Quaternary of the Thames

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Chapter 5

Essex

Introduction

Several sites in the extreme south-west of Essex have been described already, in Chapter 4, as they fall within the Lower Thames valley. Pleistocene fluvial deposits are widespread in the remainder of the county and their study has been of great importance in reconstructing the evolution of the Thames drainage system. The succession in Essex comprises not only the deposits of the River Thames (both pre- and post-diversion), but also of its major right-bank tributary, the Medway. A number of more recently formed left-bank Thames tributaries, which now drain the northern part of the county (Fig. 5.1), are also represented. Pleistocene sites in this area included in the Geological Conservation Review invariably reflect aspects of drainage development. At a few sites, interbedded glacial sediments are included, from which can be demonstrated the advance of the Anglian ice sheets into the area. Buried soil layers form an important part of the interest at some sites. There are also a number of important Palaeolithic localities, the most notable of which is at Clacton, the type locality for the Clactonian Industry and a site of great importance to Pleistocene geology.

A large part of Essex is covered by Pleistocene deposits. In addition to fluvial sediments, a widespread covering of till dominates the higher land in the north-western half of the county (Fig. 5.1; Whiteman, 1987). Considerable spreads of mostly fluviatile gravel both underlie and overlie much of the till and extend over large parts of the remaining, unglaciated districts. In addition to the Lower Thames deposits, described in Chapter 4, these gravels can be separated into three main divisions (Fig. 5.1): (1) the Kesgrave Sands and Gravels of central and northern Essex, which are pre-diversion Thames deposits laid down prior to the Anglian glaciation, (2) the East Essex Gravels, Medway and Thames-Medway deposits that form terraces running parallel to the Essex coast, and (3) the deposits of local rivers that have developed as tributaries of the Thames-Medway system following the Anglian glaciation. This chapter is divided into three parts, corresponding to these three categories of fluvial deposits.

Both the Kesgrave and East Essex Gravel Groups are made up of several component (terrace) gravel formations; High-level and Low-level Subgroups can be recognized within both groups (Table 5.1).

Research in this area has been less extensive than in the present Thames valley, although the fluvial record in Essex is now acknowledged as critical for reconstructing the development of Thames drainage during the Pleistocene. Prior to the definition of the Kesgrave Sands and Gravels by Rose and Allen (1977; Rose *et al.*, 1976), few authors regarded any of the gravels in Essex outside the Lower Thames valley as products of that river. Because the pre-diversion (Kesgrave) Thames gravels are overlain by Lowestoft Till over a wide area (Fig. 5.1), they were commonly attributed to glaciofluvial processes, an interpretation that has continued to receive support (Wilson and Lake, 1983). Recent work in north-eastern Essex has revealed remnants of temperate-climate deposits interbedded with the various formations of the Low-level Kesgrave Subgroup (Bridgland, 1988a;

Table 5.1 Lithostratigraphy of fluvial gravels in Essex.

Central and northern Essex		Eastern Essex	
		Deposits of local rivers	
Deposits of local rivers		Low-level East Essex Gravel Subgroup	East Essex Gravel Group
Anglian glacial deposits			
Low-level Kesgrave Subgroup	Kesgrave Sands and Gravels Group	High-level East Essex Gravel Subgroup	
High-level Kesgrave Subgroup			

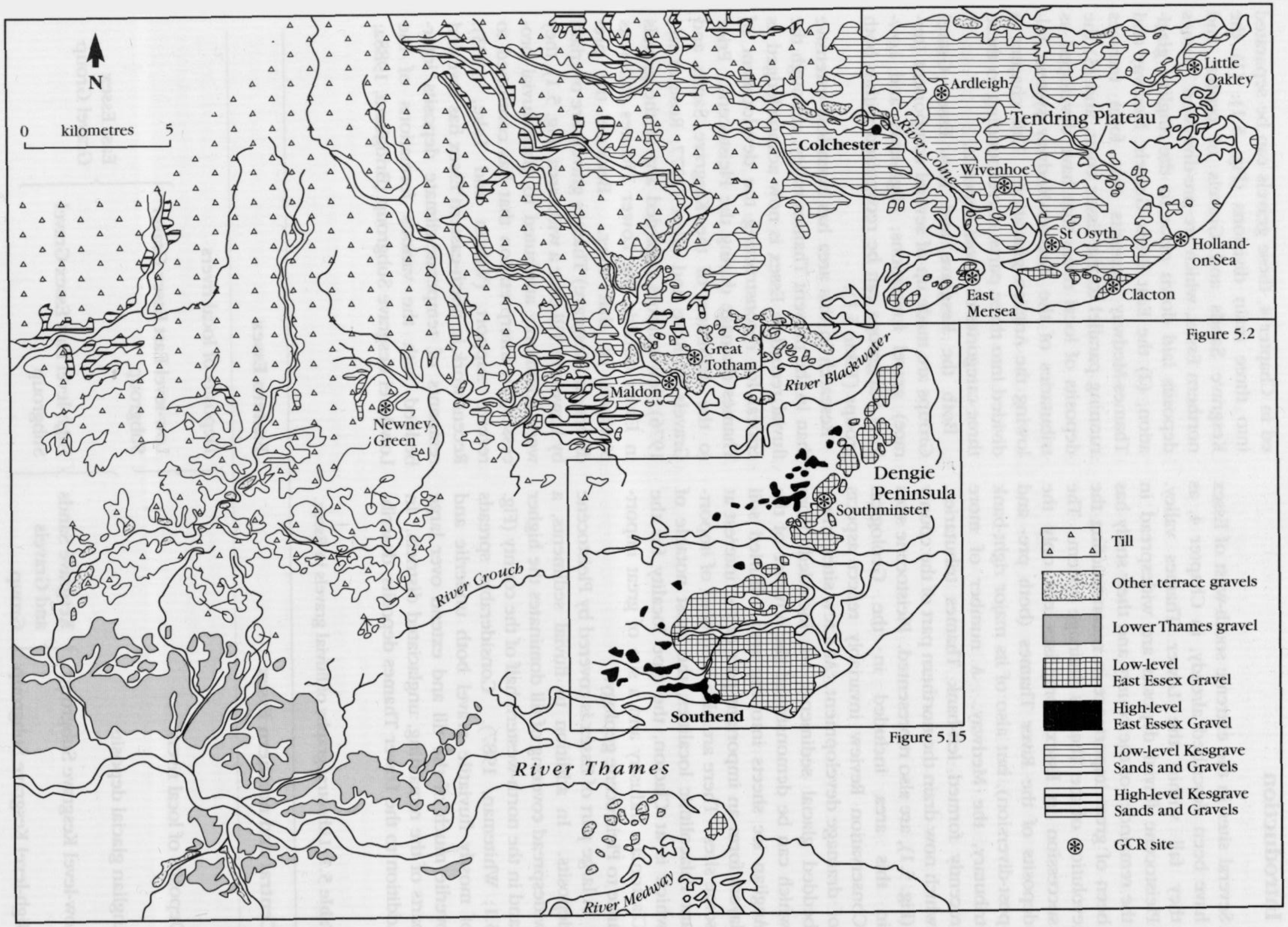


Figure 5.1 Pleistocene geology of Essex, showing the various types of gravel described in this chapter, the extent of the Anglian till sheet and the relation of these to the existing drainage systems (modified from Bridgland, 1988a).

Bridgland *et al.*, 1988). These promise to facilitate both the dating of the pre-diversion Thames formations and correlation of the Thames sequence as a whole with the established Pleistocene stratigraphy of East Anglia and that of north-west Europe (Gibbard *et al.*, 1991).

The East Essex Gravels have been variously attributed to marine processes, to the River Medway, to the Thames-Medway, or to glaciofluvial sedimentation (see Part 2 of this chapter). Recent work (Bridgland, 1980, 1983a, 1983b, 1988a) has shown that Medway and Thames-Medway deposits are represented by the High-level East Essex Gravel and Low-level East Essex Gravel Subgroups, respectively. The change from the former to the latter coincided with the diversion of the Thames (by Anglian ice) into its modern valley and, thereby, into the old Medway valley, which was already in existence across eastern Essex. The Low-level East Essex Gravel is represented in GCR sites at Clacton, East Mersea and Southminster.

Relatively little information has come from the deposits of the more recently formed tributary rivers, those which now have separate estuaries on the North Sea coast. Their deposits have yielded occasional artefacts and fossils, but interglacial sediments have rarely been recorded. However, these rivers provide the only fluvial record of the Late Pleistocene in Essex, as a combination of subsidence of the North Sea Basin and the low base level of the main river during the Late Pleistocene have resulted in Thames deposits of this age being confined, east of London, to the buried channel beneath the modern floodplain (see Chapter 4). The complex GCR site at East Mersea includes the only sediments within the GCR Thames coverage that can be ascribed with any confidence to the Ipswichian Stage (*sensu* Trafalgar Square); these are the Blackwater deposits described in Part 3 of this chapter, not the complex Thames-Medway sequence at Cudmore Grove, which appears in Part 2. Another Blackwater site, at Great Totham, provides probably the only example of Devensian fossiliferous deposits in the present volume (see, however, Chapter 3, Brimpton).

Part 1:

THE KESGRAVE SANDS AND GRAVELS

D.R. Bridgland

Introduction

The first of the three divisions of this chapter is devoted to sites associated with the pre-diversion Thames deposits of the Kesgrave Group. These deposits have only been accepted as the direct products of Thames drainage since the definition of the Kesgrave Sands and Gravels (Rose *et al.*, 1976; Rose and Allen, 1977). However, the typical sequence of Pleistocene sediments in which they occur, which is widespread in East Anglia, has been the subject of research extending back over a century. The main components of this sequence are the Kesgrave Sands and Gravels, mapped until very recent years as 'Glacial' by the Geological Survey, and the (Anglian Stage) Lowestoft Till, which overlies the early Thames gravels over much of their distribution. Localized occurrences of outwash gravel and aeolian deposits (coversand and loess) have been observed between the Thames gravels and the till. Other stratigraphically important parts of the sequence are superimposed warm- and cold-climate fossil soils, which occur at the top of the Kesgrave Group deposits throughout the area.

Early research

The occurrence of gravels beneath the East Anglian till sheet was first noted by Wood (1867, 1870; Wood and Harmer, 1868), who devised a tripartite stratigraphical scheme, based on the till-sand-till sequence of north-eastern Norfolk (now classified as Cromer Till, overlain by Corton Sands, overlain in turn by Lowestoft Till). In this scheme, the three divisions were respectively classified as 'Lower Glacial', 'Middle Glacial' and 'Upper Glacial'. Wood's classification was subsequently used by the Geological Survey when mapping Essex (Whitaker, 1877, 1889; Dalton, 1880). The upper (Lowestoft) till was widely recognized in this area and gravels underlying it were assumed to equate with those classified as 'Middle Glacial' in Norfolk. This view was strengthened by the recognition, at a few sites (such as Maldon – see below), of a till below gravel of similar type (Whitaker, 1889).

Prestwich (1881) observed that the majority of gravels underlying the till in eastern Suffolk were composed of large quantities of rounded flint and quartz, with significant amounts of subangular flint and Lower Greensand material, suggesting a southern derivation, in contrast to the northern provenance associated with the 'Glacial' drifts (including the 'Middle Glacial Gravel' of north-east Norfolk). He noted that these gravels, which he termed 'Westleton Beds', ranged as far afield as Essex and the Thames valley. He later traced possible equivalents of these beds, which he regarded as pre-'Glacial' marine deposits, over much of southern England (Prestwich, 1890b, 1890c). The distinction between the 'Glacial Beds' and 'Westleton Beds' of the Braintree area was outlined in some detail by French (1891). Despite these early attempts at clarification, the deposits later to be recognized as early Thames gravels (belonging to the Kesgrave Group) were variously classified by early workers as both 'Glacial Gravel' and 'Westleton Beds'. Furthermore, the early Geological Survey mapping recognized only 'Glacial Gravel', a category that included both the early Thames deposits and true glaciofluvial deposits. Whitaker (1889, p. 299) emphasized that the term 'Glacial' (with a capital G), as applied by the Geological Survey, was 'a proper name for a geologic period' (this can be correlated broadly with the post-Cromerian Pleistocene of modern usage) and not to be confused with the adjective meaning associated with or produced by ice. Unfortunately, such confusion became commonplace, the deposits mapped as 'Glacial Gravel' being widely interpreted as glaciofluvial outwash until the 1970s (see below).

Salter (1896) disputed the evidence for the marine origin of the deposits in Essex classified as 'Westleton Beds' by Prestwich. He pointed out that the rounded character of many of the flints in these gravels was inherited from the Palaeogene pebble beds that were their immediate source. Salter (1905) later included these beds in a series of gravels, traceable along the Chiltern dip slope from the Goring Gap towards the North Sea (Chapter 3), which he regarded as the product of an early north-eastward flowing drainage system that existed prior to the formation of the modern Lower Thames valley. Important evidence for the former existence of this drainage system, according to Salter, was the concentration of southern rocks in high-level deposits between the Lower Thames valley and the Chilterns. He realized that such gravels, containing abundant clasts of southern origin, were the products of right-bank tributaries of the old north-eastward flowing river.

Gregory (1894, 1922) regarded the bulk of the gravels of central Essex as 'pre-glacial' and divided them into 'High Level Quartzite Gravels' (or 'Danbury Gravels') and 'Low Level Quartzite Gravels' (or 'Brain Valley Gravels'), the latter coinciding largely with Prestwich's 'Westleton Beds'. Gregory believed that all these gravels had been deposited by streams flowing from the west, on a regional slope resulting from late Oligocene to early Miocene uplift. However, Solomon (1935) considered the two levels of 'Quartzite Gravels' recognized by Gregory to belong to a single series disturbed by tectonic activity, incorporating the 'Westleton Beds' (*sensu* Prestwich) and Wood's 'Middle Glacial Gravel'. Solomon classified these deposits as his 'Westleton Series', which he regarded as marine, although with a glacial intercalation in Norfolk. He ascribed lateral differences in composition to local variations in provenance within a single depositional basin. Solomon (in Clayton, 1957) claimed a distinction, based on heavy-mineral analysis, between two types of gravels in Essex: one, previously classified as 'Middle Glacial Gravel' or 'Westleton Gravel', pre-dated the Essex till sheet, whereas the other he regarded as a true outwash deposit, intimately associated with the till.

Warren (1955, 1957) reported that gravels deposited by the Thames in pre-Chalky/Jurassic Till (Lowestoft Till) times had been traced by Baden-Powell and himself from Oxford, across central Essex to the Clacton area. This interpretation, which confirmed the views of Salter (1905), was the first to indicate that Thames deposits could be recognized within the Pleistocene record of southern East Anglia. Based on clast lithology, but without systematic analyses, it anticipated the results of later work by Rose *et al.* (1976; Rose and Allen, 1977; see below).

Tills in Essex

Whilst progress was being made in the interpretation of the early gravel aggradations of southern East Anglia, research was being carried out in parallel on the glacial deposits that commonly overlie them. The 'monoglacial' model favoured by the 19th century workers was replaced by one that recognized four separate glaciations, as first envisaged in the Alpine region by Penck and Brückner (1901–1909). However, deposits of only the last three of these were identified in East Anglia, with the last confined to the extreme north-western corner of Norfolk (West, 1963). The two previous glaciations were considered to be represented by superimposed tills in East Anglia, differentiated on the basis of composition by Baden-Powell (1948) into a lower 'Lowestoft Till' and an upper 'Gipping Till'. Confirmation of this distinction was provided by studies of till fabrics by West and Donner (1956), who found significant differences in this respect between the Lowestoft and Gipping Tills and suggested respective correlations with the continental Elsterian and Saalian glaciations.

