Chapter 11

The Thames River Crossing

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The Thames River Crossing (Zones T18–27)

Construction Impacts

Construction impacts on the southern side of the river at Swanscombe (Figs 28 and 29) consisted of the excavation of a 450m long box (including a tunnel boring machine (TBM) launch chamber) (Pl 21) taking the railway through the Holocene floodplain deposits and underlying Pleistocene river gravel sediments into the underlying Chalk. Construction of the passage beneath the river was by bored tunnel through the Chalk. An excavated box was also constructed on the north side of the river at Thurrock to receive the TBM along with a new viaduct carrying HS1 over the A282 (Figs 27 and 28). The main archaeological investigation focused on the southern side of the river, where impact was likely to be considerable, in particular near to the floodplain edge where evidence of human activity was considered most likely. Full details of all investigations are listed in Table 55.

Key Archaeological Issues

Early in the project construction through the southern crossing area was considered likely to impact on a broad transect of Holocene sediments across a substantial portion of the floodplain (Chap 6, *Window 12*). The 1999 model designated Zones T25–T27 medium to high priority areas (Figs 28 and 29) The projected length of the construction impact offered the opportunity to investigate a broad slice of floodplain sediments (through a full sequence of Holocene deposits) from floodplain edge nearly 0.5km into the floodplain. Evidence from elsewhere in the region (Bates and Whittaker 2004) suggested that such sequences might contain archaeological remains, particularly towards the edge of the floodplain and in dry ground situations marginal to the wetland. Construction impacts in the northern crossing area at Thurrock were more limited with HS1 continuing westwards on a purpose built viaduct after exiting the Thames Tunnel. The northern portal in Zones T20–21 was considered in the 1999 model to be of medium to low priority (Chap 6, *Window 11*; Figs 27 and 28).

Strategy, Aims and Objectives

Following the route-wide desk-top assessment (Chap 6, *Windows 11* and *12*) a three stage investigation was undertaken within the study area. An initial programme of works (Stage 1) was developed in Swanscombe Marshes (Figs 59 and 60) in order to determine the nature and distribution of the main sediment bodies present and, in particular, to locate the precise position within the route corridor of any topographic highs, adjacent to the wetland, on which evidence for human activity may exist. These objectives were addressed using a combination of geophysics and intrusive borehole/cone penetration methods (Fig 60). Following this stage of works an area of high archaeological potential was identified at the south eastern end of the works area where a purposive archaeological excavation (Stage 2) was undertaken at the appropriate location on the line of the route. This was achieved through the excavation of a cofferdam (3880TT) to ascertain the nature of any human activity associated with the gravel high (Fig 60). A final phase of works (Stage 3) was a watching brief during construction on the full area of excavation for the route tunnel approaches.

Table 55 Summary of fieldwork events, Thames River Crossing

Event name	Event code	Type	Zone	Interventions	Archaeological contractor
Archaeological boreholes at Thames Crossing	ARC TMS00	Evaluation	20	Geophysical survey 2BH(CP), 7BH(MOS), 5BH(RES), 11BH(PIEZ)	Wessex Archaeology
Thames Crossing	ARC TMS01	Excavation	25	3880TT	Wessex Archaeology
Thames Crossing	ARC 32001	Watching brief	25		Wessex Archaeology

BH = borehole (CP) = Cable percussion (MOS) = Mostap (RES) = Resistivity (PIEZ) = Piezocone TT = trench

Plate 21 View of construction of cut and cover tunnel boring machine launch chamber, Swanscombe

Methodologies

Initial desk-top investigation (Chap 6, *Window 12*) was undertaken using extant geotechnical data from boreholes, cone penetration tests and the published literature. The results of the desk-top investigation were a detailed cross-section illustration (Fig 28) that provided an impetus for the field investigations of Stage 1. The desk-top investigation identified that a wedge of Holocene alluvium thinned towards the valley margins and buried a sequence of one or more bodies of Pleistocene sediment. These bodies of sand and gravel, coupled with the bedrock surface topography, defined the topographic template on which human activity occurred. However, insufficient data existed to adequately map this surface and predict foci of human activity. Because of sequence depths (5–10m of Holocene deposits) trial trenching in advance of construction activity, following standard archaeological practice, was both impractical and costly. Furthermore excavation during the construction window would be an expensive exercise that also ran the risk of causing major delays following unexpected discoveries. Consequently Stage 1 involved a mixed method approach in order to attempt to define precisely areas of high archaeological potential and/or interesting palaeoenvironmental sequences and, therefore, focus excavation attention (Stage 2) to limited areas of the construction footprint. Those areas identified as of high archaeological potential could then be examined either in advance, in targeted trenching exercises, or excavated during planned time slots within the overall construction timetable (Bates *et al* 2007).

Field investigation in Stage 1 (Fig 60) involved geophysical survey, purposive cone penetration tests (CPT) and boreholes. This work was undertaken by Martin and Richard Bates (see Bates *et al* 2007). The electromagnetic survey was conducted using the Geonics EM–31 and EM–34 terrain conductivity instruments across the full width of the route corridor and an Abem Lund electrical resistivity instrument along the line of the route. The initial geophysical survey was conducted in order to investigate the sub-surface electrical properties of the deposits and provide more localised targets for CPT and borehole sample recovery.

Following the non-invasive geophysical survey, targets for sub-surface investigation were noted and ground investigation techniques were employed to rapidly characterise sedimentary properties of the deposits (using CPT) and recover sediment samples (shell and auger boreholes and Mostap boreholes) (Fig 60). The principal considerations in selecting techniques involved the need to recover sample material for characterisation and dating as well as the need to cover large areas of the site to recover proxy information on sub-surface sediment types. The CPT survey was used to inform the location of Mostap

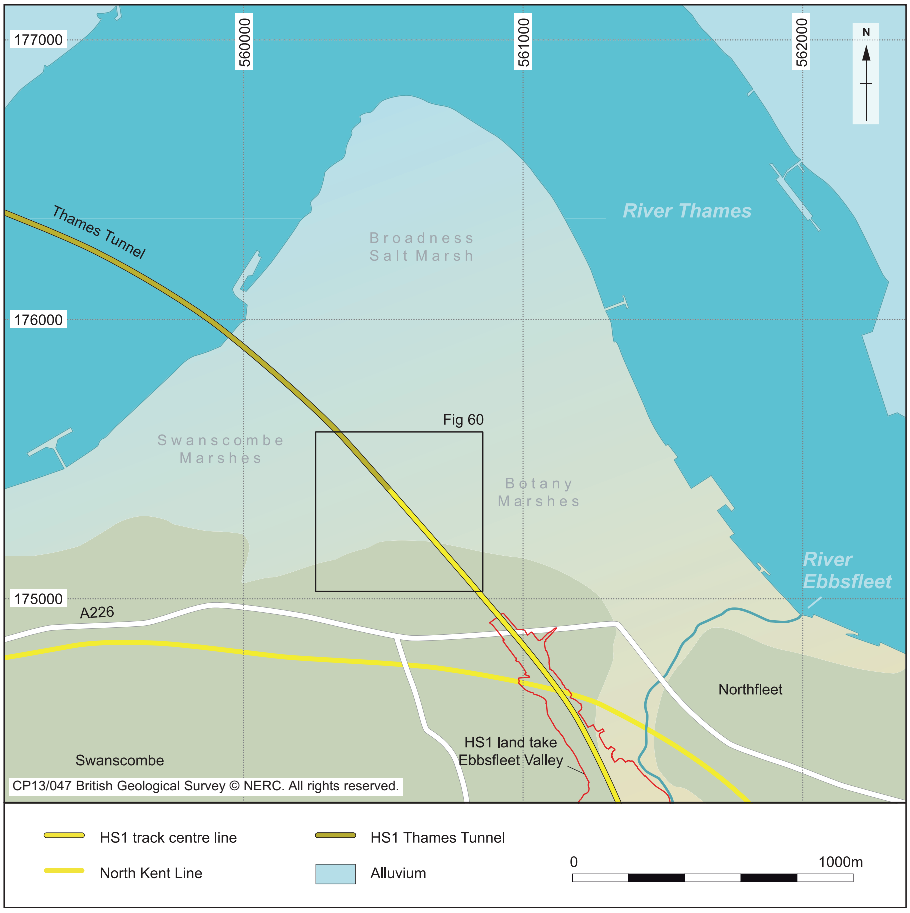


Figure 59 Site location plan showing Thames River Crossing (south bank) for HS1, area of cut/tunnel and edge of alluvium

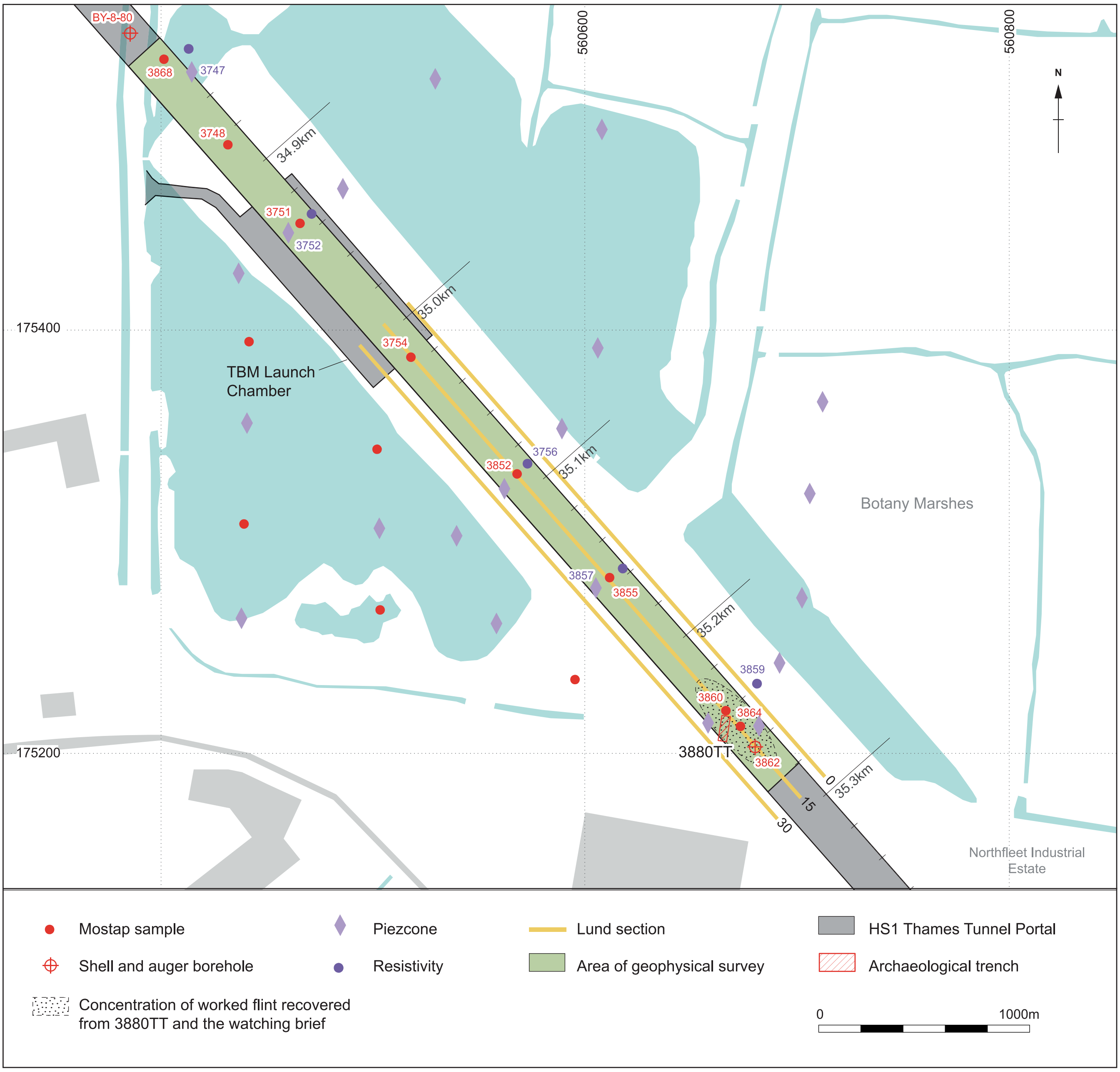


Figure 60 Distribution of geophysical survey areas and cone penetration tests/boreholes undertaken as part of purposive geoarchaeological investigations in Stage 1 Thames River Crossing (south bank) works

cores in order to obtain samples for palaeo-environmental analysis and absolute dating. The use of shell and auger boreholes at either end of the sample transect was governed by the need to penetrate the underlying gravels (which CPT/Mostap cores cannot) and record the level of the Chalk rockhead. Consequently a combination of sampling techniques was used to recover 1.5m continuous cores through the soft sediments (Mostap cores), 0.45m cores through the soft sediments and bulk samples from the underlying gravels (shell and auger cores). The intensity of survey points and transects and the number of sample locations was limited to an extent by cost implications and access constraints, but the final sampling resolution (in this case beyond the construction footprint in order to adequately understand the sub-surface stratigraphy; Fig 60) was predicted to be adequate to enable a detailed reconstruction of the buried stratigraphy and to identify the sub-surface location of the key topographic locations for archaeological activity.

Confirmation of the nature of the stratigraphic sequences within the study area was subsequently possible through direct observation of the deposits during trench excavation (Stage 2) and the watching brief (Stage 3). For the Stage 2 response, a single, sheet piled, trench (3880TT) was sited and excavated by mechanical excavator through the alluvium (Pl 22). Finally a watching brief was undertaken on the full length of the excavated box.

Post-excavation work included the analysis of a number of sample profiles for palaeoenvironmental remains in order to characterise the environments of

Plate 22 Cofferdam excavation 3880TT, Swanscombe

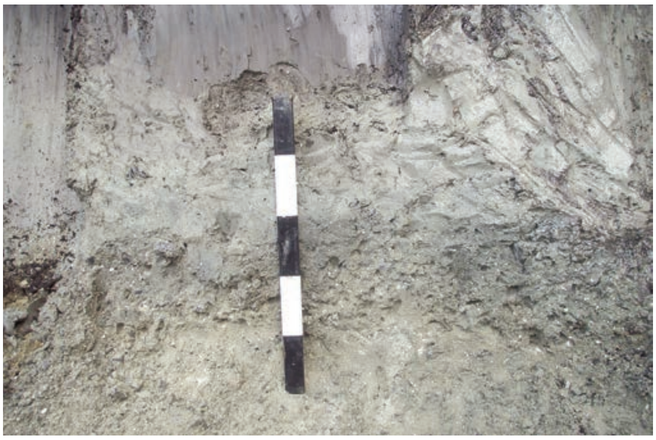


Plate 23 Basal sands and gravels observed during watching brief excavations of the main TBM launch chamber, Swanscombe

deposition associated with the sediments and the artefactual evidence. Interpretation of the sedimentary sequences was carried out by Martin Bates and Elizabeth Stafford. The palaeoenvironmental work was carried out by Sylvia Peglar and Lucy Verrill (pollen), David Smith (insects), Wendy Smith (waterlogged plant remains), John Whittaker (ostracods and foraminifera), Nigel Cameron (diatoms), Richard Macphail and John Crowther (micromorphology and soil chemistry). A chronological framework for the analysis was provided by 15 radiocarbon dates (Appendix A).

Results of the Investigations

Geophysical survey, cone penetration tests and borehole ground-truthing

The results of both electromagnetic surveys (Figs 61 and 62) indicated lower conductivity at the south-east end of the section (shown as darker shades on the figures). This decrease in conductivity is consistent with the expected rise towards the surface of the Chalk bedrock surface as it rises steeply southwards beneath the site from approximately 20m depth to less than 4m depth. Furthermore, the pseudo-section (Figs 63 and 64) indicated two possible steps in the gravel profile and it is proposed that these might represent terraces.

Above the Chalk, a gravel layer was identified on the CPT data by cone refusal (base of logged data) (Figs 65 and 66) and this was correlated with a small increase in resistivity on the 2D geoelectric pseudo-section data (Figs 63 and 64). Direct observations of the sediment bodies were achieved through the drilling of Mostap and shell and auger boreholes across the site (Fig 66B). Examples of the typical logs are shown in Figures 67 and 68. In order to understand the nature of the sequences, and compare results between techniques, the information from the CPT testing and Mostap/shell and auger drilling have been combined and a number of key stratigraphic units identified within the study area (*Table 56*). Many of these units can be traced laterally across the site and provide a framework for the interpretation of site history and archaeological potential.

Borehole 'off-site' sequence history

The pattern of sediment distribution across the majority of the study area (Fig 66C) is clearly illustrated by the boreholes presented in Figures 67 and 68 in which a complex of intercalated peat and clay-silt units overlie coarser sands and gravels (Pl 7 and 8). The underlying sand/gravel (III/IV, *Table 56*) is clearly seen in the CPT data (Fig 66A) where cone refusal has taken place (Pl 23). In the majority of the boreholes two distinctive peat units are clearly seen above the basal sand/gravel unit (Fig 66B). This is also reflected in the CPT data that shows the peats through the presence of two peaks in the friction ratio below the high associated with the modern ground surface (Fig 66A). The main peat unit (VIII), occurring between depths of -3m and -6m OD towards the northern end of the box, rises in the southerly direction. In places this peat can be seen to be divided into two units by an intervening clay-silt unit (seen in the borehole samples, eg, BH3751, Fig 68). The lower peat or organic silt (-9m rising to -7m OD southwards before disappearing) is less marked. Both organic units are overlain by clay-silts.

