographic models with relevant radiocarbon dates showing. © Crown Copyright and Database Right [2015]. Ordnance Survey (Digimap Licence). The bathymetric data products have been derived from the EMODnet Bathymetry portal - http://www.emodnet-bathymetry.eu. and UKHO INSPIRE Open Government Licence

Step 6: Slope Analysis

Calculations of slope are frequently used within both deductive and inductive modelling approaches (Kvamme 1983; Verhargen 2007; Peeters 2007). This relates to the fact that in areas of high relief steep sided slopes are often deemed less suitable for occupation and thus have a lower potential for encountering evidence for past settlements *in-situ*. Slope analysis can help to identify areas of high incision and potential erosion. This, when considered alongside hydrological modelling outputs, can help when considering the likelihood for encountering derived secondary context material. These surfaces were created here as a bi-product of the hydrological analysis, described above.

Step 6a: Curvature analysis

The discussion in chapter four has established that while comparatively little is known about the archaeology of the study area, considerable work has been carried out in the broader environs. This has helped to produce an understanding of past human activity in the area that can be used as an input within a deductive model. It was determining the nature of this input that provided the point of articulation with Historic England's 'Mesolithic of the Wetland/dryland edge in the Somerset Levels' project 6624 (Bell et al. 2015). The work carried out by Bell et al. (2015, 3) established that "small islands of dry ground may have been foci for activity" within the Mesolithic and Neolithic. This corroborates similar observations of Mesolithic and Neolithic activity within the Fenland basin of East Anglia (Sturt 2006).

Given this hypothesised preference for island and ridge locations the curvature tool was used within ArcGIS to query the pre-Holocene land surface and identify 'island like features'. Curvature can be defined as "the second derivative of a surface, or the slope of the slope" (Kimerling et al. 2011, 360). Within this model, the raster curvature surface created (shown in figure 7.4 below) was a composite of both plan and profile curvature, as this helped better identify variability in slope, and thus potential 'island' presence. The difficulty with the curvature output is that it produces contour like raster values which denote boundaries between islands, ridges and plains rather than the area of the island or ridge. As such, the curvature outputs were used to help determine and verify the criteria of more sensitive analysis described in the next section.

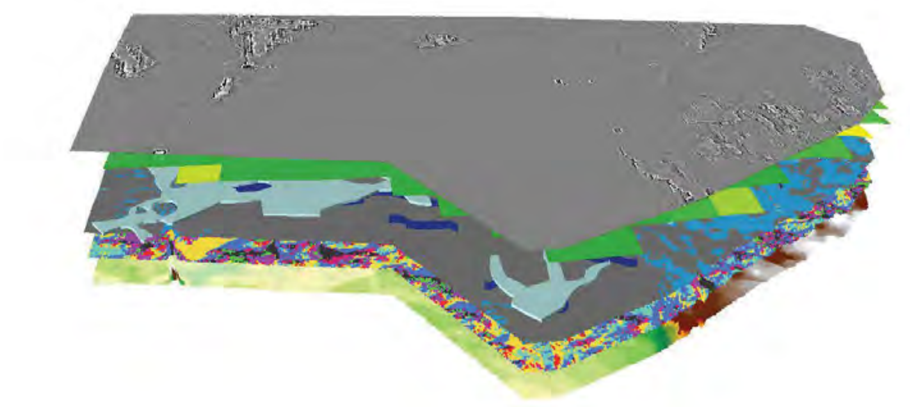


Figure 7.4 image showing the curvature surface overlying preceding analysis steps. © Crown Copyright and Database Right [2015]. Ordnance Survey (Digimap Licence). The bathymetric data products have been derived from the EMODnet Bathymetry portal - http://www.emodnet-bathymetry.eu. and UKHO INSPIRE Open Government Licence

Step 7: Calculation of Topographic Position Index (TPI) and Deviation from Mean Elevation (DEV)

Weiss (2001) created a GIS application which allowed semi-automated landform classification from digital elevation models. The output from this application was described as a topographic position index (TPI); a value derived from a reclassification of the measurement of difference for a given point from the surrounding mean elevation. As De Reu et al. (2013, 39) note, this allows "landscapes [to] be classified in slope position classes" with consistency and ease. The wide variety of disciplines interested in consistently classifying landforms from digital datasets has meant there has been a rapid uptake of TPI across a variety of fields (e.g. Tagil and Jenness (2008) in Geomorphology; Mora-Valleejo et al. (2008) in geology; Coulon et al. (2008) in behavioural ecology; and Young et al. (2011) exploring the equivalent Bathymetric position index (BPI) in seafloor mapping).

Within archaeology there has been a more limited uptake, with Watts et al. (2011) pioneering its use for considering submerged prehistoric landscapes in California, and De Reu et al. (2013) offering a detailed assessment of its performance within lowland landscapes in Northwest Belgium. In the case of Watts et al. (2011) TPI was used to identify areas likely to have been chosen by Palaeoindian groups for occupation/activity, in a similar vein to its use here to help identify island and ridge locations. De Reu et al's (2013) work adopted a more critical approach, considering the efficacy of TPI for landscape characterisation in relation to the known archaeological record. In this study TPI classification seemed to struggle with subtle topography, falsely attributing barrow sites to middle slopes/flat areas, when in fact they were found on ridges (De Reu et al. 2013, 47). Based on this De Reu et al. (2013, 47) recommend that methods such as deviation from mean elevation (DEV) also be considered when attempting landscape classification.

Following the results De Reu et al's work, both TPI and DEV classifications were run for the study area via the following procedure. These calculations were run for the pre-Holocene land surface and subsequent GIA corrected elevations (described in step 4). However, as the model does not account for aggradation the TPI outputs simply reflect the reduced prominence and size of the islands and ridges as sea-level rises.

For TPI Majka et al's (2007) TPI calculation script for ArcGIS was used. This works in two steps. First a raster representing relative elevation change is created through measuring the difference between elevation at a given point (Z_0) and the average elevation around it for a given radius (R).

$$TPI = Z_0 - \overline{Z}$$

$$\overline{Z} = \frac{1}{n_R} \sum i \in R^Z i$$

TPI is scale dependent, meaning that the search radius needs to be adjusted for the phenomenon/landscape features being considered (De Reu et al. 2013, 45). For example, in areas with deep but highly incised river systems the radius for comparison may need to be constrained to capture large elevation differences over small areas. In order to ascertain the most appropriate radius TPI was run at 100m, 200m, and 500m intervals to assess its ability to detect topographic variation and island features within the modelled dataset. As figure 7.5 below demonstrates, 100m radius picked up on elevation differences created due to the resolution of the deposit model (steps from isochore values), 200m detected a range of values, with some noise still present. A five hundred metre radius did well at removing noise and detecting large ridges and islands, but missed the smaller islands. As such, 200m was deemed an appropriate scale for this study. The output from this step were compared to the curvature analysis results in order to make sure that an appropriate level of detail had been captured.

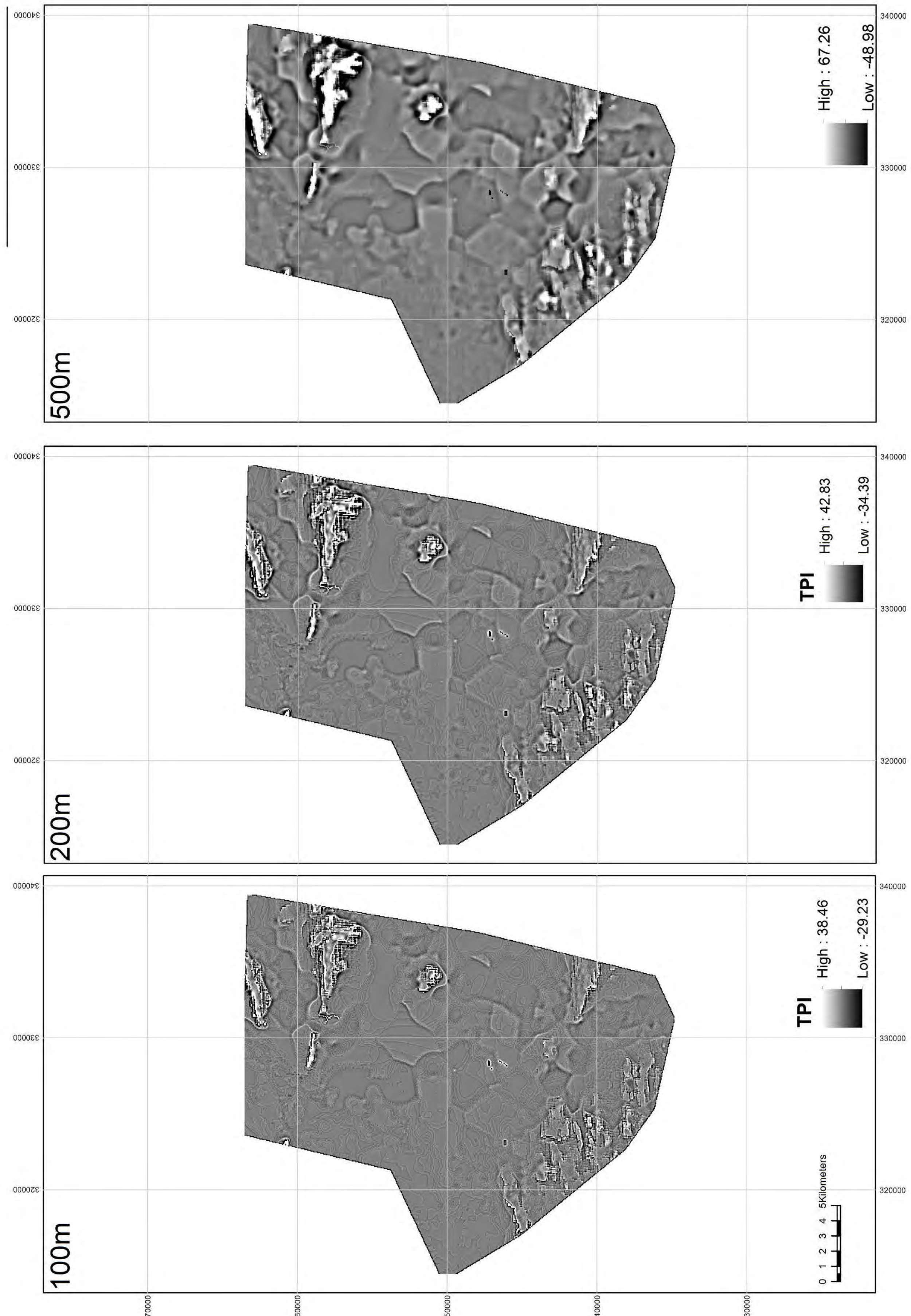


Figure 7.5 TPI classifications 100m, 200 and 300m. © Crown Copyright and Database Right [2015]. Ordnance Survey (Digimap Licence). The bathymetric data products have been derived from the EMODnet Bathymetry portal - http://www.emodnet-bathymetry.eu. and UKHO INSPIRE Open Government Licence

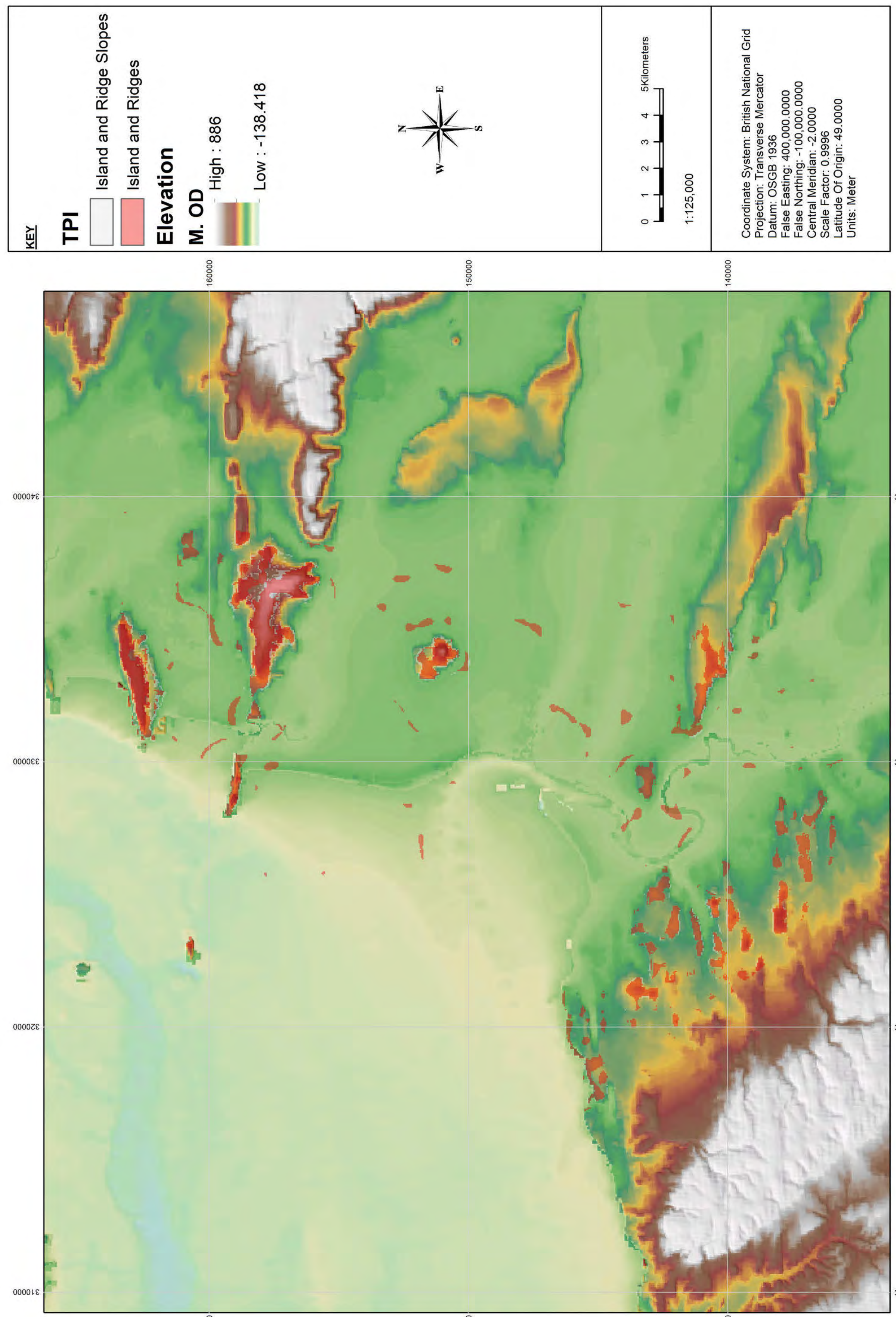


Figure 7.6 Island features extracted by TPI classification. © Crown Copyright and Database Right [2015]. Ordnance Survey (Digimap Licence). The bathymetric data products have been derived from the EMODnet Bathymetry portal - http://www.emodnet-bathymetry.eu. and UKHO INSPIRE Open Government Licence

Once the TPI base surface has been created it is possible to classify the output raster. Three classifications were created: River floor (-6m below mean), Ridge top/island (6m above mean) and Floodplain (all other cells). In Figure 7.6 the areas identified as islands have been highlighted.

A DEV surface was generated following the method set out in De Reu et al. (2013, 42). DEV measures the topographic position of the central point (Z_0) using TPI and the standard deviation of the elevation (SD). In order to generate a raster of the standard deviation for elevations in the pre-Holocene land surface model the following procedure was used. First, a mean elevation raster for the dataset was created using the 'Focal Statistics' tool in ArcGIS. For this process a rectangular 3x3 cell search was used. Following this a raster of the range of elevation variation was created, once again using the 'Focal Statistics' tool with the same rectangular search area. Using the raster calculator the mean elevation DEM was then subtracted from the pre-Holocene land surface model DEM with the resultant output divided by the range DEM. This method produces a raster surface of the standard deviation of Elevation. The TPI raster is then divided by the standard deviation raster to create a DEV surface. This procedure can expressed through the following equations:

$$DEV = \frac{Z_O - \overline{Z}}{SD}$$

$$SD = \sqrt{\frac{1}{ng-1} \sum i = 1 (Z_i - \overline{Z})^2}$$

As De Reu et al. (2013) note, the output of the DEV process helps to highlight flaws in the input DEM. This is a useful feature when considering 'real' landscapes, but serves to focus attention on the coarse nature of modelled land surfaces. As such, in this instance the outputs from the TPI process were found to more useful in identifying island and ridge features. As such, it was the output from the 200m TPI raster that was used in the subsequent steps of the modelling process.

It should be noted that TPI is only one of a range of 'surface roughness' calculation methods, with a range of alternative routes to describing difference across topographic space currently available to researchers. In this instance TPI was adopted due to its ability to account for variation from a mean for a given area, and due to the fact that it is a well understood method with the broader ecological modelling community. As research continues into morphometrics for landscape and hydrological processes it is anticipated that GIS based technqies will become more sophisticated and better suited to this form of analysis.

Step 8: Buffer of stream lines

Distance from water has frequently been used as a factor within deductive modelling processes (e.g. Dalla Bonna 1994). The rationale is that human occupation activity is most likely to occur within easy access to fresh water resources. Following the argument of Wheatley (2004) there is a danger in presuming the exact nature of this relationship, without a clear understanding of regional preferences/human behaviour for a given period. However, distance from fresh water courses is an interesting ecological characteristic and is one method of initially shaping first order model outputs. Given the uncertainty of the relationship between water course and prehistoric activity, a 1km buffer distance was chosen for this initial trial (shown in Figure 7.7 below). However, as noted above, the step wise nature of model construction within this project meant it was possible to re-run the model with and without stream buffers included as a weighting factor.

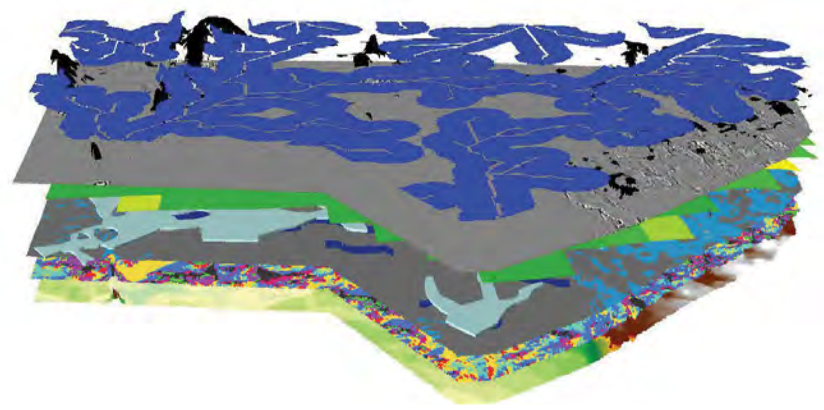


Figure 7.7 image showing model output including 1km buffer of potential stream and river courses. © Crown Copyright and Database Right [2015]. Ordnance Survey (Digimap Licence). The bathymetric data products have been derived from the EMODnet Bathymetry portal - http://www.emodnet-bathymetry.eu. and UKHO INSPIRE Open Government Licence

Step 9: Cumulative layer generation

With the above steps complete it is possible to collapse the different layers together and generate a composite surface. For the final predictive model in this project the following outputs were selected, with a value of 1 or 0 according to the following criteria:

TPI and curvature analysis indicates island, ridge or upland location = 1

Within 1km of a major water course = 1

Deposits of interest survive above bedrock = 1

This resulted in a cumulative score of 0, 1, 2 or 3 (moving from lowest to highest potential), with areas of highest value coloured red in figure 7.8 below. This output is a raw model of archaeological potential following the deductive methods described above.

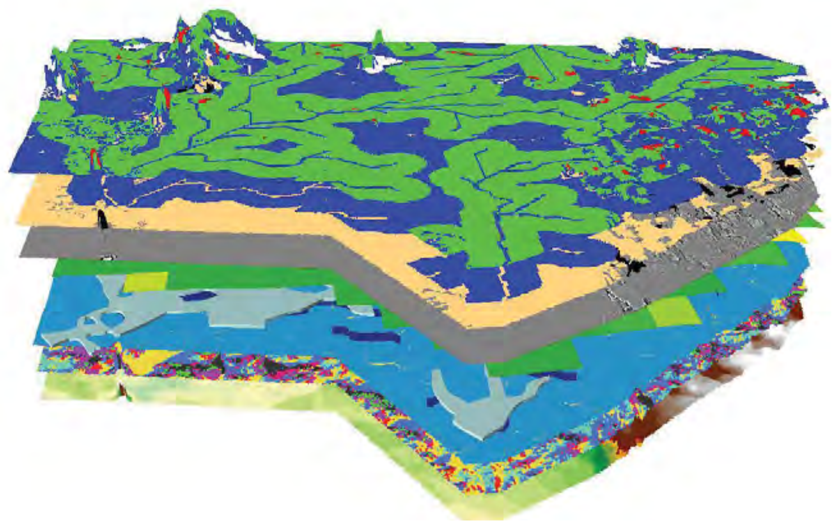


Figure 7.8 Cumulative model output. Red = 3, Green= 2, Blue =1, Grey = 0. A plan view of the model is shown on the right hand side. © Crown Copyright and Database Right [2015]. Ordnance Survey (Digimap Licence). The bathymetric data products have been derived from the EMODnet Bathymetry portal - http://www.emodnet-bathymetry.eu. and UKHO INSPIRE Open Government Licence

Step 10: Determining accessible areas

The cumulative score layer provided a map of potential for the entire study area. Using the isochore data it was then possible to clip the layer based on 'accessibility'. In this instance accessibility was an evaluation of the depth of deposit that could be excavated in order to assess a particular location. For this study a depth of 2m was chosen as hand test pitting was the preferred method of investigation. This helped to refine the model of potential through consideration as to what might realistically be tested through ground-truthing. Figure 7.9 below shows the output from the clipped model.

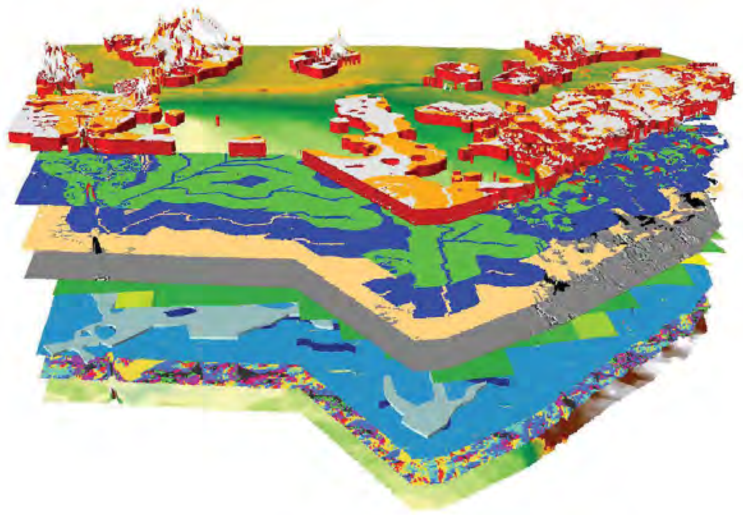


Figure 7.9 Model with 'accessible' areas calculated. © Crown Copyright and Database Right [2015]. Ordnance Survey (Digimap Licence). The bathymetric data products have been derived from the EMODnet Bathymetry portal - http://www.emodnet-bathymetry.eu. and UKHO INSPIRE Open Government Licence

Step 11: Chronological specificity

To further assist selection of locations for ground-truthing an understanding of the impact of palaeogeographic change through time can be added to the model (shown in figure 7.10 below). Here the 500 year palaeogeographic time-slices generated in step four are integrated with the clipped model outputs. This allows for site specific analysis with regards to landscape characteristics (i.e. was the site located on the edge of the estuary and, if so, for how long before it became inundated). It is this aspect of the model that is directly portable to any area that can be back-stripped of over burden and glacio isostatically corrected to produce an understanding of landscape change. Step eleven can also be automated to give a value for how long an area maintains a particular ecological setting. This was achieved through TPI classification of each palaeogeographic time slice, with the same caveat standing with regard to the impact of scale on analysis.

The radiocarbon database (discussed in chapter four) can then be queried against these generated surfaces. This is important as it should be recognised that while visually compelling the palaeogeographic model outputs are approximations operating at a 500 year temporal and 50mx50m spatial scale. In addition, as noted above, they do not allow for the complexities of aggradation. This is an aspect of the model that could be radically improved through increased data density and a higher frequency of cores with multiple dates across the study area. As discussed by Sturt (2006), with a greater number of dated cores, with a regular distribution across a study area, it becomes possible to split a model such as this into smaller regions, and from the dated material model local groundwater level change and aggradation. This follows the theme developing throughout this chapter that acquisition and analysis of core material is fundamental for improving our ability to understand

change through time. This stands as much for deeply buried terrestrial sequences and offshore areas even when high quality seismic data is available. With improved chronological and environmental control it becomes possible to more accurately model both deposits and ecological change. Together these can radically alter strategies for ground truthing.

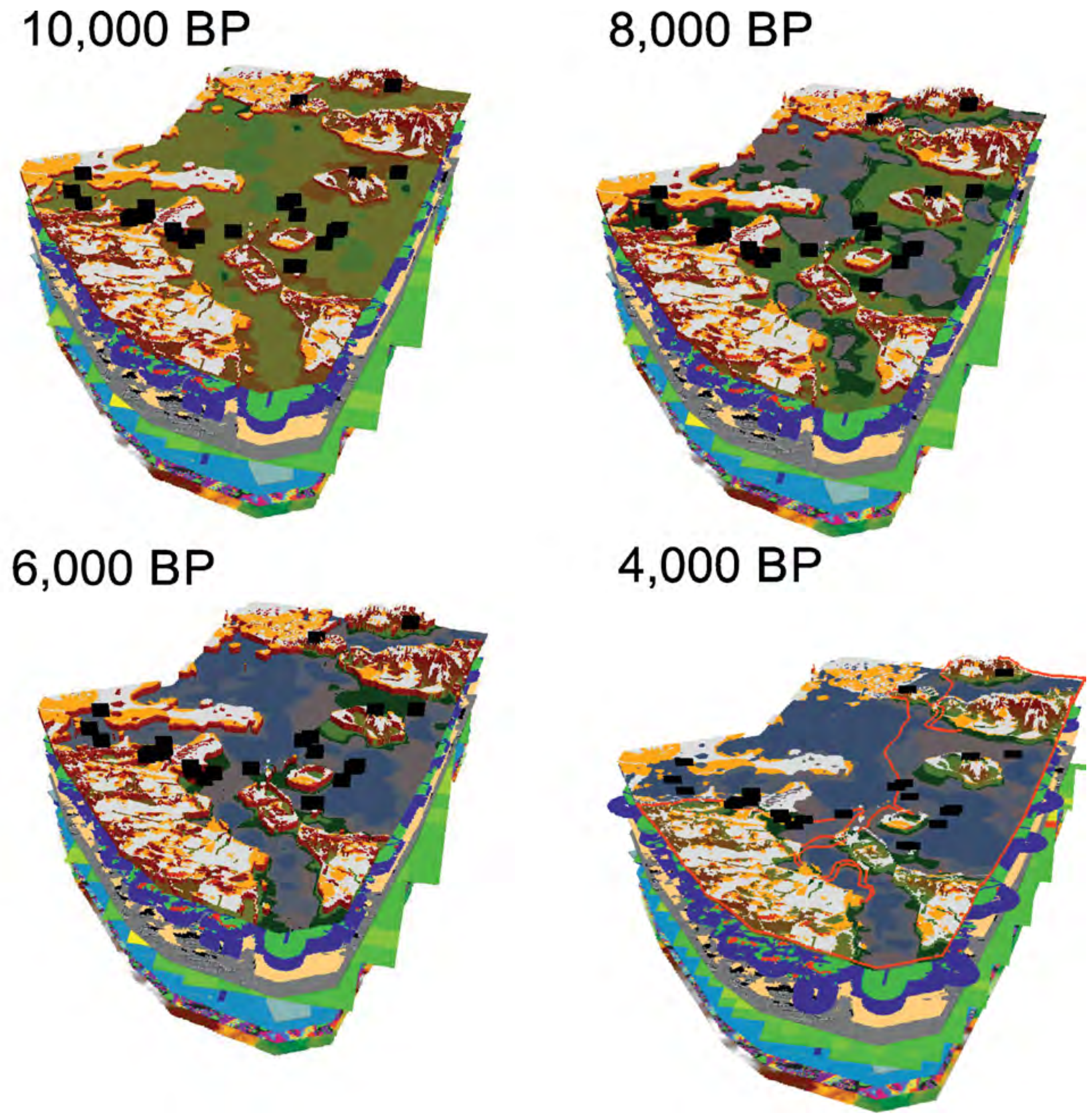


Figure 7.10 Model outputs integrated with palaeogeographic data and radiocarbon date location. The location of the modern coast is given in the panel for 2,000 BC. Elevations for each palaeogeographic output are as for figure 7.3. © Crown Copyright and Database Right [2015]. Ordnance Survey (Digimap Licence). The bathymetric data products have been derived from the EMODnet Bathymetry portal - http://www.emodnet-bathymetry.eu. and UKHO INSPIRE Open Government Licence

Blind testing of the model

As noted in the introduction, one of the main aims of this project was to join onshore and offshore data to allow an improved understanding of the past and archaeological potential. A benefit of this approach is that it allowed for blind testing of the model outputs against the known archaeological record. In order to achieve this Historic Environment Record (HER) data relating to all known prehistoric (Palaeolithic, Mesolithic, Neolithic, Bronze, Iron and generic prehistoric) sites and finds within the study area was obtained from Somerset and North Somerset County Councils.

By extracting those features recorded as prehistoric in date (Palaeolithic, Mesolithic, Neolithic, Bronze Age, Iron Age or generically 'prehistoric') the list of records fell from 1596 to 112 in the central study area. These 112 polygon records were then converted to point features in ArcGIS, and the value from the predictive model extracted for each point location. Table 7.1 (below) shows the histogram of results from this operation for all prehistoric sites, with the bins at the bottom being from 0 (very low potential) on the far left through to 3 (highest potential) on the far right.

In order for the above analysis to be meaningful it has to be compared against the distribution of values in the deductive model. Table 7.1 contains a column to show the percentage of 50x50m cells corresponding to a given model value (0-3). As the deductive model stretches beyond the current mean low water (MLW) mark, and all prehistoric sites within the HER lie above this position, the model was clipped in order to allow for this bias, the second to last column in the table shows the distribution of model values for the clipped zone. Finally, these data can be used to assess the performance of predictive model. Kvamme (1988, 320) proposed a gain function to determine the utility of a predictive model (1-[percentage of total area covered by model)/(percentage of total sites within model area)]) . Values closer to 0 indicate no predictive utility, while values closer to 1 suggest a degree of utility. Negative values indicate reverse predictive utility.

Predictive Model Score	Blind test result for 'Prehistoric' (number)	Percentage of Prehistoric sites per Model score	Percentage of cells for given model value (whole model)	Percentage of cells for given model value (above MLW)	Kvamme's Gain for area above MLW
0	7	6.25%	7.3%	9.47%	-0.52
1	51	45.4%	34.66%	35.74%	0.21
2	44	39.29%	56.75%	53.08%	-0.35
3	10	8.93%	1.29%	1.71%	0.81

Table 7.1: Results of blind testing of the predictive model with accompanying baseline data for percentage of cells within the model for each predictive score.

Clipping the model drastically reduces the cell counts for values 1 and 2. However, the overall trend remains constant. When the data in table 7.1 are compared it is clear that a disproportionately large number of sites fall within value category 1 and value category 3, given their representation in the model more broadly. On the one hand this would appear to support the idea that there is a preferential selection for islands (and that the model can pick this out), but on the other, that it fails to identify significant zones of activity within the larger and less differentiated landscape (zone value 1). The gain score supports this assertion. However, their is still a degree of circularity, in that island areas were targeted due to knowledge gained from previous archaeological work, we have then tested to see if we can identify island sites, which unsurprisingly have a record of more archaeological activity. Thus while statistically supported their is a degree of teleology to be accounted for.

It is recognised that within the additional 1484 records held by the HER, but excluded from the above analysis through limiting it to 'prehistoric', that additional prehistoric material will have been discounted. In order to consider the impact of this an additional comparison was made between the complete HER dataset and the deductive model. Given that this now includes data for periods of activity when the floodplain became more broadly habitable, it is perhaps unsurprising that the result (Figure 7.11 panel h) closely mirrors the distribution of values within the clipped and original model (table 7.1). This suggests a fairly even spread of material

across the entire study area when all periods are considered.

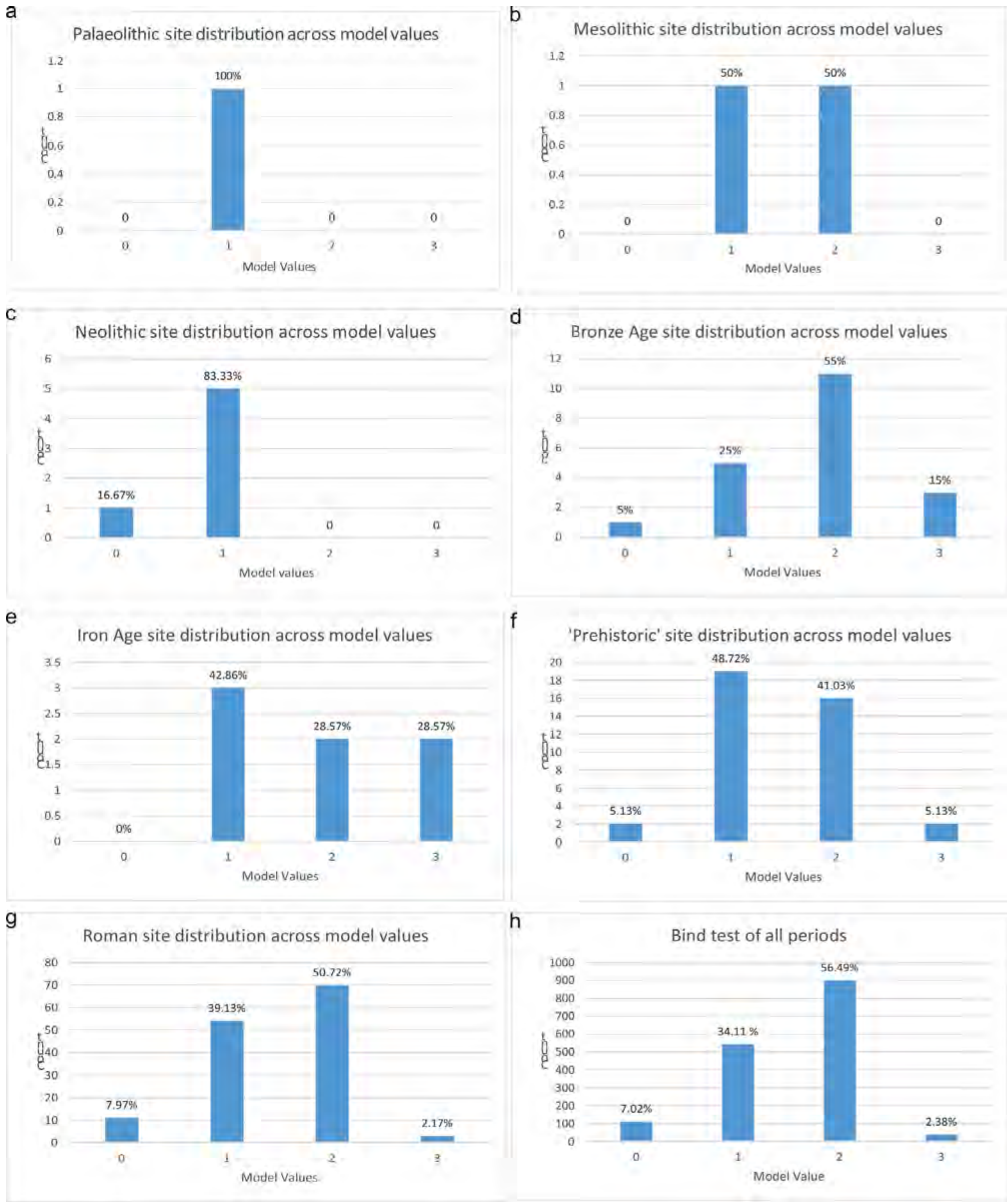


Figure 7.11: Histograms of values extracted from model for HER records for different periods and all periods.

Figure 7.11 panels a-g review the correspondence between sites identified by the HER as belonging to individual period from Palaeolithic to Roman era, along with generically 'prehistoric' finds. The first thing to note is the low number of sites directly attribute to a specific period. This means that it is hard to meaningfully evaluate how the model performs for any one period based on currently held data. As such the aggregated 'prehistoric' dataset shown in table 7.1 is perhaps most illuminating. Figure 7.11 panel g (Roman Period) is however interesting for its close correspondence to the frequency of values in the clipped model (table 7.1), suggesting an even distribution of Roman activity across the study area.

The above comparison indicates that there is a limited degree of usefulness for the deductive model. It did manage to preferentially select for areas that had records of prehistoric activity (islands), but struggled to cope with the wider dispersal of material across a less differentiated surface. This observation lends weight to Wheatley's (2004) argument that the adoption of such a model would be problematic if only areas of 'highest' potential were ever investigated.

There are some caveats that need to be considered alongside the above observations. First, in converting polygon features from the HER into points a centroid position is taken. This resulted in some large features which overlapped model cells of differing values gaining a lower final score (i.e. the polygon overlapped zones 3 and 2, but the final value attributed was 2). As figure 7.12 below makes clear, the Somerset HER incorporates large numbers of these polygon features, and as such the tendency for this to have happened is high when the whole dataset is considered. However, the impact was much smaller when restricted to the period of interest. As such, rather than covert the polygon data to a raster format, the centroid method was maintained. Second, the resolution of the model at 50m means that some topographic variability will have been missed. Third, while both HERs are of a high standard and include good levels of detail, a number of the recorded features are drawn from aerial photographic interpretation or are based on evidence from limited investigations, a number of which occurred a considerable number of years ago. As such, while suggestive it is certainly not a definitive, nor indeed 'accurate' (in the sense that would be truly useful for the above analysis) record.

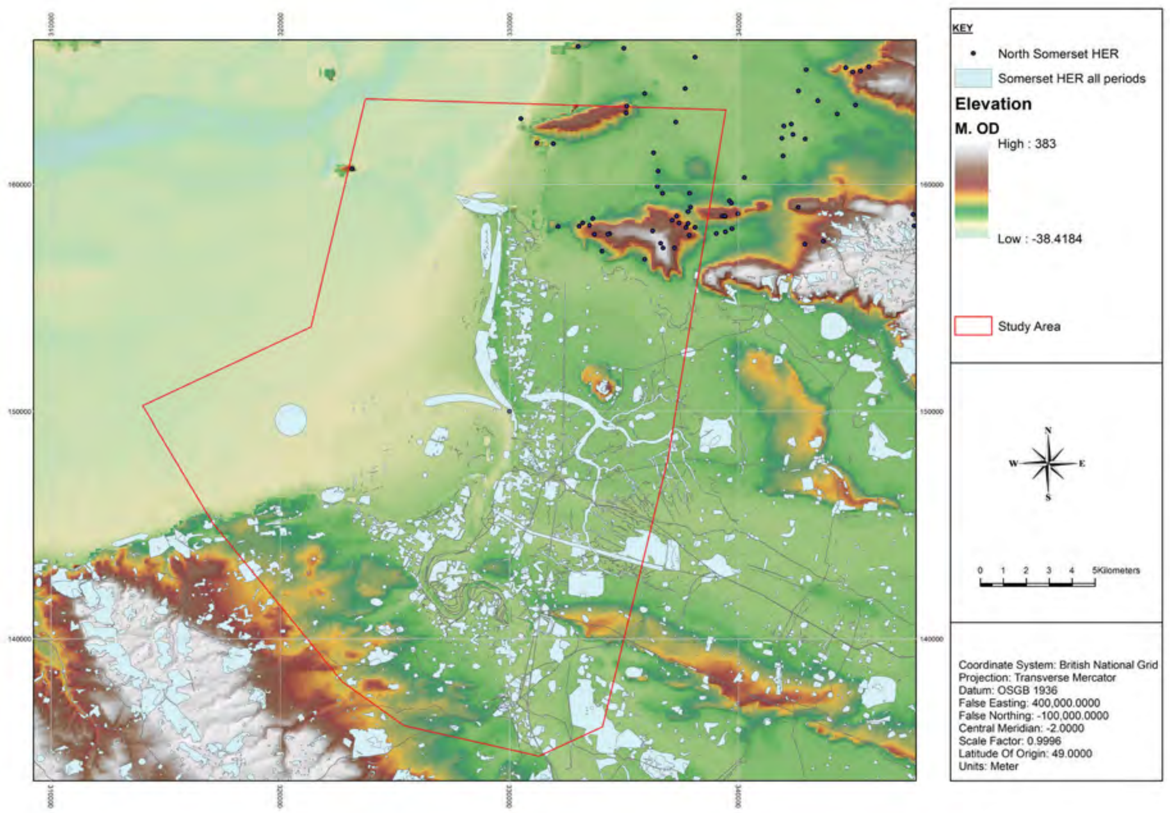


Figure 7.12. Map showing distribution of polygon site feature records in the Somerset HER. © Crown Copyright and Database Right [2015]. Ordnance Survey (Digimap Licence). The bathymetric data products have been derived from the EMODnet Bathymetry portal - http://www.emodnet-bathymetry.eu. and UKHO INSPIRE Open Government Licence

Conclusions

It would be easy to become pessimistic about the value of modelling based on the results above. However, while it is clear that only limited confidence can be had in the reliability of the cumulative deductive model, during the process of developing it a number of important products were created and realisations made. The production of a deposit model of the buried geological surface spanning the current onshore-offshore zone, refined palaeogeographic models and landform classification enabled an improved understanding of the complexity of the study area. Each step in the modelling process developed an in-depth knowledge of the strengths and weaknesses of the datasets available. This in turn permits clear rationales to be developed for any subsequent targeted fieldwork. In many ways this should not be seen as surprising. The real strengths of any form of modelling often lie in what they reveal about the limits of current knowledge and data quality. In this sense, the deductive modelling carried out here is best seen as a heuristic device. It forces a focused and engaged assessment of the data, and pushes it to its most useful limits.