Clayton (1957) proposed a complex subdivision of the glacial deposits of the Chelmsford area, in which he recognized an older, weathered and dissected till (Hanningfield Till), largely covering plateaux, and a younger 'sandwich' of deposits filling valleys, comprising lower and upper tills separated by gravel. To this later tripartite sequence he applied the names Maldon Till, Chelmsford Gravels and Springfield Till, in ascending stratigraphical sequence. The Maldon Till was thought to be highly localized, whereas the Springfield Till was considerably more widespread. The Chelmsford Gravels, generally equivalent to the 'Middle Glacial Gravel' of Wood and Harmer (1868), were interpreted as outwash deposits. Clayton (1957) suggested a correlation between the Hanningfield Till and the continental Elsterian (= Anglian) glaciation and between the later tripartite sequence (Maldon Till, Chelmsford Gravels and Springfield Till) and the Saalian Stage. However, in an appendix to a later paper he proposed correlations with glacial drifts in Norfolk and Suffolk that implied an Anglian age for the Hanningfield and Maldon Tills (seen as equivalent to the Cromer and Lowestoft Tills, respectively) and a Saalian (Gipping Till) age for the Springfield Till (Clayton, 1960). In this later paper he suggested a Hoxnian age for the Chelmsford Gravels, which would seem to preclude their interpretation as glaciofluvial sediments, although no explanation of the change of view was provided. Clayton's earlier interpretation of the gravels as glaciofluvial was largely reiterated by Baker (1971), who suggested that the area may have been occupied by a pre-glacial Thames and that the deposits of this river may have been reworked and incorporated in the outwash.

The distinction of the products of two separate glaciations in southern East Anglia was seriously questioned by Baker (1971), who found that the Hanningfield and Springfield tills could not be differentiated either by lithological, stratigraphical or morphological evidence in north-west Essex. Baker also suggested that the Maldon Till resulted from a minor advance of the main 'Chalky Boulder Clay' glaciation of East Anglia (see below, Maldon), implying that all the glacial deposits of Essex are the product of a single glaciation. Subsequent mapping and lithological analyses of tills throughout East Anglia and the East Midlands led to confirmation that only a single glacial episode is represented amongst the Chalk-rich glacial deposits of these areas, equivalent to the Lowestoft Till of Norfolk (Bristow and Cox, 1973; Perrin *et al.*, 1973; Perrin *et al.*, 1979). Separate recognition of the partly Scandinavian Cromer Tills/ North Sea Drift glaciation was maintained, but the Gipping Till in its type area (the Gipping valley, near Ipswich) was found to be nothing more than a weathered profile in the upper part of the Lowestoft Till. Evidence for a glaciation equivalent to the continental Saalian was, however, accepted in the West Midlands and, with a good deal of caution, in the Breckland (Turner, 1973); a new name 'Wolstonian' was given to this post-Hoxnian and pre-Ipswichian glaciation (Shotton, 1973b; Chapter 1). Straw (1979, 1983) has continued to argue for an earlier 'Wolstonian' glaciation in northern East Anglia, principally on geomorphological grounds, and Wymer (1985b) has described sites in Suffolk and Norfolk where glacial deposits might overlie Hoxnian sediments. However, the view that only a single (Anglian Stage) glaciation, albeit with multiple ice advances, can be recognized in Essex has been consolidated in recent reviews (Baker and Jones, 1980; Whiteman, 1987; Allen *et al.*, 1991).

Even in the Wolstonian type area around Coventry there is growing uncertainty over the distinction between the deposits attributed to this glaciation and the Anglian deposits to the east (Perrin *et al.*, 1979; Sumbler, 1983; Rose, 1987). There are clear stratigraphical reasons for considering the whole of the 'Chalky till' to have been deposited during a single glaciation, during the Anglian Stage. Doubts have, however, been expressed elsewhere in this volume about the tenability of any model that places all these glacial deposits within a single glacial episode. These doubts stem from stratigraphical correlations of Chalk-rich tills on the Cotswolds and in the Vale of St Albans with the Thames terrace sequence, which suggest that the glaciations recognized in these two areas may have been separated by a temperate episode (see Chapter 1; Chapter 2, Long Hanborough and Wolvercote; Chapter 3, Part 2). It may be feasible, in the light of the more complex chronology indicated by the record from deep-sea cores (Chapter 1), for two separate glacial episodes to be represented within the 'Chalky Till' of eastern England, both of them post-Cromerian (*sensu* West Runton) and pre-Hoxnian (*sensu* Hoxne).

The recognition of early Thames deposits in southern East Anglia

Re-evaluation of the gravels underlying the till sheet of southern East Anglia has also taken place over the past quarter of a century. Hey (1967), following considerable reinvestigation of the deposits, concluded that the 'Westleton Beds' of the type area in north-east Suffolk were truly marine. However, he found elsewhere that gravels described by Prestwich (1881, 1890b, 1890c) under that name, and attributed by Solomon (1935) to his 'Westleton Series', differed from the type Westleton Beds and could frequently be shown to be younger. These gravels, generally mapped by the Geological Survey as part of the glacial sequence, were defined as the Kesgrave Sands and Gravels by Rose *et al.* (1976) and Rose and Allen (1977), who interpreted them as periglacial fluvial deposits of probable Thames origin. These authors demonstrated a distinction, on the basis of clast-composition, between the early Thames gravels and less extensive glacial outwash deposits, which they named Barham Sands and Gravels. They confirmed, therefore, the distinction made by Solomon (in Clayton, 1957) using heavy-mineral analysis.

Rose *et al.* (1976) proposed an important new stratigraphical scheme for southern East Anglia. From a study of sites throughout the area between Ongar (in the south-west), Thetford (in the north-west) and the coast, they found that the Lowestoft Till overlies widespread fluvial deposits of the pre-diversion Thames, their Kesgrave Sands and Gravels. The upper part of these deposits was frequently found to be rubified and clay-enriched, features indicative of pedogenic activity in a warm climate (Rose and Allen, 1977; Kemp, 1985a; Rose *et al.*, 1985b). This horizon occurs immediately beneath the Lowestoft Till or its associated outwash (Barham Sands and Gravels), indicating that soil development occurred prior to the Anglian glaciation. It was therefore concluded that the uppermost parts of the Kesgrave Group gravels incorporate the illuvial horizon of an interglacial soil, named the Valley Farm Soil (Rose *et al.*, 1976; Rose and Allen, 1977; Kemp, 1985a). As the Kesgrave Sands and Gravels overlie the Chillesford Beds at Chillesford Church Pit, which at that time were ascribed to the Pastonian Stage (Turner, 1973), the early Thames gravels were placed by Rose *et al.* (1976) and Rose and Allen (1977) in the subsequent cold stage, the Beestonian, and the palaeosol, its age constrained by the overlying Anglian glacial sediments, in the Cromerian Stage.

It is clear that intensely cold conditions prevailed following the formation of the Valley Farm Soil, even before the deposition of the Lowestoft Till; at many localities, including the GCR site at Newney Green, a periglacial soil is superimposed on the earlier warm-climate one. This periglacial soil, termed the Barham Soil, was recognized from both large- and small-scale structures related to frost activity; the larger structures include involutions and ice-wedge casts, whereas the smaller ones include disrupted clay skins and fractured gravel clasts (Rose *et al.*, 1976, 1985a; Rose and Allen, 1977). As well as being developed in the upper parts of the Kesgrave Group gravels (incorporating the earlier Valley Farm Soil), the Barham Soil has been shown to have developed in Cromerian interglacial sediments in north Norfolk. In such cases, where overlain by Anglian Stage tills, this soil has been established as a 'soil stratigraphic unit' of early Anglian age (Rose *et al.*, 1985a). Without these overlying deposits, in areas where Kesgrave Group gravels form the present land surface, it is possible to identify relict features of both the Barham and Valley Farm Soils (Rose *et al.*, 1976, 1985a, 1985b; Rose and Allen, 1977; Kemp, 1985a). However, later temperate-climate soils have been developed in the top of the Lowestoft Till (Rose *et al.*, 1978; Sturdy *et al.*, 1978) and cryoturbation has probably occurred during several cold episodes since the Anglian glaciation, so the recognition of pedogenic features characteristic of the Valley Farm and Barham Soils is of equivocal stratigraphical value beyond the glaciated area. Loess and coversand have also been recorded between the Kesgrave Sands and Gravels and the Lowestoft Till (Rose *et al.*, 1976, 1985a; Rose and Allen, 1977). These sediments, ascribed to the Anglian Stage, are frequently incorporated in the large-scale cryoturbation structures of the Barham Soil.

The recognition of a widespread Cromerian soil developed on the early Thames deposits of central and northern Essex led Rose *et al.* (1976) to suggest that the river had migrated to a more southerly route by that stage. However, subsequent work in the Vale of St Albans (Gibbard, 1974, 1977, 1978a; Green and McGregor, 1978a, 1978b; Chapter 3) and in eastern Essex (Bridgland, 1980, 1983a, 1983b, 1988a; Part 2 of this chapter) has indicated that the Thames was not diverted from its early course through Hertfordshire and central Essex until the Anglian glacial maximum. A possible explanation for this apparent contradiction is that the palaeosol seen beneath the Lowestoft Till in many gravel pits in southern East Anglia was formed on the terraces of the pre-glacial Thames valley, whereas the valley floor and channel occupied by the river immediately prior to its diversion, in the centre of the Mid-Essex Depression of Wooldridge and Henderson (1955), is deeply buried by Lowestoft Till and not exposed. In the unglaciated area east of Colchester, the lowest formation within the Low-level Kesgrave Subgroup has been ascribed to the Anglian Stage (Bridgland, 1980, 1983a, 1988a; Bridgland *et al.*, 1988, 1990). The Valley Farm Soil is not developed on this formation (see below, St Osyth and Holland-on-Sea).

Study of the clast composition of the Kesgrave Sands and Gravels reveals important minor components of value as provenance indicators. The gravels generally contain 0.5–2% sponge-spicular chert derived from the Lower Greensand of Kent and Surrey (Bridgland, 1980, 1986b; Green *et al.*, 1982). Carboniferous chert, for which there are a number of potential sources to the north and west, all of them outside the London Basin (Bridgland, 1986b), typically accounts for 1–2% of the total gravel content (Bridgland *et al.*, 1990). Also important is a restricted suite of volcanic rocks, some of which have been tentatively traced to sources in North Wales (Hey and Brenchley, 1977; Whiteman, 1983). The abundant quartz and quartzite (up to 35%) must also have been derived from outside the London Basin, the Midlands and Welsh borderlands representing the most likely source areas (Bridgland, 1986b). As was recognized by Rose *et al.* (1976), these various non-flint components are, when found in gravels in the London Basin, indicative of a Thames origin. A similar assemblage of component rocks has been recognized in the early terrace gravels of the Middle Thames (Green and McGregor, 1978a; McGregor and Green, 1978; Gibbard, 1985) and in the Northern Drift of Oxfordshire, also believed to represent early Thames aggradations (Hey, 1986; Chapter 2). Whether these rock-types were introduced into the Thames system by glaciation(s), by fluvial transport in a more extensive catchment or by a combination of the two remains a subject of controversy (Bowen *et al.*, 1986a; Bridgland, 1986b, 1988c; Hey, 1986; Whiteman, 1990; see Chapter 1).

Rose *et al.* (1976) and Rose and Allen (1977) recognized that their Kesgrave Sands and Gravels might represent a series of terrace aggradations, but the first formal subdivision was proposed by Hey (1980), who recognized the downstream continuation of his Westland Green Gravels of the Middle Thames (Hey, 1965; Chapter 3) within the older, higher-level part of the group (Fig. 5.1). Hey's distinction of the Westland Green Gravels from other Kesgrave Group deposits was based on both altitudinal and compositional considerations, which enabled him to trace that unit to Suffolk and Norfolk. Allen (1983, 1984) has further subdivided the Kesgrave Group in Suffolk, recognizing new terrace formations immediately above and below Hey's 'Westland Green Gravels', the Baylham Common Gravel and Waldringfield Gravel respectively. The Waldringfield Gravel has also been identified in northern Essex (Bridgland, 1988a; Fig. 5.2). Later studies of the Valley Farm Soil have shown that it is more complex than previously recognized, particularly on the older and higher formations within the Kesgrave Group, where evidence for several alternating phases of temperate-climate pedogenesis and periglacial disturbance have been determined from micromorphological studies (Rose, 1983a; Kemp, 1985a; Rose *et al.*, 1985b; see below, Newney Green). A distinction, based partly on clast lithologies, between high-level and low-level divisions of the Kesgrave Sands and Gravels, was first recognized by Hey (1980) and was adopted in the Chelmsford area by Bristow (1985). These divisions are each made up of a number of component formations and are regarded here as subgroups. Similar categories to these subgroups were proposed by Gregory (1922), his High Level and Low Level Quartzite Gravels.

Recent work by Whiteman (1990) has shown that the Westland Green Gravels as recognized in Suffolk do not, in fact, correlate with the unit of the same name originally defined by Hey (1965) in Hertfordshire and the Middle Thames. By determining (largely from borehole records) the distribution of the various formations within the Kesgrave Group in Essex and Suffolk, Whiteman has demonstrated that the formation in Suffolk that has been termed Westland Green Gravels is, in fact, the downstream continuation of the Gerrards Cross Gravel of the Middle Thames (see Chapters 1 and 3). It is therefore necessary to make considerable changes to the schemes for correlating the pre-diversion gravels of the Thames valley with the formations of the Kesgrave Group that have been published in recent years (Hey, 1980; Green *et al.*, 1982; Gibbard, 1983; Green and McGregor, 1983; Bowen *et al.*, 1986a; Bridgland, 1988a).

Whiteman's work has wider repercussions than are outlined above. He was able to suggest correlations, based on altitude and variations in clast composition, between central Essex and the higher parts of the terrace sequences upstream in both the Middle and Upper Thames regions (see Chapters 3 and 2 respectively). He concluded that the earliest true Thames deposits, from the Stoke Row Gravel up to and including the Gerrards Cross Gravel, are the product of a very large river, with a catchment extending far beyond the present Upper Thames (as already envisaged by Hey (1986)). In East Anglia these formations have all been included within the High-level Kesgrave Subgroup.