Examination of palaeoenvironmental remains was primarily carried out from the deep sequence of sediments in borehole BH3751 (Fig 68). Diatoms, waterlogged plant remains and insects were present in a number of the samples initially assessed, however the abundance, quality of preservation and species diversity was low and the samples were not subject to detailed analysis. The results of the assessment of these remains do provide information on the environments of deposition and have therefore been presented along with the better preserved pollen, ostracod and foraminiferal evidence for completeness. Eleven radiocarbon dates were obtained from borehole BH3751 (Appendix A) providing a chronological framework. Additional detailed analysis of ostracods and foraminifera along with soil micromorphology was also carried out on the lower clay silts in borehole BH3748 (Fig 67).

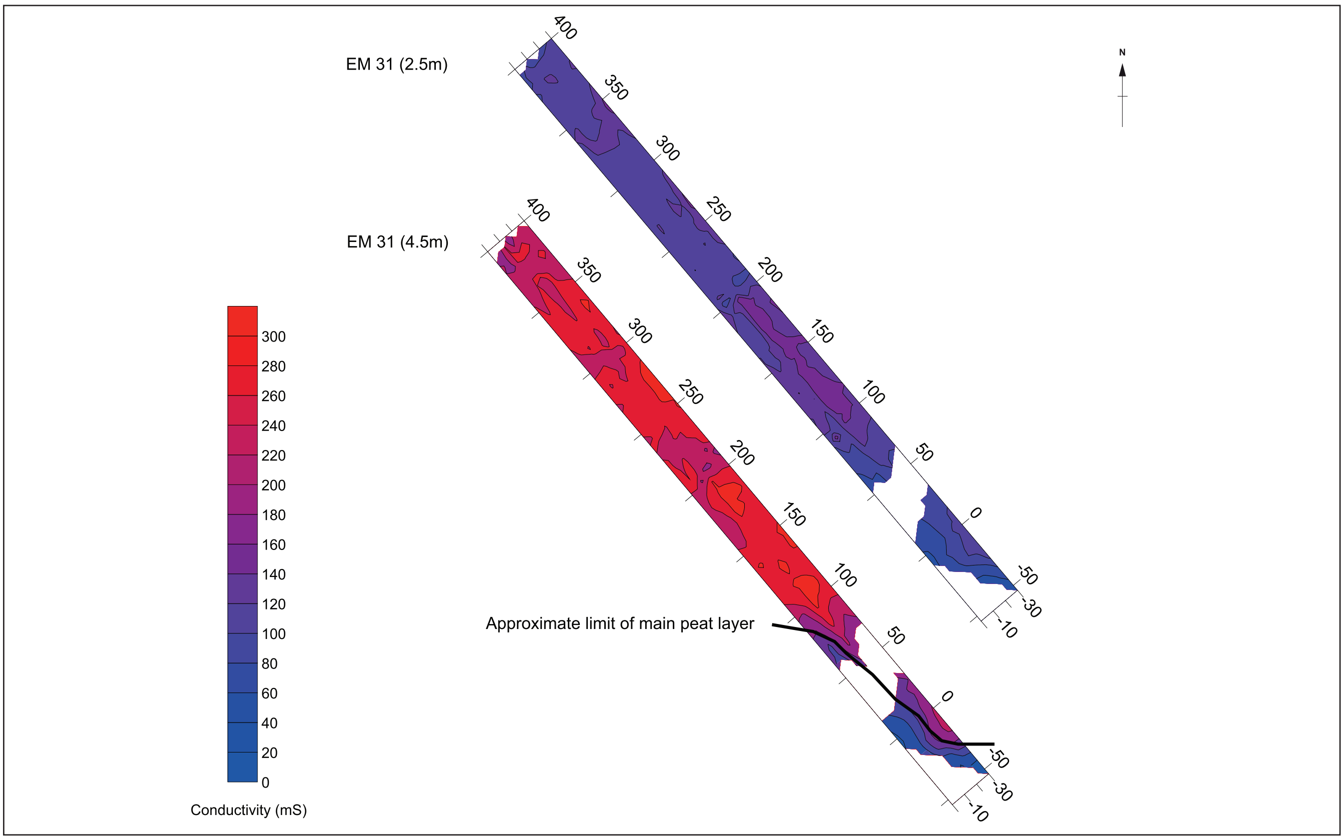


Figure 61 EM Conductivity maps from EM-31 orientated in line with route corridor in Swanscombe Marsh showing gradients in electrical conductivity at depths of 2.5m and 4.5m below ground surface. Red colours indicate high conductivity, blue colours low conductivity. At 2.5m depth sediments are typically of low conductivity indicative of likely over-consolidated near surface sediments. At 4.5m depth conductive sediments mapped across much of the route corridor with low conductivity mapped at the southern end. This southern zone probably marks the extent of bedrock or sand and gravel at depths in excess of 4m below ground surface

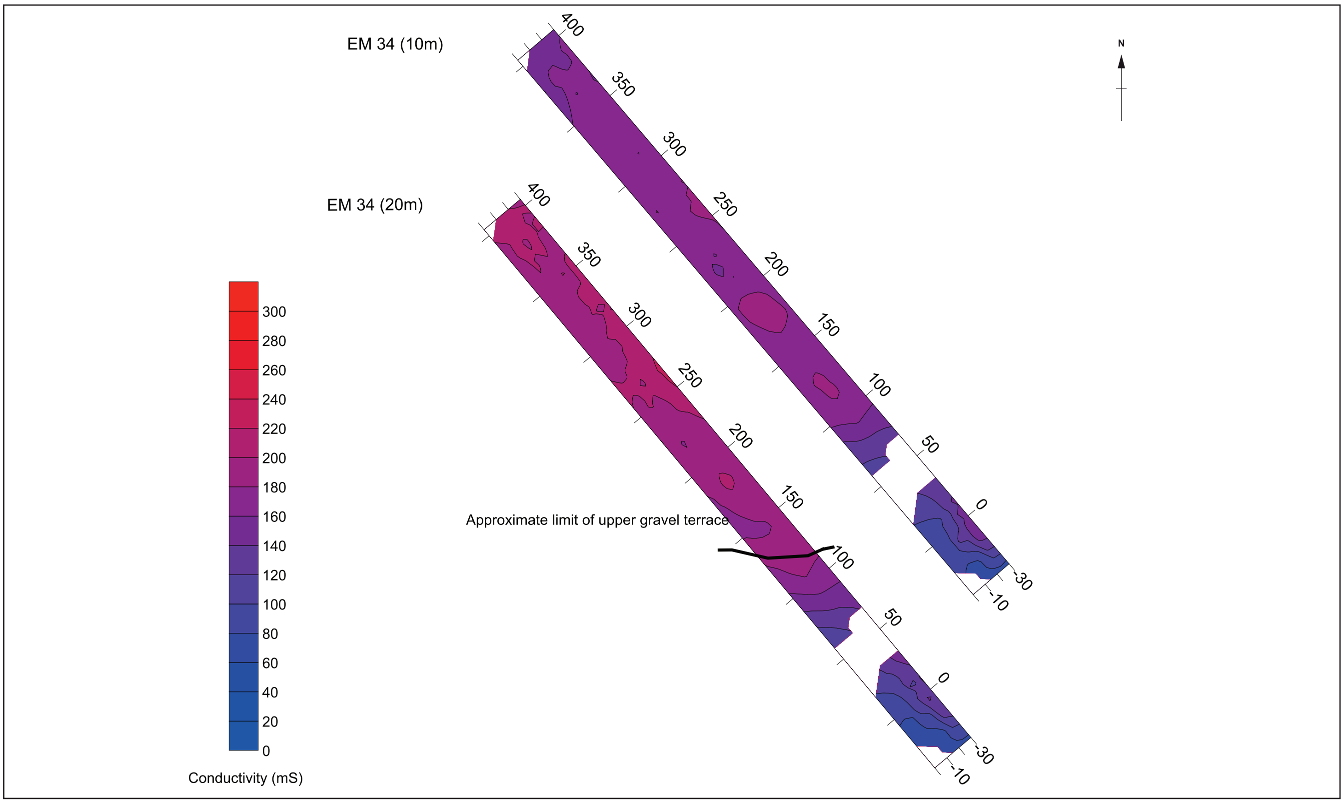


Figure 62 EM Conductivity maps from EM-34 orientated in line with route corridor in Swanscombe Marsh. Typically at 10 and 20m depths relatively low conductivity values are associated with bedrock presence

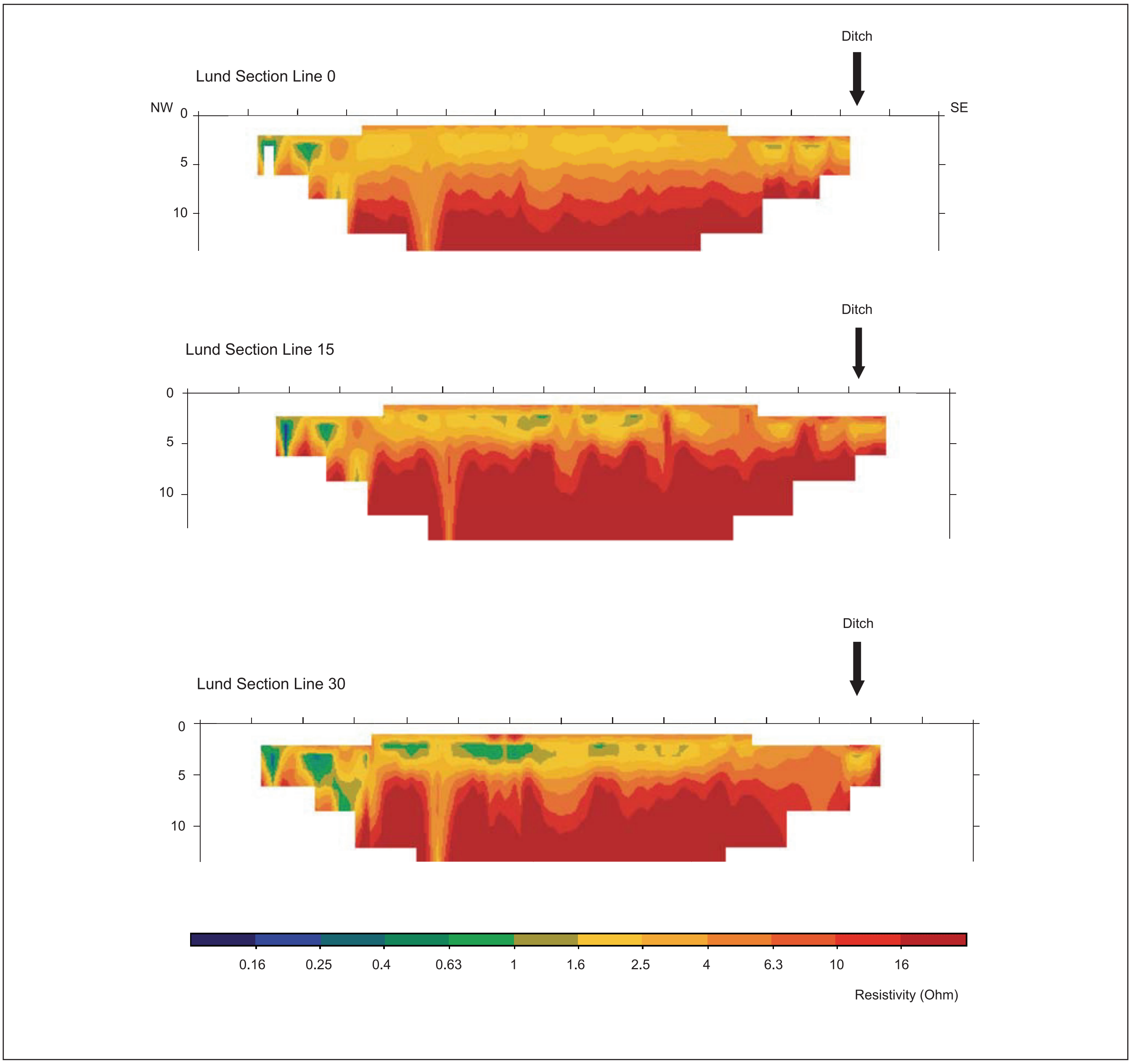


Figure 63 LUND electrical resistivity profiles along line of route corridor. Yellow/green colours represent low resistances (higher conductivities) associated with the Holocene alluvium. Red colours are areas of high resistance (low conductivity) associated with bedrock Chalk or gravel

Basal gravels

The Holocene sediments are underlain by sands and gravels below -8m OD throughout much of the northern area of investigation (as evidenced in the shell and auger boreholes at the northern end of the box). This sand and gravel was not investigated in detail but is likely to correlate with the Shepperton Member of the Lower Thames and was probably deposited after 15ka BP (Gibbard 1994). The sediments to the south, within the area of the archaeological excavation, will be considered later (see below).

Lower peat and organic silts

The onset of sedimentation above the gravels is characterised by the accumulation of organic material. Examination of the remains from borehole BH3751 (Fig 68) indicate that this sediment and the minerogenic material immediately above it contained occasional diatoms (*Table 57*) and plant remains (*Table 58*). Initial assessment of the organic silt at the base of the sequence produced a pollen spectra which is almost entirely composed of *Pteridium* (bracken) spores. The overlying peat contained some *Alnus glutinosa* (common alder) pollen, with lesser amounts of indeterminate ferns but in general the counts were low and this part of the sequence was not analysed in detail. The plant assemblages, however, showed an abundance of *A. glutinosa*, some *Scripus sylvaticus* (wood club-rush) and Cyperaceae (sedge). In the same interval diatoms are either absent or rare. Only two fresh water, non-planktonic, diatom species (*Meridion circulare* and *Gomphonema olivaceum*) were recorded, the latter with optimal growth in fresh water of slightly elevated conductivity and the former associated with flowing, fresh waters. Radiocarbon dating (Fig 68 and Appendix A) indicates that the basal organic silt began

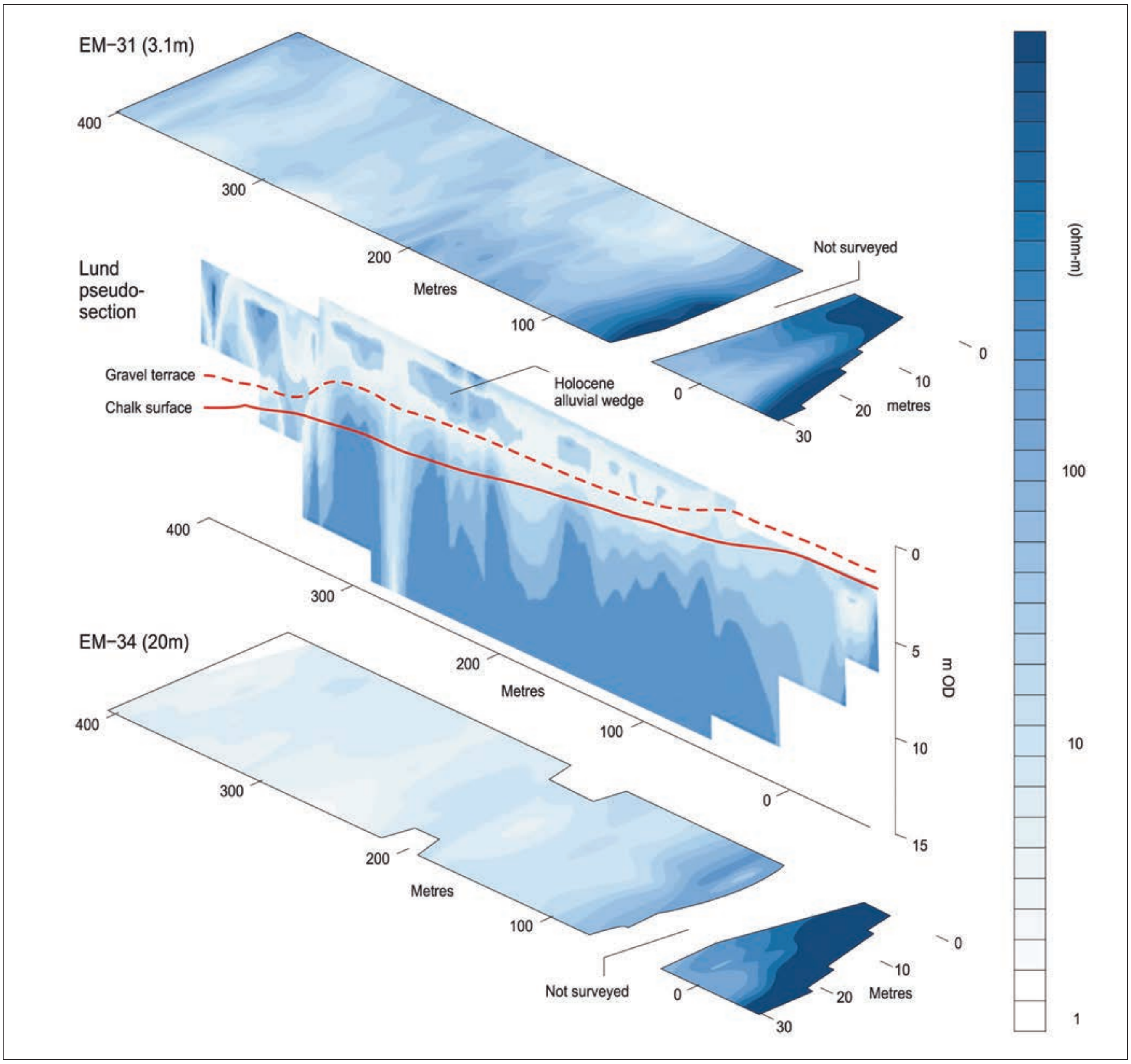


Figure 64 Combined EM Conductivity maps and LUND electrical resistivity survey in route corridor. Top EM-31 surface geophysics, middle LUND pseudosection, base EM-34 surface geophysics (Bates *et al* 2007). Data used to interpret the geometry of the Holocene alluvial wedge, gravel and bedrock surfaces

accumulating around 6610–6430 cal BC (NZA-27599, 7669±50 BP) with the onset of peat accumulation around 5900–5730 cal BC (KIA-14479, 6935±35 BP). A date for the top of the peat of 5470–5220 cal BC (NZA-27603, 6357±35 BP) provides a maximum age for the start of minerogenic sedimentation.