In particular, TPI analysis of modelled palaeolandsurfaces holds real potential with regard to differentiating the offshore zone. Through this process it should be possible to better characterise the nature of the offshore resource, and its potential to improve our understanding of palaeoenvironmental change, and potentially human occupation. Added to this, and to echo the recent Mesolithic Research Framework (Blinkhorn and Milner 2013, 30) while it is widely acknowledged (Ransley et al. 2013) that we know little of the specifics of the offshore prehistoric record, it is also apparent that we know remarkably little about the onshore record for large areas. This makes any attempt to understand or model potential for any prehistoric period difficult to achieve. As such, it is clear that additional wide area survey, or ground-truthing of models such as this is urgently required to provide a reasonable baseline understanding. In addition, we should ensure that in our attempt to do this that we do not forget to play to our strengths, through continuing to develop our understanding of palaeolandscape and environmental change.

It is through focusing on the task on modelling the changing form of the land and seascape that we can best hope to make significant gains. As noted in the discussion above, the ideal situation would be to be able to model sea-level rise, associated groundwater level rise, the development of accommodation space within a given study area, and then to be able to account for how that space became infilled. In doing this we can move to a better rendered account of changing ecology, rather than simply rendered elevation surfaces. It is these ecological spaces which are really of interest. How did the shift from dryland to wetland take place? How rapid was the inundation and what was its impact on local flora and fauna? Although these sound like difficult questions to answer, we have seen that with an appropriate number of dated and analysed cores, sections and excavated material it becomes possible to do so (Cohen 2003; Sturt 2006; Peeters 2007). Significantly, this is as true of offshore palaeolandscapes as it is onshore terrestrial sequences.

Chapter 8
Onshore Investigations

Introduction

Between the 28th June and 18th July 2014 the 'onshore' component of the project's fieldwork was conducted at two locations in western Somerset. The primary objective of these archaeological investigations was to ground truth some of the outputs of the predictive model, principally through small-scale excavations. However, the opportunity to acquire additional geological data to help refine the deposit model for the study area was also exploited through a series of auger transects conducted across fields of interest.

The selection process for the onshore fieldwork locations was largely driven by the outputs of the predictive model, although consultations with local landowners determined the final fields selected for investigation. The first site targeted for archaeological investigation consisted of a large field on Pawlett Hill (PWLT14), focusing on the wetland/dryland edge of the Burtle 'island' and stretching out onto the adjacent floodplain towards Stretcholt. The second set of onshore excavations were conducted at Stolford (STFD14) where the opportunity to investigate onshore, inter-tidal (chapter 9) and offshore (chapter 10) deposits of particular interest was exploited.

Methodology

Prior to the excavations, a magnetometer survey was conducted using a Bartington gradiometer in 30 x 30 meter grids. This technique was largely utilised to determine whether a linear or 'cursus' monument was present within the field at Pawlett, as suggested in the country historic environment record (HER PRN 10700). However,

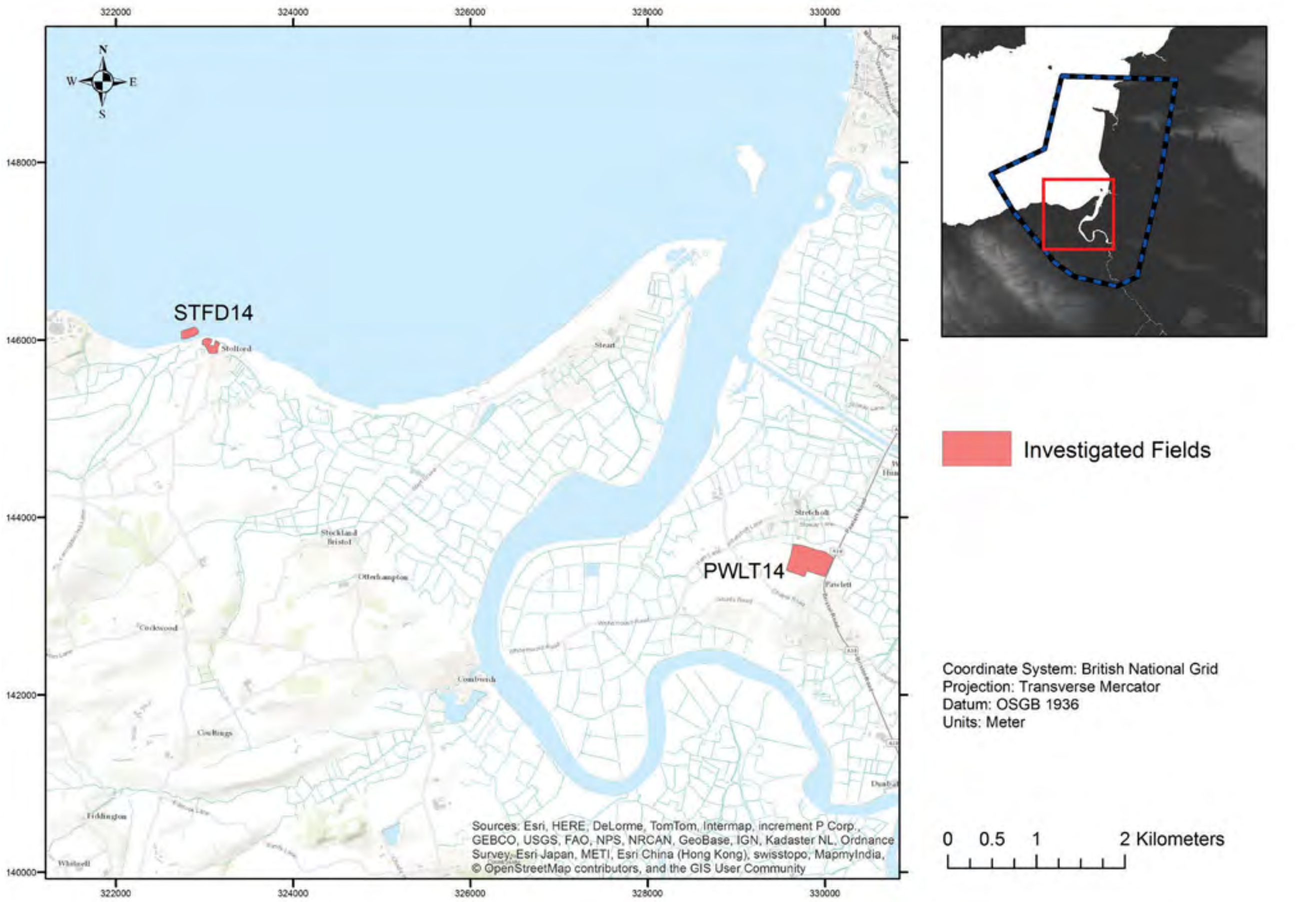


Figure 8.1 Location of onshore site investigations. © Crown Copyright and Database Right [2015]. Ordnance Survey (Digimap Licence)

the use of geophysical surveying techniques onshore also provided a proxy dataset comparable to those commonly used when prospecting for sites within offshore contexts.

At each site a series of test pits, each covering a surface area of $4m^2$, were excavated using a mattock and spade in order to sub-sample the area of interest. Auger surveys were also conducted using an eijkelkamp auger with a dutch head attachment or, where necessary, an Atlas cobra TT two-stroke hammer system. The stratigraphic sequences revealed during these interventions were recorded using Hodgson's (1997) geological terminology. A Leica GPS RTK system, set up using a base station or rover setting (spatial and vertical accuracy ±0.01m) was used to survey in the locations of test pits, finds of interest and environmental samples.

Pawlett (PWLT14)

The first set of onshore investigations focused on the Pawlett area. This location was identified as an area of increased likelihood for prehistoric activity due to its island/ ridge location and potential access to buried soils and wetland sequences. In addition, the outcrop of dry land at Pawlett was recently noted as an area of possible archaeological interest given its close proximity to the comparable 'island' of the Walpole Landfill Site (c. 1.5km to the east), where a number of prehistoric wooden structures have been recorded. Additionally, it has been suggested that the Lias island at Walpole may be an eastern extension of Pawlett and thus any occupation at Walpole would be secondary to occupation at Pawlett (Hollinrake and Hollinrake 2007: 158). Further investigations in this area therefore offered the opportunity to test the outputs of the project's modelling phases and help better contextualise the important prehistoric discoveries at Walpole within the wider landscape.

The field investigated as part of the current study (ST 298 435; shown in figure 8.2) provided access to land stretching from the top of the hill, down its northern flank and out onto the floodplain towards Stretcholt. This allowed access to any buried deposits preserved along the wetland/ dryland edge of the 'island'. The county HER indicated that no prehistoric finds had been previously recorded at the site, although a late Bronze Age

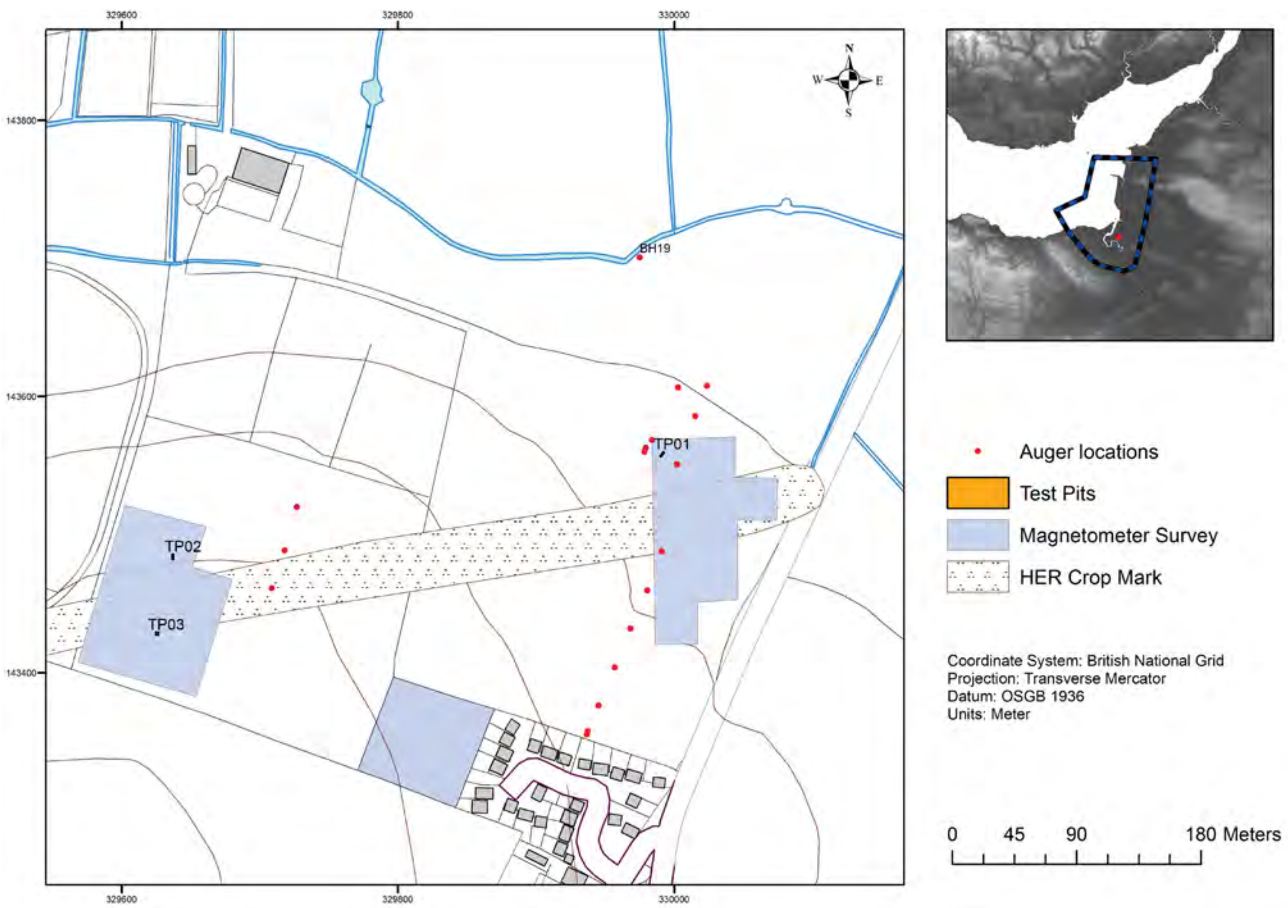


Figure 8.2 Site investigations at Pawlett (PWLT14). © Crown Copyright and Database Right [2015]. Ordnance Survey (Digimap Licence).

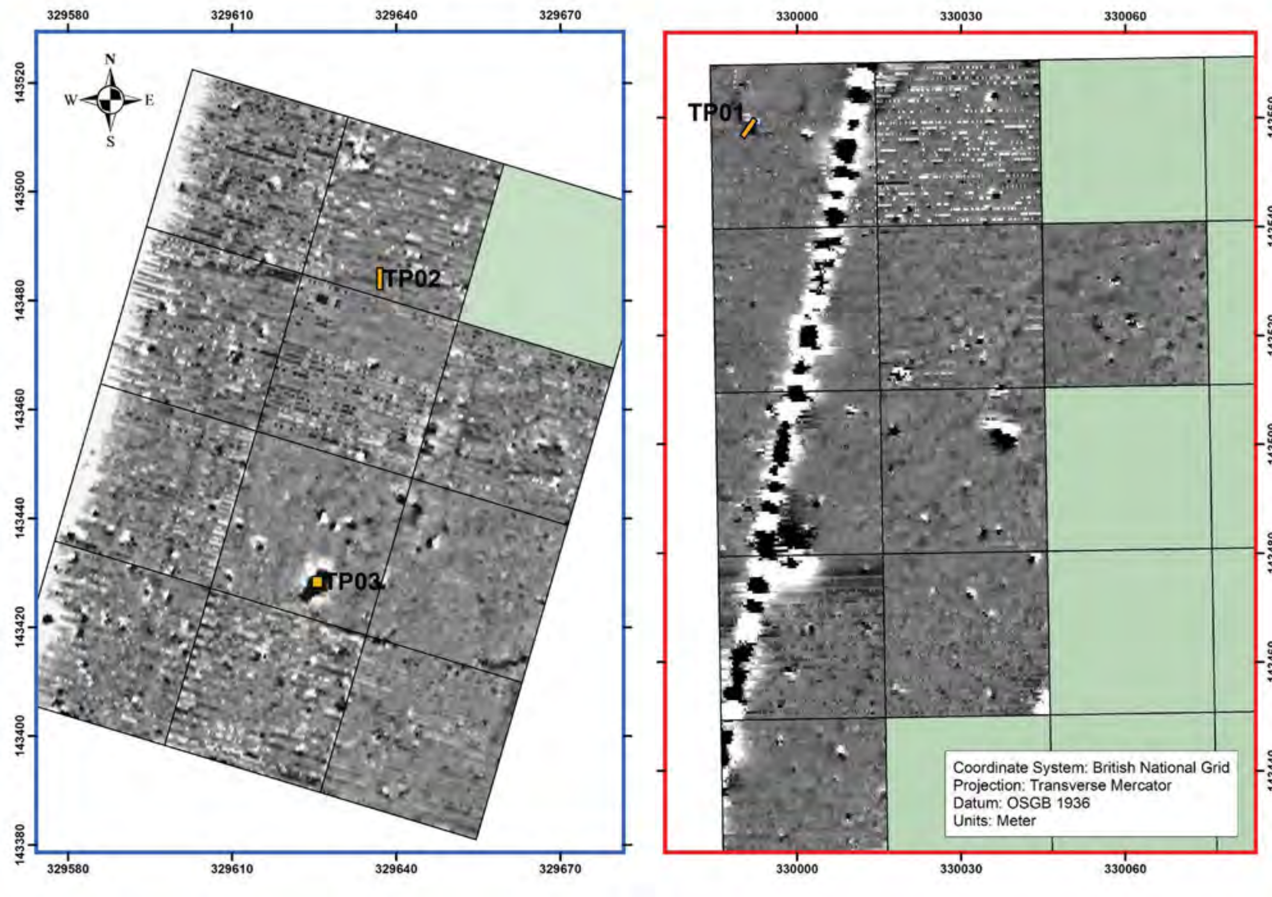


Figure 8.3 Results of magnetometer survey

palstave was found in the neighbouring area during ditching at Stretcholt (PRN 10701). In addition, a crop mark of a potential 'cursus' or linear monument had also been identified within the field from an aerial photograph (PRN 10700), again suggesting the potential for preserved prehistoric material within this area.

Magnetometer survey

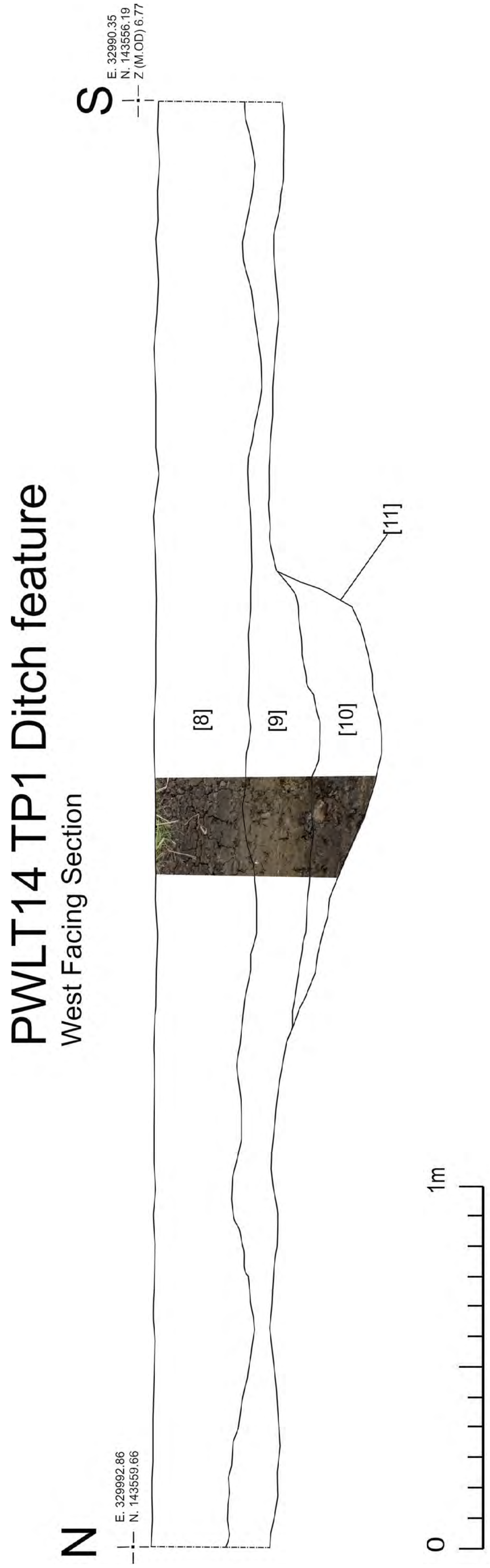
Prior to the excavations, a magnetometer survey was conducted using a Bartington gradiometer. Given the possible presence of a linear monument, and large area of the site, this work focused on the eastward terminal end of the possible 'cursus' and at the southern corner of the field (at the topographic high point).

The results (figure 8.2) gave no indication of a linear feature being present within the field, thus indicating that a 'cursus' monument was unlikely to be present at the site. However, there was an interesting circular anomaly (c. 12-3 meters in diameter) identified at the base of the slope, along with additional small areas of potential activity towards the top of the hill.

Excavations

Due to delays relating to the removal of crops from within the field, excavations were postponed at short notice until the final two days of the fieldwork season. As a result, it was only possible to investigate a very small fraction of the field through test pit excavations. Test pits therefore targeted anomalies identified within the geophysics, in order to maximise the chances of recovering archaeological material.

The first test pit (test pit 1) was a four by one metre trench, which cut across part of the circular anomaly identified near the base of the slope. The final two test pits targeted a possible linear feature (test pit 2) and an irregular-shaped anomaly (test pit 3), both located towards the western part of the field.



Context No.	Description
8	10YR 4/3 Brown clay loam, very firm c. 30cm thick with frequent small stone and rootlet inclusions
9	2.5y 6/4 Light yellowish brown silty loam, firm, c. 10-20cm thick with frequent angular to sub rounded pebble inclusions. Infrequent sherds of postmed(?) pottery small sherd of possibly prehistoric pottery, bone fragments
10	2.5Y 5/3 Light olive brown silt loam, to dark olive brown c. 10-15cm thick, fairly firm, infrequent pebble inclusions c. 2%, large pieces of bone, infrequent pottery. Fill of feature (ring ditch?) visible on geophysical survey.
11	Cut of ditch feature, steep sides at southern edge, more tapered on the northern slope. Very distinct boundary between [10] and underlying geology giving a clear indication of the form of the cut of the ditch.

Figure 8.4 Section drawing of test pit 1 with ditch feature

Test pit 1

Feature 2. Ditch.

Test pit 1 revealed a stratigraphic sequence, which followed that seen more broadly across the field: a clay loam topsoil (10YR 4/3 Brown), with frequent small stones and rootlets, overlaying a yellowish brown (2.5Y 6/4) silt loam, with infrequent pebble inclusions, which in turn overlay Burtle Formation sand and gravels.

Excavations also exposed a 1.1m wide ditch (context 11), c. 50cm below the field surface, which cut through the subsoil and into the Burtle formation. The ditch was 'u' shaped in section with a flat bottom and filled with a dark brown clayey silt (context 10). A total of 22.5 litres of the ditch fill was retained for floatation but did not produce any additional archaeological or botanical material.

The ditch fill produced few finds, including animal bone and fragments of slag recovered from the base. A bone sample (identified as probably part of a cow's tibia) was sampled for radiocarbon dating and produced a date of 2273-2154 cal BP (2240±31 BP; SUERC-58166, for further details see appendix 2), thus suggesting that the circular feature identified within the geophysics represents an Iron Age 'ring ditch'.

Additional finds

The topsoil (context 8) and subsoil (context 9) produced a low number of finds, including a fragment of a clay pipe stem, two pieces of fired clay, and an iron nail. The subsoil also produced a couple of pieces of worked flint which were not diagnostic in nature. The majority of finds recovered consisted of small pottery sherds of medieval and post-medieval date though, along with a few pieces of ceramic building material.

Test pit 2

Feature 3. Field Boundary.

Test pit 2 revealed a very shallow, linear feature (context 4) which was cut into the subsoil (context 2) and scraping the top of the Burtle sand and gravels. There was no clear fill to this feature and it was devoid of finds. Taken together, these findings indicated that this feature probably represented a relatively recent field boundary.

Test pit 3

Feature 1. Pit.

The final test pit revealed a shallow (20cm deep) circular pit (context 7). The finds from the fill (context 6) included some iron nails, two sherds of post-medieval (17^{th}/ 18^{th} century) pottery and ceramic building material. This feature was interpreted as a post-medieval/modern refuse pit.

Additional finds

Once again, the majority of finds recovered represented small pieces of pottery of post-medieval date. The topsoil/ subsoil (context 5) also produced four pieces of metal, including a square cut nail, nine small pieces of ceramic building material and a discarded field drain.

Table 8.1 Finds recovered from Test pit 1. All pottery assessed by Dr Elaine Morris, Uni. of Southampton.

Context No.	Context description	Material type	Period	Quantity	Weight (g)	Diagnostics
8	Ploughsoil	Pottery	Late medieval	1	4	1 x late medieval, glazed sherd, white media - Quartz sand
		Pottery	Late/ post-medieval	3	17	3 x redwares, late medieval/ post medieval
		Pottery	C19th	1	3	1 x stoneware, 19th century
		Pottery	C18th	2	1	2 x pearlware (1 blue and white), 18th century
		Clay pipe		1	1	1 x clay pipe stem fragment
		Fired clay		2	6	2 x fragments of fired clay
9	Subsoil	Pottery	Late/ post-medieval	9	25	9 x redware sherds
		Pottery	C11-early C13th	1	11	1 x Early medieval Gritty Ware (previously thought to be Late Bronze Age); c. 11th- early13th Century. Jar/ possible cooking pot sherd.
		Metal		1	6	1 x iron nail
		Flint	Prehistoric	2	3	2 x worked flint (no diagnostic characteristics)
		Ceramic building material		3	14	3 x CBM
		Glass		1	1	1 x bottle glass
10	Ditch fill	Bone	Iron Age	1		Fragment of proximal end of cow's left tibia* (2204±31 BP, SUERC-58166)
		Slag		5		Small pieces of slag

Table 8.2 Finds recovered from Test pit 3

Context No.	Context description	Material type	Period	Quantity	Weight (g)	Diagnostics
5	Top/ subsoil	Pottery	Post-medieval	1	2	1 x slip decorated, post-medieval
		Pottery	Post-medieval	1	4	1 x Buff fabric, glazed interior
		Pottery	Post-medieval	1	1	1 x redware, unglazed
		Pottery	Post-medieval	1	7	1x pearlware fragment
		Metal		4	45	4 x metal pieces, including a square cut nail
		Fired clay object		1	75	1 x fired CBM - hearth edge?
		CBM		2	348	2 x Brick
		Field drain		1		1 x modern discarded field drain
		Ceramic building material		9	35	9 x Ceramic building material pieces
6	Pit (feature 1)	Pottery	C17th-C18th	1	2	1 x redware (glazed on both surfaces), c. 17th/ 18th century
		Pottery	C17th	1	10	1 x tigerware slip, buff-coloured fabric, 17th century
		Metal		3	14	3x nails
		Rock		1	408	1 x Rock (shaped)
		CBM		5	282	5 x Ceramic building material

Auger Survey

In addition to the small-scale excavations, the collection of auger holes offered the opportunity to acquire additional data to refine the deposit model. A long auger transect (BH1-10) was therefore conducted down the slope of the field, at c. 30m intervals, and out onto the alluvial plane (as shown in Figure 8.2). An additional transect was carried out, c. 250m to the west of this long transect, to confirm uniformity in the underlying deposits of the large field. However, the second transect was terminated after three auger holes (BH12-14) due to the tenant farmer requiring work to cease in the field at short notice.

The auger transects indicated that the general sequence down the northern flank of Pawlett Hill consisted of a shallow clay loam topsoil, overlaying a silt loam subsoil, with infrequent pebble inclusions; which in turn overlay Burtle Formation sand and gravels. This stratigraphic sequence was confirmed during the excavations (as described above).

A power auger was also used to target three locations (on the flank of the hill, by the field boundary and out onto the floodplain (BH15-19W) in an attempt to access the deeper alluvial sequences believed to be present at the island edge. This process confirmed that the topsoil and subsoils overlay alluvial silts and clays, which were covering the underlying gravels and sands. Borehole 19W also demonstrated that interbedded organic horizons are preserved at the wetland/dryland edge of Pawlett Hill, thus indicating that the local stratigraphic sequence was comparable to that seen at Walpole. A second auger hole was therefore extracted at this

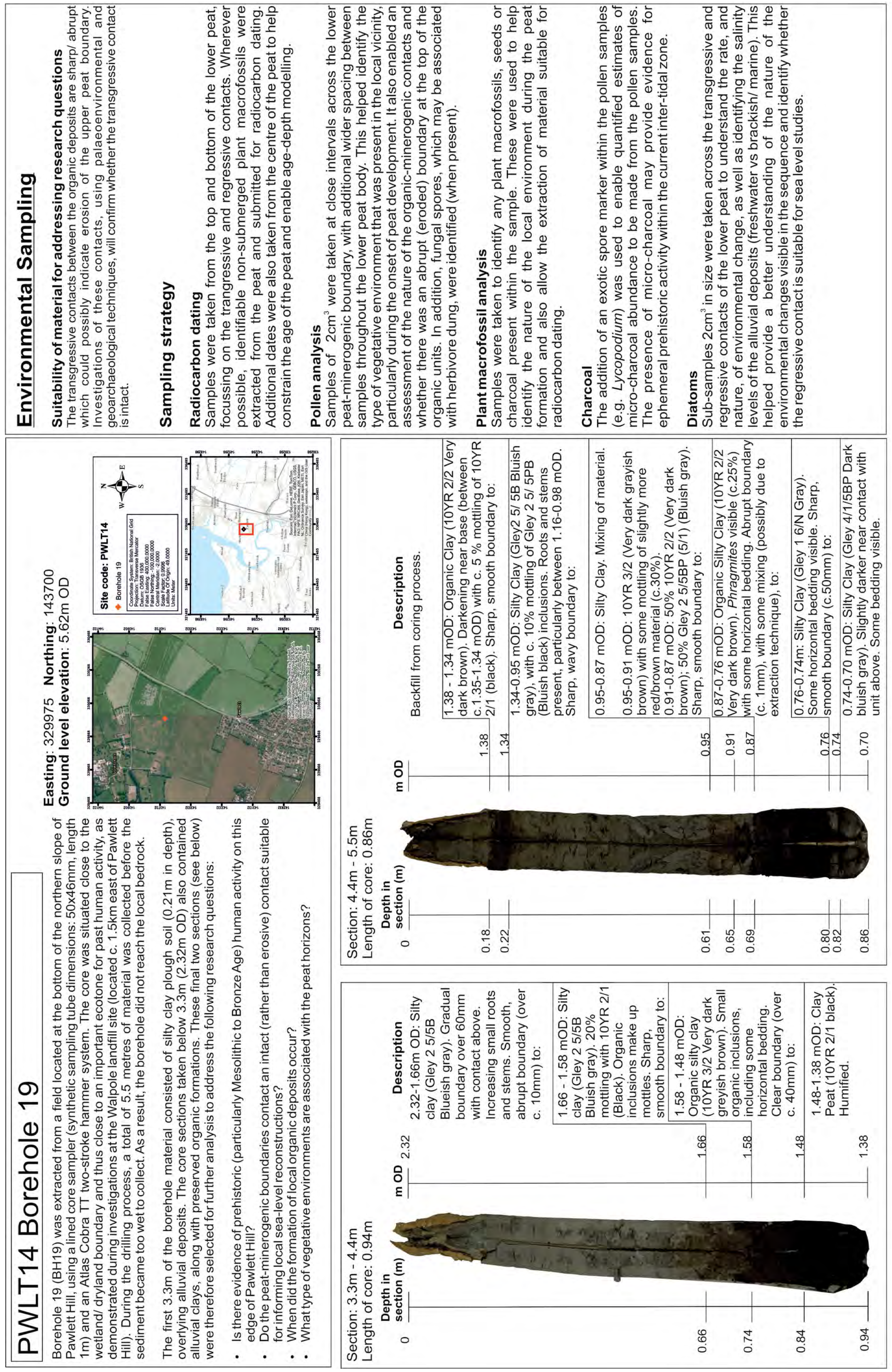


Figure 8.5 Sampling strategy for borehole 19

location (borehole 19), using a lined core sampler, with the collected material retained for radiocarbon and environmental sampling.

Borehole 19: Radiocarbon dating and palaeoenvironmental assessment results

M.J. Grant, N. Cameron, P. Marshall and P.D.M. Hughes

Borehole 19 (BH19) was extracted from a field located at the bottom of the northern slope of Pawlett Hill, using a lined core sampler (synthetic sampling tube dimensions: 50x46mm, length 1m) and an Atlas Cobra TT two-stroke hammer system. The core was situated near to the wetland/ dryland boundary and thus close to an important ecotone for past human activity, as demonstrated during investigations at the Walpole landfill site (located c. 1.5km east of Pawlett Hill). During the drilling process, a total of 5.5 metres of material was collected before the sediment became too wet to be retained within the corer. As a result, the borehole did not reach the local bedrock. Figure 8.5 presents the stratigraphic sequence of the lower sections of the borehole along with a description of the environmental sampling strategy, with full details of palaeoenvironmental assessment methodologies area outlined in appendix 1.

Radiocarbon dating

Five samples were submitted for dating, all extracted from the lower peat horizon identified within the borehole. These included four single *Phragmites australis* macrofossils and a 'bulk' peat sample (Table RC2). One of the duplicate *Phragmites* samples from 0.81m OD [GU36308] failed due to producing insufficient carbon during pretreatment. Measurements on the humic and humin fractions of the peat sample from 0.87–0.86m OD are statistically consistent (T'=3.8; T'(5%)=3.8; v=1; Ward and Wilson 1978) and a weighted mean (5261±22 BP) has been taken as providing the best estimate for the age of the deposit. The age-depth model estimates that the Lower Peat [0.76m OD] started to accumulate in 6460–6055 cal BP (95.4% probability) and ended in 6110–5925 cal BP (95.4% probability), with a relatively uniform rate for peat formation. A full report of the radiocarbon dating results is presented in Appendix 2.

Table 8.3 Radiocarbon dates from Borehole 19

Laboratory Number	Sample Depth (m ODN)	Material Dated	Radiocarbon Age (BP)	δ^{13}C (‰)	Calibrated Date (95.4% confidence) cal. BP
SUERC-57809	0.87–0.86	Peat, humic acid	5219±30	−29.0	
SUERC-57810	0.87–0.86	Peat, humin	5302±30	−29.2	
		T'=3.8; T'(5%)=3.8; v=1	5261±22		6180–5940
GU36308	0.81	*Phragmites australis,* single fragment, horizontally bedded: 100mg	Failed insufficient carbon		
UBA-27975	0.81	*Phragmites australis, single fragment,* horizontally bedded: 100mg	5368±47	−27.9	6290–5990
SUERC-57814	0.78	*Phragmites australis, single fragment,* horizontally bedded: 400mg	5367±30	−25.1	6280–6010
UBA-27976	0.76	*Phragmites australis*, single fragment, horizontally bedded: 228mg	5431±45	−28.1	6310–6120

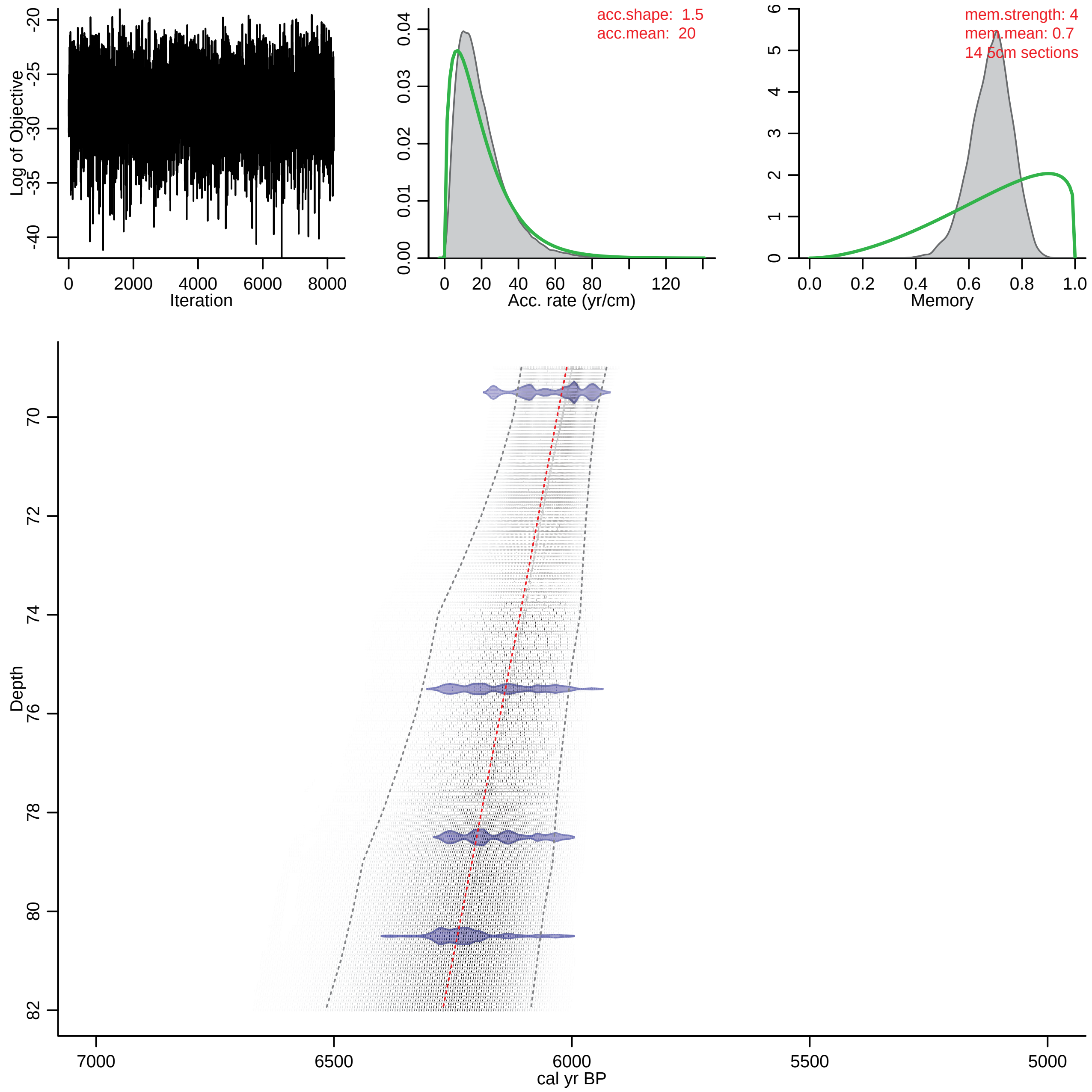


Figure 8.6 Age – depth model for Borehole 19

Plant Macrofossil Remains

Three samples for plant macrofossil assessment were taken throughout the peat. After sieving a minerogenic component was still visible within the residue. The peat contains a range of remains. Within the basal two samples Phragmites australis (common reed) remains, including leaf / stem fragments, are present, though by the uppermost sample Monocotyledon fragments are frequent. Degraded wood fragments are also present in the middle sample (0.81-0.80 mODN). In addition to Phragmites remains there were seeds of *Juncus* spp. (rushes), *Carex* spp. (sedges) and *Eupatorium cannabinum* (Hemp-agrimony) typical of damp wetland locations. Within the uppermost two samples Unidentified Organic Matter (UOM) was abundant, with the peat being highly humified. Additional material present within the samples included insect fragments, fungal hyphae in the uppermost sample, and occasional charcoal fragments.

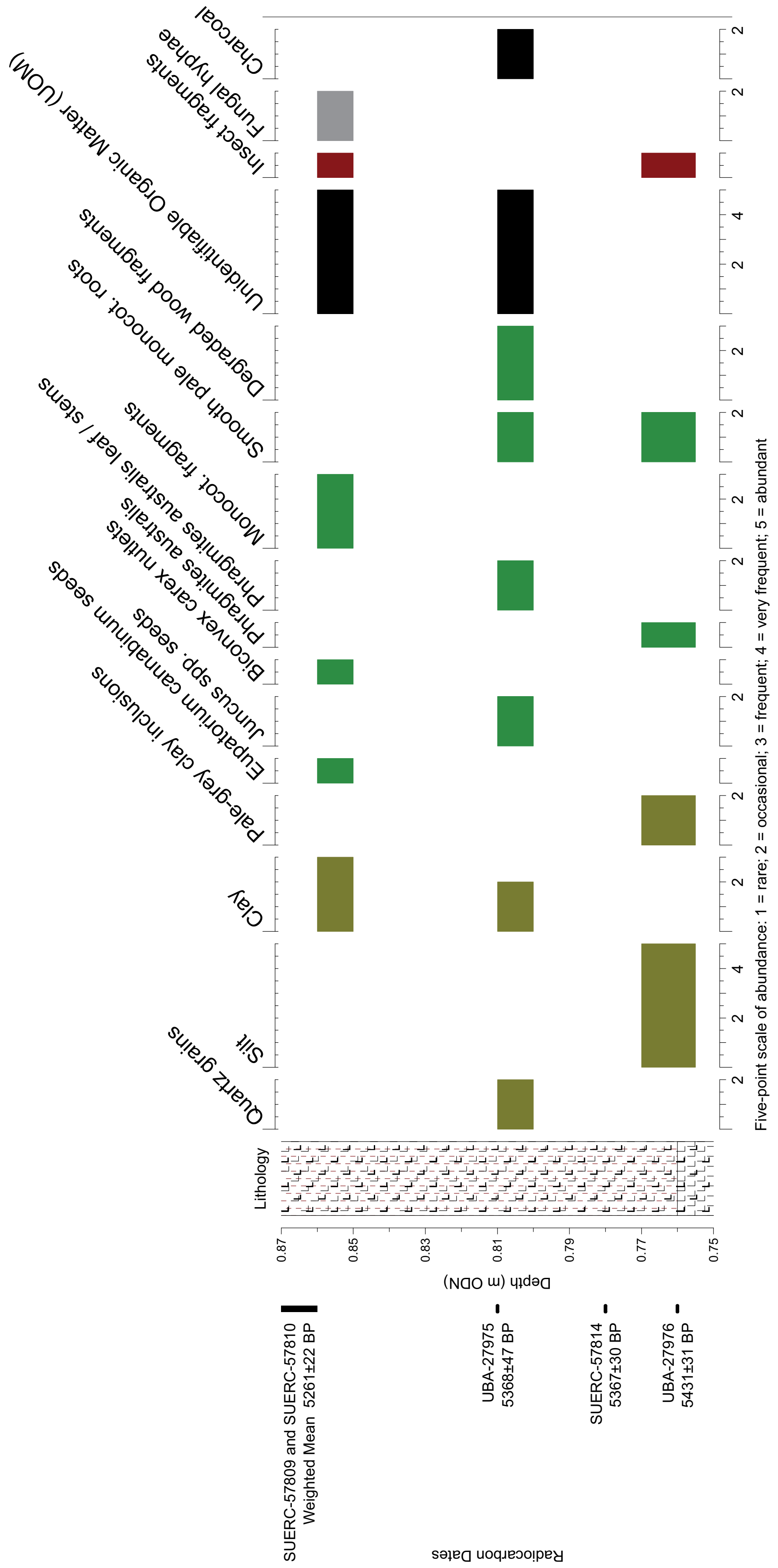


Figure 8.7 Plant macrofossil diagram for borehole 19

Pollen

Pollen assessment was undertaken on nine samples through the peat layer, between 0.87 and 0.72m ODN. Pollen preservation and concentrations were sufficient to permit full assessment to take place. Three local pollen assemblage zones (LPAZ) were defined for the sequence (see Figure 8.8 and Table 8.4).