The formations of the Low-level Kesgrave Subgroup, thought until recently to represent the downstream continuation of Middle Thames terrace formations between the Satwell and Winter Hill Gravels (inclusive), have been shown by Whiteman to fall entirely between the deposition of the Gerrards Cross Gravel (last of the High-level Kesgrave Subgroup formations) and

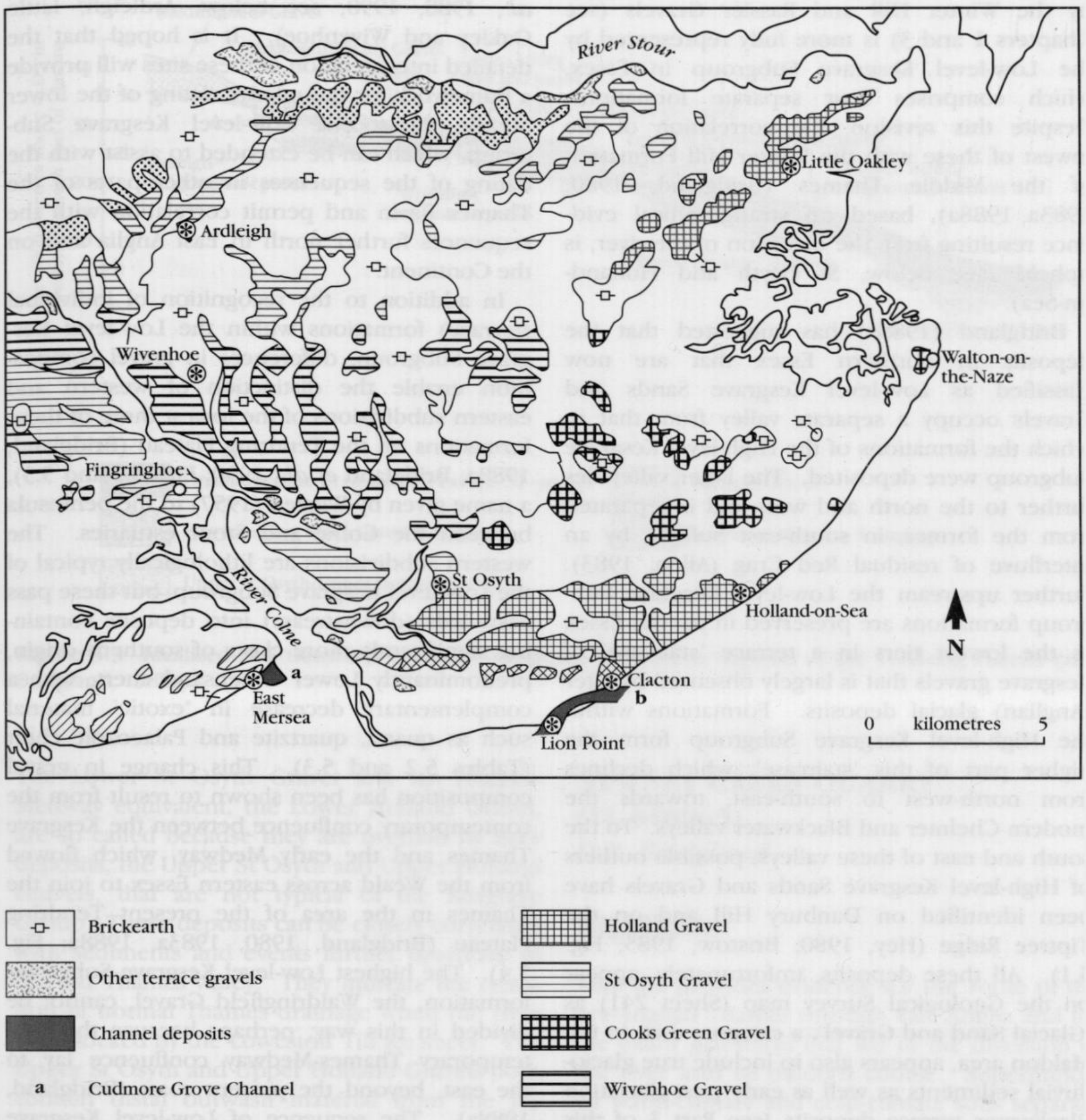


Figure 5.2 Pleistocene gravels of the Tendring Plateau (after Bridgland, 1988a).

the diversion of the river. Therefore an interval that in the Middle Thames is represented only by the Winter Hill and Rassler Gravels (see Chapters 1 and 3) is more fully represented by the Low-level Kesgrave Subgroup in Essex, which comprises four separate formations. Despite this revision, the correlation of the lowest of these with the Winter Hill Formation of the Middle Thames (Bridgland, 1980, 1983a, 1988a), based on stratigraphical evidence resulting from the diversion of the river, is upheld (see below, St Osyth and Holland-on-Sea).

Bridgland (1988a) has suggested that the deposits in northern Essex that are now classified as Low-level Kesgrave Sands and Gravels occupy a separate valley from that in which the formations of the High-level Kesgrave Subgroup were deposited. The latter valley lies further to the north and west and is separated from the former, in south-east Suffolk, by an interfluve of residual Red Crag (Allen, 1983). Further upstream the Low-level Kesgrave Subgroup formations are preserved in central Essex as the lowest tiers in a terrace 'staircase' of Kesgrave gravels that is largely obscured by later (Anglian) glacial deposits. Formations within the High-level Kesgrave Subgroup form the higher part of this 'staircase', which declines from north-west to south-east, towards the modern Chelmer and Blackwater valleys. To the south and east of these valleys, possible outliers of High-level Kesgrave Sands and Gravels have been identified on Danbury Hill and on the Tiptree Ridge (Hey, 1980; Bristow, 1985; Fig. 5.1). All these deposits, unfortunately, appear on the Geological Survey map (Sheet 241) as 'Glacial Sand and Gravel', a category that, in the Maldon area, appears also to include true glaciofluvial sediments as well as early post-glaciation Blackwater terrace deposits (see Part 3 of this Chapter, Maldon). Furthermore, the high-level outliers at Danbury and Tiptree have been thought to be affected by glaciotectonic processes at the edge of the ice sheet that filled the old Thames valley (Clayton, 1957; Hey, 1980; Bristow, 1985), which raises the possibility that they might have been substantially disturbed, elevated or even transported for some distance by the ice.

Important information about the age and stratigraphy of the Low-level Kesgrave Sands and Gravels has been gained in recent years from the discovery, at a number of sites in Essex, of interglacial sediments interbedded with these early Thames gravels (Bridgland, 1988a; Bridgland *et al.*, 1988, 1990; see below, Ardleigh, Little Oakley and Wivenhoe). It is hoped that the detailed interpretation of these sites will provide a framework for the relative dating of the lower Middle Pleistocene Low-level Kesgrave Subgroup, which can be extended to assist with the dating of the sequences in other parts of the Thames Basin and permit correlation with the sequences further north in East Anglia and on the Continent.

In addition to the recognition of individual (terrace) formations within the Low-level Kesgrave Subgroup, differences in gravel composition enable the distinction of western and eastern subdivisions of the lowest three of these formations on the Tendring Plateau (Bridgland, 1988a; Bridgland *et al.*, 1990; Figs 5.2 and 5.3), a name given by Warren (1957) to the peninsula between the Colne and Stour estuaries. The western subdivisions are lithologically typical of the Low-level Kesgrave Subgroup, but these pass eastwards (downstream) into deposits containing significantly more clasts of southern origin, predominantly Lower Greensand chert, with a complementary decrease in 'exotic' material such as quartz, quartzite and Palaeozoic chert (Tables 5.2 and 5.3). This change in gravel composition has been shown to result from the contemporary confluence between the Kesgrave Thames and the early Medway, which flowed from the Weald across eastern Essex to join the Thames in the area of the present Tendring Plateau (Bridgland, 1980, 1983a, 1988a; Fig. 5.4). The highest Low-level Kesgrave Subgroup formation, the Waldringfield Gravel, cannot be divided in this way, perhaps because the contemporary Thames-Medway confluence lay to the east, beyond the present coast (Bridgland, 1988a). The sequence of Low-level Kesgrave Subgroup formations on the Tendring Plateau is therefore as follows (Figs 5.2 and 5.3 and Table 5.3:

West (Thames)	**East (Thames-Medway)**
Waldringfield Gravel	
Ardleigh Gravel	Oakley Gravel
Wivenhoe Gravel	Cooks Green Gravel
Lower St Osyth Gravel	Lower Holland Gravel

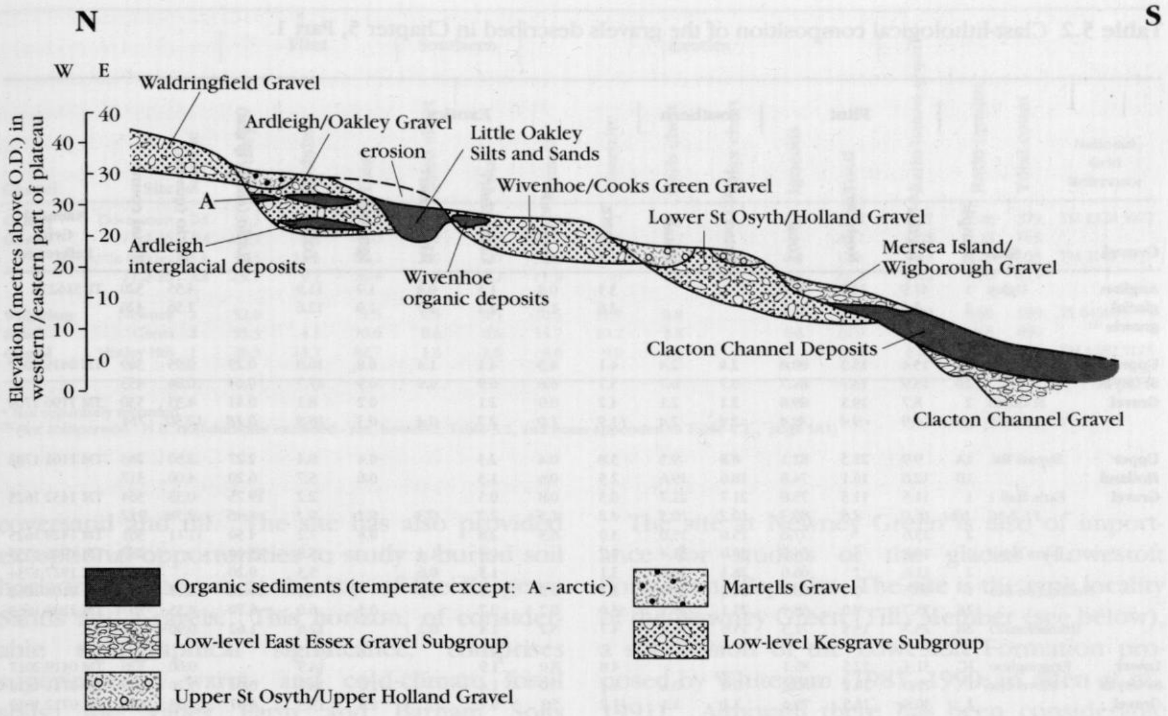


Figure 5.3 Idealized N–S transverse section through the Pleistocene deposits of the Tendring Plateau (after Bridgland, 1988a).

The Lower St Osyth Gravel and its Thames-Medway equivalent, the Lower Holland Gravel, are so called because they are overlain by later deposits, the Upper St Osyth and Upper Holland Gravels, that are not typical of the Kesgrave Group. These deposits can be closely correlated with sediments and events further upstream in the old Thames valley. They indicate the cessation of normal Thames drainage when the river was blocked by the Lowestoft Till ice sheet. The Upper St Osyth and Upper Holland Gravels both contain distal outwash material from the ice sheet, but as the Medway valley was unglaciated, the latter river made a significant and uninterrupted contribution to the Upper Holland Gravel (Bridgland, 1983a, 1988a; Fig. 5.4F; see St Osyth and Holland-on-Sea). The newly diverted Thames adopted its modern valley through London, from which it joined the former Medway valley across eastern Essex (Bridgland, 1980, 1983a, 1983b, 1988a). The deposits of this newly diverted Thames are represented on the Tendring Plateau as part of the Low-level East Essex Gravel Subgroup (Fig. 5.5A and 5.5B; see Part 2 of this chapter, especially Clacton-on-Sea).

NEWNEY GREEN QUARRY (TL 648065)

D.R. Bridgland

Highlights

This site provides evidence for the route of the pre-Anglian Thames through East Anglia and for the major glaciation that led to the diversion of the river into its modern course. Superimposed warm-climate and cold-climate soils separate Thames gravels and Anglian till at Newney Green and represent an important element of the regional stratigraphy.

Introduction

Newney Green Quarry is a key site that has been used to establish the lower Middle Pleistocene succession of the Chelmsford area (Rose *et al.*, 1976, 1978). This sequence comprises fluvial deposits, part of the Kesgrave Group, overlain by various products of glaciation during the Anglian Stage, including outwash gravel,

Table 5.2 Clast-lithological composition of the gravels described in Chapter 5, Part 1.