Lower clay silts

Minerogenic clay-silts dominated between -8.43m and -5.05m OD in BH3751 (Fig 68). Low numbers of brackish water, benthic diatoms (eg, *Campylodiscus echeneis, Nitschia navicularis*) and marine plankton (*Paralia sulcata*) occur at -8.43m OD. Although the number of diatoms present is low, these species indicate that the sediments formed under estuarine conditions. The first brackish foraminifera occur at -7.93m to -7.98m OD (Table 59). Thereafter, the interval up to and including -6.03m to -6.08m OD contains a mixture of saltmarsh agglutinating foraminifera and tidal mudflat-living calcareous foraminifera (mainly small *Ammonia* spp.) which occur in very large numbers. Murray (2006, 66–67) points out that the typical high- to mid-marsh species are *Jadammina macrescens* and *Trochammina inflata* and these occur as dominant or subsidiary taxa. Other species confined to marshes include *Haplophragmoides wilberti* and *Tiphotrocha comprimata*, and to these indigenous species we can add *Arenoparrella mexicana*, which are quite rare in the European context. Species found on the seaward side of marshes and on adjacent intertidal and shallow subtidal areas include the calcareous *Ammonia* group, which are particularly common in sediments with >80% mud/silt (*ibid*, 67).

These sediments also contain numbers of discernable diatoms (>75 microns), which is of interest as foraminifera not

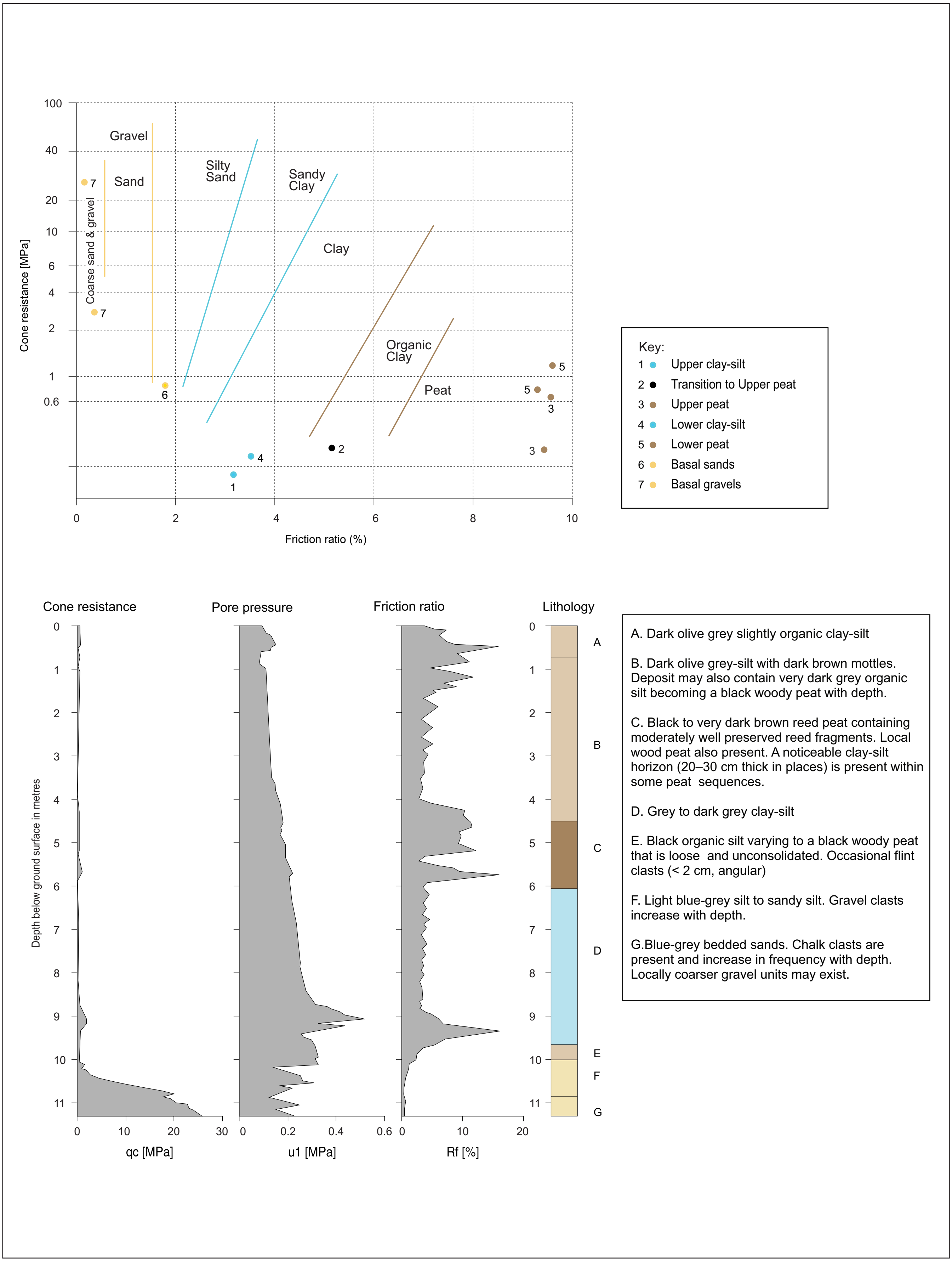


Figure 65 Top: Cone resistance (MPa) plotted against friction ratio (%) for selected samples from the CPT data including recognised zonations of differing sediment types. Base: Cone resistance, pore pressure and friction ratio plotted against lithology from representative profile at Thames River Crossing (Bates *et al* 2007)

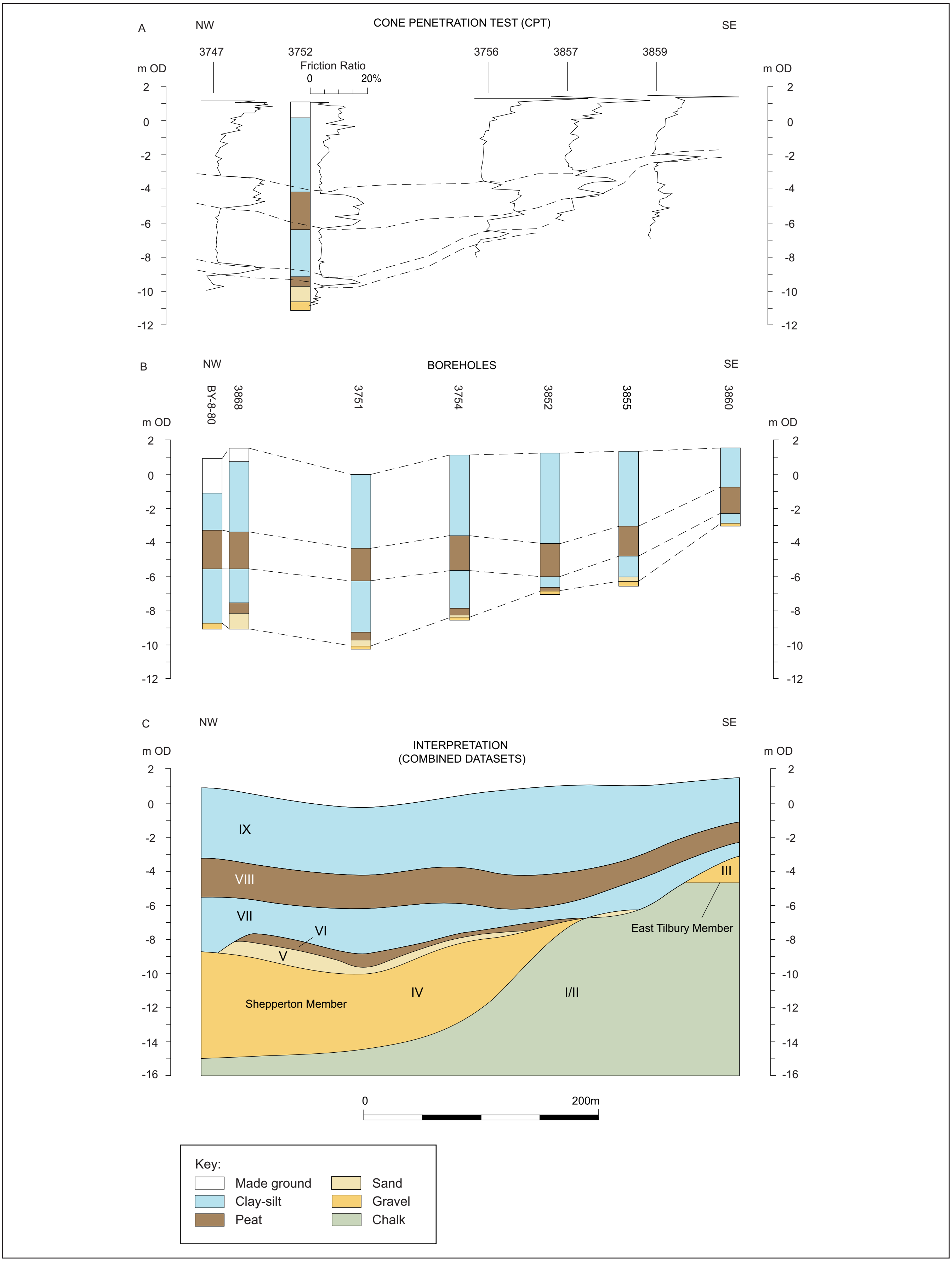


Figure 66 A) Cone penetration test (CPT) results from selected test locations B) Lithology of selected boreholes C) Interpreted lithostratigraphic section based on CPT and borehole information (Bates *et al* 2007)