Table 8.4 PWLT BH19 Pollen Zone Descriptions

LPAZ	Depth (m ODN)	Description
PWLT-3	0.84 to 0.86	Dominated by *Quercus* (17-23%), *Alnus glutinosa* (12-23%) and *Populus* (11-19%). Tree and taxa present include *Ulmus* (4-7%), *Betula* (1-3%), *Tilia cordata* (1-6%), and *Corylus* avellana-type (%). Dwarf shrub and herb taxa include Chenopodiaceae (1-3%), Rubiaceae (up to 6%), *Solidago virgaurea*-type (1%), Cyperaceae (4-12%) and Poaceae (6-15%) along with occurrences of *Filipendula* (up to 1%). *Sparganium emersum*-type (2-13% TLP + Aquatics) and *Typha latifolia* (up to 2% TLP + Aquatics) decrease through the zone. Pteropsida (monolete) indet. (23-85% TLP + Pteridophytes) and *Polypodium* (1-2% TLP + Pteridophytes) are present throughout the zone. *Podospora* (up to 1% TLP + NPP) were also recorded. Pollen concentrations decrease from 290370 to 35070 grains cm^{-3}. Micro-charcoal values decrease from 6370 to 480 particles cm^{-3}.
PWLT-2	0.78 to 0.84	Dominated by Poaceae (42-45%) and *Quercus* (15-19%) along with *Corylus avellana*-type (%) and Cyperaceae (8-12%). Tree and shrub taxa present include *Ulmus* (2-5%), *Alnus glutinosa* (4-7%) and *Salix* (3-4%). Dwarf shrub and herb taxa include Chenopodiaceae (up to 5%) and Rubiaceae (1-2%), along with single occurrences of *Filipendula* (up to 1%) and *Lotus* (up to 1%). *Sparganium emersum*-type (up to 19% TLP + Aquatics) and *Typha latifolia* (up to 6% TLP + Aquatics) peak at the end of the zone. Pteropsida (monolete) indet. (11-63% TLP + Pteridophytes) and *Polypodium* (1-2% TLP + Pteridophytes) are present throughout the zone. *Sporormiella*-type (up to 1% TLP + NPP) and *Podospora* (up to 2% TLP + NPP) were also recorded. Pollen concentrations increase through the zone from 32970 to 63830 grains cm^{-3}. Micro-charcoal values vary between 16350 and 43710 particles cm^{-3}.
PWLT-1	0.72 to 0.78	Dominated by Poaceae (17-36%), Cyperaceae (16-22%) and *Quercus* (11-22%) along with *Corylus avellana*-type (%). Tree and shrub taxa present include *Pinus sylvestris* (1-4%), *Ulmus* (2-5%), *Betula* (1-2%), *Alnus glutinosa* (3-5%), *Tilia cordata* (2-3%) and *Salix* (up to 2%). Dwarf shrub and herb taxa include Chenopodiaceae (4-9%), Rubiaceae (up to 2%) and *Solidago virgaurea*-type (up to 3%), along with single occurrences of *Rumex acetosa* (up to 1%) and *Plantago lanceolata* (up to 1%). *Sparganium emersum*-type (1-6% TLP + Aquatics) is present throughout along with an occurrence of *Typha latifolia* (up to 1% TLP + Aquatics). Pteropsida (monolete) indet. (3-9% TLP + Pteridophytes) is present throughout the zone. Occurrences of *Podospora* (up to 1% TLP + NPP) were also recorded. Pollen concentrations increase through the zone from 3590 to 27400 grains cm^{-3}. Micro-charcoal values vary between 4310 and 14660 particles cm^{-3}.

The lowermost pollen zone (PWLT-1) shows an assemblage dominated by Poaceae (grasses) and Cyperaceae (sedges) with a mixed woodland component consisting of *Ulmus* (elm), *Quercus* (oak), *Betula* (birch), *Tilia cordata* (small-leaved lime) and *Corylus avellana*-type (hazel), while the more local (wetland) woodland component also includes *Alnus glutinosa* (alder) and *Salix* (willow). The presence of *Lornicera periclymneum* (honeysuckle) can also be attributed to a local canopy component. The strong presence of Chenopodiaceae (goosefoots) throughout the sequence may be attributed to local saltmarsh / coastal communities. The presence of *Sparganium-emersum* type (bur-reeds) and *Typha latifolia* (bulrushes) also indicate areas of standing

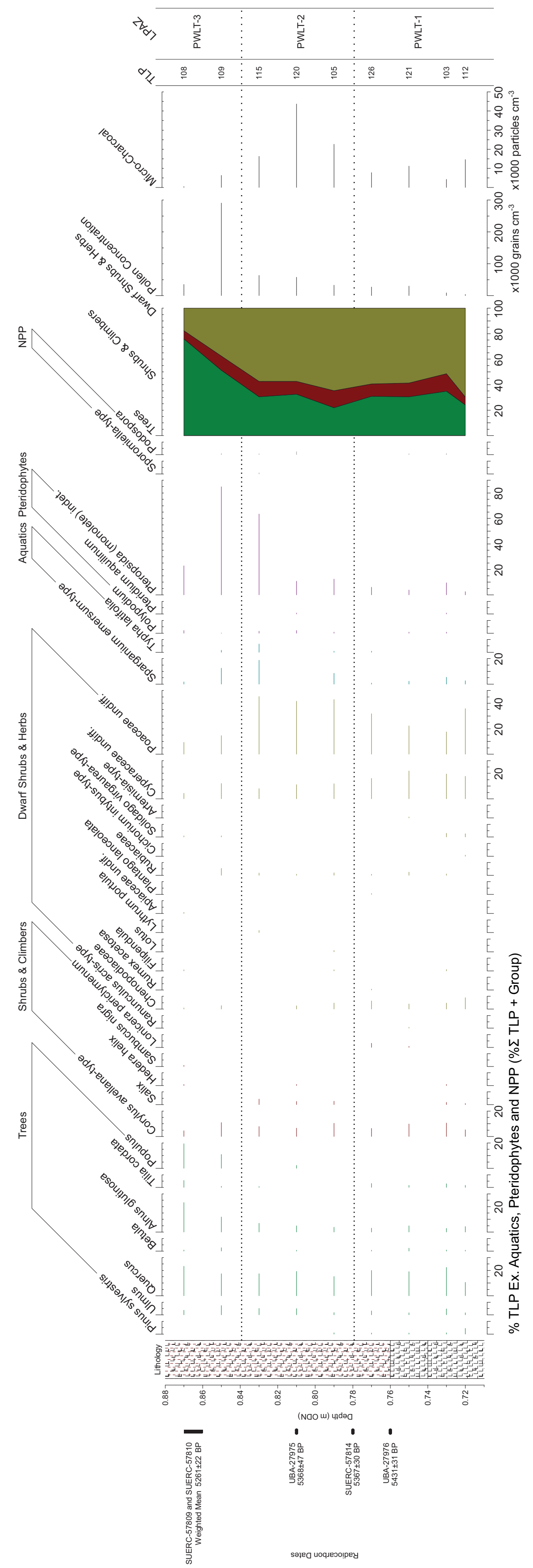


Figure 8.8 Pollen diagram for borehole 19

/ slow moving water. The pollen assemblage therefore suggests a lowland estuarine wetland community, with some local wetland woodland, while areas of dryland woodland are also present within the pollen source area. Micro-charcoal and *Podospora* concentrations are low suggesting limited activity upon the marsh, though the presence of *Rumex acetosa* (common sorrel) and *Plantago lanceolata* (ribwort plantain) at the end of the zone may suggest some disturbed ground within the pollen source area.

The expansion of Poaceae, probably attributable to *Phragmites australis* (common reed), along with *Sparganium-emersum* type and *Typha latifolia*, in PWLT-2 suggests an expansion of shallow water communities, with increases in *Salix* also indicating some expansion of wetland woodland communities. There is an increase in micro-charcoal, along with an increased presence of *Sporormiella*-type and *Podospora*, which may indicate local burning, possible increases in local grazing activity, and might suggest some local wetland management (e.g. reed burning).

By PWLT-3 the open ground component has decreased, coinciding with a reduction in micro-charcoal, with an expansion of woodland components, notably *Alnus glutinosa* and *Populus* (poplars; probably *Populus tremula* – aspen), along with *Sambucus nigra* (elder) which may indicate an expansion of wetland woodland communities. Chenopodiaceae is present throughout the zone suggesting the continued local presence of some saltmarsh / coastal communities.

Diatoms

Eleven samples were assessed for diatoms from the BH19 sequence (see appendix 4 for full report). Diatoms were found in ten samples and are absent from one sample. However, the diatom assemblages are very poorly preserved throughout BH19. The number of diatoms recovered from the BH19 samples is very low and the quality of diatom valve preservation is very poor. There is no potential or only low potential for further diatom analysis of the lower sediments, within samples between 0.72 and 0.85 m ODN, and there is only some or low potential for analysis of the top three samples between 0.87 m and 0.91 m ODN.

The ten diatomaceous samples contain brackish water and marine diatoms that throughout the sequence are indicative of contact with tidal waters. Polyhalobous, marine diatoms appear to be most abundant in the top samples between 0.83 to 0.91m ODN. The coastal planktonic diatom *Paralia sulcata* is relatively abundant in the top five samples, and is also present in samples lower down the sequence (0.79 and 0.75 to 0.72m ODN). Other polyhalobous taxa present, particularly in the top of the core, are *Podosira stelligera*, *Cymatosira belgica*, *Campylosira cymbelliformis*, *Rhaphoneis surirella* and *Trachyneis aspera*.

Mesohalobous diatoms, notably the brackish marine species *Nitzschia navicularis*, are also common in the top five samples. This benthic diatom is associated with mud surface habitats in tidal environments. Other benthic mesohalobous diatoms found in the top part of BH19 are *Nitzschia punctata*, *Diploneis interrupta*, *Diploneis aestuari* and *Diploneis didyma*.

Oligohalobous indifferent and halophilous (e.g. *Navicula cincta* and *Rhoicosphaenia curvata*) taxa are also present in the top five samples. The oligohalobous indifferent diatoms include *Fragilaria brevistriata*, *Fragilaria construens* var. *venter* and *Fragilaria pinnata*. These taxa have growth optima in freshwater, but have broad salinity tolerances. The two bottom samples, 0.72 and 0.73m ODN, contain more aerophilous, desiccation-tolerant, diatoms. These aerophilous diatom species include *Navicula cincta*, *Navicula mutica*, *Hantzschia amphioxys* and *Nitzschia terrestris*. These diatoms may, for example, reflect the in wash of terrestrial material or an ephemeral aquatic habitat that was prone to drying out.

Synthesis of palaeoenvironment results

The palaeoenvironmental assessments have demonstrated that the peat sequence encountered in BH19 initiated c. 6460–6055 cal BP (95.4% probability) with the end of peat formation recorded as c. 6110–5925 cal BP. The diatoms and pollen indicate that this organic deposit formed within an estuarine setting with close links to brackish / marine water and local saltmarsh communities present. The strong minerogenic component indicates that the location was repeatedly flooded, probably contributing to the strong marine / brackish component recorded within the diatoms. The organic layer itself relates to open ground plant communities dominated by rushes and reeds, though areas of both wetland and dryland woodland are also recorded within the local area, the latter probably occupying the slopes of Pawlett Hill. An expansion of micro-charcoal within the middle of the peat sequence is replicated by the presence of charcoal during the plant macrofossil assessment and coincides with a period of increases in grass and reed pollen which may be related. These coincide with small increases in *Sporormiella*-type and *Podospora* spores, possibly attributed to increased grazing, which may suggest a causal relationship with deliberate burning of the wetland vegetation to stimulate new plant growth and entice grazing herbivores onto the marsh. Towards the top of the sequence some local open wetland communities have transitioned towards carr woodland communities, with alder being the dominant taxa, though a strong marine / brackish water component persists, albeit with a number of oligohalobous indifferent diatoms more suited to freshwater conditions. This again probably indicates seasonal flooding and minerogenic sediment deposition within the marsh environment and a gradual transition away from saltmarsh.

These results correlate well with site investigations undertaken at the Walpole Landfill Site where contemporary organic horizons are encountered interbedded within the estuarine silts, with excavations at the site providing evidence for grazing of the marshes through both animal footprints within the minerogenic deposits and associated animal bone assemblages (Hollinrake and Hollinrake 2007). Pollen work at this site (Hill and Cairns 2011) also shows a similar pollen assemblage though with a greater saltmarsh and reduced woodland components at this time.

Summary of investigations at PWLT14

The investigations conducted at Pawlett confirmed the presence of buried organic deposits at the wetland/ dryland edge of Pawlett 'island', which were shown to broadly correspond to sequences recorded at the multi-period, prehistoric site at Walpole Landfill. The data obtained from borehole 19 thus offers the opportunity to better contextualise the archaeological material at Walpole within the broader landscape, as well as providing additional data to help refine our general understanding of past environmental changes in this region.

Through the use of a gradiometer survey, it was shown that no linear or 'cursus' monument is present at this location. A previously unrecorded Iron Age 'ring ditch' was identified at the base of Pawlett Hill near the wetland/ dryland edge, through the use of geophysics and test pit excavation. These findings will therefore help refine our understanding of prehistoric land-use patterns within the region and also demonstrate that our understanding of the onshore prehistoric archaeological record is not always as robust as we may hope.

Although permission was forthcoming from the landowner regarding access to the site, delays in crop removal ultimately impacted upon the scale at which the site could be sampled through test pit excavation. As a result, only a very small fraction of the field was subjected to archaeological interventions – the locations of which were driven by the geophysical survey results. It was therefore not overly surprising that little prehistoric material was encountered during the excavations, particularly as two out of the three test pits were found to target relatively modern features. A greater sampling rate of the field would have therefore been preferred during the ground truthing exercises, in order to more conclusively test the archaeological potential of the site, but unfortunately on this occasion it was not possible.

The presence of organic deposits at the base of the hill and out onto the floodplain, as identified during the auger survey, suggests that further investigations conducted at the wetland/ dryland edge of the hill could result in the recovery of earlier prehistoric material in the future. However, given the depths of the deposits at the wetland/dryland edge, such interventions would ideally need to be conducted at a much larger scale than those employed during this study.

Stolford (STFD14, Onshore)

The second location targeted during the ground truthing phase of the project was at Stolford. This part of the Bristol Channel coastline has long been recognised as an important location for enhancing our understanding of Holocene environmental changes, due to the submerged forest-beds and peat deposits preserved along the local foreshore (e.g. Heyworth 1985). Investigations of the Stolford stratigraphic sequences were most notably

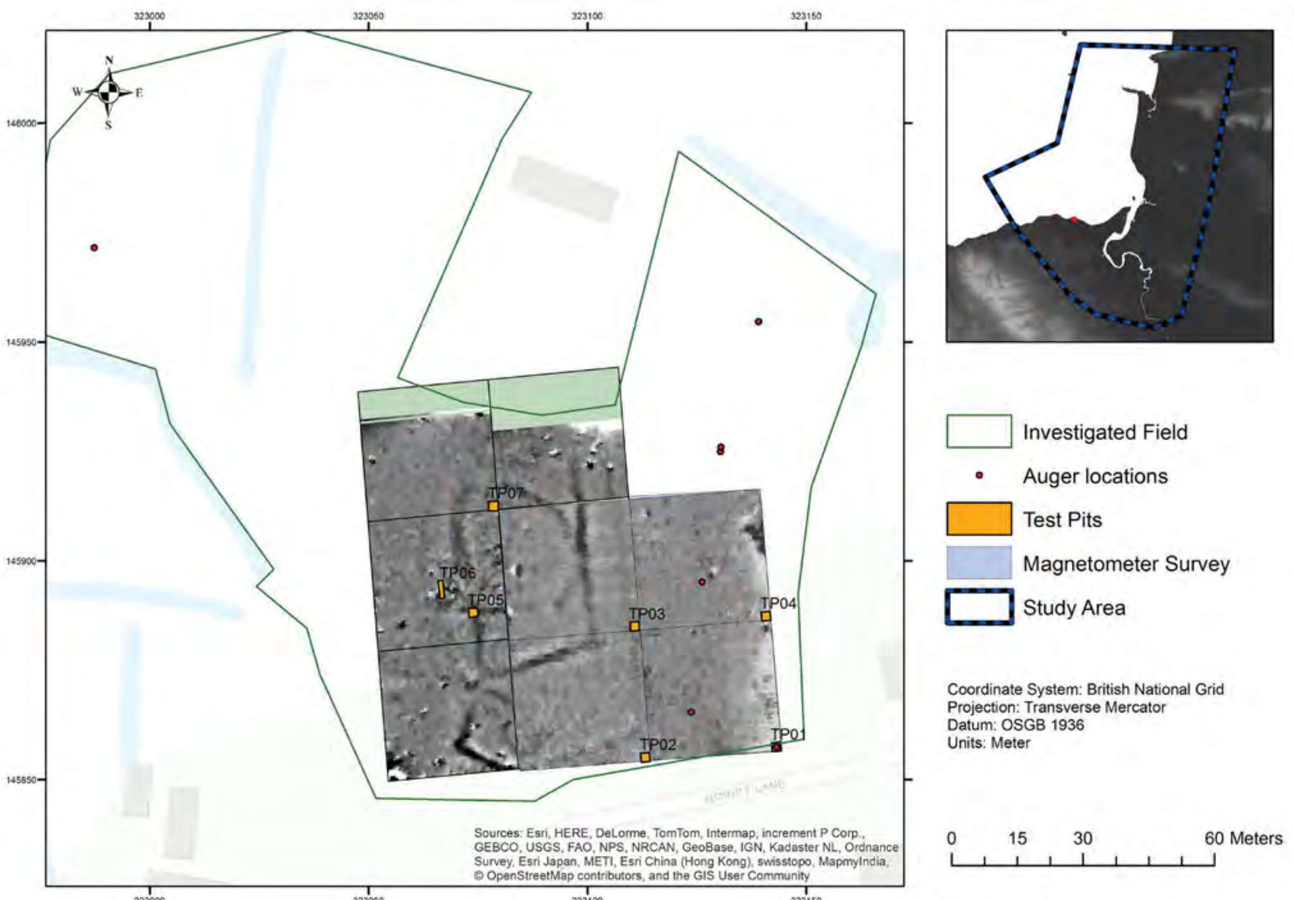


Figure 8.9 Onshore site investigations at Stolford (STFD14)

undertaken by Kidson and Heyworth (1973; 1976; Heyworth 1985). During these investigations a number of peat shelves and submerged forest deposit were identified both exposed on the foreshore and also sampled within coring transects across the intertidal zone down to low water, with further coring of the hinterland to track identified peat deposits inland. Water-worn flints were also recovered from this area in the early twentieth century (Gray 1908), thus suggesting evidence for prehistoric activity may be preserved within the local deposits. This area was therefore identified as an area of particular archaeological interest, offering the opportunity to investigate preserved deposits onshore, within the inter-tidal zone and possibly offshore.

The fieldwork conducted at Stolford was split into two main components: one which targeted the onshore buried deposits and one that targeted the preserved organic deposits within the inter-tidal zone (chapter 9). At a later date, in August 2014, a Remotely Operated Vehicle (ROV) and divers were used to target deposits of potential interest offshore (chapter 10). After consultations with local landowners, the onshore component of this fieldwork was conducted in the field located behind 'Chapel Cottages'; a series of small cottages built where a 14th century chapel once stood (PRN 34895). The field is situated on a slight topographic rise, set back from the sea wall. Here investigations looked to explore the extent of the buried alluvial sequences known to exist within the area, as well as attempt to recover evidence for prehistoric human activity.

Preliminary surveys

An auger transect was carried out to determine the site's stratigraphic sequence and thus help guide the positioning of the test pit excavations. The transect covered the length of the field, from the south-eastern side heading seawards, with auger holes collected at 30 metre intervals. This process demonstrated that a shallow modern ploughsoil and a compact subsoil overlay a gravelly head deposit, with the auger holes only achieving a depth between 0.18 and 0.84 meters before the deposits became too difficult to auger.

To ensure a comparable methodology was adopted at both 'onshore' locations, a preliminary magnetometer survey was also conducted using a Bartington gradiometer. This survey highlighted the presence of a number of linear features, and an irregular-shaped anomaly within the western half of the field (see Figure 8.9).

Excavations

Using the results of both the magnetometry and auger transect, a total of seven test pits were excavated within the field. In all the test pits, a gravelly 'head' deposit was encountered beneath the fairly compact, but shallow, topsoil (depth: c.0.05-0.10m) and subsoil (depth: c. 0.11-0.15m) deposits. This suggested that the shallow sequence identified during the auger survey was relatively uniform across the field. The majority of the test pits were therefore terminated when they reached the gravelly head deposit. However, in test pits 2 and 4, a 1 by 1 meter sub-section was excavated through the head deposit to investigate the nature of the underlying geology. This process determined that the gravelly head deposit was overlying a sandy head deposit.

Test pits 1-4

Test pits 1 -4 were positioned at 30 meter intervals, to sample the south eastern corner of the field. These test pits were excavated primarily to provide a better insight into the nature of the underlying deposits of the field, than was achieved through the auger transect. No features were identified in any of these four trenches.

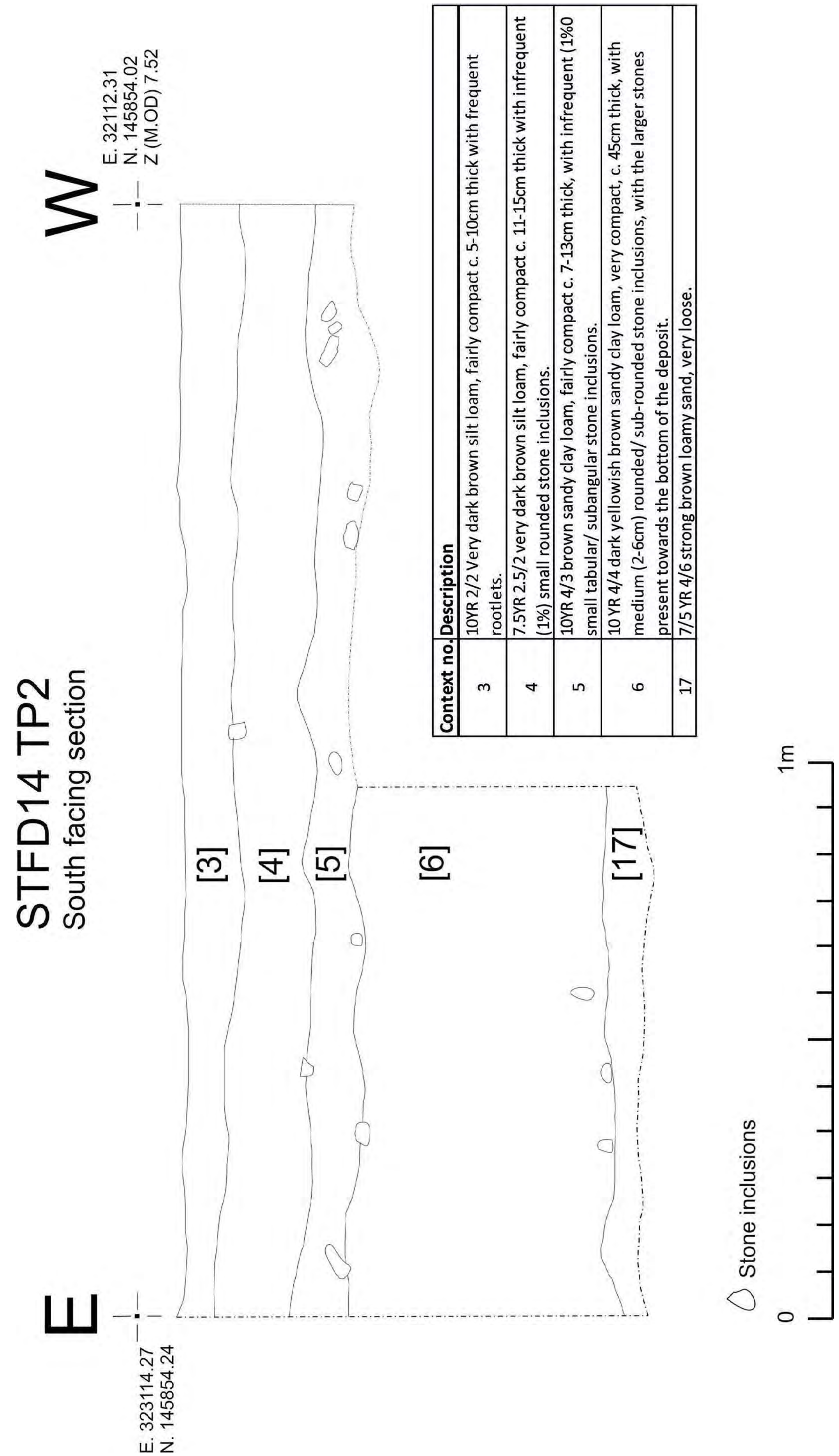
A few items of pottery were recovered from the plough soil in test pits 3 and 4 and from the subsoil in test pits 2-4. The majority of these were dated typologically to the medieval or post-medieval periods, although one piece from the topsoil of test pit 3 was identified as potentially Iron Age in date. Thirteen small pieces of metal were also recovered from the topsoil in test pit 1.

Table 8.5 Finds recovered from Test pit 1

Context No.	Context description	Material type	Period	Quantity	Weight (g)	Diagnostics
1	Topsoil	Pottery	C18th	2	2	2 x very small sherds (1 blue and 1 lead glaze red ware), 18th Century
		Metal		13	36	13 pieces of metal
2	Head deposit	Pottery	Medieval	1	4	1 x medieval pot sherd, sandy fabric rim (cooking pot)
		Pottery		4	22	4 x Lead glazed redware
		Pottery		1	10	1x Stone ware

Table 8.6 Finds recovered from Test pit 2

Context No.	Context description	Material type	Period	Quantity	Weight (g)	Diagnostics
3	Topsoil	Pottery	C16th	7	62	7 x lead redware - 4 glazed and 1 thick red glaze (remnant of tudor green); 16th Century
4	Subsoil	Pottery	Late Medieval/ C18th	5	36	5 x redwares: 2 x late med (14th/ 15th century) non-glazed sandy wares; 2 x lead glaze (18th century)
		Fired clay		1	9	1 x fired clay fragment



Context no.	Description
3	10YR 2/2 Very dark brown silt loam, fairly compact c. 5-10cm thick with frequent rootlets.
4	7.5YR 2.5/2 very dark brown silt loam, fairly compact c. 11-15cm thick with infrequent (1%) small rounded stone inclusions.
5	10YR 4/3 brown sandy clay loam, fairly compact c. 7-13cm thick, with infrequent (1%0 small tabular/ subangular stone inclusions.
6	10 YR 4/4 dark yellowish brown sandy clay loam, very compact, c. 45cm thick, with medium (2-6cm) rounded/ sub-rounded stone inclusions, with the larger stones present towards the bottom of the deposit.
17	7/5 YR 4/6 strong brown loamy sand, very loose.

Figure 8.10 Section of Test pit 2 demonstrating the stratigraphic sequence at STFD14 (onshore)

Table 8.7 Finds recovered from Test pit 3

Context No.	Context description	Material type	Period	Quantity	Weight (g)	Diagnostics
7	Topsoil	Pottery	Post-medieval	1	26	1 x glazed stoneware
		Pottery	Late post-medieval?	3	22	3 x late post-medieval(?) potsherds
		Pottery	Post-medieval (C16th; 17th;18th; 19th)	3	7	3x redwares including a rim. Post-medieval - 16th, 17th, 18th, 19th century?
		Pottery	Late Medieval	1	1	1 x late medieval fine sandy ware (jug form)
		Pottery	Medieval	1	2	1 x medieval sandware cooking pot body sherd
		Pottery	LIA or Medieval	1	2	LIA/ Medieval sandyware - curved form of small sherd suggests small vessel thus points to IA
		Slate roof tile		1	1	1 x slate roof tile fragment
		Bone		1		Piece of animal bone

Table 8.8 Finds recovered from Test pit 4

Context No.	Context description	Material type	Period	Quantity	Weight (g)	Diagnostics
9	Topsoil	Pottery	Post-medieval (probably C17th-18th)	6	46	6 x potsherds - post-medieval, probably 17th-18th century

Test pits 5 & 7

Test pits 5 and 7 were positioned to target one of the linear anomalies and the irregular-shaped anomaly identified within the gradiometer survey. No features were identified during these excavations but a few finds were recovered. These included six pieces of metal and six potsherds from the ploughsoil in test pit 5, whilst the ploughsoil in test pit 7 produced eighteen pieces of pottery, one piece of CBM and a complete small horse/ donkey shoe.

Table 8.9 Finds recovered from Test pit 5

Context No.	Context description	Material type	Period	Quantity	Weight (g)	Diagnostics
12	Topsoil	Pottery		4	19	4 x redware (no glaze)
		Pottery	Late Medieval	1	1	1 x late medieval sandyware, glazed exterior
		Pottery	Post-medieval (C17th-18th)	1	1	1 x post-medieval, thin-walled, wheel-thrown pottery sherd; c.17th-18th century
		Metal		6	18	6 pieces of metal

Table 8.10 Finds recovered from Test pit 7

Context No.	Context description	Material type	Period	Quantity	Weight (g)	Diagnostics
18	Topsoil	Pottery	C16th/ C17th	2	13	2 x North Devon gravel tempered ware, 16th-17th century
		Pottery	C16th/ C17th	1	7	1 x slipped ware (glazed), 16th/17th century
		Pottery	C16th/ C17th	1	7	1x slipped ware (glazed), 16th/17th century
		Pottery		12	66	12 x redware, some glaze
		Pottery	Post-medieval	1	3	1 x pearl ware with transfer print (blue and white), post-medieval
		Pottery	Post-medieval	1	1	1 x white ware; post-medieval
		Metal		1	35	1 small horse/ donkey shoe (complete)
		Ceramic building material		1	16	1 x piece of ceramic building material

Test pit 6

Feature 1

Test pit 6 produced a shallow (c. 0.2meter in depth), linear feature with a curved base, positioned in an east-west orientation. The fill was a dark brown (7.5YR 3/2) clay loam which contained seven small fragments of pottery, part of a clay pipe, four fragments of fired clay, two pieces of slate roof tile and four iron pieces. The feature is thought to represent an old drainage ditch.

Table 8.11 Finds recovered from Test pit 6

Context No.	Context description	Material type	Period	Quantity	Weight (g)	Diagnostics
14	Topsoil	Pottery	Post-medieval (C18th?)	5	65	5 x sherds; post-medieval potsherds; including a piece from a large conical bowl (used for dairying?); 18th century(?)

15	F1 fill	Pottery	LIA/ Roman	1	2	1 x LIA/Roman Black burnished ware - burnished still present
		Pottery		3	13	3 x redware (unglazed)
		Pottery	Late Medieval	3	14	3 x sandy ware, late medieval
		Metal		4	19	4 pieces of metal
		Slate roof tile		2	11	2 x slate roof tile fragments
		fired clay fragments		4	8	4 x pieces of fired clay fragments; including 1 possible piece of briquetage
		Clay pipe		1	11	1 x piece of clay pipe

Figure 8.11 Test pit 6 prior pre-excavation of the ditch feature

Additional borehole

As no alluvial deposits were encountered during the excavations it was thought that the buried alluvial deposits known to be present at Stolford, were possibly located to the west of the field. A power auger was therefore used to collect a window sample (BHA2) at the far northwest boundary of the field, in an attempt to find the valley edge. The window sample indicated that an intermixing of sands and clays were present c.0.41-0.63 meters below the surface, with possible alluvial deposits appearing to be intermixed with the local head deposit throughout the section. This intermixing of deposits was interpreted as the onlapping of alluvium on the edge of the topographic rise; thus indicating that preserved alluvial deposits were probably located to the west of the field investigated during this project.

Summary of STFD14 (onshore) investigations

The seven test pits excavated behind Chapel Cottages produced very little in the way of features and demonstrated that the shallow stratigraphic sequence detected during the preliminary auger transect was fairly uniform across the field. No palaeoenvironmental data was recovered during the these investigations, with borehole BHA2 indicating that any organic deposits preserved behind the sea wall are probably buried to the west of Chapel Cottages.

The number of finds recovered during these investigations was also relatively low. The main find type was pottery, most of which was medieval or post-medieval in date along with a couple of possible Iron Age/ Late Iron Age pieces being identified. Once again no evidence of earlier prehistoric activity was detected during these investigations.

Taken together, these findings indicate that the fields to the west of Chapel Cottages, towards Hinkley Point, may have a higher potential in producing prehistoric archaeological material due to the increased likelihood of encountered buried organic horizons. Unfortunately access to these areas was not granted to investigate this hypothesis further.

Summary of onshore investigations

Neither site targeted during the onshore investigations produced any archaeological material conclusively dating to main chronological focus of the current study (Palaeolithic to Bronze Age). However, two important findings were made at Pawlett in relation to prehistoric land-use patterns. Firstly, it was established that a 'cursus' monument (PRN 10700) was not present at the site, thus disproving a previous interpretation of a crop mark identified within an aerial photograph. Secondary, the use of a gradiometer survey helped identify a previously unrecorded circular feature, which was shown to represent an Iron Age 'ring ditch' positioned at the base of Pawlett Hill. These findings demonstrate the importance of ground truthing areas thought to be of archaeological interest, in order to move our understandings of the archaeological record away from speculation and towards one founded on evidence.

The small number of finds and features recovered at both onshore sites emphasises the difficulty in prospecting for earlier prehistoric sites in England, where the majority of the preserved material culture consists of relatively sparse lithic scatters. This difficulty is compounded when issues relating to access to landand time constraints restrict the level of sampling that can be achieved across a very broad area of 'high potential'. Furthermore, the challenges of accessing the deeper, buried deposits in certain areas of the current study area also places considerable constraints on our ability to truly explore and understand the preservation of prehistoric archaeological material within Somerset. These factors all have considerable implications when attempting to determine the archaeological potential of key areas within the landscape and need to be particularly acknowledged when attempting to translate our understanding of the terrestrial record into intertidal and offshore contexts.

Alluvial deposits were identified at the edge of Pawlett Hill and out onto Pawlett Level, towards Stretcholt. The sub-samples taken across the lower organic deposits of borehole 19 allowed for a series of radiocarbon dates to be obtained, in conjunction with pollen, diatom and plant macrofossil assessments. The results indicated that the stratigraphic sequences at this location are broadly comparable to those found elsewhere within the region, e.g. Walpole, thus providing the data necessary to contextualise changes witnessed at the site within broader understandings of environmental change. Whilst no palaeoenvironmental data was recovered from the onshore site at Stolford, it seems likely that deposits of archaeological interest are preserved in the adjacent field. It is therefore clear that whilst prospecting for unrecorded prehistoric finds and sites proved to be incredibly challenging, the modelling phases of the project were successful in identifying areas that had a high potential for preserved organic deposits.

Chapter 9
Inter-tidal investigations

Introduction

The project's inter-tidal ground truthing exercises were conducted along the foreshore at Stolford, Somerset (ST 233 460), between the 13th and 16th July 2014. As noted in the previous chapter, this stretch of the Bristol Channel coastline has long been recognised as an important location for enhancing our understanding of Holocene environmental change, due to the submerged forest-beds and intercalated peat and clay deposits preserved along the local foreshore (e.g. Heyworth 1985; PRN 34078).

A few water worn flints have also been recovered from this area (Gray 1908), highlighting the potential for preserved prehistoric archaeological material within the inter-tidal zone. However the Somerset Historic Environment Record (HER) also notes that the area was searched in 1988, albeit when there was considerable deposit of mud present, and no further finds were recovered (PRN 34893). The main objective of these investigations was therefore to excavate a number of test pits within the peat outcrops visible at low tide, in an attempt to identify and recover further evidence for prehistoric activity. In addition, the opportunity to sample some of the peat exposures present within the inter-tidal zone was also exploited in order to enhance our understanding of the local early to mid-Holocene environment. The findings from these palaeoenvironmental investigations provided additional information to help link the onshore and offshore datasets available for the region, thus allowing a more seamless discussion of the changing environment of the early Holocene and any associated archaeological material.

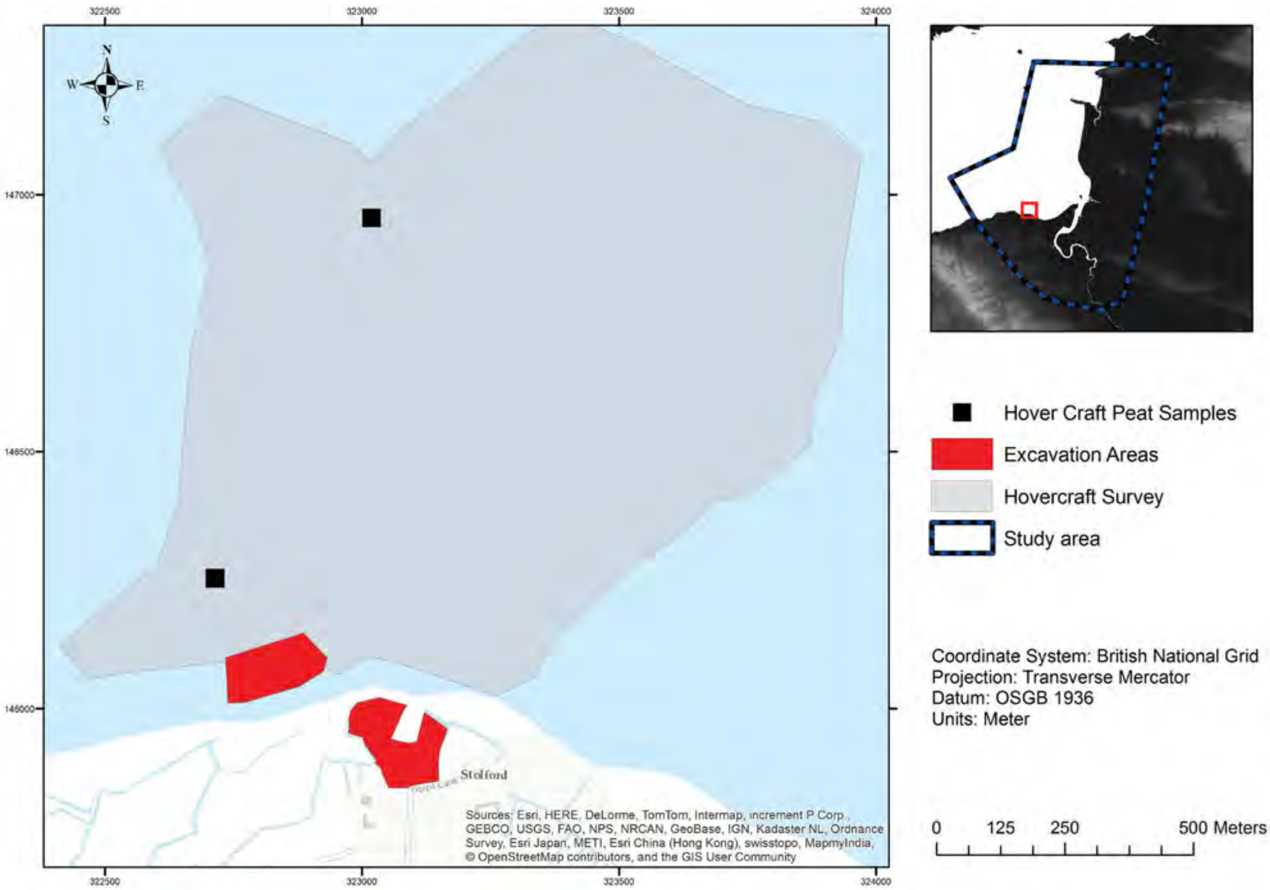


Figure 9.1 Site investigations at Stolford (STFD14). © Crown Copyright and Database Right [2015]. Ordnance Survey

Figure 9.2 Undergraduate students excavating at Stolford

Methodology

A walkover survey was conducted prior to any excavations in order to areas of interest. The main interventions consisted of a series of 1 x 1m test pits, dug by hand using spades, mattocks and troewls. These were excavated in 5cm spits, with the stratigraphic sequences recorded using Hodgson's (1997) terminology. A Leica GPS RTK system, set up using a base station (spatial and vertical accuracy ±0.01m), was used to survey in the locations of test pits, finds of interest and environmental samples.