Gravel	Site	Sample	Flint: Tertiary	Flint: Nodular	Flint: Total	Southern: Gnsd chert	Southern: Total	Exotics: Quartz	Exotics: Quartzite	Exotics: Carb chert	Exotics: Rhax chert	Exotics: Igneous	Exotics: Total	Ratio (sthrn:qtz)	Ratio (qtz:qtzt)	Total count	National Grid Reference
Anglian	Ugley	1	41.9	23.7	87.9			3.5	0.8	1.5	0.4	1.9	11.9		4.55	520	TL 516278
glacial		2	3.6	37.6	87.1			2.6	1.7	2.1	1.7	1.9	12.6		1.56	420	
gravels (1)																	
Upper	Fingringhoe	1A	15.4	13.0	80.8	2.4	2.4	4.1	4.3	4.1	1.4	0.8	16.8	0.29	0.95	369	TM 0419 2017
St Osyth		1B	15.9	13.7	81.7	0.7	0.7	5.7	6.8	0.9	0.9	0.9	17.7	0.05	0.84	453	
Gravel	St Osyth	2	8.7	19.1	89.8	2.1	2.1	4.2	0.9	2.1		0.2	8.1	0.41	4.35	530	TM 1196 1704
	11.2-16	*2(b)*	*14.9*	*9.4*	*78.4*	*2.4*	*2.4*	*11.9*	*1.0*	*2.7*	*0.4*	*0.3*	*18.8*	*0.18*	*12.50*	*714*	
Upper	Bypass Rd.	1A	9.9	21.3	82.1	8.8	9.5	3.8	0.4	2.3		0.4	8.4	2.27	2.50	263	TM 1161 1703
Holland		1B	12.6	16.1	74.8	18.6	19.6	2.5	0.6	1.3		0.6	5.7	6.20	4.00	317	
Gravel	Earls Hall 1	1	11.5	11.3	75.8	21.7	21.7	0.3	0.8	0.5			2.2	19.75	0.33	364	TM 1432 1625
	11.2-16	*1(b)*	*16.0*	*8.8*	*80.3*	*10.2*	*10.5*	*4.2*	*1.5*	*2.7*	*0.3*	*0.1*	*9.1*	*1.86*	*2.78*	*932*	
		2	13.6	•	77.6	15.0	15.0	3.0	0.3	2.8		0.8	7.2	4.50	11.11	361	TM 1429 1625
	Burrs Road	1	10.8	•	64.8	30.0	31.4	0.7		1.4	1.4		3.8	45.00		287	TM 1926 1735
		2	11.6	•	66.0	28.4	28.8	3.1		1.3	0.6		5.3	9.20		320	TM 1927 1734
	Holland-on-Sea	1	15.5	9.7	70.7	24.5	24.7	2.2	0.2	1.0	0.5		4.6	10.20	11.11	413	TM 2108 1662
		2A	15.7	9.0	68.9	25.1	25.1	3.0	0.7	0.7		0.3	6.0	6.70	4.35	267	TM 2109 1663
	(transitional?)	2B	23.7	13.5	71.3	15.6	16.1	4.7	5.2	1.4	0.2		12.6	1.62	0.90	422	
Lower	Fingringhoe	1C	31.4	12.5	85.1			4.8	8.0	1.9			14.9		0.60	376	TM 0419 2017
St Osyth	Moverons	1	29.0	16.0	80.8	0.6	0.6	8.4	7.0	1.4		1.0	18.3	0.04	1.20	929	TM 0711 1818
Gravel		2	30.8	16.5	79.6	1.1	1.1	11.2	5.3	0.7		0.5	19.3	0.07	2.13	1031	TM 0712 1819
	11.2-16	*2*	*32.3*	*5.9*	*73.5*	*1.6*	*1.7*	*14.2*	*7.6*	*1.7*		*0.8*	*24.7*	*0.08*	*1.89*	*1330*	
		3	31.8	13.1	77.5	0.6	0.7	11.4	7.8	1.3		0.7	21.7	0.04	1.47	994	TM 0699 1825
	St Osyth	1A	35.4	•	77.1	0.5	0.5	11.1	7.7	1.8		0.2	22.4	0.03	1.45	559	TM 1161 1704
		1B	30.6	•	79.8	1.5	1.6	10.4	4.9	1.3		0.7	18.6	0.10	2.13	748	
	11.2-16	*1B*	*30.1*	*7.7*	*78.0*	*1.7*	*1.7*	*12.5*	*4.8*	*2.0*		*0.5*	*20.2*	*0.10*	*2.63*	*1325*	
Lower	St Osyth	3	31.6	16.8	83.1	1.4	1.4	10.3	2.7	1.6		0.5	15.3	0.11	3.29	561	TM 1201 1703
Holland		5	21.8	10.8	80.0	4.6	4.9	5.8	6.8	1.8		0.3	15.1	0.39	0.85	325	TM 1213 1665
Gravel		6	29.5	16.0	81.2	2.2	2.5	8.8	5.3	1.3			16.0	0.18	1.67	319	TM 1225 1688
	Bush Paddock	1	43.3	10.5	83.9	4.8	5.1	5.9	3.7	0.8		0.3	11.0	0.53	1.59	647	TM 1357 1611
	11.2-16	*1*	*40.8*	*5.7*	*75.6*	*10.5*	*10.8*	*9.2*	*2.4*	*0.8*	*0.1*	*0.2*	*13.6*	*0.79*	*3.85*	*1215*	
	Holland-on-Sea	2C	32.8	11.9	80.6	2.2	2.2	8.0	7.5	1.0		0.2	17.2	0.14	1.06	412	TM 2109 1663
		2D	26.7	13.9	81.5	1.8	1.8	9.2	5.6	1.1		0.3	16.5	0.12	1.64	655	
	Holland Haven	1A	24.9	•	84.0	2.4	2.9	7.3	3.7	1.6	0.3	0.3	13.1	0.26	1.96	382	TM 2208 1744
		1B	34.6	14.6	83.1	2.3	3.1	9.6	4.6	0.4			13.9	0.24	2.08	260	
		2	25.3	•	82.2	2.8	3.0	8.4	3.9	1.7	0.2	0.2	14.8	0.24	2.17	534	TM 2205 1743
	11.2-16	*2*	*31.4*	*7.2*	*76.8*	*5.2*	*5.2*	*12.4*	*2.2*	*1.4*	*0.2*	*0.9*	*18.0*	*0.36*	*5.64*	*939*	
	Clacton cliffs	4C	33.9	15.2	81.3	8.5	9.0	3.2	4.4	1.2	0.7		9.7	1.18	0.72	433	TM 1739 1433
		4D	38.7	12.6	81.5	5.3	5.6	6.4	2.8	2.0		0.3	12.9	0.61	2.27	357	
	11.2-16	*4D*	*39.9*	*6.6*	*78.7*	*10.2*	*10.4*	*5.5*	*3.6*	*1.2*	*0.4*		*10.8*	*1.15*	*1.52*	*804*	
Wivenhoe	Wivenhoe	1B	25.1	17.8	80.1	0.8	0.8	5.4	9.7	2.7		0.3	18.3	0.05	0.56	371	TM 0494 2330
Gravel	(Wiv.U.Gr.)	2A	30.4	14.7	74.6	0.4	0.7	12.4	9.5	1.4		0.4	24.7	0.03	1.31	283	TM 0495 2358
	Arlesford	1	36.0	8.1	73.6	0.4	0.4	14.2	8.1	2.6		0.7	26.0	0.02	1.75	458	TM 0711 2192
	11.2-16	*1*	*31.1*	*4.7*	*66.1*	*1.4*	*1.4*	*17.7*	*10.6*	*2.1*		*1.1*	*32.4*	*0.05*	*1.67*	*716*	
		2	21.5	16.9	82.6	0.9	0.9	7.3	7.0	1.5		0.6	16.6	0.06	1.04	344	TM 0711 2192
Cooks	Cooks Grn	1A	21.3	•	83.8	3.2	3.2	7.2	3.5	1.0		0.5	13.0	0.30	2.04	625	TM 1889 1856
Green		1B	27.2	14.4	84.2	2.0	2.0	8.3	2.2	2.8			13.8	0.19	3.70	492	
Gravel	*11.2-16*	*1B*	*26.9*	*7.1*	*72.6*	*3.7*	*3.7*	*16.4*	*4.7*	*1.2*		*0.3*	*23.7*	*0.17*	*3.45*	*1205*	
		2	29.4	12.7	83.0	3.3	3.3	8.1	4.1	0.3		0.3	13.5	0.27	1.96	394	TM 1898 1840
	Gt Holland	1	25.5	19.1	84.0	1.7	1.7	8.4	6.0	0.7			16.0	0.12	1.41	419	TM 2112 1892
	11.2-16	*1*	*25.9*	*8.6*	*80.3*	*3.1*	*3.2*	*8.9*	*5.5*	*1.8*	*0.1*	*0.2*	*16.5*	*0.22*	*1.61*	*1289*	
Little	L Oakley	AB	33.6	12.6	87.4	0.8	0.8	4.2	5.9	1.7			11.8	0.08	0.71	119	TM 2233 2952
Oakley	*11.2-16*	*AB*	*26.4*	*7.2*	*72.9*	*2.0*	*2.0*	*11.2*	*9.8*	*2.0*			*24.8*	*0.09*	*1.14*	*295*	
Silts and	AC	33.7	16.7	83.7	0.4	0.4	9.5	4.8	0.4			0.4	15.9	0.03	1.96	252	TM 2223 2951
Sands	*11.2-16*	*AC*	*29.7*	*8.5*	*73.1*	*1.6*	*1.6*	*13.2*	*9.1*	*1.2*	*0.1*	*0.6*	*25.2*	*0.07*	*1.45*	*674*	
		AF	26.0	14.3	80.3	1.8	1.8	9.4	6.3	1.3			17.9	0.11	1.49	223	TM 2233 2946
	11.2-16	*AF*	*28.8*	*6.4*	*70.8*	*2.2*	*2.3*	*15.3*	*6.9*	*3.8*		*0.6*	*26.9*	*0.11*	*2.23*	*640*	
Martells	Ardleigh	3	20.5	14.1	76.6	1.6	1.6	10.4	8.2	1.4	0.2	0.8	21.9	0.08	1.26	512	TM 0515 2800
Gravel		4C	19.3	13.2	76.7	0.7	0.7	11.7	7.3	2.5	0.2	0.5	22.6	0.03	1.61	605	TM 0519 2807
	11.2-16	*4C*	*26.2*	*6.5*	*72.5*	*1.0*	*1.2*	*14.3*	*7.6*	*2.7*	*0.3*	*1.0*	*21.8*	*0.05*	*1.89*	*596*	
Ardleigh	Ardleigh	1	26.8	15.4	75.6	0.7	0.7	11.9	7.5	0.8		1.5	23.6	0.04	1.58	590	TM 0536 2802
Gravel	*11.2-16*	*1*	*27.1*	*7.7*	*72.3*	*1.3*	*1.7*	*15.4*	*7.3*	*2.2*		*0.2*	*25.9*	*0.07*	*2.13*	*1008*	
		2	23.7	19.2	80.0	1.3	1.5	9.3	5.4	2.0			17.7	0.10	1.72	615	TM 0533 2805
	11.2-16	*2*	*29.0*	*6.4*	*69.9*	*0.7*	*1.0*	*14.9*	*9.5*	*3.0*		*0.7*	*29.1*	*0.04*	*1.57*	*1219*	
		4B	29.3	13.0	75.4	1.3	1.3	9.8	9.4	1.1		1.1	23.0	0.07	1.04	447	TM 0519 2807
	(Ardleigh L.Gr.)	4A	33.3	12.7	72.0	0.4	0.4	11.4	13.9	1.1		0.9	27.5	0.01	0.82	553	

Gravel	Site	Sample	Flint: Tertiary	Flint: Nodular	Flint: Total	Southern: Gnsd chert	Southern: Total	Exotics: Quartz	Exotics: Quartzite	Exotics: Carb chert	Exotics: Rhax chert	Exotics: Igneous	Exotics: Total	Ratio (sthrn: q/qtzt)	Ratio (qtz:qtzt)	Total count	National Grid Reference
Oakley	Dovercourt	DA	30.3	12.1	79.2	2.1	2.4	9.8	4.7	1.6		1.1	18.5	0.17	2.08	379	TM 2328 3027
Gravel	*11.2-16*	*DA*	*25.3*	*8.3*	*75.0*	*4.7*	*4.9*	*11.7*	*5.5*	*1.7*			*20.1*	*0.28*	*2.13*	*783*	
	Little Oakley	KA	30.3	15.5	80.2	2.0	2.0	8.6	7.2	0.6	0.2	0.3	17.8	0.13	1.19	653	TM 2191 2947
	11.2-16	*KA*	*25.7*	*9.1*	*76.4*	*2.1*	*2.2*	*11.9*	*7.0*	*1.9*	*0.2*	*0.3*	*21.3*	*0.12*	*1.70*	*673*	
Waldring-	Newney	1	52.9	*	72.5	0.5	0.5	10.5	11.7	0.8		1.2	26.5	0.02	0.90	599	TL 645064
field	Green	2	55.3	4.1	70.6	0.6	0.6	14.7	10.2	0.8		0.6	24.9	0.02	1.45	490	
Gravel	Mistley Hth	1	26.3	13.7	82.7	1.6	1.6	9.6	9.0	1.6			15.6	0.09	1.06	365	TM 1282 3125

*** Not separately recorded**
(1) (for comparison. N.B. non-durables excluded - see, however, Table 3.1, and notes appended to Table 4.2., page 181)

coversand and till. The site has also provided exceptional opportunities to study a buried soil horizon that occurs at the top of the Kesgrave Sands and Gravels. This horizon, of considerable stratigraphical significance, comprises superimposed warm- and cold-climate fossil soils, the Valley Farm and Barham Soils respectively (Rose *et al.*, 1976, 1985a, 1985b; Rose and Allen, 1977; Kemp, 1985a).

The site at Newney Green is also of importance for studies of the glacial (Lowestoft Formation) deposits. The site is the type locality of the Newney Green (Till) Member (see below), a subdivision of the Lowestoft Formation proposed by Whiteman (1987, 1990; in Allen *et al.*, 1991). Although there has been considerable work on the palaeosols and till at Newney Green, the regional stratigraphical relations of

Table 5.3 Correlation of gravel formations in Essex within the Kesgrave Group with deposits in other areas.

See Chapter 3, Part 2		**Tendring Plateau**		**South of Blackwater**		
Middle Thames	**Vale of St Albans**	**Low-level Kesgrave Thames**	**Low-level Kesgrave Thames - Medway**	**High-level East Essex Gravel Medway**	**Climate**	**Stage**
Winter Hill U.Gr.	Moor Mill Clay	Upper St Osyth Gr.[1]	Upper Holland Gr.[1]	Chalkwell/Caidge Gr.	Glacial	Anglian[2]
Winter Hill L.Gr.	Westmill L.Gravel	Lower St Osyth Gr.	Lower Holland Gr.	Chalkwell/Caidge Gr.	Periglacial	early Anglian
No equivalent formations recognized in the area upstream from Essex, with the possible exception of the Rassler Gravel of the Reading area (see Chapter 1 and Fig. 1.3)		—Rejuvenation event—				
		Wivenhoe Formation { Wiv.U.Gr. / intgl.seds / Wiv.L.Gr.	Cooks Green Gravel	Canewdon/St Lawr.Gr.	Periglacial / Temperate / Periglacial	
		—Rejuvenation event—				
		Ardleigh Formation { Ard.U.Gr. / intgl.seds / Ard.L.Gr.	? / L.Oakley Slts & Sds[3] / Oakley Gravel	Belfairs/Mayland Gr.	Periglacial / Temperate / Periglacial / Temperate / Periglacial	'Cromerian Complex'
		—Rejuvenation event—				
		Waldringfield Gr.	None recognized	Ashingdon Gravel?	Periglacial	

1 Not part of the Kesgrave Group (deposited while the Thames was blocked).
2 Anglian glacial maximum.
3 The Little Oakley Silts and Sands may date from the same temperate episode as the Ardleigh interglacial deposits.

the underlying Kesgrave Group gravels have been largely overlooked. This same situation exists throughout central Essex, where the various formations of the Low-level Kesgrave Subgroup are largely buried by Anglian Stage glacial deposits, precluding a regional synthesis using normal mapping techniques. A recent evaluation of borehole data (Whiteman, 1990) promises, however, to resolve this problem.

Description

Sections at Newney Green have varied considerably over the 15 years of the quarry's life. In particular, the till sequence is missing in lower areas, where it has been removed by post-Anglian erosion. The stratigraphical sequence is set out in Table 5.4 (see also Fig. 5.6).

The Kesgrave Sands and Gravels (1) are represented by the lowest and most extensive Pleistocene unit present at Newney Green. This comprises predominantly cross-stratified sands and gravels with foreset orientations indicating an eastward palaeocurrent direction (Rose *et al.*, 1978). The sedimentary characteristics of this deposit point to deposition by a braided river (Rose *et al.*, 1976). It has a gravel composition typical of the Kesgrave Group, with conspicuous cobble-sized clasts of volcanic rocks of the type attributed by Hey and Brenchley (1977) to sources in North Wales.

The Valley Farm Soil is well-developed at the top of the fluvial deposits, except in areas where the till has a strongly erosive base and directly overlies the lower parts of the Kesgrave gravels. This soil is apparent as a clay-rich, reddened horizon, with patches of grey mottling. This represents the illuvial horizon of an argillic soil, the formation of which required a temperate climate. The higher layers of this soil were presumably removed by erosion prior to the deposition of the overlying sediments. Other indications of clay illuviation in this temperate

Table 5.4 The Pleistocene sequence at Newney Green (after Rose *et al.*, 1978; Whiteman, 1990; see also Fig. 5.6).

			Thickness
6. Glaciofluvial gravel with laminated sand and silts			0–2.5 m
5. Lowestoft Till Formation	Great Waltham Member	5d Decalcified till	up to 3.75 m
		5c Chalk-rich till	
	Newney Green Member	5b Brown sandy till, rich in material reworked from the underlying deposits	
		5a Deformation till: comprises remobilized palaeosol and coversand, attenuated into laminae	
4. Glaciofluvial gravels (Barham Sands and Gravels)			0–1.5 m
3. Coversand and, rarely, loess. Both in localized lenses or, more commonly, in involutions within 2			0–1.0 m
2. Complex buried soil horizon (Valley Farm and Barham Soils)			0–1.0 m
1. Kesgrave Sands and Gravels (Waldringfield Formation?)			up to 3.4 m
London Clay			

soil are the presence of clay skins around gravel clasts and clay infillings of voids. The red coloration comes from haematite, the formation of which is evidence of a warm temperate environment with high seasonality (J. Rose, pers. comm.). Whiteman (1990) recognized five separate horizons within this soil in part of the Newney Green Pit, but these appeared to be primarily of sedimentary origin, reflecting original differences in parent lithologies.