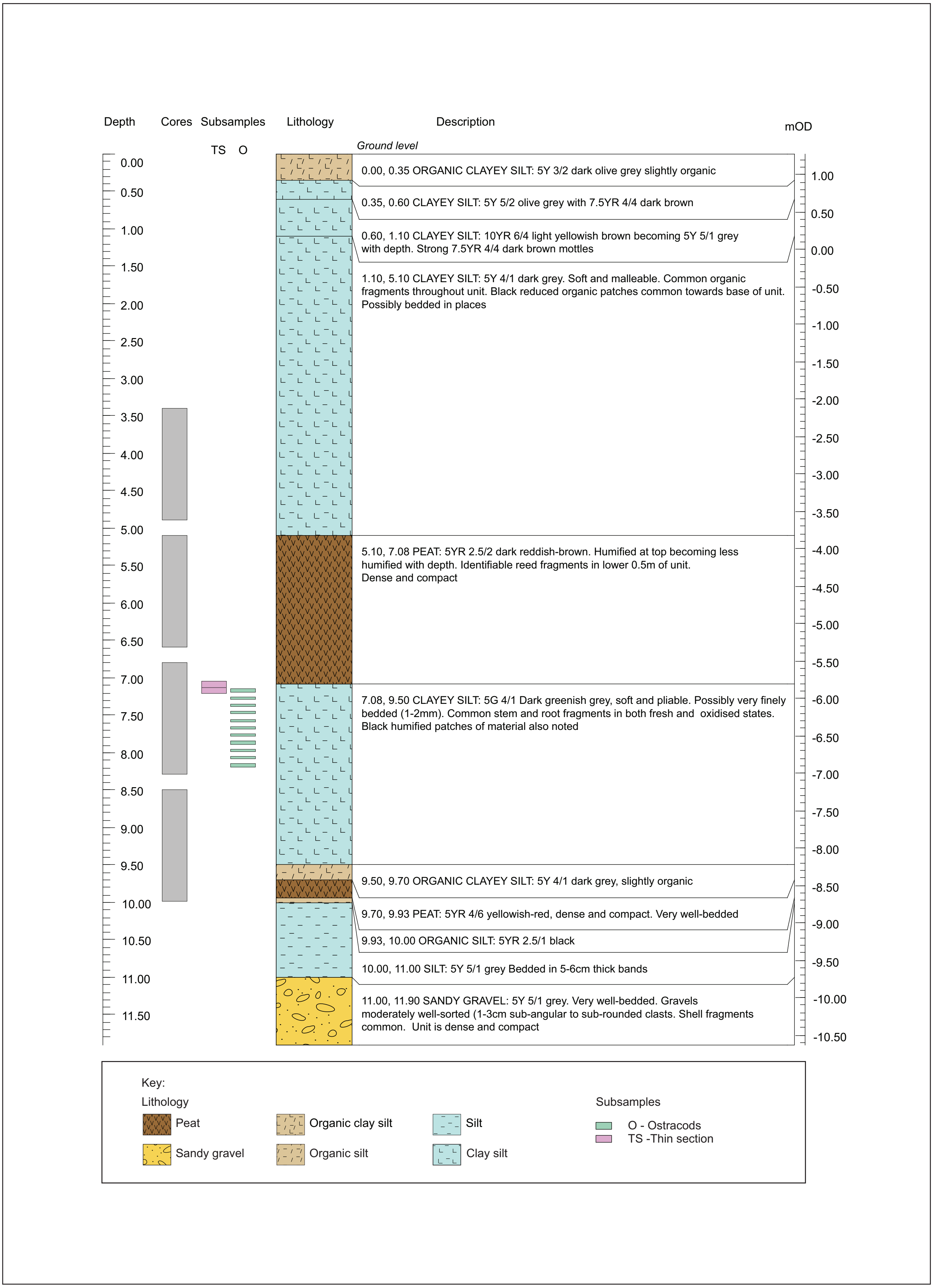


Figure 67 Lithological log and sample locations from BH3748

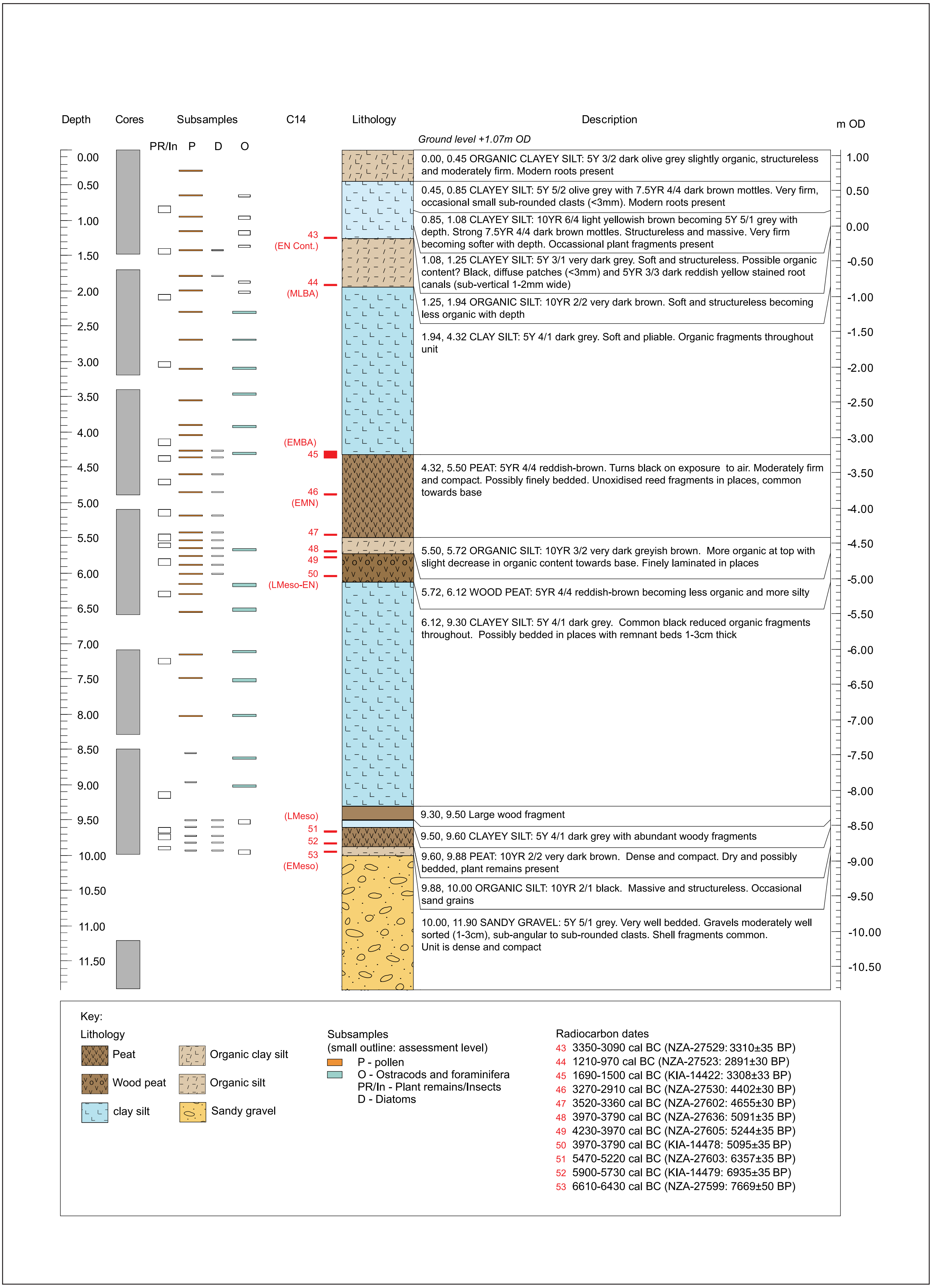


Figure 68 Lithological log and sample locations from BH3751

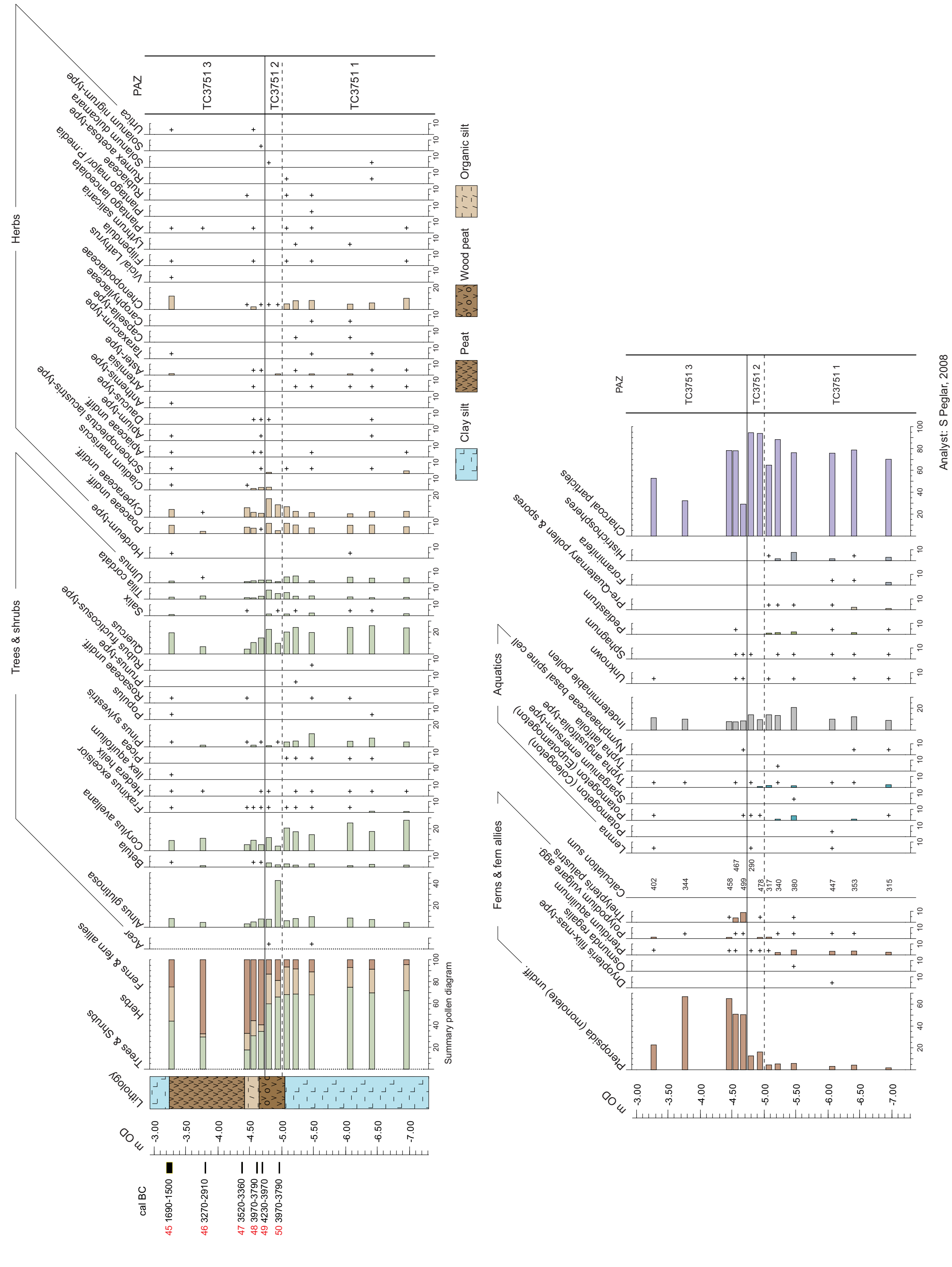


Figure 69 Pollen diagram from BH3751

only harbour symbiotic diatoms within their shells, but also ingest them for food. The two together in large numbers indicates, therefore, a healthy *in situ* mudflat fauna. Brackish creek and mudflat ostracods are much rarer but occur between -6.98m and -6.03m OD. Both foraminifera and ostracods are totally absent in the interval -5.48m to -5.08m OD immediately below the main peat unit.

Evidence from the pollen profile (PAZ TC3751 1, Fig 69) suggests the pollen assemblages are dominated by about 70% tree and shrub pollen (AP), mainly of *Quercus* (oak), *Ulmus* (elm), *Tilia* (lime) and *Corylus* (hazel), but also with some *Pinus* (pine). Some Poaceae (grasses) and Cyperaceae (sedges) pollen is present, but other herbaceous and fern taxa are quite rare apart from Chenopodiaceae (goosefoots) which is characteristic ofsaltmarshes. Aquatic taxa and the remains of the green alga *Pediastrum*, which grow in freshwater, are also present. The remains of hystrichospheres, restricted to brackish/salt water, were also found, but could possibly be reworked from earlier sediments. The assemblages therefore suggest that both fresh and brackish water sediments are represented within the zone, being of estuarine origin, with saltmarsh and reedswamp vegetation growing close by on the floodplain. On higher, drier ground regionally, mixed deciduous woodland with *Quercus, Ulmus, Tilia* and *Corylus* was growing. There is no evidence for any human impact locally during this zone although charcoal particle values are quite high, but these may originate from some distance.

A close sampling interval for ostracods and foraminifera was undertaken on sediments immediately below the main peat in BH3748 (Fig 67; *Table 60*). Here, 11 samples (10cm thick at 5cm interval) were examined between -6.93m and -5.88m OD. Below -6.43m OD the sediments were deposited in saltmarsh and tidal mudflats with full tidal access. Between -6.43m and -6.18m OD mid–high saltmarsh, a period of accretion and undoubtedly the onset of the sea-level regression was recorded. The three samples immediately below the peat at -5.88m to -6.13m OD were entirely devoid of foraminifera.

Thin section analysis of the upper part of the minerogenic silts at -5.93m to -5.83m OD (Fig 67; Appendix B) show that the sediments are composed of laminated (1–2mm thick) humic clays, with sparse coarse silt, and are characterised by very abundant and generally horizontally oriented detrital plant fragments; their character suggests a mudflat situation (Pl 24 A–C). There are also very abundant coarse roots producing sediment disruption and working. The sediment features minor iron staining, probable carbonate concentrations, and occasional fine gypsum crystal formation throughout. By contrast the basal parts of the main peat unit at -5.79m to -5.77m OD consist of horizontally layered monocotyledonous plant fragments in a humic clayey matrix with very sparse silt (Pls 24D–E). The sediment shows iron staining, probable carbonate concentrations, and occasional fine gypsum crystal formation throughout. Laminated *in situ* formed peat becomes dominant upwards (Pls 24D–E). The boundary between this peat and the underlying minerogenic sediments is subtle but sharp and differs by featuring greater amounts of horizontally layered plant fragments and less mineral material (Pls 24A–C). There is no evidence of sediment ripening/soil formation in the underlying minerogenic sediments (Pls 24A–C) although the presence of the sharp boundary between the two units does suggest a degree of disconformity between them and the presence perhaps of a short lived hiatus in sequence accumulation.

The main peat bed

The nature of the main peat varies across the site. The principal feature of the peat is the intermittent presence of a two-fold sub-division into a thin lower peat (below -4.63m OD in borehole 3751) and a thicker upper peat (starting at -4.43m OD), with an intervening silt horizon. The lower part of the peat did not appear to contain diatoms except for a fragment cf *Cyclotella striata* (an estuarine planktonic species) at -4.81m OD and a number of chrysophyte stomatotcysts from the sample at -4.95m OD. The majority of chrysophytes are associated with fresh water; although there are also brackish water taxa. The chrysophyte taxa here are all of indeterminate type. As in the examples found here, chrysophyte stomatocysts are usually heavily silicified and it is common to find them in sediments subject to drying out where they are less susceptible to complete dissolution than less robust silica algae remains.

A major change in pollen spectra is noted at the transition from the clayey silts to wood peat (PAZ TC3751 1/2 boundary). *Ulmus* values drop sharply at the base of the peat, possibly signifying the 'elm decline', a synchronous event generally dated to about 5500–5000 BP throughout north-west Europe. Sediment from 0.06m above the PAZ TC3751 1/2 boundary gave a radiocarbon determination of 3970–3790 cal BC (KIA-14478, 5095±35 BP). The pollen assemblages are dominated by *Alnus* and *Quercus* pollen, together with fern spores (Pteropsida (monolete) undiff.). High values of *Alnus*, with Cyperaceae (including *Schoenoplectrus lacustris*-type (bristle club-rush)) and *Cladium mariscus* (great fen sedge) support an interpretation of alder woodland on the floodplain. *Tilia* pollen has its highest values during this PAZ and suggests that *Tilia* dominated mixed woodland was growing on drier higher land in the area. There is no evidence of any marine influence during this PAZ and Chenopodiaceae pollen values, often characteristic of saltmarshes, are almost absent. Age estimates for the accumulation of the lower part of the peat between 3970–3790 cal BC (KIA-14478, 5095±35 BP) and 4230–3970 cal BC (NZA-27605, 5245±33 BP) have been obtained from this sequence. A change in pollen spectra occurs at -4.75m OD. Fern spores completely dominate the assemblages, suppressing all other pollen taxa. The ferns include the marsh fern *Thelypteris palustris* and suggest that the local vegetation was fern-rich fen/marsh at this time. *Tilia* values decrease at the PAZ TC3751 2/3 boundary. This may be the so-called 'lime decline' which is thought to be human induced, but it could also be that the land on which the *Tilia* was growing was inundated by water which *Tilia* could not tolerate.

The clay-silt horizon separating the lower from the upper parts of this peat unit suggests that a phase of channelling, flooding or temporary submergence may have occurred. At -4.57m and -4.47m OD within this horizon a few poorly preserved diatoms indicative of estuarine conditions, including benthic brackish water taxa such as *Nitzschia navicularis, Diploneis didyma, Campylodiscus echeneis* and *Nitzschia granulate* have been recorded. The planktonic marine diatom *Podosira*

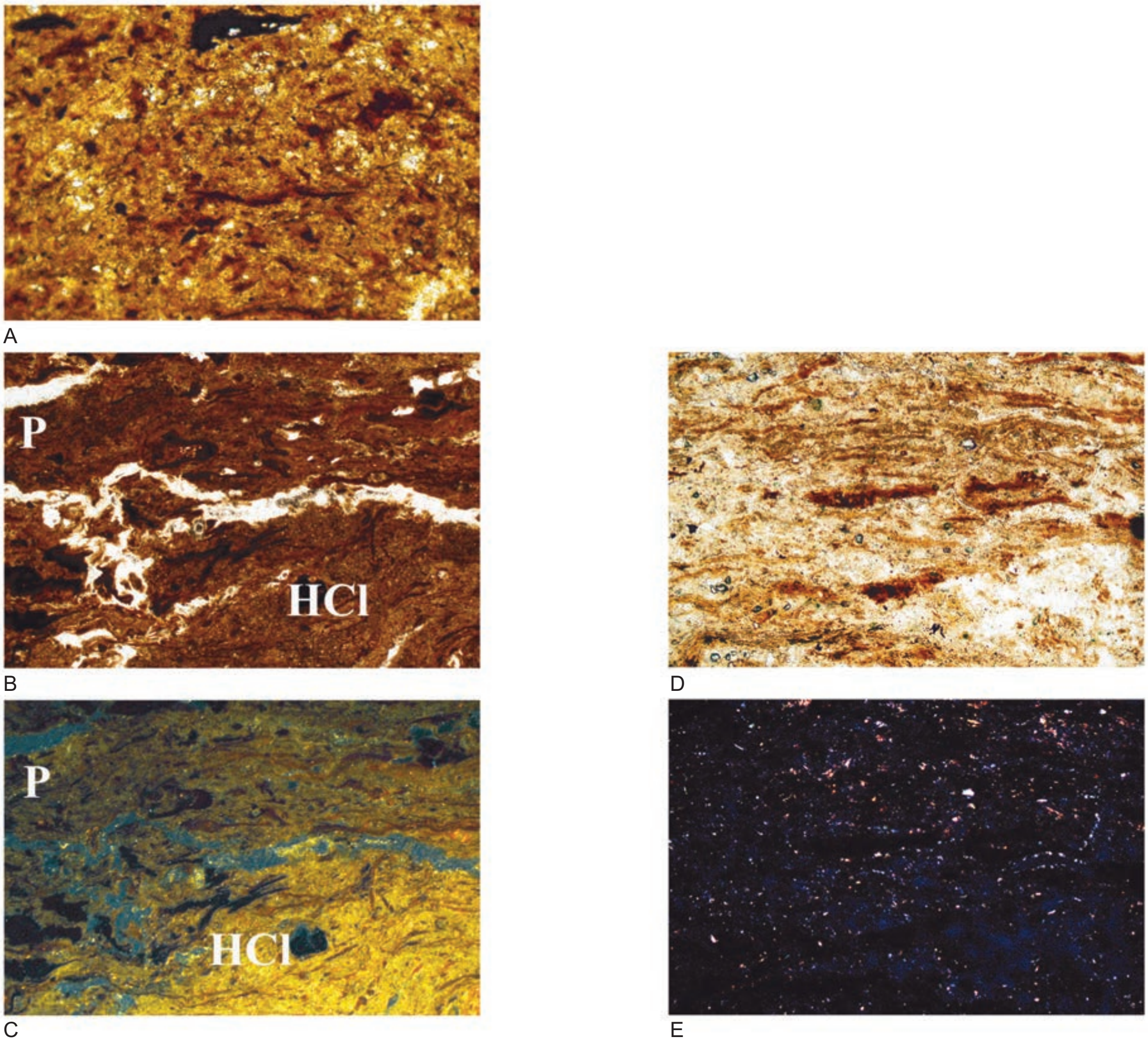


Plate 24 Photomicrographs from Borehole 3748, Swanscombe. A) Borehole BH3748(B): Detail of humic clays, with sub-horizontally oriented humifying (brown staining) detrital organic matter (size-range and staining also infers moderately local origin). Plane polarised light (PPL), frame width is ~0.92mm. B) Borehole BH3748(A): Junction between humic clay (HCl) and overlying peat. PPL, frame width is ~4.6mm. C) As B: Under oblique incident light (OIL), showing more humic clay (HCl) with sub-horizontally oriented detrital organic matter, and overlying peat (P), which is richer in organic fragments and less clay-rich; note absence of any biological working or ripening features between the two sediments. D) Borehole BH 3748(A): Detail of laminated peat. PPL, frame width is ~0.92mm. E) As D: Under cross polarised light (XPL); note sparse and 'laminated' silt content

stelligera is present at -4.47m OD. Agglutinating foraminifera of mid- to high saltmarsh situations have also been recorded within this clay-silt horizon.

The upper part of the peat at -4.35m OD contained only the fresh water diatom species *Meridion circulare* associated with flowing water. Diatoms were absent from the samples taken at -4.11m and -3.78m OD. A single fragment tentatively identified as the marine planktonic diatom *Thalassionema nitzschiodes* was found in the sample at -3.53m OD towards the top of the upper peat. However, this diatom has a robust, heavily silicified valve and its presence may reflect preferential preservation. At the top of the upper peat at -3.29m OD, near the transition into the overlying clay-silt, marine (*Rhaphoneis surirella*, *Rhaphoneis* spp.) and estuarine (*Cyclotella striata*) plankton diatoms and a single valve of the freshwater diatom *Achnanthes minutissima* occurred. Samples from -4.13m to -4.03m OD and -4.58m and -4.5m OD both produced single individuals of the 'reed beetle' *Plateumaris braccata* (*Table 61*) which is usually associated with *Phragmites australis* (common reed) (Koch 1992). The sample from -4.13m to -4.03m OD also contained several individuals of the small 'water beetle' *Chaetarthria seminulum* which often is held to be typical of stagnant and still waters (Hansen 1986). This information therefore confirms the presence of fresh water peats becoming influenced by encroaching brackish conditions up-profile. The sediments change from wood peat at the base to an organic silt with reed fragments suggesting that the water level had risen.