A hovercraft was utilised to gain access to peat exposures present nearer the low water mark, as well as provide additional safety measures whilst working on the local foreshore. The survey took place at low tide between the 13th and 14th July 2014, just after the month's spring tide, when a tidal range of 11m was available at Stolford. Environmental samples were collected from two peat outcrops identified during the hovercraft survey (STFD14 <1>, <2> and <3>) and stored for further analysis at a later date. Bulk environmental samples were also retained from each test pit (c. 45 litres per 5cm spit) for wet sieving.

Excavations

A total of six test pits (no. 8-13) were excavated in order to target some of the peat outcrops visible within the foreshore, though the tidal range of the Bristol Channel meant that the foreshore was only exposed for short periods of time each day. Excavations were timed to safely utilise the low tide periods with excavations limited to test pitting through the exposed wood peat down to the underlying clays, often c. 0.15m below the surface.

Figure 9.2 Example test pit excavated within the Stolford foreshore (Test pit 9)

The majority of the test pits produced no finds, although a number of hazelnut fragments were recovered from test pit 11. The exception to this was test pit 13, which was excavated around an *in situ* auroch (*Bos primigenius*) tooth, identified within one of the peat outcrops during the first day of excavations. Prior to excavations, the tooth appeared to be positioned near a series of wooden 'stakes' which were thought to possibly represent a wooden structure. However, further investigation revealed that the pieces of wood were not the result of past anthropogenic activity.

Only one small (c. 1cm in length), undiagnostic flint was identified within the alluvial clays in test pit 13, with no additional animal bones or prehistoric material recovered during the inter-tidal excavations.

Additional finds

A deer metacarpal was found eroding out of the upper peat, next to a long (double) tree trunk during the first day of excavations but this showed no signs of anthropogenic modification.

The beach at Stolford was also visited briefly for a walkover survey in August 2014, after the offshore component of the project's fieldwork. During this visit, a small deer (cf. *Capreolus capreolus*) scapula and long bone were discovered in the submerged forest outcrop, with the location recorded as 322602 146170. Although blackened in colour, probably due to staining from the peat, these bones did not produce any evidence for anthropogenic modifications.

Table 9.1 Locations of finds recovered from Stolford foreshore

Type	Easting	Northing	Elevation	Comments
Bone	322602.5	146170.38		2 x animal bones (1 scapula and 1 long bone), probably small (roe?) deer, found in situ within a submerged forest/ peat outcrop in the foreshore at Stolford in August 2014. Bones stained black by intertial peat. No evidence of anthropogenic modifications. Bones identified by Dr J. Weinstock, Uni. of Southampton, August 2014.
Bone	327772.3	217343.62	0-1m	1 x left deer metacarpal found during walkover survey of foreshore at Stolford, July 2014. Bone found eroding out of the upper peat (wood peat) next to a long (double) tree trunk. Identified by Dr E Williams, Uni. of Southampton
Bone	322753.1	146044.46	0.944	Auroch tooth. Bone found in situ within a peat outcrop. No evidence of anthropogenic modification. Excavated within Test pit 13.

Summary

The extremely low number of finds recovered from the Stolford foreshore highlights the difficulty in successfully prospecting for new prehistoric material, even at locations where early Holocene organic deposits are known to exist. In this case, it was clear that the local tidal conditions placed considerable constraints on the time available to excavate and thus test pits did not expose the full sedimentary sequence overlying the local bedrock. In addition, the test pits could only target the peat outcrops accessible by foot which restricted the coverage of the archaeological interventions. Given the relatively small fraction of the foreshore that was sampled as a result, it is perhaps not too surprising that very little anthropogenic material was recovered, particularly as the majority of the archaeological record for the Mesolithic and Neolithic periods consists of small lithic scatters or single flint implements.

Assuming that archaeological material is preserved within some of the deposits within the area, any future archaeological investigations would therefore need to consider conducting larger scale interventions (if possible) in order to have the best chance of recovering new material. However, permission is unlikely to be forthcoming for this due to its highly protected status. Alternatively, walkover surveys in the area could possibly produce new evidence as sedimentary changes exposed different parts of the local foreshore. It is therefore clear that identifying areas of archaeological interest, with preserved organic deposits, is a task that can be conducted reasonably successfully. However determining how best to investigate these areas in order to truly enhance our understanding of the British prehistory is still extremely problematic, whether the deposits of interest are onshore, offshore or within the intertidal zone. The corollary of this is that if we use submerged peats as markers of 'high potential' it must be recognised that accessing that potential with regard to material culture may require large scale removal.

Inter-tidal hovercraft survey and environmental sampling

In addition to the inter-tidal excavations, a hovercraft was utilised to survey a more extensive area of the foreshore. This was beneficial to the project as it provided a rapid transportation method to identify exposures within the outer foreshore area that could not be accessed by foot, due to the presence of deep mudflat deposits. This was particularly the case for peat exposures close to that low water mark that were only uncovered for a very short time period. During this survey two locations of possible peat outcrops were identified and positions recorded using a Leica RTK GPS system. Environmental sampling of these outcrops was subsequently undertaken during a second trip using the hovercraft.

The first location (323018 146955) was situated near the low water mark. Here a monolith sample (STFD14

Sample <1>) was taken from the section of a small pit that was excavated down to the underlying clays. No further excavations could take place due to the very short window of opportunity to excavate this site before the peat shelf became submerged again.

At the second location (322714 146254) the peat was too compact to allow sampling in section using a monolith tin. Instead the peat face was carefully cut using a spade and the released sections STFD14 <2> and <3>) were carefully wrapped and supported with plastic boarding and packing materials. Sample <3> recovered a larger quantity of the underlying clay deposits so was selected for further investigation as it retained the most intact regressive sedimentary contact. Sample <2> was retained, as reserve material, and kept in cold storage.

Palaeoenvironmetnal and radiocarbon results

M.J. Grant, N. Cameron, P. Marshall and P.D.M. Hughes

Sediments

STFD14 <1>

Monolith STFD14 <1> measured 0.28m (see Table 9.2) in length and consisted of a gradual regressive contact from silty clay at the base of the sequence to a clay peat at the top. Increased dark colour and organic inclusions suggested that there was a gradual transition from the underlying minerogenic deposits into the upper organic deposits that contained numerous horizontally bedded *Phragmites australis* leaves. The upper clay peat was 0.11m thick and had been clearly eroded at its surface.

Table 9.2 Sediment description for STFD14 <1>

STFD14 <1>. Easting: 323018 Northing: 146955 Ground level elevation: -5.28m ODN	
m ODN	Description
-5.28 to -5.39	Clay Peat (10YR 2/1 Black) with *Phragmites* remains. Contains red inclusions, horizontally bedded. Sharp, smooth boundary to:
-5.39 to -5.41	Peaty/ Silty Clay (10YR 3/2 Very dark grayish brown). Part of boundary with contact above
-5.41 to -5.47	Silty Clay (10YR 4/1 Dark grey). Occasional mottling with 10YR 2/1 (Black). Rootlets visible. Clear boundary over 20-30mm to:
-5.47 to -5.56	Silty Clay (10YR 6/1 Bluish Gray). Mottled (10%) with 10YR 2/1 (Black) staining.

STFD 14<3>

Sample STFD14 <3> measured 0.27m (see Table 9.3) in length and consisted of a sharp regressive contact from clay at the base of the sequence to a peat at the top. The peat contained numerous horizontal bands of *Phragmites australis* leaves, particularly in the lower half of the peat, that were carefully extracted for radiocarbon dating. These *Phragmites australis* bands reduced towards the top of the sample though large macrofossils were observed upon the cleaned peat surface. These includes a number of whole *Corylus avellana* nuts, along with a *Quercus* sp. acorn and a number of woody twigs / roots. The peat itself was 0.44m thick and had been clearly eroded at its surface.

STFD14 Environmental Sample 1

Easting: 323018 **Northing:** 146955
Ground level elevation: -5.28 mOD

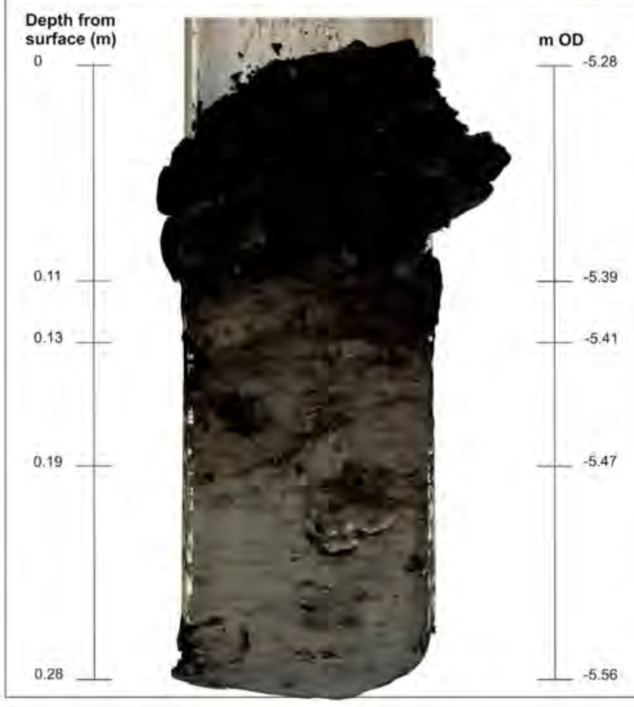
This monolith was taken from a vertical section of a small pit excavated rapidly, near the low water mark (c. 0.92km offshore) at Stolford, Somerset in July 2014.

The pit was excavated on a peat exposure that had been identified during a survey of the intertidal zone using a hovercraft. Due to local tidal conditions and extensive mudflats preventing access by foot, the site could only be reached via a hovercraft. The tidal range on the day was 11.64m and so the peat was only exposed for a short period of time. This meant that there was insufficient time to excavate to the base of the minerogenic deposits before the exposure became submerged again.

The monolith will be analysed in order to address the following research questions:

- Did the peats form over freshwater or marine clays?
- What age is the offshore peat shelf?
- What was the local vegetation associated with the peat formation?
- Can any evidence of human activity be identified within these deposits?

Left: Photograph taken using a GoPro camera showing the monolith in section.
Below: Map showing the locations of environmental samples 1 and 3.



Description

-5.28 to - 5.39mOD: Clay Peat (10YR 2/1 Black) with *Phragmites* remains. Contains red inclusions, horizontally bedded. Sharp, smooth boundary to:

-5.39 to - 5.41mOD: Peaty/ Silty Clay (10YR 3/2 Very dark grayish brown). Part of boundary with contact above.

-5.41 to -5.47mOD: Silty Clay (10YR 4/1 Dark grey). Occasional mottling with 10YR 2/1 (Black). Rootlets visible. Clear boundary over 20-30mm to:

-5.47 to - 5.56mOD: Silty Clay (10YR 6/1 Bluish Gray). Mottled (10%) with 10YR 2/1 (Black) staining.

Environmental Sampling

Suitability of material for addressing research questions

The boundary between the organic deposit and underlying minerogenic (alluvial) clays is gradual, with the transition horizon clearly visible. As a result, this regressive contact appeared to be in tact and could therefor provide information on the timing, and nature of the transition, from alluvial clays to organic [semi-] terrestrial peat deposits.

Sampling strategy

Radiocarbon dating

Radiocarbon dates were obtained from the top and bottom of the peat, with particular focus on the regressive contact. Wherever possible identifiable non-submerged plant macrofossils were extracted from the peat and submitted for radiocarbon dating. An additional samples were also taken from the centre of the peat to help constrain the age of the peat and enable age-depth modelling.

Pollen analysis

Samples of 2cm^3 were taken at close intervals across the peat-minerogenic boundary, with additional wider spacing between samples throughout the main peat body. This helped to identify the type of vegetative environment that was present in the local vicinity, particularly during the onset of peat development. In addition fungal spores, which may be associated with herbivore dung, were identified (when present).

Plant macrofossil analysis

Samples were taken to identify any plant macrofossils, seeds or charcoal present within the sample. This helped identify the nature of the local environment during the peat formation and also allowed the extraction of material suitable for radiocarbon dating.

Charcoal

The addition of an exotic spore marker within the pollen samples (e.g. *Lycopodium*) enabled quantified estimates of micro-charcoal abundance to be made from the pollen samples. The presence of micro-charcoal may provide evidence for ephemeral prehistoric activity within the current inter-tidal zone.

Diatoms

Sub-samples 2cm^3 in size were taken across the regressive contact to understand the nature of environmental change associated with this transition, as well as identifying the salinity levels of the alluvial deposits (freshwater vs brackish / marine). This provided a better understanding of the nature of the environmental changes visible in the sequence and helped identify whether the regressive contact is suitable for sea level studies.

Figure 9.4 Environmental Sampling Strategy for STFD <1>

STFD14 Environmental Sample 3

Easting: 322714 **Northing:** 146254
Ground level elevation: -2.42 mOD

This sample was collected from a peat exposure located c. 0.3km offshore, in the intertidal zone at Stolford, Somerset. The exposure was identified during a survey of the intertidal zone conducted using a hovercraft. The peat exposure was situated between some mudflats, and so could only be accessed safely via a hovercraft.

The deposits at this location were extremely compact on the surface and so it was not possible to successfully collect a sample using a monolith tin. As a result, a spade was used to sample material from a natural section, which had been created within a channel of water draining out of the local mudflats at low tide. Environmental sample 3 (below) was collected during this process and will be used to address the following questions:

- Did the peats form over freshwater or marine clays?
- What age is the offshore peat shelf?
- What was the local vegetation associated with the peat formation?
- Can any evidence of human activity be identified within these deposits?

Left: Photograph taken using a GoPro camera showing the section from which samples were extracted.
Below: Map showing locations of environmental samples 1 and 3.

Description

-2.42 to - 2.66 mOD: Peat (10YR 2/1 Black). Very minor clay component in bands towards base of peat (below -2.61mOD). Clear horizontal organic banding and highly compressed. Notable Phragmites band at -2.51mOD across width of monolith with similar, albeit laterally more constrained, at -2.49mOD and -2.66mOD. Notable wood inclusions, horizontal at -2.57mOD, 10-20mm in thickness. Other small twig/root inclusions cf. *Alnus glutinosa*. Base of peat grades into underlying context through an organic clay, still 10YR 2/1, at -2.64 to -2.66mOD. Sharp straight boundary to:

-2.66 to -2.69mOD: Clay (Gley 2 5/10B (5/1) Bluish Gray). Rare (<2.5%) inclusions (organic), possible rooting. Mottling barely visible.

Environmental Sampling

Suitability of material for addressing research questions

The top of the peat shelf is clearly eroded. The focus of the sampling strategy was therefore on the basal regressive contact, which provided information on the nature, and timing, of the transition from alluvial clays to organic [semi-] terrestrial peat deposits.

Sampling strategy

Radiocarbon dating

Radiocarbon dates were obtained from the top and bottom of the peat, with particular focus on the regressive contact. Wherever possible identifiable non-submerged plant macrofossils were extracted from the peat and submitted for radiocarbon dating. Additional date were also taken from the centre of the peat to help constrain the age of the peat and enable age-depth modelling.

Pollen analysis

Samples of 2cm^3 were taken at close intervals across the peat-minerogenic boundary, with additional wider spacing between samples throughout the main peat body. This helped identify the type of vegetative environment that was present in the local vicinity, particularly during the onset of peat development. In addition fungal spores, which may be associated with herbivore dung, were identified (when present).

Plant macrofossil analysis

Samples were taken to identify any plant macrofossils, seeds or charcoal present within the sample. This helped to identify the nature of the local environment during the peat formation and also allowed the extraction of material suitable for radiocarbon dating.

Charcoal

The addition of an exotic spore marker within the pollen samples (e.g. *Lycopodium*) enabled quantified estimates of micro-charcoal abundance to be made from the pollen samples. The presence of micro-charcoal may provide evidence for ephemeral prehistoric activity within the current inter-tidal zone.

Diatoms

Sub-samples 2cm^3 in size were taken through the basal contact (1 either side of the contact, plus one on the organic clay lens at -2.64 to -2.66m OD) to understand the nature of environmental change associated with this transition, as well as identifying the salinity levels of the alluvial deposits (freshwater vs brackish / marine). This provided a better understanding of the nature of the environmental changes visible in the sequence and so helped identify whether the regressive contact was suitable for sea level studies.

Figure 9.5 Environmental Sampling Strategy for STFD14<3>

Table 9.3 Sediment description for STFD14 <3>

STFD14 <3>. Easting: 322714 Northing: 146254 Ground level elevation: -2.42m ODN	
m ODN	Description
-2.42 to -2.66	Peat (10YR 2/1 Black). Very minor clay component in bands towards base of peat (below -2.61mOD). Clear horizontal organic banding and highly compressed. Notable *Phragmites* band at -2.51mOD across width of monolith with similar, albeit laterally more constrained, at -2.49mOD and -2.66mOD. Notable wood inclusions, horizontal at -2.57mOD, 10-20mm in thickness. Other small twig/root inclusions cf. *Alnus glutinosa*. Base of peat grades into underlying context through an organic clay, still 10YR 2/1, at -2.64 to -2.66mOD. Sharp straight boundary to:
-2.66 to -2.69	Clay (Gley 2 5/10B (5/1) Bluish Gray). Rare (<2.5%) inclusions (organic), possible rooting. Mottling barely visible.

See appendix 1 for full details of environmental assessment methodologies.

Radiocarbon Dating

STFD14 <1>.

Five samples, four single *Phragmites australis* macrofossils and a 'bulk' peat sample were submitted for dating (Table 9.4) from STFD14 <1>. The *Phragmites australis* samples from −5.36m ODN [GU36302] failed to produce sufficient carbon during pretreatment. Measurements on the humic and humin fractions of the peat sample at -5.39m ODN (UBA-27979 and UBA-27980) are statistically consistent (T'=0.0; T'(5%)=3.8; v=1; Ward and Wilson 1978) but inconsistent with a single fragment (UBA-27978) of horizontally bedded *Phragmites australis* (T'=11.1; T'(5%)=6.0; v=2). Given that the *Phragmites australis* fragment might be expected to be the youngest constituent part of the 1cm slice of peat from this depth then this discrepancy is not unexpected and as such a weighted mean of all three determinations has been calculated as providing the best estimate for the age of deposit (7065±31 BP). Using these dates an age-depth model estimates that the start of peat accumulation (equivalent to a *terminus ante quem* for the regressive contact) at −5.39m OD dates to 8030–7820 cal. BP (95.4% probability), with peat accumulation ending in 7875–7730 cal. BP (95.4% probability). See Appendix 2 for full radiocarbon dating report.

Table 9.4 Radiocarbon dates from STFD14 <1>

Laboratory Number	Sample Depth (m ODN)	Material Dated	Radiocarbon Age (BP)	δ^{13}C (‰)	Calibrated Date (95.4% confidence) cal. BP
SUERC-57871	-5.31	*Phragmites australis, single fragment,* horizontally bedded: 190mg	7002±29	−28.6	7940–7750
UBA-27977	-5.35	*Phragmites australis, single fragment,* horizontally bedded: 105mg	7059±52	−28.1	7980–7780
GU36302	-5.36	*Phragmites australis, single fragment,* horizontally bedded: 119mg	Failed: insufficient carbon		
UBA-27978	-5.39	*Phragmites australis,* single fragment, horizontally bedded: 129mg	6918±53	−29.5	7920–7660
UBA-27979	-5.39	Peat, humic acid	7139±53	−28.2	
UBA-27980	-5.39	Peat, humin	7132±53	−28.3	
		T'=0.0; T'(5%)=3.8; v=1	7136±38		8020–7870

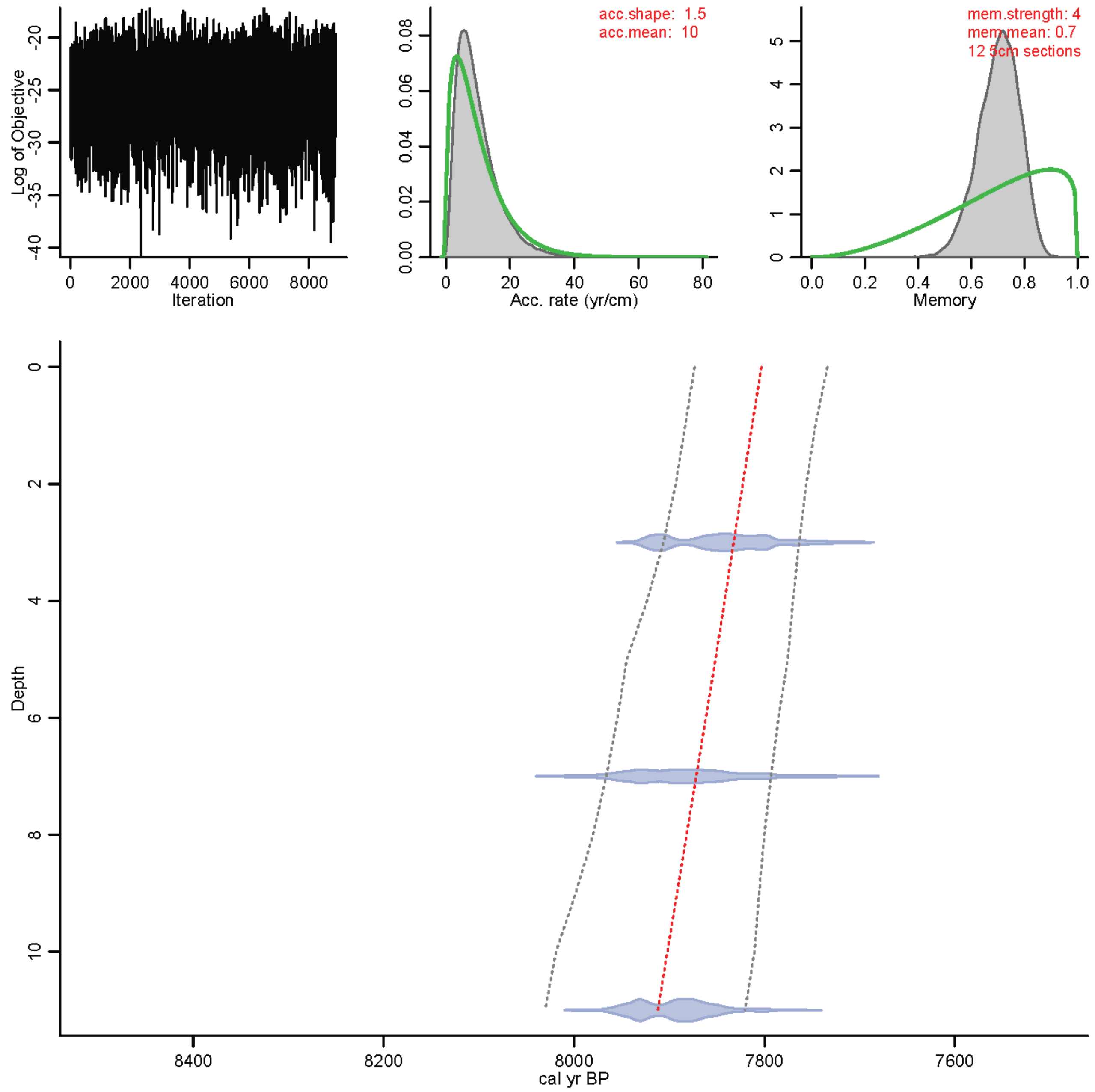


Figure 9.6 Age –depth model for STFD14<01>

STFD14 <3>

Six radiocarbon determinations (Table 9.5) were obtained on single identifiable macrosfossils (*Phragmites australis, Corylus avellana* nuts and *Quercus* acorn) from STFD14 <3>. The age-depth model estimates that the start of peat accumulation at −2.66m ODN dates to 7455–7002 cal BP (95.4% probability), with peat accumulation ending, at −2.42m ODN, in 6825–6615 cal BP (95.4% probability).

Table 9.5 Radiocarbon dates from STFD14 <3>

Laboratory Number	Sample Depth (m ODN)	Material Dated	Radiocarbon Age (BP)	δ^{13}C (‰)	Calibrated Date (95.4% confidence) cal. BP
SUERC-57872	-2.44	*Corylus avellana* nut	5931±27	−29.0	6850–6670
UBA-27981	-2.51	*Quercus* acorn	6120±50	−30.4	7170–6860
SUERC-57873	-2.55	*Corylus avellana* nut	6086±27	−26.6	7150–6880
UBA-27982	-2.60	*Phragmites australis,* single fragment, horizontally bedded: 126mg	6190±47	−28.7	7250–6950
SUERC-57877	-2.62	*Phragmites australis,* single fragment, horizontally bedded: 252mg	6225±28	−27.9	7250–7010
UBA-27983	-2.65	*Phragmites australis,* single fragment, horizontally bedded: 173mg	6278±48	−27.3	7310–7220

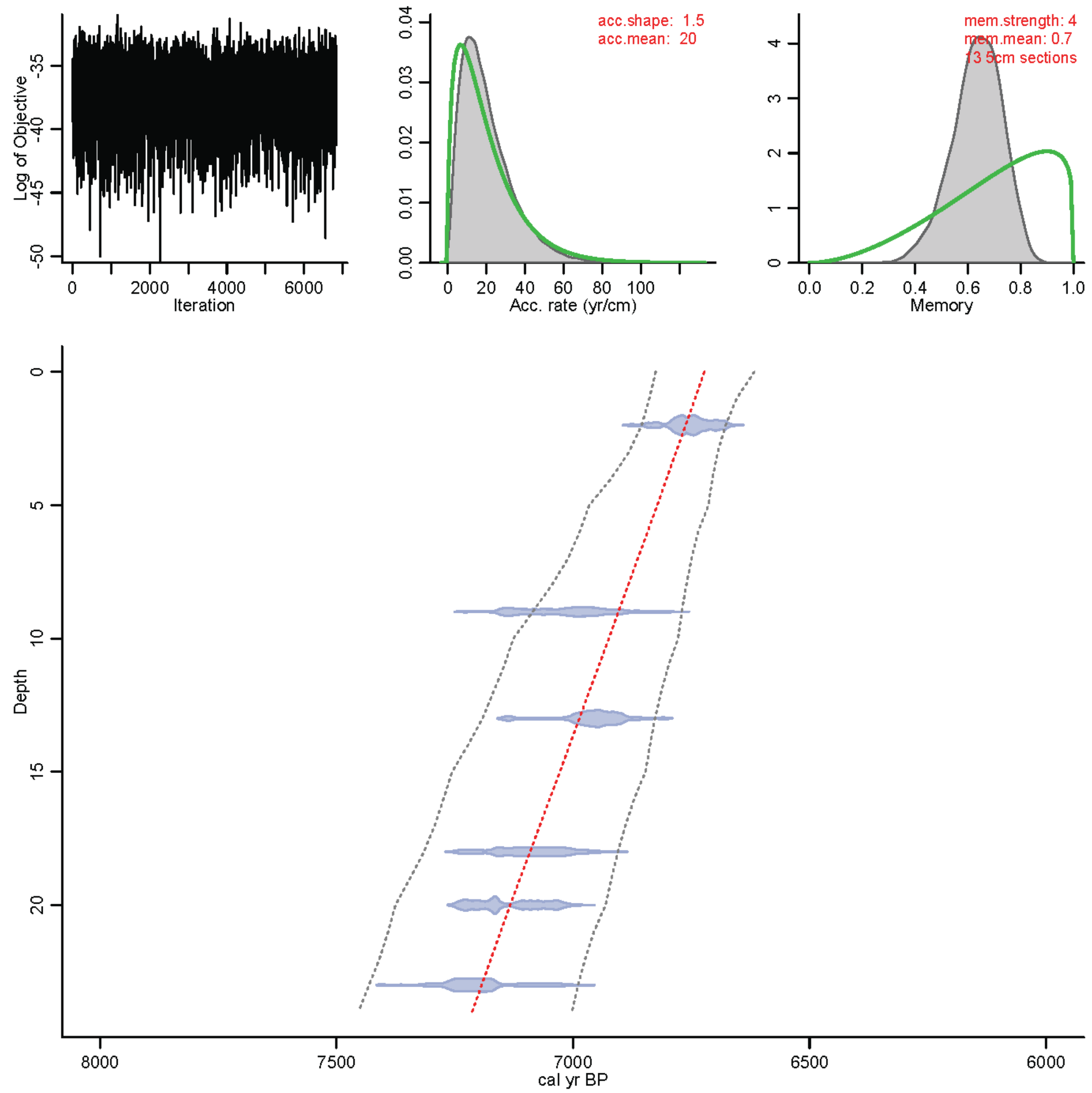


Figure 9.7 Age –depth model for STFD14<3>

Plant Macrofossil assessment

Two 4cm thick samples were taken from the peat in STFD14 <1> for plant macrofossil assessment while in STFD14 <1> six 1cm thick samples were assessed. After sieving a minerogenic component was still visible within the residue from both sequences.

STFD14 <1>

The plant macrofossil assessment from STFD14 <1> showed an assembalge with *Phragmites australis* present throughout the sampled peat. Within the basal sample (between -5.32 and -5.36m ODN) monocotyledon roots are frequent, along with seeds of *Mentha aquatica* (water mint), *Cirsium* sp. (thistles), *Eupatorium cannabinum* (hemp-agrimony) and *Juncus* spp. (rushes), all indicative of damp areas. Occasional wood fragments were also present. Within the upper sample (between -5.28 and -5.32m ODN) *E. cannabinum* seeds were frequent along with wood fragments, with *Phragmites australis* occasional and monocotyledon roots rare. Charcoal was also occasionally present. Unidentifiable Organic Matter (UOM) was abundant in both samples reflecting the humified state of the peat, with insect remains present in both samples.

STFD14 <3>

The plant macrofossil assessment from STFD14 <3> shows a clearly defined stratification of the short (20cm) peat with local changes in the on-site vegetation discernible. At the base of the sequence (-2.63m ODN) the peat is dominated by *Phragmites australis* remains along with monocotyledon roots and some *Cirsium* sp. (thistle) seeds. The overlying samples (between -2.50 and -2.59m ODN) show a dominance of wood fragments, including frequent bark fragments, with a smaller component of monocotyledon roots. Within the uppermost samples (-2.42 and -2.46m ODN) the wood component has reduced to rare / occasional, with *Phragmites australis*, and monocotyledon fragments and roots once again present. Throughout the sequence UOM is frequent to abundant reflecting the humified state of the peat. Insect fragments and acarid mites are also present within the sequence.

Pollen assessment

STFD14 <1>

Pollen assessment was undertaken on nine samples from STFD14 <1>. Insufficient pollen was obtained from samples between -5.43 and -5.39m ODN, with only low numbers (48 TLP) obtained from the sample at -5.38m ODN. Although pollen concentrations are reasonable in the lowermost sample (68080 grains cm^{-3}), this is attributable to the high Pteropsida (monolete) indet. presence, with TLP pollen sparsely distributed across the prepared slides (three slides were assessed to obtain this pollen count). Two local pollen assemblage zones (LPAZ) were defined for the sequence (see Figure 9.10 and Table 9.6).

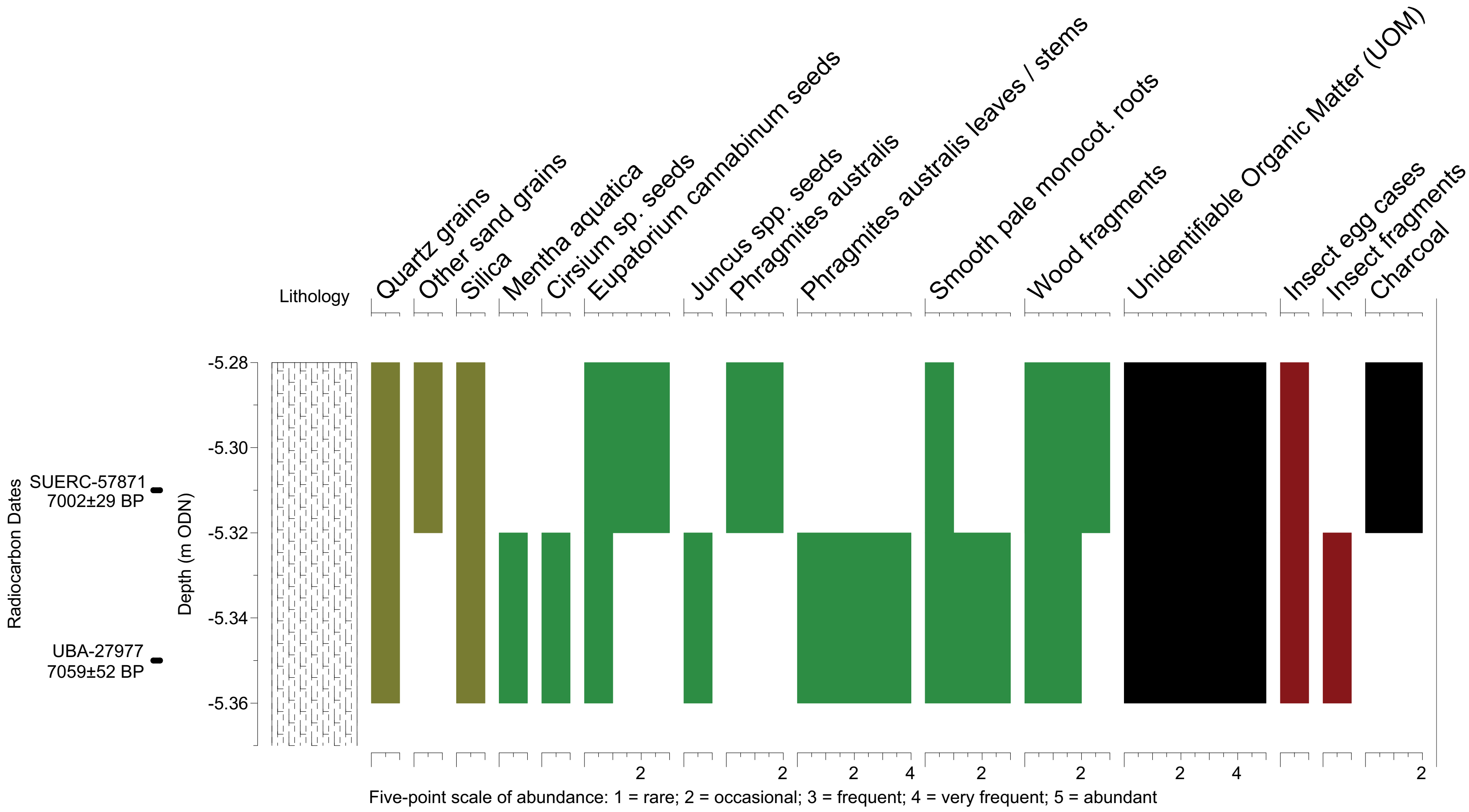


Figure 9.8 Plant macrofossil diagram for STFD14<1>

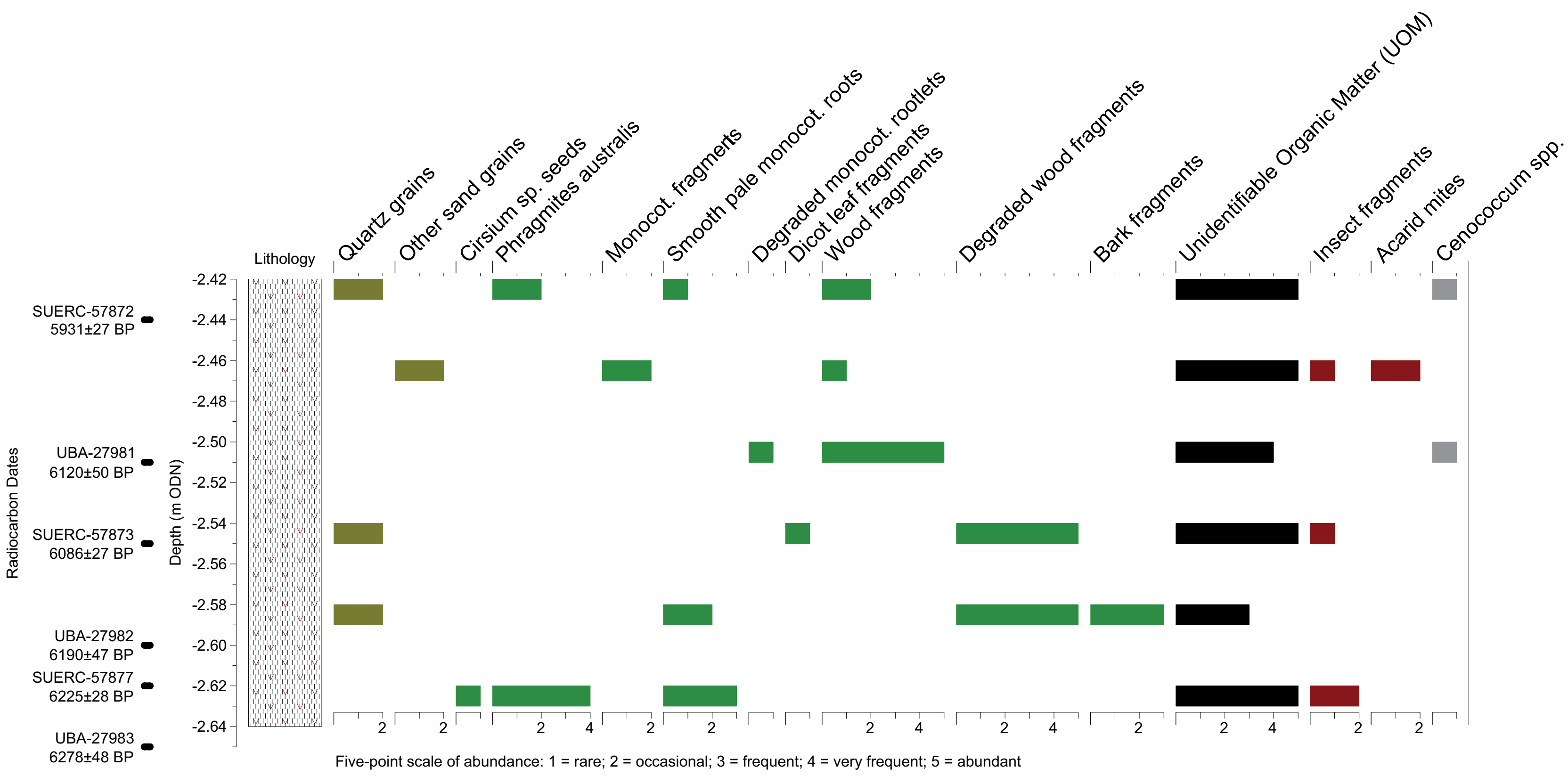


Figure 9.9 Plant macrofossil diagram for STFD14<3>

Table 9.6 STFD14 <1> Pollen Zone Descriptions

LPAZ	Depth (m ODN)	Description
STFD1-2	-5.28 to -5.34	Dominated by *Corylus avellana*-type (22-23%), *Salix* (8-31%), Poaceae (%) and Pteropsida (monolete) indet. (2-46% TLP + Pteridophytes). Tree and shrub taxa present include *Ulmus* (1-2%), *Quercus* (5-7%), *Betula* (1%), *Alnus glutinosa* (7%), *Populus* (1-7%), *Fraxnus excelsior* (up to 2%) and *Sambucus nigra* (2-11%). Dwarf shrub and herb taxa include Chenopodiaceae (1%), Brassicaceae (up to 3%), *Filipendula* (up to 2%), *Solidago virgaurea*-type (up to 4%) and Cyperaceae (4-12%). *Sparganium emersum*-type (up to 12% TLP + Aquatics) disappears by the end of the zone. *Sporormiella*-type (6-9% TLP + NPP) and *Podospora* (2-3% TLP + NPP) are present throughout the zone. Pollen concentrations increase from 68080 to 102610 grains cm^{-3}. Micro-charcoal values decrease from 48510 to 1250 particles cm^{-3}.
STFD1-1	5.34 to -5.38	Dominated by Poaceae (55-57%), *Sparganium emersum*-type (26-46% TLP + Aquatics) and Pteropsida (monolete) indet. (85-88% TLP + Pteridophytes). Tree and shrub taxa present include *Pinus sylvestris* (5-9%), Ulmus (1-2%), *Quercus* (4-7%), *Corylus avellana*-type (11-13%), *Salix* (2-5%) and *Populus* (up to 2%). Dwarf shrub and herb taxa include *Ranunculus acris*-type (1-8%), Chenopodiaceae (up to 1%), *Filipendula* (up to 1%), *Plantago lanceolata* (up to 2%), Cyperaceae (2-8%) and *Arrhenatherum*-type (up to 1%). *Typha latifolia* (1-3% TLP + Aquatics) reduces through the zone. *Thelypteris palustris* (1-2% TLP + Pteridophytes) is present throughout the zone. *Sporormiella*-type (1-2% TLP + NPP) and *Podospora* (2% TLP + NPP) were also recorded. Pollen concentrations increase from 68080 to 102610 grains cm^{-3}. Micro-charcoal values increase from 10410 to 48570 particles cm^{-3}.

The lowermost pollen zone (STFD1-1) shows an assemblage dominated by Poaceae (grasses) and *Sparganium-emersum* type (bur-reeds), along with the presence of *Typha latifolia* (bulrushes) and a probable understorey consisting of *Thelypteris palustris* (marsh fern), along with Cyperaceae (sedges) and *Ranunculus acris*-type (buttercup). This probably represents a tall herb fen community occupying permanently wet and organic soils. A woodland component including *Quercus* (oak), *Corylus avellana*-type (hazel) and *Salix* (willow) is also recorded, probably associated with a damp woodland community. *Sporormiella*-type and *Podospora* are present throughout the zone, while micro-charcoal increases towards the end of the zone coinciding with a reduction in Poaceae and *Sparganium emersum*-type.

The uppermost pollen zone (STFD1-2) shows a reduction in the herb fen community and an expansion of woodland taxa, notably through increases in *Alnus glutinosa* (alder), *Corylus avellana*-type, *Salix* and *Sambucus nigra* (elder). Also present are increases in *Betula* (birch) and *Populus* (poplar; probably *Populus tremula*; aspen). By the end of the zone *Sparganium emersum*-type and *Thelypteris palustris* are absent suggesting that establishment of a dense woodland canopy which may account for the reduction in micro-charcoal. *Sporormiella*-type and *Podospora* are present throughout the zone which may suggest a continuation of grazing after woodland establishment on-site.

STFD14 <3>

Pollen assessment was undertaken on nine samples from STFD14 <3>. Three local pollen assemblage zones (LPAZ) were defined for the sequence (see Figure 9.11 and Table 9.7).

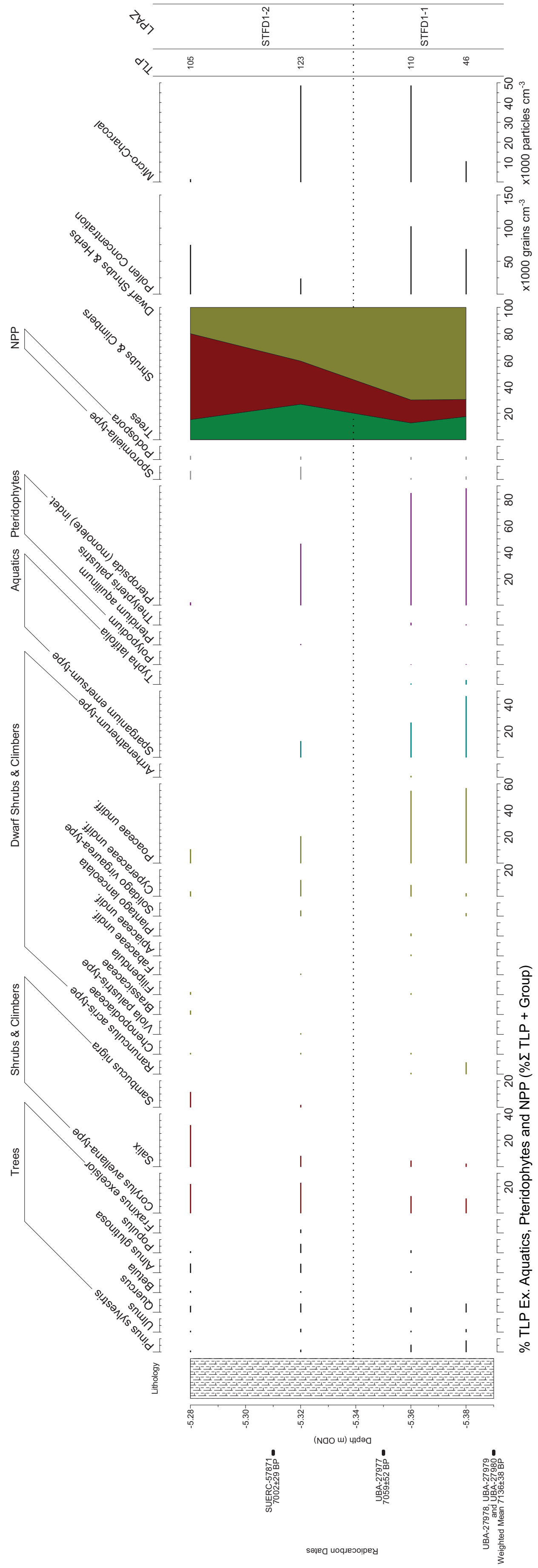


Figure 9.10 Pollen diagram for STFD14<1>

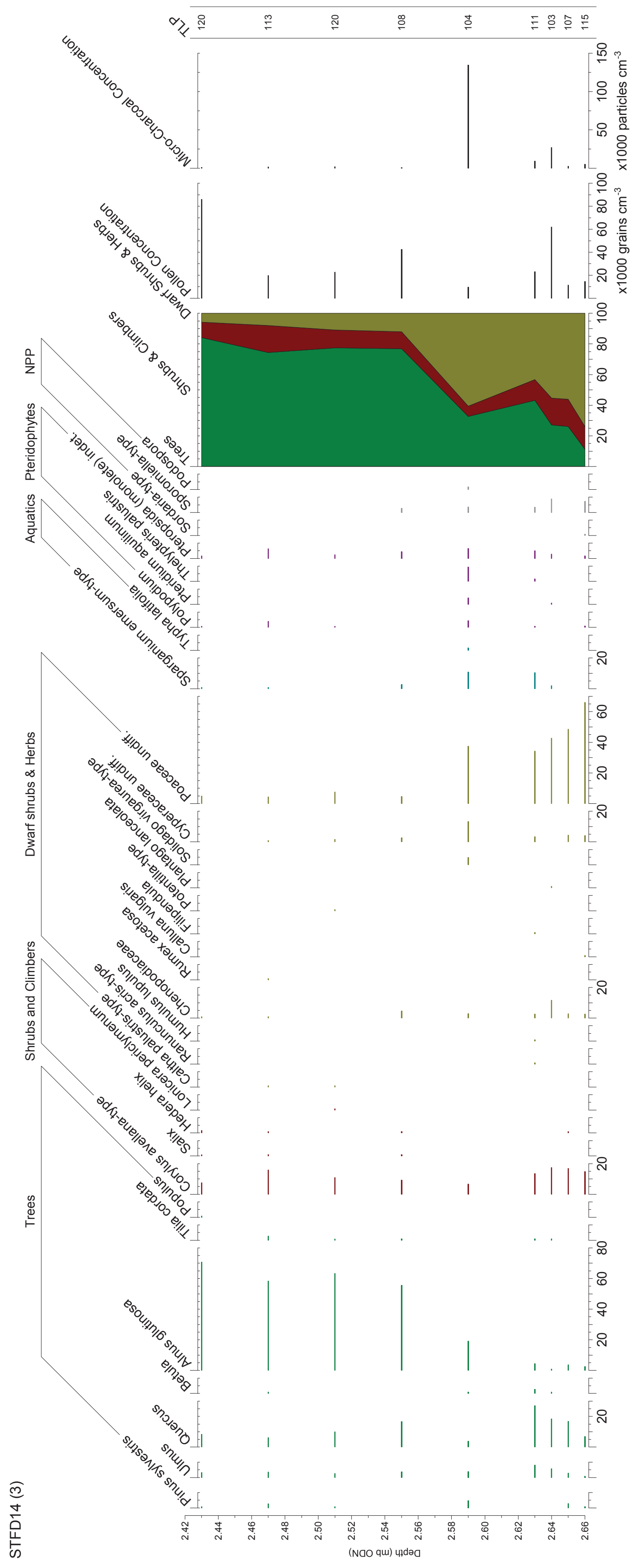


Figure 9.11 Pollen diagram for STFD14<3>

Table 9.7 STFD14 <1> Pollen Zone Descriptions

LPAZ	Depth (m ODN)	Description
STFD3-3	-2.42 to --2.57	Dominated by *Alnus glutinosa* (56-71%). Tree and shrub taxa present include *Ulmus* (3-4%), *Quercus* (6-17%), *Tilia cordata* (up to 3%), *Corylus avellana*-type (8-16%), *Salix* (up to 1%) and *Hedera helix* (up to 2%). Dwarf shrub and herb taxa include Chenopodiaceae (up to 5%), *Rumex acetosa* (up to 1%), *Potentilla*-type (up to 1%), Cyperaceae (up to 3%) and Poaceae (4-8%). *Sparganium emersum*-type (up to 3% TLP + Aquatics), *Polypodium* (up to 4% TLP + Pteridophytes) and Pteropsida (monolete) indet. (2-6% TLP + Pteridophytes) are also present. *Sporormiella*-type (up to 3% TLP + NPP) is present at the start of the zone. Pollen concentrations are between 19830 and 86040 grains cm^{-3}. Micro-charcoal values are between 780 and 1870 particles cm^{-3}.
STFD3-2	-2.57 to -2.645	Dominated by Poaceae (34-43%) and *Quercus* (4-27%). and Pteropsida (monolete) indet. (% TLP + Pteridophytes). Tree and shrub taxa present include *Ulmus* (4-8%), *Betula* (1-3%), *Alnus glutinosa* (1-19%), *Tilia cordata* (up to 1%) and *Corylus avellana*-type (7-17%). Dwarf shrub and herb taxa include *Ranunculus acris*-type (%), *Humulus lupulus* (up to 1%), Chenopodiaceae (3-12%), *Filipendula* (up to 1%), *Plantago lanceolata* (up to 1%), *Solidago virgaurea*-type (up to 5%) and Cyperaceae (up to 13%). *Sparganium emersum*-type (2-11% TLP + Aquatics) and *Typha latifolia* (up to 2% TLP + Aquatics) are present, along with *Polypodium* (up to 4% TLP + Pteridophytes), *Pteridium* aquilinum (up to 4% TLP + Pteridophytes), *Thelypteris palustris* (up to 9% TLP + Pteridophytes) and Pteropsida (monolete) indet. (3-7% TLP + Pteridophytes). *Sporormiella*-type (3-9% TLP + NPP) and *Podospora* (up to 2% TLP + NPP) were also recorded. Pollen concentrations decrease from 61880 to 9750 grains cm^{-3}. Micro-charcoal values are between 9170 and 134600 particles cm^{-3}.
STRD3-1	-2.645 to -2.66	Dominated by Poaceae (49-66%). Tree and shrub taxa present include *Pinus sylvestris* (up to 3%), *Ulmus* (1-3%), *Quercus* (7-17%), *Alnus glutinosa* (3-4%) and *Corylus avellana*-type (15-17%). Dwarf shrub and herb taxa include Chenopodiaceae (3%) and Cyperaceae (4%). *Sordaria*-type (up to 1%TLP + NPP) and *Sporormiella*-type (up to 7% TLP + NPP) were recorded at the start of the zone. Pollen concentrations are between 11320 and 14450 grains cm^{-3}. Micro-charcoal values are between 2430 and 5160 particles cm^{-3}.

The lowermost pollen zone (STFD3-1) shows an assemblage dominated by Poaceae (grasses) with a woodland component dominated by *Quercus* and *Corylus avellana*-type, with *Ulmus* and *Alnus glutinosa*. Chenopodiaceae is present which may indicate the local presence of saltmarsh communities. *Sordaria*-type and *Sporormiella*-type are present in the lowermost sample which might indicate some grazing activity of the local herbaceous fen communities. Micro-charcoal values are low suggesting no on-site burning at this time.

LPAZ STFD3-2 shows an expansion of aquatic pollen types, notably *Sparganium emersum*-type, along with a richer Pteridophyte assemblage including *Pteridium aquilinum* (bracken) and *Thelypteris palustris*, suggesting a change in the local marsh vegetation with bulrushes more prevalent. *Alnus glutinosa* and *Betula* increase and this may represent the local establishment of some carr vegetation with the change in the herbaceous pollen assemblage representing shifting herbaceous vegetation mosaics adjacent to the emerging woodland communities. Increases in *Ulmus* and *Tilia cordata* suggest an emergence of dryland woodland community [representation] as well. Increases in *Sporormiella*-type and the presence of *Podospora* coincide with these observed changes in the local vegetation patterns and increases in micro-charcoal, as well as the presence of *Plantago lanceolata* and *Pteridium aquilinum*, all of which may indicate increases in grazing activity upon the marsh.

LPAZ STFD3-3 shows the full expansion of woodland communities upon the site, dominated by *Alnus glutinosa*. *Ulmus, Quercus*, *Tilia cordata, Corylus avellana*-type and *Salix* are also present, along with *Hedera helix* (ivy). Herbaceous vegetation is underrepresented in the pollen assemblage with notable reductions in Poaceae, Cyperacerae and *Sparganium emersum*-type. Chenopodiaceae is present throughout much of the zone suggesting a continued local presence of saltmarsh communities. *Sporormiella*-type is only present at the beginning of the zone which may suggest a reduction in grazing activity locally, while the reduction of micro-charcoal to low values throughout the zone may be the result of the development of the woodland canopy and / or reduced burning activity as the marsh became wooded.

Diatoms

STFD14 <1>

Seven samples were assessed for diatoms from STFD14 <1> between -5.43 and -5.28m ODN. Diatoms are present in five samples. However, with the exception of the top sample the numbers of diatoms are extremely low and the quality of diatom preservation is extremely poor with only one or two valve fragments found in most of these samples. For full report see appendix 4.

The poor preservation or absence of diatom remains in this sequence can be attributed to taphonomic processes (Flower 1993, Ryves et al. 2001). This may be the result of diatom silica dissolution and breakage caused by factors such as extremes of sediment alkalinity or acidity, the under-saturation of sediment pore water with dissolved silica, cycles of prolonged drying and rehydration, or physical damage to diatom valves from abrasion or wave action.

Despite the poor preservation of diatom assemblages in the STFD14 <1> sequence, the diatoms present do nevertheless provide some useful palaeoenvironmental data. In the bottom section of the sequence, -5.43 to -5.40m ODN, samples spanned the transition from a silty clay into the overlying peaty/silty clay with *Phragmites australis* remains. Although present in very low numbers, the diatom valves in these samples are consistently of freshwater and aerophilous taxa. These aerophilous diatoms are *Hantzschia amphioxys*, *Navicula pusilla*, *Pinnularia* cf *major* and other *Pinnularia* sp. The freshwater epiphyte *Epithemia turgida* was found in the samples from -5.42m ODN.

In the top sample from -5.28m ODN the diatom assemblage is comprised of marine and brackish water diatom taxa. The polyhalobous and polyhalobous to mesohalobous (marine, and marine-brackish) diatoms are *Paralia sulcata*, *Cymatosira belgica*, *Rhaphoneis minutissima*, *Rhaphoneis surirella*, *Actinoptychus undulatus* and *Navicula flanatica*. The mesohalobous taxa are *Cyclotella striata*, *Melosira moniliformis* and *Actinocyclus normanii*. With the exception of the benthic diatom *Navicula flanatica*, both the marine and brackish water diatoms are open water planktonic or semi-planktonic species which live in relatively deep water.

STFD14 <3>

Four samples were assessed for diatoms from the STFD14 <3> sequence. Diatoms are present in all four samples, however the numbers of diatoms are very low or extremely low, the quality of preservation is very poor or extremely poor and the diversity of diatom taxa is low. Three samples have only low potential for percentage diatom counting to be carried out, and the top sample has no potential for further diatom analysis.

The bottom three samples, between -2.66 and -2.64m ODN, are from the base of the peat immediately overlying an estuarine blue grey clay. The diatom assemblages are dominated by the planktonic coastal species *Paralia sulcata*, with other polyhalobous taxa including *Cymatosira belgica*, *Podosira stelligera* and *Rhaphoneis surirella*. The mesohalobous diatoms are mainly benthic, mud-surface diatoms and these include *Nitzschia navicularis*, *Nitzschia hungarica*, *Nitzschia punctata*, *Diploneis didyma* and *Diploneis interrupta*. The brackish water planktonic species *Cyclotella striata* is present in the sample from -2.65m ODN. Aerophilous diatoms are present in samples from -2.64 and -2.66m ODN; these diatoms are *Navicula cincta*, *Navicula pusilla* and *Hantzschia amphioxys*. The top sample, from -2.63m ODN, contains low numbers of the brackish and marine diatoms *Cyclotella striata*, *Nitzschia navicularis* and *Paralia sulcata*. The freshwater aerophilous diatom *Pinnularia major* is also present in sample from -2.63m ODN.

The presence of polyhalobous and brackish-marine mesohalobous diatoms throughout the STFD14 <3> sequence indicates that the sedimentary environment was consistently under the influence of coastal water.

Synthesis of palaeoenvironmental results

The two sequences investigated from the Stolford Intertidal zone have demonstrated that each exposure has a very different formation history and associated vegetation communities. The lowermost peat sequence investigated (STFD14 <1>) initiated 8030–7820 cal. BP (95.4% probability), with peat accumulation ending in 7875–7730 cal. BP (95.4% probability). The diatoms and pollen both suggest that the peat formed under freshwater conditions and was dominated by a tall herb marsh community which subsequently became colonised by woodland taxa, notably hazel, willow and elder, with oak and alder also present. The micro-charcoal, as well as charcoal observed in the plant microfossil assessment, shows highest concentrations associated with the tall herb communities, with a consistent presence of Non-Pollen Palynomorphs indicative of grazing activity throughout the sequence. The sampled peat is situated c. 350m east one encountered by Kidson and Heyworth (1973; Figure 2) in Core 6J. This peat, buried beneath c. 1.5m of estuarine clays and silts, was 0.9m thick with the surface of the peat, at c. -7.3m ODN, dated 8190-7590 cal. BP (7060±160 BP; I2688). While this peat is at a deeper altitude than that encountered in STFD14 <1>, the radiocarbon dates (within the wide dating errors) are broadly contemporary.

The STFD14 <3> is later and at a higher altitude closer to the modern shoreline, with the start of peat accumulation dated 7455–7002 cal BP (95.4% probability), with peat accumulation ending at 6825–6615 cal BP (95.4% probability). The diatom and pollen assemblages both indicate that brackish / marine estuarine conditions were present during this peat bed forming. The plant macrofossil assessment suggests an on-site progression from an open herb marsh community to woodland conditions and then a return towards more open conditions at the top of the peat. By contrast the pollen shows the steady progression from a grass (probably common reed) dominated vegetation community, at the base of the peat, towards a mixed tall herb community and subsequent on-site development of an alder carr community. The possible opening up of the canopy at the top of the peat alluded to in the plant macrofossil assessment, which might suggest the progression towards a marine transgression, may not be recorded within the pollen as a result of the high pollen influx from the extra-local woodland vegetation.

The STFD14 <3> sequence may be broadly comparable with the Peat Sequence C investigated by Heyworth (1985), situated c. 150m east, where *Alnus* wood was dated 7420-6890 cal. BP (NPL-148; 6230±95 BP), and contained a pollen assemblage dominated by alder with oak, hazel, willow and lime also present. However the 80cm sequence studied by Heyworth (1985, 108) doesn't contain any information about the vegetation communities prior to the development of the peat bed containing the dominance by woodland taxa. In that sequence the sampled peat directly overlays the Lias pavement which might indicate that precursor vegetation communities, associated with the marine regression, were not present / eroded prior to the submerged forest formation. Heyworth (1985, 109) does suggest in this location that the peat was formed in a freshwater environment behind a contemporaneous barrier, though does acknowledge that appreciable Chenopodiaceae values do imply that brackish conditions were not far away. The investigations of the contemporary peat from STFD14 <3> demonstrates the persistence of brackish conditions at this site, particularly during the early peat formation phases, and may cast doubt over the presence of a continuous barrier at this location acting as a shield from the main estuary when this peat bed was forming.

Both the STFD14 <1> and <3> samples lie beyond the main Stolford Submerged Forest deposits and demonstrate the longevity of peat formation within the Stolford area. The improved chronologies acquired from these peats are timely and provide an opportunity to reassess sea-level change in the area, including the opportunity to be correlated with the recently investigated offshore peat deposits north of Hinkley Point (Sturt et al. 2014; Griffiths et al. 2015), the high precision dated tree ring sequences from the main Stolford submerged forest nearer inshore (see Heyworth 1985), and recent sea level index points generated from borehole investigations at Steart (Elliott 2015).

Within both sequences there has been identified a clear stratification in the micro-charcoal record (which correlates with charcoal observed in the plant macrofossil assessment). This adds further evidence for Mesolithic burning along the margins of the Bristol Channel and Severn Estuary (e.g. Brown 2005; Timpany 2005; Jones et

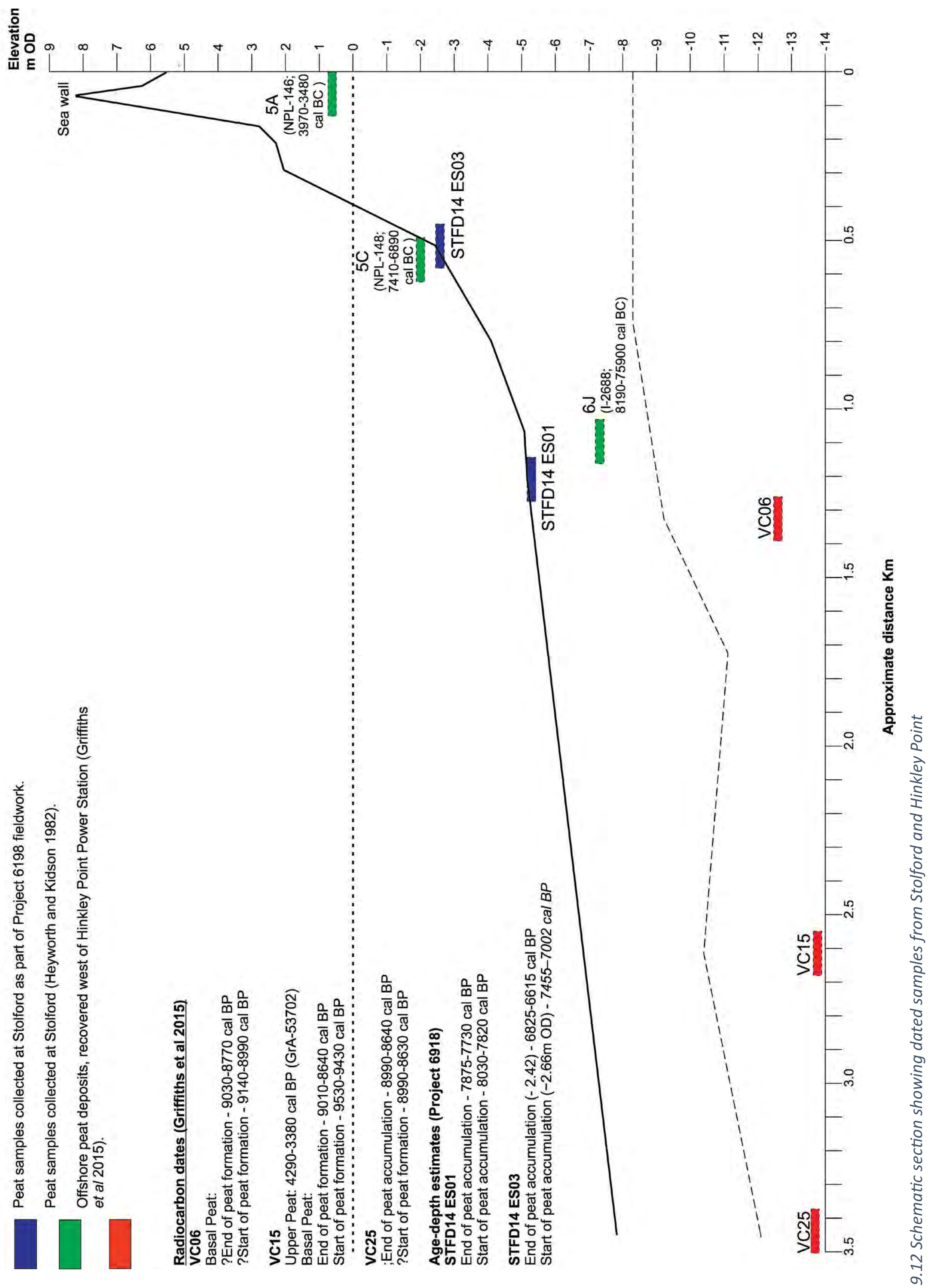


Figure 9.12 Schematic section showing dated samples from Stolford and Hinkley Point

al. 2005; Bell 2007), identified as early as c 9000 cal BP in offshore peats nearby north of Hinkley Point (Sturt et al. 2014). Within the offshore deposits charred plant remains demonstrate the burning of herbaceous plants which has been suggested as a clear sign of the deliberate burning of reed-swamp by humans. Such burning may have been utilised to remove the build-up of litter and encourage edible plants and tender new growth that may have enticed game to specific locations on the floodplain, as well as maintaining route ways through the wider landscape, as witnessed at important Mesolithic sites such as Star Carr (Mellars and Dark 1998), Thatcham (Barnett 2009) and Three Ways Wharf (Grant et al. 2014a). This pattern certainly matches that identified in the Stolford sequences where charcoal is present in association with herbaceous vegetation communities but reduces / ends when local woodland establishment takes place. This pattern was also identified by Brown (2005) at a number of Severn Estuary sites.

If these burning events are related to deliberate human activity then it supports the view that Mesolithic people expanded natural openings, including those at the edge of water, by manipulating them through fire. However the possibility that these fires are the result of natural factors and ecological processes cannot be ruled out (eg Brown 1997; Moore 2000; Tipping 1996), with several recent studies suggesting that episodes of fire activity were relatively common in the Early Holocene and were consistent with climate changes (e.g. Marlon et al. 2013; Grant et al. 2014b). Whether the burning is natural or anthropogenic in origin, the extensive evidence within the wider area clearly demonstrates that the Early Holocene wetland vegetation in this area did burn, with the investigated Stolford peats broadly contemporary with sites such as Goldcliff (Bell et al. 2002; Timpany 2005).

Summary of inter-tidal investigations

Although the main aim of these investigations was to attempt to recover prehistoric material, the site investigations at Stolford produced no conclusive evidence for prehistoric human activity. This highlights the complexities in locating previously unrecorded areas of prehistoric human activity, as well as revisiting known sites, within a dynamic environment. However the methodologies adopted within the intertidal survey have permitted rapid field evaluations of this area, through both walk over surveys of the upper intertidal zone and hovercraft to access the lower intertidal zone. The latter has been invaluable to the project as it enabled access to a far more extensive area within the inter-tidal zone than would have been possible otherwise. Such an approach was also used during the Severn Estuary RCZAS Phase 2 fieldwork to assess a number of intertidal sites and provides the safest means to access exposed sites close to the low water mark, as well as having minimum impact upon the sediments it crosses over. The hovercraft permitted the identification and sampling of two peat outcrops, c. 0.3km and c. 0.9km offshore, the latter only exposed for a brief period of time during low water. The use of high precision survey equipment has meant that both the altitude and position of these peat exposures is better constrained and, as demonstrated from the hovercraft survey, can be successfully revisited.

The investigation of both these peat sequences has enabled a reassessment of nearby peat deposits identified by Heyworth (1985; Kidson and Heyworth 1973)) and confirmed that some of these peat deposits still exist within the lower intertidal zone and have not been fully eroded away. In addition, the dating strategy and palaeoenvironmental assessments have provided the opportunity to re-evaluate both the age and archaeological potential of these deposits. The addition of diatom assessments has been invaluable at these locations for understanding the prevailing estuarine conditions during each peat initiation, whilst pollen, micro-charcoal and plant macrofossil assessments have revealed new details about both the changing vegetation recorded in the peat sequences and the possible archaeological signals contained within them. The latter providing further evidence for burning of the herbaceous marshes during the Early Holocene, with the dating of these peats comparable to other sites within the wider area, some of which have provided unequivocal archaeological evidence for Mesolithic activity. The improved chronologies obtained from the Stolford sequence will provide greater controls over our predictions of palaeogeography changes within the wider area, including Holocene sea-level change, and provide a timely continuation from the offshore studies undertaken nearby on organic deposits north of Hinkley Point (Sturt et al. 2014).

Chapter 10
Offshore Investigations

Introduction

Given this project's goals to link onshore, inter-tidal and offshore approaches, integration of an element of underwater fieldwork was required. However, the challenging nature of the Bristol Channel led to Historic England suggesting that initial goals be kept manageable, with a project aim of carrying out two camera drops to allow visual inspection suggested. This chapter provides details of the offshore work undertaken as part of this project, the lessons learned and recommendations with regards to future work.

Deductive model outputs: offshore

The deductive model described in chapter 5 indicated areas of moderate potential close to or near to the current surface (values of 1 and 2 and within 1m sediment depth) offshore. The 50m resolution model output proved suitable for targeting onshore, and to a lesser degree inter-tidal areas due to relatively pronounced topographic differences. As the model moves offshore the shallowly shelving nature of the study area meant little differentiation in the model, other than when palaeochannel proximity was included (figure 10.1).

Given this lack of differentiation the decision was made to run a Bathymetric Position Index (BPI) analysis on higher resolution (1x1m) bathymetric data for the area offshore of Hinkley point, (figure 10.2). This allowed for identification of features of topographic relief, suitable for closer analysis. This confirmed the presence of ridge/platform like features identified in previous work (Dix et al. 2015), and discussed below. The fact that these features were not detected at the 50x50m resolution reiterates the significance of scale when carrying

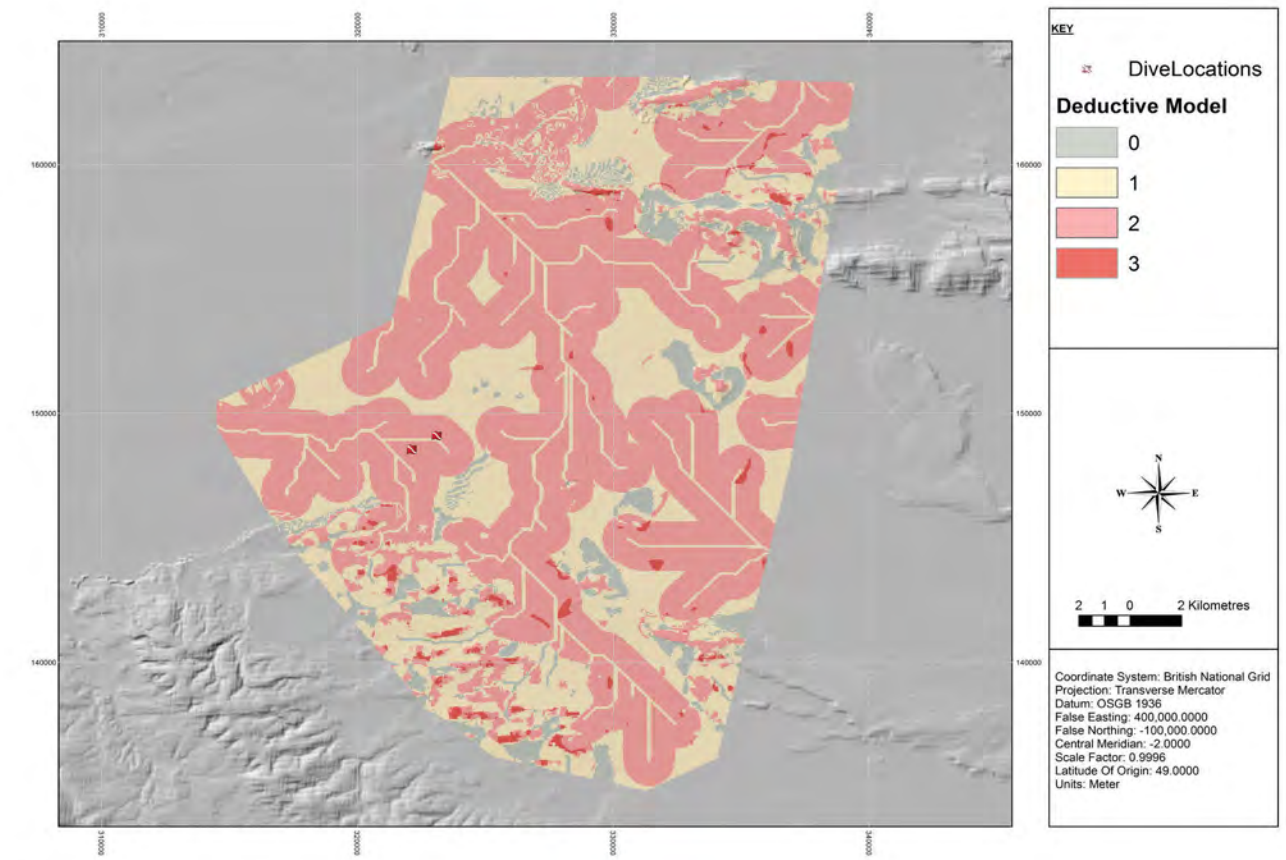


Figure 10.1 Map showing the deductive model output with palaeochannel buffer included The bathymetric data may include products have been derived from the EMODnet Bathymetry portal - http://www.emodnet-bathymetry.eu. and UKHO INSPIRE Open Govern-

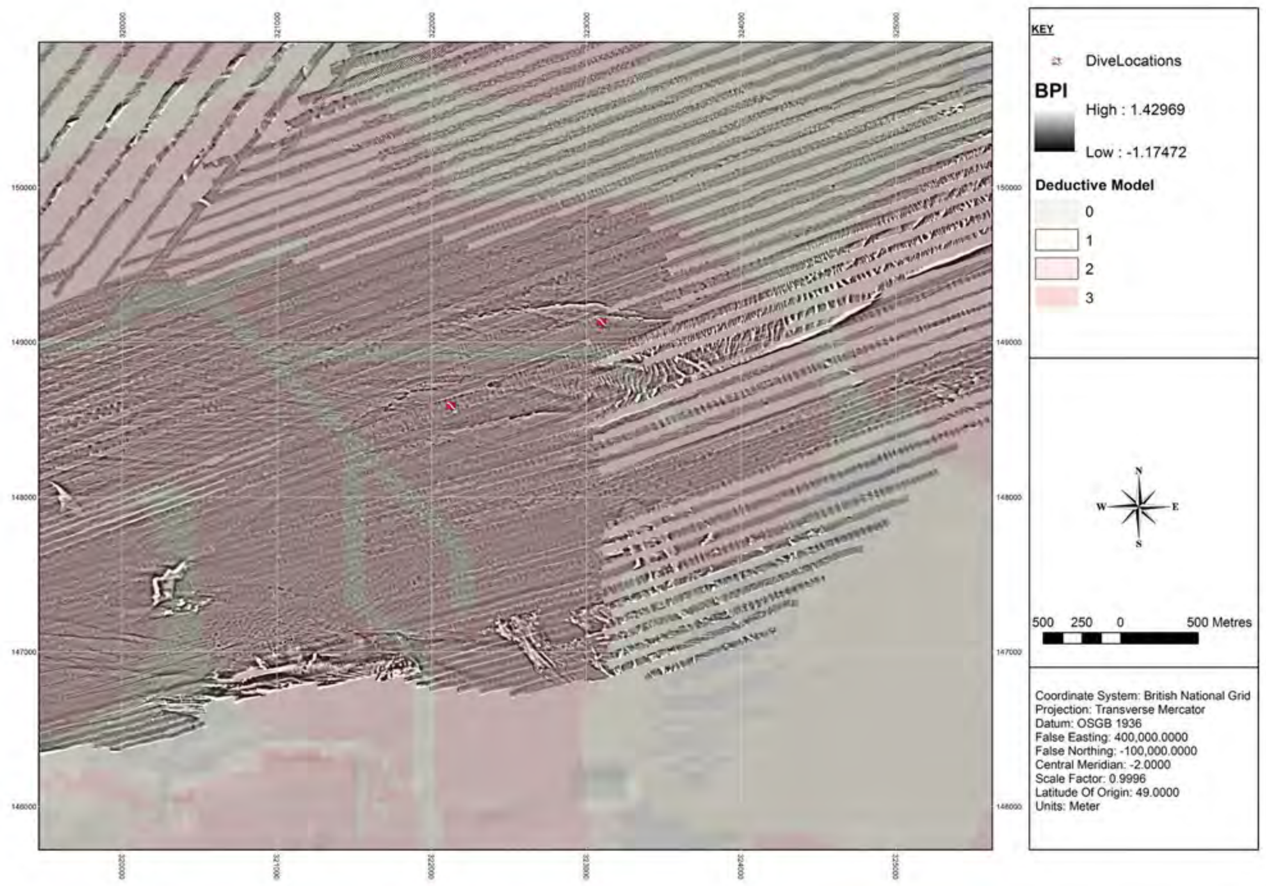


Figure 10.2 Map showing BPI analysis overlain with deductive model

out these forms of analysis.

Geophysical analysis and target identification

Recent acquisition of marine geophysical (swath bathymetry and side scan sonar) and geotechnical (borehole and grab) data, collected as part of the consents work for recent infrastructure work at Hinkley Point, provided an unprecedented opportunity to investigate the submerged landscapes of the inner Bristol Channel (Dix et al. 2015; Sturt et al. 2014, 2015). Three swath bathymetry datasets were acquired (IHO Order 1) offshore of Hinkley Point (Fig. 10.1): two by Titan Surveys Ltd under commission from CEFAS; one in 2008 covering an extended area of 90 km^2 (in order to provided background data for regional hydrodynamic models and habitat mapping), from Lilstock in the west to Howe Rock in the north-east and extending 4.5 km offshore at Hinkley and shorewards in Bridgwater Bay to the margins of Stert Flats; and one in 2010, which covered an area of 37 km^2 from Lilstock westwards to Warren Farm, extending 4.5 km offshore. The third survey was conducted in 2008 by EMU Environmental Ltd., which represented an expanding polygon oriented north-west from Hinkley Point to 6.5 km offshore and covering 21 km^2. More recently the area between Hurlstone Point and Hinkley Point (HI1449) was surveyed in 2015, to IHO Order 1a, by Gardline Geosurvey as part of the Long Term Shallow Water Civil Hydrographic Programme. While this data was unavailable during the project it is shown in Figure 10.3 and used, where relevant, to inform the wider context of the offshore record.

All datasets were binned at 1 m resolution, tidally corrected and converted to Ordnance Datum Newlyn using fixed offsets from local tide gauges. Concurrent side scan sonar data was acquired from all three 2008-2010 areas and provided as georectified tif images. This latter data gives backscatter information which can be used to qualitatively assess both small-scale bed morphology and seabed sediment type.

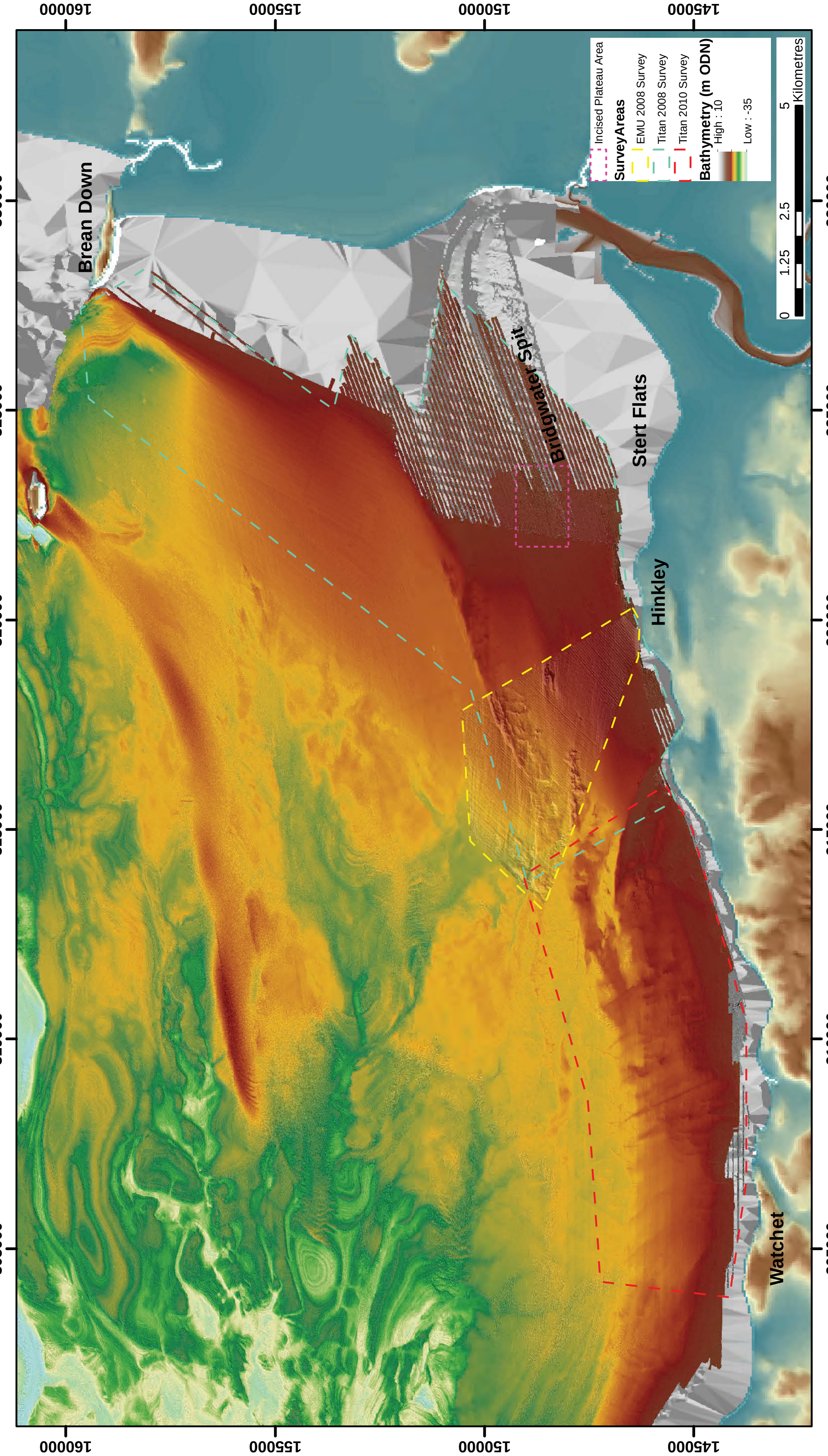


Figure 10.3 The full data coverage of the swath bathymetry datasets (CEFAS, EMU and Titan and public sector information, licensed under the Open Government Licence v2.0, from UKHO) acquired off Bridgwater Bay and the north Somerset coastlines. *The bathymetric data may include products have been derived from the EMODnet Bathymetry portal - http://www.emodnet-bathymetry.eu. and UKHO INSPIRE Open Government Licence*

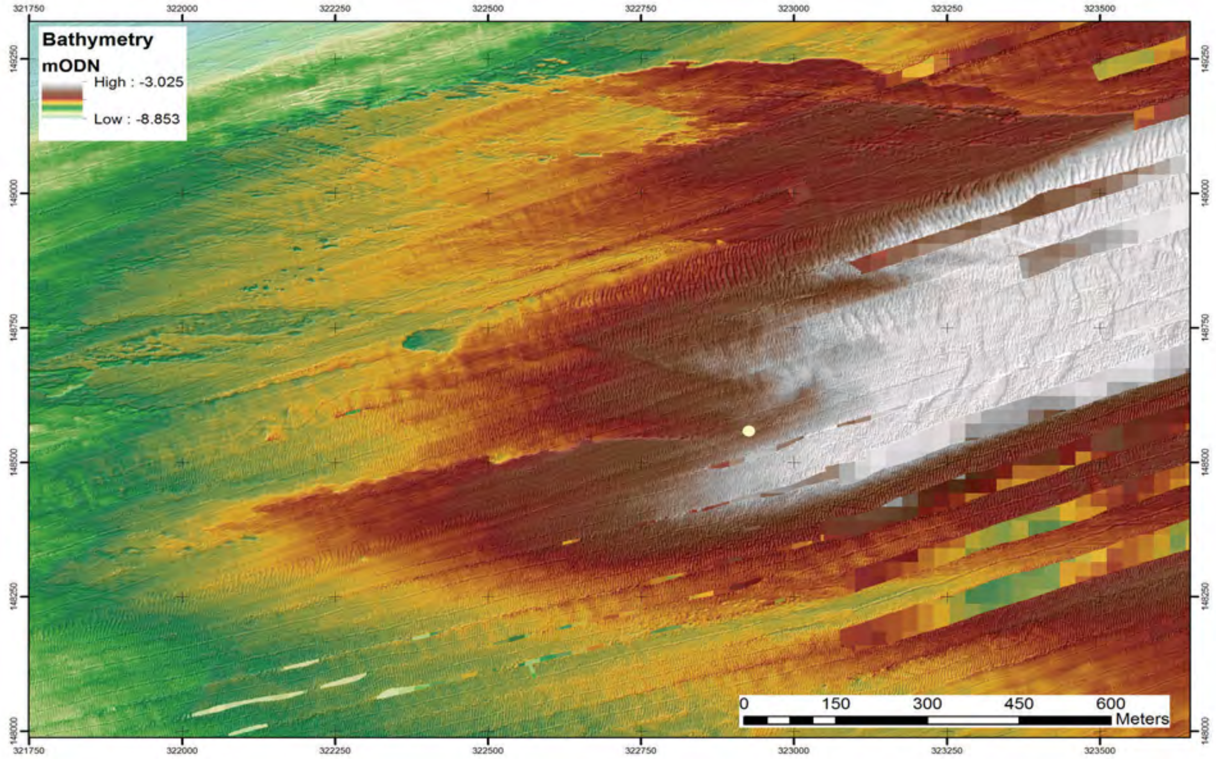


Figure 10.4 CEFAS swath bathymetry data showing the exposed incised plateau of potential peat exposure at the tip of the Bridgwater Spit. The cream circle shows the approximate location of the Mantz & Wakeling (1981) borehole that identified two peat horizons at a depth of 4-5 m beneath contemporary seabed. The bathymetric data may include products have been derived from the EMODnet Bathymetry portal - http://www.emodnet-bathymetry.eu. and UKHO INSPIRE Open Government Licence

By contrast to the sediment starved, bedrock exposed seabed that dominates the central Bristol Channel, Bridgwater Bay is characterized by increasing sediment accumulation in a shoreward direction. Bridgwater Bay itself is dominated by a settled mud patch, a thin accumulation of intercalated sands and muds that is believed to have been deposited, below wave base, in response to human management of the adjacent Somerset Levels since the Roman period (Long et al., 2002). The surface of the mud patch is dominated by sandy silts (coarse enough to be able to maintain small-scale, flow perpendicular, bedforms with amplitudes of 0.05m and wavelengths of 4 m) and silty and sandy clays, which exhibit shore and flow parallel linear tidal flute marks immediately offshore of Hinkley Point. The exceptions to this are: coarser sandy sediments associated with Bridgwater Spit, which has developed in response to rapid coarse grained sediment accumulation as the River Parrett enters the bay (Figure 10.3).

Immediately north of the tip of the Bridgwater Spit, an area of seabed, c. 45 hectares in size, has an abrupt external margin with a relief of c. 0.7 m which trends east-west, an almost horizontal upper surface which gently shelves offshore from -6.5 to -7.5 m ODN (Figure 10.4) and is cut by linear depressions (5-15 m wide, depths of 20 cm, steep slopes of up to 15^{o} and atypical of the area (Figure 10.5), and linear extents of up to 250 m) that are at an oblique angle to the flow, oriented east-west close to the Spit, but which rotate to a south-east to north-west orientation further offshore. The side scan sonar mosaic of this area, does not show a significant overarching change in the low backscatter intensity levels typical of the mud patch, except associated with the breaks in slope associated with the margin of this feature or the margins of the linear depressions (Figure 10.6). This morphology is inconsistent with the typical modern sediment surface of the mud patch or the Lower Lias outcrops, but is comparable with compacted peat outcrops that are found within the intertidal zone at Stolford, at almost identical altitudes (-7.3 m ODN), and which have been dated to 8190-7590 cal BP (I2688; 7060±160 BP; Core 6J; Heyworth and Kidson, 1982). However, the low backscatter levels may suggest a thin veneer of mud covering these potential peat outcrops. This features directly corresponds the area identified in the BPI analysis shown in figure 10.2 above.

A thorough review of the extant core data identified a single core taken in the early 80's coincides with an exposure of the inferred peat platform right at the tip of Bridgwater Spit (322927, 148561: Mantz & Wakeling, 1981). The borehole description suggests two, firm dark brown/black peat, each c. 10 cm thick, intercalated with soft medium grey silty clay, at a depth of 4-4.5m beneath the contemporary seabed. These depths do not coincide with the seabed/near surface exposures described above, however: the close proximity to the Bridgwater Spit; the potential for mobility of the overlying silts and sands (clearly seen in the flow perpendicular bedforms on the adjacent spit); and the known dynamism, in terms of bed level change of the mudpatch as whole (Kirby and Parker, 1980) may suggest that surfaces that were buried under four metres of sediment thirty years ago could now be exposed.

Such an exposure in a relatively elevated area offered the chance for recovery of environmental and material cultural data. The original deductive model suggested a moderately high (value 2) potential (the highest value given offshore) with revised BPI analysis moving this to 3 (simply due to its more pronounced relief, and thus island like status). As such, this area was selected for further investigation.

Offshore fieldwork

As discussed in chapter three, the decision had been taken to adopt the 'Danish model' for evaluation. Effectively, this meant that if it were safe to do so the preferred method would be to place divers on the seafloor to directly assess conditions. As noted above, a minimum target had been provided by Historic England to drop a camera at two locations of our choice. With this in mind the follow method was followed.

Method and Results

Given the extreme nature of marine conditions within the Bristol Channel and Severn Estuary (12.3m tidal range and high sediment load), few survey boats, and even fewer dive support operations are present in the area. However, this project was fortunate in working with Steave Yeandle, and his vessel *Scooby Doo Too* (a Bullet DS 38), who used by contractors for offshore survey in the region. Operations were mobilized from Watchet harbor, with long working days required due to the extreme tidal range limiting entry and exit form port.

In an effort to improve the chance of success with the camera drop, a Video Ray Remotely Operated Vehicle (ROV) with Ultra Short Baseline (USBL) tracking system was selected. This would allow for movement over the seabed and away from the survey vessel in an effort to find areas of visibility. The USBL topside unit was connected to a Leica Viva RTK GPS system, offering centrimetric levels of precision and accuracy with regard to survey location. ROV operation was undertaken by Justin Dix, Michael Grant and Tyra Standen. In addition a representative from Historic England (Philippa Naylor) was onboard to observe.

In hope that more than video drops alone could be accomplished, a Health and Safety Executive compliant dive team was assembled. Divers on the project were Fraser Sturt, Dan Pascoe, Rodrigo Ortiz, Rodrigo Pacheco-Ruiz, Tony Burgess and Bob Mackintosh. Divers were equipped with Full-face masks, helmet cameras, communications equipment and a USBL tracker. Harnesses and lifelines were provided due to the uncertain nature of conditions on site.

ROV and diving operations took place on the neap tides of 20th and 21st August 2014. The large tidal range and associated strong tidal currents, meant the tidal windows were very limited (c. 35 minutes). The first ROV drop took place at coordinates 322124, 148592 (Ordnance survey national grid, shown in figure 10.7 below) at 15.15 on the 20th August. Visibility was 0m, with no differentiation of surface features visible on the camera. As such, the decision was taken to deploy divers to investigate surface features. D. Pascoe and F. Sturt dived on the same coordinates at 15.45, with a dive time of 15 minutes and a maximum depth of 8 metres.

The divers reported true zero visibility conditions but carried out a search sample of the seafloor. The samples recovered revealed a consistent depth of more than 50cm of very dark grey/black sandy silt covering the location. It was not possible to sample more than 50cm due to the unconsolidated nature of the sediments. Due to the challenges of the environment the decision was made that it would not be safe to prolong the search at that location.

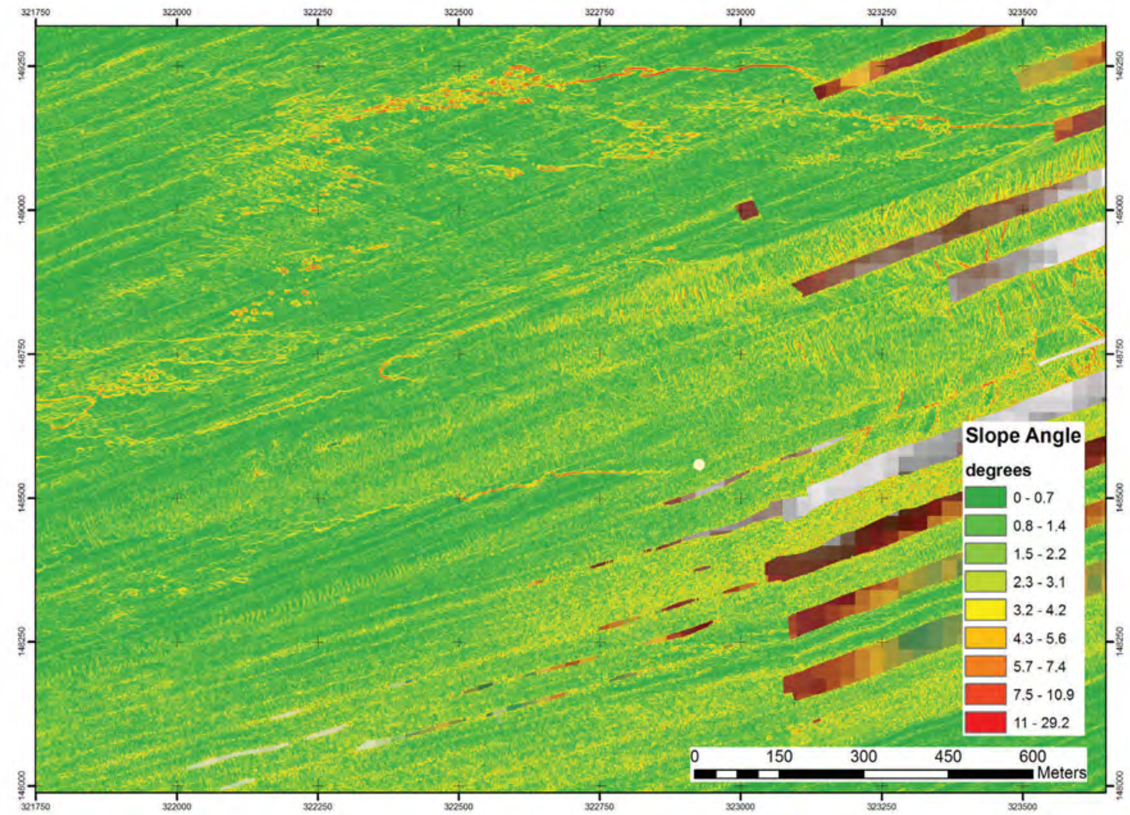


Figure 10.5 A slope map derived from the CEFAS swath bathymetry data. Clearly showing the steep slopes associated with the potential peat exposures on the seabed. The bathymetric data may include products have been derived from the EMODnet Bathymetry portal - http://www.emodnet-bathymetry.eu. and UKHO INSPIRE Open Government Licence

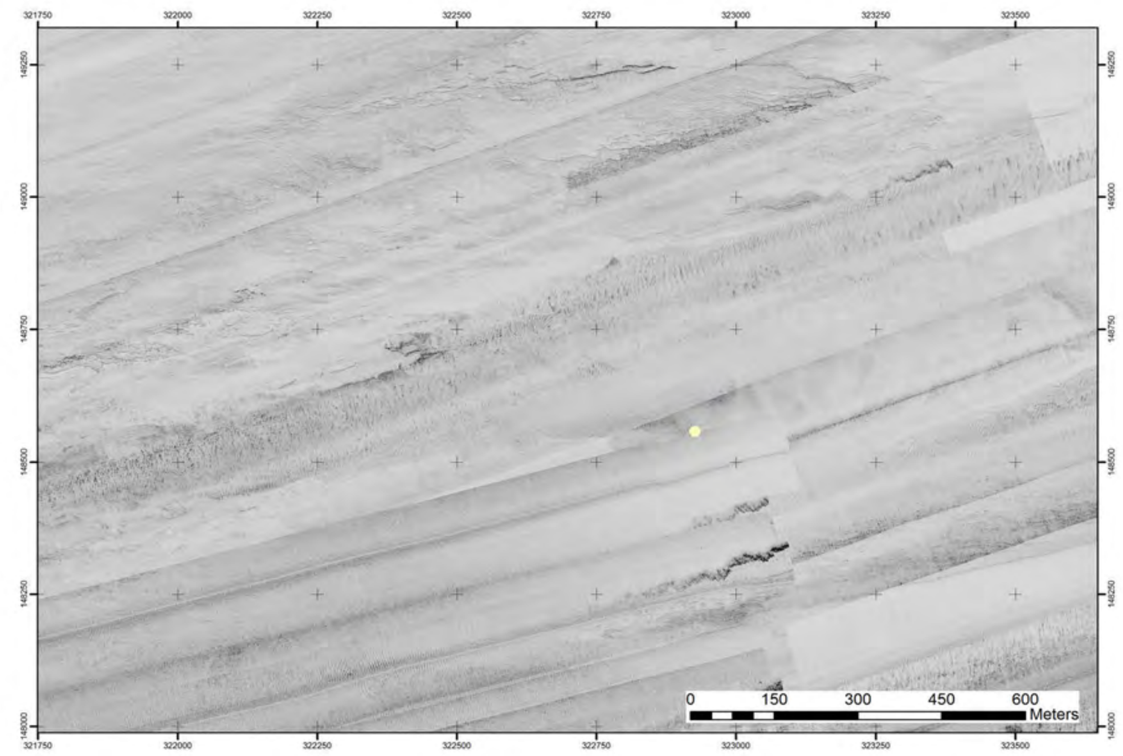


Figure 10.6 The CEFAS side scan geotiff showing the relatively uniform low backscatter intensity that dominates this region. Only the steep breaks in slope associated with the potential peat platform and the bedforms on the main part of the spit are clearly distinct.

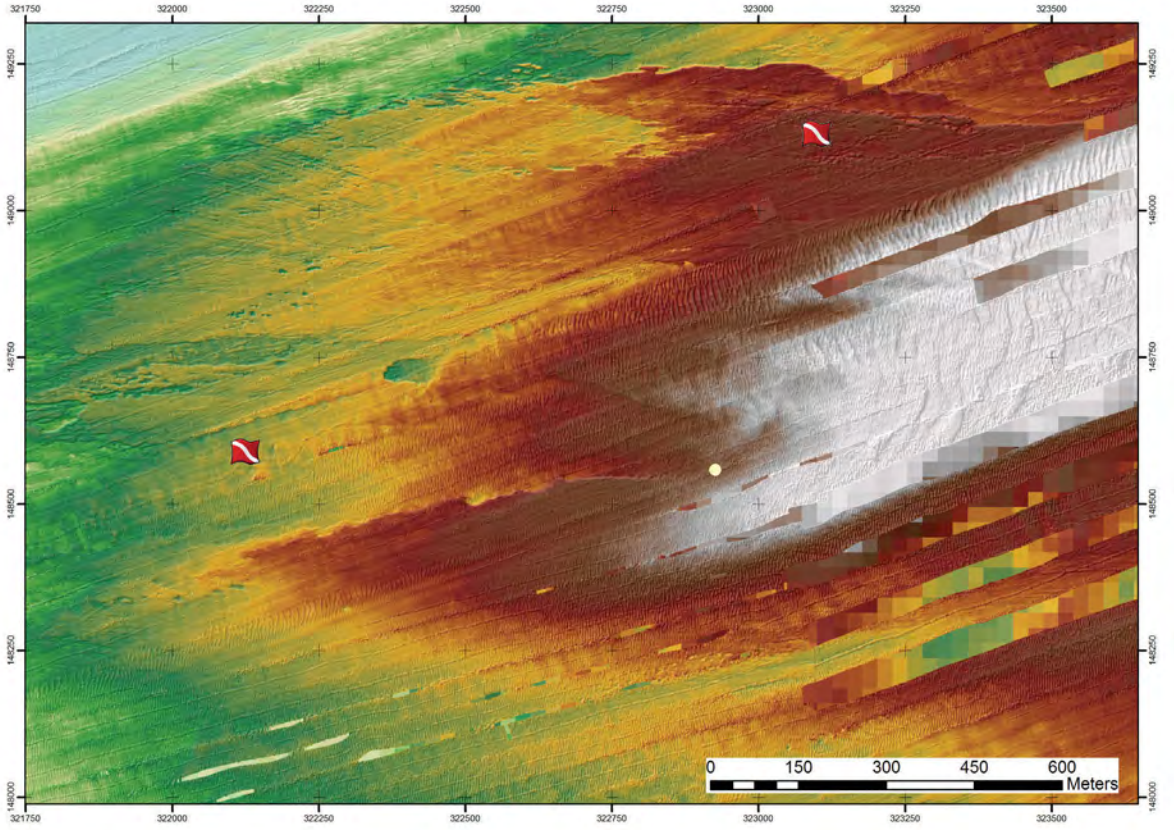


Figure 10.7 The two dive sites from the August 2014 dive season. The bathymetric data may include products have been derived from the EMODnet Bathymetry portal - http://www.emodnet-bathymetry.eu. and UKHO INSPIRE Open Government Licence

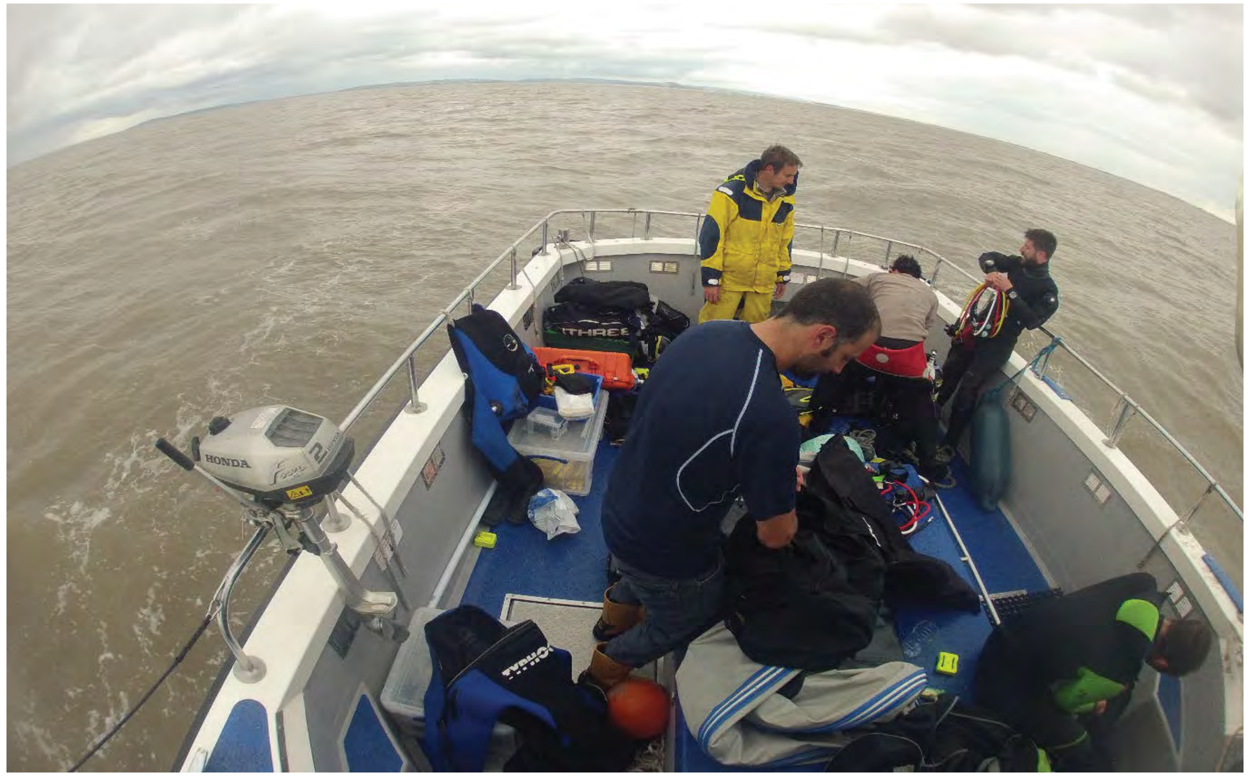


Figure 10.8 divers kitting up off Hinkley Point.

On the 21st August three further dives were made at coordinates 323099, 149134 by Ortiz, Pacheco-Ruiz, Mackintosh and Burgess. Again, conditions were zero visibility with a c. 50cm covering of sandy silt with no trace of organics found over the survey area (representing a circle 50m from the coordinates given above). On both days strong tides developed quickly across the site, limiting the dive window.

Conclusions

There is little doubt that the Bristol Channel and Severn Estuary represent one of the most challenging environments for archaeological work in England. The large tidal range limits the working window considerably, and the high sediment load reduces visibility. It is clear that for work in this area either a grab sampling, or core based approach would be more productive in verifying the presence of features such as peat platforms. However, as noted by Tizzard and Russell (2010), and as learned from the work of Moree and Sier (2015), if the focus is on recovering potential material culture, this would require high percentage sampling of the area if any confidence were to be had. In this instance, the highly protected nature of the Bridgwater Bay Mudpatch and environs would mean this is unlikely to occur, unless there was a planned dredging programme or infrastructure requirement.

The strong morphological indicators and the previous identification of peat in cores, may still suggest the presence of peat at greater depth than was sampled here, but ultimate confirmation will only be possible via other methods. It would be all too easy to be pessimistic about the results of this phase of the project. However, more than the baseline requirement was achieved, and while only limited data was recovered, a considerable amount was learnt. Experience was gained of deploying archaeologists onto extremely challenging locations, whilst maintaining a high degree of precision and accuracy for working practices. It has also helped to highlight what 'determining potential' might mean for some offshore areas around the UK. If it ever were decided to carry out an excavation of a submerged landscape in this region it would require large scale coffer damming to provide quite water conditions. As such, one of the questions we need to ask of ourselves as discipline is not only where might we have areas of high potential, but where can they most effectively be reached.

Chapter 11
Discussion and Conclusions

Introduction

This was an ambitious project driven by an increasing awareness within the discipline of the significance of submerged prehistoric archaeology for our understanding of the past. This awareness, alongside increasing development of England's territorial waters, forces us to consider how best to engage with this material. The act of reflecting on this, and constructing strategies for engaging with large offshore areas is challenging. However, in facing up to this challenge benefits accrue not only to our understanding of the submerged resource, but also its terrestrial counterpart. Through acknowledging that the onshore/offshore divide is a contemporary environmental classification, whose impact is exacerbated by the disciplinary divides created by histories of study and methodological differences, we begin to better understand the context of the more frequently investigated terrestrial record.

This chapter reviews the results from this project in relation to the aims and objectives given in Chapter one. This is followed by a broader discussion of the challenges currently facing archaeology and the difficult decisions that lie ahead. To reiterate the observation made in chapter one, it indicates a loss of innocence within maritime archaeology, echoing Clarke's (1973, 6) observation that when we cross a threshold of understanding considerable changes may need to be made in how we practice and think about our subject. The challenge which lies ahead for UK waters is to determine if we are content with the potential we can realise from the offshore record via current methods, or if we now think we aren't doing enough to realise it fully.

Aims and results

Three overarching aims were given for this project:

a. Assess the efficacy of predictive modelling for the determination of the potential for submerged prehistoric archaeology in English waters;

b. Evaluate the range of methods open to archaeologists when assessing the potential for submerged prehistoric archaeology offshore, and how best to investigate/mitigate for it; and

c. Extend our knowledge of key inter-tidal and offshore sequences in a region already known for its nationally significant inter-tidal and onshore prehistoric record.

Each of the above was closely tied to a series of more specific research, methodological, management and outreach goals.

The efficacy of predicative modelling for determining potential for submerged prehistoric archaeology

Chapters three and seven explored the issues surrounding predictive modelling and the various approaches available. Through this work the research aims of 'articulating methods' and 'quantifying applicability' were met. Methodological goals, with regard to developing an exemplar approach, have also been achieved, but with the strong caveat that the strength of the final method was seen to be in its deposit modelling focus and flexibility. As such, the real value in modelling approaches was seen to be their ability to highlight strengths and weaknesses within available datasets. The methodology employed within this project has identified that the topographic position index (TPI) and bathymetric position index (BPI) classification systems can be highly useful when quantifying landscape variability.

The above work has clear resonance when considering how we can manage the offshore resource. As such it has directly contributed to the management aims of reflecting on how we can 'develop effective strategies for managing and mitigating impact', as well as developing best practice through learning from international

exemplars. Here the expert meeting on predictive modelling and wider literature review have allowed an integration of published examples and personal experiences with regard to modelling both offshore and onshore environs. One of the key issues to emerge from this review and wider engagement were the problems with the application of inductive modelling approaches for regions with either little prior archaeological data, or where extant data reflects a very different series of ecological settings.

The systematic approach taken in this project clearly outlines a deductive modelling method, allowing the reader to begin to understand the different stages that can be utilised in order to identify areas of the landscape where quantifiable features, thought to be associated with archaeological activity, might be located. This provides a valuable methodological insight as, all too often, such modelling approaches don't supply sufficient transparency into how the end result is derived, which has the danger of being used inappropriately for a range of applications including planning control.

With all of the above in mind, the outcome of this project is positive with regard to the application of modelling methods for determining potential or, more specifically, determining understanding. The process of creating a linked deposit and deductive model required careful review of extant datasets and archaeological thought. It forces detailed consideration of what at times has been considered uncritically, with regard to what we mean by potential. The questions we ask of the archaeological record are now so intricate and wide ranging that 'potential' extends beyond the possibility of recovering in-situ material culture alone. As such, the deductive model becomes a record of extant knowledge through which gaps and opportunities can be targeted. In essence it becomes an act of data audit and integration matched to archaeological priorities.

With this in mind the following statements can be made. First, the ideal starting point for any account of potential for submerged prehistory should include a detailed deposit model. Ideally, this would go well beyond anything we are currently capable of producing in the UK outside of spatially limited areas of previous high intensity research. Gaining an understanding of change through time, particularly for the Holocene requires detailed mapping and dating activities. Where data points become too sparse any attempt to interpolate between them becomes problematic, meaning that a lower order/lower resolution method will need to be adopted. It was illustrative that within the relatively well studied region selected for this study, data density did not lend itself to complex lithostratigraphic or aggradational modelling in a meaningful sense. This in turn limited the value of any predictive model generated, restricting it to a simplistic categorisation of space. Fortunately this is a goal that we can, and indeed are, beginning to work gradually towards through increased awareness of the importance of refined chronometric understanding and data sharing. Through working alongside commercial contractors early on in the planning process we becoming better placed at both generating data that is useful in the context of a single project and that which speaks to longer term programmes of knowledge development.

Second, deterministic predictive models of high potential locations offshore are currently very problematic. At present we do not know regional records well enough to do this on land (and as argued by some, never will) and certainly do not have the level of knowledge required to do it at sea. However, this should not prevent us from considering adopting a more robust sampling method, as the only way we will improve our understanding of the archaeological record offshore is through by directly engaging with it. The techniques described in chapters six and seven can help with this, through documenting what we do know and characterising space to enable sampling across a range of locations. As discussed below, recent work in the Netherlands has demonstrated how this can be taken a step further. This is significant as it helps to demonstrate that if we choose/determine it necessary, it is possible to go beyond engagement with submerged prehistory by geophysical and core based methods alone.

Evaluation of the range of methods open to archaeologists when assessing the potential for submerged prehistoric archaeology offshore

Given the scope of this project the above goal, and project research aims, was largely met through literature review, expert meetings and limited targeted fieldwork. As chapters seven, eight, nine and ten document, two issues have emerged as of key significance:

1. appreciating our current level of understanding of the prehistoric record
2. the importance of acquiring a 'representative sample'.

Point 1 has significance for both modelling and evaluation methods (as the two are tied in a recursive relationship). As Bell et al. (2015, 231) note in their report on understanding the Mesolithic of Somerset:

> "The problem is that the Mesolithic period, covering 5700 years, half of the postglacial, has received far less archaeological attention than other periods."

This problem extends far further than Somerset and beyond the Mesolithic alone. As chapter three made clear, when attempting to create a model of prehistoric activity the quality of the input data has to be carefully considered. In doing this it has become painfully clear that for the study area it is not only the Mesolithic that is poorly understood, but also the Palaeolithic, Neolithic, Bronze and Iron Ages. This statement requires some qualification. Within the broader national narrative we have a good understanding of how the material found to date relates to larger scale processes. However, the specifics of regional records (and with this, how valid the broader national narratives are), is hard to determine. As Blinkhorn and Milner (2013) have noted for the Mesolithic, part of this problem lies with the disparity in data density we have between areas undergoing substantial development, and those where little work has been carried out. In addition, there is a strong need for more in the way of extensive surveys to better appreciate the density and spread of prehistoric sites. For a region often noted for its high potential, when examined carefully, the study area selected here contained remarkably few data points, or examples of detailed excavation.

To a large part this is the result of working in areas with deeply buried archaeology where, all too often, prehistoric archaeological potential may only be inferred through a range of complementary techniques. As a consequence areas of the landscape that are most easily accessible have become the main focus of archaeological activity and have led to our definitions of prehistoric activity within these wetland environs. There is little doubt along the Bristol Channel and Severn Estuary that prehistoric finds within intertidal exposures (e.g. Bell 2007) and raised topographies (e.g. Burtle Beds (Bell et al. 2014) and rockhead exposures (Hollinrake and Hollinrake (2002)) have probably resulted in a bias of the representation of prehistoric archaeology from these wetland areas, that have led to the development of traits that feed into, and reinforce, our current predictive model. Such issues become exacerbated when we move offshore, and in this respect reflects the broader picture nationally. With only two English prehistoric sites/finds investigated in detail offshore (Momber et al. 2011, Tizzard et al. 2014) we have very little to base any understanding on. As Bynoe (2014) has recently demonstrated, this lack of direct investigation stands markedly opposed to the clear significance of offshore deposits being tracked off shore.

Within this project the Danish approach of test pitting was adopted due to being able to apply this across all three environments (onshore, inter-tidal and offshore). Test pitting is a well known archaeological approach, but one that requires either a high density or good understanding to the spatial limits of an archaeological scatter (e.g. Westley 2015). In the absence of either of the above its chance of encountering in-situ remains is clearly limited, and in turn reflects the observations of the Russell and Tizzard (2010) with regard to other offshore evaluation methods (camera drops, grab sampling and trawling. The offshore prehistoric sites of Area 240 and Bouldnor Cliff are both exposed near the seabed which contributed to both their initial identification (trawled / dredged material) and subsequent archaeological investigation as there is comparatively easier access and retrieval of material compared to areas nearer inshore where the archaeology may be buried many metres below the seabed. We can, however, learn from recent work overseas. Moree and Sier's (2015) work on the Yangtze Harbour site has shown what can be achieved when large areas are sampled, based on the result of detailed geoarchaeological/deposit modelling work.

The significance of the Yangtze Harbour team's work (Moree and Sier (2015)) should not be underestimated. It marks a watershed in scale and yield with regard to archaeological methods for submerged prehistory. The use of large grab samplers to recover material in a highly monitored manner, matched with detailed geophysical and geotechnical work has helped to realise a potential that was identified early in the planning process.

Critically, without the change in intervention intensity and method, there would have been an exceptionally well reconstructed landscape, but a poorly understood history of occupation. This is significant as recent work has shown (Anderson-Whymark et al. 2015) that recovery of even small amounts of material culture still has the potential to transform our understanding of prehistoric activity. It is often tempting to think that the large narratives of European prehistory have been written, and that we are now filling in the detail, but this is not the case.

This observation returns us to Clarke's (1973, 6) assertion that there is a price to pay for loss of innocence. If we wish to fully realise the potential of the submerged archaeological record, then we will need to adopt a more robust direct sampling method. This will entail removal of potentially large volumes of material, and, just as on land, may at times produces a null result.

Archaeology is a cumulative discipline, where each find builds on the last in terms of adding to our understanding, and each null result reflects better appreciation of variability in human ecology. It is clear that this is the price we have to pay if we wish to access the conventional archaeological potential discussed in recent publications (Peeters et al. 2010, Ransley et al. 2013). Alternatively we have to consider if we can ask different questions to gain comparable knowledge, or agree that the potential we wish to describe and account for relates to specific questions of landscape and environmental change. Significantly, this would render unanswerable key questions of national significance within research frameworks (Peeters et al. 2010, Ransley et al. 2013).

Extend our knowledge of key inter-tidal and offshore sequences in a region already known for its nationally significant inter-tidal and onshore prehistoric record.

As noted above and documented in chapters eight, nine and ten this project has only been able to make a small direct contribution to our understanding of the regional prehistoric record. However, through the datasets gathered for the modelling work it has created a digital archive of considerable value to future researchers. The 3D deposit model, new models of palaeogeographic change and radiocarbon dating results have significantly built upon the vast array of previous research in the study area and has helped to define new areas of research priorities, as well as providing important baseline datasets by which the existent archaeological knowledge can be reassessed, most notably a revised palaeogeography of the region encapsulating the full onshore-offshore gradient. The re-dating of the peat exposures at both Pawlett and Stolford have significantly improved upon the existent chronologies provided by Kidson and Heyworth (1973; 1976; Heyworth 1985). Coupled with the work of Griffiths et al. (2015) the Stolford-Hinkley peat deposits, as well as the submerged forests from the upper peat deposits at Stolford (Heyworth 1985; Nayling unpublished), this area is now one of the best dated intertidal-subtidal palaeoenvironments in England.

The results of this research have been deposited with the HER and archaeological data service to enable future researchers to build on and further refine them. In addition, although the limited test pitting, diver based survey and coring work did not produce extensive results, they have added to local understanding. These have also provided an important stage in the predictive modelling validation stage by clearly demonstrating that further developments are required and our preconceived ideas over the distribution of prehistoric archaeology in the landscape may be too generalised. The ground-truthing of the potential cursus feature in Pawlett and subsequent queries raised as to its likely existence directly answers questions being posed as to its relationship with finds at Walpole immediately to the east of this site. The coring work at Pawlett traced surviving organic deposits and demonstrated their depth locally. This will permit later researchers to consider how they might be accessed to extend our knowledge of Mesolithic/Neolithic activity in the region. In addition, the use of hovercraft for inter-tidal survey was found to be highly effective, allowing for mapping and sampling of deposits over large areas within a window of opportunity at low tide that would otherwise prove almost impossible and unsafe to access under other means, particularly due to the extreme tidal range found within the Bristol Channel and Severn Estuary.

As such, although limited in findings the work described in this report has met the methodological aim of undertaking fieldwork in the area, and ,exceeded it with regard to the diver based survey.

Outreach

Alongside the research, methodological and management aims were a series of goals associated with broader outreach. These goals were achieved through inclusion of two case studies on submerged prehistory and the Bristol Channel within the *Shipwrecks and Submerged Worlds* Massive Open Online Course (MOOC), created by the University of Southampton and hosted on the Futurelearn platform[1].

The course was run twice over the duration of this project (October 2014 and May/June 2015). In total 15,269 people participated in the MOOC, learning about all aspects of maritime archaeology, but gaining direct insights into the nature of submerged prehistory, the Bristol Channel and Somerset Levels area in particular.

One of the outreach aims was to "raise awareness in industry of the methods we can adopt and justifications for the measures put in place". As the project wore on it became clear that the work undertaken would raise more questions about how we work offshore (and what we might like to do in the future) rather than justifying current approaches. As such this aim was not fully met. This being said, in an attempt to understand attitudes to, and knowledge of the sea and heritage within MOOC participants an online survey was created which attracted 1073 participants. All participants were asked about how they currently engage with heritage and the sea, and 162 of the respondents self identified as working in offshore industries. Thus while not directly targeted the work carried out for this project has tangentially engaged those working offshore and made them aware of the questions, methods and approaches adopted by archaeologists. Finally, the webcasts from the expert meeting on predictive modelling and submerged prehistoric archaeology remain live and have been viewed over 250 unique users.

As the preceding chapters make clear, this project has met the project aims with variable degrees of success. This reflects the challenges in carrying out archaeological research, where multiple factors impact on the trajectory and final outcomes; from physical access to fields, inter-tidal and sub-tidal spaces for ground-truthing, through to more conceptual realignments. As the text in the following section documents, one of the greatest challenges we face is being clear about the data required to answer the questions we currently pose of the archaeological record and the steps we take to answer them. This project has deliberately laid bare the steps taken to determine potential as any exclusion of the processes gone through can result in the presentation of a 'smoothed output' that looks convincing but hides a myriad of more interesting ,and challenging, problems.

Discussion

The loss of disciplinary innocence has emerged as key theme within this work. Since Reid's (1913) observations, through initial forays into survey (Crawford 1927), ground-truthing (Clark 1936) and more recent reflections (Coles 1998) and innovations (Gaffney et al. 2007; 2009; Smith et al. 2015); archaeology has struggled to know how best to realise the apparent potential that lies offshore. Regional and national research frameworks continue to single out offshore sedimentary sequences as of high potential for answering key questions from the lower Palaeolithic onwards (Ransley et al. 2013) yet we are restricting the methodologies used i to address them. While we have made significant advances with regard to landscape reconstruction and environmental analysis, we have not made the same steps forward with addressing questions relating to patterns of occupation and connectivity.

Recent work on sedimentary DNA by Smith et al. (2015) hints that new techniques are on the horizon that may allow us to populate submerged landscape and understand dynamics of movement and connectivity through analysis of sedimentary cores, though these are not without their own taphonomic problems which need to be overcome. This is a heady thought, as it would allow research to continue to develop along a trajectory that has already produced results that have transformed our understanding of the past. This line of data potentially allows for human activity to be more clearly identified while continuing to build our understanding of landscape change from geophysical and geotechnical datasets.

1 There are a range of references to this project, but the two most pertinent are an article on methods for submerged landscapes https://www.futurelearn.com/courses/shipwrecks/steps/14436, and one on the Bristol Channel https://www.futurelearn.com/courses/shipwrecks/steps/9753

However, this is a new approach for archaeological science offshore, and will take time to be assessed and understood. It is also unlikely to overcome one of the largest problems that has become clear through this project. This problem relates to categories of data and the nature of archaeological enquiry. Over the last hundred years archaeology has developed a detailed understanding of material culture sequences on which our accounts of the past are predicated. While environmental signatures and improved understanding of context are now crucial, material culture still provides the backbone to archaeological research and forms the knowledge base from which key questions are posed.

As such, our ability to answer those questions from offshore contexts will always be limited while we fail to adopt strategies suitable for recovering data of that nature. The potential for recovery is clear (Momber 2011; Moree and Sier 2015; Bicket and Tizzard 2015; Bynoe 2014) and we are better able than ever to identify deposits which may contain in-situ material. However, the landscapes to be sampled are vast, and our broader archaeological understanding of prehistoric activity limited to the extent that predicting exactly where to dig is hard to do. Within England data for recovered archaeology from the offshore zone are poorly consolidated, and the aspirations of the Heritage Information Access Strategy (Historic England Action Plan Objective 2.6.1. "Improve access to heritage information") to create a national marine Historic Environment Record (HER) capability (Oakleigh Consulting Ltd 2015) will provide an important platform from which inductive modelling approaches can be better derived and applied within an offshore context.

Given the above observations it would appear that if we wish to recover artefactual material, or to better understand the impact of offshore works on submerged prehistoric remains, we need to change our approach to sampling and data collation. The implications of this statement are not insignificant, but they do logically follow on from mapping discipline identified research priorities with our ability to answer them. Specifically the outcomes of this project indicate that we should strongly consider the following actions:

a. Establish and build on mechanisms for enabling open access to geotechnical and offshore geophysical data. Improving our understanding of the potential of submerged landscapes hinges on our ability to rapidly incorporate new data as they become available.

b. Develop open access to chronometric data from onshore and offshore cores and sites, matched with continued support for scientific dating advice to ensure robust data collection and dissemination.

c. Encourage increased terrestrial landscape sampling, to improve our understanding of earlier and later prehistory onshore. As discussed above, recent work by Oxford Archaeology on the Bexhill to Hastings relief road has demonstrated how testing pitting through soil sequences can radically improve identification of Mesolithic sites. This may prove pivotal in helping to justify how we approach larger areas offshore.

d. Continue to engage with offshore industries in a positive manner, to allow for identification of opportunities where direct sampling of the seabed can be combined with detailed deposit modelling in a manner similar to that carried out by Moree and Sier (2015). It is only after trialling such approaches on a relatively large scale that we will be better placed to understand the difference they might make to our understanding of the past, and from such trials, to determine if we consider them worthwhile.

e. Encourage deposit modelling to become an active part of desk-based assessment prior to development both onshore and offshore. This is for two reasons First, to help quantify what we understand from the extant record, and second, to help highlight areas in need of additional investigation. At present projects are too fragmented and output models not shared beyond static two-dimensional graphical representations. This prevents more rapid improvement of understanding through sharing knowledge.

f. To favour deposit modelling/geoarchaeologically focused approaches to deductive predictive models of potential site location.

g. To remove the terrestrial/marine boundary from investigation wherever relevant. This is particularly important for large commercial projects that impact both onshore and offshore. Here different groups of specialists are often employed for each modern environmental zone. This again prevents stitching of data and a combined approach to investigation and mitigation.

Conclusions

This project has been focused on predictive modelling and improving our understanding of submerged prehistory through joining the onshore to offshore. When discussing onshore and offshore we often find ourselves discussing how the environmental differences lead to different forms of data collection, with a focus on the types of geophysical and geotechnical data acquired. What has emerged from the above discussion is that the greatest challenge lies in gaining equivalency, of creating datasets that permit onshore and offshore to be joined through addressing the same questions at similar resolutions. As Wheatley (2004) has made clear, predictive models without ground-truthing are pointless endeavours. Furthermore, models which are not checked and refined through testing areas deemed to be of high potential with those of low potential run the risk of detrimentally biasing our understanding of the past. The scale of the landscapes that we are considering offshore, and our limited pre-existing knowledge of the level of occupation means that we now need to carefully reflect on what an appropriate sampling density might be and how we might carry this out.

The alternative is that we accept that we are not going to answer the questions we have set out in research agendas, and that we will not act on the possibility of recovering material culture in preference of reaching other goals, or acquiescing to external pressures. Archaeology should not be daunted by this as it has already overcome these challenges terrestrially. At times in the past development has been seen to negatively impact on the archaeological resource, but, through productive collaboration we now know more about the archaeology of England than ever before, and much of this is due to the scale of commercial operations. It is unlikely that any research council funded project will have either the scope or financial means of the industrial work occurring offshore. As such, the challenge would appear to lie in finding mutually beneficial methods of investigation, where multiple parties can gain relevant information through a shared approach. This has already been seen to work with geophysical and geotechnical data acquisition for landscape reconstruction, and has the potential to address the issues described above. However we achieve it, we may finally realise the need to act on Reid's (1913) advice, and begin to actively search for archaeological material. This may mean both expanding our repertoire of investigative techniques to change the sorts of data we acquire, whilst also improving ability to share data and better describe the spaces within which prehistoric activity occurred.

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Appendix 1 Assessment Methodologies

Sediment description

Monoliths / cores were described according to Hodgson (1997) and following the recommendations made within Ayala et al. (2007). Interpretations regarding mode of deposition, formation processes, likely environments represented and potential for palaeoenvironmental investigation were then made, and decisions taken regarding subsampling. All samples were refrigerated on return from the field and subsequent to sampling.

Radiocarbon Dating

Seventeen samples were selected for radiocarbon dating. Identifiable non-submerged plant macrofossils from rich assemblages, with an unambiguous above-ground origin, were targeted for dating. These included most frequently (11 samples) horizontally bedded single *Phragmites australis* leaves, with *Corylus avellana* nuts (SUERC-57872 and SUERC-57873) and a *Quercus* acorn (UBA-27981) cup from STFD14 <3>. In addition a proximal end of a left cf. *Bos* tibia (SUERC-58166) was dated from the Pawlett excavations. However deposits from the base of STFD14 <1> (SUERC-57809 and SUERC-57810) and the top of the main peat in PWLT14 BH19 (0.87-0.86m ODN; UBA-27979 and UBA-27980)) failed to yield suitable plant material for radiocarbon dating. In these cases 1cm slices of peat were sampled and submitted for sediment fraction (humin / humic acids) dating. Samples were carefully samples, cleaned with distilled water, and packaged in plastic bags / vials and submitted to the Historic England Scientific Dating team.

The Nine samples dated at The Queen's University Belfast were processed and dated by Accelerator Mass Spectrometry (AMS) as described in Reimer et al (2015). For the peat sample from STFD14 <1> both the alkali-soluble ('humic acid') and alkali- and acid-insoluble ('humin') fractions were dated.

Eight samples were dated at SUERC. The single animal bone sample from Pawlett was pre-treated using a modified Longin method (Longin 1971) and the waterlogged plant macrofossils and peat samples from Pawlett and Stolford as described by Stenhouse and Baxter (1983). CO_2 obtained from the pre-treated samples was combusted in pre-cleaned sealed quartz tubes (Vandeputte et al. 1996) and then converted to graphite (Slota et al. 1987). For each of the PWLT14 BH19 peat samples both the alkali-soluble ('humic acid') and alkali- and acid-insoluble ('humin') fractions were dated. The samples were dated by AMS as described by Freeman et al (2010).

Both laboratories maintain continual programmes of quality assurance procedures, in addition to participating in international inter-comparisons (Scott 2003; Scott et al 2010). These tests indicate no significant offsets and demonstrate the validity of the precision quoted.

The results are conventional radiocarbon ages (Stuiver and Polach 1977), and are quoted in accordance with the international standard known as the Trondheim convention (Stuiver and Kra 1986). These dates have been calibrated to the calendrical time scale using the IntCal13 dataset (Reimer et al. 2013) and calibrated within OxCal v4.2 (Bronk Ramsey 1995; 1998; 2001; 2009). The calibrated date ranges cited are quoted in the form recommended by Mook (1986), with the end points rounded outward to 10 years. The ranges in Tables RC1–4 have been calculated according to the maximum intercept method (Stuiver and Reimer 1986); the probability distributions shown in Figures 1–4 are derived from the probability method (Stuiver and Reimer 1993). Age-depth modelling was undertaken within Bacon (Blaauw and Christen 2011) using IntCal13 (Reimer et al 2013).

Pollen Assessment

Standard preparation procedures were used (Moore *et al*. 1991). $2cm^{-3}$ of sediment was sampled with a *Lycopodium* spike added (batch 212761) to allow the calculation of pollen concentrations (Stockmarr 1971). All samples received the following treatment: 20 mls of 10% KOH (80°C for 30 minutes); 20mls of 60% HF (80°C for 120 minutes); 15 mls of acetolysis mix (80°C for 3 minutes); stained in 0.2% aqueous solution of safranin and mounted in silicone oil following dehydration with tert-butyl alcohol.

Pollen counting was undertaken at a magnification of x400 using a Nikon SE transmitted light microscope. Determinable pollen and spore types were identified to the lowest possible taxonomic level with the aid of a reference collection kept at the University of Southampton.

The pollen and spore types used are those defined by Bennett (1994; Bennett *et al*. 1994), with the exception of Poaceae which follow the classification given by Küster (1988), with plant nomenclature ordered according to Stace (2010). To enable the possible identification of grazing herbivores fungal Non-Pollen Palynomorphs (NPPs) associated with animal dung were also recorded. Following the recommendations of Baker et al. (2013) the following three NPP types were recorded as these were thought to provide the more reliable indication of grazing activity: *Sporormiella*-type (HdV-113), *Sordaria*-type (HdV-55A) and *Podospora*-type (HdV-368).

The pollen assessment results are drawn as a diagrams using Tilia v 1.7.16 (Grimm 1991). The pollen results from each sample were statistically compared to each other using CONISS (constrained incremental sum of squares clustering) (Grimm 1987). A total land pollen (TLP) sum of 100 grains was used for the initial pollen assessment. The TLP sum excludes aquatics, pteridophyes and NPPs, which are calculated as % Σ TLP + Group.

Diatoms

Diatom preparation followed standard techniques (Battarbee et al. 2001). Two coverslips were made from each sample (1cm^{-3}) and fixed in Naphrax for diatom microscopy. A large area of the coverslips on each slide was scanned for diatoms at magnifications of x400 and x1000 under phase contrast illumination.

Diatom floras and taxonomic publications were consulted to assist with diatom identification; these include Hendey (1964), Werff and Huls (1957-1974), Hartley et al. (1996), Krammer and Lange-Bertalot (1986; 1988; 1991a; 1991b) and Witkowski et al. (2000). Diatom species' salinity preferences are indicated using the halobian groups of Hustedt (1953; 1957: 199), these salinity groups are summarised as follows:

1. Polyhalobian: >30 g l^{-1}
2. Mesohalobian: 0.2-30 g l^{-1}
3. Oligohalobian - Halophilous: optimum in slightly brackish water
4. Oligohalobian - Indifferent: optimum in freshwater but tolerant of slightly brackish water
5. Halophobous: exclusively freshwater
6. Unknown: taxa of unknown salinity preference.

Plant Macrofossil Remains

Samples measuring 4-8 cm^3 were extracted from the cleaned monolith blocks / borehole. Disaggregated sediment was washed through a 125 µm sieve using a standard 5 l of water. Quantification followed the standard five-point scale of abundance (rare = 1, occasional = 2, frequent = 3, very frequent = 4, abundant = 5; Barber, 1981) method (Barber 1981) with identification of plant remains to the highest taxonomic precision possible, given the constraints imposed by peat humification. Identifications were made using the reference collection at the Palaeoecology Laboratory University of Southampton (PLUS). Plant nomenclature follows Stace (2010). Diagrams were drawn using Tilia v 1.7.16 (Grimm 1991).

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Appendix 2
Determining potential: onshore/offshore prehistory – radiocarbon dating

P Marshall, E Dunbar, and P Reimer

Introduction

Seventeen radiocarbon age determinations were obtained on samples submitted for dating from Pawlett and Stolford, two samples during pretreatment. The samples were dated at The Queen's University Belfast (UBA-), and Scottish Universities Environmental Research Centre (SUERC-) in 2015.

Laboratory methods

The nine samples dated at The Queen's University Belfast were processed and dated by Accelerator Mass Spectrometry (AMS) as described in Reimer *et al* (2015). For the peat sample from Stolford both the alkali-soluble ('humic acid') and alkali- and acid-insoluble ('humin') fractions were dated.

Eight samples were dated at SUERC. The single animal bone sample from Pawlett was pre-treated using a modified Longin method (Longin 1971) and the waterlogged plant macrofossils and peat samples from Pawlett and Stolford as described by Stenhouse and Baxter (1983). CO_2 obtained from the pre-treated samples was combusted in pre-cleaned sealed quartz tubes (Vandeputte*et al* 1996) and then converted to graphite (Slota *et al* 1987). For each of the peat samples both the alkali-soluble ('humic acid') and alkali- and acid-insoluble ('humin') fractions were dated. The samples were dated by AMS as described by Freeman *et al* (2010).

Both laboratories maintain continual programmes of quality assurance procedures, in addition to participating in international inter-comparisons (Scott 2003; Scott *et al* 2010). These tests indicate no significant offsets and demonstrate the validity of the precision quoted.

The results (Tables RC1–4) are conventional radiocarbon ages (Stuiver and Polach 1977), and are quoted in accordance with the international standard known as the Trondheim convention (Stuiver and Kra 1986).

Radiocarbon calibration

The calibrations of these results, which relate the radiocarbon measurements directly to the calendrical time scale, are given in Tables RC1–4 and in Figures RC1–4. All have been calculated using the datasets published by Reimer *et al* (2013) and the computer program OxCal v4.2 (Bronk Ramsey 1995; 1998; 2001; 2009). The calibrated date ranges cited are quoted in the form recommended by Mook (1986), with the end points rounded outward to 10 years. The ranges in Tables RC1–4 have been calculated according to the maximum intercept method (Stuiver and Reimer 1986); the probability distributions shown in Figures 1–4 are derived from the probability method (Stuiver and Reimer 1993).

Results

Pawlett PWLT14TP1

The single relatively fresh bone dated (SUERC-58166; Table RC1) from the fill (context 10) at the base of the possible ring-ditch identified in Test Pit 1 provides a *terminus post quem* for its digging of 380–170 cal BC (95% confidence; Fig. RC1). The elevated $\delta^{15}N$ of the sample suggested the animal consumed coastal and salt-marsh plants (Britton *et al* 2008).

Age-depth modelling

The age-depth models shown in Figures RC5 and 7–8 were derived from Bacon (Blaauw and Christen 2011) using IntCal13 (Reimer *et al* 2013). Bacon is Bayesian age-depth modelling software used to reconstruct accumulation histories for deposits by combining radiocarbon dates with prior information – other Bayesian age-depth software includes Bchron (Haslett and Parnell 2008), Bpeat (Blauuw and Christen 2005, and OxCal (Bronk Ramsey 2008; Bronk Ramsey and Lee 2013). Parnell *et al* (2011) provides information on the background, workings, and results obtained from OxCal, Bchron, and Bpeat, and Blaauw and Christen (2011) provide a comparison of the output from Bacon, OxCal, and Bchron.

All age-depth models produce estimates of accumulation rates. The simple connection of the mid-points of dated levels using linear sections (Blaauw, 2010), for example assumes linear accumulation between each dated level, and that changes in accumulation rate took place abruptly and exactly at the dated depths. Prior information in the form of assumptions about the accumulation rate of a deposit and its variability over time are taken into account explicitly in Bacon. Thus information on the expected deposition time for a region can be defined (Goring *et al* 2012).

Pawlett PWLT14BH19

Objectives

The main objective for dating samples from BH19 were to establish the timing, and accumulation rates, of the lower local organic formation to enable age-depth modelling of part of the local stratigraphic sequence. The chronology will be used with pollen, diatom and plant macro analysis to better inform our understanding of the timing of local early to mid-Holocene environmental changes, and how they compared to changes at other sites within the Bridgewater Bay region (eg Walpole).

Radiocarbon samples

Five samples, four single *Phragmites* macrofossils and a 'bulk' peat sample were submitted for dating (Table RC2). One of the duplicate *Phragmites* samples from 0.81m OD [GU36308] failed due to producing insufficient carbon during pretreatment. Measurements on the humic and humin fractions of the peat sample from 0.87–0.86m OD are statistically consistent (T'=3.8; T'(5%)=3.8; v=1; Ward and Wilson 1978) and a weighted mean (5261±22 BP) has been taken as providing the best estimate for the age of the deposit.

Age-depth model

The accumulation rate prior consists of a gamma distribution (Fig RC5, left panel), that is much like a normal/Gaussian distribution but is often asymmetric and always positive - we can assume that deposits did not accumulate backwards in time! The accumulation rate mean prior is defined at a mean of 20 yr/cm, and the section thickness at 1.5cm.

The posterior for the memory indicates that our prior belief of a high correlation between peat accumulation at a distance of 1cm (approximately equivalent to 20 years) is not entirely accurate. The lower correlation (compare the prior and posterior in Fig RC5 (right) possibly suggests a higher than expected variability. On the other hand, the average distribution of all accumulation rates is quite similar to the (prior) distribution). This means that the prior is sufficiently strong and the likelihood (data) does not provide further information on accumulation rates.

The age-depth model (Fig RC5) estimates that the Lower Peat [0.76m OD] started to accumulate in *6460–6055 cal BP* (*95% probability*) and ended in 6110–5925 cal BP (*95% probability*). The plot (Fig RC6) of accu-

mulation rate (yr/cm) shows a relatively uniform rate for peat deposition.

Stolford core [ST14ES01]

Sampling and objectives

Five samples, four single *Phragmites* macrofossils and a 'bulk' peat sample were submitted for dating (Table RC3) from STFD14 Environmental sample 1, a monolith that was extracted from a peat exposure identified *c* 0.92km offshore at Stolford. The monolith was taken from a vertical section of a small pit that was excavated into the peat outcrop, and demonstrated that the offshore peat shelf was overlying some silty clays Age-depth modelling will provide a useful comparison to the timing of peat development at other locations within the local foreshore and samples taken from the regressive contact will complement pollen, diatom and plant macrofossil analysis, thus providing temporal information relating to changes in the local vegetative environment.

The *Phragmites* samples from −5.36m OD [GU36302] failed to produce sufficient carbon during pretreatment. Measurements on the humic and humin fractions of the peat sample (UBA-27979 and UBA-27980) [−5.39m OD are statistically consistent (T'=0.0; T'(5%)=3.8; v=1; Ward and Wilson 1978) but inconsistent with a single fragment (UBA-27978) of horizontally bedded *Phragmites* (T'=11.1; T'(5%)=6.0; v=2). Given that the *Phragmites* fragment might be expected to be the youngest constituent part of the 1cm slice of peat from this depth then this discrepancy is not unexpected and as such a weighted mean of all three determinations has been calculated as providing the best estimate for the age of deposit (7065±31 BP).

Age-depth model

The accumulation rate mean prior for the model was defined at a mean of 10 yr/cm, and the section thickness at 1.5cm (Fig RC7, middle)

The posterior for the memory indicates that our prior belief of a high correlation between peat accumulation at a distance of 1cm (approximately equivalent to 10 years) is not entirely accurate. The lower correlation (compare the prior and posterior in Fig RC7 (right)) possibly suggests a higher than expected variability. On the other hand, the average distribution of all accumulation rates is quite similar to the (prior) distribution (Fig RC7 (centre). This means that the prior is sufficiently strong and the likelihood (data) does not provide further information on accumulation rates.

The age-depth model (Fig RC7) estimates that the start of peat accumulation (equivalent to a *terminus ante quem* for the regressive contact [−5.39m OD] dates to *8030–7820 cal BP* (*95% probability*). Peat accumulation ended in *7875–7730 cal BP* (*95% probability).*

Stolford STFD14ES03

Sampling and objectives

Six radiocarbon determinations (Table RC4) were obtained on single identifiable macrosfossils (Phragmites, hazenults and an acorn) from STFD14 Environmental sample 3 (STFD14ES3). The sample was collected from a natural section exposed between some mudflats, *c* 0.3km offshore.

Age-depth modelling of this short 24cm sequence would it is hoped provide a useful comparison to the timing of peat development at other locations within the local foreshore and together with pollen, diatom and plant macrofossil analysis, provide additional information regarding the timing of particular environmental changes that occurred in the local area.

Age-depth model

The accumulation rate mean prior for the model was defined at a mean of 20 yr/cm, and the section thickness at 1.5cm (Fig RC8, middle)

The posterior for the memory indicates that our prior belief of a high correlation between peat accumulation at a distance of 1cm (approximately equivalent to 20 years) is not entirely accurate. The lower correlation (compare the prior and posterior in Fig RC8 (right)) possibly suggests a higher than expected variability. On the other hand, the average distribution of all accumulation rates is quite similar to the (prior) distribution (Fig RC8 (centre). This means that the prior is sufficiently strong and the likelihood (data) does not provide further information on accumulation rates.

The age-depth model (Fig RC8) estimates that the start of peat accumulation (−2.66m OD) dates to *7455–7002 cal BP* (*95% probability*). Peat accumulation ended in *6825–6615 cal BP* (*95% probability)* at −2.42m OD.

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Figures

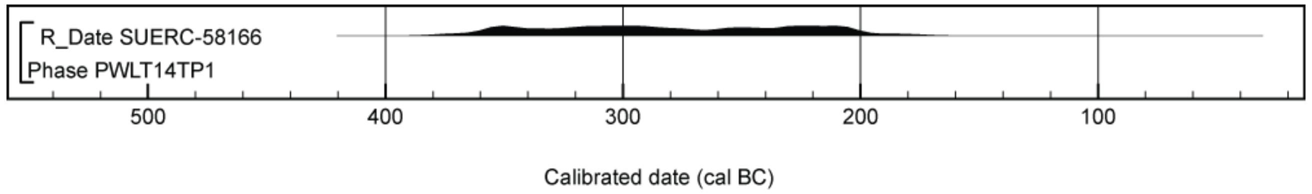

Figure RC1: Probability distributions of date from Pawlett. The distribution is the result of simple radiocarbon calibration (Stuiver and Reimer 1993)

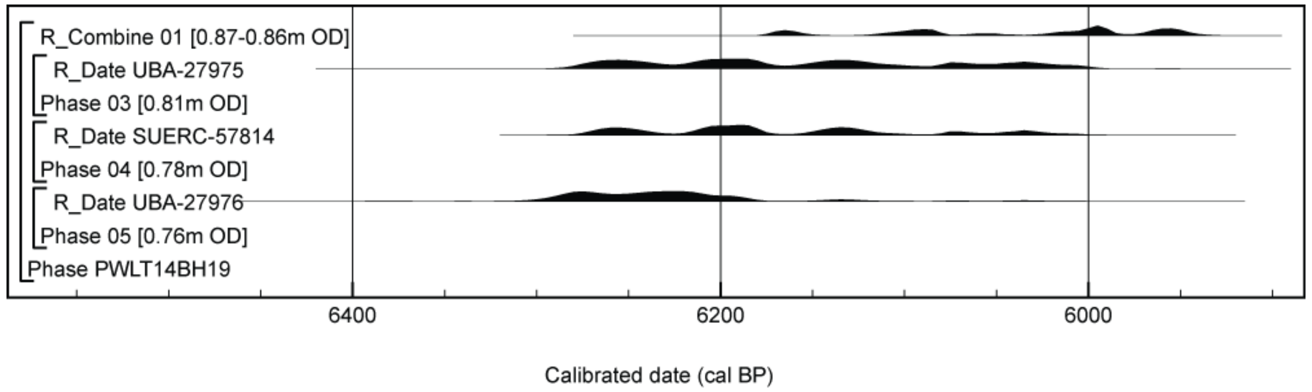

Figure RC2: Probability distributions of dates from Pawlett (PWLT14BH19). The distributions are the result of simple radiocarbon calibration (Stuiver and Reimer 1993)

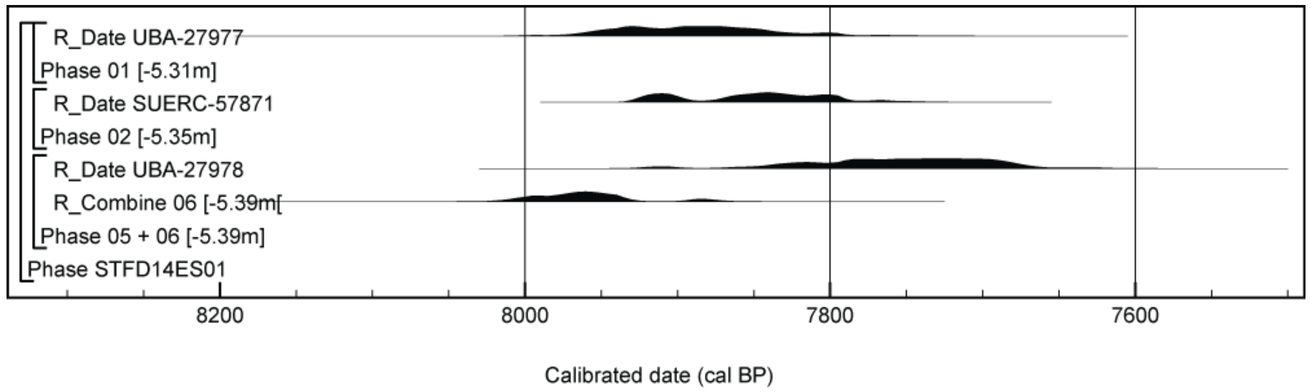

Figure RC3: Probability distributions of dates from Stolford (STFD14ES01). The distributions are the result of simple radiocarbon calibration (Stuiver and Reimer 1993)

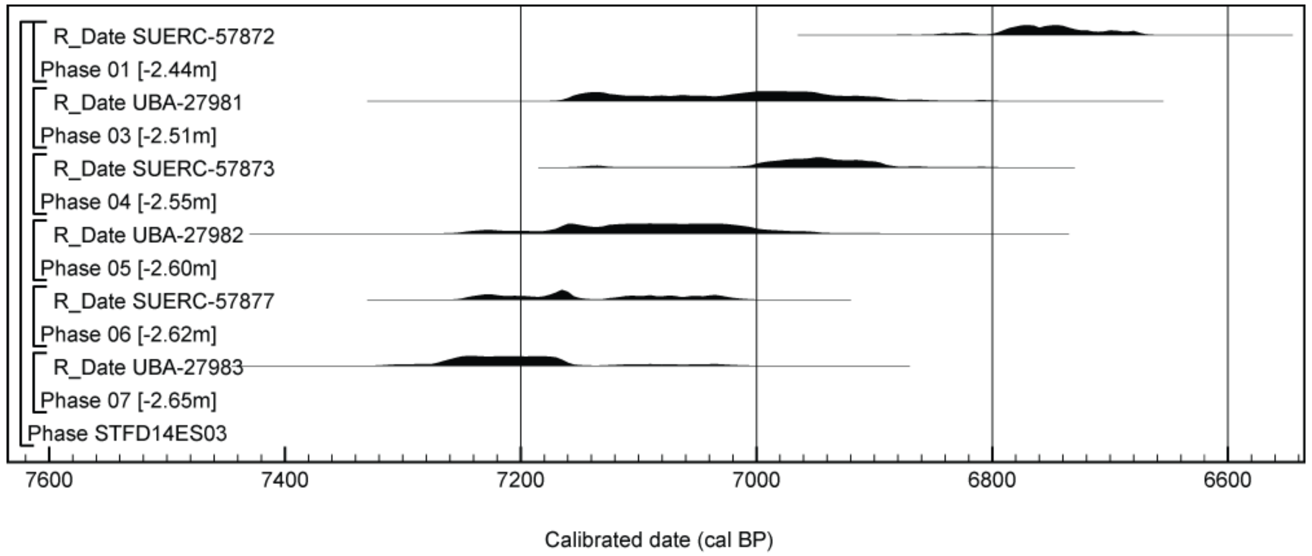

Figure RC4: Probability distributions of dates from Stolford (STFD14ES03). The distributions are the result of simple radiocarbon calibration (Stuiver and Reimer 1993)

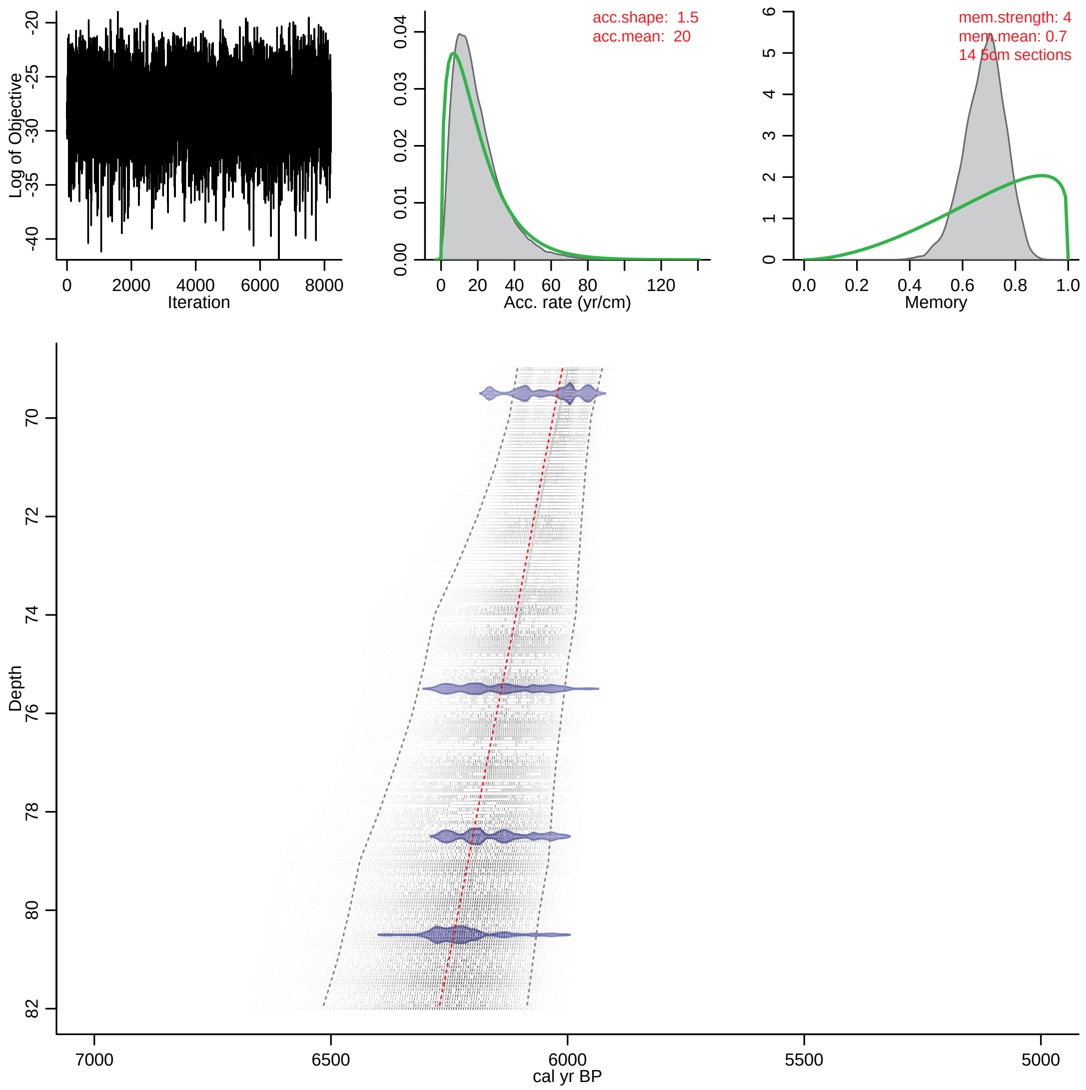

Figure RC5: Age-depth model for the Pawlett core [PWLT14BH19] – 69–82cm based on Bacon (Blauuw and Christen 2011). The upper three panels depict the MCMC iterations (top – left panel; a stationary distribution with little structure among neighbouring iterations = good run), the prior (green curve) and posterior (grey histogram) distributions for the accumulation rate (top - middle panel) and the prior (green curve) and posterior (grey histogram) distributions for memory (top - right panel). The main bottom panel shows the calibrated radiocarbon dates (transparent blue) and the age-depth model (darker greys indicate more likely calendar ages; grey stippled lines show 95% confidence intervals and the red curve shows the single 'best' model) based on the weighted mean age for each depth

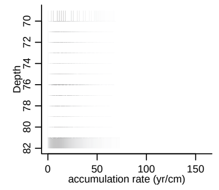

Figure RC6: Plot showing accumulation rate (yr/cm) through the Lower Peat in Pawlett core [PWLT-14BH19] – derived from the age-depth model

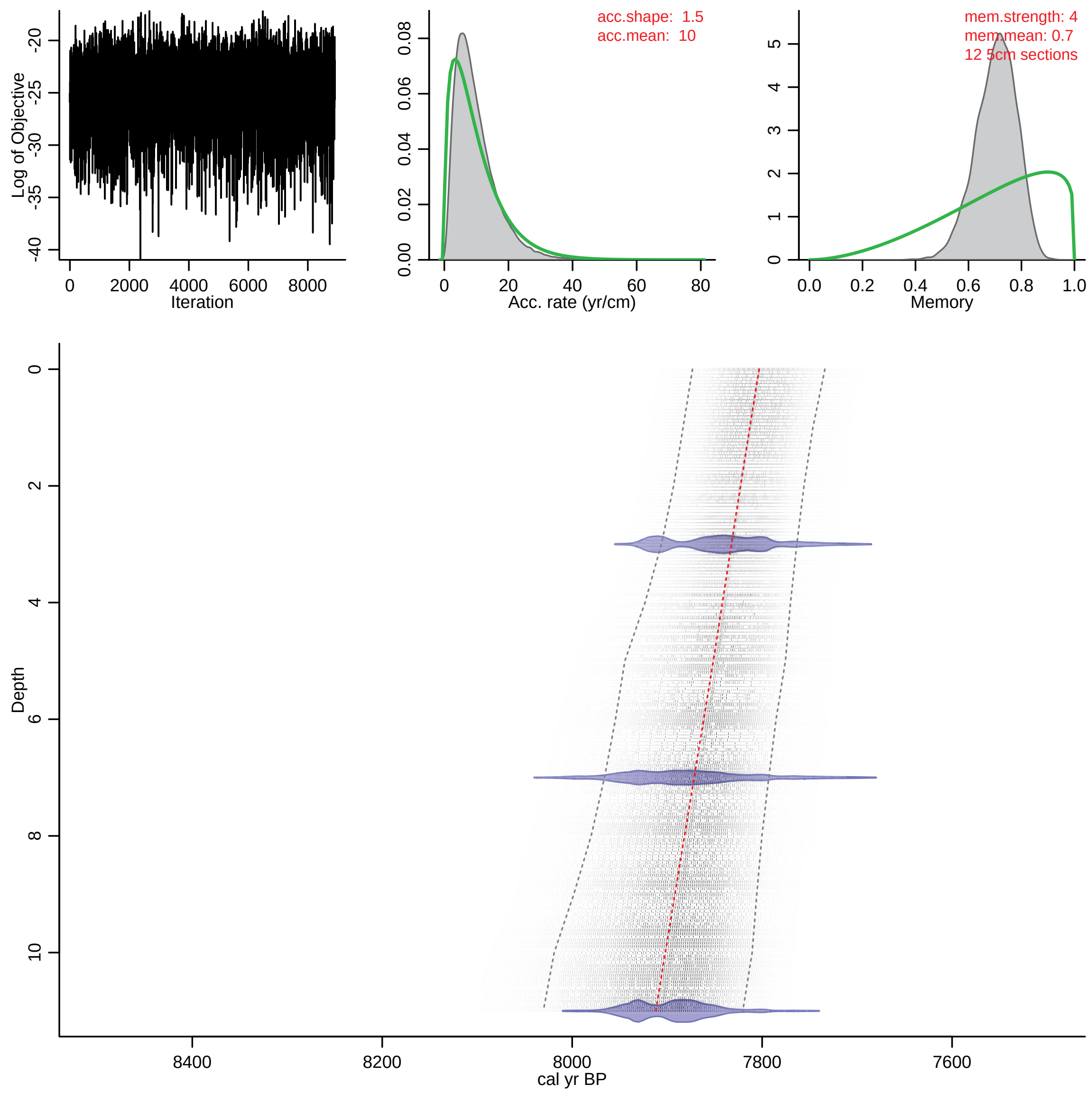

Figure RC7: Age-depth model for the Stolford core [ST14ES01] - 0–11cm based on Bacon (Blauuw and Christen 2011). The format is identical to Figure RC1

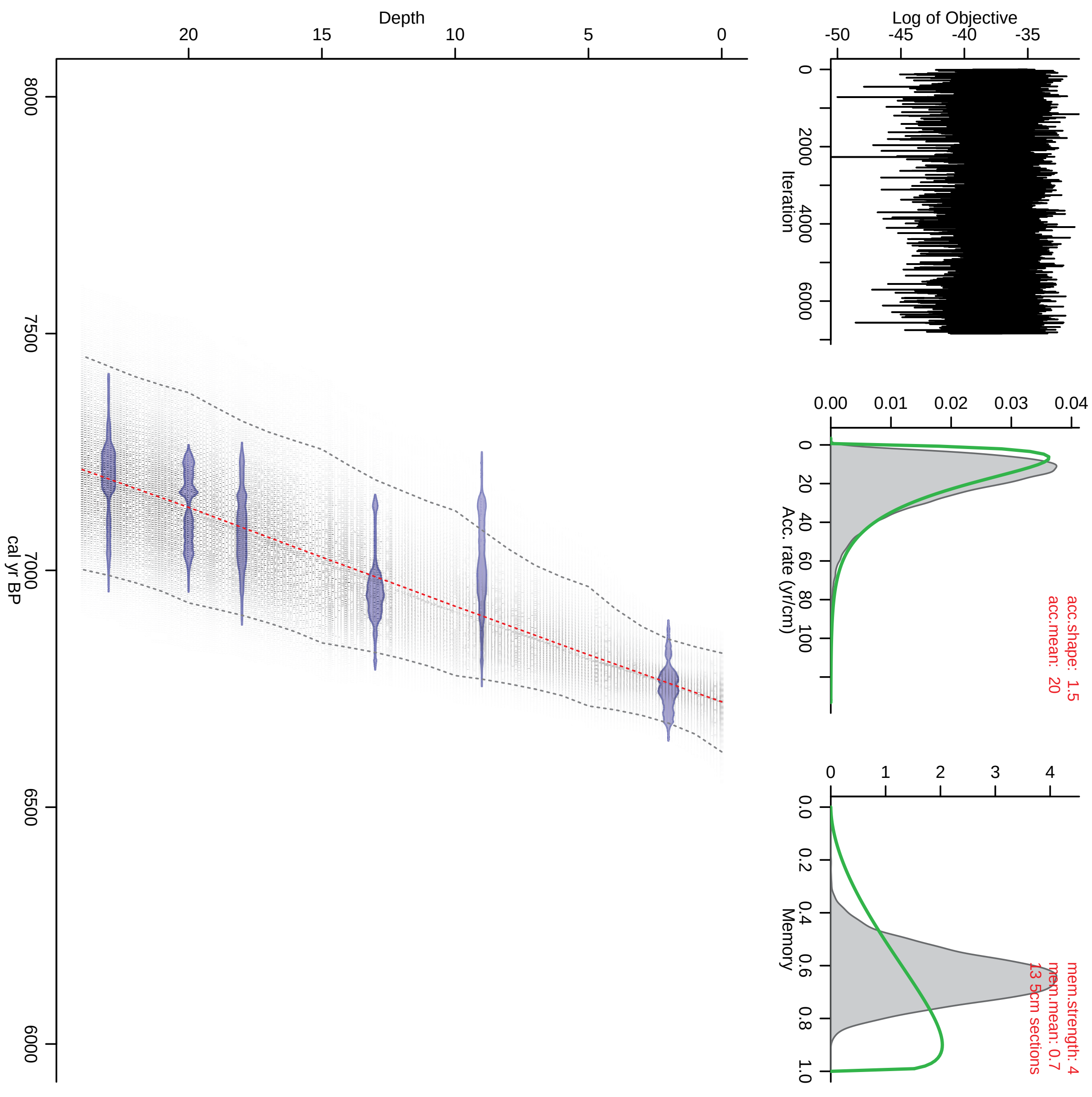

Figure RC8: Age-depth model for the Stolford core [ST14ES03] - 0–22cm based on Bacon (Blauuw and Christen 2011). The format is identical to Figure RC1

Table RC1: Pawlett

Lab Number	Material	Context	Radiocarbon Age (BP)	δ¹³C (‰)	δ¹⁵N (‰)	C:N	Calibrated date range (95% confidence)
SUERC-58166	Animal bone, *Bos*? sp., proximal end of left tibia	From the fill (context 10) of the possible ring-ditch, found within a distinct context at the base of the feature	2204±31	−21.4	7.2	3.3	380–170 cal BC

Table RC2: Pawlett PWLT14BH19

Laboratory Number	Sample reference	Material	Radiocarbon Age (BP)	δ¹³C (‰)	Calibrated Date (95% confidence) – cal BP
SUERC-57809	01 - [0.87–0.86m OD]	Peat, humic acid	5219±30	−29.0	
SUERC-57810	01 - [0.87–0.86m OD]	Peat, humin	5302±30	−29.2	
		T'=3.8; T'(5%)=3.8; v=1	5261±22		6180–5940
GU36308	03 – [0.81m OD] sample A	*Phragmites* (single fragment) horizontally bedded – 100mg	Failed insufficient carbon		
UBA-27975	03 – [0.81m OD] sample B	*Phragmites* (four fragments, ?originally one), horizontally bedded – 100mg	5368±47	−27.9	6290–5990
SUERC-57814	04 – [0.78m OD]	*Phragmites* (horizontally bedded one fragment – 400mg	5367±30	−25.1	6280–6010
UBA-27976	05 – [0.76m OD]	*Phragmites*, (single fragment) horizontally bedded – 228mg	5431±45	−28.1	6310–6120

Table RC3: *Stolford STFD14ES01*

Laboratory Number	Sample reference	Material	Radiocarbon Age (BP)	δ^{13}C (‰)	Calibrated Date (95% confidence) – cal BP
SUERC-57871	01 – [−5.31m OD]	*Phragmites* leaf (horizontally bedded) (single fragment), 190mg	7002±29	−28.6	7940–7750
UBA-27977	02 – [−5.35m OD]	*Phragmites* leaf (single fragment) horizontally bedded, 105mg	7059±52	−28.1	7980–7780
GU36302	03 – [−5.36m OD]	*Phragmites* leaf (single fragment), horizontally bedded, 119mg	Failed: insufficient carbon	–	
UBA-27978	05 – [−5.39m OD]	*Phragmites* (single fragment), horizontally bedded, 129mg	6918±53	−29.5	7920–7660
UBA-27979	06 – [−5.39m OD]	Peat, humic acid	7139±53	−28.2	
UBA-27980	06 – [−5.39m OD]	Peat, humin	7132±53	−28.3	
		T'=0.0; T'(5%)=3.8; v=1	7136±38	–	8020–7870

Table RC4: Stolford STFD14ES03

Laboratory Number	Sample reference	Material	Radiocarbon Age (BP)	δ^{13}C (‰)	Calibrated Date (95% confidence) – cal BP
SUERC-57872	01 [−2.44m OD]	*Corylus avellana* nut	5931±27	−29	6850–6670
UBA-27981	03 [−2.51m OD]	*Quercus* acorn	6120±50	−30.4	7170–6860
SUERC-57873	04 [−2.55m OD]	*Corylus avellana* nut	6086±27	−26.6	7150–6880
UBA-27982	05 [−2.6m OD]	*Phragmites* (single fragment), horizontally bedded, 126mg	6190±47	−28.7	7250–6950
SUERC-57877	06 [−2.62m OD]	*Phragmites*, single fragment, horizontally bedded, 252mg	6225±28	−27.9	7250–7010
UBA-27983	07 [−2.65m OD]	*Phragmites*, single fragment, horizontally bedded, 173mg	6278±48	−27.3	7310–7220

Appendix 3
Radiocarbon dates from the study area

Please see attached electronic MS Excel (.xls) file.

Appendix 4
Diatom assessment of samples from three sediment sequences taken in the Somerset Levels

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Introduction

Sites on the western edge of the Somerset Levels were sampled during the summer of 2014. Three stratified sequences have been subsampled for diatom assessment to determine their potential for full diatom analysis. The samples were taken across alluvium-peat transgressive / regressive contacts

The purpose of carrying out a diatom assessment is to evaluate the presence or absence of diatoms and the potential of the sediments for further diatom analysis. The diatom assessment of each sample takes into account the numbers of diatoms, the state of preservation of the diatom assemblages, species diversity and diatom species environmental preferences.

Methods

Diatom preparation followed standard techniques (Battarbee *et al.* 2001). Two coverslips were made from each sample and fixed in Naphrax for diatom microscopy. A large area of the coverslips on each slide was scanned for diatoms at magnifications of x400 and x1000 under phase contrast illumination.

Diatom floras and taxonomic publications were consulted to assist with diatom identification; these include Hendey (1964), Werff & Huls (1957-1974), Hartley et al. (1996), Krammer & Lange-Bertalot (1986-1991) and Witkowski *et al.* (2000). Diatom species' salinity preferences are indicated using the halobian groups of Hustedt (1953, 1957: 199), these salinity groups are summarised as follows:

1. Polyhalobian: >30 g l-1

2. Mesohalobian: 0.2-30 g l-1

3. Oligohalobian - Halophilous: optimum in slightly brackish water

4. Oligohalobian - Indifferent: optimum in freshwater but tolerant of slightly brackish water

5. Halophobous: exclusively freshwater

6. Unknown: taxa of unknown salinity preference.

Results & Discussion

The laboratory diatom subsample numbers with corresponding borehole or sample numbers and sample elevations are shown in Table 1. The results of the diatom evaluation for the three sediment sequences are summarised in Table 2 and diatom species data are presented in Table 3 (Excel file attached).

Table 1. Samples selected for diatom evaluation from three sediment sequences in the Somerset Levels.

Series code	(base) elevation mODN	Notes	Diatom Sample
PWLT14BH19	0.91	(1cm interval)	D1
PWLT14BH19	0.89	(1cm interval)	D2
PWLT14BH19	0.87	(1cm interval)	D3
PWLT14BH19	0.85	(1cm interval)	D4
PWLT14BH19	0.83	(1cm interval)	D5
PWLT14BH19	0.81	(1cm interval)	D6
PWLT14BH19	0.79	(1cm interval)	D7
PWLT14BH19	0.77	(1cm interval)	D8
PWLT14BH19	0.75	(1cm interval)	D9
PWLT14BH19	0.73	(1cm interval)	D10
PWLT14BH19	0.72	(1cm interval)	D11
STFD14ES1	-5.28	(1cm interval)	D12
STFD14ES1	-5.38	(1cm interval)	D13
STFD14ES1	-5.39	(1cm interval)	D14
STFD14ES1	-5.40	(1cm interval)	D15
STFD14ES1	-5.41	(1cm interval)	D16
STFD14ES1	-5.42	(1cm interval)	D17
STFD14ES1	-5.43	(1cm interval)	D18
STFD14ES3	-2.63	(1cm interval)	D19
STFD14ES3	-2.64	(1cm interval)	D20
STFD14ES3	-2.65	(1cm interval)	D21
STFD14ES3	-2.66	(1cm interval)	D22

Table 2. Summary of diatom evaluation results for Somerset Levels sites (+ present; - absent; mod moderate; ex extremely; bk brackish; mar marine; fw freshwater; aero aerophilous; hal halophilous; pk planktonic)

Diatom Sample No.	Diatoms	Diatom Numbers	Quality of Preservation	Diversity	Assemblage type	Potential for % count
D1	+	v low	v poor	low/mod	bk mar (fw)	some/low
D2	+	v low	v poor	low/mod	bk mar (fw)	some/low
D3	+	v low	v poor	low/mod	bk mar (fw)	some/low
D4	+	v low	v poor	low	bk mar (fw)	low
D5	+	v low	v poor	mod	bk fw mar	low
D6	-	-	-	-	-	none
D7	+	ex low	v poor	low	bk mar (fw)	none
D8	+	ex low	v poor	one sp.	bk mar	none
D9	+	ex low	ex poor	v low	bk mar (fw)	none
D10	+	ex low	ex poor	low	mar bk fw aero	none
D11	+	v low	v poor	low/mod	mar bk fw aero	low
D12	+	v low	v poor	low/mod	mar (bk)	low
D13	-	-	-	-	-	none
D14	-	-	-	-	-	none
D15	+	ex low	ex poor	one sp.	fw aero	none
D16	+	ex low	ex poor	two sp.	fw aero	none
D17	+	ex low	ex poor	two sp.	fw aero epiphyte	none
D18	+	ex low	ex poor	one sp.	fw	none
D19	+	ex low	ex poor	low	bk mar fw aero	none
D20	+	v low	v poor	low	mar bk	low
D21	+	v low	v poor	low	mar bk	low
D22	+	v low	v poor	low	mar bk	low

PWLT14 BH19 (Diatom Samples D1-D11)

Eleven samples were assessed for diatoms from the BH19 sequence. Diatoms were found in ten samples and are absent from one sample.

However, the diatom assemblages are very poorly preserved throughout BH19. The number of diatoms recovered from the BH19 samples is very low and the quality of diatom valve preservation is very poor. There is no potential or only low potential for further diatom analysis of the lower sediments, samples D11 to D4 (0.72 m OD to 0.85 m OD), and there is only some or low potential for analysis of the top three samples D3-D1(0.87 m OD to 0.91 m OD). Nevertheless some useful palaeoenvironmental information may be derived from the diatom assemblages that were assessed here.

The ten diatomaceous samples contain brackish water and marine diatoms that throughout the sequence are indicative of contact with tidal waters. Polyhalobous, marine diatoms appear to be most abundant in the top samples D5-D1 that were taken from organic silty clay with *Phragmites*. The coastal planktonic diatom *Paralia sulcata* is relatively abundant in the top five samples, and is also present in samples lower down the sequence (D7, D9-D11). Other polyhalobous taxa present, particularly in the top of the core, are *Podosira stelligera, Cymatosira belgica, Campylosira cymbelliformis, Rhaphoneis surirella* and *Trachyneis aspera*.

Mesohalobous diatoms, notably the brackish marine species *Nitzschia navicularis*, are also common in the top five samples. This benthic diatom is associated with mud surface habitats in tidal environments. Other benthic mesohalobous diatoms found in the top part of BH19 are *Nitzschia punctata, Diploneis interrupta, Diploneis aestuari* and *Diploneis didyma*.

Oligohalobous indifferent and halophilous (e.g. *Navicula cincta* and *Rhoicosphaenia curvata*) taxa are also present in samples D5-D1. The oligohalobous indifferent diatoms include *Fragilaria brevistriata, Fragilaria construens* var. *venter* and *Fragilaria pinnata*. These taxa have growth optima in freshwater, but have broad salinity tolerances. The two bottom samples (D11 and D10) contain more aerophilous, desiccation-tolerant, diatoms. These aerophilous diatom species include *Navicula cincta, Navicula mutica, Hantzschia amphioxys* and *Nitzschia terrestris*. These diatoms may, for example, reflect the inwash of terrestrial material or an ephemeral aquatic habitat that was prone to drying out.

STFD14 ES1 (Diatom Samples D12-D18)

Seven samples were assessed for diatoms from the ES1 sequence. Diatoms are present in five samples. However, with the exception of the top sample the numbers of diatoms are extremely low and the quality of diatom preservation is extremely poor with only one or two valve fragments found in most of these samples. There is therefore no potential for diatom analysis of six samples and low potential for diatom analysis of the top sample (D12) from ES1.

The poor preservation or absence of diatom remains in this sequence, and in some other samples assessed from the three sequences from the Somerset Levels, can be attributed to taphonomic processes (Flower 1993, Ryves et al. 2001). This may be the result of diatom silica dissolution and breakage caused by factors such as extremes of sediment alkalinity or acidity, the under-saturation of sediment pore water with dissolved silica, cycles of prolonged drying and rehydration, or physical damage to diatom valves from abrasion or wave action.

Despite the poor preservation of diatom assemblages in the ES1 sequence, the diatoms present do nevertheless provide some useful palaeoenvironmental data. In the bottom section of the sequence (-5.43 m OD to -5.40 m OD), samples D18 to D15 were taken across the boundary of a silty clay merging into a peaty/silty clay with *Phragmites* remains. Although present in very low numbers, the diatom valves in these samples are consistently of freshwater and aerophilous taxa (see BH19 above). These aerophilous diatoms are *Hantzschia amphioxys, Navicula pusilla*, *Pinnularia* cf *major* and other *Pinnularia* sp. The freshwater epiphyte *Epithemia turgida* was found in Sample D17.

In the top sample of ES1 (D12, -5.28 m OD), taken from a clay peat with *Phragmites* remains, the diatom assemblage is comprised of marine and brackish water diatom taxa. The polyhalobous and polyhalobous to mesohalobous (marine, and marine-brackish) diatoms are *Paralia sulcata, Cymatosira belgica, Rhaphoneis minutissima, Rhaphoneis surirella, Actinoptychus undulatus* and *Navicula flanatica*. The mesohalobous taxa are *Cyclotella striata, Melosira moniliformis* and *Actinocyclus normanii*. With the exception of the benthic diatom *Navicula flanatica*, both the marine and brackish water diatoms in sample D12 are open water planktonic or semi-planktonic species which live in relatively deep water.

STFD14 ES3 (Diatom Samples D19-D22)

Four samples were assessed for diatoms from the ES3 sequence. Diatoms are present in all four samples, however the numbers of diatoms are very low or extremely low, the quality of preservation is very poor or extremely poor and the diversity of diatom taxa is low. Three samples have only low potential for percentage diatom counting to be carried out, and the top sample has no potential for further diatom analysis.

The bottom three samples (-2.66 m OD to -2.64 m OD) are from peat, at the base lying on a blue grey clay. The diatom assemblages are dominated by the planktonic coastal species *Paralia sulcata*, with other polyhalobous taxa including *Cymatosira belgica, Podosira stelligera* and *Rhaphoneis surirella*. The mesohalobous diatoms are mainly benthic, mud-surface diatoms and these include *Nitzschia navicularis, Nitzschia hungarica, Nitzschia punctata, Diploneis didyma* and *Diploneis interrupta*. The brackish water planktonic species *Cyclotella striata* is present in D21. Aerophilous diatoms are present in samples D20 and

D22, these diatoms are *Navicula cincta, Navicula pusilla* and *Hantzschia amphioxys*. The top sample (-2.63 m OD), also taken from peat, contains low numbers of the brackish and marine diatoms *Cyclotella striata, Nitzschia navicularis* and *Paralia sulcata*. The freshwater aerophilous diatom *Pinnularia major* is also present in sample D19.

The presence of polyhalobous and brackish-marine mesohalobous diatoms throughout the ES3 sequence indicates that the sedimentary environment was consistently under the influence of coastal water.

Conclusions

1. Diatoms were assessed from twenty-two samples taken from three sediment sequences at the Somerset Levels sites. Diatoms are present in nineteen of the samples.

2. Eleven samples were assessed for diatoms from the BH19 sequence Diatoms were found in ten samples and are absent from one sample. However, the diatom assemblages are very poorly preserved throughout BH19 and there is no potential or only low potential for further diatom analysis of the lower sediments, (0.72 m OD to 0.85 m OD); and low potential for analysis of the top three samples (0.87 m OD to 0.91 m OD). Nevertheless some useful palaeoenvironmental information was derived from these diatom assemblages. The ten diatomaceous samples contain mainly brackish water and planktonic marine diatoms that throughout the sequence are indicative of contact with tidal waters. In the top five samples benthic, brackish-marine diatoms are present. These diatoms are associated with shallow water, mud surface habitats such as mudflats and tidal creeks. The most common oligohalobous indifferent taxa found in the top samples have broad salinity tolerances. The two bottom samples contain more aerophilous diatom species which may reflect the inwash of terrestrial material or an ephemeral aquatic habitat.

3. Seven samples were assessed for diatoms from the ES1 sequence. Diatoms are present in five samples, however there is only low potential for diatom analysis of the top sample. The poor preservation or absence of diatom remains in this and the other two sequences from the Somerset Levels is attributed to taphonomic processes. Despite the poor preservation of diatom assemblages in the ES1 sequence, the diatoms present do provide some useful palaeoenvironmental data. In the bottom section of the sequence (-5.43 m OD to -5.40 m OD) across the boundary of a silty clay merging into a peaty/silty clay with *Phragmites* remains the diatom assemblages are consistently of freshwater and aerophilous taxa, with a freshwater epiphyte present at -5.42 m OD. In the top sample of ES1 (-5.28 m OD), the diatom assemblage is composed of marine and brackish water diatom taxa. With the exception of one benthic diatom, both the marine and brackish water diatoms in top sample are open water planktonic or semi-planktonic species which live in relatively deep water.

4. Diatoms are present in all four samples assessed from ES3, however as a result of poor diatom preservation, the three lower samples have low potential for percentage diatom counting and the top sample has no potential for further diatom analysis. The bottom three samples (-2.66 m OD to -2.64 m OD) are dominated by planktonic coastal species along with brackish-marine benthic, mud-surface diatoms. Aerophilous diatoms are present in two of these samples The top sample (-2.63 m OD) contains low numbers of brackish and marine diatoms and a freshwater aerophilous diatom is also present. The presence of polyhalobous and brackish-marine mesohalobous diatoms throughout the ES3 sequence indicates that the sedimentary environment was consistently under the influence of coastal water.

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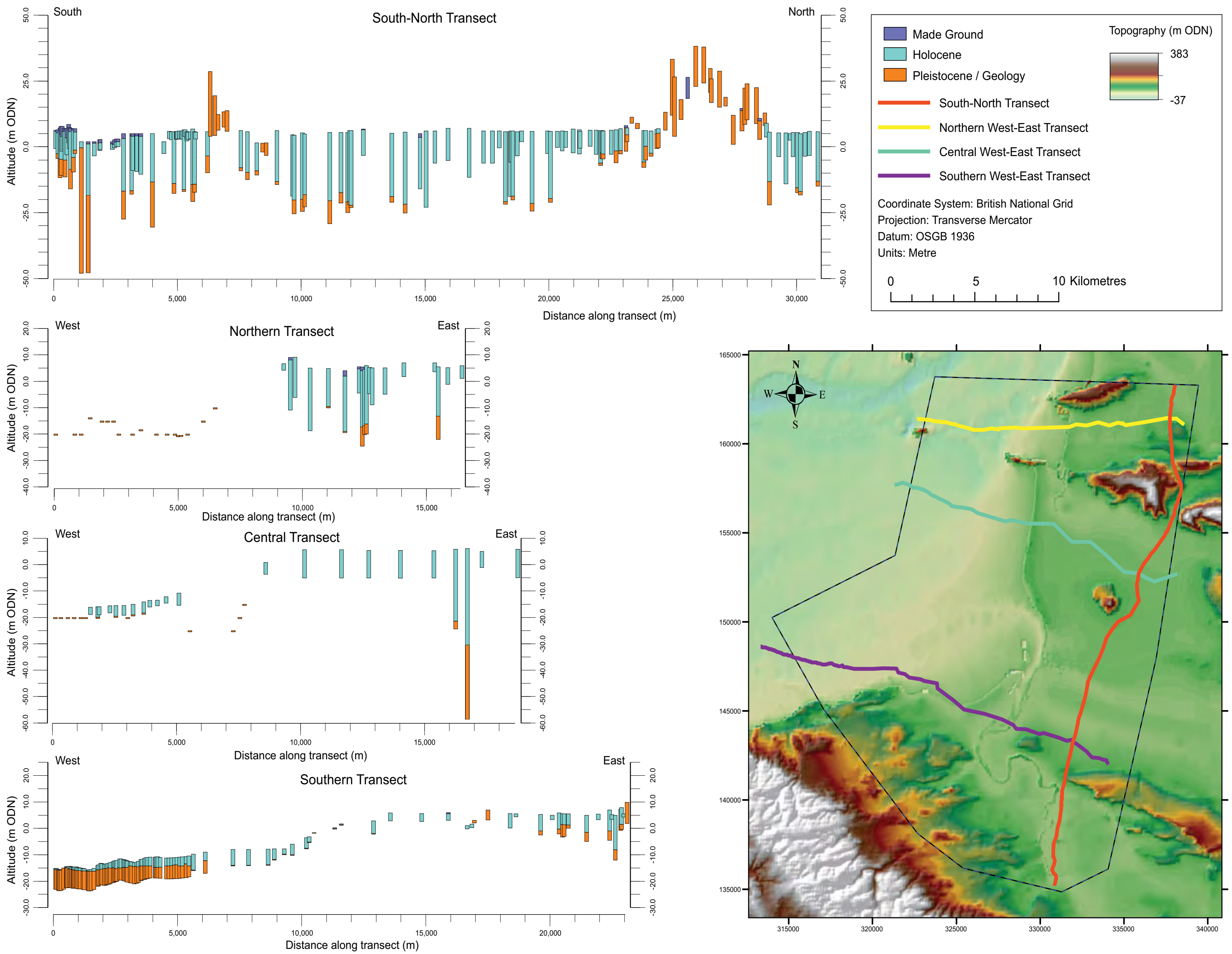

Fig: Appendix 5.1.1 Cross section of deposit model

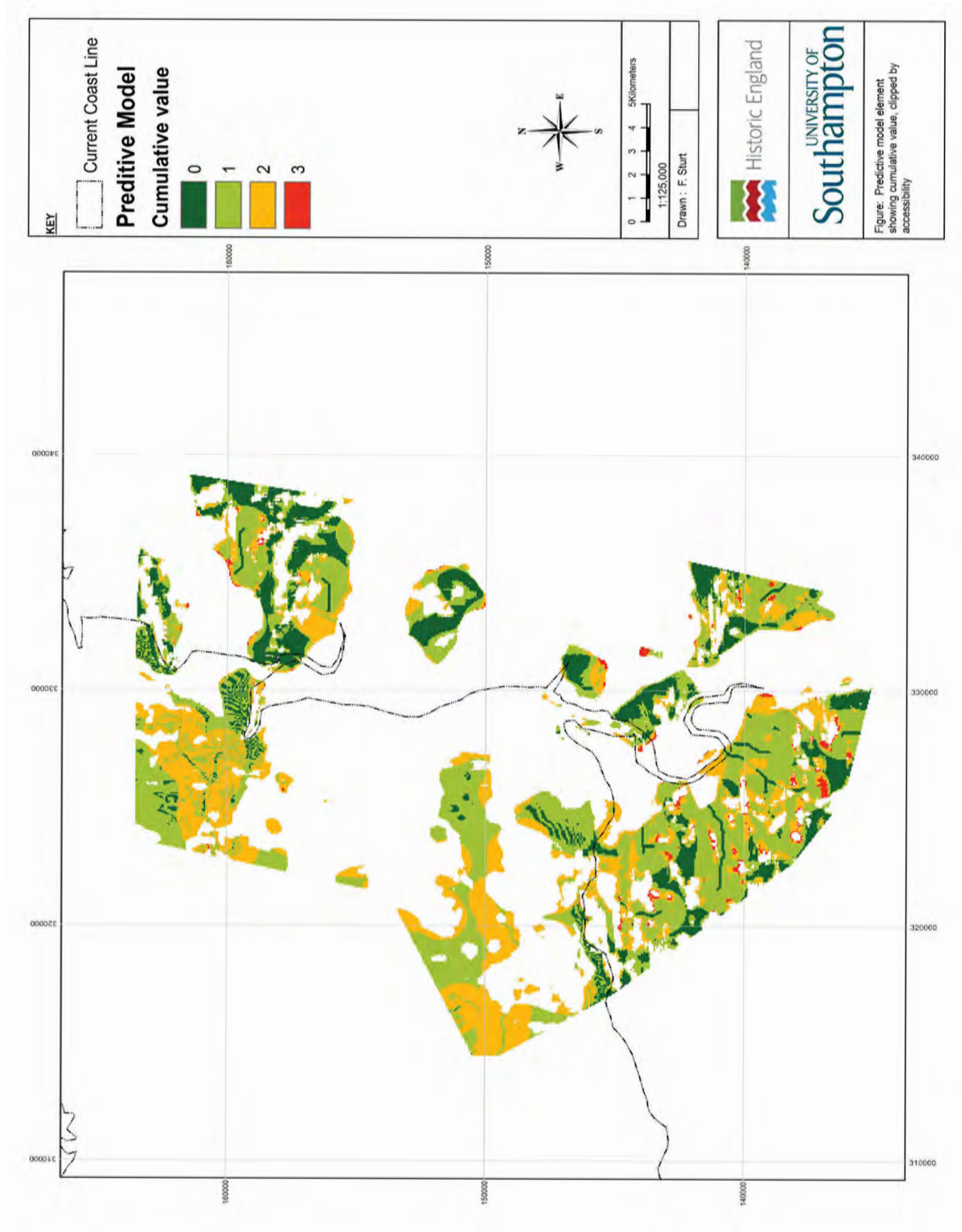

Fig: Appendix 5.1.2 Cumulative predictive model output

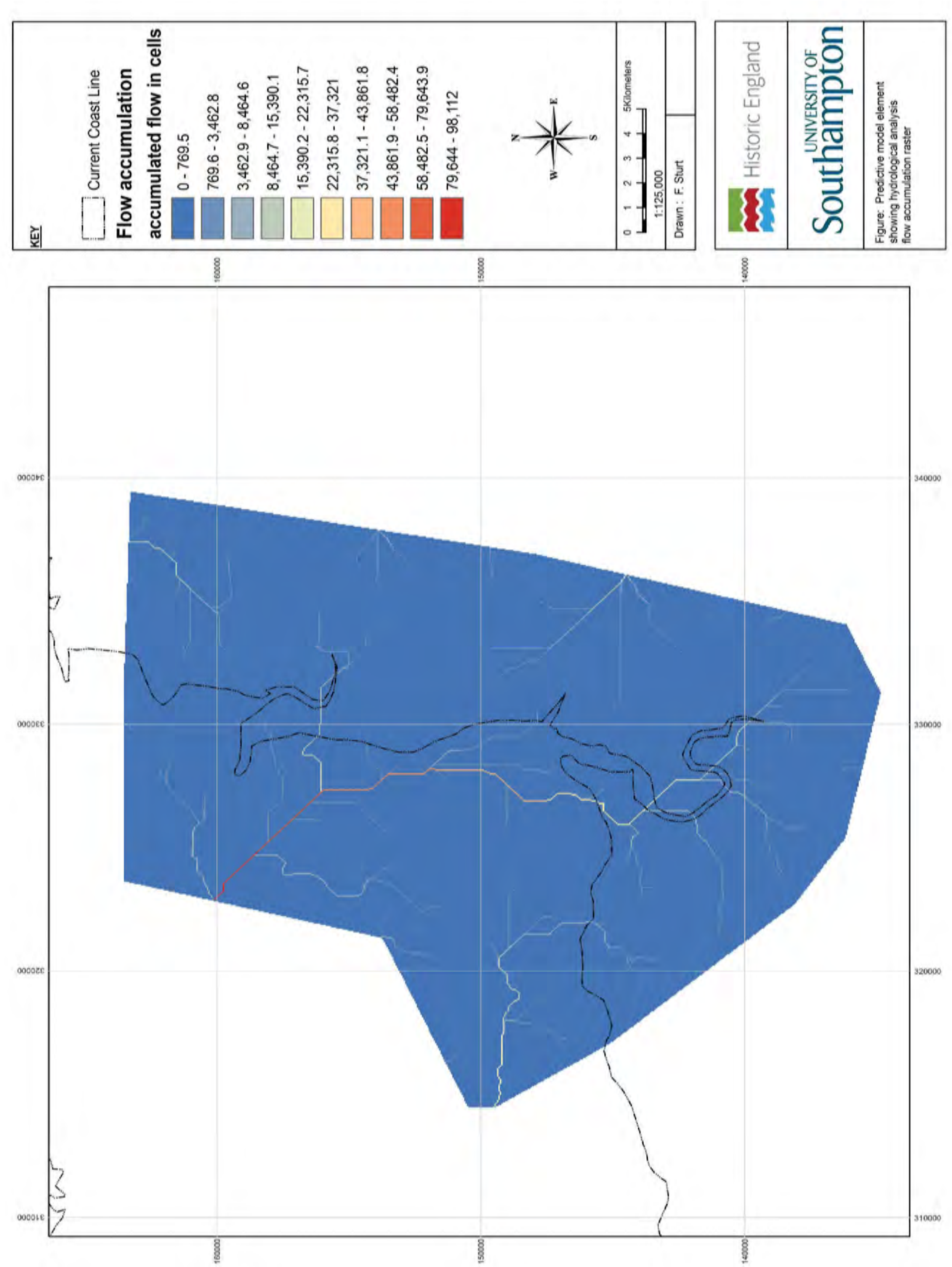

Fig: Appendix 5.1.3 Flow accumulation output

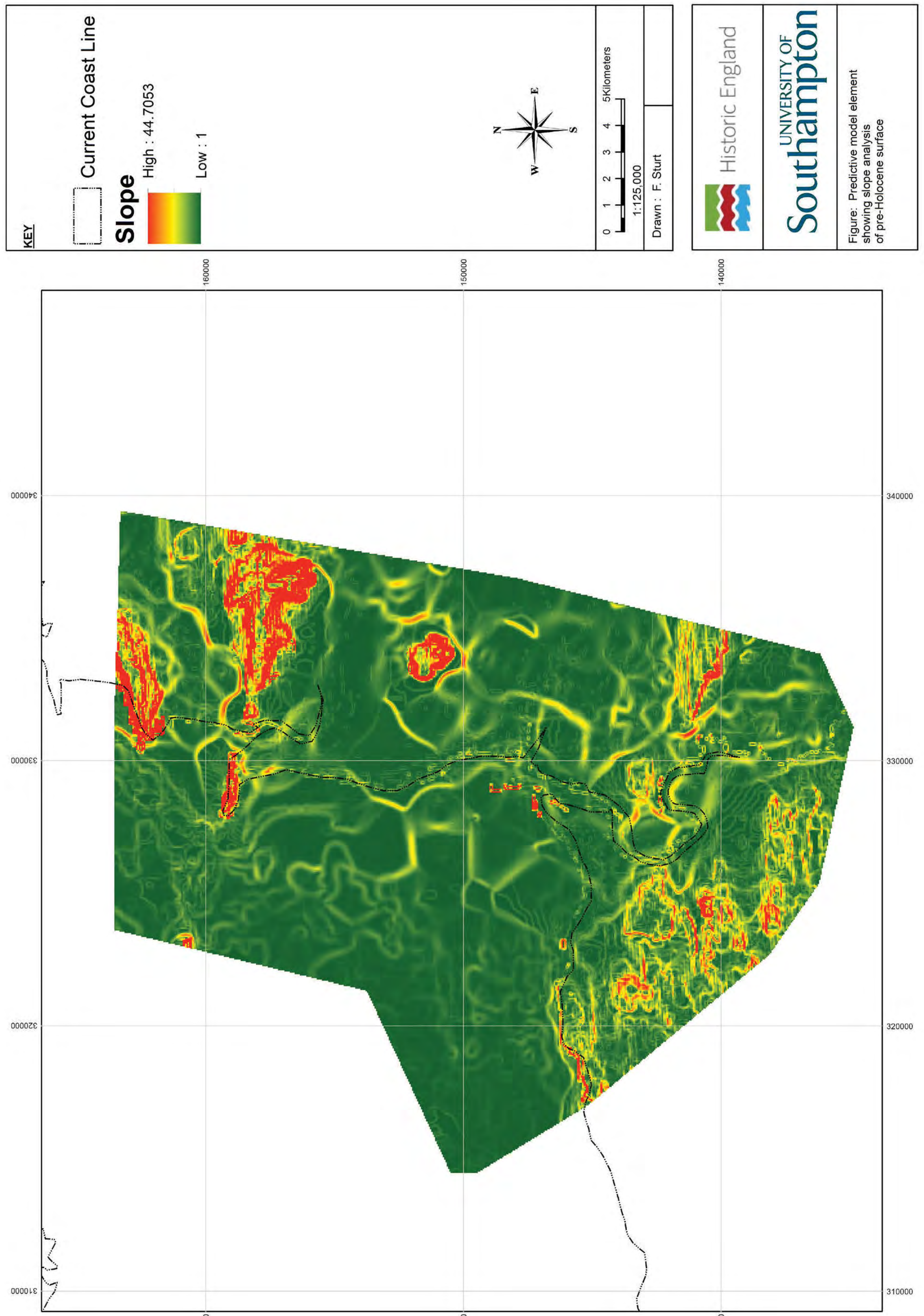

Fig: Appendix 5.1.4 Slope analysis of model area

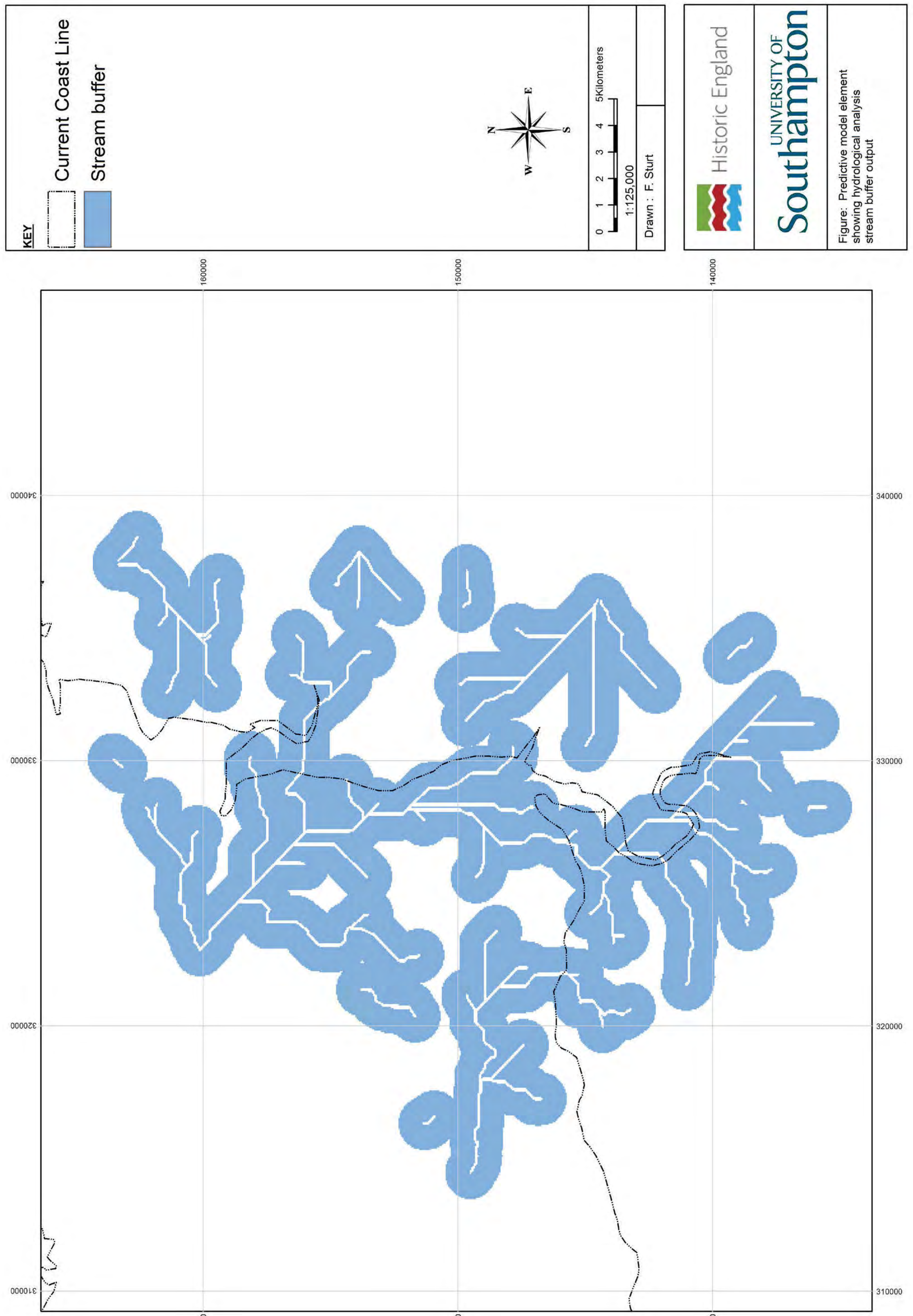

Fig: Appendix 5.1.5 Stream buffer of hydrological network (stream order)

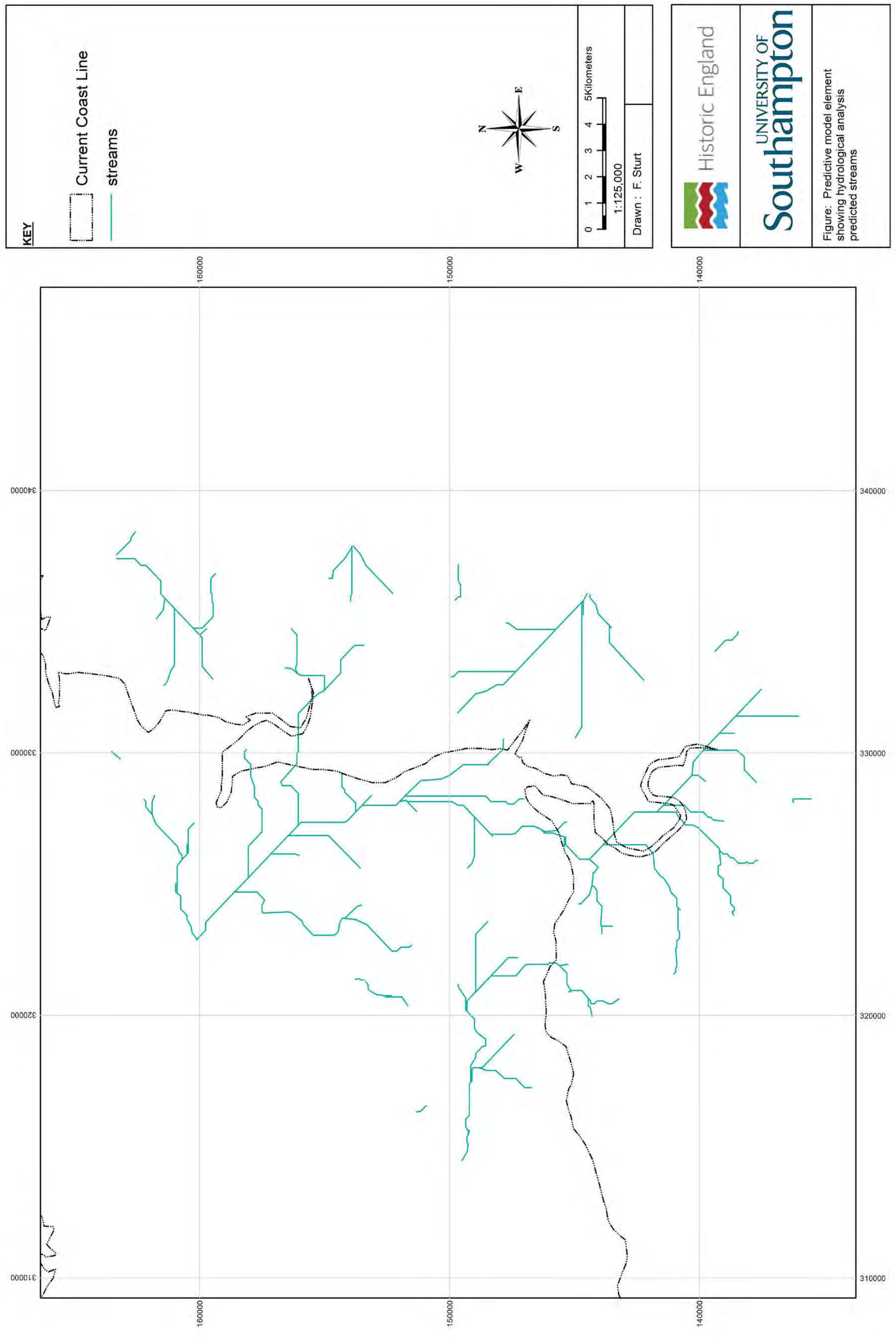

Fig: Appendix 5.1.6 Stream order network (from hydrological analysis of pre-Holocene surface)

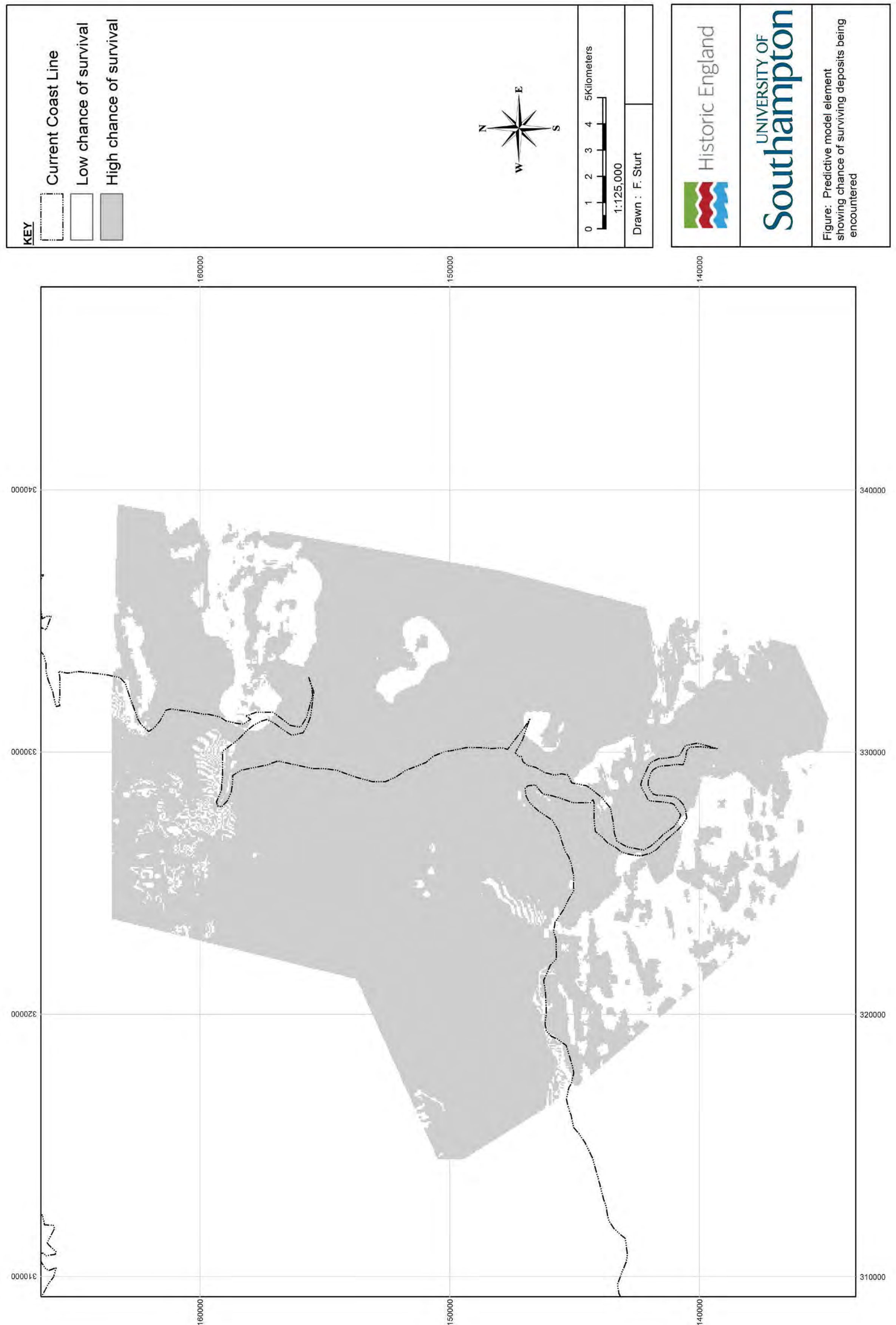

Fig: Appendix 5.1.7 Potential for surviving deposits of interest within the study area