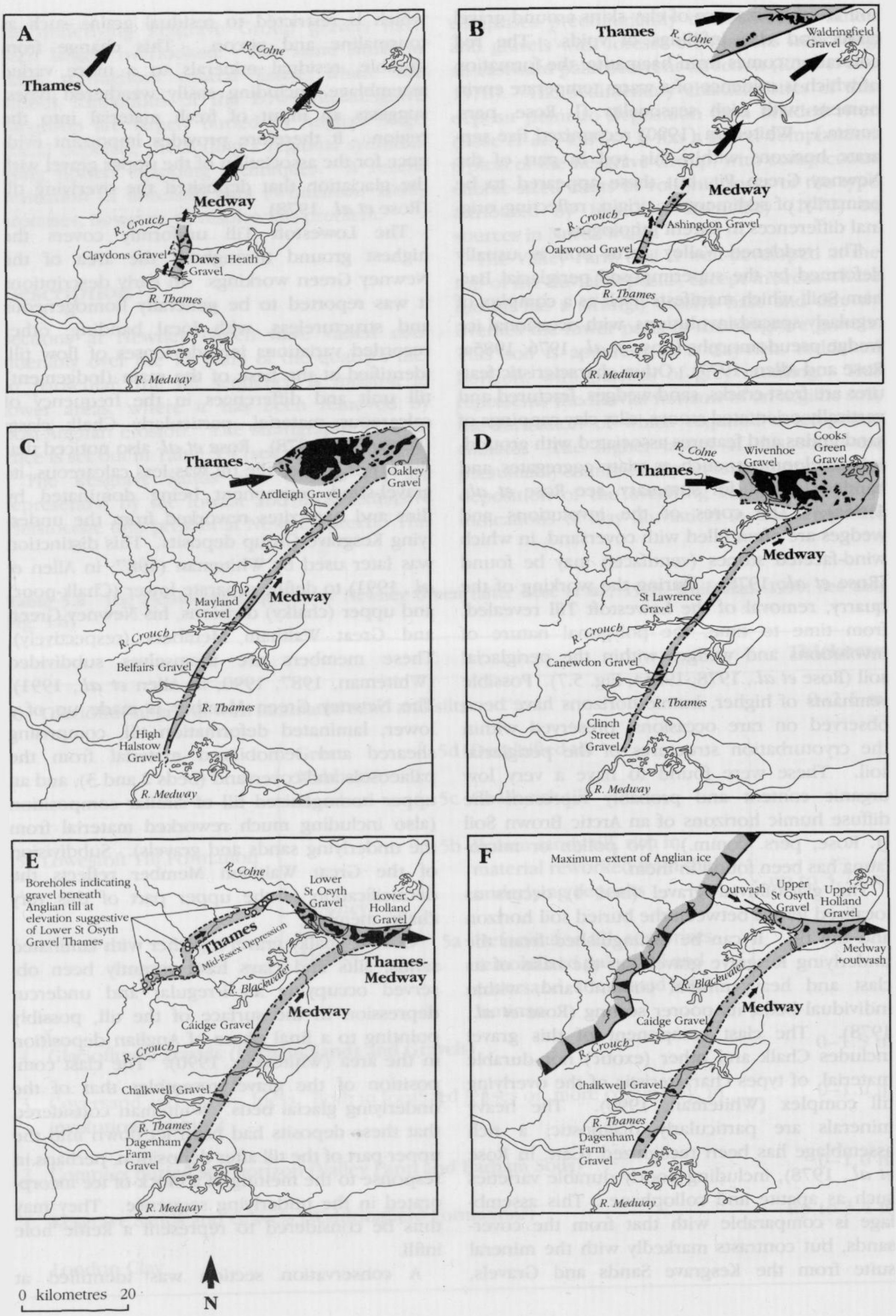
The reddened Valley Farm Soil is usually deformed by the superimposed periglacial Barham Soil, which manifests itself as a complex of regularly spaced involutions, with occasional ice wedge pseudomorphs (Rose *et al.*, 1976, 1985a; Rose and Allen, 1977). Other characteristic features are frost-cracks, sand-wedges, fractured and vertically orientated stones, silty-clay cappings of sand grains and features associated with ground-ice development, such as platy aggregates and banded fabrics (for summary, see Rose *et al.*, 1985a). The cores of the involutions and wedges are often filled with coversand, in which wind-faceted stones (ventifacts) may be found (Rose *et al.*, 1978). During the working of the quarry, removal of the Lowestoft Till revealed, from time to time, the polygonal nature of involutions and wedges within the periglacial soil (Rose *et al.*, 1978, 1985a; Fig. 5.7). Possible remnants of higher, humic horizons have been observed on rare occasions, preserved within the cryoturbation structures of the periglacial soil. These were found to have a very low organic content and probably represent the diffuse humic horizons of an Arctic Brown Soil (J. Rose, pers. comm.). No pollen or microfauna has been found in them.

The glaciofluvial gravel (bed 4) occurs as localized lenses between the buried soil horizon and the till. It can be distinguished from the underlying Kesgrave gravels on the basis of its clast and heavy-mineral content and, within individual beds, its poorer sorting (Rose *et al.*, 1978). The clast component of this gravel includes Chalk and other (exotic) non-durable material, of types characteristic of the overlying till complex (Whiteman, 1990). The heavy minerals are particularly diagnostic; a rich assemblage has been recognized (Catt, in Rose *et al.*, 1978), including poorly durable varieties such as apatite and collophane. This assemblage is comparable with that from the coversands, but contrasts markedly with the mineral suite from the Kesgrave Sands and Gravels, which is restricted to residual grains such as tourmaline and zircon. This change from durable, residual minerals to a more varied assemblage, including easily weathered types, suggests an input of fresh material into the region. It therefore provides important evidence for the association of the upper gravel with the glaciation that deposited the overlying till (Rose *et al.*, 1978).

The Lowestoft Till uniformly covers the highest ground throughout the area of the Newney Green workings. In early descriptions it was reported to be generally homogeneous and structureless, with local banding; other recorded variations include lenses of flow till, identified at the base of the main (lodgement) till unit and differences in the frequency of calcareous material, particularly Chalk clasts (Rose *et al.*, 1978). Rose *et al.* also noticed that the lower part of the till was less calcareous, its gravel-sized component being dominated by flint and quartzites reworked from the underlying Kesgrave Group deposits. This distinction was later used by Whiteman (1987; in Allen *et al.*, 1991) to define separate lower (Chalk-poor) and upper (chalky) divisions, his Newney Green and Great Waltham Members (respectively). These members are themselves subdivided (Whiteman, 1987, 1990; in Allen *et al.*, 1991). The Newney Green Member is made up of a lower, laminated deformation till, comprising sheared and remobilized material from the palaeosols and coversand (beds 2 and 3), and an upper homogenized till of similar composition (also including much reworked material from the underlying sands and gravels). Subdivision of the Great Waltham Member reflects the decalcification of the upper part of this very chalky member.

Coarse, chalky gravel together with laminated sands, silts and clays have recently been observed occupying an irregular and undercut depression in the surface of the till, possibly pointing to a final phase of Anglian deposition in the area (Whiteman, 1990). The clast composition of the gravel resembles that of the underlying glacial beds. Whiteman considered that these deposits had been let down into the upper part of the till after deposition, perhaps in response to the melting of a block of ice incorporated in the underlying sequence. They may thus be considered to represent a kettle hole infill.

A conservation section was identified at


A
Thames
R. Colne
Medway
R. Crouch
Claydons Gravel
Daws Heath Gravel
R. Thames
R. Medway
B
Thames
R. Colne
Waldringfield Gravel
Medway
R. Crouch
Ashingdon Gravel
Oakwood Gravel
R. Thames
R. Medway
C
Thames
Oakley Gravel
Ardleigh Gravel
Mayland Gravel
Medway
R. Crouch
Belfairs Gravel
R. Thames
High Halstow Gravel
R. Medway
D
R. Colne
Wivenhoe Gravel
Cooks Green Gravel
Thames
Medway
St Lawrence Gravel
R. Crouch
Canewdon Gravel
R. Thames
Clinch Street Gravel
R. Medway
E
Boreholes indicating gravel beneath Anglian till at elevation suggestive of Lower St Osyth Gravel Thames
R. Colne
Lower St Osyth Gravel
Lower Holland Gravel
Thames
Mid-Essex Depression
Thames-Medway
R. Blackwater
Medway
Caidge Gravel
R. Crouch
Chalkwell Gravel
R. Thames
Dagenham Farm Gravel
R. Medway
F
Maximum extent of Anglian ice
Outwash
Upper St Osyth Gravel
Upper Holland Gravel
Medway +outwash
R. Blackwater
Medway
Caidge Gravel
R. Crouch
Chalkwell Gravel
R. Thames
Dagenham Farm Gravel
R. Medway
0 kilometres 20
N

Newney Green in 1988, as commercial operations were drawing to a close. A preliminary excavation revealed that all the essential elements of the stratigraphy for which the site is important are present (Fig. 5.8). The complex palaeosol is well-developed in the northern part of the section, but is cut out by the erosive base of the glacial deposits to the south. Incorporated in the cryoturbation features of the Barham Soil are unweathered gravels and sands of presumed Kesgrave affinities, as well as reddened material from the Valley Farm Soil. A bed of grey clay is also incorporated in these structures, mottled with the red coloration of the warm-climate palaeosol. This material appears to be derived from the London Clay bedrock; it may have been redeposited in standing water, but a more likely explanation is that it was brought to its present level, prior to the cryoturbation episode, by diapirism, a phenomenon that has been observed at this site previously (Rose *et al.*, 1978; Whiteman, 1990). Whiteman (1990) noted that both London Clay and till have been injected into the lower sands and gravels by this process. An upper orange sand, probably cover-sand, is also present in the cores of involutions and, unusually, as a small undisturbed remnant above the cryoturbated palaeosol (Fig. 5.8).

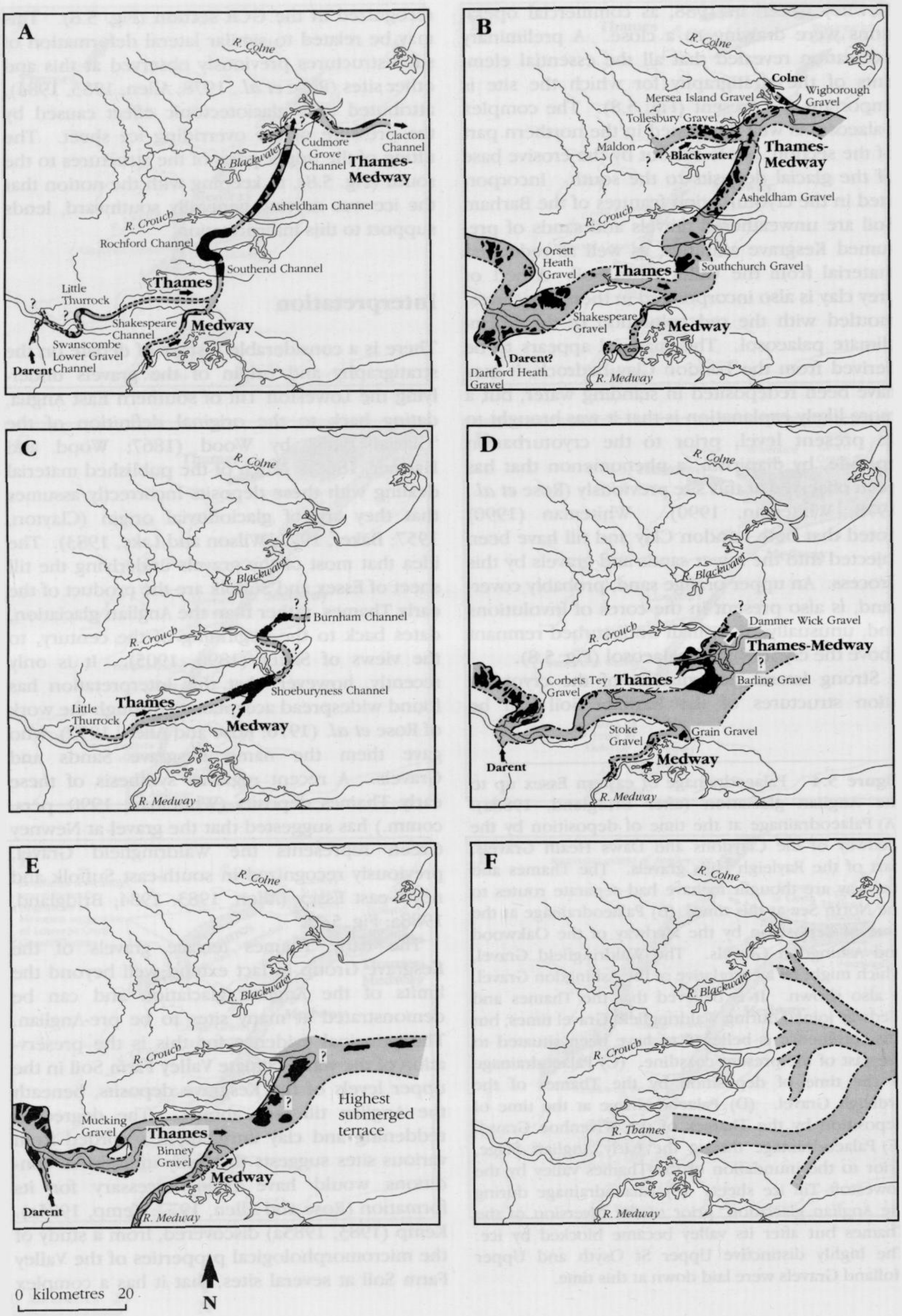
Strong lateral deformation of the cryoturbation structures of the Barham Soil can be recognized in the GCR section (Fig. 5.8). This may be related to similar lateral deformation of such structures previously observed at this and other sites (Rose *et al.*, 1978; Allen, 1983, 1984), attributed to a glaciotectonic effect caused by the pressure of the overriding ice sheet. The tilting of the upper parts of the structures to the south (Fig. 5.8), in keeping with the notion that the ice was moving generally southward, lends support to this interpretation.

Figure 5.4 Palaeodrainage of eastern Essex up to the Anglian glaciation (after Bridgland, 1988a): (A) Palaeodrainage at the time of deposition by the Medway of the Claydons and Daws Heath Gravels, part of the Rayleigh Hills gravels. The Thames and Medway are thought to have had separate routes to the North Sea at this time. (B) Palaeodrainage at the time of deposition by the Medway of the Oakwood and Ashingdon Gravels. The Waldringfield Gravel, which might be a correlative of the Ashingdon Gravel, is also shown. It is believed that the Thames and Medway joined during Waldringfield Gravel times, but this confluence is believed to have been situated to the east of the present coastline. (C) Palaeodrainage at the time of deposition by the Thames of the Ardleigh Gravel. (D) Palaeodrainage at the time of deposition by the Thames of the Wivenhoe Gravel. (E) Palaeodrainage during the early Anglian Stage, prior to the inundation of the Thames valley by the Lowestoft Till ice sheet. (F) Palaeodrainage during the Anglian glaciation, prior to the diversion of the Thames but after its valley became blocked by ice. The highly distinctive Upper St Osyth and Upper Holland Gravels were laid down at this time.