Few subsamples within the upper part of the peat, PAZ TC37513, had a sufficiently high concentration of pollen and spores for full analysis. The two sub-samples that were countable were dominated by fern spores. There is an increase in Chenopodiaceae pollen at the top of the PAZ perhaps marking an increase in marine influence with the growth of saltmarsh, but fresh water aquatic pollen taxa are also present. Regionally

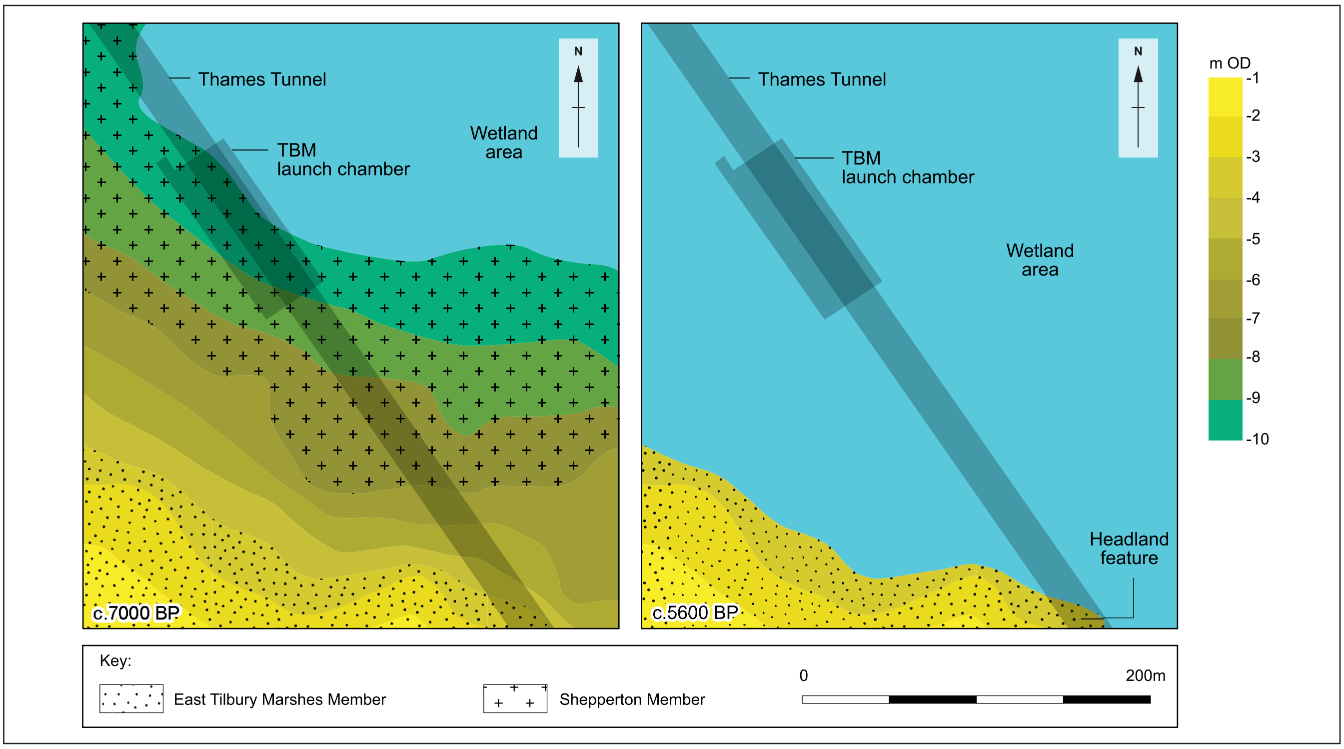


Figure 70 Early Holocene topography of the route corridor beneath Swanscombe Marsh based on borehole, CPT and geophysical survey data showing position of the headland feature (Bates *et al* 2007)

some mixed deciduous woodland with *Quercus* and *Corylus* continued. Age estimates date the start of peat formation above the clay-silt horizon to 3520–3360 cal BC (NZA-27602, 4665±30 BP), while the top of the peat is dated to 1690–1500 cal BC (KIA-14422, 3310±35 BP).

The upper clay silts

The minerogenic sediments above the main peat at -3.27m to -1.21m OD contain ostracods and foraminifera indicative of mid–low saltmarsh, tidal flats and creeks (*Table 59*). Within this sequence diatoms are well preserved and the assemblages are relatively diverse with a moderately high number of valves. The assemblage represents estuarine conditions with a component of mesohalobous benthic diatoms (eg, *Nitzschia Granulata* and *N. navicularis*) along with brackish and marine plankton (eg, *Cyclotella striata* and *Paralia sulcata*).

Above -1.21m OD, the lithology changes and ostracods and foraminifera were absent. This appears to be a real disappearance rather than a problem due to decalcification of the sediment as agglutinating foraminifera of mid–high saltmarsh, such as *Jadammina macrescens*, have a shell of mineral grains stuck together with an organic cement on an organic template. Even in the most reducing environments they occur, often in a collapsed state, but they can still be found, albeit with difficulty within the organic debris. In spite of a careful search they do not occur above -1.21m OD and this interval might be taken to indicate a shift to a fresh water environment. The two uppermost diatom samples examined, lying between -0.72m and -0.35m OD are taken from an organic silt. The diatom assemblages are well preserved and contain a mixed assemblage ranging from freshwater to marine species. However, the marine component is of planktonic species eg, *Paraliasulcata* and *Rhaphoneis* spp. and is allochthonous, whilst the brackish (and smaller freshwater) part of the assemblage is of probable autochthonous diatoms. Notable amongst the mesohalobous diatoms here are the high numbers of *Diploneis interrupta*, a brackish water aerophile that when it occurs in large numbers is often, although not exclusively, associated with the supra-tidal zone, for example pool habitats in saltmarshes (Vos and de Wolf 1993). The occurrence of substantial numbers of oligohalobous indifferent diatoms such as *Navicula rhyncocephala* is also consistent with an upper shore habitat. However, the diatom preservation here is good and this is unusual for saltmarsh depositional environments.

Headland sequence history

Of particular significance from the archaeological perspective was the identification at the southern end of the route corridor of a topographic high or headland feature. This headland was identified by rises in the gravel surface and sufficient data was available for an attempt to be made to model the shape of this feature (Fig 70). This promontory was considered a likely location for human activity predating the period of submergence of the landscape beneath the ever encroaching alluvial envelope. On the basis of previous work in the Thames (Bates and Whittaker 2004) the higher parts of this headland will have been flooded during the late Mesolithic *c* 4500–4300 cal BC (ie, ^{14}C 5600 BP). Changes to the modelled topography consequent with flooding are postulated in Figure 71. To investigate this situation a purposive cofferdam (3880TT) was sited and excavated in advance of construction (Pl 22). This was followed by a watching brief during construction.

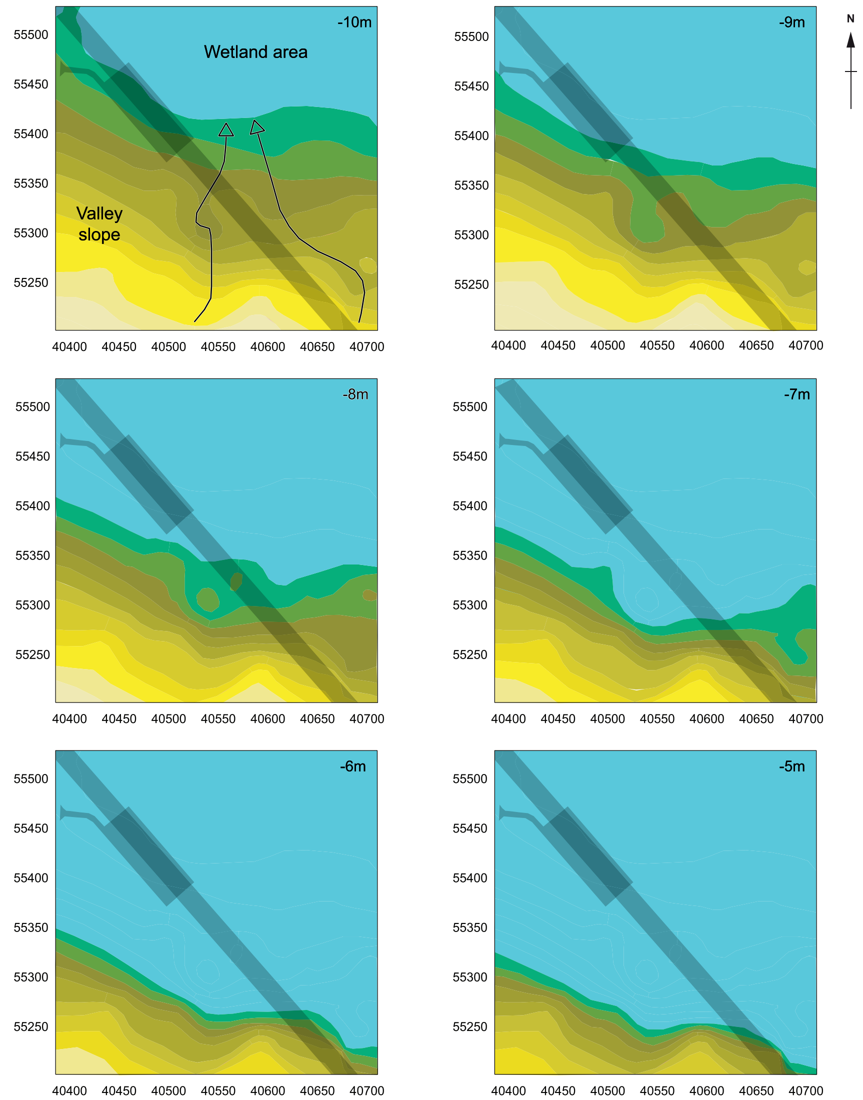


Figure 71 Topographic reconstruction of the site showing successive 'drowning' of landscape during rising water levels at successive 1m intervals (-10m to -5m OD)

Table 62 Excavated stratigraphy, 3880TT

Context	Description	Finds / Interpretation	General WB context
388001	Mid-orangey brown clayey silt. Contained frequent root holes	Alluvium	1
388002	Mid-grey clayey silt. Contained occasional root holes	Alluvium. Occasional struck flint, one sherd Late Bronze Age pottery	1
388003	Mid-grey clayey silt	Alluvium. Occasional struck flint	1
388004	Dark greyish brown peat	Occasional worked flint. Much increased in density in lowest 100mm. Animal bone	2 (upper) 10 and 11 (lower)
388006	Mid-greenish grey (clayey) sandy silt containing occasional roots and branches. (Surface slopes down steeply to the NE, possible channel truncation)	Remnant alluvial deposit. Frequent worked and burnt flint on the surface and in the top 100mm but little below. One sherd pottery and one frag possible ground stone tool	3
388005	Mid-grey and white speckled mix of silty clay and chalk. Contains occasional broken flint becomes paler and chalkier with depth	Degraded upper part of chalk bedrock	-

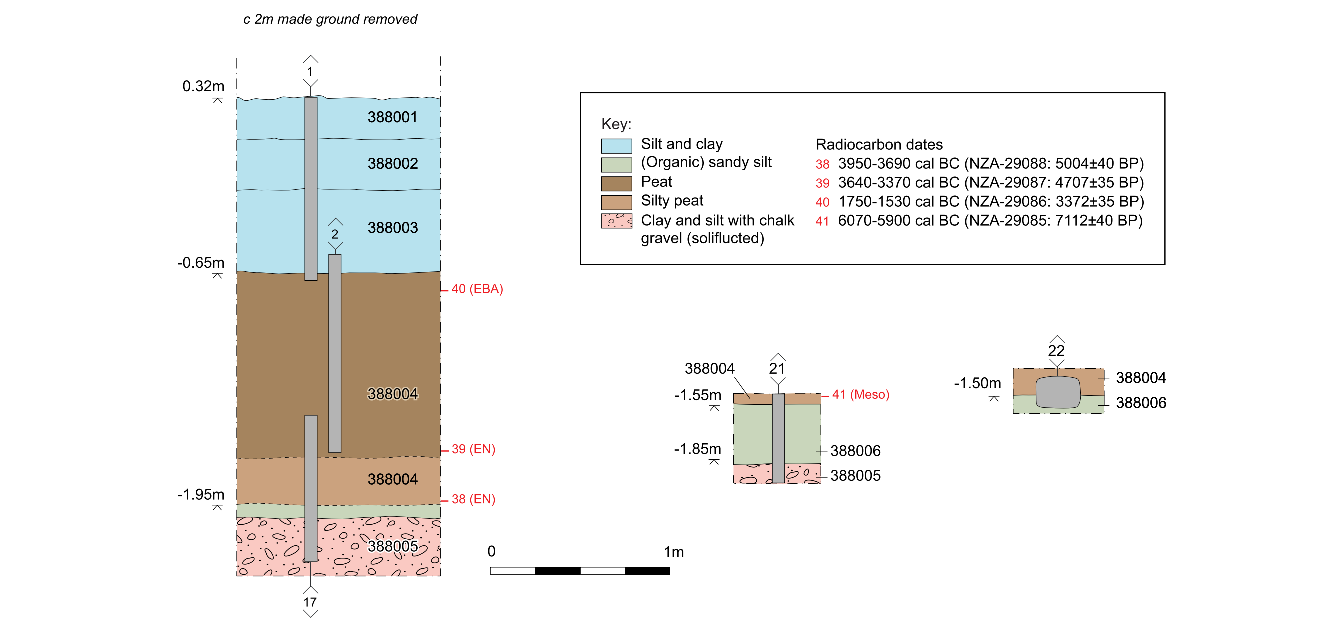


Figure 72 Sections through excavated sequences in 3880TT

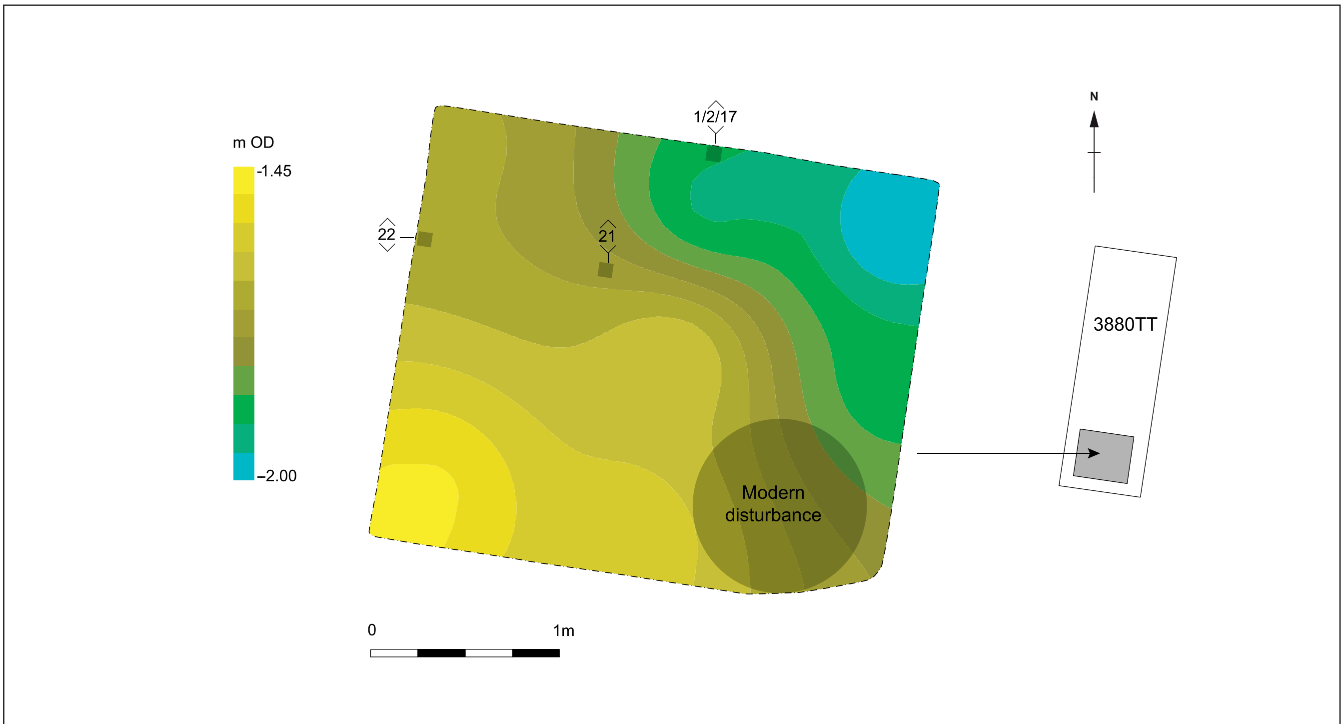


Figure 73 Modelled surfaced of context 6 and location of sample profiles in 3380TT

Borehole data (*Table 56*) indicated that the main peat (VIII) thinned out and rested on the gravel high (Fig 66) potentially sealing any artefacts. This provided a target depth for excavation. Once the cofferdam was completed it was decided that mechanical excavation would remove the bulk of the minerogenic and organic sediment but it should cease some 20cm above the base of the peat. Hand excavation followed to expose the peat base and the contact with the underlying clastic sediments. The excavated stratigraphy (Table 62) produced a significant number of artefacts associated with a disturbed landsurface beneath the peat confirming the predictions made on the basis of the various phases of ground investigation (the lowermost peat (VI) and overlying clay-silt (VII) is missing in this part of the site). As a result of this strategy being adopted minimal risk to development was taken and the works were scheduled into a complex construction programme from an early stage. An additional check on the broad patterns of sediment accumulation was possible through careful monitoring of the deposits excavated during the construction of the cut and cover works associated with the railway (Pl 21). These observations confirmed the patterns identified from the borehole/CPT and geophysical surveys.

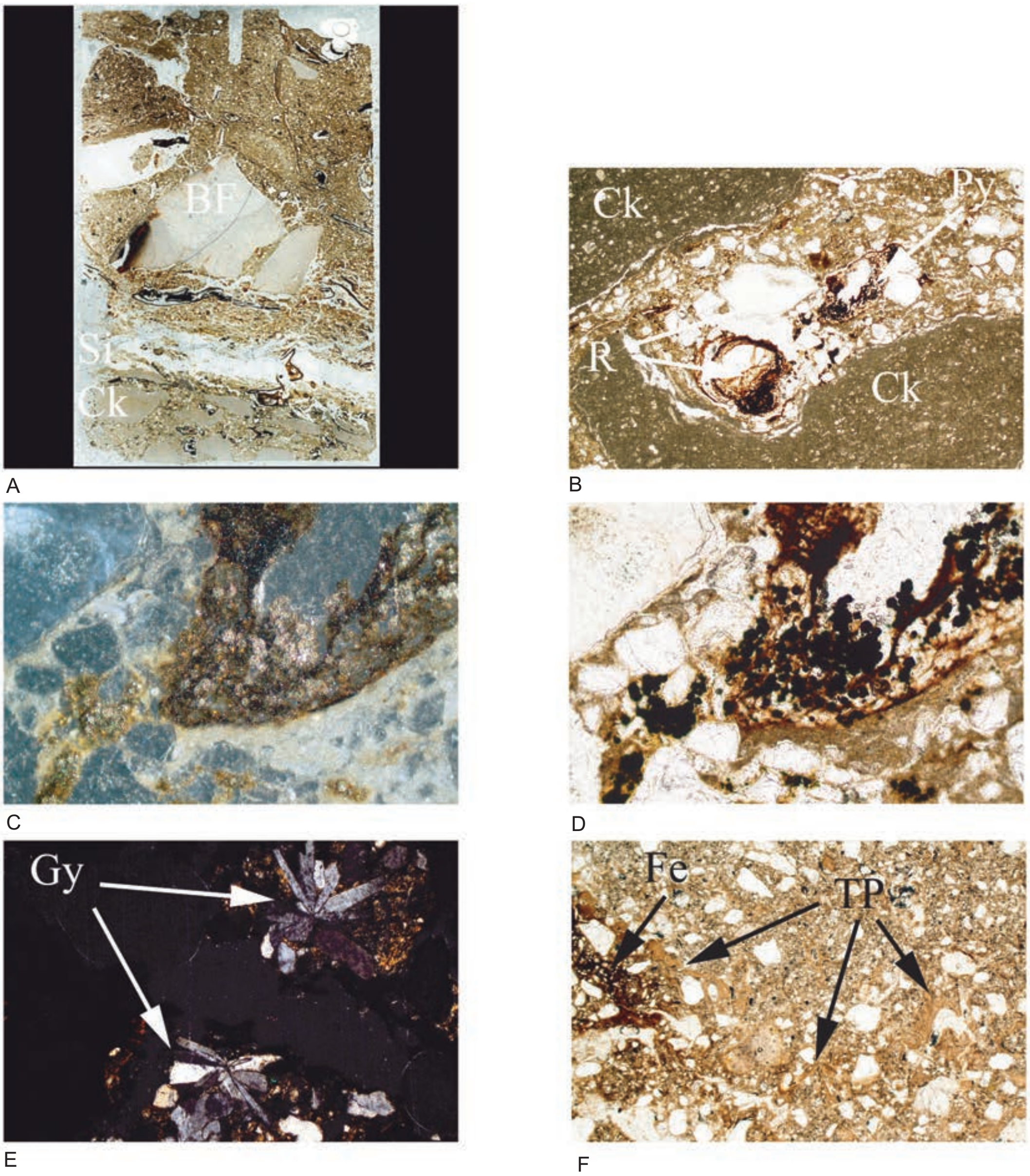
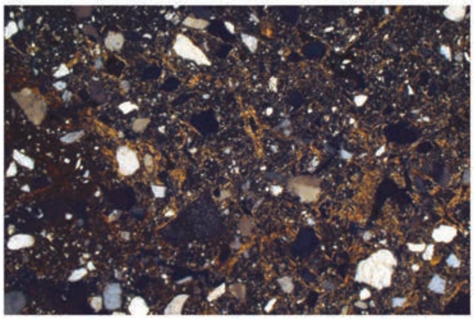


Plate 25 Photomicrographs from 3880TT, Swanscombe. A) Monolith 17(B) thin section, contexts 388005 and 388006: Late Glacial chalky (Ck) and silty clay (Si) beds, below a palaeosol containing coarse burned flint (BF). Frame width is ~50mm B) Monolith 17(B), context 388005: Late Glacial chalk clast (Ck) slurry (soliflual) deposit, with post-depositional rooting (R) and associated pyrite formation (Py; see C and D). Plane polarised light (PPL), frame width is ~4.6mm. C) As B: Detail of pyrite framboids associated with the decay of organic matter under waterlogged conditions. PPL, frame width is ~0.92mm. D) As C: Under oblique incident light (OIL); note typical 'brassy' colour of pyrite. E) Monolith 21(C), context 388005: secondary calcium sulphate (gypsum, Gy). Cross polarised light (XPL), frame width is ~2.3mm. F) Monolith 21(C), context 388005: Textural pedofeatures (TP), intercalations and void coatings and infills associated with structural collapse; later rooting associated with secondary ferruginous hypocoatings (Fe). PPL, frame width is ~4.6mm

Stratigraphy and palaeoenvironment from 3880TT

A rectangular cofferdam, 12m by 4m in plan (3880TT, Fig 60), was constructed and the uppermost 2m of material inside the cofferdam was removed without archaeological supervision. This included more than a metre of hardcore makeup that had been deposited across the whole site area to form a suitable working surface for heavy plant. From a depth of 2m the deposits were then mechanically excavated under constant archaeological supervision. Running sections through the sediment sequence were maintained and sampling was undertaken of each 1m profile before removal. A sequence of clay-silts and peat was removed in this way.

Hand excavation commenced when the base of the peat was shown to lie not far beneath the existing level of excavation. Worked flint was recovered from the lowest 100mm of the peat, from the surface and through the top 100mm of the underlying sandy silt. The sedimentary sequence within the excavated area consisted of seven main units (Table 62). The sampled sequences and locations within the cofferdam are illustrated in Figures 72 and 73.



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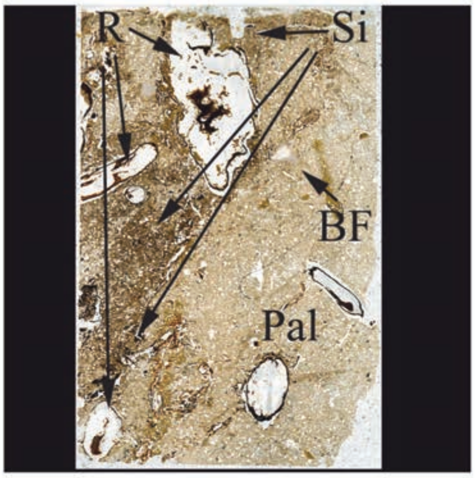

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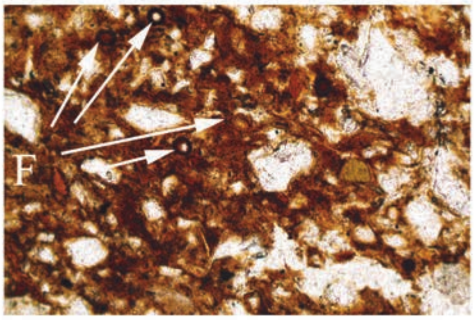

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Plate 25 continued: G) As F: XPL, showing moderately well oriented (~birefringent) textural pedofeatures. H) Monolith 21(C) thin section: 'Sandy' palaeosol (Pal) contains burned flint (BF), markedly affected by post-inundation rooting (R) and associated inwash of humic and peaty silts and clays. Width is ~50mm. I) Monolith 21(B), context 388006: Detail of peaty infill of root channel (from context 388004 above) that contains much fungal material (F). PPL, frame width is 0.92mm

Basal chalky solifluction deposits

The basal unit consisted of a mixture of silt and chalk that appeared to become less chalky up-profile (context 388005). It contained the occasional piece of flint (occasionally frost-shattered) but no humanly worked material. Thin-section analysis (monolith 17, Fig 72; Appendix B) showed that the upper part of this unit was composed of 10mm of finely bedded silts and silty clay over more than 2mm of weakly bedded chalk gravel (Pls 25A and B). These chalk clasts are set in a calcareous silt and sand loam matrix, which also records in-washed yellow clay from above. Secondary features include rooting and localised pyrite (Pls 25B–D) and traces of nodular carbonate formation, possibly including $NaCO_3$ and not simply $CaCO_3$. In monolith 21 (Fig 72; Appendix B) context 388005 is again a gravel-rich deposit, but here it is ironstone- and flint-rich, with only traces of the original calcareous matrix mixed with silty clay. Secondary gypsum is associated with root traces (Pl 25E). In general biological material was absent from this deposit although a single sample did produce a small amount of pollen including tree and open-ground taxa as well as a high microscopic charcoal particle count (although this is likely to be intrusive). The deposit appears to be a chalk- and silt-rich solifluction deposit that resembles chalky head deposits found at other HS1 sites such as White Horse Stone, Kent (Macphail and Crowther 2004) and Holywell Combe, Folkestone (Preece and Bridgland 1998). Subsequently, these deposits were rooted and anaerobic breakdown of organic matter is associated with pyrite formation (Kooistra 1978; Miedema *et al* 1974; Wiltshire *et al* 1994).

Lower (clayey) sandy silt

Overlying the solifluction deposits was a greenish-grey clayey and sandy silt unit (context 388006). The surface of this deposit appeared eroded and was steeply sloping. A number of pieces of worked flint and burnt flint were recovered from the top 100mm of this deposit. Artefacts were also recorded on the surface of the deposit at the interface with the overlying peat, along with an assemblage of animal bone (see below; *The archaeological evidence*).

Thin section analysis (monolith 17, Fig 72; Appendix B) revealed this deposit, just below the interface with the peat, to be a massive, poorly mixed humic silt and medium sand containing numerous coarse burnt flints (Pl 25A), and trace amounts of charcoal. The micromorphology appears to record a short-lived episode of weak biological working and alteration related to inundation, and associated rooting by semi-aquatic plants, which transformed the 'soil' through slaking and related structural collapse. Upwards this context becomes increasingly humic, with very abundant coarse roots and mixing the fabric. Secondary nodular carbonate formation along root channels probably reflects periodically fluctuating water tables and the calcareous nature of the underlying Late Glacial deposits. Stratigraphically this deposit in monolith 17 is correlated with similar sediment in monolith 21. However it should be noted that this correlation was not observed directly in the field and radiocarbon dates from the peat above this deposit in both monoliths exhibit very different ages, perhaps reflecting erosion of 388006 within monolith 17 by local channel activity (Fig 72; Appendix A).

As in monolith 17, thin section analysis of monolith 21 revealed this 388006 to be a massive, partially mixed silt and medium sandy loam, dominated by textural pedofeatures (intercalations and void infills; Pls 25F and 25G) caused by structural collapse, mixing and 'bedding'. Secondary features include roots and rare gypsum (Kooistra 1978), and many ferruginous (Pl 25F) and carbonate impregnations, with some finely dusty clay void coatings associated with rooting. In the upper part of this unit down-profile clay movement and slickenside-like fabric features relate to rooting and structural collapse higher up. The fabric features indicate *in situ*

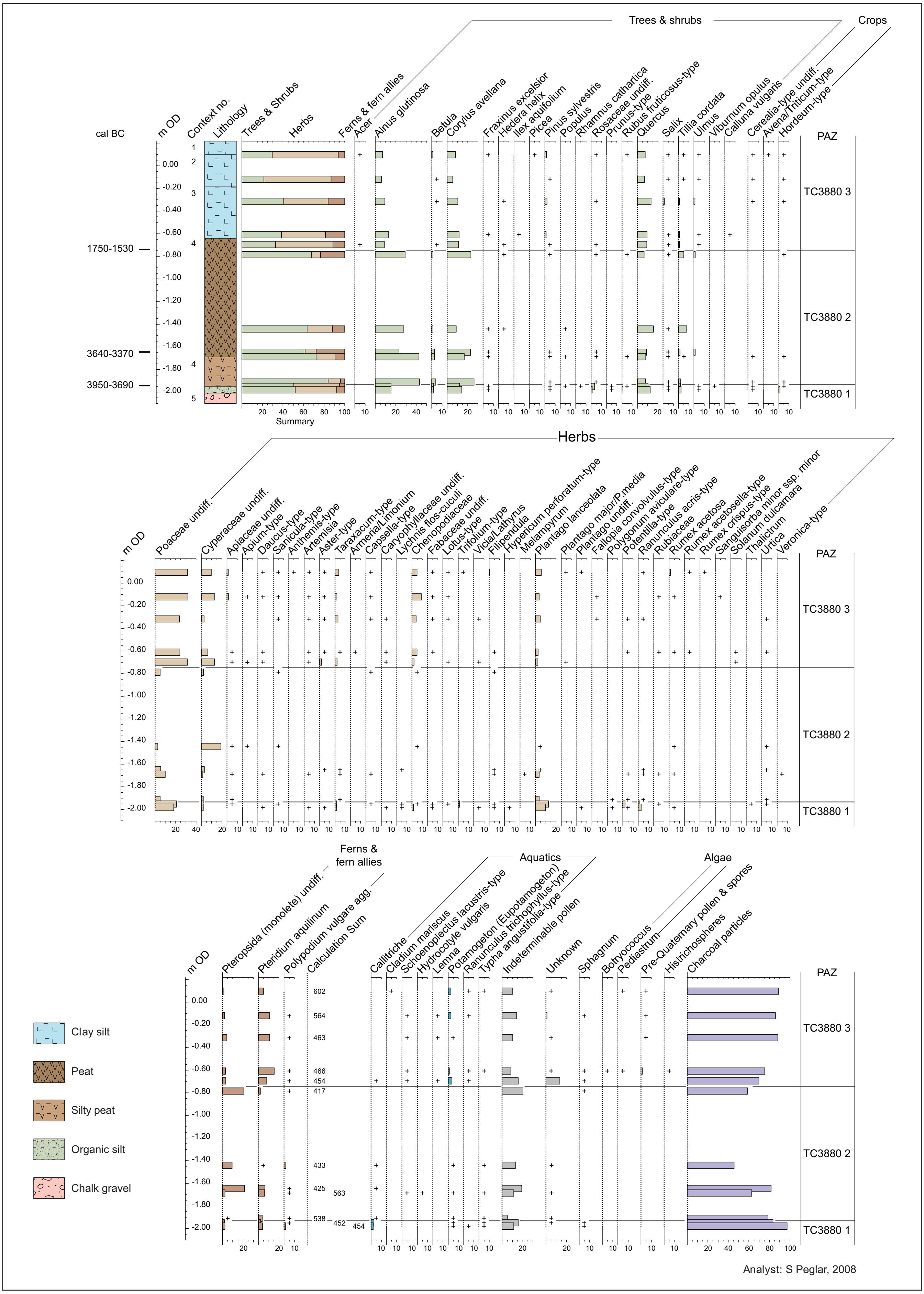

Figure 74 Pollen diagram from 3880TT

thixotrophic (water saturated) conditions. Iron and calcium carbonate impregnation is again linked to rooting into calcareous gravels below, and ensuing oxygenation (iron movement) because of root penetration and water table fluctuations. This deposit, at the interface with the overlying peat, is markedly affected by root mixing with humic silt and silty clay rich in plant tissues and fungal material (Pl 25I), possibly related to fleshy semi-aquatic rooting. Rare charcoal and possible fine burned mineral is evidence of local burning, possibly related to resource use or occupation.

The pollen (monolith 17, Fig 74; PAZ TC3880–1) contained quite high values of obligate aquatic taxa (eg, *Callitriche* (starwort), *Potamogeton* (pondweed) and *Typha angustifolia*-type (lesser bulrush) typical of freshwater, suggesting that open areas of reedswamp were present. The pollen assemblage (bottom two samples) contain about 50% tree and shrub pollen (arboreal pollen; AP) and 50% herb pollen (non-arboreal pollen; NAP) and fern spores. The NAP is dominated by Poaceae and *Plantago lanceolata* (ribwort plantain) together with many other herbs characteristic of grassland/pastures (eg, *Taraxacum*-type (dandelion), *Trifolium*-type (clover), *Potentilla*-type (cinquefoil) and *Ranunculus acris*-type (buttercup)). Also present are cereal-type grains including possibly barley (*Hordeum*-type) and pollen taxa characteristic of weeds of arable crops or open ground. The AP, with pollen of *Quercus, Tilia* and *Corylus*, is evidence for mixed deciduous woodland growing on the dryland, with *Alnus* growing on the wetland. Also present are pollen of shrubs and trees which may be characteristic of woodland edge (though some are also found naturally occurring in alder carr): Rosaceae undiff. (rose), *Prunus*-type (sloe/cherry), *Rubus fruticosus*-type (blackberry), *Rhamnus cathartica* (buckthorn) and *Viburnum opulus* (guelder rose). These assemblages indicate that mixed deciduous woodland was present regionally possibly with small patches of cleared and thinned woodland used for pasturing and growing cereals quite close to the site.

The main peat and upper clay silts

The peat (context 388004) was approximately 1.4m thick and the base of this unit has been dated to the Early Neolithic, 3950–3690 cal BC (NZA-29088, 5004±40 BP) in monolith 17 (Fig 72). Here, peat composition varies; between -1.95m and -1.73m OD it is silty peat while between -1.73m and -0.74m OD it contains abundant woody fragments and roots. The top of the peat in this location (monolith 2) has been dated to the Early Bronze Age, 1750–1530 cal BC (NZA-29086, 3372±35 BP). Occasional pieces of struck or burnt flint were recorded throughout this unit (see below; *The archaeological evidence*) along with an assemblage of animal bone, although the frequency was much greater within the lowest 100mm of the peat.

The pollen assemblage (PAZ TC3880–2) is dominated by *Alnus* with *Quercus*, *Corylus*, *Tilia* and ferns. NAP are at lower values than in PAZ TC3880–1, particularly towards the top of the zone. These results would indicate that alder fen carr with an understory of ferns was growing on the site at this time, with the loss of the woodland openings which were used for pasture and cereal growth in PAZ TC3880–1. Further evidence of alder carr growing on the site is provided by clumps of *Alnus*, *Salix* and Cyperaceae pollen which would have been broken up if they had travelled some distance. The development of the alder carr may have been in response to dropping water levels associated with estuary contraction and relative lower sea-levels, allowing alder carr to grow on areas that were previously reedswamp. Raised values of *Betula* (birch) at the base of the zone may give further evidence of abandonment of the openings in the woodland as *Betula* is often the first colonising shrub/tree of abandoned cleared ground. Charcoal values are also down on those of PAZ TC3880–1 suggesting less human impact on the local environment. Mixed deciduous woodland with *Tilia, Quercus* and *Corylus* was growing on drier ground away from the site. It is possible that there is a hiatus towards the top of the main peat unit, at the PAZ TC3880–2/3 boundary. Pollen assemblages between the two zones are very different. The top of the peat at -0.74m and -0.64m OD is recorded as dried out peat whereas -0.64m to 0.12m OD are silty clays (contexts 388003–1). The dried out peat could suggest that some of the sediment could have been eroded away, particularly as the site became waterlogged and the silty clay was then laid down. At the PAZ TC3880–2/3 boundary there is a drop in *Tilia* values and this may represent the ‘lime decline’. It is here dated to 1750–1530 cal BC (NZA-29086, 3372±35 BP), in the Early to Middle Bronze Age, which is found to occur in many wetland sequences at this time (see Grant *et al* 2011) including those listed in this study (see Chap 10) and often associated with human activity (though see Waller and Grant 2012).

NAP values are much higher in PAZ TC3880–3, particularly grasses, with concomitant drops in AP values. Charcoal values also rise. There is evidence of marshes/fens (Cyperaceae), but also of pastures and, in the overlying silty clays, cereal growth. These changes may be indicative of increased human impact around the site, probably on the higher drier ground, with some clearance of woodland for agriculture. Obligate aquatic pollen values rise and remains of the green algae *Pediastrum* and *Botryococcus* indicate the presence of fresh water, but Chenopodiaceae pollen values also rise, a taxon characteristic of saltmarsh, suggesting that saltmarshes may have been present not far away at this time. The pollen assemblages may suggest fluctuating fresh and saline conditions such as found under tidal conditions and that saltmarsh may have been gradually approaching the site throughout the zone. There is evidence for reworking of sediment during this zone with the recording of pre-Quaternary pollen and spores, and the very variable preservation of the pollen.

The uppermost sediments consisted of a series of stratified clay-silts. The top layer (388001)had been partly oxidised to a pale brown colour. Diatoms were present in both 388002 and 388003 and in both cases samples produced brackish and marine diatom species (*Table 63*). Halophilous species occur in the sample from context 388003. However, these halophiles, *Navicula cincta* and *N. mutica*, are also tolerant of desiccation (aerophilous diatoms) and occur in habitats such as ephemeral pools and on the banks of water bodies. From the evaluation counts, it appears that allochthonous marine planktonic diatoms are more common in the sample from context 388003 than in the sample from context 388002 (eg, *Paralia sulcata, Cymatosira belgica* and *Rhaphoneis* spp.). In the sample from context 388002 mesohalobous, benthic or epipelic (mud-

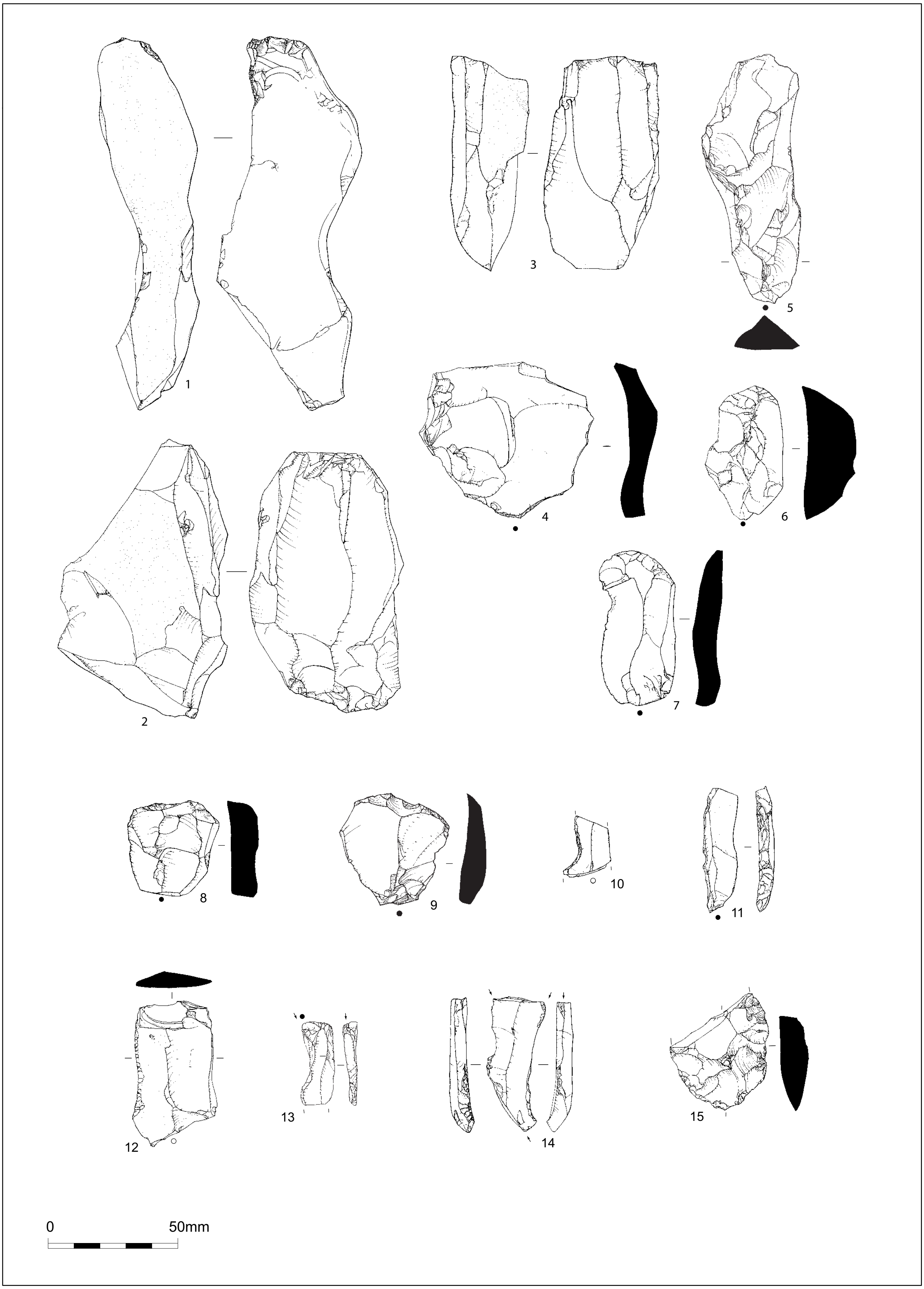

Figure 75 Worked flint from the Thames Crossing at Swanscombe

surface) diatoms such as *Nitzschia navicularis, N. granulata, Diploneis interrupta* and *D. smithii* (a polyhalobous to mesohalobous species) appear to be more common. Both samples contain *Cyclotella striata*, a planktonic diatom typical of the estuaries in general.

Summary

The evidence from the excavated sequence indicates that the site was located on a small area of high ground projecting from the valley side into the floodplain of the river. This finger of land was defined by a sequence of solifluction lobes that had undergone reworking and local mobilisation on the slope after initial deposition. Subsequently fluvial erosion of the sediment resulted in the trimming and incision noted to the north and east by presumed local stream activity. These minor channels were subsequently infilled by peaty-silt and eventually by a thick deposit of peat. Finally mudflat conditions developed across the site.

The Archaeological Evidence

The artefactual material recovered from both the coffer excavation (3880TT) and the watching brief included a small assemblage of pottery along with animal bone, with a large assemblage of worked flint, analysed by Hugo Anderson-Whymark (*Tables 64–71*). In total the assemblage comprises 521 worked flints and 302 fragments (7541g) of burnt unworked flint, the majority recovered from either the base of the main peat unit (388004) or the upper part of the underlying sandy silt alluvial deposits (context 388006) and the equivalent watching brief contexts (see *Table 64* and Fig 75).

Catalogue of illustrated flint from the Thames Crossing at Swanscombe

(Fig 75)

1. Bruised flint? A thermally fractured piece of flint exhibiting two areas of edge-damage along one side and further damage at one end. The edge-damage is consistent with heavy use, but is less prominent than on bruised blades in known long blade assemblages. A Late Upper Palaeolithic date is possible, but equally this flint may be contemporary with the Upper Palaeolithic flint it is associated with (ARC TMS00, 388006).
2. Prismatic bi-polar blade core. Note the one dominant platform for blade removal and the minimally prepared back of the core. Abandoned due to an internal thermal flaw. 343g. Upper Palaeolithic (ARC TMS00, 3 88006, SF74).
3. Single-platform blade core. Plain platform with platform-edge abrasion. Note the minimally prepared rear of the core. 112 g. Upper Palaeolithic (Chainage 35.250km).
4. Platform rejuvenation tablet. Plunging removal from a blade core with platform-edge abrasion. Note the presence of more than one removal on the platform surface. Upper Palaeolithic (Chainage 35.250km).
5. Crested blade. Upper Palaeolithic (Chainage 35.250km).
6. End scraper manufactured on a small plunging unifacially crested flake. Upper Palaeolithic (ARC TMS00, 388006, SF107).
7. End scraper on a flake. Burnt. Upper Palaeolithic. (Chainage 35.250km).
8. End scraper on a flake. Upper Palaeolithic (Chainage 35.250km).
9. End scraper on a flake. Upper Palaeolithic (Chainage 35.250km).
10. Edge retouched flake. Slight abrupt concave edge retouch along the right-hand side of a blade-like flake. Proximal and distal breaks. Upper Palaeolithic (Chainage 35.250km).
11. Curved backed blade. Distal end intentionally broken. Upper Palaeolithic (ARC TMS00, 388006, SS196).
12. Edge-retouched blade-like flake. Straight semi-abrupt edge-retouch along left hand side of a side trimming flake (ARC TMS00, 388006, SS196).
13. Burin on a platform edge. Note retouch after the burin removal. Upper Palaeolithic (residual, Chainage 35.250km).
14. Burin. Two burin on truncation removals and one dihedral burin removal. Note additional edge retouch after the burin removals had been made. Upper Palaeolithic (residual, Chainage 35.250km).
15. Laurel leaf. Tip broken. Early Neolithic (Chainage 35.250km)

The vast majority of the flint assemblage from the watching brief was recovered close to 3880TT excavation (*c* 35.245–*c* 35.260km, *Table 65*, Fig 60). The flints from the sandy silt are in pristine condition and may have been preserved *in situ*, although no distinct concentrations or scatters were observed. Many of the flints from the overlying peat are technologically similar to those recovered from the sandy silt and are likely to have been reworked from there.

Two distinct groups of flints were identified; Upper Palaeolithic and Neolithic. The raw material exploited was relatively consistent across the excavation areas and between the two periods; it was exclusively flint procured in the form of reasonably-sized derived nodules. The cortical surface of nodules either exhibited a thin 1–2mm chalky crust or was entirely abraded. The cortex was generally white to grey in colour and the flint was dark grey with variable degrees of lighter grey mottling. The flint was of good flaking quality, but contained occasional large thermal flaws which hindered knapping. Thermal faults were more prominent in this raw material than among the large nodules exploited at Springhead. The original size of the nodules is indicated by three refitting flints from the watching brief (35.250km) that were struck from a nodule in excess of 150mm long.

The flint was generally in pristine condition, due to preservation within peat and alluvial deposits. The flint from the upper part of the peat and alluvial deposits in the watching brief (contexts 1 and 2) and the unstratified flints generally exhibited moderate post-

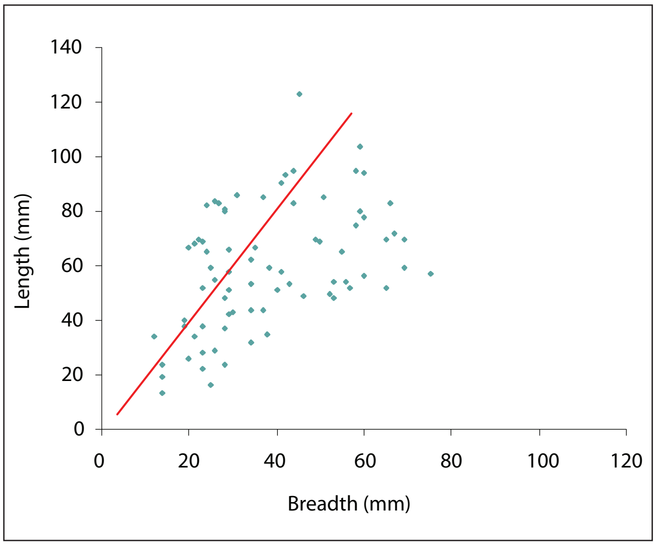

Figure 76 The length to breadth ratio of flakes from 388006 and 3

depositional edge-damage suggesting redeposition. Several Upper Palaeolithic flints were present in the lower levels of the peat deposits exhibited slight edge-damage. This indicates that these flints were probably reworked from the lower alluvial deposits. The distribution of these flints was comparable to the scatter in the underlying deposits and indicates limited horizontal movement.

The majority of the flint exhibited no surface cortication. A small number exhibited a slight mottled bluish/white surface cortication and others bore a dark surface staining typical of flints recovered from peat. A significant proportion of the flint assemblage was burnt (18%), notably six of ten end scrapers. A large proportion of the assemblage was also broken (47.7%); this total includes numerous breaks resulting from burning.

Upper Palaeolithic worked flint

The Upper Palaeolithic flint assemblage was recovered over an area 53m in length from 35.220km to 35.273km and extends laterally beyond the limits of the tunnel portal. A small number of flints from the excavation were three dimensionally recorded and demonstrate a spread with no distinct artefact concentrations. The distribution of flint from the watching brief was referenced to specific chainages (*Table 65*). These demonstrate a concentration of flint around 35.250km. The flint from the lower part of the peat also follows this distribution pattern and it appears that Upper Palaeolithic artefacts from the sandy silts have been reworked into the base of the peat. A limited number of Neolithic flints, considered below, were also present in this deposit. Due to the presence of Palaeolithic and Neolithic flints in peat, a technological attribute analysis was only undertaken on securely sealed Palaeolithic flints from the sandy silt (contexts 388006 and 3, 35.250km). The assemblage is considered below in relation to debitage and retouched tools.

Debitage

A complete reduction sequence, from core preparation to abandonment, is present in the Upper Palaeolithic assemblage. A large proportion of the flints from context 3 (35.250km) exhibit a distinctive chalky cortex and appear to derive from the reduction of a large flint nodule. The early stages of core reduction are well represented in the assemblage. Core preparation flakes form 9.1% of the flake assemblage and 56% of the assemblage exhibit some of the cortical surface (*Tables 66* and *67*); 9% of flakes also exhibit cortical butts (*Table 69*). Knapping refits were identified between three large trimming flakes removed early in the reduction sequence (35.250km). In addition, 22% of flakes exhibit cortex along one or both sides and 13% of flakes exhibit cortex at the distal end. The majority of these flakes result from the preparation of cores, rather than their final reduction.

The cores appear to have been well dressed, with much of the cortex removed from the front of the core before blade production commenced. The back of the core is generally minimally prepared and frequently exhibits some cortex. Seven crested flakes and blades were present in the assemblage. Three short crested flakes were detached from dressed nodules to prepare platforms; one of these was retouched into an end scraper (Fig 75, 6). Blade production was then initiated by the removal of a crested blade. Four uni-facially crested blades are present in the assemblage. The longest crested blade is broken, but measures 93mm in length, and two complete examples measure 80mm and 84mm respectively. These crested blades provide a good indication of the size of blade produced. Once blade production had commenced, the platforms were maintained and extended by the removal of large core tablets (Fig 75, 4); three tablets were recovered from context 3. Only two small face rejuvenation flakes were present indicating that few minor adaptations were made to cores during blade reduction. Two single-platform blade cores, two bi-polar blade cores (Fig 75, 2 and 3) and one unclassifiable blade core were recovered from contexts 388006 and 3; an additional three bi-polar cores from contexts 388804 and 11 also appear to date from the Upper Palaeolithic. One of the single-platform blade cores is pyramidal in form, whilst the other single-platform blade core and bipolar cores are prismatic. The 'other' blade core has been extensively worked, with flakes removed late in the reduction sequence, but prior to this it appears to have been a prismatic single platform blade core. In all cases, the bi-polar blade cores exhibit a primary platform, from which the majority of blades are detached, with the second platform used to modify and correct the angle of the core's face. The single-platform blade cores were abandoned at 112g and 117g, whilst the bi-polar cores were abandoned between 84g and 343g (average 227g). The final blade removals measure 50mm–76mm. In addition to the blade cores, a single-platform flake core, a multi-platform blade core and two tested nodules were recovered from contexts 388006 and 3. These cores show limited preparation and may represent the production of flakes for adaptation into scrapers.

The technological attributes of 208 complete and broken flakes from contexts 388006 and 3 (35.250km) were recorded and the 75 complete flakes were measured (Fig 76). The average flake in the assemblage measures 59mm long by 38mm wide and 12mm thick. Blades, flakes with a 2:1 or higher length to breadth ratio, represent 32% of the flake debitage, a total comparable with the blade industries of the Mesolithic (Ford 1987). This total may, however, be exaggerated as few small flakes are present in the assemblage as the flint was hand collected and no sieving was undertaken. The 24 complete blades in the assemblage measure 34–125mm in length and have average dimensions of 72mm by 28mm by 9mm thick. The 125mm blade is the only example over 100mm and falls within the size range of Late Upper Palaeolithic long blade industries. There are, however, no specific attributes to suggest this blade is not contemporary with the rest of the assemblage. The range of butt types supports the observations made from the cores (*Table 69*). The majority of flakes exhibited plain butts (67%), having been struck from platforms created by tablet removals. A further 9% of flakes exhibited more than one removal on the platform. Punctiform and linear butts (8.9% and 5.9% respectively) are not infrequent and result from the hammer being struck close to the edge of the core and removing only a minimal area of the platform. These removals are commonly associated with platform edge abrasion. Facetting was present on nine flakes (6.7% of the flake assemblage). The faceting on three of these flints reflects the removal of rejuvenation tablets, and one results from the removal of a blade across the platform. The other five examples result from the abrasion of the platform as well as the platform face. No *en éperon* butts, typical of Creswellian industries, were recorded. Platform-edge abrasion was recorded on 66% of flakes. The abrasion was particularly prominent and frequently took the form of large clusters of step fractured removals up to 10mm long. Large blades tended to exhibit the heaviest edge-abrasion and the edges of some platforms were bevelled. The termination of the flakes examined (*Table 70*) indicate the majority were successful. Feathered terminations are most frequent (56%), with roughly equal proportions of plunging and hinged removals (20% and 18% respectively). Only 4% of flakes resulted in step fractures.

Core reduction appears to have employed both hard and soft hammer percussors (*Table 71*). 41% of flakes exhibited developed hertizan cones typical percussion using hard hammer, such as stone, whilst 26% of flakes exhibited more diffuse bulbs typical of percussion with a soft hammer, such as antler (Onhuma and Bergman 1982). The pattern of hammer use is not entirely consistent, but cortical trimming flakes were more commonly removed using hard hammer percussion, whilst blades were generally removed using a soft hammer.

Retouch

The lower alluvial silts (388006 and 3) yielded three burins, nine end scrapers, four notched flakes, two edge retouched flakes and a curved backed blade; three burin spalls were also recovered. In total, retouched tools represent 7.7% of the flint assemblage recovered (excluding chips). In addition, two burins, two burin spalls and a distally truncated retouched flake were retrieved from the Neolithic deposits (388004 and 11); these may be considered as residual Upper Palaeolithic flints. The five burins are all manufactured on blades; three have one removal, one has two removals and the other had three removals. Two of the removals were dihedral, one of which was struck towards a notch. Three burins were struck on breaks, a further two were struck from the platform edge and one on a straight distal truncation (Fig 75, 13 and 14). The burin on a straight truncation was notched after the flake was removed, two other burins also bore additional edge retouch.

The nine scrapers were all manufactured on flakes. In all cases retouch was confined to the distal end of the flake and was gently curving, although occasional irregularities in the retouch were noted (Fig 75, 7–9). The retouch was generally semi-abrupt, but one scraper exhibited abrupt retouch. The scrapers were all either recovered in the excavation or at 35.250km of the watching brief. It is notable that five scrapers were burnt, breaking four of the examples. Burning is more prevalent among the scrapers than other tools or in the assemblage as a whole. This may indicate that the scrapers were used for a task undertaken close to a fire, or involving the use of fire. The task or location of the task ultimately resulted in the deliberate or accidental burning of these tools.

The four notched flints in the assemblage include one small 8mm notch in the side of a flake and a broad 21mm by 5mm deep notch in a broken blade (Fig 75, 10). Two flakes exhibited two adjacent notches. On one flake these were semi-circular and measured 5mm and 6mm wide respectively and on the other the notches measured 13mm and 5mm. It is unclear if it was the notches that were intended for use or the point created between the two. The location of the these paired notches on the side of the flakes indicate that any use would have to have been in a transverse, rather than rotary, movement; this may suggest a graving function. The two edge-retouched flakes include one blade-like flake with semi-abrupt edge retouch along the left hand side (Fig 75, 12) and a limited area of retouch on a broken flake that was used as a scraper.

The most diagnostic artefact is a curve-backed point with a distal truncation (Fig 75, 11). The blade exhibits heavy slightly curving abrupt retouch along the right hand side. This retouch has been struck from the ventral surface with the exception of one removal from the dorsal. The distal end was removed by a blow to the

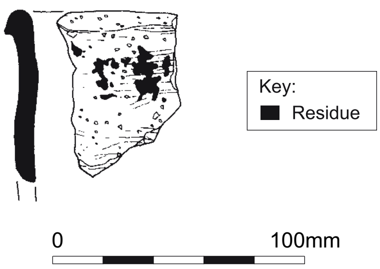

Figure 77 Early Neolithic, Plain Bowl. Rolled rim and neck sherd from a closed vessel of necked hemispherical form

dorsal surface. Comparable tools are present in many Final Upper Palaeolithic assemblages including Hengistbury Head, Dorset (Barton 1992, fig. 4.23) and Pixie's Hole, Devon among other sites (Barton and Roberts 1996).

In addition to the formally retouched tools, several flakes and blades bore edge damage consistent with use. This use-damage usually took the form of micro-flaking along the edge of artefacts but, in a few examples, was more prominent and suggested contact with hard materials. One thermally fractured piece of irregular waste measuring 125mm exhibited two areas of edge-damage along the long side of the artefact and a further area on one end (Fig 75, 1). This damage consists of clusters of scalar and step fractures extending up to 5mm into the surface of the artefact. This damage may plausibly be considered as bruising; a use-damage characteristic of Late Upper Palaeolithic long blade industries. The edge-damage on this artefact is, however, notably less prominent than the damage on bruised blades and flakes in known long blade assemblages, for example, at Springhead. Moreover, as the damage is on a thermally fractured flint, there are no technological attributes to consider if this flint belongs to the current industry or a later long blade industry. The question of the date of this flint must remain open, but, on reflection, it is probable that this artefact is contemporary with the current assemblage. It is possible the damage on the artefact results from working a hard material, such as antler, as has been proposed for the bruising on long blades (Barton 1986).

Neolithic worked flint

The Neolithic peat deposit (context 388004 and 11) yielded 221 flints and 74 pieces (3043g) of burnt unworked flint. As discussed above, many of the flints in these contexts have been reworked from the underlying alluvial silts and date from the Upper Palaeolithic. Several diagnostic Neolithic flints are, however, present and some of the debitage is also Neolithic. This is particularly apparent among the cores as, with the exception of the three Upper Palaeolithic bi-polar blade cores, considered above, the six cores in the peat exhibit a distinctly different reduction strategy to the Upper Palaeolithic material. The cores are all aimed at the production of flakes and blade-like flakes. Flakes have been struck from a single platform on two cores, whilst three cores exhibit multiple platforms. The multi-platform cores exhibit *ad hoc* working with the cores being rotated as flaking creates new surfaces that can be used as platforms. A small discoidal core, weighing 44g, was also recovered. These reduction techniques are characteristic of the Neolithic and the discoidal core is most characteristic of the later Neolithic.

The diagnostic Neolithic artefacts include a reworked fragment of a partly polished implement, a broken laurel leaf and a mis-shaped arrowhead. A serrated flake and a backed knife are also probably Neolithic. The polished implement (context 11, 35.250km) is fragmentary, but originally measured by 30mm wide by in excess of 33mm long and 13mm thick. The form of the implement is unclear, but one side was flat and the surface was only was partly polished; this may suggest an adze-like implement. An axe thinning flake may represent a further flake struck from the surface of this tool. The laurel leaf (context 11, Fig 75, 15) dates from the Early Neolithic and may be considered contemporary with the sherd of Plain Bowl pottery (Fig 77; see below). It is not possible to classify the mis-shaped arrowhead to any particular form and only a broad Neolithic/Early Bronze Age date can be suggested.

Due to the presence of residual flints, the Neolithic assemblage is difficult to characterise. The assemblage, however, includes several Neolithic tools, perhaps indicating a broad range of activities. A refitting exercise proved unsuccessful and it seems likely that only limited knapping, as suggested by the presence of cores, was undertaken at this location. The presence of a sherd of Early Neolithic pottery, various bones of cattle and sheep/goat, along with piece of worked red deer antler (see below), may suggest this was the location of short term habitation and associated activities. The discoidal core represents debitage from a technology more typical of the later Neolithic. It is possible that this core occurred higher in the peat sequence and is of later date that the other artefacts, but this cannot be confirmed as the precise location of the artefact was not recorded.

Prehistoric pottery

Eleven sherds of handmade prehistoric pottery were recovered during the watching brief (*Tables 72* and *73*). The assemblage was examined by Alistair Barclay and Lorraine Mepham. The condition of the pottery sherds is fair to poor, but most sherds are only moderately abraded (mean sherd weight overall 13.3g). Nine plain sherds are from the basal part of the main peat unit (watching brief context 11). This includes a rolled rim in a flint-tempered fabric (FA1/EN), identifiable as deriving from an Early Neolithic Plain Bowl of slightly necked hemispherical form (Fig 77). Some of the other plain body sherds could be from the same or similar vessels. Charred residue on the outer neck of the rim sherds and on the interior surfaces of two of the body sherds indicate use as cooking pots. A second rolled rim sherd in a leached shelly fabric (S1/EN) could be from a similar type of vessel. The remaining sherds (including

A

B

Plate 26 A) Worked Neolithic red deer antler from the watching brief at 35.255km, Swanscombe; B) detail of cut marks on the beam

seven from context 11), all plain sherds, in flint-tempered, shelly and sandy fabrics, could be of similar date. These include a probable neck sherd and what could be a lower vessel sherd from a cup. A further neck sherd was recovered from the upper alluvial deposits (watching brief context 001/002), although it is possible that this is of non-Neolithic date.

The rolled form of the two rims as well as the profile of the larger sherd in particular indicate affiliation with the Plain Bowl tradition of the mid-4th millennium BC (Barclay 2007, 342 and table 15.1). This type of pottery has a widespread distribution across much of Britain, occurring in occupation deposits, pits and in association with some monuments (eg, causewayed enclosures such as Staines (Robertson-Mackay 1987, figs 43–4)). The overall range of fabrics and type of temper are fairly typical for the region and it is not unusual to find similar vessels in different fabrics (eg, the rolled rims in fabrics S1/EN and FA1/EN), while the choice to manufacture the possible cup in a sandy fabric has been noted elsewhere. The relatively small assemblage has a wide range of fabrics, which could suggest that deposition was more than a single event and certainly that the 'life' assemblage was composed of vessels with different histories of manufacture. Charred residue on the illustrated vessel and two other sherds indicate use as cooking pots.

The only non-Neolithic sherd is part of a base in a flint and possible shell-tempered fabric (FS1/LBAEIA) from a vessel of probable Late Bronze Age or Early Iron Age date based on fabric. As the sherd is from the bottom of the base no further comment can be made.

Animal bone

Animal bone recovered from the surface of the sandy silt during the watching brief (context 3) was examined by Jessica Grimm. A possible partial skeleton of a sheep/goat comprised scapulae, a right humerus, right femur and left tibia. Based upon epiphiseal fusion this animal was older than 15–20 months but less than 42 months when it died. A complete fused left radius belonged to an animal older than 42 months when it died and the estimated height at the withers is *c* 0.61m (Teichert 1975). Four cattle bones comprise a left costa fragment, a complete fused left humerus (GL 295mm), a right humerus shaft fragment and a fused distal tibia fragment. A withers height of *c* 1.22m could be estimated using the factors proposed by Matolcsi (1970). The complete fused right radius of a red deer (GL 294mm) indicates an animal over 30 months when it died, while a beam and tine fragment was radiocarbon dated to the Early Neolithic, 3790–3650 cal BC (NZA-28891, 4948±30 BP) and exhibited cut marks on the beam (Pl 26A–B). The cut is clearly in its early stages (Pl 26B); not very deep or broad, and was probably made by repeatedly striking the antler with a knife (ie, parallel cuts).

Nineteen fragments (158g) of bone recovered from the base of the peat (context 388004) in 3880TT included two small fragments of bone classified as large mammal and the remaining fragments belonged to a right cattle scapula; as the processus coracoideus had fused, the animal was over 7–10 months when it died (Habermehl 1975). Bone from the upper part of the peat recovered during the watching brief (context 2) included a cranium fragment of a large mammal, a probable right ulna fragment of a red deer, and cattle bones comprising a complete fused right radius, a metacarpus shaft fragment, the fused distal part of a right metatarsus (>24–30 months) and a right tibia shaft fragment. Based on the complete cattle radius a height at the withers of *c* 1.15m was estimated (Matolcsi 1970). At the interface between the peat and overlying alluvial deposits (context 1/2) cattle bones were also recovered which included a fragment from the left side of an adult skull, the corpus of a lumbal vertebra with unfused epiphyses indicating an animal younger than 48–60 months (Habermehl 1975) and the distal part of an unfused tibia (animal <24 months), as well as the complete unfused right tibia of a juvenile pig. Of particular interest is the recovery of a complete tooth row of a right mandibula of adult cattle. Only the teeth survive and no mandibular bone. According to Grant (1982), the wear stage of this mandible is 43, indicating an older but not aged animal.

Discussion

The flint assemblage from the Thames Crossing excavation and watching brief results from two distinct episodes of activity on the headland as predicted in the original model. The scatter of flint in context 388006 dates from the Upper Palaeolithic. The industry was orientated on the production of blades up to 100mm in length, generally removed from bi-polar blade cores maintained by tablet rejuvenation. The retouched tool assemblage was dominated by short end scrapers on flakes and burins; a curve-backed blade was also present. These attributes and tools are most characteristic of Final Upper Palaeolithic assemblages, although penknife points are absent from the assemblage. Only a few radiocarbon dates are available for comparable assemblages, but they indicate a date probably in the Windermere interstadial (*c* 12,000–11,000 BC, Barton 1999, 18, table 2.2, 25). An arctic hare bone from the archaeological deposits at Broken Cavern, Devon, was AMS dated to 11,540–11,010 cal BC (OxA-3887, 11,380±120 BP). Three radiocarbon dates on animal bones related to a hearth at Pixie's Hole, Devon, produced dates around *c* 12,210–11,310 cal BC (OxA-5794–6; the three dates were statistically inconsistent so the range of the calibrated means is quoted here), while charcoal (species not given) from a hearth at Mother Grundy's Parlour, Derbyshire dated to 11,890–11,460 cal BC (OxA-5858, 11,790±901 BP) (Barton 1999, 25). The assemblage is also comparable to the open sites at Hengistbury Head, Dorset and Brockhill, Surrey. The date of these open sites is not clear, but broad TL date of 12,500±1150 years ago was obtained on burnt flint artefacts from the former site (Huxtable 1992, 60). Unfortunately the date of 3790–3650 cal BC (NZA-28891, 4948±30 BP) from the Thames River Crossing, Swanscombe obtained on a worked antler among the flints indicates that it is intrusive to the unit.

The interpretation of the scatter is hindered by archaeological and methodological issues. The Late Upper Palaeolithic scatter in the silts (contexts 388006 and 3) appears to have been preserved *in situ*, but the upper levels of the deposit have been truncated and finds reworked into later deposits, prior to the peat formation. The location of all of the finds was, however, not subject to detailed recording during the excavation and the lack of sieving resulted in the recovery of only the largest and most obvious flints. The nature of recording means that it is not possible to consider artefact distribution or activity areas. The scatter was clearly quite diffuse and spread over an area over measuring over 53m long; the lateral width is not known. The scatter contained significantly different densities of flint, with a particular focus of activity around 35.250km. A complete flint knapping sequence was present from the dressing of flint nodules to the abandonment of cores. Only a limited number of knapping refits could be made, indicating that significant elements of the sequence are missing, but this may reflect the method of excavation rather than an archaeological pattern. It is probable that many of the tools in the scatter were also manufactured at this location. This could not be demonstrated by refitting, but the presence of burin spalls indicates the manufacture of burins in the scatter. The presence of scrapers, burins and other retouched pieces indicate that several activities were performed at this location. The presence of a significant quantity of burnt unworked flint and burnt worked flints, including a high proportion of the scrapers, indicate the presence of a fire or fires. There is little evidence to suggest the that scatter resulted from prolonged or repeated activity at this location, but in the absence of detailed artefact distributions it is not possible to explore this issue further.

The Neolithic flint from the overlying horizon (contexts 388004 and 11) is likely to be of mixed character with no evidence for *in situ* activity. It indicates probable reuse and a presence in this part of the landscape during the Neolithic.

An Integrated History of Landscape Change and Human Activity

The evidence from both on- and off-site sequences investigated record a series of changes to the landscape that have largely been controlled by the process of flooding of the Early Holocene topographic template as a result of rising sea-levels. However, the initial occupation of the headland area took place in the Late Upper Palaeolithic period. Little evidence from the site exists to allow the archaeology to be dated directly and as the onset of sedimentation upon the Shepperton Gravel surface beneath the floodplain did not begin until around 6610–6430 cal BC (NZA-27599, 7669±50 BP) we do not have any evidence from the vicinity to contextualise the archaeology. The flints recovered indicate that human activity (in all probability associated with hunting and of a transitory nature) occurred at this location which would have provided a good vantage point across the lower lying floodplain. Possible contemporary deposition of sediments may have occurred (11 from watching brief) as a result of small channels crossing the headland.

The deposition of more extensive sediments upon the valley occurred around *c* 6500 cal BC with accumulation of fresh water deposits before intertidal mudflats were established. Up profile, gradually reducing relative water levels are attested in a change towards mid- to upper saltmarsh faunas prior to development of the alder carr woodland. Despite careful examination no evidence for exposure or drying of the minerogenic surface exists beneath the peat. Conditions on the headland at this time (or at least towards the end of this phase) appear to indicate local fresh water reedswamp and grassland conditions with deciduous tree growth on dry ground and significant quantities of charcoal to suggest small-scale clearings in woods. The onset of a major phase of fresh water fen carr becoming reed swamp up profile is recorded both on- and off-site. The Neolithic flint and pottery finds from the lower parts of the peat are probably broadly contemporary with the earlier fen carr phases but the diversity of the finds suggests that a number of episodes of activity are represented. These finds appear to be representative of a lower level of activity that the older Upper Palaeolithic finds and perhaps attest to intermittent visits to the water edge by people throughout an extended period of time. Significantly there was sparse evidence for artefacts and human activity within the large tract of peat exposed in the cutting of the box and we can, therefore, conclude that, based on the absence of material, evidence for human activity in the fen carr and reedswamp in this location was restricted.

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