Geological and Environmental Background

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Resource Assessment

Introduction

Environmental archaeology, together with wider aspects of archaeological science, is an integral part of archaeological research. Therefore, in this Research Framework the contribution of environmental archaeology to better understanding past economy, crafts and industry, agriculture, trade, religion, diet, population movement, exploitation of natural resources and other important issues, is dealt with in each of the period-based chapters. To a large extent the period chapters also provide the past landscape context for archaeology, describing what is known about the contemporary climate and the changing vegetation cover, sea-levels, river regimes, soils and coastlines brought about by past landscape processes and human activity. The nature of this evidence based as it often is on 'off-site' investigations (at least for the Holocene), and utilising information from non-archaeological sources is complex.

Furthermore, the way in which information is usually recovered, from sequences spanning multiple periods, is not always easy to relate to specific archaeological chronologies. Consequently, a brief overview of the environmental context of the South East is warranted here.

The purpose of this introductory chapter is to describe the physical geography of the region: the broad characteristics of the natural environment of the South East. It will set the scene for the archaeology, which is described later on, by outlining key aspects of the evolving landscape from the Palaeolithic to the present. It will summarise the geology, topography and drainage of the region and examine how these factors have influenced past landscape processes and the archaeological record. In many cases the landscape contemporary with an archaeological site was very different from its modern counterpart and we need to consider the nature of that past landscape in order to understand properly site formation, function and interactions. Understanding past landscape change will also improve understanding of the survival and taphonomy of archaeological and palaeo-environmental evidence; as well as help predict where archaeology might be found. Therefore, this chapter will provide a brief and general overview of the changing climate and environment pertinent to the South-East during the Quaternary period (approximately the last 2.6 million years). Study of these past landscapes in the South-East has shown clearly the variability in environment characteristics as well as archaeological survival, preservation and type, often between what are on the face of it similar locations. As a result, it is critical to focus on collecting and interpreting local evidence before we impose regional agendas on understanding older landscapes.

Solid Geology

The central feature of the region is the Weald (Gallois 1965; Sumbler 1996). Geomorphologically, this forms the western half of an area defined by an elongated ring of chalk hills, running anticlockwise from the north-east corner of Kent: consisting of the North Downs, the east Hampshire Downs and the South Downs. The chalk hills surround Gault and Weald Clay vales, separated by hills of Lower Greensand. At the heart of the Weald are the varied sands and clays of the Hastings Beds also forming an area of higher relief, made irregular through faulting. The Channel coastline cuts diagonally across the eastern side of the Wealden formation, creating cliffs where the Chalk and Hastings Beds face the sea. Geologically, the Weald forms an ‘unroofed anticline’, initially uplifted as a dome in the Cretaceous or Tertiary and subsequently eroded. As a result, the younger (late Cretaceous) Chalk forms the outermost hills, with outwards-facing dip slopes and inwards-facing scarps and the older bedrock outcrops in the central area (Fig. 1). Tertiary bedrock overlies the Chalk as it dips into the London Basin in the northern part of the region. In north Kent these Tertiary deposits are typically Thanet Sands and London Clay, with Barton, Bracklesham and Bagshot Beds outcropping in Surrey. Similar Tertiary deposits overlie the dip slope of South Downs in West Sussex.

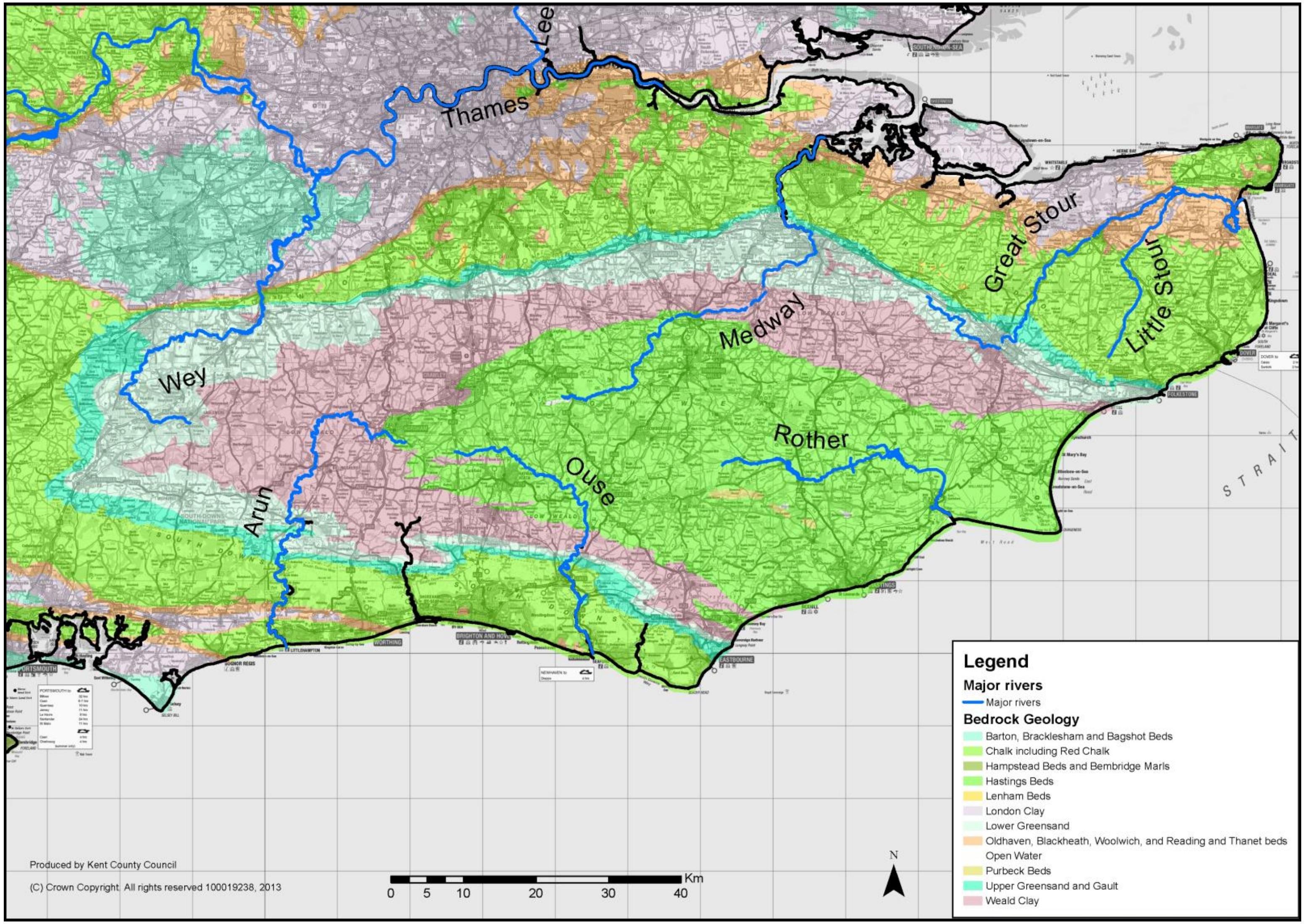

Figure 1 Solid Geology

Environmental Reconstruction

Reconstructing Pleistocene and Holocene environmental and climatic change relies on examining a range of environmental indicators (proxies) surviving in naturally as well as anthropologically accumulated deposits (Lowe and Walker 2014; Bell and Walker 2005; Ehlers et al. 2016). The data from a range of environmental proxies, together with the characteristics of the sediments themselves obtained by examination of sections, borehole cores and thin sections (soil micromorphology) begins to piece together a picture of the changing past landscape and its ecology. The modern-day ecological preferences and tolerances of each proxy is used to infer past conditions, together with evidence from the deposit sequence that shed light on how the sediments accumulated. The robustness of the reconstructions also depends on taphonomy: how the environmental indicators became incorporated into the sediment context and their state of preservation. The range of 'environmental proxies' available differs depending on survival in different situations (Historic England 2011). In waterlogged palaeochannel and fenland sequences from river valleys (e.g. Thorley 1971), as well as waterlogged locations in the Weald, evidence for environmental and climatic change during the Holocene has typically come from pollen sequences (Scaife 1987), supplemented with evidence from plant remains (and potentially insects, although these have been little studied to date in the South-East). Land snails have typically been used to infer past environment change from interspersed colluvium and buried soils from calcareous dry valley sequences on the chalk (Thomas 1982; Bell 1983; Wilkinson 2003; Allen 2017), where charred wood and plant remains could also be preserved. For Pleistocene sequences the presence of chalk across large parts of the south-east means that environmental reconstructions are often based on mammalian remains along with ostracods, molluscs, fish and rodent remains (Wenban-Smith 2013; Bates et al. 2000, 2010, 2017). Where sequences are devoid of palaeo-environmental material, for example in the fluvial sediments in the Weald, reconstructing palaeoenvironments is more difficult.

In the Holocene coastal marshlands evidence from foraminifera and diatoms can help interpret changes from estuarine to freshwater dominated environments, together with pollen, molluscs and plant remains (for example on Walland Marsh, Waller et al. 1998; Chichester Harbour, Mills et al. 2007 and in the Medway Estuary, Bates et al. 2017, Hazell 2011). Pleistocene marine sediments are typically restricted to the West Sussex Coastal Plain (Bates et al. 1997, 2010) and their interpretation has primarily involved examination of the contained ostracods and foraminifera. Pleistocene estuarine sequences exist in the Thames (Bridgland 1994) and Medway systems (Bates et al. 2017) and help to integrate the on- and offshore records (see below).

There are no hard and fast rules about preservation, however. Although bone and mollusc preservation might be expected to be good on the calcareous Chalk, but poor on the more acidic soils of the Weald and Sussex Coastal Plain, this is not the case where the Chalk is mantled by Quaternary deposits, such as Clay with Flints, Plateau Gravels or brickearth, as here bone preservation can be as bad as it is on the Sussex Coastal Plain. Considerable localised variation in survival exists and the need to assess the survival and state of preservation of environmental remains as part of any archaeological evaluation, anywhere within the region, is therefore crucial.

Allied to the palaeo-environmental data, consideration should be given to dating the sequences. Ideally a well-dated succession of deposits is required, so that changes through time can be identified and related to the archaeological time-scale. For the Holocene and Late Pleistocene sequences most archaeologists are familiar with the use of radiocarbon dating (on short-lived identified plant remains, bone or molluscs) and luminescence (on feldspars and quartz in fine sandy sediments). The increasing use of Bayesian modelling, which takes stratigraphy into account, has improved the precision of dating on many recently excavated (and reinterpreted earlier) sites (e.g. Whittle et al. 2011). For earlier Pleistocene sequences, associated with Palaeolithic archaeology other, less familiar dating methods are required that include Amino Acid Geochronology, Chlorine-36 dating as well mammalian biostratigraphic methods (Walker 2005).

While many investigations of both Pleistocene and Holocene environments have, by necessity, been conducted on a site by site basis, dictated by the developer-funded approach of the last 25 plus years, some studies have been able to take a landscape centred approach to investigation. For example, construction of HS1 across Kent and the Lower Thames enabled a phased approach to be delivered to archaeological intervention whereby the landscape provided the primary unit of analysis (Bates and Stafford 2013; Wenban-Smith et al. forthcoming). A comparable project delivered by MoLA for Chichester Harbour examined the evolution of the inland ‘harbours’ between Chichester and Portsmouth (Francis 2007; Mills et al. 2007). Some region-wide projects funded by the ALSF also delivered regional landscape-based summaries with archaeological objectives (Bates et al. 2004/2007; Wenban-Smith et al. 2007a; Wenban-Smith et al. 2007b).

Pleistocene Environments

Over much of the South-East the bedrock is masked by superficial deposits, accumulated during the Quaternary (Fig. 2; Lowe & Walker 2014). This most recent geological period, spanning the Pleistocene ‘Ice Ages’ and the present Holocene warm stage, is synonymous with human evolution and so not only do superficial deposits mantle and modify the characteristics of the underlying bedrock, but in many cases they contain evidence for the occupation of south-east England by early-humans (hominins) as well as later archaeology.

During Pleistocene times Palaeolithic human occupation was intermittent and ephemeral with occupation associated with both temperate, interglacial environments but also the much longer, cooler episodes associated with periods of climate cooling, lowered sea-levels and shifts in fauna and flora. Today we recover the remains of human activity from a range of sedimentary contexts including fluvial, peri-marine, cave and rockshelter as well as open air sites. With the possible exception of cave and rockshelter sites, such as those at Oldbury https://historicengland.org.uk/listing/the-list/list-entry/1007458, the relationship between the evidence for human activity and sedimentary sequences during the Pleistocene differs significantly to that of later periods where 'sites' are clearly identified. Evidence for human activity throughout most, if not all of the Palaeolithic, occurs within natural sequences of Pleistocene deposits scattered across the landscape in a range of contexts. Hence, we treat the primary unit of examination for Palaeolithic activity in the South-East as the landscape rather than an arbitrarily defined site. This contrasts with our approach for the Holocene (see below).

Cold stage deposits

South-east England lay beyond the extent of ice sheets during the Pleistocene cold stages, but much evidence remains of the frozen, wind-swept periglacial environments that prevailed in these periods. A range of features, deposits and landforms, visible in the modern landscape and sometimes encountered in archaeological excavations are the consequence of permafrost (frozen ground). Cracking and frost-heave resulted in ice wedges, sometimes seen singly, but often part of larger-scale patterned ground (ice-wedge polygons); as well as 'stripes' of alternate coarse gravels and fine-grained sediment; and disc-like features, known as pingos. Chalk is very susceptible to frost, and periglacial features have been well-studied on the Isle of Thanet (Murton 1998). When frozen, the porous chalk was no longer permeable and so spring run-off was able to erode the chalk to create the features we now call dry valleys that typify the chalk downland landscape today. In all areas of the South-East each spring/summer the thawed surface layer of soil, subsoil and/or bedrock, moved downslope, over the still frozen subsoil (solifluction/ gelifluction), leading to accumulation of 'Head' deposits (including the coombe rock of chalk areas) at the foot of slopes, across the valley floors and at other breaks of slope in the landscape (Preece and Bridgland 1999). Partial thawing also led to the development of involutions (flames of lower sediment protruding into overlying layers) a form of freeze-thaw disturbance known as cryoturbation (Ballantyne 2017) (Fig. 3).

Fig. 3 Evidence for Pleistocene periglacial environments (to be added)

Ice-melt episodes during periods of cold climate resulted in significant volumes of fast-flowing meltwater disgorging into river channels. These bodies of water were capable of transporting large quantities of coarse gravel, leading to the accumulation of thick gravel deposits across valley floors. At the start and end of each cold stage, lowered sea-levels (owing to water locked up in ice) caused the rivers to downcut to lowered base-levels (Bridgland and Westaway 2014). Coupled with background general tectonic uplift in southern England, these processes led to the formation of staircases of river terraces where the oldest terraces are at the highest elevation above the modern floodplain (Fig. 4). Such sequences are familiar in many of the rivers of the South-East (Bridgland 1994, 2006; Gibbard 1994; Westaway et al. 2006) which compare well with others around the world (Bridgland and Westaway, 2014). With sea-levels over 130m lower than today during these Pleistocene cold stages the rivers eroded deep channels across the exposed sea floors across significant distances in both the Channel and North Sea regions. The channels representing the continuation of our modern rivers contain cold climate gravels. They survive today as

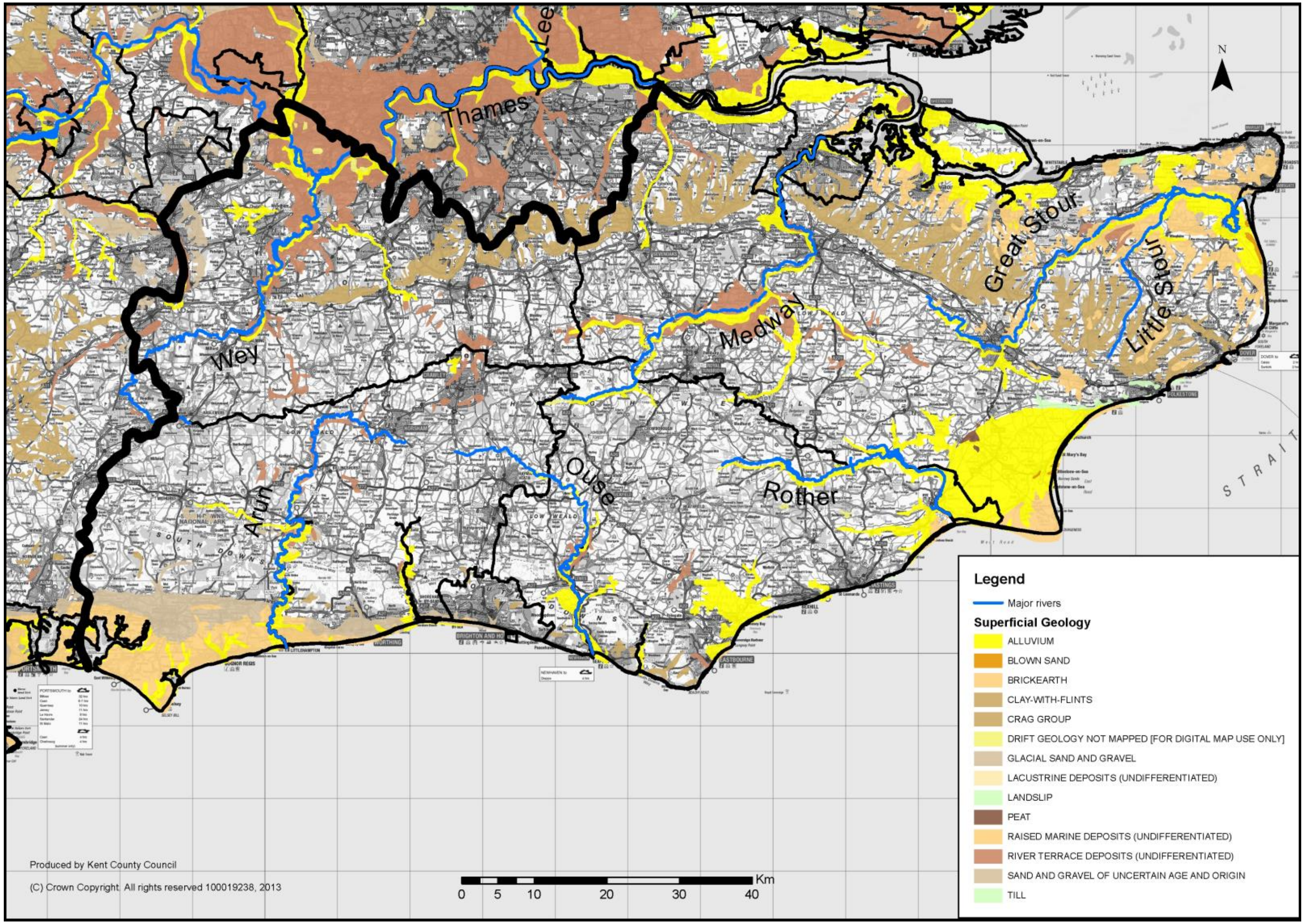

Figure 2 Superficial geology

palaeochannels, some of which, such as the palaeo-Arun, have been mapped and investigated (Gupta et al. 2004, 2007). For others, such as those of the Adur (Wessex Archaeology 2015) and Dour (Bates et al. 2015) only preliminary investigation has taken place. It is important, also, to remember that these offshore channels represent the lower reaches of Pleistocene river systems and are likely to represent an entire aspect of the Palaeolithic landscape that no longer exists in terrestrial locations today (Pope and Bates 2016).

Fig. 4 Medway river terraces (to be added)

Other, less common survivors from the Pleistocene cold stages include the erratic boulders of non-local origin found in coastal parts of the South-East, such as on the Sussex Coastal Plain. The origin and precise mechanism of emplacement of these rocks remains to be determined but one hypothesis suggests they may have been carried by icebergs. Evidence from Norton Farm in West Sussex (Bates et al. 2000) appears to provide evidence to support such a hypothesis. Elsewhere on the West Sussex Coastal Plain interbedded organic and carbonate-rich layers have been found filling shallow depressions up to 1km in width. These appear to be large, shallow lakes that existed during cool, but not cold, climate periods (Bates et al. 2009a). Finally, cold stage sediments appear to be preserved within gullies excavated into the surface of the Greensand in places in the Weald preserving evidence for Middle Palaeolithic occupation of these landscapes (Pope et al. 2015).
Calcareous silts transported by winds blowing across the dry bed of what is today the North Sea and the Channel accumulated as thick layers of Loess across South East England and Northern France during these cold stages. Mostly the Loess has been eroded, transported by colluvial (slope) and fluvial (flowing water) processes and redeposited together with sediments derived from other sources, as ‘brickearth’. Unmodified (though in its upper parts decalcified) Loess survives in parts of Kent, however, and deep Loess deposits can be seen in the cliffs at Pegwell Bay (Murton et al. 1998).

Because of its proximity to the present, deposits from the last cold stage (the Devensian, MIS 2-4, Table X.1) are potentially more common in the landscape than that of earlier periods. Therefore, the lowest fills of dry valleys, the gravels and Head deposits that underlie alluvium across the valley floor and mantle valley sides, the Loess, pingos, ice wedge casts and much of the brickearth encountered in archaeological investigations are likely to (though by no means always) relate to the later stages of the Pleistocene. In some cases, these features and deposits preserve evidence for the climatic oscillations and cold snap at the end of the Pleistocene. For example, evidence of soil formation and landsurfaces associated with the Allerod interstadial, which represented a ‘false start’ to the Holocene interglacial is occasionally found, especially in dry valley locations (Preece 1998). Such evidence is sometimes disturbed by renewed periglacial activity causing frost heave and cryoturbation or is buried by soliflucted and other periglacial sediment accumulated at the very end of the Pleistocene, during the Younger Dryas, also known as the Loch Lomond Stadial (Fig. 5). In a recent example excavated in West Sussex, what appears to be an Allerod soil is overlain by varved deposits, accumulated in a frozen lake (ASE in prep; John Mills pers. comm.).

Figure. 5 Late Glacial deposit sequence (to be added)

Locations where sediment accumulation began in the Late Glacial and continued through the Holocene are of great value for reconstructing the environments of the Pleistocene/Holocene transition and the subsequently evolving past environment. Relic cryogenic mounds, often known as pingos have been mapped across parts of the South-East and research at Elstead Bog in Surrey has demonstrated the value of these features for preserving long sequences of sediments accumulated from the end of the Ice Ages to historic time (Carpenter and Woodcock 1981; Farr 2008). Similar research in Surrey has focused on Late Glacial peat accumulated within small hollows in naturally undulating sandy geology (Simmonds 2016).

Recently, results from studies focused not on the major river valley systems of the study region but on minor valleys and dry valleys have been published and these document the important role that such contexts may play in future studies in the South-East. Among these are geomorphological contexts that have recently been examined in north Kent (Wenban-Smith and Bates 2011; Wenban-Smith et al. forthcoming) that exhibit sedimentary sequences associated with presently dry valleys which appear to exhibit patterns of sediment deposition that contrast with the main river valley terrace sequences. For example, in the Darent Valley a complex of slope and fluvial gravel sequences have been documented at numerous locations near to Darenth (Wenban-Smith and Bates 2011) in which archaeological material, including material potentially dating to just after the last interglacial, have been recorded. Further inland in the Darent Valley investigations at Lullingstone Country Park (Anderson-Whymark and Pope 2016) have also documented how interglacial sediments may be deeply buried by Holocene and Pleistocene colluvial sequences in the downland valley systems.

Temperate stage deposits

The river terrace sequences may also preserve evidence from the warm Pleistocene interglacials and include palaeosols, alluvium, peat and colluvium (Bridgland 1994; Schreve 2016). The complexity of some of these sequences is displayed by the interglacial deposits in the Swanscombe/Ebbsfleet area of north Kent (Bridgland 1994, White et al. 2017; Wenban-Smith 2013). Interglacial sediments have recently been examined in the Medway estuary (Bates et al. 2017) in which both plant and animal remains have been identified from at least two and possibly three interglacials all preserved beneath the Holocene marsh. The distribution of this interglacial material is highly skewed and while good evidence for interglacial environments is preserved in the lower Thames elsewhere the story is poor. For example, interglacial sediments of the Solent system as well as the rivers in the Weald rarely contain the fossiliferous material necessary to provide detailed evidence for environmental reconstruction.

Important interglacial evidence also includes the raised beach sequence and buried former cliff-lines of the Sussex Coastal Plain (Bates et al. 1997, 2010; Bates and Briant 2009; Roberts and Pope 2018). The relatively subdued modern topography of the Sussex Coastal Plain, mantled by successive sequences of Pleistocene Head and brickearth, belies its buried ‘staircase’ of cliff-lines and beaches (Fig. 6). Conventionally, in a similar manner to the river terrace deposits, each beach represents an older event as one passes from lower to higher beaches (Roberts and Parfitt, 1999; Roberts and Pope, 2018). This simplistic interpretation of the evidence has been questioned by Bates et al. (2010), who suggest that a far more complex history of sequence development may be preserved in the Quaternary deposits of the West Sussex Coastal Plain.

Table 1 Summary of Quaternary environment change (to be added)

Fig. 6 Ipswichian Beach overlain by brickearth and disturbed by Devensian freeze-thaw processes exposed in a low cliff behind the present day beach below Selsey Coastguard Station (West Sussex) (to be added)

Holocene Environments

Topography

By contrast with the Palaeolithic, archaeological sites become increasingly visible in the archaeological record from the Mesolithic onwards. The relationship between site and landscape changes from that in which the landscape is the primary unit of investigation to sites themselves being the focus of attention (and hence the need for off-site studies to understand past landscape context and setting). The topography resulting from solid geology and dramatic Pleistocene landscape processes created the structure for the Holocene landscape and its exploitation. The broad characteristics of topography influence settlement, transport and movement, emphasising the need for topographic assessment as a first step in predicting archaeology and understanding archaeological distributions. Topography influences Holocene landscape processes, which for the most part have been less dramatic than those of the Pleistocene. To some extent this is result of a temperate climate and the relative stabilisation of the landscape by the development of vegetation.

As for the Pleistocene, a range of contexts provide proxy information for the evolving Holocene landscape and these will be considered below.

Rivers

The Chalk hills are cut by rivers draining north and southwards from the High Weald, which forms the watershed for the headwater valleys of the Lavant, Arun, Adur, Ouse, Cuckmere, Rother, Pannel, Brede, Tillingham, Dour and Great Stour flowing into the Channel; and the Mole, Wey, Wandle, Darent, Ebbsfleet and Medway flowing north into the Thames. The headwaters of most of these lie in the east-west orientated ridges and valleys of the Hastings Beds (Fig. 7).

Fig. 7 relief, drainage and key landforms (to be added)

Holocene rivers (such as the Medway) have probably been less well studied than their Pleistocene ancestors. Where they have been investigated (Burrin and Jones 1991; Bates and Stafford 2013; Bates et al. 2017; Sidell et al. 2000; and see Brown

2009 for a useful general text) the pattern of river system evolution through the Holocene in the South-East appears to follow a generally similar pattern. The braided channels of the cold climate of the Late Pleistocene, depositing gravels and sands across a wide braidplain, were succeeded by clear, fast-flowing anastomosing channels in the early Holocene (earlier Mesolithic) with meandering channels developing, as vegetation stabilised the river banks (in the later Mesolithic and Neolithic). These watercourses are characterised by the deposition of sands, tufa and peat. Subsequently, vegetation clearance and cultivation resulting in soil erosion provided sediment influx to the river systems. During the early and middle Holocene sea-level rise continued and caused river gradients to decrease resulting in the ponding back of the lower courses of rivers, leading to a reduction in flow velocities. As a result, rivers generally became more sediment-laden and silts and organic clay deposits accumulated from the Bronze Age onward.

Changing river patterns as a result of natural processes (avulsion, cut off meanders etc) as well as their straightening and manipulation to supply mills, fishponds and drinking water, especially in historic time, has led to networks of channels being fossilised and infilled to create buried palaeochannel features on floodplains. Current investigations (for example the in the Medway valley (Bates et al. 2017) and the River Thames Scheme in Surrey https://www.gov.uk/government/news/archaeology-surveys-june-2017-river-thames-scheme) have identified palaeochannels through LiDAR, aerial photography, geophysical and geoarchaeological surveys, which have subsequently been the focus of investigations into the changing Holocene environment.

Deep organic and alluvial sequences characterise the lower reaches of many rivers of the South-East, such as the Medway (Barham et al. 1995; Bates et al. 2017), which have enabled palaeo-environmental remains to be studied, dated and used to reconstruct the development of the river and its estuary. In contrast, onshore work along the cable route for the Rampion Offshore Windfarm, in West Sussex, demonstrated the difficulties of obtaining core samples from the lower reaches of the Adur, because of running sand. Here tidal pressure on the water table prevented recovery of the thick sequence of sands and laminated clays (Wessex Archaeology 2016). Further upstream, however, the relatively shallow deposit sequences in the small tributaries of the Adur, such as the Herring Brook, were shown to have very good potential for past environment reconstruction (ASE 2018). It is possible that similar less obvious tributary stream locations elsewhere would repay future research.

Soils

It is likely that a fairly uniform cover of Loessic sediment mantled the South-East in the Early Holocene, which probably led to similar ‘brown earth’ soils developing across the region, despite the underlying bedrock. This is supported by the similarity of the earliest parts of pollen sequences from the Weald and the Chalk (Waller and Hamilton 1998). Prehistoric land clearance changed this situation, however, and prompted more distinctive vegetation development in each area, as a consequence of the erosion of the loessic soils and soil formation in the differing underlying bedrock. The resulting soil characteristics have varied through time depending on the nature of the weathered bedrock parent material, climate, living organisms and relief.

Typically brown earth type soils remain in relatively well-drained areas; with stagnogleys where drainage is impeded (such as in the Low Weald); thin calcareous rendzina soils on the Chalk; and acidic podsols where leaching has degraded the well-drained soils of the High Weald (Greensand and Hastings Beds) and heathland has developed.

Dry Valleys

Across much of the downlands, dry valleys bisect the chalk hills and are rich in proxy records for the downland history. Work by Bell (1983), Allen (2017) and others have demonstrated a two-fold sequence in many valleys that include a basal sequence of sediments associated with the Late Glacial (see Pleistocene above) and a more extensive sequence of chalky gravels and silts associated with soil erosion and colluviation from the Neolithic onwards. For many sites lying at height on the chalk (such as the Neolithic causewayed enclosures for example) dry valley sequences offer the offsite context for landscape evolution. In some cases dry valleys evolve downstream into 'wet' valleys offering the possibility for colluvial signals to be integrated with wetlands sequences. For example, the river Dour at Dover is largely dry inland of Crabble Mill (Bates et al. 2008, 2011) but contains an important tufa and wetland record downstream as far as Dover town centre.

Coasts

At the end of the Pleistocene cold stage, sea-level was over 100m below its present level. South-flowing rivers drained into a deep Channel River many kilometres offshore and deep, steep-sided valleys existed in places where today we see wide inlets of the sea, such as Chichester Harbour (Fig. 8) and the Medway Estuary. Sea level rise was rapid until about 6,000 years ago and then slowed down, until around 3,000 years ago when sea-level attained its modern levels. Considerable work has been done around the South-East coast to refine our understanding of Holocene relative sea-level rise. 'Relative' because the land itself is sinking at about 2mm per year (Shennan 2010). This is because the landmass continues to adjust to rectify the imbalance caused by the weight of Pleistocene ice, which caused the north of England to subside and the south to become elevated. Information about past sea levels typically uses evidence (OD height and date) from sediments that show a change from marine to freshwater (and freshwater to marine) deposition, especially where they are datable (for example peat) and lie directly over non-compressible bedrock or Pleistocene gravel. These 'sea-level index points', pin-pointing when and where past sea-level was rising or falling and its level, enable fluctuations in relative sea level to be recorded in different parts of the coast and sea-level curves (graphs) to be constructed, which have shown that superimposed on the broad general pattern, are fluctuations that differ from place to place (Long 1992). In the South most work has been done in the Southampton Water area (Long et al. 2000), Dungeness (Waller et al. 1998); and Thames Estuary areas (Long 1995).

Fig. 8 *Section across an inlet of Chichester Harbour (from Mills et al. 2007) (to be added)*

Coastal erosion is one consequence of rising sea-level. The rocks and sediments of the South-East are typically soft and easily eroded. Many of the seawards-facing cliffs around the coast are rapidly retreating. The retreat of the Chalk cliffs at Beachy Head of over 1m per year, for example, has led to four hectares of the scheduled hilltop enclosure of Belle Tout being lost to the sea over the past 140 years; including a deep well shaft that was exposed in section in the cliff face recently for a few years, but its base is now barely visible as a feature on the foreshore, some distance from the cliff (Fig. 9). This rapid erosion has prompted excavation of parts of the site by the National Trust (Dommett 2016; Chuter & Greatorex 2018). In other places erosion has revealed archaeological evidence and provided opportunities for examining features and deposits that might be buried by several metres of sediment further inland, such as the submerged forest at Pett (Timpany 2018) and the Pleistocene channels by Selsey Coastguard Station (Bates 2009). Bronze Age cut features were also visible in section for many years in the shallow cliffs of Quaternary sediment on Selsey's West Beach (West Sussex), before final erosion took place. Frequently, though, exposure is fleeting and is followed either by total erosion and removal, or by reburial by shifting coastal sediments. In some locations understanding coastal erosion is critical to a complete understanding of the context of an archaeological find or site. For example, at Dover, Bates (2013) has calculated a number of different coastal erosion rates for the chalk cliffs close to the location at which the Dover Boat and Langdon Bay Bronze Age hoard were found. The precise rate of coastal erosion is of significance in contextualising these finds.

Fig. 9 Cliff Erosion at Belle Tout, East Sussex, exposing a well shaft cut through the Chalk *(to be added)*

Because of the nature of sequences in the coastal zone recent work by various local groups as well as by the CITIZAN project (https://www.mola.org.uk/citizan-coastal-and-intertidal-zone-archaeological-network) in recording intertidal evidence when it is exposed before it is reburied or removed altogether by the sea has been incredibly valuable. Such work has taken place around Chichester Harbour, West Sussex (Francis 2007); at Pett (between Hastings and Dungeness), East Sussex (Timpany 2018); and on the Hoo Peninsula, Kent (Hazell 2011). An ongoing (in 2018) Historic England project, using drones and aerial photography to map the extent of peat exposed at low tide at Pett, building on the intertidal peat database (Hazell 2008) should also help elucidate for this location at least the changes brought about by coastal erosion and reburial by shifting sediment.

To combat the flooding resulting from rising sea-level, a number of coastal defence schemes have been initiated by the Environment Agency in the South-East, for example Medmerry in West Sussex. Here 'managed retreat' has led to an extensive area of salt marsh being created to act as a buffer to coastal erosion. Where geoarchaeology and deposit modelling is undertaken as part of associated archaeological work, these schemes can provide valuable information about past coastal evolution and its implications for human settlement and activity (Stephenson & Krawiec 2019; Krawiec 2018).

Longshore drift and other coastal processes along the south coast has caused the movement of substantial volumes of shingle in a generally eastwards direction. To some extent this is linked to coastal erosion, and it is partly also a result of the redistribution of sediment transported by Pleistocene rivers to areas now far offshore. It has led to the episodic blocking of harbour mouths and/or their migration and river diversion behind long shingle spits. The result is clearly visible at Shoreham, where the mouth of the Adur has been deflected a considerable distance eastward along the coast. Geoarchaeological investigations and deposit modelling in Dover have helped to map the evolution of the mouth of the Dour and the setting of the prehistoric, Roman and medieval settlement and activity; the landscape setting of the archaeology of each period being markedly different, as the configuration of the river and the coastline evolved (Bates et al. 2011). Further work has recently been undertaken as part of Dover Western Docks redevelopment to extend this model seawards (ASE in prep).

Landwards of Dungeness Foreland (a shingle bank) lies the largest area of former coastal marshland in the South-East. The marshland comprises Walland, Denge and Romney Marshes (collectively referred to as Romney Marsh). Its formation effectively cut off a former coastal cliff-line, as well as the wide former estuary developed at the mouth of the Panel, Brede, Rother and Tillingham rivers, from the sea. The geomorphological evolution of this area, the archaeological and historical context of the marsh and shingle and its relationship with the demise of the Roman Stutfall Castle, the medieval port of Winchelsea and Camber Castle, has been the subject of considerable research over the past 30 years. Much of this, together with unpublished research material, is summarised in a desk-based assessment undertaken for Kent County Council as part of the Fifth Continent Heritage Lottery funded project (Krawiec and Bates 2016). This concludes that despite considerable research into its later Holocene evolution, the nature and timing of the earlier landscape history of Romney Marsh remains unknown. Essentially the ‘creation’ of Romney Marsh was initiated approximately 6,000 years ago, by the development of a shingle barrier, formed by longshore drift, projecting in a north-easterly direction from the Hastings area. This created a sheltered tidal lagoon into which large quantities of silt were deposited, forming mudflats: the mudflats eventually developed into a saltmarsh environment with areas of vegetation and sinuous creeks. Very large quantities of shingle continued to be deposited causing the easterly advance of the Dungeness promontory. The re-advance of the sea around 3000 years ago “broke through the shingle barrier and caused the widespread redistribution of the shingle” (Krawiec and Bates 2016). Typically the shingle forms ridges, some of which are exposed at the modern ground surface and others that are overlain by silty clays. Between the ridges lie troughs, the deepest of which contain blue-grey clay often capped by a thin layer of peat and overlain by clays. Where shingle is not exposed at the ground surface the deposit sequence is generally capped by a characteristic mid yellowish-brown silty clay, which divides medieval and later archaeology from Roman and earlier remains and appears to have been laid down by flooding at some time between the 4th and 12th centuries AD.

Fig. 10 Map showing geomorphological context of Romney Marsh (to be added)

Further around the Kent coast, successive growth of spits and shingle banks extending northwards from Deal, together with the development of saltmarshes, the elaborate meander of the River Stour and river silting, led to the abandonment of Sandwich as a coastal port, as well as today’s inland location of the Roman coastal fort at Richborough. Both Sandwich and Richborough lie on the edge of the Wantsum Channel, which once separated mainland Kent from the Isle of Thanet (Robinson and Cloet 1953; Perkins 2007). Although piecemeal geoarchaeological work has been undertaken within the channel, most of which remains as unpublished geoarchaeology reports, this is an area that would benefit from a more collaborative, overarching deposit model that might lead to better understanding of its evolution from a sea channel in prehistory to reclaimed coastal marshland during the historic period (Bates et al. 2000*;* Carey et al. 2018). Recent geoarchaeological work as part of the Richborough Connection Project is beginning to pull some of this previous information together for the Monkton and Minster Marshes (ASE in prep), but less existing information is available here, as the majority of previous work has been associated with development towards the mouth of the Wantsum between Ebbsfleet and Sandwich. Understanding the evolution of this part of the coastline is particularly important, given the likelihood that this part of Kent has frequently been the ‘gateway to England’ (Andrews et al. 2015).

At a superficial level, a similar story lies behind many of the low-lying former coastal marshlands of the South-East. Essentially, rising sea-level ‘drowned’ the lower reaches of river valleys; subsequent spit growth led to river silting and fen development landwards, with intertidal mud and salt marsh development seawards; renewed inundation by the sea, when the shingle spits and barriers were breached, alternated with episodes of land reclamation. At a very basic level this pattern is evident in Pagham Harbour, the Willingdon and Pevensey Levels, Coombe Haven, Cuckmere Haven, and the Pett Levels, the Walland and Romney Marshes of the Dungeness Peninsula, as well as the Lower Medway, draining into the Thames Estuary. In all these areas, however, there is a need for geoarchaeological and palaeo-environmental work to map the evolving topography, reconstruct the changing environments and tie them in to episodes of coastal change and human activity. The association of these deep drowned valleys with Mesolithic and later prehistoric archaeology was illustrated in the recent work along the Bexhill-Hastings relief road, which cut across Coombe Haven in East Sussex (Champness 2018). These areas also have huge potential for the preservation of waterlogged archaeology, much of which is likely to be nationally significant, such as the Bronze Age platform part-excavated (under rescue conditions) at Shinewater in the Willingdon Levels (Jennings et al. 2003; Greatorex 1998) (Fig. 11). The current state of preservation of the remains that were ‘preserved *in situ*’ at Shinewater is unknown and would repay further investigation. Both the Willingdon and Pevensey Levels have been identified by Historic England as areas of Exceptional Waterlogged Heritage (Historic England 2012).

Fig. 11 Shinewater in the Willingdon Levels (to be added)

The Quaternary evolution of the tiny Ebbsfleet Valley, fed by springs in the Chalk and draining northwards into the Thames in north Kent was a focus of investigations during work for HS1, owing to its archaeological significance, with designated Palaeolithic, Neolithic and Roman sites. Much of this work was geoarchaeologically-focused as Holocene sea-level rise had a considerable effect on the nature of the valley, with corresponding implications for its occupation and use from the Mesolithic onwards. Changes in the siting of settlements, mills, quaysides and harbours in different periods as the characteristics of the valley floor evolved illustrate what might be expected in other river valley systems around the South-East coast (Bates and Stafford 2013, Chapter 12).

Holocene Vegetation History

Thinly vegetated Tundra environments existed in South-East England during the periglacial conditions of the Late Devensian. Following climatic amelioration at the close of the Pleistocene, a succession of plants and animals migrated into Britain. The sequence from Pannel Bridge, on the Pett Levels, illustrates the general vegetation succession that developed in the South-East during the Holocene (Waller 1998). Initially birch and pine colonised the Pannel valley sides, with sedge and other fen vegetation growing on the valley floor. Hazel gradually became established in the early Mesolithic, followed by oak and elm, forming fairly open woodland, as grass and weed pollen hint at woodland clearings. By the later Mesolithic lime had become a dominant element of the woodland composition, together with oak and hazel. Elm was a subordinate element of the woodland until around 6,000 years ago when its role was largely replaced by ash. This probably reflects the 'Elm Decline' of the early Neolithic and its association with Dutch Elm disease and human intervention. The demise of lime around 4,000 years ago is also considered to have been caused by human impact and led to an apparent expansion of beech. In the Pannel valley the lime decline was accompanied by an expansion of ferns and birch and later by grasses, cereal pollen and weeds of disturbed ground and cultivation. The growth and expansion of alder across the valley floor from early in the Holocene represents the alder carr common in wetland areas of the South-East in prehistory. Its abundance in pollen diagrams (alder is a heavy pollen producer) masks the signal from other vegetation, especially with the development of peat, representing the alder carr, from the Bronze Age.

Much less evidence is available for vegetation change in later periods. However, the site of 'The Hayworth' provided important paleoenvironmental remains and a rare Wealden pollen sequence for the Anglo-Saxon and medieval periods (Fig. 12). Prehistoric woodland, where oak, hazel and lime were the dominant species, was replaced by a closed oak and hazel habitat where holly was part of the understory. This habitat was cleared gradually from the 7th century, a process which began in what landscape historians have termed the 'long 8th century', a period of social and agrarian innovation that lasted from the 7th to 9th centuries. Landscape change continued until a 12th century beech-dominated, semi-wooded environment was achieved (Margetts 2017).

Fig. 12 Pollen diagram from The Hayworth (to be added)

Excavations by Archaeology South East elsewhere in the Weald have revealed important multi-period palaeo-environmental information (Margetts 2018). Fewer pollen sequences are available from the Chalk, however, owing to a lack of suitable depositional environments and poor pollen preservation (leading to less pollen and less opportunity for specific identifications). However, there are a few examples which show a similar mixed deciduous woodland cover as on the Weald until the Elm Decline and associated woodland clearings. At Horton Kirby on the chalk in Kent there is evidence of both the insect carrier of the disease and that of cereal cultivation from early Neolithic contexts (Nick Branch pers. comm.). In chalkland sequences, yew is a component of subsequent woodland regeneration shading out earlier colonisation by juniper, which as it is browse resistant, could indicate animal husbandry (Waller and Hamilton 1998; Vera 2000). In general, woodland appears to exist well into the Bronze Age on the Chalk and the origin of the chalk grassland continues to be a question for research, but it is unlikely to have existed prior to later prehistory (Waller 1998).

Preliminary GIS-based synthesis of pollen evidence from the South-East, which enables the distribution of pollen sequence data to be viewed against other layers of information, such as topography and geology, has been undertaken by Reading University (Nick Branch pers. comm.). This supports the regional applicability of the Holocene vegetation history described from Pannel Bridge and suggests that yew was not confined to woodland succession on the Chalk. Yew also appears to have been a major component of woodland development in the Holocene river valleys of the South-East more generally (Branch et al*.* 2012). Although it is from these river valleys that the majority of pollen profiles so far examined have been derived, the origin of the pollen in river valley sequences must be carefully considered, as it could represent a wide catchment spanning various geologies.

As a result of differing landscape position, soils, subsoils, aspect, drainage and the impact of people and animals, much local variation is likely to have been superimposed on the general pattern of changing vegetation. In archaeological terms, this small-scale variation is likely to have had a key influence on where and how prehistoric and later people exploited the landscape. The ecotonal zones lying between one broad environment and another would also have been important (Bates and Whittaker 2004). Therefore the need for more widespread local studies off-site, especially in areas of archaeological significance are needed, to provide information about the changing environment at a scale that more closely aligns to that of the archaeology.

In addition to cereal pollen and weeds of cultivation, charcoal is often recovered from pollen samples, providing hints of human activity. More specific information about woodland exploitation is recovered from larger fragments of charred wood found in archaeological contexts, typically associated with cremations, hearths and rake out from kilns. Although these are the stuff of later chapters, the need to mesh together the background evidence from pollen and plant remains for woodland composition and its distribution, from off-site locations, with that recovered from archaeological contexts is crucial, if we are to understand better the interactions between people and their environment.

Holocene climate change

Few studies in recent years have looked at the changing Holocene climate of the South-East. The current understanding is for a general trend of rapid climatic amelioration in the early Mesolithic, at the start of the Holocene during a generally warm and dry climatic phase. Wetter (but still warm) conditions followed, during the later Mesolithic and earlier Neolithic, with increasing dryness in the Later Neolithic and Bronze Age, but from the Iron Age onwards, climate appears to have become cooler and wetter. Considerable fluctuations have taken place during the historic period, however. The warmer climate of the 10th to early 13th centuries (the Medieval Warm Period) prompted coastal settlements and their farmland to expand into marginal areas, which included extensive saltmarsh reclamation in the coastal areas of the South-East. Many of these efforts were destroyed during the subsequent period of increased storminess in the 13th and 14th centuries, when artificial sea walls and natural shingle banks were repeatedly breached by the sea (Galloway 2009, 2010). This was the beginning of the Little Ice Age: nearly six centuries of unpredictable weather, of dramatic climatic shifts and several periods of extreme cold, culminating in the frozen winters of the late 18th and early 19th century (Lamb 1982; Fagan 2000). Future research should aim to refine this general sequence. Generally the historic era has been largely neglected as a focus for environmental reconstruction despite evidence for climate variability drawing upon data from ice core, marine, tree ring, speleothem, glaciological and lake sedimentary records. Therefore, a greater understanding of the climatic fluctuations from the Roman period onwards, perhaps targeting natural deposits accumulated in suitable natural and archaeological features dating to the historic period, would be especially useful. This is, in part, the focus of ongoing research by Reading University, where Sarah Thoma is investigating the palaeo-environmental and palaeoclimatic potential of artificial wetlands, such as ponds, lakes and moats during the last 1000 years, within South-East England (Thoma et al. 2017).

Long climate records are limited primarily because of the nature of the sediment traps that exist to record such sequences. One of the longest records presently available for the South-East is that of Holywell Coombe near Folkestone (Preece and Bridgland 1999). Other long records may exist at the foot of similar situations where the Chalk overlies pre-Cretaceous clays and silts. The absence of major lakes and other water bodies is a significant problem when attempting to obtain long Holocene records although it is possible that some long records exist in the lower reaches of the estuaries of the Medway (Bates et al. 2017), Wantsum Channel and smaller valleys such as the Cuckmere (Bates and Champness 2011). Some hitherto unexamined resources for high resolution climate records do exist in the South-East and these are primarily associated with the tufa deposits in valleys such as the Dour in east Kent. Isotope records from early to mid-Holocene sequences might well provide a very high-resolution record that should compare well with other proxy records.

Submerged Environments

Submerged landscapes (Flemming et al. 2017; Wickham-Jones 2018) have been categorised as a distinct entity here because of their unique status and the very different sets of problems and procedures associated with their creation, taphonomy and investigation, many of which will be unfamiliar to terrestrial archaeologists (Pope and Bates 2016). Submerged landscapes have been considered in conjunction with Pleistocene cold climate sequences (see above) but these submerged landscapes are also likely to contain earlier Holocene sediments as sea-levels recovered from the last glacial maximum and consequently may be associated with Mesolithic archaeological remains in places.

Reconstructing offshore topographies and mapping buried sediment sequences is both complex and costly and consequently rarely undertaken from an archaeological perspective. However, significant bodies of data collected and collated for other purposes (oil and gas prospection, wind farm foundations and cable lays) do exist and have been used to model these offshore landscapes. For example, Bynoe (2014) and Bynoe et al. (2016) have demonstrated that a wide range of different environments, of different ages exist in the southern North Sea including the Thames estuary bordering the South-East. Within the Channel region Mellett (2012; Mellett et al. 2013), Gibbard and Cohen (2015) and Gupta et al. (2007, 2017) have all provided reconstructions of submerged landscapes. Significant differences do exist between the north Kent submerged zone and that of the Straits of Dover and southern England coastline and both differ significantly from the southern North Sea scenario where the subsiding basin of the North Sea graben exhibits a series of superimposed landscapes rich in palaeo-environmental and archaeological remains (Gaffney et al. 2009; Tizzard et al. 2017). North of the Kent coastline previous work has clearly indicated that a series of submerged river terraces are present that appear to be a continuation of those mapped on land in the lower Thames estuary (Bridgland et al. 1993). By contrast the seabed of the English Channel consists of a series of incised channel forms within which sediments may be preserved (Fig. 13) (Gupta et al. 2007, 2017; Gibbard and Cohen (2015). These will have their own unique preservation issues and potentials for archaeological remains.

Fig. 13 *Map showing extent of palaeovalleys in the eastern English Channel (from Antoine et al. 2003) (to be added)*

Detailed palaeo-environmental investigations are however few and far between in the coastal waters of south-east England. Aggregate Levy funding enabled Wessex Archaeology (2008) to examine the offshore Arun and palaeo-environmental work was undertaken on vibrocores taken in this system that document late Pleistocene and early Holocene sequences. Onshore equivalent sequences have been examined in the base of some of the larger river systems such as the Medway (Bates et al. 2017) and Cuckmere (Bates and Champness 2011). There also remains the issue of correlating the on- and offshore sequences (Bickett and Tizzard 2015). Again Aggregate Levy funding has begun to address this important problem (Bates et al. 2007b).

Research Agenda

Introduction

While much has been delivered to increase knowledge of the environments of the Pleistocene and Holocene as well as submerged environments, much remains to be done to provide a comprehensive understanding of this subject.

Pleistocene Environments

Investigations such as those at Ebbsfleet in north Kent have highlighted how a relatively small tributary of the Thames contains a rich and varied record of environmental change spanning much of the last 400,000 years (Wenban-Smith

2013; Wenban-Smith et al. forthcoming). This highlights the potential of many of the chalk downland valleys.

By contrast with the Thames the Wealden area remains little understood in terms of the nature of the sequences and their archaeological potential. The relative paucity of faunal and floral remains in the Weald have made it difficult to correlate sequences of river terraces with those to the north and south of the downland blocks.

- Some parts of the Weald are now being routinely examined for palaeo-environmental records (both those associated with the river gravels as well as the ‘inland’ sequences) but the challenge remains to boost this record.
- Other regions in which important, but poorly understood Pleistocene sediments exist are the Wantsum Channel in east Kent where sequences of sediments extend beneath the East Kent Marsh surface that probably document a range of late Pleistocene environments.
- Additional investigation is required in places such as the West Sussex Coastal Plain where, although important sequences are relatively well described the number, order and nature of the warm and cold stages present remains equivocal. Furthermore, this region represents our best chance of integrating our terrestrial sequences with those of the marine province from which our yardstick for subdivision of time in the Pleistocene (the isotope records) has been derived.

Holocene Environments

A number of other geomorphological characteristics of the South-East are of relevance to the distribution, survival and nature of archaeology during the Holocene, but cannot be covered in any detail in this chapter and all warrant further investigation. These include:

- Timing of early Holocene pine expansion.
- Timing of early Holocene hazel expansion in various locations and investigation into potential links with Mesolithic activity.
- Ambiguity about the causes of the elm decline and its likely exploitation by Neolithic farmers.
- Lack of information from areas of Chalk bedrock.
- The uplands of the Chalk Downs where soil erosion has largely removed any sedimentary sequences and fragments of palaeo-environmental records are preserved in solution hollows, pits and beneath lynchets or archaeological structures.
- The susceptibility for landslides of the Wealden and Gault Clays, for example along the relict cliff line near Lympne, Kent, landslides have had a great impact on the survival of the scheduled Roman Fort of Stutfall Castle (Hutchinson 1988, 1998). Other geological units such as the London Clay can also slide, burying Holocene or Pleistocene sequences beneath otherwise apparently *in situ* bedrock.

- The susceptibility of the sandy soils of parts of the Weald for soil degradation and subsequent wind erosion, has led to the development of the Wealden heathlands and the repeated exposure and reburial of archaeology (for example: Iping Common, see Mesolithic chapter).
- The formation of rockshelters in areas of Wealden sandstone (Greatorex and Seager-Thomas 2000; also see Mesolithic chapter).
- Better understanding the onset of flooding in the lower reaches of our river valleys and the nature of the landscape transformation resulting from this transgression;
- Better understanding the nature of landscape change within the Wealden area.
- Another topic not covered here is the varied success of geophysical techniques in the South-East, especially in Surrey, where geology varies across short distances. Attempting to establish what approaches work in the many different parts of the landscape would be a valuable area for future research. Preliminary work, pulling together results for different locations in Surrey is underway (Tony Howe and David Callow pers. comm.)
- The availability and accessibility of information relating to past environments, archaeological science and environmental archaeology in the South-East is another area that would be useful to address. It can be difficult, time-consuming and unproductive to extract this information from HERs. Steps towards creating (and maintaining) a GIS-based digital platform for locating and accessing palaeo-environmental data, such as peat deposits, pollen sequences, interpreted natural deposit sequences and deposit models, would be of huge value to further research and facilitate its synthesis.

Submerged Environments

As the study of submerged landscapes is a relatively recent branch of archaeology many issues remain to be resolved and we can view the field of investigation as in its infancy. Thus despite the fact that a number of investigations have begun to demonstrate potential in these regions locating archaeological remains in these landscapes has largely been unsuccessful. Key issues are presented in the agenda below.

- Determining the nature of the Pleistocene cold stage landscapes and whether or not these landscapes represent distinct palaeo-environments for which we lack terrestrial counterparts.
- Determining the nature and speed of inundation of the landscapes during the early Holocene.
- Adopting/modifying techniques to make survey and site investigation simpler and more cost effective.

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