Interpretation

There is a considerable history of debate on the stratigraphy and origin of the gravels underlying the Lowestoft Till of southern East Anglia, dating back to the original definition of the 'Glacial Beds' by Wood (1867; Wood and Harmer, 1868). Much of the published material dealing with these deposits incorrectly assumes that they are of glaciofluvial origin (Clayton, 1957; Baker, 1971; Wilson and Lake, 1983). The idea that most of the gravels underlying the till sheet of Essex and Suffolk are the product of the early Thames, rather than the Anglian glaciation, dates back to the beginning of the century, to the views of Salter (1896, 1905). It is only recently, however, that this interpretation has found widespread acceptance, through the work of Rose *et al.* (1976; Rose and Allen, 1977), who gave them the name Kesgrave Sands and Gravels. A recent regional synthesis of these early Thames deposits (Whiteman, 1990, pers. comm.) has suggested that the gravel at Newney Green represents the Waldringfield Gravel, previously recognized in south-east Suffolk and north-east Essex (Allen, 1983, 1984; Bridgland, 1988a; Fig. 5.2).

The early Thames terrace gravels of the Kesgrave Group in fact extend well beyond the limits of the Anglian glaciation and can be demonstrated at many sites to be pre-Anglian. The principal evidence for this is the preservation of the warm-climate Valley Farm Soil in the upper levels of the Kesgrave deposits, beneath the Anglian till (see above). The degree of reddening and clay enrichment recorded from various sites suggests that fully interglacial conditions would have been necessary for its formation (Rose and Allen, 1977; Kemp, 1985a). Kemp (1983, 1985a) discovered, from a study of the micromorphological properties of the Valley Farm Soil at several sites, that it has a complex


A
R. Colne
Clacton Channel
Cudmore Grove Channel
R. Blackwater
Thames-Medway
Asheldham Channel
R. Crouch
Rochford Channel
Southend Channel
Little Thurrock
Thames
Shakespeare Channel
Medway
Swanscombe Lower Gravel Channel
Darent
B
R. Colne
Colne
Mersea Island Gravel
Wigborough Gravel
Tollesbury Gravel
Maldon
Blackwater
Thames-Medway
Asheldham Gravel
R. Crouch
Orsett Heath Gravel
Thames
Southchurch Gravel
Shakespeare Gravel
Medway
Darent?
Dartford Heath Gravel
R. Medway
C
R. Colne
R. Blackwater
Burnham Channel
R. Crouch
Shoeburyness Channel
Thames
Little Thurrock
Medway
R. Medway
D
R. Colne
R. Blackwater
Dammer Wick Gravel
R. Crouch
Thames-Medway
Corbets Tey Gravel
Thames
Barling Gravel
Stoke Gravel
Grain Gravel
Darent
Medway
R. Medway
E
R. Colne
R. Blackwater
R. Crouch
Highest submerged terrace
Mucking Gravel
Thames
Binney Gravel
Medway
Darent
R. Medway
F
R. Colne
R. Blackwater
R. Crouch
R. Thames
R. Medway
0 kilometres 20
N

history of formation, with alternating periods of rubification and disruption of its fabric by periglacial processes. Different degrees of complexity are found at various sites, with the greatest number of climatic cycles indicated where the soil is developed on formations of the High-level Kesgrave Subgroup. Unfortunately, it is difficult to determine the precise number of climatic fluctuations responsible for a particular soil type, but Kemp's work provided important new evidence that the stratigraphical sequence first outlined by Rose *et al.* (1976) was oversimplified. It is now accepted that the Valley Farm Soil, as recognized on different formations within the Kesgrave Group, represents different numbers of climatic cycles, reflecting the deposition of the Kesgrave Sands and Gravels over a considerable period of Pleistocene time (Rose, 1983a; Kemp, 1985a; Rose *et al.*, 1985b).

Whiteman (1990) found evidence from micromorphological analysis of the palaeosol (unit 2) at Newney Green for only a single period of illuviation, uninterrupted by any significant disturbance prior to the formation of the superimposed Barham Soil. Subsequent to the formation of the various disruption features associated with the Barham Soil, illuviation of calcium carbonate together with further clay had apparently occurred. However, Whiteman concluded that this later illuviation episode postdated the emplacement of the till, since he could envisage no potential source for the calcium carbonate other than Chalk clasts in the glacial deposits. Since illuviation appears, according to this interpretation, to have affected the palaeosol horizon after its burial beneath the till, Whiteman (1990) was forced to conclude that the thickness of till at Newney Green (maximum 3.75 m) was insufficient to isolate the fossil soil from post-Anglian pedogenic activity. His failure to recognize pre-Anglian disturbance of the soil fabric at Newney Green is difficult to reconcile with his attribution of the gravel there to the Waldringfield Formation. Stratigraphical evidence from north-eastern Essex suggests that several climatic cycles intervened between the deposition of the Waldringfield Gravel and the Anglian Stage glaciation (Bridgland, 1988a; see above, Introduction to Part 1). A possible explanation is that the upper layers of the gravel may have been stripped during pre-Anglian periglacial episodes, a process that is likely to have affected the upper surfaces of Kesgrave Group terrace formations throughout the area. Only on the most stable land surfaces would the full potential complexity of the Valley Farm Soil have been realized.

The superimposed Barham Soil represents the final modification, by periglacial processes during the early Anglian Stage, of the complex Valley Farm Soil. It was initially termed an Arctic structure soil (Rose *et al.*, 1976; Rose and Allen, 1977), but this term was subsequently found to be too restrictive, as a wider range of pedogenic properties was observed at different sites, and the Barham Soil was recognized as a complex and variable periglacial soil (Rose *et al.*, 1985a, 1985b). When it is developed on the complex Valley Farm Soil, it may be difficult or impossible to distinguish certain of the features of the Barham Soil, such as the fracturing of clasts and the break up of clay skins (Rose *et al.*, 1985a),

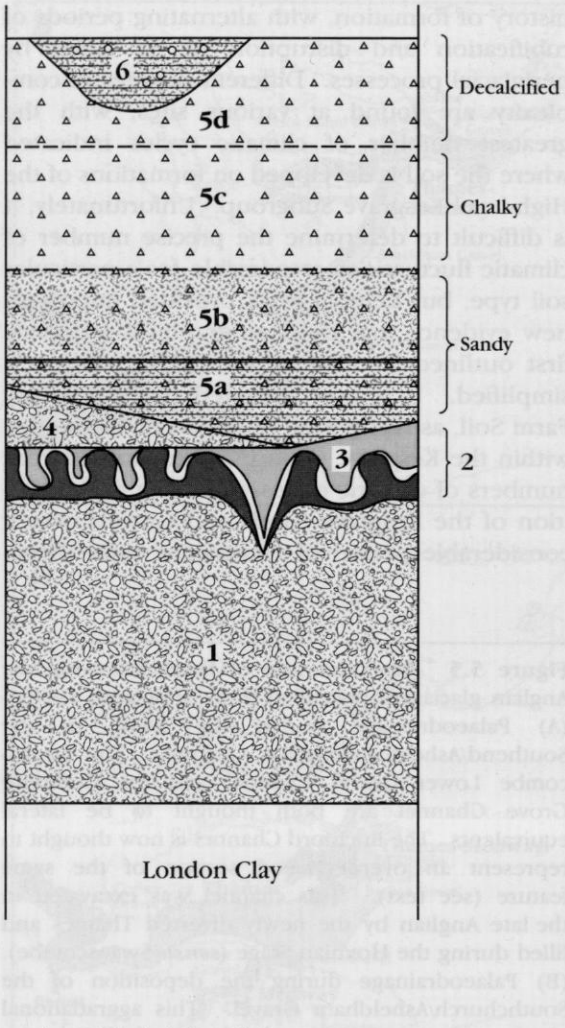
Figure 5.5 Palaeodrainage of Essex following the Anglian glaciation (modified from Bridgland, 1988a). (A) Palaeodrainage during the filling of the Southend/Asheldham/Clacton Channel. The Swanscombe Lower Gravel Channel and the Cudmore Grove Channel are both thought to be lateral equivalents. The Rochford Channel is now thought to represent an overdeepened section of the same feature (see text). This channel was excavated in the late Anglian by the newly diverted Thames and filled during the Hoxnian Stage (*sensu* Swanscombe). (B) Palaeodrainage during the deposition of the Southchurch/Asheldham Gravel.. This aggradational phase is believed to have culminated during the earliest part of the Saalian Stage, early in Oxygen Isotope Stage 10. (C) Palaeodrainage during the filling of the Shoeburyness Channel. The channel beneath the Corbets Tey Gravel of the Lower Thames is believed to be an upstream equivalent of this feature. It is thought that both the excavation and filling of the channel were intra-Saalian events, dating from Oxygen Isotope Stages 10 and 9 respectively. (D) Palaeodrainage during the deposition of the Barling Gravel. This is regarded as an intra-Saalian deposit, aggraded during Oxygen Isotope Stage 8. (E) Palaeodrainage during the deposition of the Mucking Gravel of the Lower Thames. The Thames–Medway equivalent of this formation is buried beneath the coastal alluvium east of Southend and can be traced offshore (Bridgland *et al.*, 1993). This aggradational phase occurred towards the end of the complex Saalian Stage, culminating early in Oxygen Isotope Stage 6. (F) Palaeodrainage during the last glacial. The submerged valley of the Thames–Medway has been recognized beneath Flandrian marine sediments in the area offshore from eastern Essex (after D'Olier, 1975).

from pre-existing features of the Valley Farm Soil, formed by earlier periglacial disruption (Kemp, 1985a). The characteristic features of the Barham Soil are particularly well-developed at Newney Green (Fig. 5.8). For example, the polygonal pattern of the larger-scale structures, reminiscent of landscapes in modern tundra regions, is superbly illustrated on the exhumed upper surface of the Barham Soil (Fig. 5.7).

The Barham Soil is closely associated throughout the area of its occurrence with various glacially-derived wind-blown sediments, namely coversands and loess (Rose *et al.*, 1976, 1985a; Rose and Allen, 1977). These are usually preserved in wedges and in the cores of involutions within the Barham Soil (Fig. 5.6), but occasional remnants are found, apparently in situ, between the Barham Soil and the overlying glacial sediments (see Fig. 5.8). Further evidence of the importance of aeolian activity during the early Anglian is the occurrence of wind-polished or faceted pebbles in the coversand.

The overriding of the Barham Soil, later in the Anglian, by the ice sheet that deposited the Lowestoft Till, resulted in glaciotectonic deformation of the pre-existing features, sometimes producing overfolds, shears and nappe-like structures (Rose *et al.*, 1985a). Whiteman (1987; in Allen *et al.*, 1991) recognized a basal 'deformation till', immediately overlying the palaeosol horizon, at Newney Green (Table 5.4) and at other nearby sites. He noted that it is often difficult to determine the junction between the deformed palaeosol horizon and the overlying deformation till. Ideally, however, there is a plane of *décollement* separating this lowest division of the till from the underlying, glacio-tectonically deformed sediments. This plane of *décollement* serves as the most effective lower boundary of the till sequence. In the GCR section, glaciotectonic effects can be observed in the form of lateral deformation of the structures within the Barham Soil (Fig. 5.7), broadly reflecting ice movement towards the south or south-east.

Whiteman (1987, 1990; in Allen *et al.*, 1991) has subdivided the Anglian till of central Essex into a number of facies-related beds, the gross lithological properties of which suggest that the sequence as a whole represents two distinct members of the Lowestoft Till Formation. The sections at Newney Green have been of considerable importance in the definition of these members, the lower of which is named after



6 ? Kettle hole infill (see text)

5 Lowestoft Till { d Decalcified till, c Chalky till } Great Waltham Member; { b Sandy till, a Deformation till } Newney Green Member

4 Barham Sand and Gravel (glaciofluvial)

3 Coversand (in wedges, cores of involutions and occasionally in discrete lenses)

2 Complex buried soils horizon (superimposed palaeosols) comprising:

involutions and wedges of intensely cold-climate soil (Barham Soil) and :-

Rubified and mottled temperate soil (Valley Farm Soil)

1 Kesgrave Group Gravel (Waldringfield Formation?)

Figure 5.6 Idealized stratigraphical sequence through the Pleistocene deposits at Newney Green (after Whiteman, 1990).

Figure 5.7 'Patterned ground' at the top of the Kesgrave Group gravel at Newney Green, as exhumed from beneath the Lowestoft Till by quarrying. The pattern results from the polygonal distribution of sand wedges in the Barham Soil (see text). (Photo: P. Allen.)

the site. The higher, stratigraphically younger 'Great Waltham Member' is named after another site in the Chelmsford area, 8 km to the north of Newney Green.

The Newney Green Member, largely derived from the underlying gravels, palaeosol and coversand, is commonly banded throughout, not just in its lower 'deformation till' division, in which the banding is attributed to shearing and attenuation of layers within the original sediment (see above). Many different mechanisms to explain banding in tills have been proposed and the origin of this phenomenon in the upper part of the Newney Green Member is uncertain at present (see Allen *et al.*, 1991).

The overlying Great Waltham Member is a compact grey, chalky till of classic 'Chalky Boulder Clay' type, although Whiteman subdivided it into lower and upper units, the latter representing its weathered and decalcified form. Decalcified Great Waltham Till may account for the full sequence in areas where the till cover is thin. In some instances differences between the lower and upper divisions of the Great Waltham Member cannot be explained entirely as the result of weathering. This led Whiteman (in Allen *et al.*, 1991) to suggest that differences in the direction of ice-movement and, therefore, in provenance are implicated.

The junction between the Newney Green and Great Waltham members is generally sharp, but Whiteman (1987, 1990; in Allen *et al.*, 1991) found no indication that they represent more than a single ice advance. There is no evidence as yet to relate this advance to the more complex glacial sequence in south-west Essex and Hertfordshire, where four separate ice advances occurred during the Anglian Stage (Cheshire, 1986a; Chapter 3, Part 2). One important difference between the two till members at Newney Green, however, is that their fabrics are generally at 90° to one another, with that in the Great Waltham Till most closely in agreement with other evidence for ice flow direction, such as the configuration of subglacial

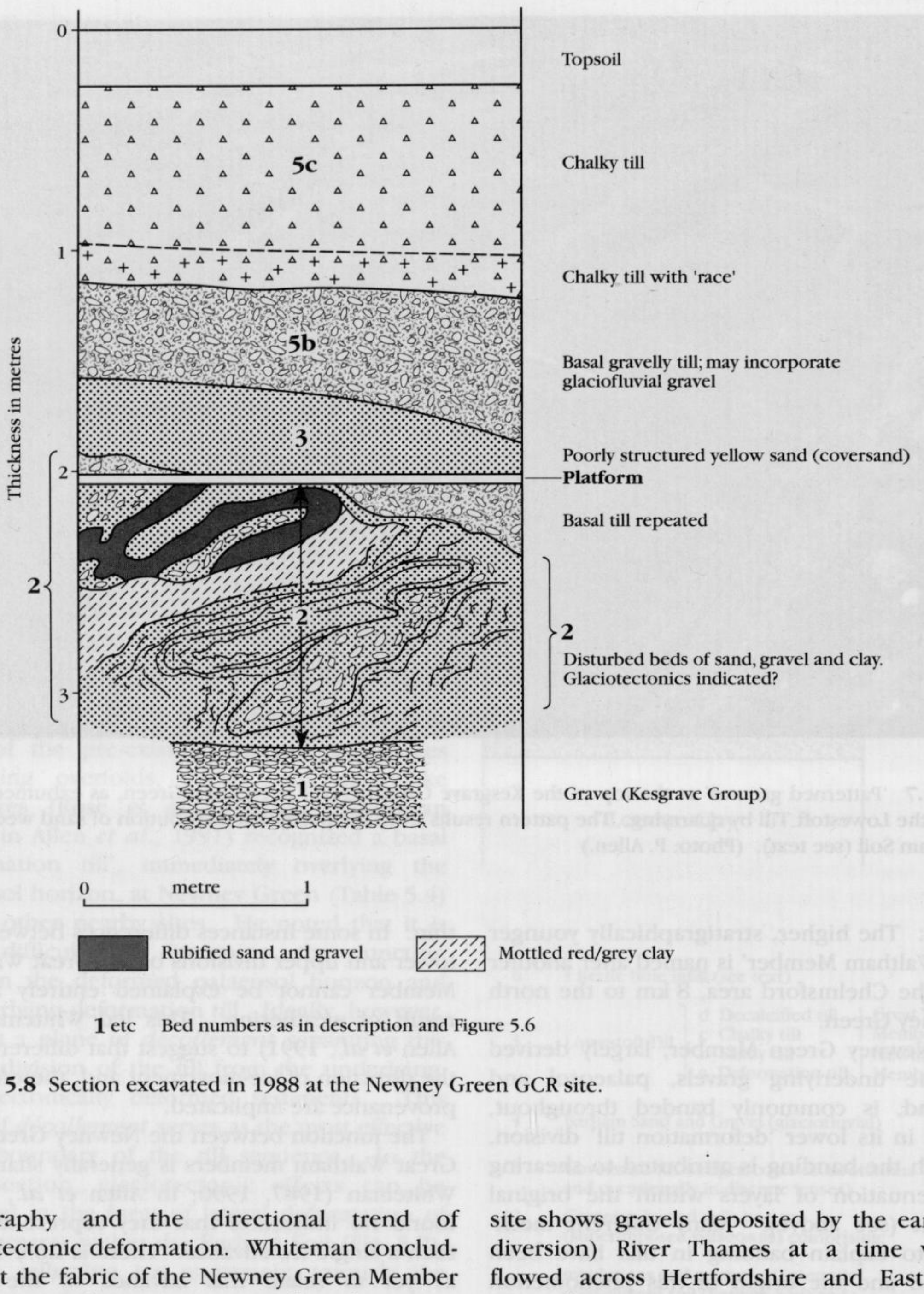


Figure 5.8 Section excavated in 1988 at the Newney Green GCR site.

topography and the directional trend of glaciotectonic deformation. Whiteman concluded that the fabric of the Newney Green Member was orientated transverse to ice flow directions. He regarded this as suggestive of strong compressional forces within a highly deformed till, formed above a rough glacier bed.

Conclusions

There are four important elements to the geological interest at Newney Green. Firstly, the site shows gravels deposited by the early (prediversion) River Thames at a time when it flowed across Hertfordshire and East Anglia. Secondly, a temperate-climate soil was developed at the top of this gravel. Following this temperate phase, the climate deteriorated until permafrost conditions prevailed, leading to the formation of a periglacial soil with characteristic structures (large-scale structures include patterned ground and ice wedges, such as are formed at the present day in tundra regions through the growth and subsequent melting of ground-ice). This period of extreme cold culminated in the covering of the area by (Anglian) ice, which moved southwards, depositing till (boulder clay), the fourth element in the Newney Green sequence. It was at this time that the course of the Thames was blocked by the ice and the river adopted a new route through what is now the London area. The temperate-climate soil is of considerable importance, as it shows that the gravels were not deposited in the same cold episode as the overlying glacial deposits.

ARDLEIGH (MARTELLS QUARRY; TM 053280)

D.R. Bridgland

Highlights

At this site cold-climate river gravels, assigned to the pre-diversion Thames, are interbedded with various organic sediments, some of which are indicative of temperate (interglacial) conditions. The latter have yielded the remains of deciduous trees. The site therefore reveals an early Middle Pleistocene cold-warm-cold climatic cycle expressed in Thames sediments. The complex sequence at Ardleigh also includes cold-climate organic deposits, a later (?tributary) gravel and soils formed under both warm and cold climatic conditions.

Introduction

Martells Quarry, Ardleigh, is the type locality for the Ardleigh Gravel, second highest of the four Low-level Kesgrave Group formations recognized on the Tendring Plateau (Bridgland, 1988a; see above, Introduction to Part 1; Figs 5.2 and 5.3 and Table 5.3). There has been a pit at Ardleigh for many years, attention first being drawn to the site by Spencer (1966), following the discovery of bones, including a skull fragment of a ziphiid whale. Later work has revealed the presence at Ardleigh of lenses and beds of organic sediments within the Ardleigh Formation, two distinct types being recognized, one indicative of a temperate climate and the other, higher in the sequence, of intensely cold conditions (Bridgland, 1988a; Bridgland *et al.*, 1988; Bridgland and Gibbard, 1990).

A complex succession of Pleistocene deposits is now recognized at Ardleigh, with evidence for periglacial conditions at more than one level and a complex palaeosol at the top of the sequence (Bridgland *et al.*, 1988). The interglacial represented by the lower set of organic sediments at Ardleigh is thought to correlate broadly with the 'Cromerian Complex' of The Netherlands (see Chapter 1; Zagwijn *et al.*, 1971; Zagwijn, 1986; de Jong, 1988).

Description

Spencer (1966) produced a diagrammatic illustration of a section at Ardleigh (without a scale), showing a partly submerged sequence of sands and gravels with a cryoturbated zone just above the water level. He considered the deposits above this zone of cryoturbation to be glacial outwash and those below to be of fluvial origin.

Recent work at this site has revealed a much greater stratigraphical complexity than was envisaged by Spencer (Bridgland *et al.*, 1988). The sequence now recognized is as follows:

			Thickness
4a.	Complex rubified and cryoturbated relict soil	(Valley Farm and Barham Soils)	up to 1.5 m
4.	Brown/orange gravel and sand. This has a low frequency of rounded flint pebbles; *Rhaxella* chert is present (Table 5.2). Palaeocurrents are towards the south-west	(Martells Gravel)	up to 3 m
3a.	Silty clay, dark grey and organic, with plant macrofossils. This occurs as variable beds and lenses *c.* 1.5 m below the top of member 3	(cold-climate deposits)	0.1–1 m
3.	Pale buff gravel and sand. This has a relatively high frequency of rounded flint pebbles; *Rhaxella* chert is absent (Table 5.2); palaeocurrents are towards the north-east	(Ardleigh Upper Gravel)	up to 5 m

2. Sand, dark grey/black and organic. This has high silt, clay and organic contents. It contains plant macrofossils and pollen. It occurs as variable beds and lenses.	(Ardleigh interglacial deposits)	up to 0.5 m
1. Pale, buff gravel and sand. This has a relatively high frequency of rounded flint pebbles; *Rhaxella* chert is absent; palaeocurrents are towards the north-east	(Ardleigh Lower Gravel)	up to 2 m
London Clay		

Two separate gravel deposits occur here in superposition. They are distinguished on the bases of differences in clast lithology and sedimentological criteria, particularly palaeocurrent evidence. These are the Ardleigh Gravel (members 1 and 3) and the Martells Gravel (member 4). With member 2, the Ardleigh interglacial deposits, members 1 and 3 combine to form the Ardleigh Gravel Formation, which belongs to the Low-level Kesgrave Subgroup. The GCR site is the type locality for all these units.

The Ardleigh Gravel has a composition typical of the Low-level Kesgrave Subgroup in this area (Table 5.2), with evidence for north-eastward palaeocurrents adding support to its interpretation as a Thames deposit (Bridgland, 1988a; Bridgland *et al.*, 1988). It is divided into two members, (1) the Ardleigh Upper Gravel and (3) the Ardleigh Lower Gravel, by the interglacial deposits (member 2), which represent a temperate interval (Bridgland *et al.*, 1988; Fig. 5.9). The Ardleigh Lower and Upper Gravels clearly represent different cold-climate episodes, but they cannot be distinguished in the absence of the organic interglacial deposits.

The temperate-climate organic sediments comprise variable lenses and beds of predominantly sandy deposits, frequently showing deformation structures suggestive of internal collapse while waterlogged (Fig. 5.10). These beds contain pollen, plant macrofossils and beetle remains. Poorly preserved wood remains and occasional indeterminate, abraded mammal bones that have been found in the lower parts of the Ardleigh Upper Gravel may have been reworked from the interglacial level. The Ardleigh interglacial deposits have been revealed intermittently by continued quarrying over a wide area, occurrences probably representing fills of isolated shallow channels (Bridgland and Gibbard, 1990). Pollen analyses have indicated that these various remnants are not all contemporaneous (Bridgland and Gibbard, 1990). These analyses have allowed the compilation of a preliminary and fragmentary pollen diagram, combining evidence from three of these isolated channel-fills (Bridgland and Gibbard, 1990). All three parts of this diagram record the occurrence of deciduous trees, namely birch (*Betula*), oak (*Quercus*), elm (*Ulmus*), alder (*Alnus*), willow (*Salix*) and hazel (*Corylus*). Pine and spruce were also present throughout (with the exception of the basal part of the oldest channel-fill). In two of the channel-fills, regarded as earlier than the third, the pollen was dominated by herb taxa, indicating cooler conditions and suggesting an earlier part of the interglacial. The basal layers of one of the channel-fills was practically devoid of tree pollen, suggesting that the very onset of interglacial conditions was represented. It was presumed that this was the oldest of the sampled sediment bodies (Bridgland and Gibbard, 1990). In the third part of the diagram, tree pollen constitutes over 60% of the total and a greater diversity of forest trees is indicated, suggesting the middle part of an interglacial.

At a higher stratigraphical level within the Ardleigh (Upper) Gravel there occur further organic sediments. These contain macrofossils of cold-climate plants, predominantly mosses, grasses and sedges, and clearly represent the vegetation of a periglacial episode. It is apparent, from the occurrence of ice-wedge casts originating from the upper surface of the Ardleigh (Upper) Gravel (Fig. 5.9), that permafrost conditions prevailed prior to the deposition of the overlying Martells Gravel.

In contrast to the Ardleigh Gravel, the Martells Gravel (member 4) contains a lower proportion of rounded flint pebbles (of the type reworked from the Palaeogene) than is usual in the Kesgrave Group. It contains significant amounts of *Rhaxella* chert, a rock that is extremely scarce in the Kesgrave Sands and Gravels upstream (to the south and west) of the Crag basin (Table 5.2). Foreset orientations indicate palaeocurrents towards the west-south-west, essentially a reversal of the flow direction indicated by palaeocurrent measurements from the Ardleigh

Gravel (Fig. 5.9). The combination of these various lines of evidence implies that the Martells Gravel was deposited by a river flowing from the north-east, which leads to the conclusion that it is not a Thames deposit and not part of the Kesgrave Group.

At the top of the sequence at Ardleigh, a rubified and cryoturbated palaeosol is developed in the upper part of the Martells Gravel, immediately beneath the modern topsoil (Fig. 5.9). Ice-wedge casts originating from the top of the fluvial sequence have also been recognized, superimposed on the earlier system of wedges developed from the surface of the Ardleigh (Upper) Gravel (Fig. 5.9).

Interpretation

The principal significance of the Ardleigh GCR site lies in the occurrence there, within a gravel formation ascribed to the Low-level Kesgrave Subgroup, of lower Middle Pleistocene temperate-climate sediments. As yet the

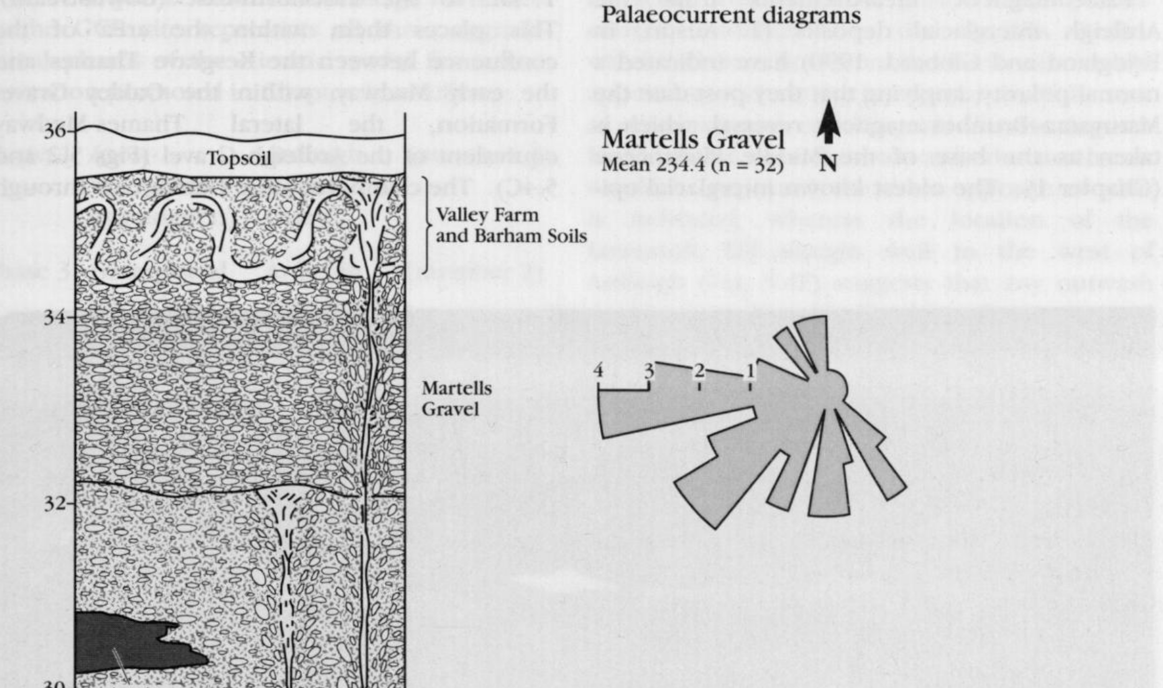


Figure 5.9 Idealized Pleistocene sequence at Ardleigh (after Bridgland *et al.*, 1988).

palaeontological evidence from these sediments is insufficiently distinctive to allow the temperate episode they represent to be identified. The vegetational sequence revealed in the fragmentary pollen diagram (Bridgland and Gibbard, 1990) is similar to that found in the early parts of other lower Middle Pleistocene interglacial deposits. The presence and persistence of spruce, the early expansion of elm and the low frequency of hazel were all identified as significant by Bridgland and Gibbard (1990), but there are no features in the pollen record at Ardleigh that are of biostratigraphical or chronostratigraphical significance.

Palaeomagnetic measurements from the Ardleigh interglacial deposits (T. Austin, in Bridgland and Gibbard, 1990) have indicated a normal polarity, implying that they post-date the Matuyama–Brunhes magnetic reversal, which is taken as the base of the Middle Pleistocene (Chapter 1). The oldest known interglacial episode with which they could be correlated is therefore 'Cromerian Complex Interglacial II' of the Dutch sequence (see Chapter 1).

The relation of these sediments, which lie near the base of the Ardleigh Gravel sequence, to the interglacial channel-fill at Little Oakley (Bridgland *et al.*, 1988, 1990; see below) is of great importance. The latter deposits, which contain molluscan and vertebrate remains as well as pollen, are interpreted as of broadly Cromerian age and thought to belong within the 'Cromerian Complex' as identified in The Netherlands. They occur in the same terrace formation as the Ardleigh sediments, but are 17 km to the east-north-east (downstream). This places them within the area of the confluence between the Kesgrave Thames and the early Medway, within the Oakley Gravel Formation, the lateral Thames-Medway equivalent of the Ardleigh Gravel (Figs 5.2 and 5.4C). The channel at Little Oakley cuts through

Figure 5.10 The Ardleigh interglacial deposits exposed above Ardleigh Lower Gravel in a drainage channel in the floor of Martells Quarry, Ardleigh (1987). (Photo: D.R. Bridgland.)

the local Oakley Gravel, implying that the interglacial represented there may be later than that at Ardleigh. This would suggest that the Ardleigh Upper Gravel was laid down in the interval between the Ardleigh and Little Oakley interglacials (see, however, Little Oakley). Gibbard (1988b) has attributed the Ardleigh interglacial deposits to a temperate interval between the Pastonian and Cromerian and has suggested correlation with either Interglacial II or Interglacial III of the 'Cromerian Complex' (see Chapter 1).

With cold-climate gravels both above and below the interglacial sediments, it is apparent that the sequence within the Ardleigh Formation at the GCR site represents all three aggradational phases of the climatic model for terrace formation promoted in Chapter 1, as follows:

Phase 4	(post-interglacial aggradation)	Ardleigh Upper Gravel	(member 3)
Phase 3	(interglacial aggradation)	Ardleigh interglacial sediments	(member 2)
Phase 2	(pre-interglacial aggradation)	Ardleigh Lower Gravel	(member 1)

The relation of the Little Oakley channel deposits to this model will be discussed below (see Little Oakley).

Assuming the Ardleigh temperate episode to be earlier than that represented at Little Oakley, only one other site is currently known in Britain where a possible correlative of the Ardleigh interglacial sediments occurs, this being at Broomfield, near Chelmsford. As at Ardleigh, both temperate- and cold-climate organic deposits occur at Broomfield (Gibbard, 1988b; Whiteman, 1990). Whiteman (pers. comm.) considers that the gravel at Broomfield, which is buried beneath Lowestoft Till, may be an upstream continuation of the Ardleigh Formation.

The interpretation of the Martells Gravel, which overlies the Ardleigh Gravel at the GCR site, is somewhat problematic. As described above, the Martells Gravel contains significantly less rounded flint (reworked from the Palaeogene) than the underlying Ardleigh Gravel and it also differs in that it contains *Rhaxella* chert. Both differences suggest an apparent affinity to outwash gravels from the Anglian glaciation, which also have these particular ('northern') characteristics (Bridgland, 1980, 1986b; Bridgland *et al.*, 1988). However, Anglian outwash deposits also differ from Kesgrave Group gravels in that about half of their exotic component (derived from the north and west) is made up of non-quartzose lithologies (an example is the ice-proximal Ugley Gravel at Ugley Park Quarry (see Chapter 3, Part 2). The exotic suite found in Kesgrave Group gravels typically includes over 80% quartz and quartzites. The Martells Gravel shares this high proportion of quartzose exotics with the Kesgrave Group, thus differing markedly from outwash gravel. The palaeocurrent evidence from the Martells Gravel, which indicates flow from the north-east, would appear to preclude the interpretation of the unit as either outwash or a Kesgrave Thames deposit. In the latter case flow towards the north-east would be expected, the exact opposite of what is indicated, whereas the location of the Lowestoft Till margin well to the west of Ardleigh (Fig. 5.4F) suggests that any outwash streams crossing the Tendring Plateau would have flowed in a broadly eastward or south-eastward direction.

The most plausible interpretation of the Martells Gravel, based on these facts, is as the product of a river flowing from the north-east into the pre-diversion Thames valley or, if of post-Anglian age, into the Colne valley (Bridgland *et al.*, 1988). Such a river would have drained an area covered by earlier Kesgrave Group Thames gravels and by Red Crag. The former would have supplied much of the material in the Martells Gravel, ensuring a high quartz and quartzite content, but the inclusion of pebbles reworked from the Crag would have diluted the rounded flint, which is not found in quantity in the Crag, and added the *Rhaxella* chert, which is an important component of Crag pebble beds. The river presumably had an insufficiently large catchment to tap the Westleton Beds of northern Suffolk, as these would have yielded abundant rounded flint, largely indistinguishable from that reworked from the Palaeogene of the London Basin. No other remnants of gravels that may have been aggraded by this hypothetical river have been identified.

There is little evidence for the age of the Martells Gravel. It is clearly later than the Ardleigh/Oakley Gravel and presumably post-dates Thames occupation of the Ardleigh/Oakley

Formation floodplain. No soil development has been observed at the top of the Ardleigh Gravel, beneath the Martells Gravel, in recent studies. However, Spencer (1966) recorded a zone of cryoturbation at Ardleigh beneath an upper gravel, although no details of thickness were given. He quoted the grid reference of his section, which leaves no doubt that he referred to earlier sections in the present Martells Pit. If the upper gravel identified by Spencer was the Martells Gravel, his description may record a zone of cryoturbation at the top of the Ardleigh Gravel, where only ice-wedge casts have been seen in recent exposures. Spencer's record was cited by Rose *et al.* (1985a), who claimed that his cryoturbated zone represented the early Anglian Barham Soil. The only cryoturbated horizon recorded recently is that developed in the top of the Martells Gravel (Fig. 5.9); this would appear to lie too close to the modern land surface to be the horizon identified by Spencer, unless his section revealed a higher, later gravel that is missing from more recent exposures. Confirmation of a cryoturbated and/ or weathered horizon at the top of the Ardleigh Gravel might provide additional information about the difference in age between it and the overlying Martells Gravel. C. Turner (pers. comm.) has suggested, however, that Spencer's cryoturbation layer was in fact the deformed lower (temperate) organic member, the penecontemporaneous deformation structures that disrupt this deposit (see Description and Fig. 5.10) having been mistaken for involutions.

The rubified and cryoturbated zone at the top of the Martells Gravel is reminiscent of the superimposed (temperate) Valley Farm and (cold) Barham Soils, which have been identified in the upper levels of the various Kesgrave Group formations (Rose *et al.*, 1976, 1985a, 1985b; Rose and Allen, 1977; Kemp, 1985a; see above, Introduction to Part 1). The Valley Farm Soil was recorded at the top of a sequence at Ardleigh by Rose *et al.* (1976), although the later Barham Soil was not recognized. The combination of this record and the reinterpretation by Rose *et al.* (1985a) of Spencer's section suggests that palaeosols may be represented at two different stratigraphical levels at Ardleigh. The Valley Farm Soil has recently been tentatively identified over much of the Tendring Plateau 'in relict form' (Kemp, 1985a). However, in this area, where it is at or near the modern surface and not overlain by Anglian glacial deposits, it is impossible to demonstrate the pre-Anglian origin of the reddened material. The correlation of this soil layer with the pre-Anglian Valley Farm Soil would be of considerable significance, since the age and origin of the Martells Gravel cannot be established by other means. However, a post-Anglian rubified soil has been recorded from the Chelmsford area (Rose *et al.*, 1978), so the presence of a reddened zone in the Martells Gravel may be of little stratigraphical value.

Spencer (1966) suggested that the lower part of the sequence at Ardleigh was of Hoxnian age. He appears to have based this suggestion on the occurrence of the whale bone. However, as Spencer noted, ziphiid whale bones of this type are common in the basement bed of the Red Crag at Walton-on-the-Naze, some 20 km to the east of Ardleigh. It seems likely that this bone had been reworked from such a source and that its provenance at Ardleigh was the Martells Gravel, which has already been claimed to contain certain gravel material reworked from the Crag, and has been shown to be the product of a river flowing from the direction of the Crag outcrop (see above). Further investigation of sections in the area may throw more light on the relation of Spencer's section to the sequence described at the GCR site and on the relations of the relict soils at Ardleigh to the Valley Farm and Barham Soils of East Anglia.

Conclusions

Martells Quarry, Ardleigh, is an important site for Pleistocene stratigraphy and palaeoenvironmental reconstruction. The sequence here includes sediments deposited by an ancestral River Thames at a time when it flowed across East Anglia, long before its diversion, by ice, into its modern valley. Deposits from two cold-climate episodes separated by a temperate (interglacial) interval are represented here. The interglacial deposits are of considerable significance in that they may be unique in Britain. The interglacial represented probably belongs within a complex of cold and warm episodes recognized in The Netherlands (referred to as the 'Cromerian Complex', after the most famous site of this general age, near Cromer in Norfolk), implying a date somewhere between 750,000 and 450,000 years BP. The site has been identified as the type locality for an important formation within the Kesgrave Group of early Thames deposits, the Ardleigh Gravel, which is itself subdivided by the interglacial beds where these are present. The Ardleigh Lower and Ardleigh Upper gravels therefore represent two different cold periods. Further fossiliferous beds occur within the Ardleigh Upper Gravel. These are most unusual in that they contain plant remains representative of a tundra environment. A later, enigmatic upper deposit, the Martells Gravel, appears to be the product of a later river draining from the north-east, but its age is indeterminate at present.

LITTLE OAKLEY (TM 223294)

D.R. Bridgland

Highlights

Extremely rare Cromerian deposits, with important molluscan and mammalian faunas, occur here in a channel cut through pre-diversion Thames-Medway gravels. This association is important for the correlation of the Thames terrace sequence with the type Cromerian of Norfolk and the more complete 'Cromerian Complex' succession of The Netherlands.

Introduction

At Little Oakley, in the north-eastern corner of the Tendring Plateau (Fig. 5.2), fossiliferous interglacial sediments occupy a large river channel cut through the local Oakley Gravel Formation (this is the oldest Thames-Medway gravel within the Low-level Kesgrave Subgroup, no Thames-Medway equivalent of the older Waldringfield Gravel having yet been identified – see above, Introduction to Part 1). The channel is believed, on the basis of the clast content of its infill, to have been formed by the pre-diversion Thames at a point immediately upstream from its confluence with the Medway (Bridgland *et al.*, 1988, 1990). The palaeontological evidence, which includes rich assemblages of mammals, molluscs and ostracods as well as a detailed pollen record, suggests correlation with an early Middle Pleistocene interglacial, probably within the 'Cromerian Complex' as defined in The Netherlands (Zagwijn *et al.*, 1971) and possibly the Cromerian Stage *sensu* West Runton (Bridgland, 1990b; Bridgland *et al.*, 1990; Gibbard and Peglar, 1990; Lister *et al.*, 1990; Preece, 1990b; Robinson, 1990). This correlation is supported by results of amino acid analyses of shells from this and other sites (Bowen *et al.*, 1989; Bridgland *et al.*, 1990), as well as by palaeomagnetic measurements, which indicate a normal geomagnetic polarity (Bridgland *et al.*, 1988, 1990).

The interglacial deposits at Little Oakley were first discovered in 1939 by Warren (1940; Sutcliffe *et al.*, 1979), who recognized that they were of 'Forest Beds' (Cromerian) age. The site has been frequently cited in subsequent literature as an important Cromerian locality, a considerable rarity outside the type area of north Norfolk (Oakley, 1943; Kerney, 1959a; Turner, 1973; Sutcliffe *et al.*, 1979). However, prior to the recent investigations (Bridgland *et al.*, 1988, 1990), which included re-excavation of the deposits as part of the GCR programme (Bridgland, 1985a), no detailed study of the sediments or *in situ* sampling had been attempted.

Description

Little Oakley lies near the eastern end of a ridge of London Clay, capped with Pleistocene gravels and small remnants of Red Crag, lying between the Stour estuary to the north, Hamford Water to the south and the North Sea to the east. On the only available Geological Survey map (Old Series, Sheet 48), the deposits capping this ridge are classified as 'Glacial Gravel' (Whitaker, 1877). However, gravels of this type throughout Suffolk and Essex have been shown to pre-date the Anglian Stage, during which the principal glacial deposits in this region were laid down, from the fact that their upper layers show evidence of warm-climate soil formation (the Valley Farm Soil) prior to burial by Anglian till. Such gravels are now interpreted as deposits of the pre-diversion Thames and classified as the Kesgrave Sands and Gravels Group (Rose *et al.*, 1976; see above, Introduction to Part 1).

The Kesgrave Sands and Gravels have been progressively subdivided during the past decade (Hey, 1980; Allen, 1983, 1984; Bridgland, 1988a; Whiteman, 1990) and are now considered to represent various formations within High-level and Low-level Kesgrave Subgroups. The gravel in the vicinity of Little Oakley is attributed to the Oakley Formation, which represents the downstream continuation of the Ardleigh Formation (Fig. 5.2; see above, Ardleigh). The Ardleigh and Oakley Gravels are distinguished on the basis of clast content, the latter deposit containing significantly more material of southern origin (Table 5.2). The change from Ardleigh to Oakley Gravel composition is considered to record the contemporary confluence of the Thames with the Medway (Bridgland, 1988a; Fig. 5.4C).

The Little Oakley channel deposits were not recognized in the Old Series Geological Survey mapping, although a patch of Red Crag is indicated on the map at their approximate location, suggesting that the fluviatile shelly sand may have been mistaken for part of the Crag. In recent investigations, however, a remnant of Red Crag was encountered between the interglacial channel sediments and the London Clay (Bridgland *et al.*, 1990).

No permanent section has ever existed at Little Oakley, the sediments originally being discovered in spoil from sewer trenches (Warren, 1940). Detailed work at the locality has been carried out in recent years (Bridgland *et al.*, 1988, 1990). Using Warren's notes, the fossiliferous channel was relocated by augering near to the site of the original discovery (borehole LOA, Fig. 5.11; TM 233294). Numerous further auger holes were sunk in the area, enabling the form of the sedimentary body, its internal variability and its relation to the neighbouring sediments to be determined. A strip of undeveloped land, including the site of the original discovery, was selected as a potential GCR site. Temporary exposures were excavated mechanically on this land, allowing the examination of sedimentary characteristics and relations and the bulk sampling of sediments.

Detailed mapping of the interglacial deposits at Little Oakley has demonstrated that they fill a WSW–ENE trending channel between 150 m and 175 m wide (Fig. 5.11). The overall geometry and sedimentary facies of these deposits suggest deposition in the channel of a single-thread river flowing under a relatively low-energy regime. They have been given the formal lithostratigraphical name 'Little Oakley Silts and Sands' (Bridgland *et al.*, 1988, 1990). Up to 4 m thick, this member predominantly comprises material in the fine sand, silt and clay grades, with scattered pebbles and occasional thin sand laminae. Mollusca are abundant throughout the deposits (Preece, 1990b; Fig. 5.12, see below), although they are rarer in the upper levels, which are rather poorly bedded and may have suffered some post-depositional decalcification. The dominant species are the gastropods *Valvata naticina* and *Tanousia* cf. *stenostoma* (Nordmann) and the bivalves *Pisidium moitessierianum* Paladilhe and *P. supinum*. The deposits also contain ostracods (Robinson, 1990), pollen (Gibbard and Peglar, 1990) and an important vertebrate assemblage. The vertebrates include two species of early giant deer (*Megaloceros verticornis* Dawkins and *M. dawkinsi* (Newton)), wild boar, horse, spotted hyaena and eight species of small mammal as well as amphibians, reptiles and a large variety of river-dwelling fish (Bridgland *et al.*, 1988; