RESEARCH DEPARTMENT REPORT SERIES no. 17-2009

ISSN 1749-8775

A REVIEW OF GEOARCHAEOLOGY IN THE MIDLANDS OF ENGLAND

Matthew Canti

ARCHAEOLOGICAL
SCIENCE

ENGLISH HERITAGE

Research Department Report 17/2009

A Review of Geoarchaeology in the Midlands of England

Matthew Canti

© English Heritage 2009

ISSN 1749-8775

The Research Department Report Series, incorporates reports from all the specialist teams within the English Heritage Research Department: Archaeological Science; Archaeological Archives; Historic Interiors Research and Conservation; Archaeological Projects; Aerial Survey and Investigation; Archaeological Survey and Investigation; Architectural Investigation; Imaging, Graphics and Survey, and the Survey of London. It replaces the former Centre for Archaeology Reports Series and the Archaeological Investigation Report Series.

Many of these are interim reports which make available the results of specialist investigations in advance of full publication. They are not usually subject to external refereeing, and their conclusions may sometimes have to be modified in the light of information not available at the time of the investigation. Where no final project report is available, readers are advised to consult the author before citing these reports in any publication. Opinions expressed in Research Department reports are those of the author(s) and are not necessarily those of English Heritage.

Requests for further hard copies, after the initial print run, can be made by emailing: Res.reports@english-heritage.org.uk or by writing to English Heritage, Fort Cumberland, Fort Cumberland Road, Eastney, Portsmouth PO4 9LD. Please note that a charge will be made to cover printing and postage.

Research Department Report 17/2009

A Review of Geoarchaeology in the Midlands of England

Matthew Canti

Summary

Geoarchaeology forms the backbone of many modern archaeological projects or provides additional specialist information where stratigraphic issues arise during excavation. It involves the study of a wide range of deposits from aeolian silt to anthropogenic wastes, and utilises information from a number of specialist methodologies including various forms of soil analysis, sedimentology, and chemical survey. The activities carried out are diverse and the significance of the results may be apparent at a range of scales.

Only some areas of the geoarchaeological spectrum are suitable for regional synthesis, particularly where site-specific processes being studied have some form of regional significance or control. These can be natural or anthropogenic processes, and may be interactions of the two. This review concentrates on these regionally significant aspects of geoarchaeology, providing a review of major work already carried out, and pointers to future priorities.

Keywords

Geoarchaeology
Geochronology
Optically Stimulated-Luminescence
Burial Environments
Soil/Sediment

Author's address

English Heritage, Fort Cumberland Eastney PO4 9LD, UK

3.4 Dark Earth

BIBLIOGRAPHY

1. INTRODUCTION

The term 'geoarchaeology' covers a broad spectrum of activities, and is frequently defined in different ways by different authors (Gladfelter 1977; Hassan 1979). For some, it centres around natural processes such as alluviation and their interplay with archaeology; for others a more site-specific approach is emphasised, looking at human and animal processes evident in the stratigraphy. Rather than revisit those definitions (see Canti 2001), it seems preferable simply to work within a broad boundary that allows the various component areas of the subject the freedom they need. An example might be that *geoarchaeology should concerned with the processes going on in the ground and in the wider landscape immediately before, during and after the accumulation of archaeological stratigraphy*. There is no reason for this sort of loose definition to exclude other specialisms. Indeed some aspects of geoarchaeology, for example taphonomy, are partly about those other specialisms. Equally, work on sedimentary stratigraphy may be important to the understanding of, for example, plant remains or pollen analysis.

When examining geoarchaeology from a regional perspective, it becomes clear that not all these component areas are necessarily suitable material for a review. Numerous geoarchaeological reports exist whose function was to be part of a very site-specific study with no implications for a region at all. This is partly because of the geographical limitations of the data. If, for example, evidence of animal trampling was found for the first time on an early Iron Age site in the Midlands, we would not feel justified in saying either that animal trampling or the number of animals was increasing in the Midlands during the early Iron Age. The evidence has a purely local significance. A similar argument can be applied to soil formation processes. The idea of some threshold event such as clay eluviation or podzolisation sweeping through a region at a given time in the past is deeply misleading. Although Holocene climate and parent material interactions have broadly followed expected pathways, the local timing of this sort of threshold event is clearly affected both by small variations in initial conditions (the butterfly effect) as well as by differences induced by human activities (Canti 1992a).

Those areas of the geoarchaeological spectrum that *are* suitable for regional synthesis are found where the site-specific processes being studied have some form of regional significance or control. These can be natural or anthropogenic processes, and may be interactions of the two. This review will concentrate on these particular aspects of geoarchaeology.

2. REGIONAL GEOARCHAEOLOGY

2.1 Alluvium

Alluviation is a major example of a process studied at the site scale but controlled (at least in part) regionally. Alluvium underlies or covers many archaeological sites in the Midlands, and its presence signifies changes in the environment that directly affected people's lives. Although alluvium has attracted an enormous amount of study in the past twenty years, universal truths covering its development in either time or space have not been easily deduced. This wealth of work has, however, led to considerable conceptual development in the field as a whole, and the ideas provide useful echoes in other complex areas of geoarchaeological study.

The Basic Stratigraphy of Midlands Rivers

Most valley fills in the UK midlands (see Figure 1) have a similar basic stratigraphy consisting of various fine materials overlying gravel resting on the bedrock. This remains broadly true despite considerable variation in valley morphologies, and the complications presented by questions such as the origin of terraces which need to be studied in their own right (Dawson and Gardiner 1987). The underlying gravels show clear evidence of having been deposited in a cold climate (Bryant 1983) and have attracted considerable research interest of which only a summary will be presented here.

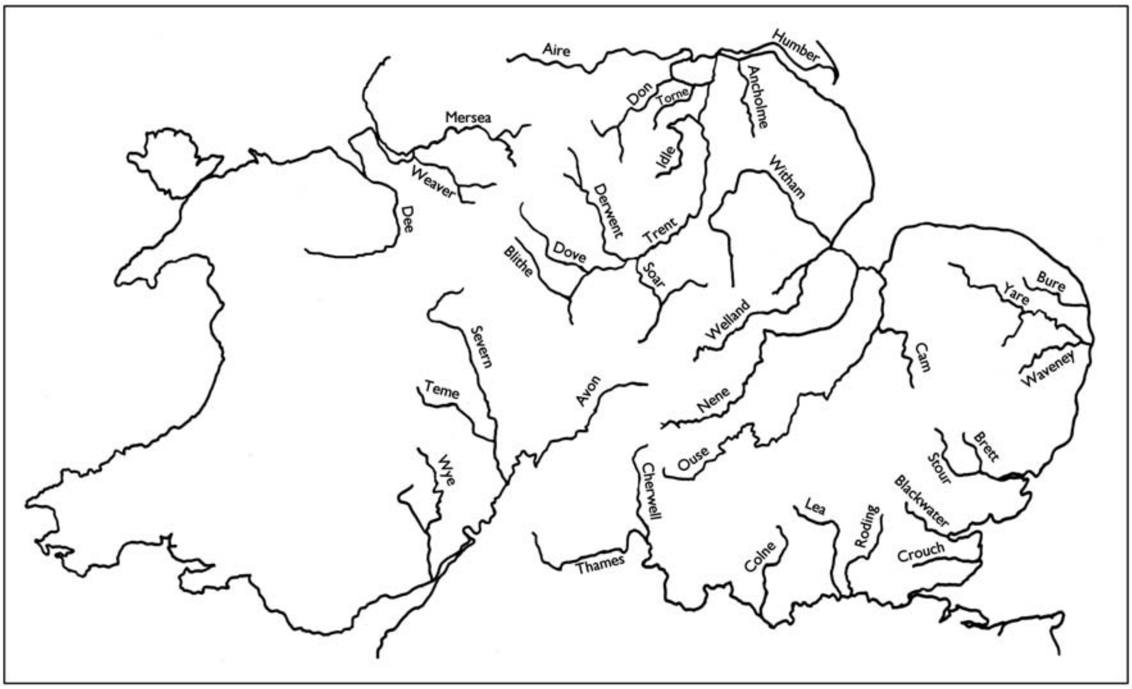


Figure 1: The major Midlands rivers

Starting on the eastern side of the region, on the river Gipping at Sproughton, Ipswich, Rose *et al* (1980) showed that all the underlying gravels were deposited during the Younger Dryas and first few centuries of the Holocene. On the Middle and Lower Thames most gravels under the alluvium are Devensian (Gibbard 1985), but alluvium occasionally overlies Saalian (^{18}O stage 8-6) in Essex (Bridgland 1994: 175-177).

The upper Thames valley gravels (see Sandford 1924) including the lower reaches of the rivers Coln, Leach, Windrush, Evenlode, Cherwell, Ray, Thame and Ock all appear to have been deposited during Devensian cold stages (Aalto *et al* 1984; Briggs and Gilbertson 1980). Channels were established by the early Holocene, e.g. 9380 ± 110 BP (HAR-8366, calibrating as 9610 - 9160 BP at 95.4% using Oxcal 3.10) from temperate biological material in a channel cutting the gravel at Mingies Ditch (Allen and Robinson 1993). However, there is clear variation evident in depositional dates, e.g. the Shepperton gravels in east London had ceased forming before 15500 cal. BP, whereas aggradation west of London continued after 13500 cal. BP (Sidell *et al* 2000).

In the east Midlands, a mid to late glacial range of dates is described by Brown *et al* (1994) and Brown (1995). Several sites on the Nene show late glacial activity, for example Ditchford, where the whole gravel suite was deposited between 11200 and 10200 BP. However, evidence from only 60 km north on the Soar, suggests that gravel deposition started before 28000 BP.

To the west, on the Severn at Stourport in Worcestershire, Shotton and Coope (1983) found a date of 12570 ± 220 BP (Birm. 1021, which calibrates to 13950 - 15350 BP at 95.4% using Oxcal 3.10) representing the culmination of a gravel.

Lowland Midlands Alluviation

An early paper by Shotton (1978) described a number of exposures in the Severn and Avon valleys. These were characterised by a gravel base (thought to be either the bed of the river or the remains of its levées) with various clay-rich or silty layers above, representing the accumulation of thin flood deposits and the remains of cutoffs. Although considerable variability was noted within these layers, the stratigraphy was always topped with a reddish clay or silty clay layer that had clearly been derived from the Mercia Mudstone (formerly Keuper Marl). The dating evidence suggested that the accretion of this reddish layer had mostly been initiated in the late Bronze Age and an increase in ploughing following clearance seemed the most likely explanation. This view was backed up at the base of one section by the discovery of driftwood trees attributed to the clearance event before ploughing started.

Also in the Severn system, the Ripple Brook study of Brown and Barber (1985) used pollen, diatom and sedimentary evidence to put forward a similar, but more detailed chronology for deforestation and alluviation (see also Brown 1983). Some level of clearance is apparent in the pollen diagrams from the Late Bronze Age onwards, followed by total deforestation by mid Iron Age times. This led to increases in the estimated catchment erosion rate from 20 tons km^{-2} yr^{-1} to 140 tons km^{-2} yr^{-1}. Published data from modern catchment studies makes this figure seem surprisingly low. Loss of tree cover increases the quantity of water reaching the ground by around 50%, greatly sharpening hydrograph peaks (up to 40%), and allowing as much as 2000 times the sediment load to enter rivers (Leyton *et al* 1967; Robinson 1981; Higgs 1987; Limbrey 1978). Detailed catchment characteristics perhaps make it difficult to compare modern studies with data from the past. The actual quantity of sediment released is more likely to be controlled by subtleties of the system and the ongoing events after deforestation. Thus, management practices may well have been what really mattered rather than the degree of clearance (Limbrey 1983).

Similar evidence also emerged to the east. Hazelden and Jarvis (1979) reported an early Iron Age date on roots truncated by alluvium in the Windrush valley, Oxfordshire. This was a single case and not entirely secure, but was followed by another Windrush site and eight Thames sites all summarised by Robinson and Lambrick (1984). Their sites generally showed a rise in water-table and the onset of flooding taking place in the late Bronze Age, followed by alluviation mainly beginning in the Iron Age. This occurred alongside a parallel increase in the density of occupation sites, as well as more incidental evidence such as plough marks and large numbers of grain storage pits from sites of the same period. The upper Thames dates are broadly in agreement with some tentative London alluvial dates around 3500-2500 yrs BP given by Merriman (1992).

In the Fens, Godwin and Vishnu-Mittre (1975) found clay layers dated to the middle Bronze Age, intruding into raised bogs around Holme Fen and Whittlesey Mere, Huntingdonshire. Combined with pollen evidence, these layers were interpreted as the result of soil erosion and flooding from the adjacent uplands after forest clearance. The cleared area was expanded in the late Bronze Age, and substantial areas of pasture were then maintained.

The various strands were summarised by Bell (1982), who argued for a largely Bronze Age to Romano-British time period for the initiation of the mid-Holocene alluviation, with later large scale deforestation being responsible for further accretion during the historic period. This has echoes in the Nene valley, where Keevill (1992) reported Neolithic and Bronze Age archaeology sealed by alluvium but argued that the greater part had been deposited later, probably in the Mediaeval period. A similar view was put by Evans *et al* (1988) for the upper Kennet valley, and by French (2003a) for the Great Ouse. Although Lobb and Rose (1996) suggested that the beginning of the alluvial build-up had been slightly earlier in the Bronze Age, the differences of timing seem fairly slight. Even elsewhere in lowland Europe, similar periods of alluviation have been noted (Salvador *et al* 1993). This overall sense of an identifiable period led Brown and Barber (1985) to compare the geomorphological results of the expansion of 3000-2000 BP to those produced by the European colonisation of the American Midwest. This is a useful comparison because modern studies enable likely sediment budgets to be analysed; for example, the up to thirtyfold increase in sediment delivery found in a Michigan lake (Davis 1976) after the arrival of the settlers in the 1820s (see Figure 2).

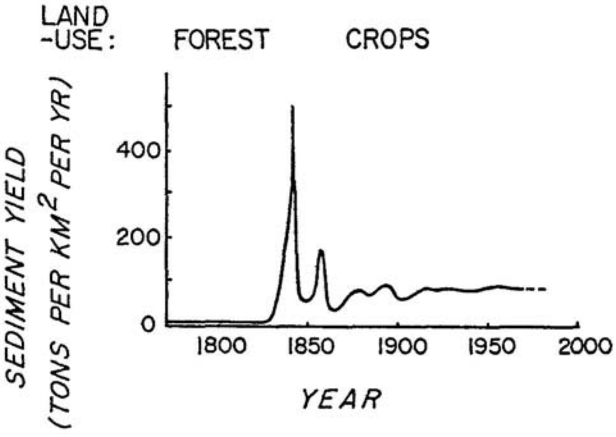


Figure 2: Generalised sediment yields resulting from clearance by settlers and subsequent agriculture in Southern Michigan in the last two centuries (from Davis 1976; © Cambridge University Press)

The transformation of the Midlands lowland floodplains during the Holocene was considerable, and appears to have followed a developmental pathway from braided streams through an anastomosing pattern, tri- or bi- channel systems, and eventually leading to a single sinuous channel (Brown *et al* 1994). The mid-Holocene events involved major changes to the channel and floodplain dimensions as well as channel abandonment, flattening of the floodplain surface, and broad scale alterations to deposit texture. Brown and Keough (1992a) viewed these changes as a metamorphosis (in the sense of Schumm 1969) and showed generalised examples of the commonest features. Figure 3 is a reproduction of their summary for the Soar and Nene valleys.

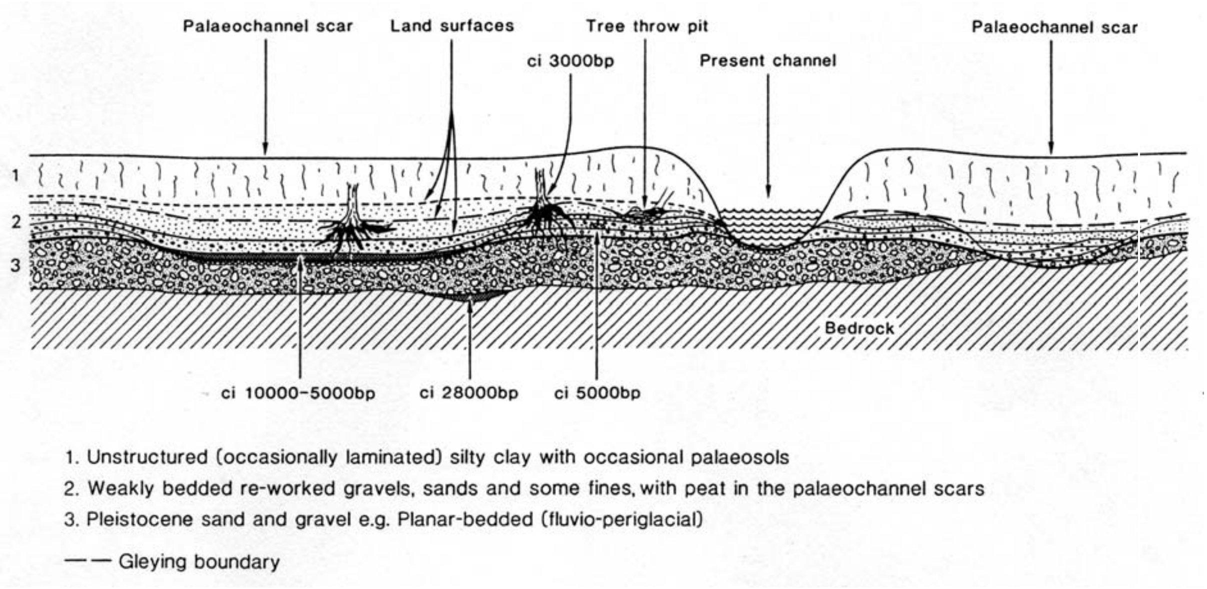


Figure 3: Generalised floodplain features in the Soar and Nene valleys (from Brown and Keough 1992a; reproduced with permission from Elsevier Ltd.)

In general, most authors support the view expressed by Shotton (1978) that this period of fine sedimentation occurred as a result of the expansion of cultivation (e.g. Lambrick 1992; Limbrey and Robinson 1988) rather than climate change. Although river discharges undoubtedly do respond to climatic change (Probst 1989), this is not the same as saying that alluvial deposition is directly correlated to that change. Furthermore, as Brown and Keough (1992b) pointed out, the relatively slight changes in climate during the mid-Holocene would be hard-pressed to generate the scale of floodplain metamorphoses found at their Midlands sites. In their view, metamorphosis resulted predominantly from variations in sediment supply. That this single cause could have such a large effect was shown with great clarity by the aerial photography study of a minewaste-influenced floodplain in Wales by Lewin *et al* (1983). Despite almost no alteration of the water supply, very large changes occurred in the pattern of floodplain alluviation in response to changes in spoil output. A similar result was obtained by Macklin (1985) who measured about four times the sedimentation rate in a Mendip floodplain when local mining was in operation. However, Macklin *et al* (1992) suggested that anthropogenic and climatic factors should be viewed as a continuum rather than as opposing views, since they act together to control water and sediment supply.

Not all the available lowland data fits conveniently into the model. Burrin and Scaife (1988) found more material variation than normal amongst the valleys they studied in Sussex. Layers of peat, and complex interbedded sands, marls and tufa did not match the simplicity of the recorded valley fills. They also found significant lateral variability from one location to another in the same valley. It is now more widely understood by authors that anthropogenic effects have to be disentangled from the individual site-based evidence that may appear to fit the basic erosion model. Parker and Robinson (2003), for example, found significant increases of sedimentation after 5200 BP at Dorney on the river Thames, but cautioned that much of this was in fact calcium carbonate that had entered the system in solution.

Some data does not match the late Bronze Age - early Iron Age time period for erosion. Needham (1991; 1992) found evidence at Runnymede for increased flood risk during the Neolithic, culminating in a severe flooding episode in the early Bronze Age. After that, there was a cessation of flooding in the late Bronze Age. Major alluviation episodes were dated as Iron Age or later by Robinson (1992) in the upper Thames, Nene and Ouse valleys; by French and Heathcote (2003) in the lower Great Ouse valley; and by Pryor *et al* (1985) at Etton in the lower Welland valley (see also Pryor 1998). However, as noted by French (1990) this latter example was preceded by some seasonal alluviation in the Middle Neolithic.

Upland Midlands Alluviation

In the Midlands, upland is mostly represented by the Peak District and Southern Pennines which ultimately drain west to the Mersey or east to the Humber. The former route is fairly simple, consisting of the relatively short rivers Bollin, Dane and Mersey. The latter route has one direct spur, the Don flowing northeast through Doncaster, but the Derwent, Dove, Manifold, Blithe and Trent all head south east for a thirty to fifty kilometres before turning north-east to join the Humber.

On the Dane in Cheshire, Hooke *et al* (1990) found a major stillstand phase in the early to mid Holocene followed by deposition of gravel, sand and clay layers by meandering in a relatively stable vegetated environment. The major phase of woodland clearance and alluvial deposition occurred later, mainly between about 1200 BP and the 19th century.

Although outside the Midlands, a comparison with work in a stream valley on the Howgill Fells, Cumbria is pertinent here. After the stream had deeply incised through periglacial materials, the valley remained relatively stable through Iron Age and Roman times, only undergoing severe erosion around 940 BP (940±95 (UB-2213) calibrating as1140-750 BP at 95.4% using Oxcal 3.10). This, the authors suggest, is best correlated with the Scandinavian introduction of sheep farming (Harvey *et al* 1981). On the Trent in Nottinghamshire, Lillie and Grattan (1995) described evidence for high energy deposition including human and faunal material as well as large tree trunks of oak, ash and elm in gravel deposits. They saw this as clear evidence for a different model to that applicable in the lowlands. Other channels in the Middle Trent valley have been dated to between approximately 5400 and 3300 BP (Salisbury *et al* 1984). Howard and Knight (1995) cautioned against too dramatic an interpretation of Lillie and Grattan's (1995) evidence and argued that continuous reworking of the gravels had operated from the Neolithic through to the medieval period, probably in an environment of mobile migrating channels (Knight and Howard 1995). If this view applies to the wider area, it would certainly go some of the way to explaining the apparent contradiction implicit in having indicators of stability (tree-trunks, bridges, fish weirs etc.) regularly found buried by gravels (see Salisbury *et al* 1984; Salisbury 1992; Cooper 2003). It also calls into question, at least for this area, the assumption so regularly made by many workers, that the gravels at the base of alluvial sections are the result of early Holocene deposition from high energy periglacial streams.

However, the large part of the Trent evidence points to a post Iron Age and probably post Roman alluvial maximum (Knight and Howard 1994), a clear example being provided by the site at Littleborough, where Roman remains are interstratified with and buried by alluvium, the latter deposit being 1.5 m thick (Riley *et al* 1995). In the lower Trent, the extreme prevalence of warping (see Warp Sediments) makes assessment of alluvial history more problematic. More than three-quarters of the floodplain area of the lower Trent valley is covered in deliberate warp silt rather than natural alluvium (Lillie and Weir 1998).

Recent Changes to Rivers

The full extent of man's influence on river valleys during the prehistoric period is still debatable. The effects of relatively small scale structures such as bridges, weirs and causeways (see, for example the Bronze age causeway found at Yarnton in Oxfordshire http://thehumanjourney.net/html_pages/microsites/yarnton/pages/images.htm) could be out of proportion to their size, but it would be difficult to trace. There can be little doubt, however, that the effect of activities in the last few hundred years has been very significant indeed. Canalization and navigation improvement works were beginning in Italy in the 15th century, followed by a Europe-wide development of flood control and reclamation programs by the 18th century (Petts 1989). Work started early in the English Midlands, particularly with the huge amounts of major works carried out by the Dutchman Cornelius Vermuyden. In Lincolnshire in the 1620s, for example, he diverted the Idle, blocked off the Don and built a new channel (the Dutch River) to Goole (Sheail 1988). In the Fens, he built two channels between Earith and Denver to take both drainage water and the Ouse headwater more easily to the sea. The works transformed the fenland regions of Cambridgeshire and Huntingdonshire, mainly during the period 1600-1700 (see Figure 4) although some had gone on as early as 1478 (Darby 1983). The effect of these activities on the fluvial regime must have been considerable and were recorded in a local song:-

> *They'll sow both beans and oats where never man yet thought it.*
> *Where men did row in boats, ere undertakers bought it;*
> *But Ceres thou behold us now, let wild oats be their venture*
> *Oh let the frogs and miry bogs destroy where they do enter.*
>
> (from Darby 1983)

However, the greatest amount of work was inevitably carried out in the twentieth century (Figure 5). Studies of modern rivers suggest that there has been no great change in average sedimentation rates since the prehistoric/historic periods discussed above (Walling *et al* 1992; He and Walling 1996; Marriott 1992; Walling *et al* 1998). However, where there have been no improvement works, considerable changes of plan form have still been taking place over the last 100 years. This is especially marked on the fringes of upland areas, and is characterised by variability from one river to another, even when these are close together. Thus the river Bollin in Cheshire underwent a 43% decrease in net sinuosity while the Dane, only a few miles to the south, had a 10% increase during similar periods. This variability extends to different reaches of the same river, for example the Lugg in Shropshire which showed sinuosity decreasing in one section and increasing in another (Hooke and Redmond 1989).

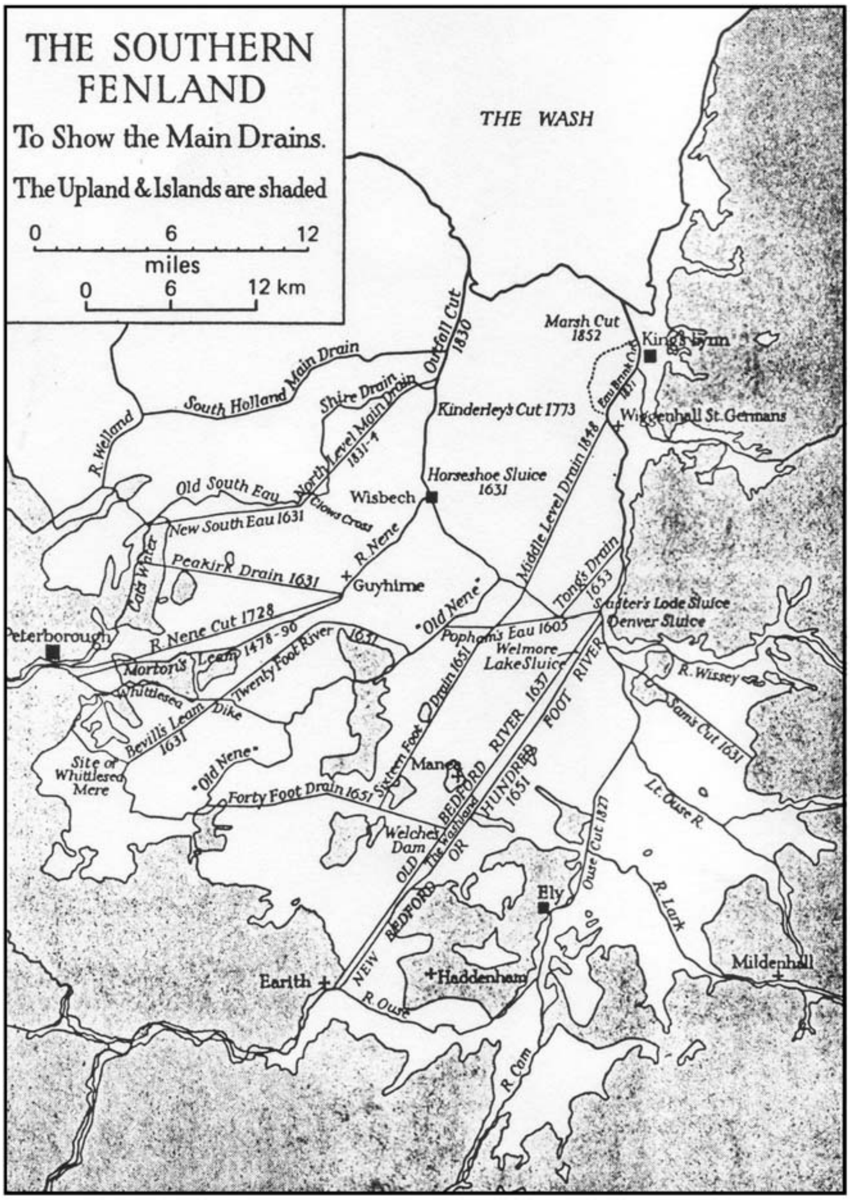


Figure 4: The main drainage works in the southern Fenland and their dates (from Darby 1983; © Cambridge University Press)

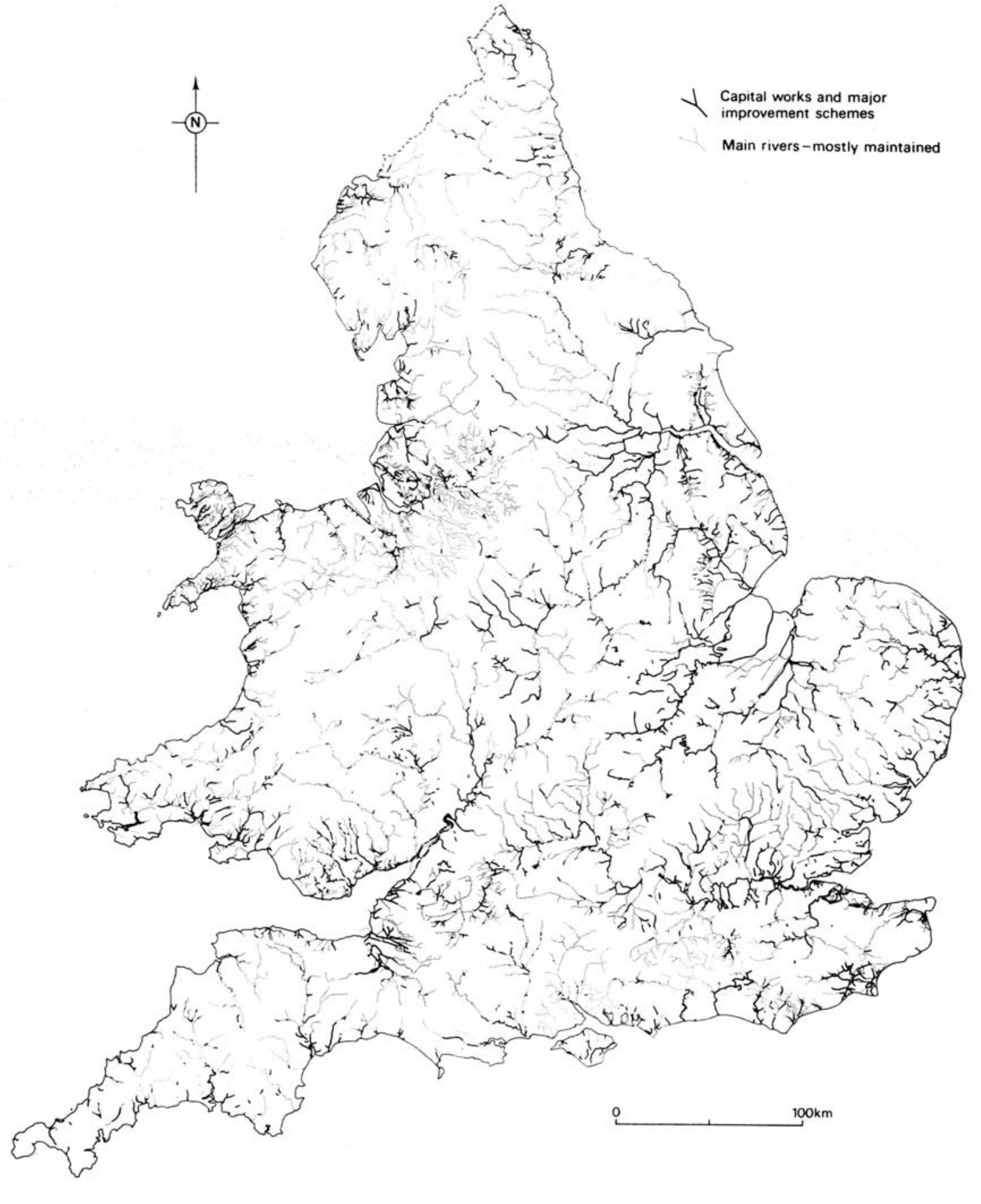


Figure 5: Rivers channelised between 1930-1980 (from Brookes et al 1983; reproduced with permission from Elsevier Ltd.))

Problems of Correlation

The complexity of alluvial systems has been clearly signalled in a number of different papers. Aside from the inter-related vegetation and climate responses, real channel systems differ considerably from their classical models (Lewin *et al* 1983). The floodplain is essentially a composite environment generated by a range of processes (Burrin and Scaife 1984), so at the outset, there is a fundamental difficulty of correctly conceiving the size of area to study when events are occurring at different scales. There are problems of understanding in the relationship between actual channel changes and the processes responsible for them (Lewin 1982; see also, for example, Thorne and Tovey 1981), particularly if the effect lags behind the cause (Allen 1974). In addition, interpretation is hampered by the results of diachronism, process variation within relatively short stretches of floodplain (Brown 1990), and the predictability of relationships between valley side land use and erosional or depositional results (Burrin and Scaife 1988).

In a discussion of hemispheric/global scale alluvial correlations, Karl Butzer wrote:

> "*Simplistic, long-range correlations are more likely to be wrong than right because dating is only approximate, multiple changes are difficult to pinpoint with accuracy, and directions of change may well differ in different regions.*" (Butzer 1980:140).

The extent to which this view applies to smaller regions such as the English Midlands is debatable and essentially centres around questions of scale. It would seem plausible, on first principles alone, to view the correlation between clearance/ploughing and alluviation as leading to a wide range of alluvial dates across the region. The additional complexity provided by intra-regional variations of relief, climate and sediment supply should introduce a significantly chaotic element to that simple correlation. Thus, it is not ultimately possible to view the mid-Holocene events as arising from linear relationships. Various authors have discussed the applicability of catastrophe theory to environmental systems (Burrin and Scaife 1988; Canti 1992a). The specific concept of geomorphic thresholds has been used to explain major landscape transformations occurring without *any* change to the external controls and later expanded to include rapid transformations under conditions of progressive change to those controls (Schumm 1979). The remaining question simply becomes - is there any further pattern to be discerned in all this data, or have we reached the limits of useful analysis?

2.2 Mining and related sedimentation

Introduction

There are a number of valuable resource deposits in the UK (Figure 6). Many have been exploited to some degree in the past, often starting as small surface digging operations but ending up as large scale mining by the 19th century. The rather quiet geological nature of most of the Midlands (Dury 1963; Haines and Horton 1969) means that the majority of the thermally deposited metalliferous ores are outside the area - principally occurring in the intrusive rocks of the South West or the metamorphic and igneous provinces of Wales and the North. Quiet geological conditions do, however, lead to deposits of both coal and ironstone - often in some form of association. These therefore occur widely in the Midlands - particularly in Nottinghamshire, Leicestershire and Derbyshire. Evaporation of the Zechstein and other brine bodies during Permo-Triassic times led to the formation of thick rock salt deposits in Cheshire, with gypsum found eastward as far as Nottinghamshire. These deposits vary in type, depositional conditions and the effect that their exploitation has had on the environment. Salt mining in Cheshire,

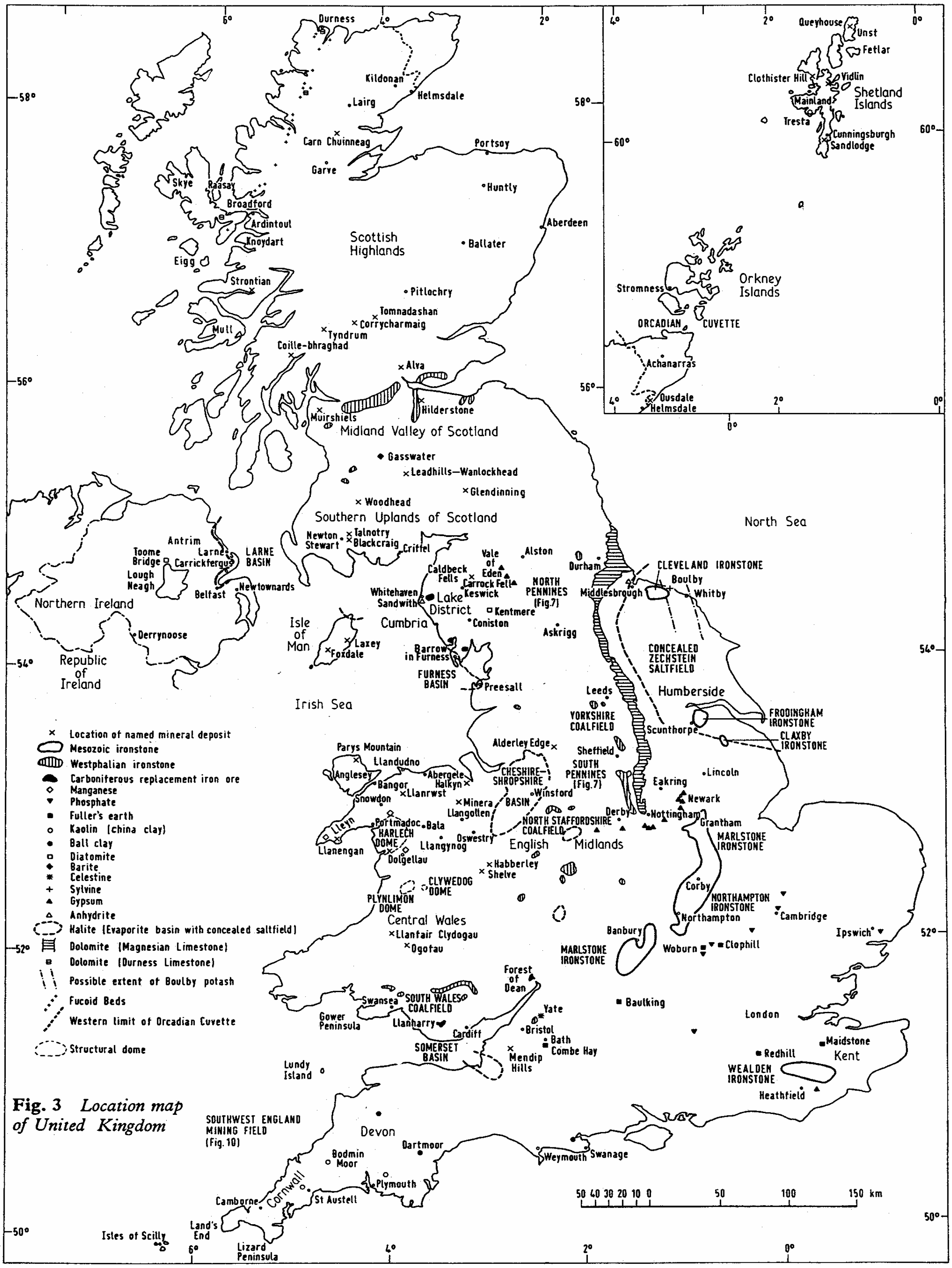


Figure 6: Britain's major mineral resources (from Dunham et al (1978); reproduced with the permission of the Mineralogical Society of Great Britain & Ireland and Maney Publishing (www. maney.co.uk/journals/ma)

for example, has left behind quite small scale archaeological sites (e.g. the brine wells and wattle-lined pit (Dennison 2001) in Middlewich, Cheshire), but the Midlands do not have large scale activities that have lead to the fine preservation found at continental sites (Barth 1991).

For all these resources, modern large scale extraction tends to obliterate the evidence of earlier workings, particularly the traces left in the landscape around the mines and quarries. Mitigation against this tendency occurs where exhaustion of the deposit preceded the expansion of industrialised mining. Thus, actual shafts or faces are sometimes left intact, because a particular vein or seam was worked-out and abandoned. Similarly, the adits and leats which characterise small scale mining operations can often still be seen in upland areas where economics still prevent further exploitation to this day.

Midlands Mining

Only two small areas of metal ores are found in the Midlands and both are on the periphery - in the Peak District and Shropshire (see Figure 7). Details of their industrial histories can be found in Raistrick and Jennings (1965), Brown (1976) and Burt *et al* (1990). A summary of this history is similar to nearly all the other UK metal mining operations. The areas both show some evidence of early working, going back at least to Roman times; they develop a large (for its day) operation in the eighteenth and nineteenth centuries; the twentieth century improvements in long distance transport make competition impossible with larger and more accessible deposits elsewhere in the world, and the industry declines. Nevertheless, quite significant amounts of base metals have been mined. According to Schnellmann and Scott (1970), the UK has produced around 6.0 to 6.5 million tons of both lead and zinc, of which about 678,000 tons of the lead (8%) came from the Derbyshire orefield. During the Roman period, lead was apparently so abundant in Britain that the supply had to be deliberately restricted (Pliny quoted by Raistrick and Jennings 1965).

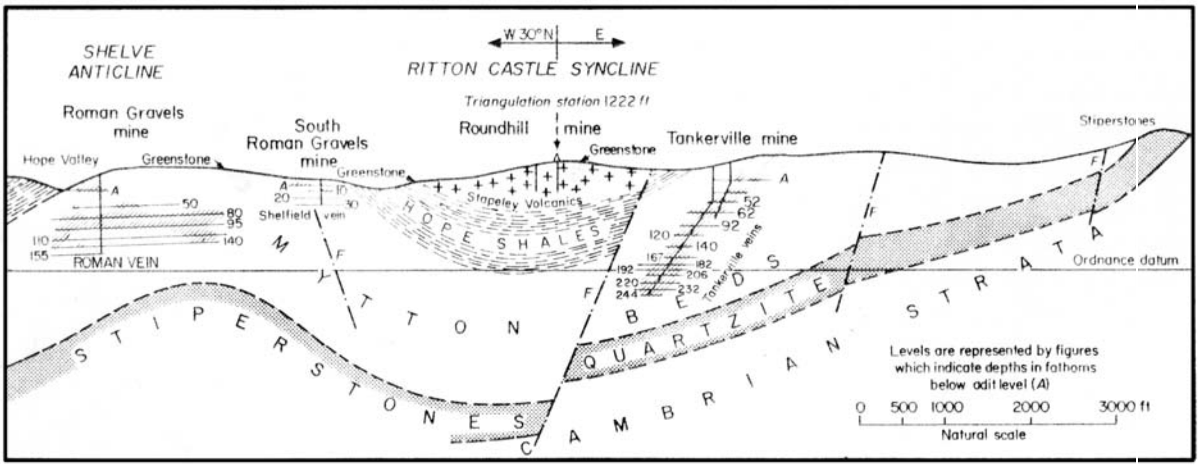


Figure 7: The west Shropshire orefield (from Schnellman and Scott 1970; reproduced with the permission of Maney Publishing (www. maney.co.uk/journals/ma))

Metalliferous Sediments

The possibility that these mining operations would leave elemental traces in the river valleys draining the metalliferous areas was embraced by geoarchaeologists and sedimentologists during the 1980s both as an archaeological exercise in itself, and as a possible way of helping to date sediments that lacked suitable organics for radiocarbon. Lewin *et al* (1983) had already examined the sedimentation that occurred after the growth of lead, zinc and copper mining in the catchment of the Afon Ystwyth in mid-Wales, finding significant increases in sediment accretion during the 1890s when the industry was in its boom period. Macklin (1985) took this further in the Mendips, relating peaks and troughs of sedimentary lead content to historical facts about the mining activity, such as mine re-opening and pollution control. The results also indicated a quadrupling of floodplain sedimentation rates from about 2.4 - 4.6 mm per year to 8.8 - 16 mm per year, the highest rate (as in mid-Wales) reflecting the main period of Mendip lead output. Whether these were floodplain-wide phenomena was not tested, however, because the sampling was restricted to a single core.

A slightly different approach was used by Bradley and Cox (1986; 1987) to examine contaminated soils in the Hamps and Manifold valleys of North Staffordshire. These sediments have received drainage water and tailings from the lead-zinc-copper mines at Ecton and Mixon. They appear to have been worked since prehistoric times (Guilbert 1994) and went through their peak outputs during the late eighteenth century, rather earlier than is typical for UK mining as a whole. Various metal concentrations were found to be negatively correlated with distance downstream from the mines, not returning to background levels until 9.5 and 11 miles for Hamps and Manifold respectively. The concentrations were also clearly related to complex factors concerning the actual mines and the sedimentation systems. The ores themselves, for example, have different particle size distributions; and details of dressing methods (for example different crushing regimes and different grading practices) produced different particle size inputs. Different types of sedimentation have been found to be responsible for varying metal concentrations as a result of, for example, overbank deposition versus lateral accretion (Lewin and Macklin 1987), local pollution attaching to the clay fraction of the alluvium (Leenaers *et al* 1988), or differences in taphonomic conditions in different parts of the catchment (Hudson-Edwards *et al* 1996).

Lewin *et al* (1977) summarised all the problems of chemical and sedimentary linkage as follows:-

> *"It is highly unlikely that even identical mining operations in contrasting fluvial conditions would produce similar patterns of environmental interaction.... "*

Another major factor affecting accumulation rates has now been shown to be the erosion of banks containing old spoil (Sear and Carver 1996; Macklin and Dowsett 1989). Diminution of the metal content of a sediment can thus be offset by recontamination from spoil heaps as they are re-entrained by natural erosion. These events can extend to simply reworking of the ordinary bank materials; in Tyneside for example, the major cause of lead pollution is erosion of the contaminated alluvium already present in the system (Macklin 1992). There can also be changes of elemental inputs to the system if a previously worthless mineral is mined from the spoil heaps when economics change. In the Welsh study of Davies and Lewin (1974), zinc ore went through just such a cycle. At the time of the main mining boom it was thrown away; but later it became economic to rework the spoil thus creating a new peak in sediment contamination.

This complex of processes does not invalidate the approach of examining metal wastes in sediment, but they do change the scale at which it can inform us about alluviation. The early concepts of measuring concentrations in the sediment and then being able to relate these to given events in the upstream mining history are clearly untenable. Taylor and Lewin's (1996) abstract described it thus:

> "*...an apparently simple planar floodplain is in reality underlain by complex sedimentation units. Floodplain construction has involved the development of inset units, in cut-offs and adjacent to migrating channels, as well as the expected contrasts between in-channel and overbank environments. This has implications both for alluvial sedimentation modelling and for identification of high-pollution zones on the floodplain. These cannot be predicted on the basis of simple 'in-channel' and 'overbank' environments given the historically complex evolution.*

However, by acting as a broadly dated marker, the metals have served to illustrate the complexity of sedimentation on floodplains beyond what was possible by morphology alone. This complexity must be faced up to by practitioners, and the level of detail interpretable from stratigraphy by dating and correlation broadened accordingly.

2.3 Marine Sediments

Introduction

For the purposes of discussion, the Midlands coastal geoarchaeology (Figure 8) will be divided into four large sections – Humberside, Lincolnshire and the Wash, East Anglia, and Essex (merging into the Thames estuary). These sections will be examined individually but it is worth initially discussing the geological basis of the area. The whole coastline is undergoing progressive sinking on an axis from northeast to southwest UK as a result of crustal rebound following deglaciation centred over Scotland. The rates vary between 0 mm per year in the north of the Midlands and 1.5 mm per year in the south (Shennan 1989). This does not translate into an equivalent sea-level rise at these locations because of complex additional effects at both a local and global scale (Long and Roberts 1997). Also, when examining the results of environmental changes on the archaeological record, further issues must be considered. The preservation and discovery of maritime archaeological remains depends on factors such as local sediment patterns, erosion and reclamation. Thus, for example, the lack of intertidal archaeology from the area of the Wash can be ascribed to its long history of accretion and reclamation (Allen *et al* 1997).

Allen *et al* (1997) emphasise the importance of old land surfaces in coastal archaeology. They argue that old land surfaces preserved by marine inundation give high quality environmental evidence from submerged forests and animals tracks and cultural evidence from find spots, hoards and scatters which would normally be lost or dispersed through soil processes or agricultural disturbance.

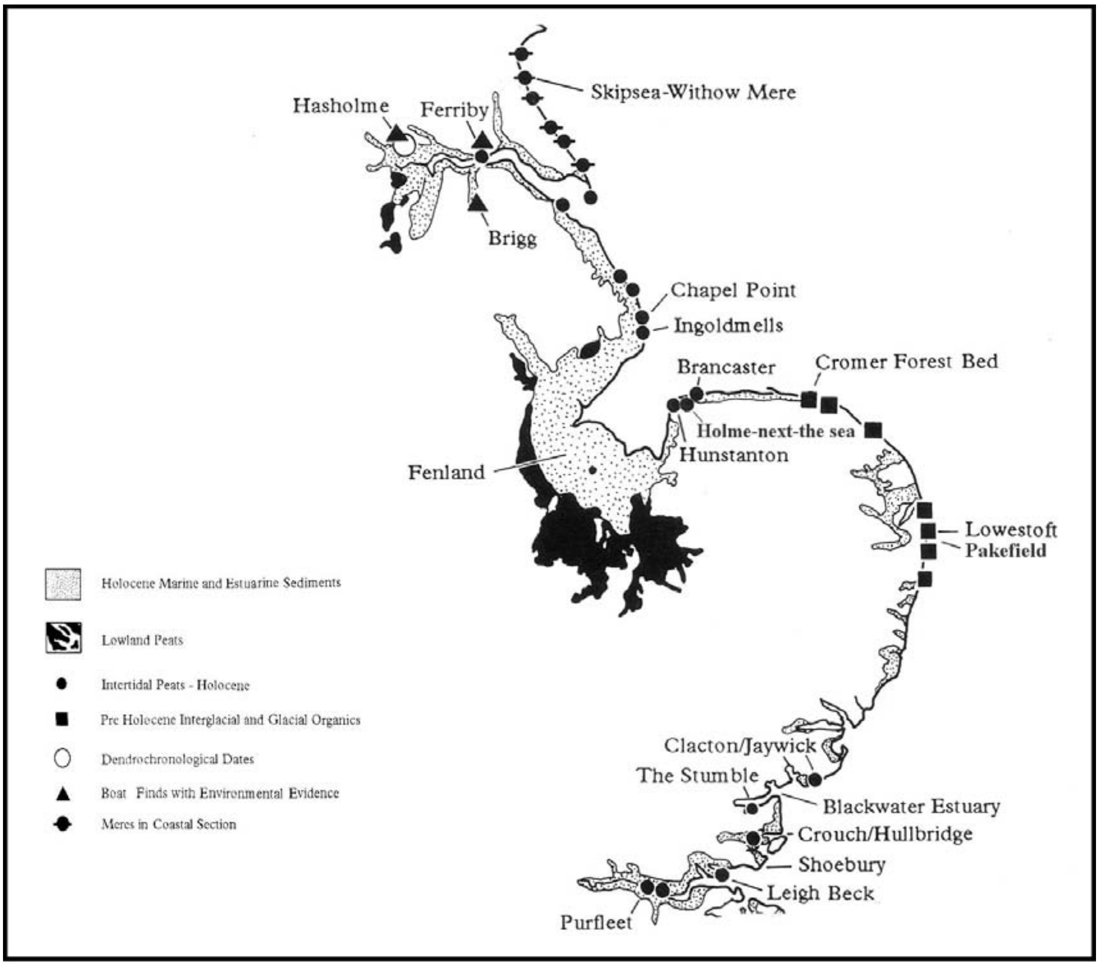


Figure 8: The Midlands coastline showing major sites (adapted and updated from Bell 1997)

The complexity of the crustal, sedimentary and anthropogenic interactions point up the necessity for a generalisation on which to base our understanding of intertidal archaeology. A primary model was introduced by Allen (1997a) summarising coastal change by focussing on different types of coastline and their typical stratigraphy. The model shows a number of typical situations of coastal erosion/aggradation under different sea-level trends. The example most relevant to the Midlands throughout the Holocene is the lowland coast under rising sea level, showing both the normal retreat producing successive landward occupation zones, and the land claim retreat model where sea wall construction produces a stepped sequence. The real life results are always subject to variation within the basic model, but a typical pattern of deposits is illustrated in Figure 9.

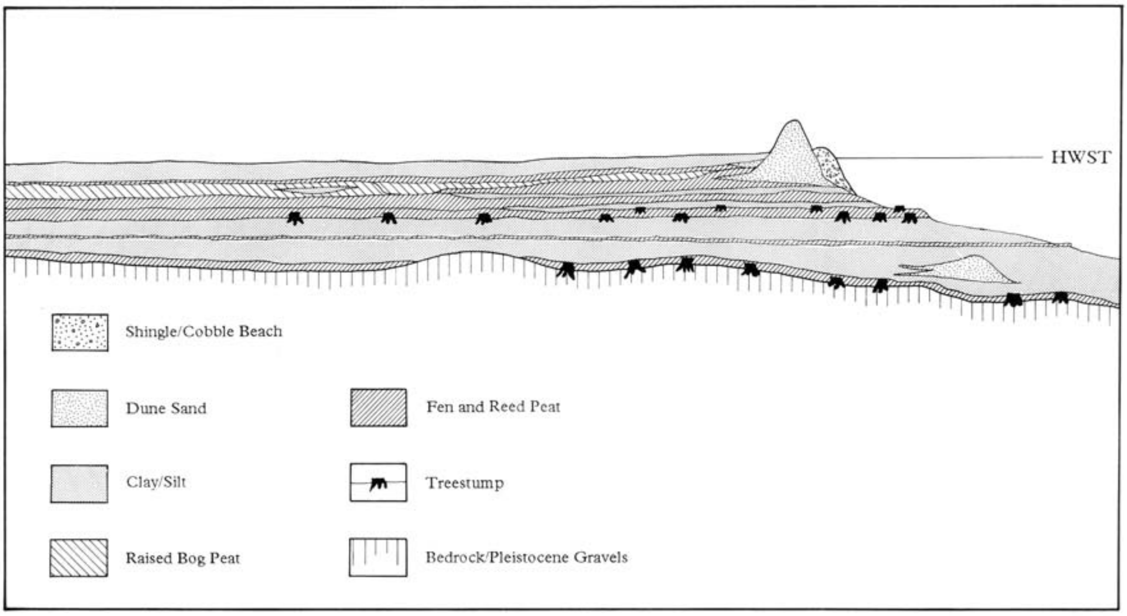


Figure 9: An idealised transect across a Holocene coastline showing typical relationships (from Bell 1997, fig 28)

Humberside

Humberside as an archaeological area (Figure 10) is dominated by the river Humber and its estuary. The interplay between this sediment source and sea level throughout the Holocene has defined the types of preservation that occur. At some point before 6970+/-100 BP (IGS C14/99, calibrating to 7970-7610 cal BP at 95.4% probability using Oxcal 3.10), when sea level was at -9 m OD, the river Humber reached equilibrium with sea level and peat formed beneath the Market Place in Hull (Gaunt and Tooley 1974). Thereafter, lower parts of the drainage system became increasingly estuarine (Halkon 2007; Van de Noort and Ellis 1995) leading to widespread burial of archaeological remains under or within alluvial deposits. Mean High Water of spring tides in the Humber had reached -9 m OD by 7500 cal. years BP (Figure 11) and was at current OD by 4000 cal. BP (Long *et al* 1998).

The stratigraphy of the Ancholme valley gives a good example of the progressive burial of archaeology by alluvium. It contains a basal peat from which Bronze Age finds including a trackway have been recovered, followed by brackish water clay which contained various boat finds (Smith 1958). At Melton, a hurdle trackway was excavated dating around 3000 BP with laid timber being separated by alluvial clay suggesting rebuilds in a changeable environment (Crowther *et al* 1990); and coin evidence has now led to the realisation that deep alluvium overlies Roman archaeology in the Hull valley (Didsbury 1990).

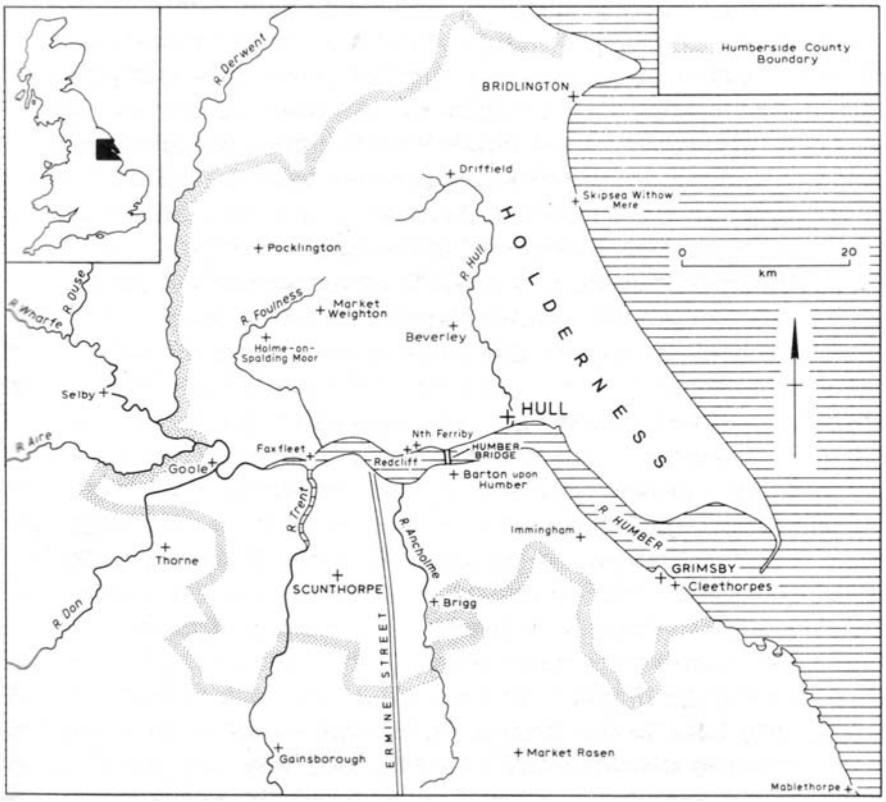


Figure 10: The Humber region (from Ellis and Crowther 1990)

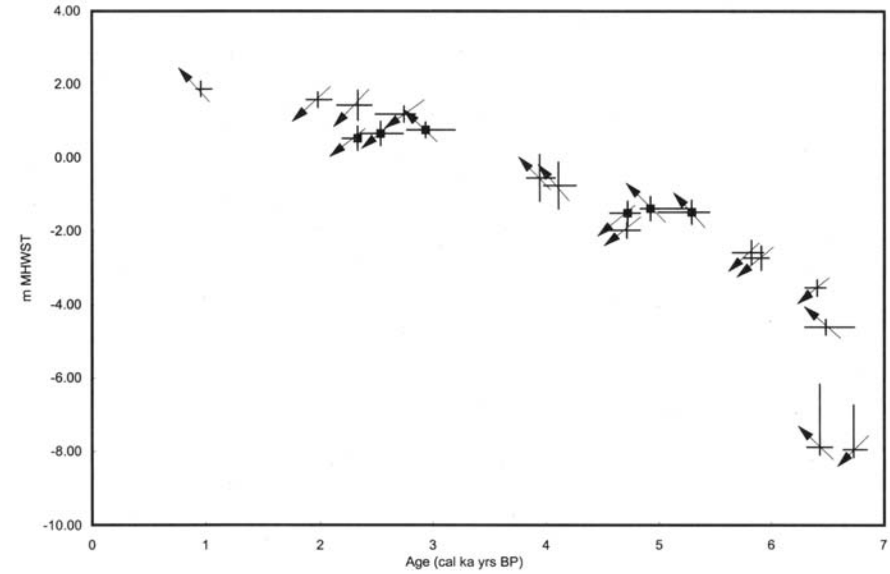


Figure 11: Age altitude graph of sea-level index points from the Humber estuary. The y-axis error bar is equivalent to the indicative meaning of the dated index point and the x-axis bar to the two sigma calibrated age range of the dated sample. An upward pointing arrow denotes a positive sea-level tendency, a downward pointing arrow a negative sea level tendency. Basal peats are denoted by a solid square; all other index points are from intercalated or surface peats (from Long et al 1998; reproduced with permission from Sage Publications)

In the next section, we will examine the practice of warping, which exploited the extraordinary sedimentary parameters of the Humber to generate new high quality agricultural land. These same characteristics provide the central mechanism for intertidal archaeological preservation. The dominant flood currents in the estuary mean that there is a net input of material from the North Sea and suspended sediment concentrations of 2000 ppm are common. This represents 3 million tonnes of sediment in the whole estuary, and explains the strong accretionary tendency found at many sites. As a result of the process, the Humber has decreased in size by 14% between 1851 and 1966 (Pethick 1990).

The main archaeological finds have been boats. Three have been salvaged at North Ferriby since 1945 (Wright 1990; Wright and Churchill 1965). Along with the Brigg 'raft' (McGrail 1981) this makes the Humber by far the most significant area in Northern Europe for contributing to our knowledge of early plank boat building (McGrail 1990). In geoarchaeological terms, the main challenge is to understand the sedimentary environment in which the boats were deposited. This is not easy, since the estuary in general is characterised by discontinuous and interdigitating beds of peat and poorly sorted clay-silts, with a high variability of sediments. Even within 150 m of the Ferriby boat site, for example, tufaceous marl is found under the peat with a reddish oxidised alluvium overlying. However, combining sedimentary and other environmental data led Buckland *et al* (1990) to conclude that the Ferriby boats were abandoned on saline mudflats below contemporary high tide, probably in a shallow creek on the foreshore.

The Brigg 'raft' was found in the Ancholme valley (see Figure 10). It was not actually a raft but a flat-bottomed boat (Figure 12) in use around 2820 - 2860 cal. BP (the calibration performed on an average date of 2597±117 derived from Q1199, Q1200, Q1255-1263 and Q1499-1500, see Switsur 1981) A borehole made in the north western end of the main boat trench recorded the following stratigraphy:-

0 - 115 cm	Made ground
115 - 125 cm	Certainly disturbed brecciated clay and peat.
125 - 127 cm	Possibly undisturbed laminated reedswamp peat with some clay content.
127 - 130 cm	Undisturbed brown laminated reedswamp peat with possibly some clay content but no silt.
130 - 135 cm	Becoming more clayey and grey brown in colour.
135 - 170 cm	Mottled, grey brown (iron-stained) and silty clay with monocotyledonous leaves or rhizomes
170 - 215 cm	Softer, grey silty clay with monocotyledonous leaves or rhizomes. Borer stopped by rock.

Soil description and particle size analysis was carried out on 4 sediment samples from the raft and concluded that it was deposited in very slow water (Hood 1981). Combining the various forms of evidence, the raft appears to have come to rest on a mudflat in recently formed marginal saltmarsh and then been covered by further sediment (Smith *et al* 1981).

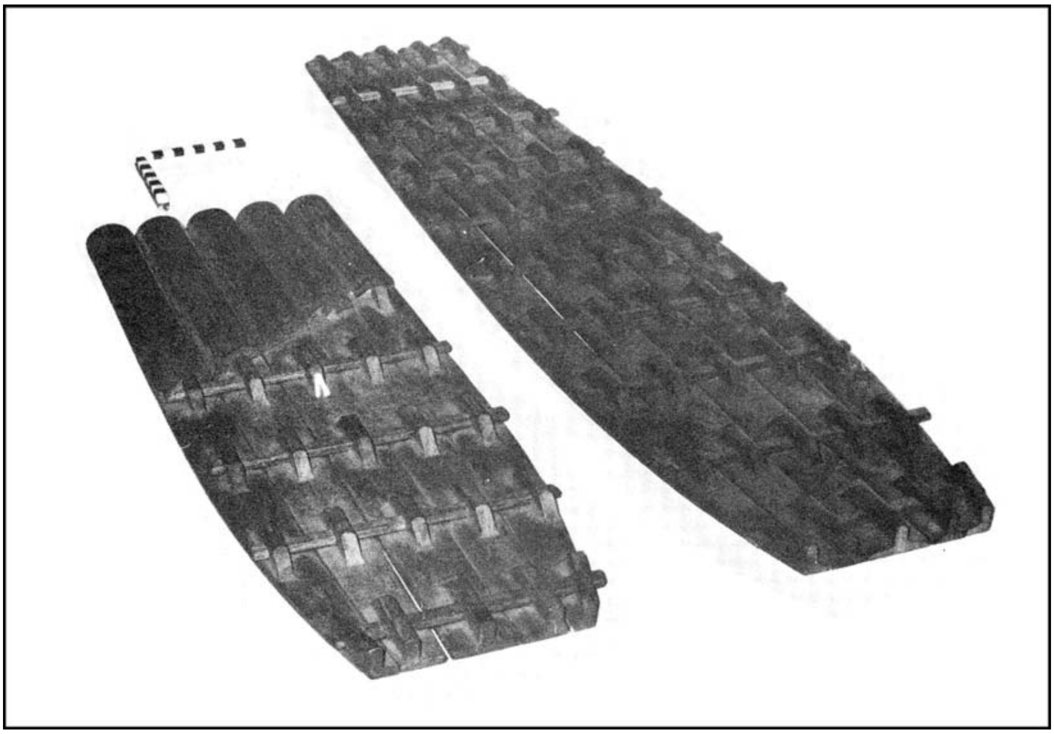


Figure 12: Two scale models of the Brigg 'raft' from Lincoln Museum. Scale is in centimeters (from McGrail 1981)

More extensive geoarchaeological work was carried out for the Hasholme boat excavations (Figure 13). This log boat was found close to the river Foulness near Holme-on-Spalding Moor (see Figure 10) in a simple sequence of clay-peat-clay. Colours used to subdivide the clay during excavation turned out to be due to oxidation differences. The sequence was examined in detail using reflected light microscopy in order to identify the origin and depositional history of the clay and relate it to the boat, identify any marine transgression occurring in the sequence, and draw inferences on the rate of deposition.

The study, together with air-photograph and diatom evidence, suggested that the boat had been deposited in the north side of a channel, in brackish water of varying depth but with distinctly freshwater deposits at the base. The clayey material in which the boat was found appears to have been formed by marine transgression around 800-540 BC which eroded the top of the peat before depositing the clay in increasingly deep then shallowing water. The boat was deposited coincident with the period of deepest water, after which the creek dried up in the 1st millennium AD (Millett and McGrail 1987; Jordan 1987). The fringes of the estuarine areas provided bog iron-ore, and at Welham Bridge, 5 tonnes of iron slag were excavated – enough to have produced 800 bars of trade iron (Halkon 2007).

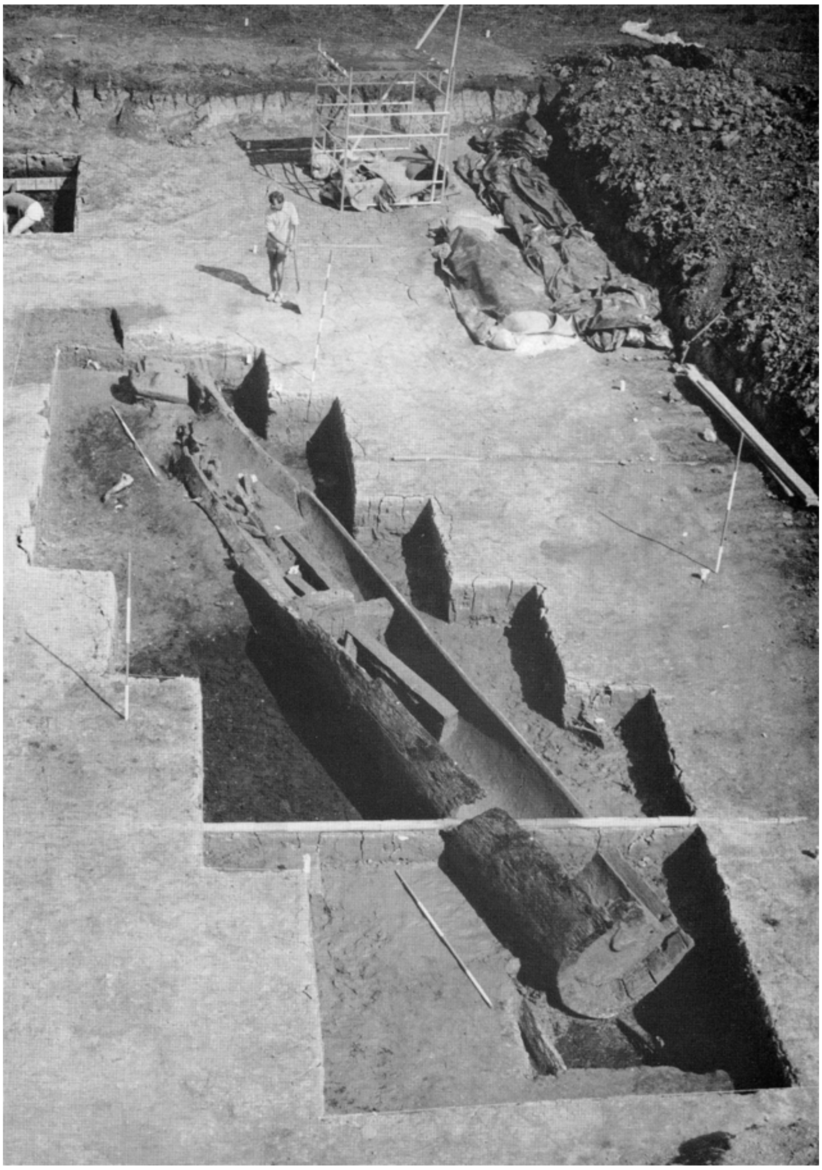


Figure 13: The Hasholme logboat (from Millett and McGrail 1987; reproduced with permission from the Archaeological Institute)

Lincolnshire and the Wash

In Lincolnshire, a narrow band of low lying coastal land occurs between the sea and the higher ground formed by the Lincolnshire Wolds (Figure 14). This is the Lincolnshire Marsh, where salt manufacture has been carried out to some extent throughout history and on an industrial scale during the last millennium. Stukeley visited the area in the eighteenth century and wrote "*in this county upon the sea shore they made salt formerly in great abundance. The hills all along the sea-bank, the remains of these works, are still called salt hills.*" (Stukeley 1723).

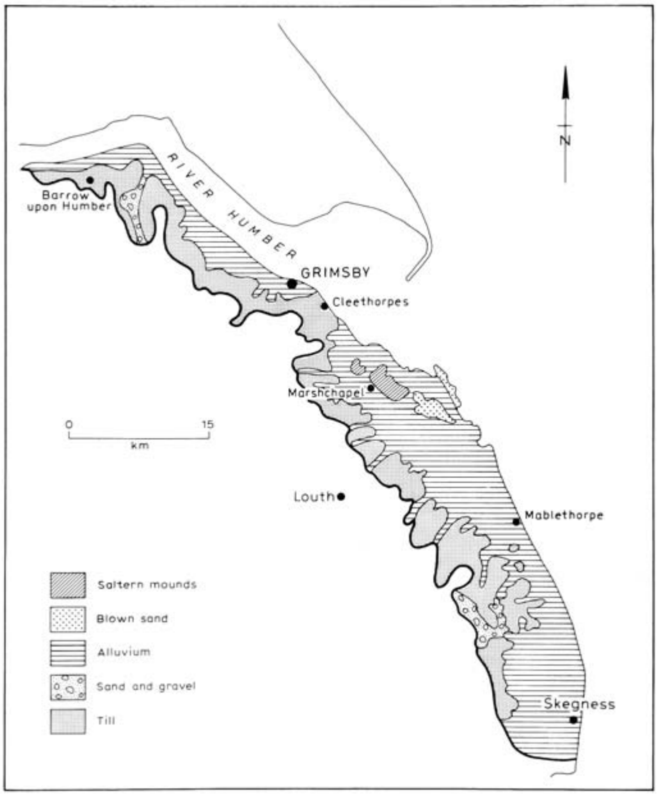


Figure 14: The Lincolnshire Marsh, geology and saltern locations (from Ellis 2001; © Humber Wetlands Project; reproduced with permission of Wetland Archaeology and Environments Research Centre)

The Lincolnshire marsh is underlain by hummocky boulder clay forming promontories where it rises significantly above the sea level (Swinnerton 1931). The uneven surface is covered first by a peat containing the remains of trees, and then by a sequence consisting of saltmarsh clay, freshwater clay and an upper peat layer. Tidal silts and windblown sands variably cap this basic stratigraphy (Figure15) and the relatively flat, sandy shore eroded from the soft layers was ideal for salt making (Robinson 1970).

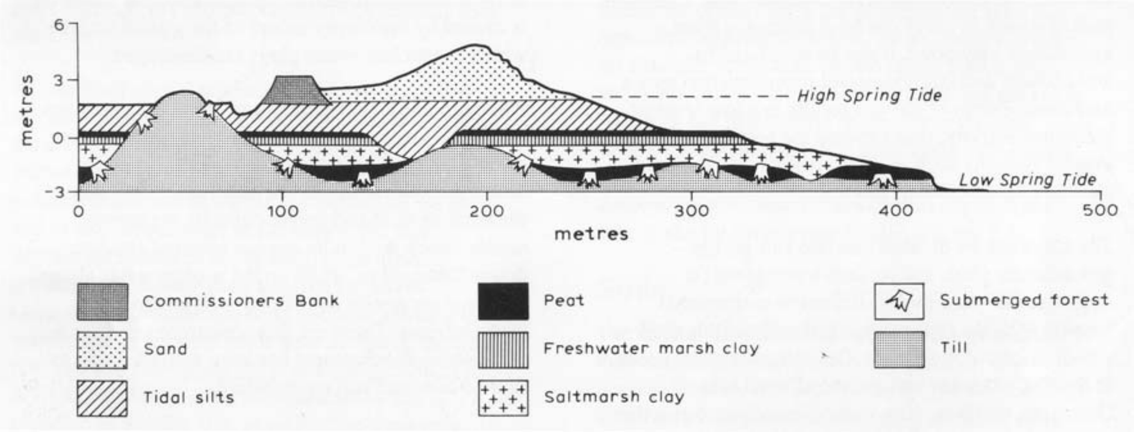


Figure 15: Typical section of the coastal stratigraphy of the Lincolnshire Marsh (from Ellis 2001 based on Swinnerton 1931; © Humber Wetlands Project; reproduced with permission of Wetland Archaeology and Environments Research Centre)

Salt making has clearly been carried out here since prehistoric times, as shown by the sites at Tetney (Palmer Brown 1993) and Hogsthorpe (Kirkham 1981). These sorts of early sites are rare, however, probably because they would have been flooded by gradual marine incursion during Iron Age and Romano-British times. Tetney (Palmer Brown 1993) is an unusual example of a Bronze Age salt making site preserved in the middle of Medieval sites. Roman evidence is patchy, but the presence of the word 'Salinae' near Skegness on Ptolemy's map of Britain (Strang 1997) suggests that it was important (Thomas and Fletcher 2001). The only Anglo-Saxon evidence for salterns is from the excavations at Marshchapel (Fenwick *et al* 2001). Pattison and Williamson (1986) carried out an auger survey to a depth of 5 m and found the mounds to be a mix of marine silt, shell, ash and brick. These generally overlie firm to very firm, slightly silty, commonly laminated clays representing the topmost deposits of the estuary flats, sometimes containing soft peaty clay seams.

It was during Medieval times that salt making really started to leave a significant mark on the landscape. The basic production method consisted of collecting the saline mud left behind after high spring tides. This silt, known as 'muldefang' was scraped onto wooden sledges, heaped up and protected from the rain ready for extraction (Rudkin and Owen 1960). Written accounts are rare, but similar processing in Scotland was described as follows:-

> "*A pit is next prepared, about 18 feet long, 4 feet broad and 2 feet deep, which is lined with clay. In the bottom of this pit is placed a layer of peats….covered over with turfs and the pit is filled with the collected sleech to form a kind of basin. The basin is filled with water which…pervades the mass, and oozing through the filter of the turf, carries with it the solution of salt. Having reached the clayed bottom ...issues for a spout into a reservoir…the strength of the brine is tried from time to time by floating an egg* (Duncan, 1812)."

After the filtration (Figure 16), the resultant strong brine was boiled down, possibly using peat as a fuel. Many of the monastic houses that held rights to salt production also held turbary rights elsewhere (Fenwick 2007).

Figure 16: Excavation of a filtration unit and collection vat (from McAvoy 1994; reproduced with permission from the Society for Medieval Archaeology (www.maney.co.uk/journals/ma))

The desalinated silt was thrown up to produce the mounds, which now form an extensive network in the coastal zone (Figure 17).

Figure 17: Saltern mounds at Wainfleet St Mary from the air (from McAvoy 1994; reproduced with permission from the Society for Medieval Archaeology (www.maney.co.uk/journals/ma)

At Wrangle Toft (Bannister 1983) features were made of blue clay which was thought to leave the salt white, where red clay left it grey (Brownrigg 1749). The scale of the salt hills can be determined from the dimensions of this site which was around 12 acres in size and rose to an average of 4.5 m OD, although it may have taken in more than one mound. Another feature of the saltern sites is that briquetage was left behind on an enormous scale. For example, Swinnerton (1931) found twelve circles of saltworking debris (about 20 - 40 m diameter and 0.6 m deep) between Seabank Villa and Skegness. At Hogsthorpe, the sections all exposed thicknesses of ploughed briquetage overlying hearths (Figure 18).

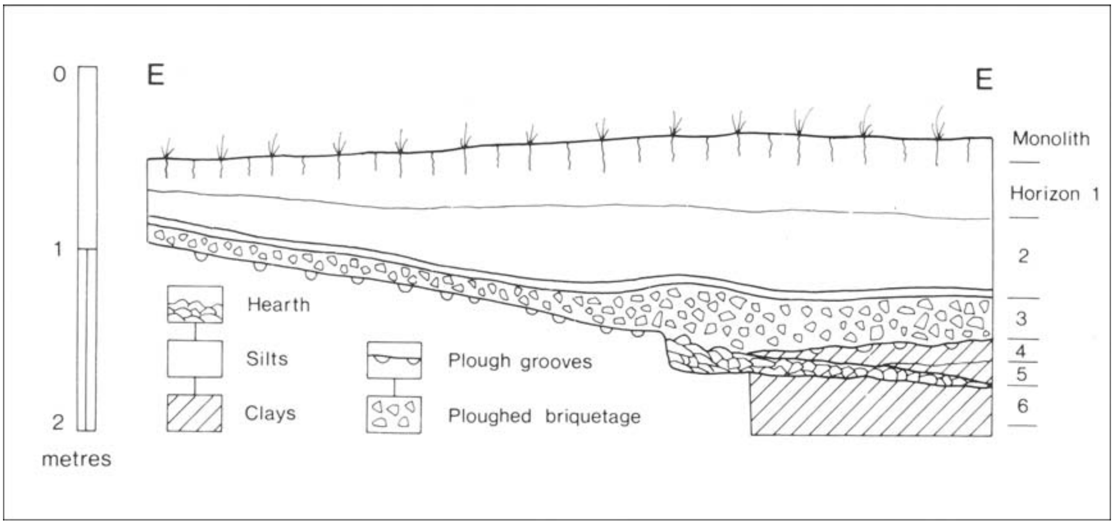


Figure 18: Section and soil profile at Hogsthorpe (from Kirkham 1981; © Society of Lincolnshire History and Archaeology)

The section in Figure 18 had the following description:-

1 Dark brown to brown (7.5YR 4/2) silty clay; moderately developed medium subangular blocky structure; rare round chalk stone; calcareous (added lime); clear boundary.

2 Grey (10YR 5/1) and strong brown (7.5YR 5/6) prominently mottled silty clay; strongly developed coarse angular blocky becoming prismatic with depth; ped faces greyish brown (10YR 5/3); stoneless; slightly calcareous becoming non-calcareous with depth; very porous; fine macropores; some relic platy structure within peds; abrupt boundary.

3 Dark grey to dark greyish brown (10YR 4/1.5) clay loam; moderately developed medium subangular blocky structure; common reddish brown (5YR 4/4) root mottles and red (10R 5/8) briquetage fragments; slightly calcareous; distinct sand grains present (contrast layers above and below); abrupt boundary.

4 Brown (7.5YR 5/2) ped faces, interiors mottled reddish brown (5YR 4/3) and grey (5YR 5/1) silty clay; moderately developed coarse angular blocky structure; moderately porous; fine macropores; stoneless; slightly calcareous; sharp boundary.

5 Dark grey (10YR 5/1) clay loam; weakly developed medium subangular blocky structure; common fine yellowish red (5YR 4/6) root mottles and black (5YR 2/1) inclusions of carbon; slightly stony; slightly calcareous; sharp boundary.

6 Yellowish red (5YR 5/1) and grey (N 5/0) mottled clay; weakly developed coarse angular blocky structure; common very fine pores, slightly stony, some reddish yellow (7.5YR 6/8) patches of weathered micaceous sandstone giving more loamy texture; slightly calcareous.

Figure 19: Excavated section through Ingoldmells 6 – a saltern mound. (from Ellis et al (eds) 2001; © Humber Wetlands Project; reproduced with permission of Wetland Archaeology and Environments Research Centre)

The salt industry not only encouraged settlement in the area generally, but it allowed for new settlement in this marginal zone by leaving behind the elevated spoil heaps. Rudkin and Owen (1960) quote from text on Haiwarde's map of 1595 which describes this dynamic process:

> "*The rounde groundes at the easte end of Marsh Chappell are called Maures and are first framed by laying together of great quantities of moulde for the making of salte. When the maures growe great the saltmakers remove more este and come nearer the sea and then the former maures in some fewe yeres good pasture groundes.*"

The huge scale of the industry is highlighted by Pattison and Williamson's (1986) calculation that, even with modest assumptions, the salt hills represented 23 million cubic metres (roughly tonnes) of waste silt. Ultimately, the wealth generated from this activity

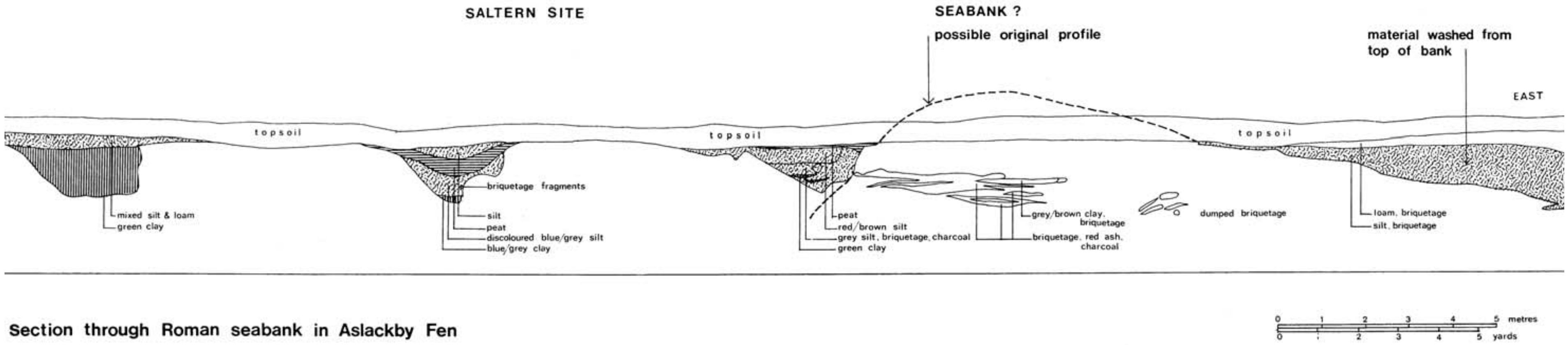


Figure 20: Simmons' (1980) section through the Roman seabank at Aslackby fen (reproduced with permission from the Society of Antiquaries)

allowed for the construction of high status churches (Morris 1989) and left behind a complete distinctive settlement landscape (Grady 1998) before declining after the seventeenth century when it became uneconomic (Brookes *et al* 1990).

Salterns have also played a significant part in geoarchaeological studies of the Wash, especially with regard to the location of the old coast. Simmons (1980) used a variety of geographical and archaeological data to determine the Iron Age and Roman coastline. The area is rich not only in salt making sites and briquetage, but also banks and dykes which together can help deduce the position of the coast at a given moment in time. For example, the section through the Roman seabank at Aslackby Fen (Figure 20) shows the *Mifendic (*an enigmatic possible waterway running parallel to the Car Dyke) on the westernmost side, with briquetage-filled pits close to and abutting the sea bank. Simmons argued that salt making had been going on just inside the sea bank at this point, and that briquetage had been later eroded along with silts either side of the bank.

Numerous other Fenland salt making sites have been studied (Lane and Morris 2001) and geoarchaeological work has contributed both to our knowledge of this important activity, and to the archaeology of the area in general (Figure 21). At Cowbit, for example, excavation revealed feeder channels bringing in the brine, as well as storage tanks and pits. However, complex muds sandwiched the site, and natural was difficult to define because silts and sands deposited in the Middle Ages overlay identical deposits from the Bronze Age. French (2001a) found an immature leached and reworked soil on the Iron Age surface, but the micromorphology did not give any clues as to past land use. Similar soils were found at Morton Fen, and Blackborough End, Middleton (French 2001b).

Accretion of sediment has been continuously active in the Fenland area as a result of the erosion of the Yorkshire - Lincolnshire coastline, and this has led to significant land claim from the intertidal zone of the Wash (Pye 1995). The reclamation of the Wash has been going on since Saxon times with the largest proportion occurring in the 14th to 18th centuries AD. Sea wall structures are sometimes many metres tall, and have mostly been archaeologically neglected (Allen 1997b).

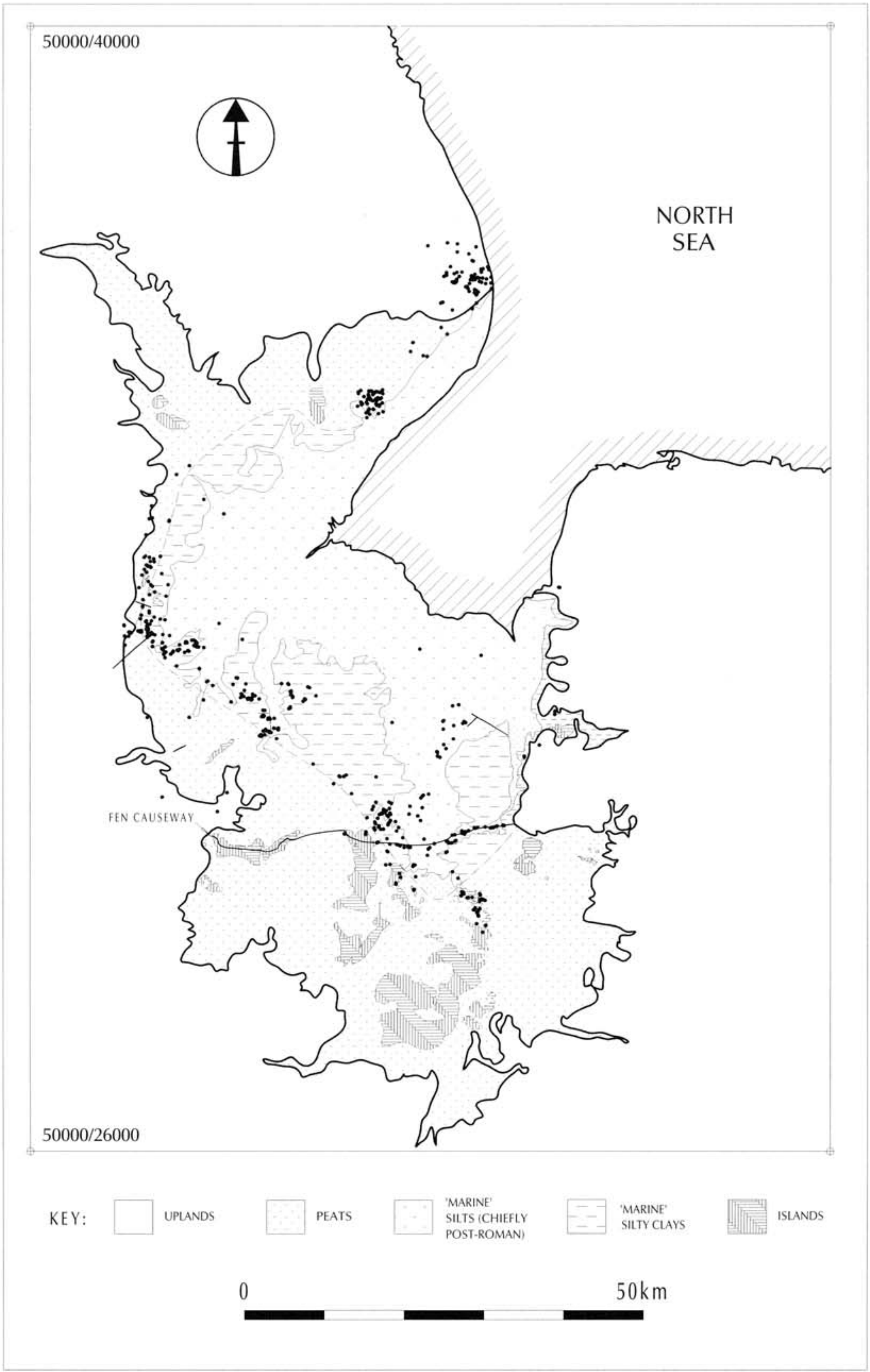


Figure 21: Iron age and Roman salterns in the Fenland (from Lane and Morris 2001; ©Heritage Trust of Lincolnshire)

East Anglia

Pakefield

For many years, archaeological finds have come from the East Anglian coastline (Allen *et al* 1997) but they were mostly unstratified until the recent discovery of flints from the Cromer Forest-bed Formation at Happisburgh, Norfolk and Pakefield, Suffolk (Wymer and Robins 2006). The Cromer Forest-bed consists of organic-rich interglacial sediments laid down within channels and on the floodplains of rivers draining central and eastern England around 450,000 years ago (Parfitt *et al* 2005). Lithostratigraphy, palaeomagnetism, amino acid geochronology and biostratigraphy indicated that the artefacts are about 700,000 years old which would make them the earliest evidence for human presence north of the Alps (Parfitt *et al* 2005). Detailed micromorphology and isotope geochemistry of the 'Rootlet bed' at Pakefield suggest an interglacial notably warmer than today and having a pronounced soil moisture deficit for some of the year, roughly equating to a Mediterranean climate (Candy *et al* 2006). Two of the flints came from this bed, but the majority came from the lag gravel partially overlying the rootlet bed, known as the 'Unio bed'. This material is found at the base of the laminated silts that fill the channel cut into the overbank sediments.

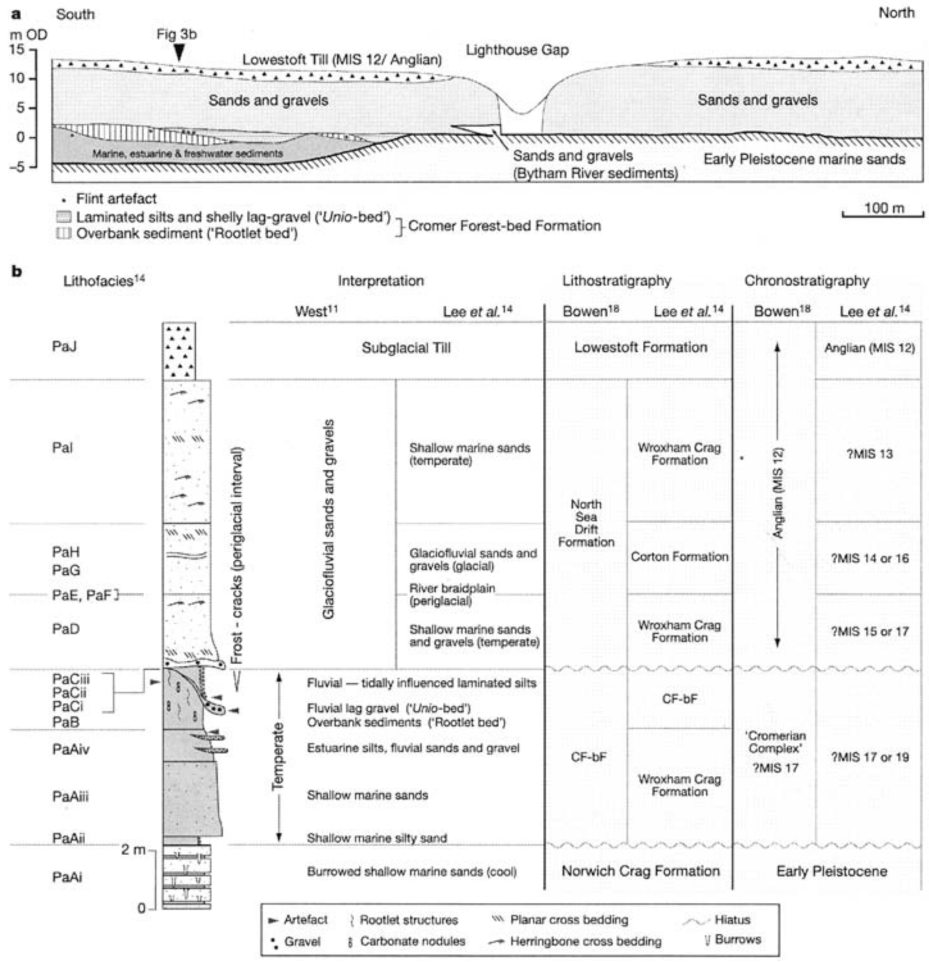


Figure 22: Stratigraphical context of the Pakefield artefacts (from Parfitt et al 2005;

reproduced with permission of Nature Publishing Group)

Holme-next-the-Sea

In 1998, the excavation of a unique monument consisting of an upturned tree stump inside a ring of wooden uprights (Figure 23) at Holme-next-the-Sea on the North Norfolk Coast (see Figure 8) led to an unprecedented level of scientific examination of the associated evidence including a number of geoarchaeological studies.

Figure 23: The wooden circle at Holme before excavation began

The uprights appeared to be buried in a trench, the outline of which was sometimes clearly defined by colour changes in the intertidal sediment and sometimes not. These colours were due to different redox potentials affecting the iron salts in the sediments, and could clearly be changed by exposure to the air. This led Canti (2003a) to question whether a trench-like morphology could arise from the presence of the posts rather than a true trench being cut – a view that would explain the areas where no trench edge could be found. Consideration was given to variation in starting characteristics (e.g. texture), acquired characteristics (e.g. compaction), and whether the presence of the timbers themselves could have played a part. On balance however, it was concluded that the oxidation and reduction differences appeared to be following the cut of a trench, and the areas where this edge could not be found (e.g. much of Figure 24) must have been affected by some other process. This was confirmed when French (2003b) was able to clearly identify the trench cut lines in some of the micromorphological slides, mainly by differences in the density of the fill versus the surrounding natural, but also, in some cases, by the natural having distinct microlaminations.

Figure 24: A view of the main trench including timbers (photo Jen Heathcote)

Additional geoarchaeological work was carried out on the mineralogy and X-radiography of the sediments. Linford (2003) examined the magnetic susceptibility and concluded that the presence of the iron sulphides suggested that little weathering had taken place within the near-surface sediments. Canti (2003b) made X-radiographs of slices of sediment and related different types of features to either cracks or rust impregnated root holes.

Essex and the Thames estuary

The geology of the Essex coastline is dominated by soft rocks, with chalk outcrops occurring only in the northwest and south of the county. The area is extensively covered by boulder clay carved into channels and terraces by the Thames. The main visible archaeological features are salt hills, duck ponds and oyster pits (Buckley 2000). However, the basic geological layout coupled with Holocene sea level rise also means that soft sediment and peat layers are well preserved and the area is very rich in buried surfaces.

The coast between the Stour and Blackwater has long been a recognised area for collecting artefacts. Some of the more significant finds are Neolithic, Beaker and grooved ware found on the submerged surface, and the wooden paddle found at Lion Point. The sites were established on the shores of natural harbours formed by creeks, and the finds are often associated with firm grey or greenish silt that suggests liability to flooding before abandonment. Peat preserves the old land surface in places, and where it does, there is usually an underlying clay about 7.5 - 10 cm thick. The sea-level history is of elevation followed by a phase of subsidence (Warren *et al* 1936).

A major survey of the area was carried out in the 1980s by Wilkinson and Murphy (1995). The basic sequence they recorded for the Essex coast sites is shown on Figure 25.

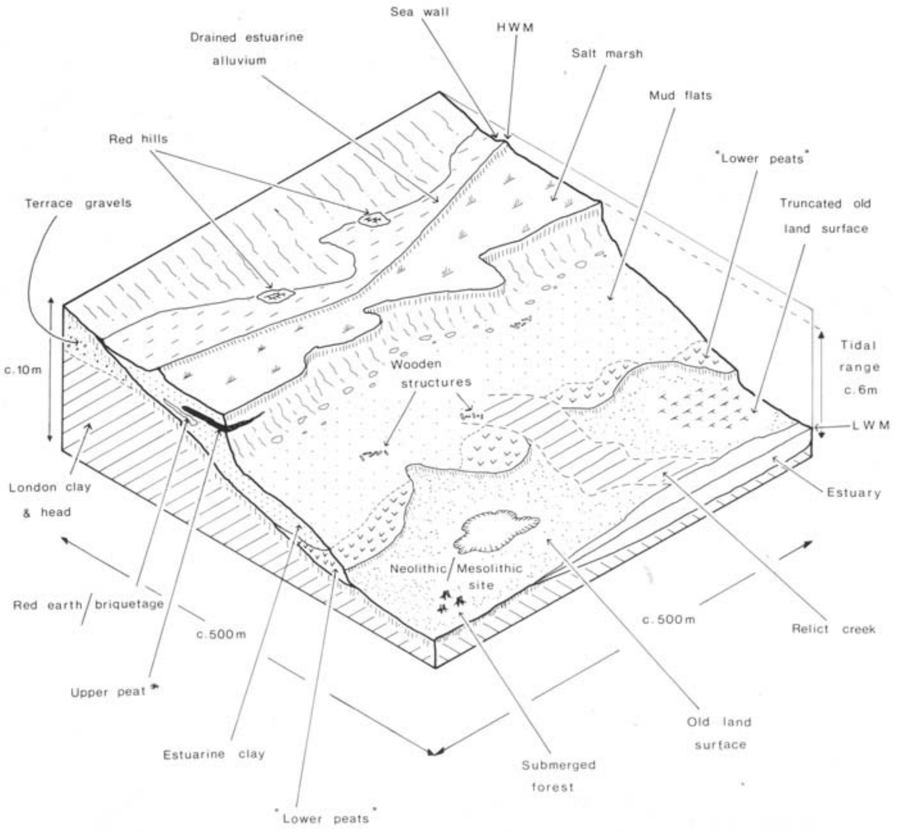


Figure 25: Typical block of stratigraphy from the Essex estuary (from Wilkinson and Murphy 1995; © Essex County Council produced with permission)

London clay and head derived from it form the geological foundation. The clay is stiff dark or blueish grey weathering to brown, on top of which the head deposit consists of disturbed London clay with gravel sometimes included. The old land surfaces and palaeosols occur on the London clay, and a peat layer generally referred to as 'The Lower Peat' is either developed or deposited on that old surface. The 'Estuarine clay' is a soft or slightly firm grey clay deposited on top of the peat. Occasional breaks in succession are marked by Upper Peat or soils. The foreshore consists of mudflats and the upper surface of the estuarine clay forms a saltmarsh.

The main site types of the area are salterns but these were not surveyed in detail, having been examined by Fawn *et al* (1990) (see below). After salterns, the most widepsread intertidal exposures consisted of either Mesolithic and Neolithic dryland sites with a scatter of occupation debris, or wooden structures - hurdles, trackways and platforms mostly Bronze Age or Iron Age. The sites are now widely disturbed by burrowing organisms.

Hullbridge (Crouch site 4) is typical of the north bank of the Crouch. The generalised stratigraphy is shown on Figure 26.

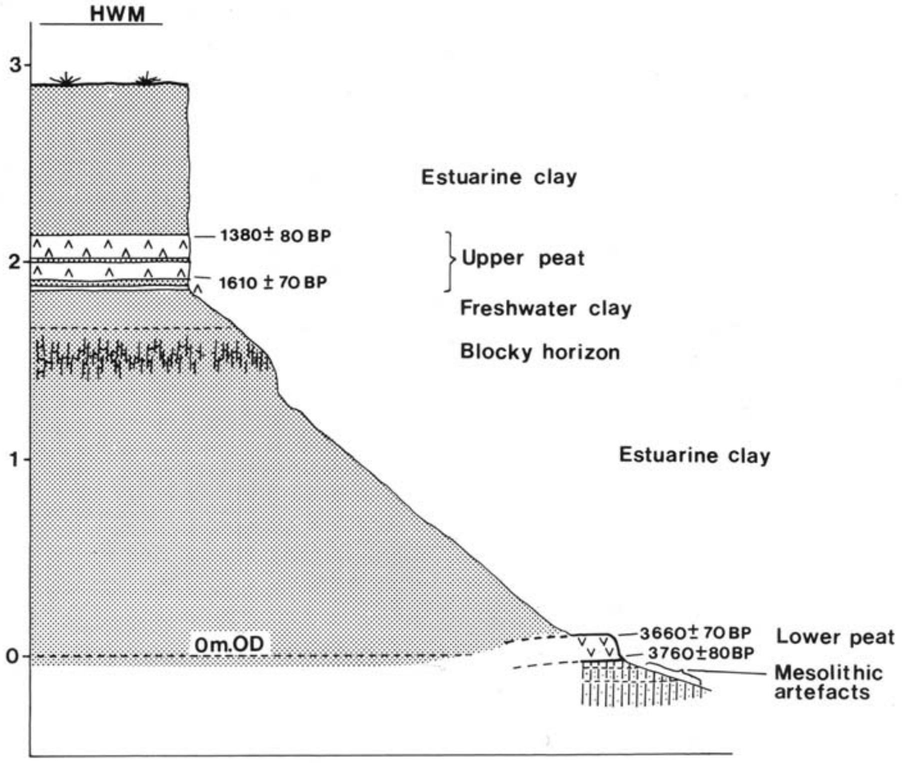


Figure 26: Generalised section at Hullbridge (from Wilkinson and Murphy 1995; © Essex County Council produced with permission)

Mesolithic artefacts were found below the Lower peat on the mineral substrate which was subsequently inundated resulting in the deposition of 1.5m of estuarine clay. Augering and examination of similar sites allowed the reconstruction of the old Crouch channel and land surface (Figure 27).

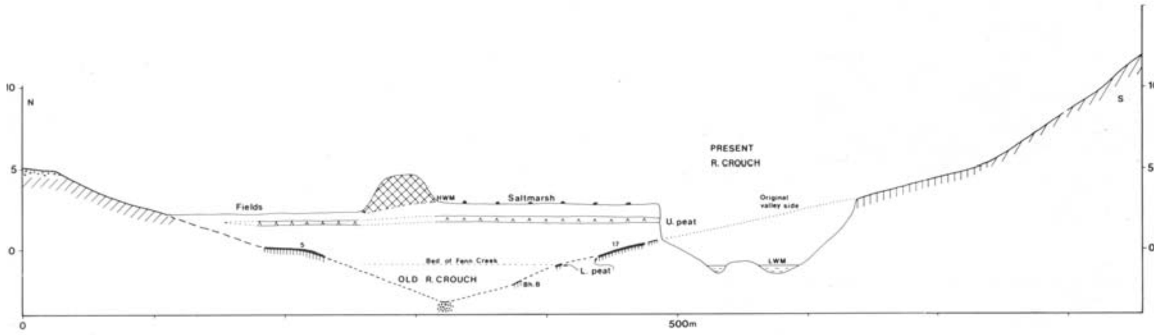


Figure 27: Section across the Crouch valley at Hullbridge, showing the old Crouch channel (from Wilkinson and Murphy 1995; © Essex County Council produced with permission)

One of the richest habitation sites excavated during the survey was Rolls Farm (Blackwater Site 18), which included Bronze Age wooden structures, late Iron Age or Roman Red hills and a deep sequence comprising more than 3 m of estuarine and saltmarsh clay overlying 'Lower Peat'. This in turn sat on a buried soil from which artefacts were recovered at a density of 10 per m^2 for struck flints, and 1 - 2 per m^2 for pottery.

At Rettendon (Crouch site 1, Page 133), a Later Bronze Age brushwood platform was found outcropping from the bank of the Fenn Creek at the level of the buried soil. This was the location where two skulls of probable Bronze age date were found in 1977 (Wilkinson and Murphy 1995:132). The platform had been built to protrude into and perhaps cross the creek. A number of wooden structures were exposed at the Stumble (Blackwater site 28, page 150), at the western end of the Neolithic site. An Iron Age hurdle bridge was the most striking of these - it was approximately 3.5 m x 0.8 m, made of oak and hazel, and appeared to make a crossing point for an infilled creek.

An oak paddle entirely enclosed in clay and dated 3204 - 2974 cal. BP (BM 2339) was found protruding from a bank at Burnham-on-Crouch (The Canewdon Paddle, Crouch Site 56). The sedimentary sequence in which the paddle was found was as follows:-

0 - 133cm	Soft grey unripened clay, slightly firmer above.
133 - 141 cm	Context 97. Dark grey brown fibrous peat, dated 180 ± 80 BP.
141 - 146 cm	Soft grey clay.
146 - 166 cm	Black, 7.5 YR 2.5/0 firm silty clay with pale grey variegations apparently along root holes. Many fine vertical root holes. Black staining may be a result of translocation of organic matter from context 79 above, or from reduction of iron. Merges down into:
166 - 208 cm	Dark greyish brown, 10YR 4/2, firm silty clay, some vertical cracks and a tendency towards prismatic structure. Common bright orange coatings, sometimes segregated into vertical bands, coat ped and crack faces. Merges down into:
208 -262 cm	Dark yellowish brown, 10YR 4/4 and grey 10YR 6/1 firm silty clay with some prismatic structures and iron oxide sheets and coatings on ped and crack faces as in the layer above. Merges down into:
262 - 287 cm	Greyish brown 10 YR 5/2 clay. Smooth soft and very sticky; without structure. Top of paddle at 0.32m OD. Immediately to west and east of shaft occurred a band of drifted plant material (Context 98).This was more common to the west where the strands appeared to be roughly parallel to the shaft and had probably accumulated against it.
Below 287	The sediments became slightly coarser, and if exposed, would probably resemble the bedded silts upstream.

The clay layer containing the paddle (262 - 287 cm) also contained drifted plant material and appeared not to have undergone the pedogenesis that produced blocky structures and iron coatings in the layer above it.

The Hullbridge survey showed that, with sea level as much as 45 m below the present day, large areas of undulating lowland were available for occupation during the Mesolithic and the sites found during the survey represent a sample only. The sites suggest inland settlements of mobile communities with a terrestrial resource base. Coastal sites such as shell middens will have been long lost to sea level rise. By the Neolithic (ca. 5500 BP), sea level would have almost reached today's level, with the high water mark roughly corresponding to the modern low water mark. The intertidal area would therefore have been dry land. The later Neolithic was characterised by increased woodland and reduced settlement. Around Clacton and Dovercourt, a coastal barrier may have developed and protected the area, judging by the brackish water deposits overlying the buried soil. The Bronze and Iron Ages were periods of rapid settlement expansion, and the large numbers of intertidal wooden structure must be viewed in this context. However, their numbers may also be related to preservational conditions which clearly deteriorated after the Late Iron Age due to slowing of sea level rise. By Roman times there is evidence for drying out of the sediments which could be due to regression or drainage. This was, however, punctuated by flood events, perhaps storm surges, which may have led directly to abandonment.

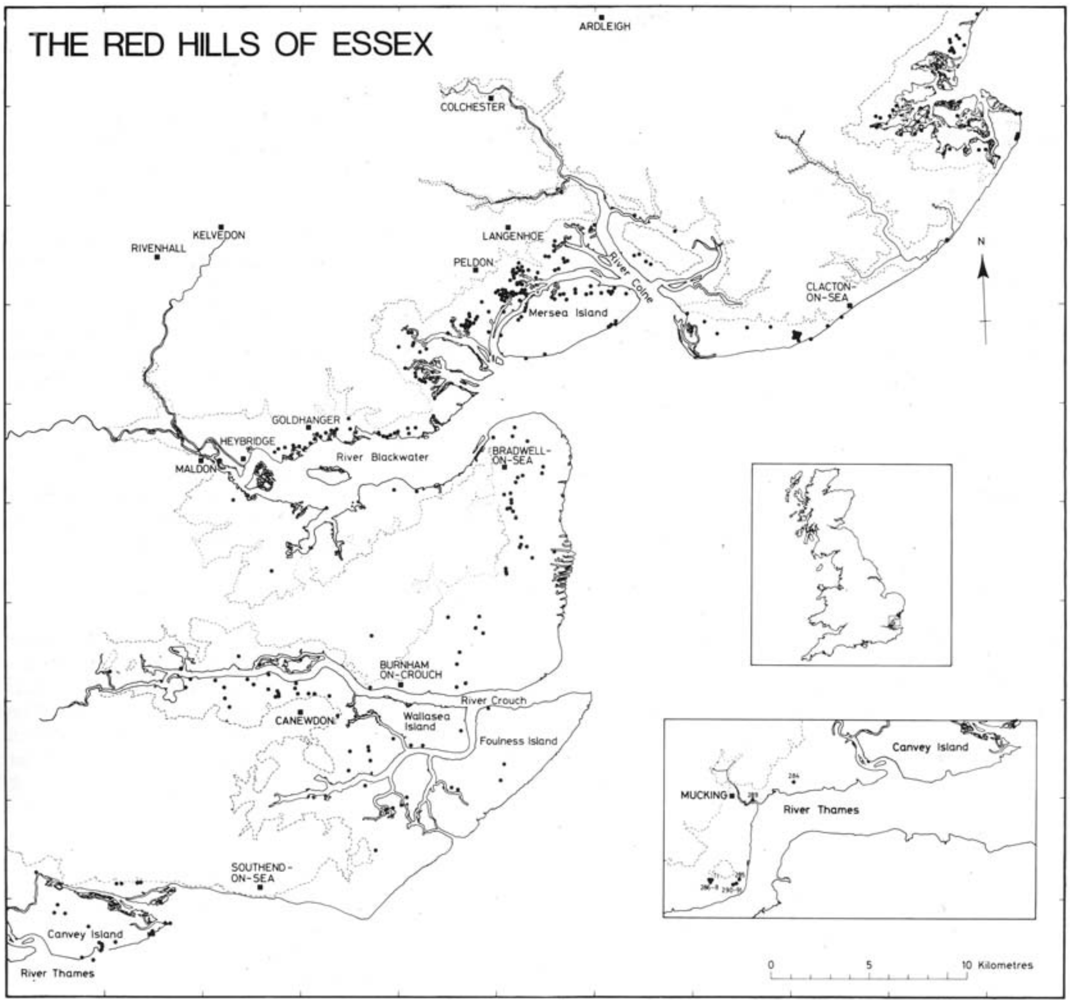


Figure 28: Distribution map of the Red Hills of Essex (Fawn et al 1990; reproduced by permission from Colchester Archaeological Group)

As well as the remarkable buried surfaces, the whole Essex coastal area is also populated by hundreds of mounds or flattened areas of reddened earth, consisting of burnt soil, briquetage, charcoal and ash. Structures made of clay, such as settling tanks and flues are also sometimes found on excavation. These are the so-called 'red hills' of Essex which are generally accepted to be salterns. The salt-making process used in Essex does not appear to have been the same as in Lincolnshire where saline silt was washed prior to evaporation (see above). Consequently, the large mounds of waste silt are not present on the Essex coast. Typically the red hills are only a few metres across although occasional spreads of up to a hectare have been recorded. They date primarily from the late Iron Age to the first century AD (Fawn *et al* 1990).

The Essex coastline has a long history of involvement with past routes of the Thames flowing further north than today. The river's current southerly exit into the North Sea has persisted throughout the Holocene and acts as an eastward facing funnel narrowing down from 27 km at its widest point, concentrating the effects of southward moving storm surges. These events rarely leave a sedimentary trace, but the longer term changes in sea level over the last 10000 years have deposited alternating biogenic and inorganic sediments. The biogenic deposits (peats and gyttjas) represent regression; the inorganic blue-grey clays and silts represent marine influence. These translate to 5 main transgressive periods as shown by the classic work of Devoy and reproduced in Table 1. In general, however, there is little direct evidence for human occupation of the low-lying areas from which the cores were taken to produce this framework (Devoy 1980).

Table 1 The main transgressive periods in the Thames estuary (from Devoy 1980)

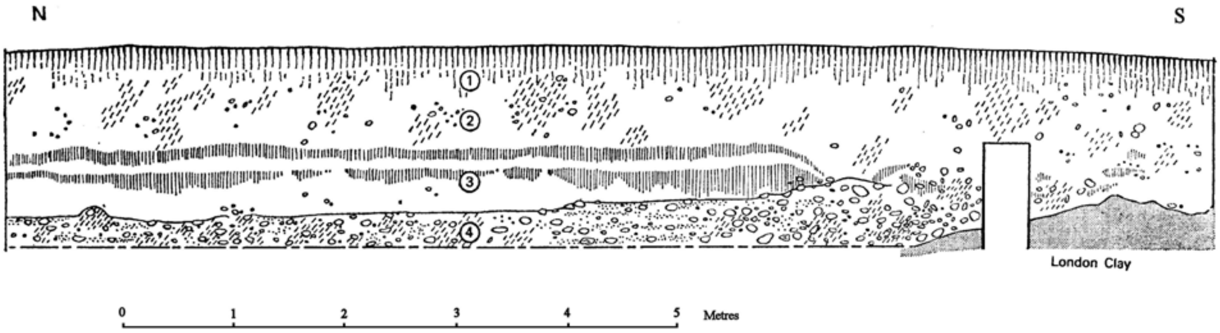
Thames V	~1750 BP
Thames IV	2600 - n.d. BP
Thames III	3850 - 2800 BP
Thames II	6575 - 5410 BP
Thames I	8200 - 6970 BP

Development has clearly biased archaeological finds away from the estuary area, but there is no reason why considerable evidence of activity should not be preserved if ever work takes place there. If the rest of East London is anything to go by (see Meddens 1996) then presumably there are large numbers of trackways to be found.

In the inner estuary, dug-out canoes and human remains have been recovered in poorly stratified positions within the sequence, but dating of these finds remains uncertain.

At Tilbury, Spurrell (1889) recorded Roman occupation remains amongst interleaved peats and tidal clays, at the same time producing a remarkable early account both of the vegetation in these layers, and also the formation processes acting on the stratigraphy. By studying exposures all along the banks of the Thames to Gravesend, he was able to clarify the distinctions between peats, driftwood and forest beds, as well as defining break patterns, and false stratigraphy caused by microfaulting. His summary of the Thames estuary coastal archaeology (Spurrell 1885) provides a lucid framework with which to understand the complex history of marshes, saltings and embankments that characterize this changing environment.

Away from the Holocene sediments, sites with significant Palaeolithic finds occur in the terrace gravels. At Clacton, Wymer and Singer (1970) found in-situ flints on a river beach bordering a meander channel of a wide silted up river. There were also flints in the marl which eventually filled this channel leading the authors to conclude that there were two phases of the Clactonian industry represented at the site (see Figure 29).



Layer 1 Sub-soil with a few flint artefacts of Neolithic aspect.

Layer 2 Brown fissile clay with occasional stones. Sterile except for a few flint flakes at the extreme southern end of the section.

Layer 3 Whitish, variegated marl with occasional shells, bone fragments and flint flakes and cores, mainly in mint condition.

Layer 4 Gravel in a variable clayey or sandy matrix. Bedding mainly disturbed by later soil movements which have confused the stratification where the London Clay rises on the south bank of the channel. There are many weathered septarian nodules in the gravel, and also small conglomerations of grey clay and stones. Flint flakes and cores are on and in the gravel, the majority in mint condition. Mammalian bone fragments are also scattered on and in the gravel, and there are a few shells, mainly broken pieces of mussels. Flint artefacts and some highly weathered bone fragments came from all levels of the confused area by the south bank. The broken horizontal line at the base of the section indicates the water table and limit.

Figure 29: Clacton-on-Sea, Essex. Section across the southern part of the subsidiary channel (adapted from Wymer and Singer 1970)

Schreve *et al* (2002) re-examined sections and material from Purfleet. They found that deposition of the Corbetts Tay gravels was most likely by the Thames rather than a tributary and that the various environmental indicators in the temperate sequence pointed to an unknown interglacial possibly correlating with OIS 9. Three phases of flint working (Clactonian, Acheulean and Levallois) are found within the deposits (Table 2). Interestingly, Bates *et al* (1998) recorded incipient pedogenesis in their boreholes from the Corbett's Tey gravel in the CTRL corridor at Purfleet, and suggested that there may be land surfaces in the sequence.

Table 2: Summary of the Purfleet sequence with suggested Oxygen Isotope Stage correlation (after Schreve et al 2002)

Bed	Lithostratigraphy	Lithology	Biological evidence	Palaeoenvironment	Climate	Archaeology	OIS
8	Botany gravel	Cross bedded sands and horizontally bedded sandy gravel	Vertebrates (rare)	?Open ground	?Cold	Levallois	8
7	Grey-brown silty clay	Mainly structureless grey-brown silty clay with occasional gravel. Weathered and decalcified.			?Warm		?9/8
6	Bluelands gravel	Horizontally and cross-bedded sand grading into horizontally bedded sandy flint gravel	Vertebrates (rare)	?Open ground	?Cooler	Acheulean	?9/8
5	Greenlands Shell bed	Horizontally bedded sand with abundant molluscs and other fossils. Decalcified in places.	Vertebrates common) Molluscs (very common Ostracods	Temperate climate mixed woodland Grassland and marshes Upper tidal reaches of a slow flowing river	Warm	Rare flakes. Possible butchered bone.	9
4	Silty clay	Silty clay laminae with partings of fine sand and silt; shell bed present within this bed.	Vertebrates (rare, shelly band only) Molluscs (rare, shelly band only) Ostracods Pollen		Warm		9
3	Shelly gravel	Gravels and sands, fining upwards, some cross bedding. Calcareous nodules and fossils present.	Vertebrates (rare) Molluscs (common)		Warm	Clactonian	9
2	Little Thurrock gravel	Thin gravel. Chalk present but no fossils.			?Cold		10
1	Angular chalk rubble 'coombe rock'	Soliflucted angular to subrounded chalk clasts in chalk matrix			Cold	Rare flakes	10

2.4 Warp Sediments

Introduction

Warping is the name given to artificial alluviation, induced with the aim of depositing water-borne sediment on the land (Gaunt 1994). Its purpose is to fertilise or otherwise improve soils that are, in some way, unfavourable for agriculture - land that is too low-lying, too acid, too peaty, too sandy - all these varied problems could be improved by a layer of warp. Warping can only be carried out along the banks of a river whose tidal range extends above and below the surrounding level of the land, so that tidal water can be directed onto the fields during a high tide episode, but normal drainage can operate the remainder of the time. An added requirement is that the tidal waters must bear a suitably fertile sediment load that can accumulate a useful thickness on flooded surfaces (Ussher 1890); this latter distinction separates warping from the commoner water-meadow management systems found in numerous river valleys but not specifically geared to the production of a fresh silt layer.

Midlands warping

These two strictures appear to have combined in such a way that the Humber-Trent-Ouse area of North Lincolnshire and South Yorkshire is the only part of the Midlands and perhaps of the UK where warping was possible or at least worthwhile. This was the view taken by Gaunt (1987). Herapath (1850) referred to the practice occurring in many counties of England and Scotland, but did not mention where. During research for this review, accounts have only been found for this Humber wetlands area. At the three-river junction, the 27,000 sq. km catchment (Atherton and Furness 1986) provides a massive 5.1 g/litre* of suspended sediment in the summer when the flow is reduced compared to an average of around 0.46 g/ litre for thirteen other UK rivers (Wheeler 1901).

The earliest recorded warping was in the 1730s at Rawcliffe (Gaunt 1994) but the practice was established at least as far back as 1669 (Robinson 1969) and earlier events doubtless went unrecorded. The most recent warping seems to be the works carried out at Blacktoft in 1948 (Ferro 1949). The process consisted of enclosing the land by banks followed by the cutting of smaller channels ("call banks") inside the area to speed up the water transfer (Heathcote 1951). It was important to get an even distribution as a well as a rapid drain-back, so as to avoid the development of particular textures in patches where water had moved too fast (developing coarse textures) or too slow (leading to fine sedimentation and heavy soil). Only certain tides could be used and only certain weather conditions were suitable. Even with considerable experience, disasters could threaten. In the post-war warping at Blacktoft, for example, a strong landward breeze caused a much higher tide than expected, and water very nearly overtopped the banks (Ferro 1949).

* Note that Heathcote (1951) miscalculated Wheeler's (1901) figure of 2240 grains per cu. ft. for the maximum value at the three river junction, leading to the low value quoted in that paper.

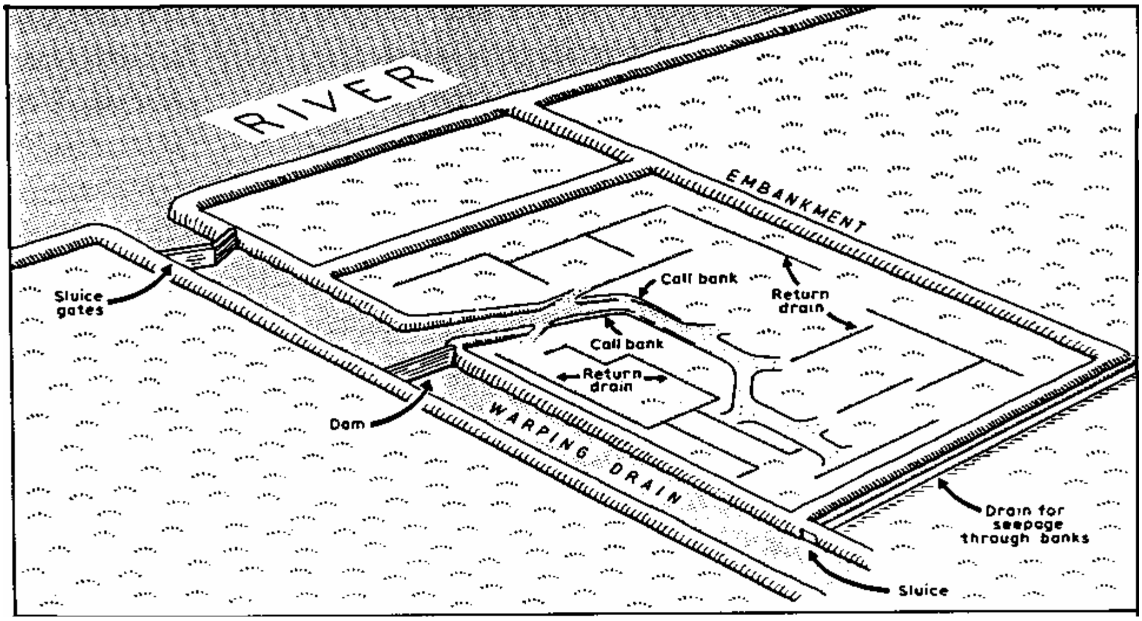


Figure 30: Schematic diagram of the earthworks used for warping (from Lillie and Weir 1997 and Ellis 1990; © Humber Wetlands Project; reproduced with permission of Wetland Archaeology and Environments Research Centre)

The time taken to warp an area successfully depended on what depth of new sediment was needed, and the altitude of the land relative to the tide levels. Herapath (1850) quoted a value of around 0.9 - 1.2 m of water depositing about 2.5 mm of sediment per tide. Thus, with only some tides active, land warped continuously from April to November would typically receive nearly 0.5 m of sediment. Under less ideal conditions, e.g. where water levels were lower, achieving this sort of thickness could take three or even four years.

One of the great warping enthusiasts of the day was Ralph Creyke of Rawcliffe House, Thorne. He was presented the Royal Agricultural Society's large gold medal in 1825 for his warping of 429 acres of 'peat moss' which was essentially peaty land. However, he had been warping since at least 1812 when he did 55 acres in Goole, then a further 225 acres on the south side of the Dutch River in the same year. He warped 1600 acres in Goole, Swinefleet and Reedness in the mid 1820s, and had completed 2000 acres in Eastoft, Whitgift, Ousefleet, Crowle, Haldenby, Fockerby and Adlingfleet by 1845 (Robinson 1969; Lillie and Weir 1997). To facilitate these huge efforts, Creyke cut his own warping drain, which was so large it could be used to ship out the products of the newly created warplands (Lillie and Weir 1998). There was no greater advocate for Creyke's ability than the man himself:-

> *"The superiority consists in creating a fine deep rich soil, more effectually, upon a larger scale, and in a shorter time, than has hitherto been practised. According to the usual practice, the tides were only admitted during the months of August, September, and October; in mine they are admitted all the year round. The sluice was not more than five feet wide; mine has two openings of sixteen feet wide. The main drain is only twelve feet wide; mine is ninety feet wide. Not more than fourteen acres were embanked in one piece;*

I have inclosed five hundred acres in one compartment. Formerly not more than one and a half feet of deposit was obtained; I have got three to four feet in the same time, upon the increased quantity of land." (Creyke, 1825)

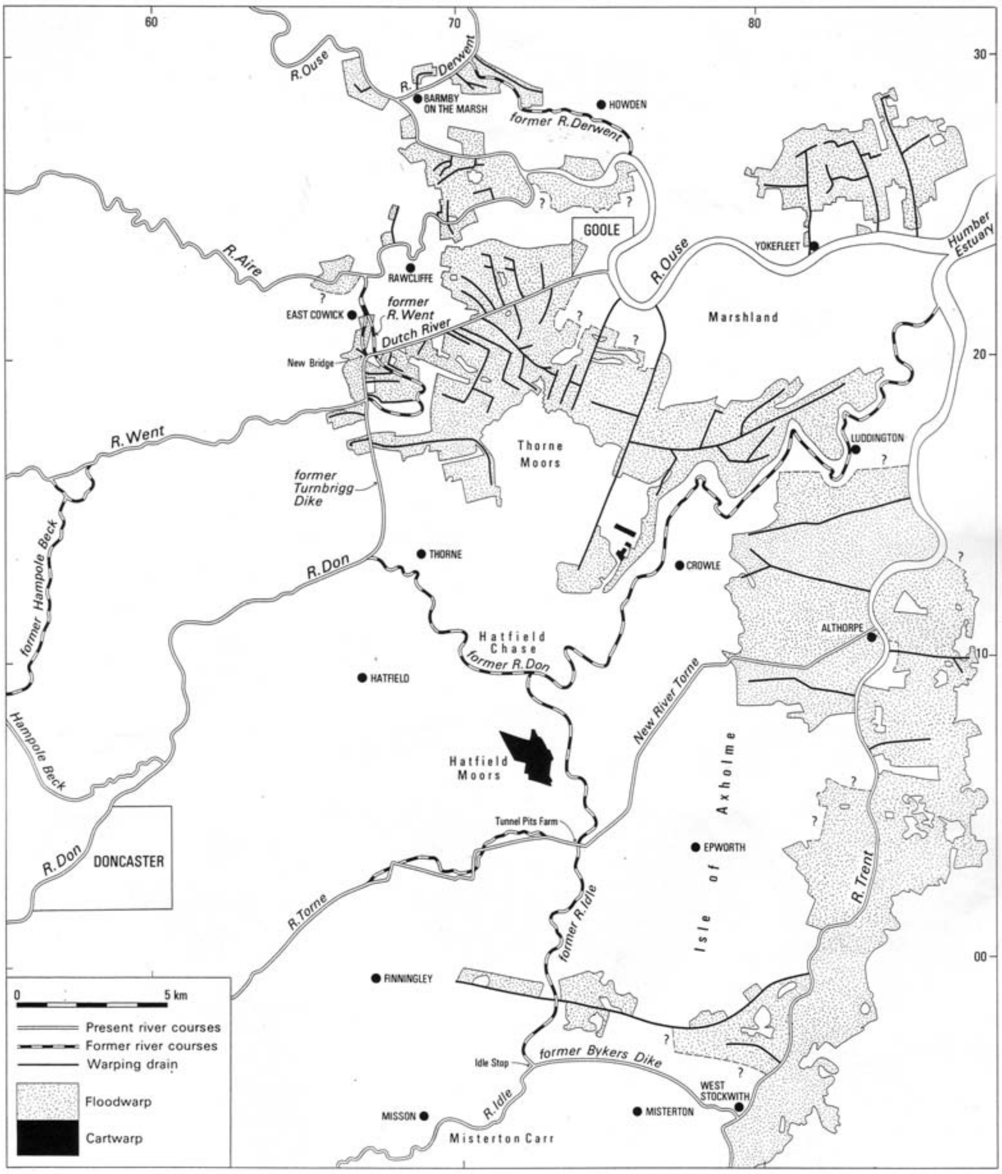


Figure 31: Warped ground in the Humber wetlands area (from Gaunt 1994). The area of 'cartwarp' separately delineated on Hatfield Moors refers to an event in the 1880 when a portion of Thorne and Hatfield Moors was spread with warp by hand (Edwards 1850). (Reproduced with the permission of the British Geological Survey ©NERC. All rights reserved)

The zeal of men like Creyke led eventually to the current situation where over 150 sq km of land around the Humber, Trent and Ouse has been artificially improved by the warping process (Figure 31). Archaeologically, this covers the old ground surface in the same way as alluvium, but with even more rapid burial (due to deliberately additive silt management where alluvium would be more chancey). Preservation through weight of sediment and depth of burial should thus be outstanding, although it is clear that the calcareous nature of the silt takes its toll on the pollen record (Lillie and Weir 1998). The land suitable for warping was not, however, particularly suitable for anything else. Consequently the warp does not tend to bury many archaeologically significant sites. In a way, the warp itself is the archaeology of the region - a testament to the extraordinary efforts of men like Ralph Creyke. The soils produced by the process are mostly placed in the highest grades of land classification and have few or no limitations on cropping capability (Webber 1986).

Warp soil profiles

When carried out correctly, warping produces a light silty soil, with laminations below the plough level, and frequently a buried soil or peat layer at depth. The following profiles are simplified from Atherton and Furness (1986):-

Location: Sandhall Farm, Kilpin, Humberside (grid ref. 76062325)
Elevation: 4m O.D. Slope and aspect: Level.
Land use: Permanent grassland.
Notes: North side of River Ouse; warpland; local relief - none; not poached. Water table in auger hole 175 cm after 2 min.

0 - 19 cm	Ah	10 YR 3/2 (Very dark greyish brown) stoneless silty clay loam (c 27% z 63%).
19-37 cm	Bw	10 YR 4/4 (Dark yellowish brown) stoneless silty clay loam (c 29%, z 61%).
37-83 cm	BC(g)	Mixed matrix colours caused by laminations; 10 YR 5/4 (Yellowish brown) associated with sandier laminae and lenses, with colour due mainly to uncoated grains; 7.5 YR 4/2 (Brown) and 7.5 YR 4/4 (Brown) associated with silty/clayey laminae; coarse textured laminae are thicker than finer; stoneless silty clay loam (c 27%) with silty clay (c 38%) and very fine sandy loam (c.10%).
83-150 cm	Cu (g)	7.5 YR 5/4 (Brown) stoneless sandy silt loam (c 14%, z 45%); very thin laminae of 5 YR 5/3 (Reddish brown).

Analytical Data

Horizons:	Ah	Bw	Bc(g)	Cu(g)
Depth (cm):	0-19	19-37	37-83	83-134
Sand %	10	9	5	41
Silt %:	63	62	68	50
Clay %:	27	29	27	9
$CaCO_3$ eqv. Q	<1	1	5.9	7.2
Organic carbon %:	3.91	0.91	0.841	0.72

pH in water (1:2.5):	6.8	7.9	8.5	8.2

Location: Blacktoft House, Yokefleet, Humberside (grid ref. 83502570)
Elevation: 5 m O.D. Slope and aspect : Level.
Land Use: Rough pasture.
Notes: North side of River Ouse; warpland; artificial warp over glacial succession; local relief - none.

0-17 cm	Ah	10 YR 4/2 (Dark greyish brown) stoneless silty clay loam (c 32%, z 50 a).
17-35 cm	Bw	10 YR 5/3 (Brown) stoneless silty clay loam (c 25%, z 60%).
35-41 cm	B2 (g)	Dominant 10 YR 4/4 (Dark yellowish brown) stoneless silty clay loam.
41-46 cm	2B (g)	Impure silty clay containing fragments of chalk and fine pieces of brick.
46-51 cm	3B (g)	Medium sand; 10 YR 2/1 (black), mixed organic debris.
51-110 cm	4Bg	7.5 YR 4/4 (Brown to dark brown) silty clay; many large N/5 (grey) prominent mottles, many medium 7.5 YR 5/6 (strong brown) distinct mottles; stoneless; coarse prismatic peds; very firm; very slightly calcareous.

Analytical Data

Horizons:	Ah	Bw	B(g)
Depth (cm):	0-17	17-35	35-41
Sand %	11	11	3
Silt %:	53	63	66
Clay %:	36	26	41
$CaCO_3$ eqv. Q	<1	3.2	5.3
Organic carbon	4.46	1.55	1.27
pH in water (1:2.5):	7.3	7.9	8.5

2.5 Windblown Deposits

Introduction

Much of northern Europe underwent a period of intense aeolian deposition during the periglacial conditions of the late Devensian. In Britain, this left behind deposits of both loess (predominantly silt, 0.063mm -0.02 mm) and coversands (predominantly sand sized

2.00 mm – 0.063 mm), which have undergone erosion and biological mixing processes since the climate ameliorated. Isolated whole deposits are mostly natural and mostly outside the Midlands, e.g. Pegwell Bay and Portsmouth (see Catt 1985, p.208), although at Caddington, Bedfordshire, solution features in the chalk contain Levalloisian assemblages within brickearth of loessic origin (Wymer 1999, 175; Catt and Hagen 1978), including both Anglian (MOIS 12) and Wolstonian (MOIS 6?) aeolian contributions (Avery *et al* 1982; Antoine *et al* 2003). The loess has more typically left its mark (Figure 32) as detectable components of topsoils (Perrin *et al* 1974; Catt 1977; Catt 1985; Catt *et al* 1974) and as brickearth deposits in many river valleys (Gibbard *et al* 1987; Parks and Rendell 1992). It forms a very high proportion of the parent material of soils on the Peak District limestone (Pigott 1962; Bryan 1970) and in parts of north Norfolk (Catt *et al* 1971). These soils therefore underlie much of the archaeology in those areas, but geoarchaeological analysis is not necessarily going to be required when excavations take place, and analytical works are therefore scarce. One example where analysis was carried out to help elucidate site formation processes was at Harpur Hill, near Buxton on the Peak District limestone (Canti 1993). Here, a heavy mineral count of the site samples yielded values for chlorite content matching well with the Peak District values for chlorite, offered by Catt (1978) as evidence for westward winnowing of windblown silts, concentrating the flaky minerals to the west. Also, at Sproxton, Leicestershire, differences in heavy mineral counts from layers under a barrow on the Oolitic limestone suggested aeolian inputs to Macphail (1979), but chlorite was not one of the species recorded.

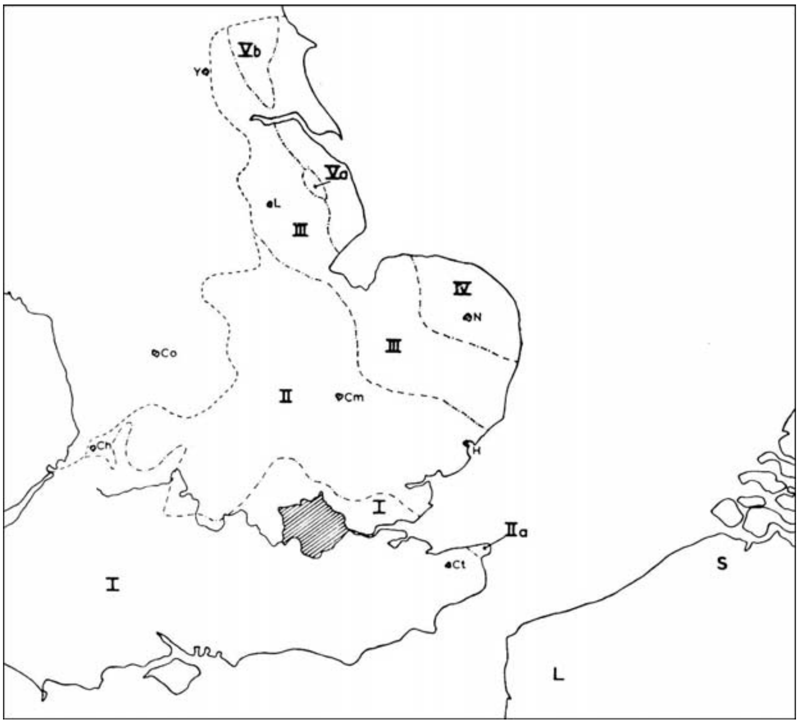


Figure 32: Perrin et al's (1974) zones of aeolian additions to modern topsoils in South and East Anglia. I – soils enriched in silt; III – soils enriched in sand; II and IV – soils enriched in silt and sand; V – silt enriched soils found within III; reproduced with permission of Nature Publishing Group)

The aeolian sands were less depleted by erosion and mixing than the loess. Although the presence of extraneous sand can be detected in many soils only by analytical techniques, the coversands, as the name implies, also occur as distinctive surface deposits. They are concentrated in two main areas of the English Midlands - Lincolnshire and East Anglia (Catt 1977). Both these deposits lie at the western edge of the European sand belt (Figure 33) whichstretches east through the Low Countries, Germany, Poland, Russia and Ukraine (Koster 1988; Zeeberg 1998).

The Lincolnshire sands were deposited in two phases from 18000 BP to 14000 BP and from 12000 BP to 11000 BP (Bateman *et al* 2000). Upper Palaeolithic implements have been found in contexts securely beneath the sand at Risby Warren (May 1976; Lacaille 1946; Buckland 1982; Jacobi 1978).

The East Anglian deposits are the remnants of the material that once formed a coversand sheet across the region. OSL dates at Grimes Graves suggest that deposition occurred between 13380 ±790 BP and 14580 ±1420 BP (Bateman 1995). This date range means that Palaeolithic material must occur beneath the sand at some locations. Examples include Beeches Pit, which contains layers of Palaeolithic burnt bone and flint of uncertain age, all covered by a windblown sand layer (Preece *et al* 2000; see also Wymer 1985).

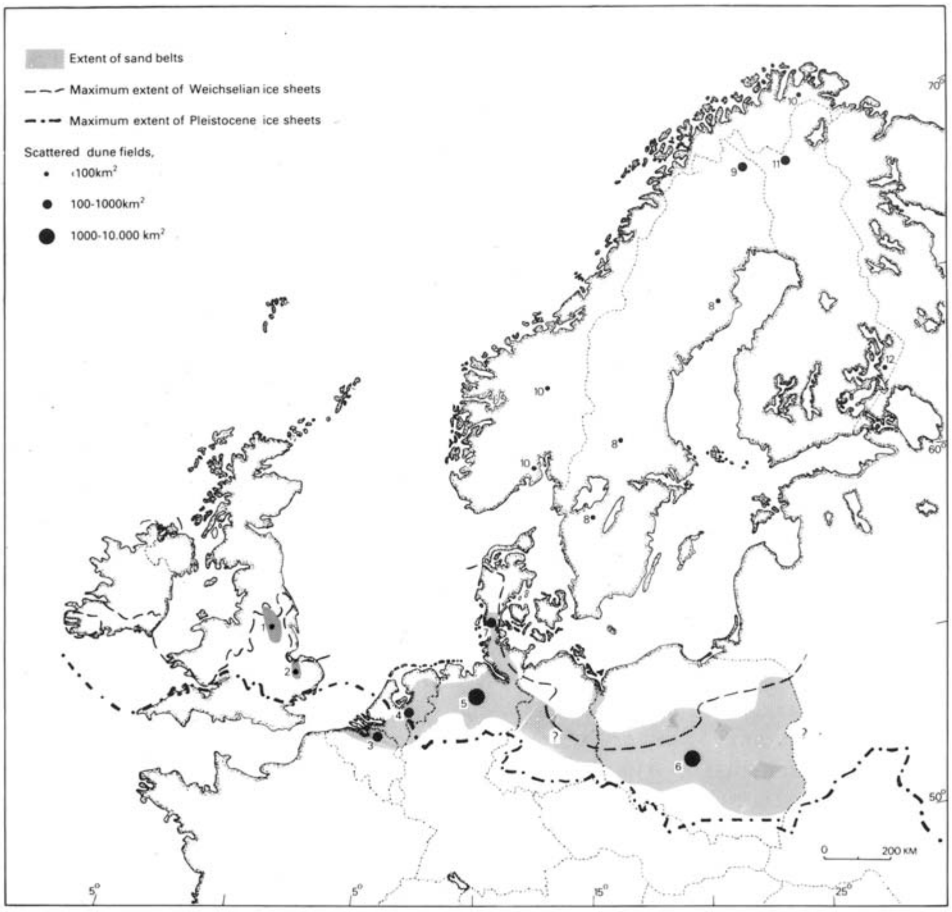


Figure 33: Major areas of European windblown sand (from Koster 1988, with permission of Wiley-Blackwell Ltd.)

Holocene Aeolian Activity

Lincolnshire

Mesolithic artefacts have been found on or in the blown sand at Sheffields Hill and Risby Warren (Buckland 1982;1984; Jacobi 1978), and it is clear from the work of Holland (1975) that movement was continuing at least up until the Iron Age. Even in the present day, the sand sometimes accumulates against hedges and blocks small roads (Gaunt *et al* 1992; Radley and Simms 1967).

At the Anglo-Saxon settlement site of Flixborough (Loveluck and Atkinson 2007), the Jurassic scarp face is mantled in blown sand, and the stratigraphy is entirely founded on it rather than the solid geology. Further re-working played a significant role during the occupation phase, so that few archaeological layers are free of the sand, and many are separated by bands representing rapid deposition.

A remarkable feature of the site was the state of bone preservation. Coarse sands will typically lead to very poor preservation because of their tendency to acidify in a high rainfall environment. However, at Flixborough, the blown sand is calcareous, with over half the samples tested from the site being above pH 7. This statistic arises, in part, from ash inclusions in many of the deposits (see Figure 34), but significant quantities of limestone, chalk, calcareous sandstone, tufa etc. were also present in the fresh sand layers (Canti 1992b; 2007).

The calcareous inclusions and ash content have all contributed to the bone preservation. Constant accretion of the sand during and after occupation meant that the residual calcium carbonate in the ash has never had to undergo the acid leaching that would be expected on such a substrate if it were pure quartz. This replenishment has slowed down the removal of calcium carbonate, even in layers relatively close to the surface, and allowed pH values as high as 8.2 (though more typically in the 7 - 8 range) to be maintained. Furthermore, there was no evidence in any of the micromorphological slides for lengthy surface exposure of the ash layers. If the ash dumps had been exposed to the air for significant periods of time, rainfall and wind would be expected to create sorted layers and microsedimentation features (e.g crusts), but these were not present. Since there appears to have been very little biological activity, it can reasonably be concluded that, in the sampled areas, the ash was laid down in deep layers rather than slowly accumulating.

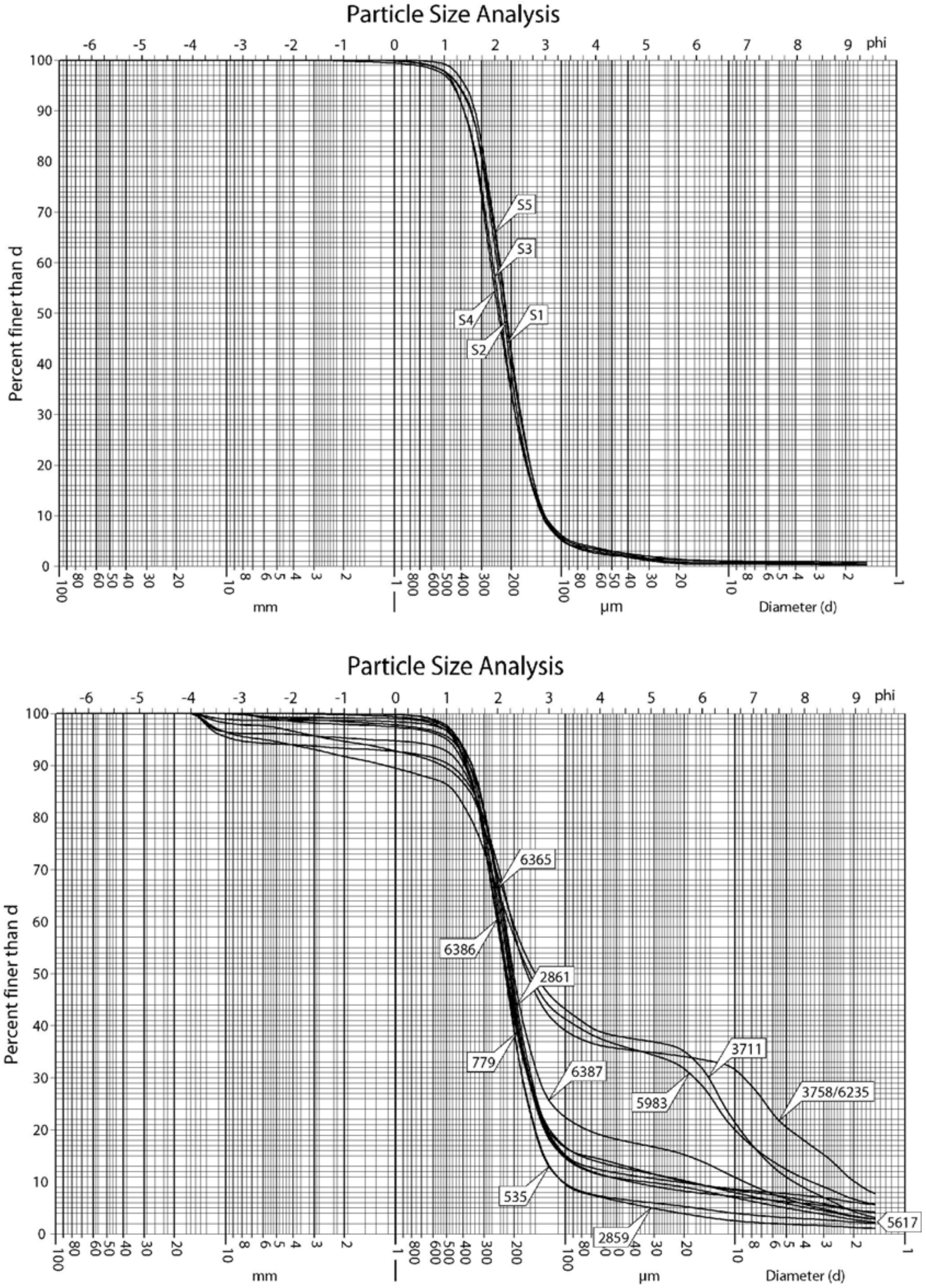


Figure 34: Particle size analyses of deposits from Flixborough, Humberside. Upper – pure windblown sand showing a very strong peak of material between 400 µm and 150 µm. Lower – archaeological deposits with similar windblown sand peaks but in some cases showing additional peaks of calcitic ash aggregates between 15 and 5 µm (see Canti 2007; 2003c)

East Anglia

Much of the coversand has been incorporated by periglacial action, but some dune activity clearly continued on into the Holocene. Mesolithic material occurs on or in the dunes at Lakenheath, and windblown sand sealed Neolithic and Roman deposits at Cavenham Mere (Bateman and Godby 2004). However, the most remarkable evidence of the continued movement of the sands in the Holocene comes from historical accounts of dune activity around Santon Downham given by various 17th century authors, such as Evelyn (1677) and Gilpin (1805). In particular, the account of Wright (1668) describes in detail how the sand mass lost its surface vegetation, and from covering 8 – 10 acres near its origin in Lakenheath, grew rapidly to 1000 acres after travelling only four miles. Subsequently, the process seems to have been the slow but inexorable destruction of the town of Santon Downham:

> " *'Tis between 30 and 40 years since it first reacht the bounds of the Town; where it continued for 10 or 12 years in the Out-skirts, without doing any considerable mischief….But the valley being once passed, it went above a mile (up-hill) in two months time, and over-ran 200 acres of very good Corn the same year. 'Tis now got into the body of this little Town where it hath buried and destroy'd divers Tenements and other Houses and has enforced us to preserve the remainder at a greater charge than they are worth…it had so possest all our Avenues as there was no passage to us but over walls of 8 or 9 ft high.* " (Wright, 1668).

The problem continued into the next century so that Francois de la Rochefoucauld, travelling in the area in 1784 remarked on:

> "*a large quantity of shifting sand in which the district abounds…everywhere sand, everywhere little clumps of reeds and bracken. A large portion of this arid country is full of rabbits, of which the numbers astonished me.*" (Scarfe (1988) p.89, quoted in Sussams (1996:13).

Activity has continued through into the twentieth century (Clarke 1937) and dunes can still be found at a few locations (Figure 35). Bateman and Godby (2004) carried out a program of OSL dating on the sands, and assembled data on a series of environmental variables that are significant controls on the aeolian activity during the Holocene (Figure 36). They concluded that local conditions leading to phases of sandblow are complex but, although no single set of conditions can be identified as causative, regional climatic forcing was a significant underlying trigger.

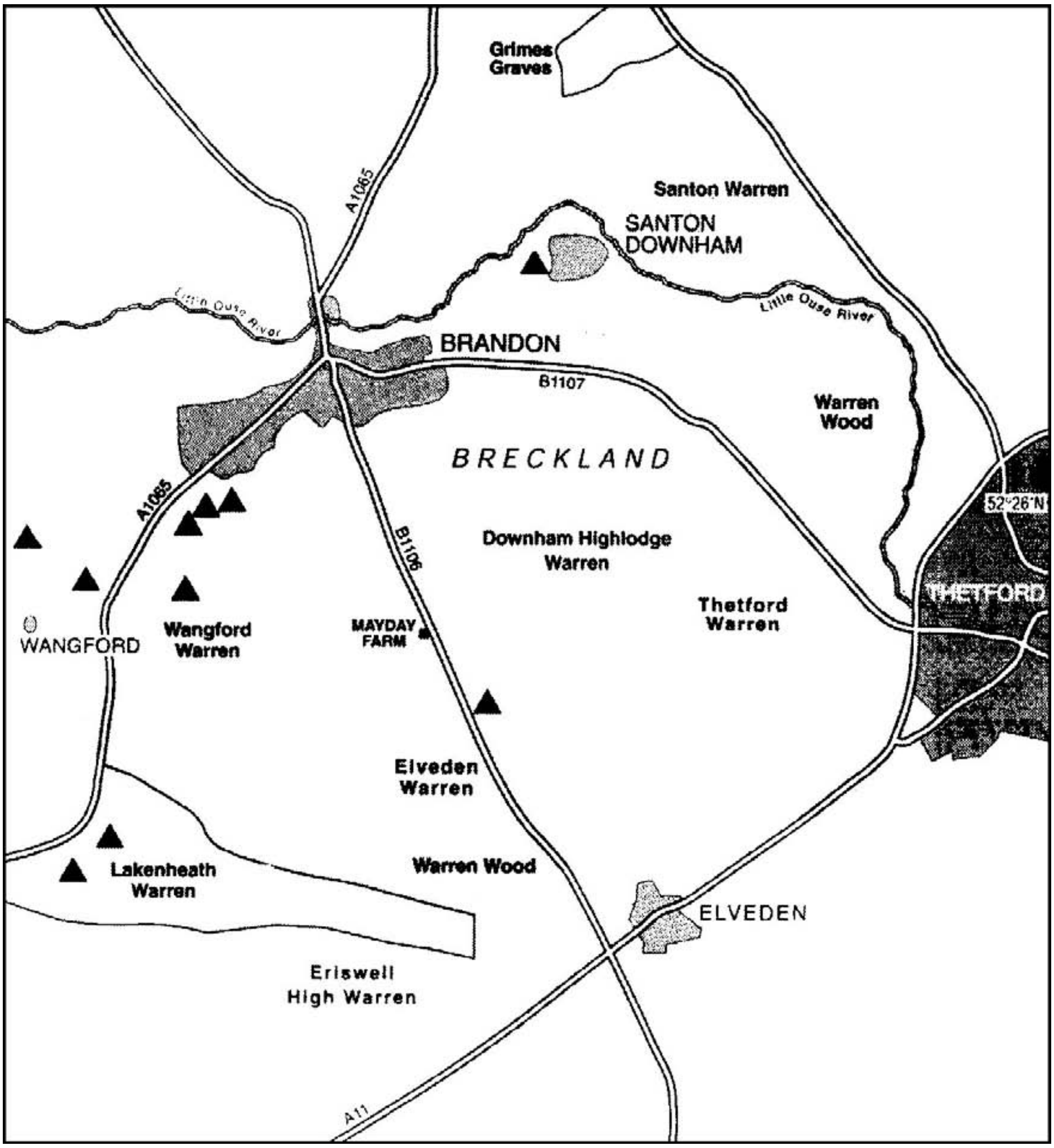


Figure 35: Location of modern dunes ▲ in Breckland (after Bateman and Godby 2004; reproduced with permission from Sage Publications)

From an archaeological point of view, the blown sand can act as a significant protection. On West Stow heath, the area between the old sewerage farm and the Icknield Way is covered with blown sand up to 1.2 m. Beneath this sand are extensive traces of a medieval open field system and evidence of earlier phases of cultivation (West 1985:3). West Stow Anglo-Saxon village itself was protected from later agriculture by a sand covering of up to 90 cm, dating to the early fourteenth century (West 1985:9).

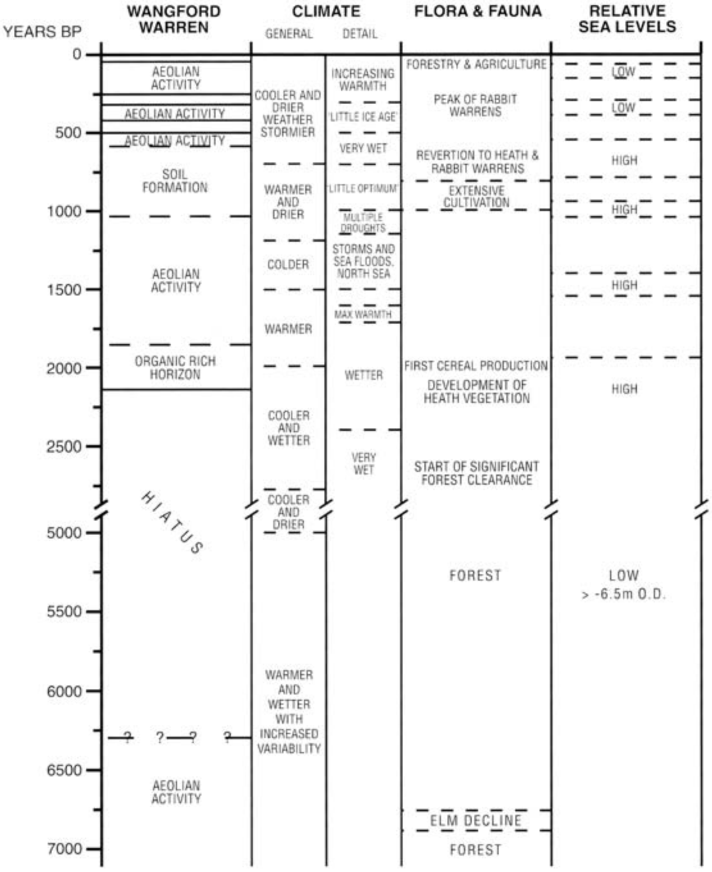


Figure 36: Summary of inferred environmental factors at Wangford Warren dunefield, based on data from various authors (see Bateman and Godby 2004; reproduced with permission from Sage Publications)

2.6 Dark Earth

Introduction

The 'dark earth' phenomenon is certainly of regional environmental or economic significance in so far as it represents a trend in late Roman and post Roman times. The key question with this enigmatic material is precisely that - does it represent such a trend, or was it produced through a variety of causes? Perhaps, even further back in the chain of reasoning, we have to be questioning whether it is a *thing* at all? If one was able to examine the entire population of Northern Europe's archaeological sites, one would undoubtedly find numerous examples from various periods of thick, dark soil layers lacking stratification and usually termed 'make-up' or sometimes probably 'plough soil'. In most cases, however, it would only be on sites from the end of the Roman period that this material would be called 'dark earth'. It is no coincidence that the descriptive and interpretative terms are indistinguishable, presenting a rich vein of misunderstanding to trip up the unwary or be mined by the unscrupulous. The implicit uniformity suggested by the term adds a second layer of uncertainty to the meanings being deployed. As Milne (1995) rightly pointed out:-

> "*Perhaps the principal problem is not the silts themselves but the use of the definite article to describe them: occupation levels were considered to be sealed by 'the' dark earth, which suggests that the same cause or a single event was responsible.*"

Thus, the dark earth problem may be as much conceptual, even linguistic, as it is technical. Nevertheless, there is a *prima facie* geoarchaeological question presented by the classic dark earth sites, and it needs to be examined more systematically if a genuine understanding is to be gained.

Geography and Characteristics

Dark earth has been reported from various Midlands cities, but the substantial deposits are confined mainly to London, Colchester (Crummy 1992) and a few examples in Chester (Carrington 1994). It may have been found in Southwark by Kenyon (1959), but her description is not detailed enough for a clear comparison. Coining of the archaeological term in 1977 was claimed by Perring and Roskams (1991), but similar names had been used already by Norman and Raeder (1912) (see Figure 37), and Grimes (1968). The term became established through constant usage in the work of the Department of Urban Archaeology and the Museum of London Archaeological Service in 1970s and 1980s excavations in London.

Dark earth consists of dark homogeneous soil usually containing little evidence of stratification or occupation, and yielding sherds of late Roman/post Roman pottery, charcoal and bone (Esmonde Cleary 1989). Whether the deposits are equally homogeneous at different sites is hard to establish from excavation records. On single sites, however, it has been clearly demonstrated. Detailed (25 mm spits) sampling of finds carried out at Milk Street (Perring and Roskams 1991; Roskams and Schofield 1978), found no pattern at all and the authors concluded that the dark earth deposition represented a single event.

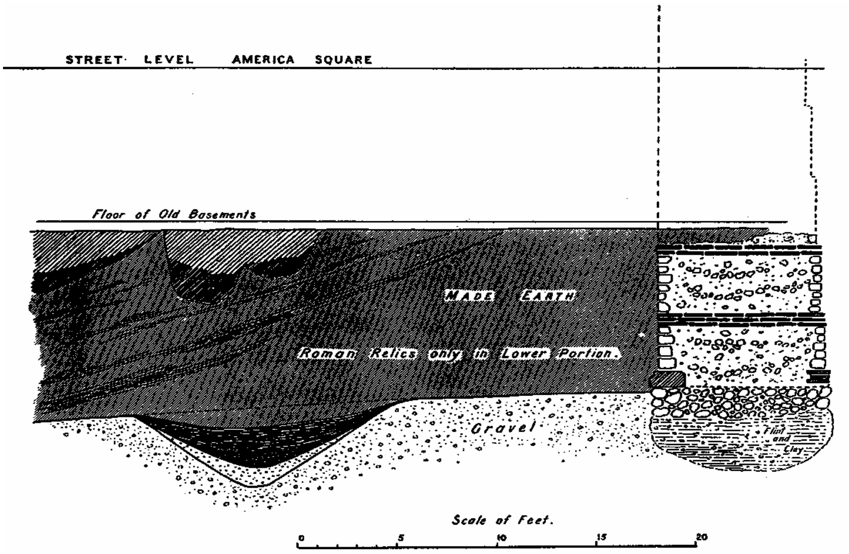


Figure 37: Early drawings of 'made earth' (From Norman and Raeder 1912)

Dark earth usually overlies truncated Roman deposits, but has occasionally been recorded amongst later deposits. Marsden (1985) quotes some typical London examples manifested by first and 2nd century occupation layers overlain by dark earth producing pottery of the 3rd and 4th centuries. At Milk Street, dark earth occurred over a mosaic (Figure 33) which had been the floor of a fine building, but had apparently been abandoned by the end of the 2nd century (Dyson and Schofield 1981; Perring and Roskams 1991).

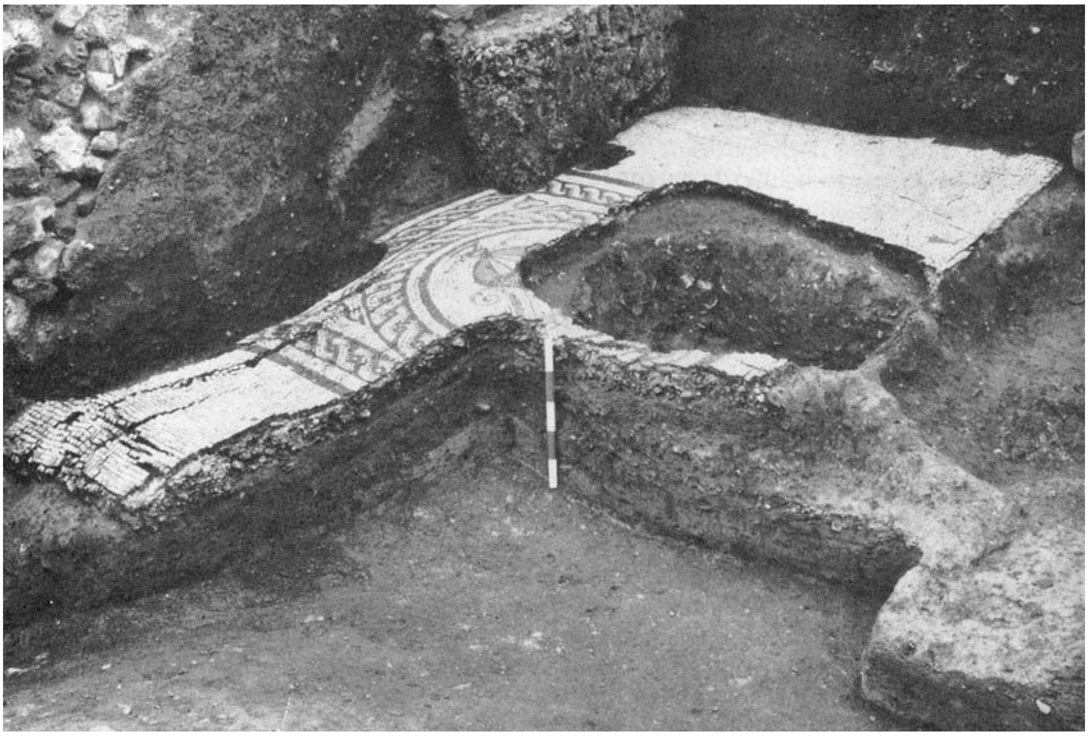


Figure 38: Mid second century mosaic sealed by dark earth at Milk Street, City of London (from Yule 1990; reproduced with permission from The Museum of London)

Accretion happened at different times in different places. Watson (1998) for example, notes the 2nd century deposits at Milk Street, and contrasts them with a 3rd century building at King Street which was sealed by dark earth, and accumulations in the late 3rd or 4th century on the east side of Londinium (Watson 1998). Well mixed dark earth accumulated over the possible late Roman church at Colchester House, and contained Tudor pottery down to its basal layers (MoLAS 2000). Interestingly, good evidence for multi period accumulation comes from Culver Street, Colchester, where the uppermost Roman layer was covered by up to 1.5 m of dark earth. This material appeared to have been in place by the early medieval but had only reached about a spade's depth and continued to accumulate during the medieval and later periods (Crummy 1992). Thicknesses vary from site to site, but 1.0 to 1.2 m of dark earth are not unusual in London (Yule and Hinton 1988; Blair 1983; see figure 2 in Yule 1990) and 0.3 - 1.5 m in Colchester (Crummy 1992). Debate on its origin continues, and the uncertainty inhibits interpretation of the late Roman sequence (Heard *et al* 1990).

Origins of Dark Earth

Schaaf (1988) thought that the presence of dark earth at 199 Borough Street indicated 'waste ground or agriculture', a view shared by Marsden (1980) for London sites in general. Plough marks have occasionally been found in the lower levels (Reece 1980), but there does not appear to be widespread evidence for an agricultural use. Anyway, this type of interpretation immediately begs the question: how did the soil actually get there? If old dwellings etc. are left to decay, they do not accumulate a great thickness of soil by any natural process except in areas of loess or alluvium deposition; yet neither of these processes were active in the relevant parts of London at that time. Abandoned floors from recent derelict buildings can sometimes be found with around 10 cm of soil over them (e.g. Wood and Johnson 1978: 328), but this is due to the accumulation of worm casts brought up through the floor (through gaps in the flooring material) and in fact represents the floor sinking into the ground. Even under the most worm favourable conditions, the thicker deposits of dark earth cannot possibly have been created that way. It follows then that the dark earth raw parent material was actually deposited on the sites by some means, and that means would have to be anthropogenic. One theory was that night soil trenches were filled and gradually coalesced (Sankey and MacKenzie 1997); another, that plant matter and latrine waste were dumped in empty buildings (Ottaway 1993). These approaches could account for a certain amount of dark earth, but there would not really be enough mineral matter to explain the thicknesses observed today after the main part of the organic matter had been used up. Some mineral soil material would have to be additionally brought in.

Sheldon (1978:40) thought that the dark earth corresponded to Kenyon's (1959) 'silts' but that it was dumped soil not flood deposits. He considered the possibility that it was street sweepings, added for the purposes of market gardening. This reflected the need, in late Roman times, to produce more food in the city when foreign sources were failing. Ferretti and Graham (1978) came to similar conclusions about 201-211 Borough Street - dumping mainly happening in the later 4th century. Watson (1998) has argued against this view for the London dark earth on the grounds of the volume of soil needed to be dumped and the work it would entail, coupled with the fact that London is surrounded by good farmland and could never have achieved self-sufficiency through market gardening. These arguments surely hinge on motivation. Even if the gardening hypothesis is considered unlikely, this does not preclude the possibility that topsoil was dumped for some more important reason. Watson (1998) goes on to quote the lack of pollen and micromorphological evidence for cultivation as backing for the case against the market gardening hypothesis. This is misleading, since both lines of evidence would have been destroyed at some stage by the normal biological activity going on in these deposits.

Yule (1990) has argued that many of the dark earth sites show a truncated Roman stratigraphy underlying the dark earth itself, and that this rules out models involving deliberate soil deposition. He thought purposeful removal of the strata unlikely and that reworking of the lowermost layers must be the explanation for truncation. This view appeared to be backed up by micromorphological analysis (Macphail and Courty 1985; Courty *et al* 1989) showing biological reworking and the remains of constructional materials being present in the apparently homogeneous deposits. Care must be taken to put these sorts of results in context. The finding of some construction materials at the microscopic scale is not the same as showing that dark earth was made of constructional materials. Furthermore, the occurrence of possible Enchytraeid (wireworm) droppings has led to undue stress being put on these creatures by some excavators (e.g. Whytehead in Cowie *et al* 1993). Although they occur in huge numbers in most soils (Didden 1993; Van Vliet *et al* 1997), they are exceedingly small and the earthworm (Lumbricid) population would be many times more effective in terms of reworking capability. Deposits could easily be worked first by earthworms and then by wireworms, leaving very little evidence of the former species. More importantly, the fact that a soil shows evidence of biological working does not mean that it is more reworked than some other soil that does not show such evidence. Rather, it means only that the evidence was still intact at the moment of sampling.

3. FUTURE PRIORITIES

3.1 Alluvium and Mining Sediments

Four major research themes emerged from the 2003 European conference publication on alluvial archaeology (Howard *et al* 2003) and these form the basis for priorities for future research:-

Alluvial Geochronological Techniques

The importance of dating for the understanding of floodplain development has been stressed by both Brown (2003) and by Macklin *et al* (2003). Difficulties with finding enough secure material for ^{14}C are inevitable. Luminescence proved unrewarding in the 1990s because of the poorly bleached nature of the sediments, but Macklin *et al* (2003) foresaw great improvements with the single aliquot regenerative dose protocol. This is clearly happening, stimulated partly by the basic need of OSL researchers to test out the method and partly by the increased funding that was available for alluvial studies in the mid 2000s from the Aggregate Levy fund. For example, Schwenninger *et al* (2007a) carried out a total of 30 SAR determinations to provide a much improved dating framework for sediments in the Trent valley; and Rhodes (2007) tested it at St Neots showing that samples tend to have distinct groups which are likely to represent the true depositional age. Other examples are Briant *et al* 2005, who successfully used SAR on a multidisciplinary study of deposits in the Fenland basin, and Schwenninger *et al* (2007b) who applied it to clarify longstanding dating issue with the till deposits at Welton-le-Wold in Lincolnshire.

Provenancing Sediment and Linkage to Land-use

Provenancing based on geochemistry seemed successful at a number of sites where there was good correlation with geological sources. Although such approaches have been successfully carried out (e.g. Thorndycraft *et al* 2003, Hudson Edwards in Howard *et al* (2000) and Hudson-Edwards *et al* (1998)), they are mostly outside the Midlands, and there is little sign that the alluvial archaeological community generally has taken up the challenge any further in the 21st century.

Holocene Flooding, Valley Settlement and Environmental change

Macklin *et al* (2003) have charted numerous peaks in flood events and correlated them with phases of climate change. However, they argue that individual flood events are not necessarily going to be preserved by the archaeological record. Subsequently, Macklin *et al* (2005) have published a detailed Europe-wide analysis of 506 dated fluvial units, claiming that their grouping is associated with large scale climate changes. Whilst the association with climatic change is always going to be open to debate, the concept of the groupings could usefully be tested

Channel Metamorphosis and Site Survival

Howard and Macklin (1999) developed a generic process-based geomorphological approach to the survey and interpretation of Holocene alluvial archaeology in the river valleys. This was intended to help assess issues such as where archaeology would be preserved and where it would be eroded in river valley situations. Much of the activity proposed in the paper has been more-or-less fully carried out in some of the recent (pre- and post ALSF) valley studies such as the Soar (Smith *et al* 2005) and the Arrow Valley (White 2003). However, Macklin *et al* 's (2003) statement that the approach has never been fully evaluated by a blind test is still technically true. This would be a valuable exercise to determine whether any changes are needed to the methodology.

3.2 Marine Sediments

Developments in geophysical technology have opened up a new range of marine sediments that would previously have been impossible to study. A number of projects have recently considered, surveyed or reconstructed submerged landscapes on the seabed around the UK coastline (e.g. Gupta *et al* 2004; Dix e*t al* 2004), but, from the point of view of the Midlands marine deposits, the most significant piece of work to date is Gaffney *et al* (2007). This used seismic and core data to map 23,000 square kilometres of the seabed and produce cross-sections, three-dimensional topography, and images detailed enough to show ancient fluvial systems. Coupled with the methodological advancements outlined in Ward and Larcombe (2008), the North Sea presents marine sediment archaeological potential on an unprecedented scale.

3.3 Windblown Sediments

Aeolian sediments have received little attention in southern East Anglia. The Breckland deposits have preserved a significant archaeological and palaeoenvironmental record (Bateman and Godby 2004) and similar results could possibly be obtained from well-sealed deposits in the Suffolk lowlands (Hill *et al* in press). Temporal gaps also exist: aeolian activity is suggested in the Brandon area during the Neolithic (Hall 2006) and this later activity remains poorly understood (Hill *et al* in press).

3.4 Dark Earth

The first step in understanding dark earth has to be a detailed quantification of its components and process indicators in comparison to surrounding archaeological deposits and local natural sediments. If it is to be considered as a dumped soil brought from any distance, then it should be possible at some sites to prove this difference through particle size analysis, heavy mineral analysis and/or micromorphology. If it results from dumping of plant waste, then opaline silica content may vary either within the body of the dark earth or between the dark earth and other archaeological deposits. Even if plant waste was a major component, the basic soil mineral material would still have to have come from somewhere. The clear, fully quantified comparison with background materials at a number of sites is what is currently lacking in the comprehension of dark earth. Once these basic origin issues are really understood, then the more difficult conceptual basis can be tackled from a firmer footing.

4. BIBLIOGRAPHY

Aalto, M M, Coope, G R and Gibbard, P L 1984 'Late Devensian river deposits beneath the floodplain terrace of the River Thames at Abingdon, Berkshire, England'. *Proceedings of the Geologists' Association* 95, 65-79

Allen, J R L 1974 'Reaction, relaxation and lag in natural sedimentary systems; general principles examples and lessons'. *Earth Science Reviews* 10, 263-342

Allen, J R L 1997b 'The geoarchaeology of land-claim in coastal wetlands: a sketch from Britain and the north-west European Atlantic-North Sea coasts'. *Archaeological Journal* 154, 1-54

Allen, J R L 1997a 'A conceptual model for the archaeology of the English coastal zone', in Fulford, M, Champion, T and Long, A (eds) *England's Coastal Heritage*, 50-56. London: English Heritage

Allen, J R L, Bradley, R J, Fulford, M G, Mithen, S J, Rippon, S J and Tyson, H J 1997 'The archaeological resource - a chronological overview', in Fulford, M, Champion, T and Long, A (eds) England's Coastal Heritage, 103-153. London: English Heritage

Allen, T G and Robinson, M A 1993 *The prehistoric Landscape and Iron Age Settlement at Mingies Ditch, Hardwick-with-Yelford, Oxon.* Oxford: Oxford University Committee for Archaeology

Antoine, P J A, Catt, J A, Lautridou, J-P and Somme, J 2003 'The loess and coversands of northern France and southern England'. *Journal of Quaternary Science* 18, 309-18

Atherton, J K and Furness, R R 1986 'Soils of the Humber warplands'. *Proceedings of the North of England Soils Discussion Group* 23, 1-11

Avery, B W, Bullock, P, Catt, J A, Rayner, J H and Weir, A H 1982 'Composition and origin of some brickearths on the Chiltern Hills'. *Catena* 9, 153-74

Bannister, R T 1983 'Wrangle Toft'. *Lincolnshire History and Archaeology* 18, 104-105

Barth, F E 1991 'The Hallstatt Salt Mines', in Moscati, S et al (eds) *The Celts*, 163-166. Milan.

Bateman, M 1995 'Thermoluminescence dating of the British coversand deposits'. *Quaternary Science Reviews* 14, 791-798

Bateman, M D, Murton, J B and Crowe, W 2000 'Late Devensian and Holocene depositional environments associated with the coversand around Caistor, North Lincs, UK'. *Boreas* 29, 1-15

Bateman, M D and Godby, S P 2004 'Late Holocene inland dune activity in the UK: a case study from Breckland, East Anglia'. *The Holocene* 14, 579-588

Bates, M, Lambrick, G, Welsh, K and White, M J 1998 'Evaluation of Palaeolithic deposits at Purfleet, Essex'. *Lithics* 19, 72-87

Bell, M 1982 'The effects of land-use and climate on valley sedimentation', in Harding, A F (ed) *Climatic Change in later Prehistory*, 127-142 Edinburgh: Edinburgh University Press

Bell, M 1997 'Environmental archaeology in the coastal zone', in Fulford, M, Champion, T and Long, A (eds) England's Coastal Heritage, 56-74. London: English Heritage

Blair, I 1983 'Foster Lane: the finding of the Foster Lane glass'. *Popular Archaeology* 5 (Oct), 23-7

Bradley, S B and Cox, J J 1986 'Heavy metals in the Hamps and Manifold valleys, north Staffordshire, UK: Distribution in floodplain soils'. *Science of the Total Environment* 50, 103-128

Bradley, S B and Cox J J 1987 'Heavy metals in the Hamps and Manifold valleys, North Staffordshire, UK : partitioning of metals in floodplain soils'. *Science of the Total Environment* 65, 135-153

Briant, R M, Bateman, M D, Coope, G R and Gibbard, P L 2005 'Climatic control on Quaternary fluvial sedimentology of a Fenland Basin river, England'. *Sedimentology* 52, 1397 - 1423

Bridgland, D R 1994 *Quaternary of the Thames.* London: Chapman and Hall

Briggs, D J and Gilbertson, D D 1980 'Quaternary processes and environments in the upper Thames Valley'. *Transactions of the Institute of British Geographers New Series* 5, 53-65

Brookes, A, Gregory, K G and Dawson, F H 1983 'An assessment of river channelization in England and Wales'. *Science of the Total Environment* 27, 97-112

Brookes, I P, Hunt, C O, Dorning, K J, Harding, J L and Jones, A M 1990 *The Lindsey coastal survey 1989-1990*. Lincoln

Brown, A G 1983 'Floodplain deposits and accelerated sedimentation in the lower Severn basin', in Gregory, K J (ed) *Background to Palaeohydrology,* 375-398. Wiley: Chichester

Brown, A G 1990 'Holocene floodplain diachronism and inherited downstream variations in fluvial processes: A study of the River Perry, Shropshire'. *Journal of Quaternary Science* 5, 39-51

Brown, A G 1995 'Lateglacial - Holocene sedimentation in lowland temperate environments: floodplain metamorphosis and multiple channel systems, in Frenzel, B (ed) *European river activity and climatic change during the Lateglacial and early Holocene,* 31-35*.* Paleoclimate Research, Volume 14. Stuttgart: Gustav Fisher

Brown, A G 2003 ‘Time, space and causality in floodplain palaeoecology’, in Howard, AJ, Macklin, M, and Passmore, D G (eds) *Alluvial archaeology in Europe*, 15 – 24. Lisse: A A Balkema

Brown, A G and Barber, K E 1985 'Late Holocene palaeoecology and sedimentary history of a small lowland catchment in central England'. *Quaternary Research* 24, 87-102

Brown, A G and Keough, M K 1992a 'Holocene floodplain metamorphosis in the Midlands, United Kingdom'. *Geomorphology* 4, 433-466

Brown, A G and Keough, M K 1992b 'Palaeochannels, palaeoland-surfaces and the three-dimensional reconstruction of floodplain environmental change', in Carling, P A and Petts, G E (eds) *Lowland Floodplain Rivers,* 185-202. Chichester: John Wiley and Sons

Brown, A G, Keough, M K and Rice, R J 1994 'Floodplain evolution in the East Midlands, United Kingdom: the Lateglacial and Flandrian alluvial record from the Soar and Nene Valleys'. *Philosophical Transactions of the Royal Society* A 348, 261-93

Brown, L J 1976 *The mines of Shropshire.* Moorland Publishing Company

Brownrigg, W 1749 *The Art of Making Common Salt*

Bryan R B 1970 ‘Parent materials and texture of Peak District soils’. *Zeitschrift fur Geomorphologie* 14, 262-274

Bryant, I D 1983 'The utilisation of Arctic river analogue studies in the interpretation of periglacial river sediments from southern Britain', in Gregory, K J (ed) *Background to Palaeohydrology,* 413-431. Chichester: John Wiley & Sons

Buckland, P C 1982 ‘The coversands of North Lincolnshire and the Vale of York’, in Adlam, B H, Fenn C R and Morris, L (eds) *Papers in Earth Studies,* 143-178. Norwich: Geobooks

Buckland, P C 1984 ‘North-west Lincolnshire 10000 years ago, in Field, N and White, A (eds) *A prospect of Lincolnshire,* 11-17. Lincoln: Newlands

Buckland, P C Beal, C J and Heal, S V E 1990 ‘Recent work on the archaological and environmental context of the Ferriby boat', in Ellis, S and Crowther, D R (eds) *Humber perspectives, a region through the ages,* 131-146. Hull: Hull University Press

Buckley, D 2000 'Lost and found; the archaeology of the Essex coast', in Aberg, A and Lewis, C (eds) *The Rising Tide: Archaeology and Coastal Landscapes*. Oxford: Oxbow Books

Burrin, P J and Scaife, R G 1984 'Aspects of Holocene floodplain development and valley sedimentation in southern England'. *Proceedings of the Geologists' Association* 95, 81-96

Burrin, P J and Scaife, R G 1988 'Environmental thresholds, catastrophe theory and landscape sensitivity: their relevance to the impact of man on valley alluviations, in Bintliff, J L Davidson, D A and Grant, E G (eds) *Conceptual Issues in Environmental Archaeology,* 211-232. Edinburgh: Edinburgh University Press

Burt, R, Waite, P and Burnley, R 1990 *The mines of Shropshire and Montgomeryshire with Cheshire and Staffordshire.* University of Exeter Press in association with the Northern Mine Research Society

Butzer, K W 1980 'Holocene alluvial sequences: problems of dating and correlation', in Cullingford R A, Davidson, D A and Lewin, J (eds) *Timescales in Geomorphology,* 131-142. Chichester: John Wiley and Sons

Candy, I, Rose, J and Lee, J R 2006 'A seasonally dry interglacial climate in eastern England during the early Middle Pleistocene: palaeopedological and stable isotopic evidence from Pakefield, UK'. *Boreas* 35, 255-265

Canti, M G 1992a 'Anthropogenic modification of the early Holocene soil environment *SEESOIL, Journal of the South East England Soils Discussion Group* 8, 29-42

Canti, M G 1992b 'Research into natural and anthropogenic deposits from the excavations at Flixborough, Humberside'. *English Heritage: Ancient Monuments Laboratory Reports* 53/92

Canti, M G 1993 'Soil research results from the excavations at Harpur Hill, Buxton *English Heritage: Ancient Monuments Laboratory Reports* 105/93

Canti, M G 2001 'What is geoarchaeology? Re-examining the relationship between archaeology and earth-sciences', in Albarella, U (ed) *Environmental Archaeology: Meaning and Purpose*, 103-112. Dordrecht: Kluwer Academic

Canti, M G 2003a 'Aspects of sediment diagenesis and taphonomy', 41-42 in Brennand and Taylor 2003 'The survey and excavation of a Bronze Age timber circle at Holme-next-the-Sea, Norfolk 1998-9'. *Proceedings of the Prehistoric Society* 69, 1- 84

Canti, M G 2003b 'X-ray studies of the sediments', 42-43 in Brennand, M and Taylor, M 2003 'The survey and excavation of a Bronze Age timber circle at Holme-next-the-Sea, Norfolk 1998-9'. *Proceedings of the Prehistoric Society* 69, 1- 84

Canti, M G 2003c 'Aspects of the chemical and microscopic characteristics of plant ashes found in archaeological soils'. *Catena* 54, 339-361

Canti, M G 2007 'Geoarchaeological studies at Flixborough-North Conesby: understanding the burial environment, taphonomy and preservation conditions', in Loveluck, C and Atkinson, D (eds) *The Early Medieval Settlement Remains from Flixborough, Lincolnshire: The Occupation Sequence, c AD 600-1000,* 17-23. Oxford: Oxbow Books

Carrington, P 1994 *Book of Chester*. London: English Heritage and B T Batsford

Catt, J A 1977 'Loess and coversands', in Shotton, F W (ed) *British Quaternary studies: recent advances,* 221-229. Oxford: Oxford University Press

Catt, J A 1978 'The contribution of loess to soils in lowland Britain', in Limbrey, S and Evans, J G (eds) *The Effect of Man on the Landscape: the Lowland Zone*. Council for British Archaeological Research Report 21, 12-20

Catt, J A 1985 'Soil particle size distribution and mineralogy as indicators of pedogenic and geomorphic history: examples from the loessial soils of England and Wales', in Richards, K S, Arnett, R R and Ellis, S (eds) *Geomorphology and Soils,* 202-218. London: George Allen and Unwin

Catt, J A, Corbett, W M, Hodge, A H, Madgett, P A, Tatler, W and Weir, A H 1971 'Loess in the soils of north Norfolk'. *Journal of Soil Science* 22, 444-452

Catt, J A, Weir, A H and Madgett, P A 1974 'The loess of eastern Yorkshire and Lincolnshire'. *Proceedings of the Yorkshire Geological Society* 40, 23-39

Catt, J A and Hagen, R E 1978 'Geological background', in Sampson, C G (ed) *Palaeoecology and Archaeology of an Acheulian Site at Caddington, England.* Dallas: Southern Methodist University Dept of Archaeology, 17-27

Clarke, R R 1937 *In Breckland wilds* . Cambridge: Heffer and Sons

Cooper, L P 2003 'Hemington quarry, Castle Donington, Leicestershire, UK: a decade beneath the alluvium in the confluence zone', in Howard, AJ, Macklin, M, and Passmore, DG (eds) *Alluvial archaeology in Europe*, 27 - 41. Lisse: A A Balkema

Courty, M A, Goldberg, P and Macphail, R I 1989 *Soils and Micromorphology in Archaeology*. Cambridge: Cambridge University Press

Cowie, R, Whytehead, R L and Blackmore, L 1993 'Two Middle Saxon occupation sites: excavations at Jubilee Hall and 21-22 Maiden Lane'. *Transactions of the London and Middlesex Archaeological Society* 39 (for 1988), 47-163

Creyke, R 1825 'Warping peat moss'. *Transactions of the Society of Arts* 43, 2-10

Crowther, D, Willis, S and Creighton, J 1990 'The topography and archaeology of Redcliff', in Ellis, S and Crowther, D R (eds) *Humber perspectives, a region through the ages,* 172-181. Hull: Hull University Press

Crummy, P 1992 *Colchester Archaeological Report 6: Excavations at Culver St, the Gilberd School, and other sites in Colchester 1971-1985.* Colchester: Colchester Archaeological Trust Ltd

Darby, H C 1983 *The Changing Fenland.* Cambridge University Press

Davies, B E and Lewin J 1974 'Chronosequences in alluvial soils with special reference to historic lead pollution in Cardiganshire, Wales', *Environmental Pollution* 6, 49-57

Davis, M B 1976 'Erosion rates and land-use history in southern Michigan', *Environmental Conservation* 3, 139-148

Dawson, M R and Gardiner, V 1987 'River Terraces: The general model and a palaeohydrological and sedimentological interpretation of the terraces of the Lower Severn', in Gregory, K J, Lewin, J and Thornes, J B (eds) *Palaeohydrology in Practice,* 269-305. Chichester: John Wiley and Sons

Dennison, S 2001 'Roman salt manufacturing town uncovered in Cheshire'. *British Archaeology* 60, 6

Devoy R J N 1980 'Post glacial environmental change and Man in the Thames estuary: a synopsis', in Thompson, F H (ed) *Archaeology and Coastal Change*, 134-154. Society of Antiquaries of London Occasional Paper 1 (ns)

Didden, W A M 1993 'Ecology of the terrestrial Enchytraeidae', *Pedobiologia* 37, 2-291

Didsbury, P 1990 'Exploitation of the alluvium of the lower Hull valley in the Roman period', in Ellis, S and Crowther, D R (eds) *Humber perspectives, a region through the ages* 199-210. Hull: Hull University Press

Dix J, Quinn R and Westley K 2004 'A re-assessment of the archaeological potential of continental shelves'. http://arch.soton.ac.uk/Research/Aggregates/shelve-intro.htm: Southampton

Duncan, H 1812 'On the Mode of Manufacturing Salt from Sea-sand or Sleech', in Singer, W *General view of the Agriculture of Dumfries*

Dunham, K, Beer, K E, Ellis, R A, Gallagher, M J, Nutt, M J C and Webb, B C 1978 'United Kingdom ', in Bowie, S H U, Kavalheim, A and Haslam, H W (eds) *Mineral deposits of Europe, Volume 1: Northwest Europe,* 263-317. London: The Institution of Mining and Metallurgy and The Mineralogical Society

Dury, G 1963 *The East Midlands and the Peak.* London: Thomas Nelson

Dyson, T and Schofield, J 1981 'Excavations in the City of London, second interim report 1974-1978', *Transactions of the London and Middlesex Archaeological Society* 32, 24-81

Edwards, W 1850 *Journal of the Royal Agricultural Society of England* 11, 180-183

Ellis, S 1990 'Soils', in Ellis, S and Crowther, D R (eds) *Humber Perspectives: a region through the ages,* 29-42. Hull: Hull University Press

Ellis, S 2001 'Physical background to the Lincolnshire Marsh', in Ellis, S, Fenwick, H, Lillie, M and Van de Noort, R (eds) *Wetland Heritage of the Lincolnshire Marsh*, 7-12. Hull:

Humber Wetlands Project

Ellis, S and Crowther, D 1990 'Introduction', in Ellis, S and Crowther, D R (eds) *Humber perspectives, a region through the ages,* 1 - 9. Hull: Hull University Press

Ellis, S, Fenwick, H, Lillie, M and Van de Noort, R (eds) 2001 *Wetland Heritage of the Lincolnshire Marsh.* Hull: Humber Wetlands Project

Esmonde Cleary, A S 1989 *The Ending of Roman Britain.* London: B T Batsford

Evans, J G, Limbrey, S, Maté, I and Mount, R, 1988 'Environmental change and land-use history in a Wiltshire river valley in the last 14,000 years', in Barrett, J C and Kinnes, I A (eds) *The Archaeology of Context in the Neolithic and Bronze Age: Recent Trends*, 97-103 University of Sheffield: Department of Archaeology and Prehistory

Evelyn, J 1677 'Diary entry for 10 September 1677', in Bray, W (ed) *The Diary of John Evelyn*, 119. London: J M Dent and Sons

Fawn, A J, Evans, K A, McMaster, I and Davies, G M R 1990 *The Red Hills of Essex*. Colchester: Colchester Archaeological Group

Fenwick, H 2007 'Medieval coastal landscape evolution - the example of the Lincolnshire Marsh', in Lillie, M C and Ellis, S (eds) Wetland Archaeology & Environments: Regional issues, Global Perspectives, 108-118. Oxford: Oxbow Books

Fenwick, H, Chapman, H, Fletcher, W, Thomas, G, Lillie, M, Head, R and Gearey, B 2001 'The Archaeological Survey of the Lincolnshire Marsh', in Lillie, M and Ellis, S (eds) *Wetland Archaeology and Environments*, 99-202 Oxford: Oxbow Books.

Ferretti, E and Graham, A H 1978 '201-211 Borough High Street', in *Excavations in Southwark 1973-1976 Lambeth 1973-1979,* 53-176. MoL/DGLA Joint Publication 3 LAMAS/SAS

Ferro, R B 1949 'Warping at Blacktoft', *Journal of the Yorkshire Agricultural Society* 100, 59-65

French, C A I 1990 'Neolithic soils, middens and alluvium in the lower Welland Valley *Oxford Journal of Archaeology* 9, 305-311

French, C A I 2001a 'Micromorphological analysis of the buried Iron Age surface', 77-78 in Lane, T and Morris, E L (2001) *A Millennium of Saltmaking: Prehistoric and Romano British Salt Production in the Fenland* Lincolnshire Archaeology and Heritage Reports Series 4

French, C A I 2001b 'Micromorphological analysis of the buried soil and saltern mound', 219-220', in Lane, T and Morris, E L 2001 *A Millennium of Saltmaking: Prehistoric and Romano British Salt Production in the Fenland*. Lincolnshire Archaeology and Heritage Reports Series 4

French, C A I 2003a *Geoarchaeology in Action: Studies in Soil Micromorphology and Landscape Evolution.* London: Routledge

French, C A I 2003b 'Soil Micromorphology', 38-39 in Brennand and Taylor 2003 The survey and excavation of a Bronze Age timber circle at Holme-next-the-Sea, Norfolk 1998-9. *Proceedings of the Prehistoric Society* 69, 1- 84

French, C A I and Heathcote, J (2003) 'Holocene landscape change in the lower Great Ouse valley, Cambridgeshire, England', in Howard, A J, Macklin, M, and Passmore, D G (eds) *Alluvial archaeology in Europe*, 81 – 92. Lisse: A A Balkema

Gaffney, V, Thomson, K and Fitch, S (2007) Mapping Doggerland: the Mesolithic landscapes of the southern North Sea. Oxford: Archaeopress.

Gaunt, G 1987 'The geology and landscape development of the region around Thorne Moors', *Thorne Moors Papers* 1, 5-28

Gaunt, G D 1994 *Geology of the country around Goole, Doncaster and the Isle of Axholme.* London: Her Majesty's Stationery Office

Gaunt, G D and Tooley, M J 1974 'Evidence for Flandrian sea-level changes in the Humber estuary and adjacent areas', *Bulletin of the Institute of Geological Sciences* 48, 25-41

Gaunt, G D, Fletcher T P and Wood C J 1992 *Geology of the country around Kingston-upon-Hull and Brigg.* British Geological Survey, HMSO

Gibbard, P L 1985 *The Pleistocene History of the Middle Thames Valley.* Cambridge: Cambridge University Press

Gibbard, P L, Wintle, A G and Catt, J A 1987 'Age and origin of clayey silt 'brickearth' in west London, England'. *Journal of Quaternary Science* 2, 3-9

Gilpin 1805 cited in Bateman and Godby 2004

Gladfelter, B G 1977 'Geoarchaeology: the geomorphologist and archaeology *American Antiquity* 42, 519-538

Godwin, H and Vishnu-Mittre 1975 'Studies of the Post-Glacial history of the British vegetation XVI Flandrian deposits of the fenland margin at Holme Fen and Whittlesey Mere, Hunts'. *Philosophical Transactions of the Royal Society* B 270, 561-604

Grady, D M 1998 'Medieval and Post-Medieval salt extraction in North east Lincolnshire', in Bewley, R H (ed) *Lincolnshire's Archaeology from the Air*, 81-95. Lincoln: Occasional Papers in Lincolnshire History and Archaeology 11

Grimes, W F 1968 *The excavations of Roman and medieval London.* London: Routledge and Kegan Paul

Guilbert, G 1994 'Hammer-stones from the copper mining site at Ecton, Staffordshire', in Ford, T D and Willies, L (eds) *Mining before powder*, 26-27. Matlock Bath: Peak District Mines Historical Society and Historical Metallurgy Society

Gupta S, Collier J, Parmer-Felgate A, Dickinson J, Bushe K and Humber S 2004 'Submerged Palaeo-Arun river: reconstruction of prehistoric landscapes and evaluation of archaeological resource potential: final report. London: Imperial College, unpublished.

Haines, B A and Horton, A 1969 *Central England.* London: Her Majesty's Stationery Office

Halkon, P 2007 'Prehistoric wetland environments and human exploitation of the Foulness Valley, East Yorkshire, UK', in Lillie, M. and Ellis, S (eds) *Wetland Archaeology and Environments*, 91-107. Oxford: Oxbow Books

Hall, N. (2006). *Archaeological Monitoring of Ground Reduction at the Lignacite Works, Brandon, Suffolk.* Archaeological Project Services, Report 190/05.

Harvey, A M, Oldfield, F, Baron, A F and Pearson, G W 1981 'Dating of Post-glacial landforms in the Central Howgills'. *Earth Surface Processes and Landforms* 6, 401-412

Hassan, F A 1979 'Geoarchaeology: the geologist and archaeology'. *American Antiquity* 44, 267-70

Hazelden, J and Jarvis, M G 1979 'Age and significance of alluvium in the Windrush valley Oxfordshire'. *Nature* 282, 291-292

Heard, K, Sheldon, H and Thompson, P 1990 'Mapping Roman Southwark'. *Antiquity* 64, 608-619

He, Q and Walling, D E 1996 'Use of fallout Pb-210 measurements to investigate longer term rates and patterns of overbank sediment deposition on the floodplains of lowland rivers'. *Earth Surface Processes and Landforms* 21, 141-154

Heathcote, W R 1951 'A soil survey on warpland in Yorkshire'. *Journal of Soil Science* 2, 144-162

Herapath, T J 1850 'The improvement of land by warping, chemically considered'. *Journal of the Royal Agricultural Society of England* 11, 93-113

Higgs, G 1987 'Environmental change and hydrological response; flooding in the Upper Severn catchment', in Gregory, K J, Lewin, J and Thomes, J B (eds) *Palaeohydrology in Practice,* 131-159. Chichester: John Wiley and Sons

Hill, T, Fletcher, W, Gearey, B, Howard, A and Good, C in press 'The Suffolk River Valleys Project: An assessment of the potential and character of the palaeoenvironmental and geoarchaeological resource of Suffolk river valleys affected by aggregate extraction'. http://www.suffolk.gov.uk/Environment/Archaeology/MineralsAndArchaeology /SuffolkRiverValleysProject.htm

Holland, S M 1975 'Pollen analytical investigations at Crosby Warren, Lincolnshire, in the vicinity of the Iron age and Romano-British settlement of Dragonby'. *Journal of Archaeological Science* 2, 353-363

Hood, J S R 1981 'The Sedimentary Regime', in McGrail, S (ed) *The Brigg 'raft' and her Prehistoric Environment* 197-204. Oxford: British Archaeological Reports, British Series 89

Hooke, J M and Redmond, C E 1989 'River channel changes in England and Wales'. *Journal of the Institution of Water and Environmental Management* 3, 328-335

Hooke, J M, Harvey, A M, Miller, S Y and Redmond, C E 1990 'The chronology and stratigraphy of the alluvial terraces of the River Dane valley, Cheshire, N W England'. *Earth Surface Processes and Landforms* 15, 717-737

Howard, A J and Knight, D 1995 'Geomorphological and Palaeoenvironmental investigations in the Lower Trent valley: Bronze Age 'flood events' or long term reworking?'. *East Midlands Geographer* 18, 89-91

Howard, A J and Macklin, M 1999 'A generic, geomorphological approach to archaeological interpretation and prospection in British river valleys: a guide for archaeologists investigating Holocene landscapes'. *Antiquity* 73, 527-541

Howard, A J, Macklin, M G, Black, S and Hudson-Edwards, K A 2000 'Holocene river development and environmental change in Upper Wharfedale, Yorkshire Dales, England'. *Journal of Quaternary Science* 15, 239-252

Howard, A J, Macklin, M G and Passmore, D G eds. *Alluvial Archaeology in Europe*. Lisse: A.A. Balkema

Hudson-Edwards, K A, Macklin, M G, Curtis, C D and Vaughan, D 1996 'Processes of formation and distribution of Pb- Zn-, Cd and Cu-bearing minerals in the Tyne basin, northeast England: implications for metal-contaminated river systems'. *Environmental Science and Technology* 30, 72-80

Hudson-Edwards, K A, Macklin, M G, Curtis, C D and Vaughan D J 1998 'Chemical remobilisation of contaminant metals within floodplain sediments in an incising river system: implications for dating and chemostratigraphy'. *Earth Surface Processes and Landforms* 23, 671-684

Jacobi, R M 1978 'Northern England in the Eighth Millenium BC: an essay', in Mellars, P (ed) *The early postglacial settlement of northern Europe*, 295-332

Jordan, D 1987 'Diatom analysis', in Millett, M and McGrail, S 1987 'The archaeology of the Hasholme logboat'. *Archaeological Journal* 144, 69-155

Keevill, G 1992 'Life on the edge: archaeology and alluvium at Redlands Farm, Stanwick, Northants', in Needham, S and Macklin, M G (eds) *Alluvial Archaeology in Britain,* 27-35. Oxbow Monograph 27 Oxford: Oxbow Books

Kenyon, K 1959 *Excavations in Southwark.* Guildford: Surrey Archaeological Society Research Papers 5

Kirkham, B 1981 'The excavation of a prehistoric saltern at Hogsthorpe, Lincolnshire'. *Lincolnshire History and Archaeology* 16, 5-10

Knight, D and Howard, A J 1994 *Archaeology and alluvium in the Trent valley: an archaeological assessment of the floodplain and gravel terraces.* Nottingham: Trent and Peak Archaeological Trust

Knight, D and Howard, A J 1995 'The Trent valley survey'. *Transactions of the Thoroton Society of Nottinghamshire* 99, 126-129

Koster, E A 1988 'Ancient and modern cold climate aeolian sand deposition: a review'. *Journal of Quaternary Science* 3, 69-83

Lacaille, A D 1946 'Some flint implements of special interest from Lincolnshire, Hampshire and Middlesex'. *Antiquaries Journal* 26, 180-185

Lambrick, G 1992 'Alluvial archaeology of the Holocene in the Upper Thames basin 1971-1991: a review', in Needham, S and Macklin, M G (eds) *Alluvial Archaeology in Britain,* 209-226. Oxbow Monograph 27 Oxford: Oxbow Books

Lane, T and Morris, E L 2001 *A Millennium of Saltmaking: Prehistoric and Romano British Salt Production in the Fenland.* Lincolnshire Archaeology and Heritage Reports Series 4

Leenaers, H, Schouten, C J and Rang, M C 1988 'Variability of the metal content of flood deposits'. *Environmental Geology and Water Sciences* 11, 95-106

Lewin, J 1982 'British floodplains', in Adlam, B H, Fenn, C R and Morris, L (eds) *Papers in Earth Studies,* 21-36. Norwich: Geobooks

Lewin, J, Bradley, S B and Macklin, M G 1983 'Historical valley alluviation in mid-Wales'. *Geological Journal* 18, 331-350

Lewin, J and Macklin, M G 1987 'Metal mining and floodplain sedimentation in Britain', in Gardiner, V (ed) *International Geomorphology 1986,* Part 1, 1009-1027. Chichester: Wiley

Lewin, J, Davies, B E and Wolfenden P J 1977 'Interactions between channel change and historic mining sediments, in Gregory, R C (ed) *River Channel Changes,* 353-367. New York: Wiley

Leyton, L, Reynolds, E R C and Thompson, F B 1967 'Rainfall interception in forest and moorland', in Sopper, W E and Lull, H W (eds) *International Symposium on Forest Hydrology* 163-177. Oxford: Pergamon Press

Lillie, M C and Grattan, J P 1995 'Geomorphological and palaeoenvironmental investigations in the Lower Trent Valley'. *East Midlands Geographer* 18, 12-24

Lillie, M and Weir, D 1997 'Alluvium and warping in the Humberhead levels', in Van de Noort, R and Ellis, S (eds) *Wetland Heritage of the Humberhead levels: an archaeological survey*, 191-226. Hull: Humber Wetlands Project

Lillie, M and Weir, D 1998 'Alluvium and warping in the lower Trent valley', in Van de Noort, R and Ellis, S (eds) *Wetland Heritage of the Ancholme and Lower Trent valleys*, 103-122. Hull: Humber Wetlands Project

Limbrey, S 1978 'Changes in the quality and distribution of the soils of lowland Britain, in Limbrey, S and Evans, J (eds) *The effect of man on the landscape: the lowland zone*, 21-27. Council for British Archaeology Research Report 21

Limbrey, S 1983 'Archaeology and Palaeohydrology', in Gregory, K J (ed) *Background to Palaeohydrology* 189-212. Chichester: John Wiley and Son

Limbrey, S and Robinson, S 1988 'Dry land to wet land: soil resources in the Upper Thames valley', in Murphy, P and French, C (eds) *The Exploitation of Wetlands,* 129-141. Oxford: British Archaeological Reports

Linford, N 2003 'Magnetic susceptibility', 43- 44 in Brennand and Taylor 2003 'The survey and excavation of a Bronze Age timber circle at Holme-next-the-Sea, Norfolk 1998-9'. *Proceedings of the Prehistoric Society* 69, 1- 84

Lobb, S J and Rose, P G 1996 *Archaeological survey of the Lower Kennet Valley Berkshire*. Salisbury: Wessex Archaeology

Long, A J and Roberts, D H 1997 'Sea level change', in Fulford, M, Champion, T and Long, A (eds) *England's Coastal Heritage*, 25-49. London: English Heritage

Long, A J, Innes, J B, Kirby, J R, Lloyd, J M, Rutherford, M M, Shennan, I and Tooley, M 1998 'Holocene sea-level change and coastal evolution in the Humber estuary, eastern England: an assessment of rapid coastal change'. *The Holocene* 8, 229-247

Loveluck, C and Atkinson, D (eds) 2007 *The Early Medieval Settlement Remains from Flixborough, Lincolnshire: The Occupation Sequence, c AD 600-1000.* Oxford: Oxbow Books

Macklin, M G 1985 'Floodplain sedimentation in the Upper Axe valley, Mendip, England', *Transactions of the Institute of British Geographers* NS 10, 235-244

Macklin, M G 1992 'Metal pollution of soils and sediment: a geographical perspective', in

Newson, M D (ed) *Managing the Human impact on the Natural Environment: Patterns and Processes*, 172-195. London: Belhaven Press

Macklin, M G and Dowsett, R B 1989 'The chemical and physical speciation of trace metals in fine grained overbank flood sediments in the Tyne basin north-east England', *Catena* 16, 135-151

Macklin, M G, Passmore, D G and Rumsby, B T 1992 'Climatic and cultural signals in Holocene alluvial sequences; the Tyne basin, northern England', in Needham, S and Macklin, M G (eds) *Alluvial Archaeology in Britain,* 27-35. Oxbow Monograph 27. Oxford: Oxbow Books

Macklin, M, Howard, A J and Passmore, D G 2003 'The condition of Holocene alluvial archaeology in the UK: progress, constraints and opportunities', in Howard, A J, Macklin, M, and Passmore, D G (eds) *Alluvial archaeology in Europe*, 3 – 14. Lisse: A A Balkema

Macklin, M, Johnstone, E and Lewin J 2005 'Pervasive and long-term forcing of Holocene river instability and flooding in Great Britain by centennial-scale climate change'. *The Holocene* 15, 937-943.

Macphail, R I 1979 'Soil report on the barrow and buried soil at Sproxton, Leics'. *Ancient Monuments Laboratory Report* 2926

Macphail, R I and Courty, M A 1985 'Interpretation and significance of urban deposits', in Edgren, T and Jungner, H (eds) *Nordic Archaeometry* 3 Helsinki: Finnish Archaeological Society ISKOS 5

Marriott, S 1992 'Textural analysis and modelling of a flood deposit: River Severn, U K', *Earth Surface Processes and Landforms* 17, 687-697

Marsden, P 1980 *Roman London.* London: Thames and Hudson

Marsden, P 1985 'London in the 3rd and 4th centuries', in Grew, F and Hobley, B (eds) *Roman Urban Topography in Britain and Western Europe*, 99-108. CBA Research Report 59. London: Council for British Archaeology

May, J 1976 *Prehistoric Lincolnshire.* Lincoln: History of Lincolnshire Committee

McAvoy, F 1994 'Marine salt extraction. The excavation of salterns at Wainfleet St Mary Lincolnshire'. *Medieval Archaeology* 38, 134-163

McGrail, S 1981 *The Brigg 'raft' and her prehistoric environment*. Oxford BAR 89

McGrail, S 1990 'Early boats of the Humber estuary', in Ellis, S and Crowther, D R (eds) *Humber perspectives, a region through the ages,* 109-130. Hull: Hull University Press

Meddens, F M 1996 'Sites from the Thames Estuary wetlands, England, and their Bronze Age use'. *Antiquity* 70, 325-334

Merriman, N 1992 'Predicting the unexpected: prehistoric sites recently discovered under alluvium in central London', in Needham, S and Macklin, M G (eds) *Alluvial Archaeology in Britain,* 261-267. Oxbow Monograph 27 Oxford: Oxbow Books

Millett, M and McGrail, S 1987 'The archaeology of the Hasholme logboat'. *Archaeological Journal* 144, 69-155

Milne, G 1995 *Roman London: urban archaeology in the nation's capital.* London: English Heritage/B T Batsford

MoLAS 2000 *The archaeology of Greater London.* London: Museum of London/English Heritage

Morris, R 1989 *Churches in the Landscape*. London: Dent and Sons

Needham, S P 1991 *Excavation and Salvage at Runnymede Bridge 1978: The Late Bronze Age Waterfront Site.* London: British Museum Press

Needham, S P 1992 'Holocene alluviation and interstratified settlement evidence in the Thames valley at Runnymede Bridge', in Needham, S and Macklin, M G (eds) *Alluvial Archaeology in Britain,* 249-260. Oxbow Monograph 27. Oxford: Oxbow Books

Norman, P and Raeder, F W 1912 'Further discoveries relating to Roman London, 1906-12', *Archaeologia* 63, 257-344

Ottaway, P 1993 *Book of Roman York.* London: B T Batsford/English Heritage

Palmer Brown, C 1993 'Bronze Age salt production in Tetney'. *Current Archaeology* 136, 143-145

Parfitt, S A, Barendregt, W, Breda, M, Candy, I, Collins, M J, Coope, G R, Durbidge, P, Field, M H, Lee, J R, Lister, A M, Mutch, R, Penkman, K E H, Preece, R C, Rose, J, Stringer, C B, Symmons, R, Whittaker, J, Wymer, J J and Stuart, A J 2005 'The earliest record of human activity in northern Europe'. *Nature* 438, 1008-1012

Parker, A.G. and Robinson, M.A. (2003) Palaeoenvironmental investigations on the middle Thames at Dorney, UK. In Howard, A J, Macklin M G and Passmore, D G eds. *Alluvial Archaeology in Europe*, 43-60. Lisse: A.A. Balkema.

Parks, D A and Rendell, H M 1992 'TL geoachronology of brickearths from south east England'. *Quaternary Science Reviews* 11, 7-12

Pattison, J and Williamson, I T 1986 'The saltern mounds of North East Lincolnshire'. *Proceedings of the Yorkshire Geological Society* 46, 77-83

Perrin, R M S, Davies, H and Fysch, M D 1974 'Distribution of late-Pleistocene aeolian deposits in eastern and southern England'. *Nature* 248, 320-324

Perring, D and Roskams, S 1991 *Archaeology of Roman London Vol 2 Early Development of Roman London West of the Walbrook.* CBA Research Report 70. London: Council for British Archaeology

Pethick, J S 1990 'The Humber Estuary', in Ellis, S and Crowther, D R (eds) *Humber perspectives, a region through the ages,* 54-67. Hull: Hull University Press

Petts, G E 1989 'Historical analysis of fluvial hydrosystems', in Petts, G E Moller, H and Roux, A L (eds) *Historical change of large alluvial rivers: Western Europe,* 1-18. Chichester: Wiley

Pigott C D 1962 'Soil formation and development on the Carboniferous limestone of Derbyshire I Parent materials'. *Journal of Ecology* 50, 145-156

Preece, R C, Bridgland, D R, Lewis, S G, Parfitt, S A and Griffiths, H I 2000 Beeches Pit, West Stow, Suffolk (TL 798719)', in Lewis, S G, Whiteman, C A and Preece, R C (eds) *The Quaternary of Norfolk and Suffolk*, *Field Guide*, 185-195. London: Quaternary Research Association

Probst, J L 1989 'Hydroclimatic fluctuations of some European rivers since 1800', in Petts, G E Moller, H and Roux, A L (eds), *Historical change of large alluvial rivers: Western Europe,* 41-55. Chichester: John Wiley and Sons

Pryor F 1998 *Etton.* English Heritage Archaeological Report 18. London: English Heritage

Pryor, F M M, French, C A I and Taylor, M 1985 'An Interim Report on Excavations at Etton, Maxey, Cambridgeshire, 1982-84'. *Antiquaries Journal* 65, 275-311

Pye, K 1995 'Controls on the long-term saltmarsh accretion and erosion in the Wash, eastern England'. *Journal of Coastal Research* 11, 337-356

Radley, J and Simms, C 1967 'Wind erosion in East Yorkshire'. *Nature* 216, 20-22

Raistrick, A and Jennings, B 1965 *A History of Lead Mining in the Pennines.* London: Longmans

Reece, R 1980 'Town and country: the end of Roman Britain'. *World Archaeology* 12, 77-92

Rhodes, E J 2007 'Barford Road, St Neots, Cambridgeshire. Optically Stimulated Luminescence dating of single grains of quartz from sedimentary fills of two cursus monuments'. *English Heritage Research Department Report Series* 32/2007

Riley, D N, Buckland, P C and Wade, J S 1995 'Aerial reconnaissance and excavation at Littleborough on Trent, Notts'. *Britannia* 26, 253-284

Robinson, D N 1970 'Coastal evolution in North East Lincolnshire'. *East Midland*

Geographer 5, 62-70

Robinson, G G 1969 *Some aspects of the historical geography of the Humber Warplands, 1600-1940.* MA Thesis, Hull

Robinson, M 1981 'The effects of pre-afforestation drainage upon the streamflow and water quality of a small upland catchment'. *Institute of Hydrology Report* 73, 69pp

Robinson, M 1992 'Environment, archaeology and alluvium on the river gravels of the South Midlands', in Needham, S and Macklin, M G (eds) *Alluvial Archaeology in Britain,* 197-208. Oxbow Monograph 27 Oxford: Oxbow Books

Robinson, M and Lambrick, G H 1984 'Holocene alluviation and hydrology in the upper Thames basin'. *Nature* 308, 809-814

Rose, J, Turner, C, Coope, G R and Bryan, M D 1980 Channel changes in a lowland river catchment over the last 13,000 years', in Cullingford R A, Davidson, D A and Lewin, J (eds) *Timescales in Geomorphology,* 159-175. Chichester: John Wiley and Sons

Roskams, S and Schofield, J 1978 'The Milk St Excavation, Part 2'. *London Archaeologist* 3, 227-34

Rudkin, E H and Owen, D M 1960 'The medieval salt industry in the Lindsey marshland'. *Lincolnshire Architectural and Archaeological Society Papers* 8 (NS), 76-84

Salisbury, C R 1992 'The archaeological evidence for palaeochannels in the Trent Valley', in Needham, S and Macklin, M G (eds) *Alluvial Archaeology in Britain,* 155-162 Oxbow Monograph 27. Oxford: Oxbow Books

Salisbury, C R, Whitley, C B, Litton, C D and Fox, J L 1984 'Flandrian courses of the River Trent at Colwick, Nottingham'. *Mercian Geologist* 9, 189-207

Salvador, P G, Bravard, J P, Vital, J, Lyon, J L and Voruz, J L 1993 'Archaeological evidence for Holocene floodplain development in the Rhône valley, France'. *Zeitschrift fur Geomorphologie* 88, 81-95

Sandford, K S 1924 'The river gravels of the Oxford district'. *Quarterly Journal of the Geological Society* 80, 113-179

Sankey, D and McKenzie, M 1997 '7-11 Bishopsgate: a hole in the heart of London's business district'. *London Archaeologist* 8, 171-179

Scarfe, N 1988 *Francois de la Rochefoucauld: A Frenchman's year in Suffolk, 1784.* Suffolk Records Society 30. Woodbridge: Boydell Press

Schaaf, L 1988 199 'Borough High St', in *Excavations in Southwark 1973-1976 Lambeth 1973-1979,* 83-132. MoL/DGLA Joint Publication 3 LAMAS/SAS

Schnellmann, G A Q and Scott, B 1970 'Lead-Zinc mining areas of Great Britain', in Jones, M J (ed) *Proceedings of the Ninth Commonwealth Mining and Metallurgical Congress 1969*, *Volume 2*, 325-356. London: Institute of Mining and Metallurgy

Schreve, D C, Bridgland, D R, Allen, P, Blackford, J J, Gleed-Owen, P, Griffiths, H, Keen, D H, and White, M J 2002 'Sedimentology, palaeontology and archaeology of late Middle Pleistocene River Thames terrace deposits at Purfleet, Essex, UK'. *Quaternary Science Reviews* 21, 1423-1464

Schumm, S A 1969 'River metamorphosis'. *Proceedings of the American Society of Civil Engineers Journal of the Hydraulics Division* HY1 6352, 255-273

Schumm, S A 1979 'Geomorphic thresholds; the concept and its applications'. *Transactions of the Institute of British Geographers, New Series* 4, 485-515

Schwenninger, J-L, Bridgland, D R, Howard A J, and White, T 2007a 'Pleistocene sediments from the Trent Valley: optically stimulated luminescence (OSL) dating'. *English Heritage Research Department Report Series* 57/2007

Schwenninger, J-L, Williams, J, Aram, J, Hambly, J and Rackham, J 2007b 'Welton-le-Wold, Lincolnshire: optically stimulated luminescence (OSL) dating of Pleistocene glacial tills and interglacial gravels'. *English Heritage Research Department Report Series* 36/2007

Sear D and Carver, S 1996 The release and dispersal of Pb and Zn contaminated sediments within an Arctic braided river system'. *Applied Geochemistry* 11, 187-195

Sheail, J 1988 River regulation in the UK: a historical perspective'. *Regulated Rivers: Research and Management* 2, 221-232

Sheldon, H 1978 'The 1972-74 excavations: their contribution to Southwark's history', in SLAEC 1978 Southwark excavations 1972-74, 11-49. *London and Middlesex Archaeological Society and Surrey Joint Publication* 1

Shennan, I 1989 'Holocene crustal movements and sea-level changes in Great Britain'. *Journal of Quaternary Science* 4, 77-89

Shotton, F W 1978 'Archaeological inferences from the study of alluvium in the Lower Severn-Avon valleys', in Limbrey, S and Evans, J G (eds) *Man's Effect on the landscape: The Lowland Zone,* 27-32. CBA Research Report 21. London: Council for British Archaeology

Shotton, F W and Coope, G R 1983 'Exposures in the Power House terrace of the River Stour at Wilden, Worcestershire, England'. *Proceedings of the Geologists' Association* 94, 33-44

Sidell, J, Wilkinson, K, Scaife, R, and Cameron, N 2000 *The Holocene evolution of the London Thames* London: MoLAS Monograph 5

Simmons, B 1980 'Iron age and Roman coasts around the Wash', in Thompson, F H (ed) *Archaeology and Coastal Change*. London: Society of Antiquaries Occasional Paper, NS 1, 56-73

Smith, A G 1958 'The context of some late Bronze Age remains from Lincolnshire'. *Proceedings of the Prehistoric Society* 24, 78-84

Smith, A G, Brown, E A and Green, C A 1981 'Environmental evidence from pollen and stratigraphy', in McGrail, S (ed) *The Brigg 'raft' and her prehistoric environment*. Oxford: British Archaeological Reports, British Series 89, 135-145

Smith, D N, Roseff, R, Bevan, L, Brown, A G, Butler, S, Hughes, G, and Monckton, A 2005 'Archaeological and environmental investigations of a Lateglacial and Holocene river sedimentary sequence on the river Soar at Croft, Leicestershire, UK'. *The Holocene* 15, 353-377

Spurrell, F C J 1885 'Early sites and embankments on the margins of the Thames estuary'. *Archaeological Journal* 42, 269-302

Spurrell, F C J 1889 'On the estuary of the Thames and its alluvium'. *Proceedings of the Geological Society of London* 11, 210-230

Strang, A 1997 'Explaining Ptolemy's Roman Britain', *Britannia* 28, 1-30

Stukeley 1723 *Itinerarium Curiosum* I, 5

Sussams, K 1996 *The Breckland Archaeological Survey.* Ipswich: Suffolk County Council

Swinnerton, H H 1931 'The post glacial deposits of the Lincolnshire coast'. *Quarterly Journal of the Geological Society of London* 87, 360-375

Switsur, V R 1981 'Radiocarbon dating', in (McGrail, S, ed) *The Brigg 'raft' and her prehistoric environment*. Oxford: British Archaeological Reports, British Series 89, 117-121

Taylor, M P and Lewin, J 1996 'River behaviour and Holocene alluviation: the River Seven at Welshpool, mid-Wales, UK'. *Earth Surface Processes and Landforms* 21, 77-91

Thomas, G and Fletcher W 2001 'Prehistoric and Roman salt making in the Lincolnshire Marsh', in Ellis, S, Fenwick, H, Lillie, M and Van de Noort, R (eds) *Wetland Heritage of the Lincolnshire Marsh*, 215-230. Hull; Humber Wetlands Project

Thorndycraft V R, Pirrie D and Brown A G 2003 'An environmental approach to the archaeology of tin mining on Dartmoor', in Murphy, P and Wiltshire, P (eds) *The Environmental Archaeology of Industry*, 19-28. Oxford: Oxbow Books

Thorne, C R and Tovey, N K 1981 'Stability of composite river banks'. *Earth Surface Processes and Landforms* 6, 469-484

Ussher, W A E 1890 The geology of parts of North Lincolnshire and south Yorkshire. *Memoirs of the Geological Survey of England and Wales.* London: Her Majesty's Stationery Office

Van de Noort, R and Ellis, S 1995 *Wetland Heritage of Holderness*. Hull: Humber Wetlands Project

Van Vliet, P C J, Coleman, D C and Hendrix, P F 1997 'Population dynamics of Enchytraeidae (Oligochaeta) in different agricultural systems'. *Biology and Fertility of Soils* **25**, 123-129

Walling, D E, Quine, T A and He, Q 1992 in Carling, P A and Petts, G E (eds) *Lowland Floodplain Rivers,* 165-184 Chichester: John Wiley and Sons

Walling, D E, Owens, P N and Leeks, G J L 1998 'Erratum to "The characteristics of overbank deposits associated with a major flood event in the Catchment of the River Ouse, Yorkshire, UK" [Catena 31 1997) 53-75]'. *Catena* **32**, 309-311

Ward, I and Larcombe, P 2008 Determining the preservation rating of submerged archaeology in the post-glacial southern North Sea: a first order geomorphological approach. *Environmental Archaeology* **13**, 59-83

Warren, S H, Piggott, S, Clark, J G D, Burkitt, M C, Godwin, H and Godwin, M E 1936 'Archaeology of the submerged land surface of the Essex coast', *Proceedings of the Prehistoric Society* **2**, 178-210

Watson, B 1998 ''Dark earth' and urban decline in late Roman London'. *Journal of Roman Archaeology Supplementary Monograph Series* **24**, 100-106

Webber, J 1986 'Warp soils - their agriculture and land use'. *Proceedings of the North of England Soils Discussion Group* **23**, 19-22

West, S 1985 *West Stow: the Anglo-Saxon village Volume 1: the text.* East Anglian Archaeology Report 23. Ipswich: Suffolk County Planning Department

Wheeler, W H 1901 'Source of warp in the Humber'. *Geological Magazine* **8**, 569-570

White, P 2003 *The Arrow valley Herefordshire: Archaeology, Landscape Change and Conservation*. Herefordshire Studies in Archaeology Series 2. Hereford: Hereford Archaeology

Wilkinson, T J and Murphy, P L 1995 The Archaeology of the Essex Coast Volume 1: the Hullbridge Survey. Essex County Council: East Anglian Archaeology 71

Wood, W R and Johnson, D L 1978 'A survey of disturbance processes in archaeological site formation', in Schiffer, M B (ed) *Advances in Archaeological Method and Theory*, Volume 1, 315-381. New York: Academic Press

Wright, T 1668 'A curious and exact relation of a sandfloud'. *Philosophical Transactions of the Royal Society of London* 3, 722-725

Wright, E V 1990 *The North Ferriby boats: Sea craft of the Bronze Age.* London: Routledge

Wright, E V and Churchill, D M 1965 'The North Ferriby boats'. *Proceedings of the Prehistoric Society* 31, 1-24

Wymer, J J 1985 *Paleaeolithic sites in East Anglia.* Norwich: Geobooks

Wymer, J 1999 *The Lower Palaeolithic Occupation of Britain* Salisbury: Wessex Archaeology

Wymer, J and Robins, P 2006 'The earliest Britons'. *Current Archaeology* 201, 458-467

Wymer, J and Singer, R 1970 'The first season of excavations at Clacton-on-Sea, Essex, England: a brief report'. *World Archaeology* 2, 12-16

Yule, B 1990 'The 'dark earth' and late Roman London'. *Antiquity* 64, 620-628

Yule, B and Hinton, P '1988 88 Borough High St', in *Excavations in Southwark 1973-1976 Lambeth 1973-1979* MoL/DGLA, 71-81. *London and Middlesex Archaeological Society/Surrey Archaeological Society Joint Publication* 3

Zeeberg, J J 1998 'The European sand belt in Eastern Europe – and comparison of late Glacial dune orientation with GCM simulation results'. *Boreas* 72, 127-139

ENGLISH HERITAGE RESEARCH DEPARTMENT

English Heritage undertakes and commissions research into the historic environment, and the issues that affect its condition and survival, in order to provide the understanding necessary for informed policy and decision making, for sustainable management, and to promote the widest access, appreciation and enjoyment of our heritage.

The Research Department provides English Heritage with this capacity in the fields of buildings history, archaeology, and landscape history. It brings together seven teams with complementary investigative and analytical skills to provide integrated research expertise across the range of the historic environment. These are:

- *Aerial Survey and Investigation*
- *Archaeological Projects (excavation)*
- *Archaeological Science*
- *Archaeological Survey and Investigation (landscape analysis)*
- *Architectural Investigation*
- *Imaging, Graphics and Survey (including measured and metric survey, and photography)*
- *Survey of London*

The Research Department undertakes a wide range of investigative and analytical projects, and provides quality assurance and management support for externally-commissioned research. We aim for innovative work of the highest quality which will set agendas and standards for the historic environment sector. In support of this, and to build capacity and promote best practice in the sector, we also publish guidance and provide advice and training. We support outreach and education activities and build these in to our projects and programmes wherever possible.

We make the results of our work available through the Research Department Report Series, and through journal publications and monographs. Our publication Research News, which appears three times a year, aims to keep our partners within and outside English Heritage up-to-date with our projects and activities. A full list of Research Department Reports, with abstracts and information on how to obtain copies, may be found on www.english-heritage.org.uk/researchreports

For further information visit www.english-heritage.org.uk

ENGLISH HERITAGE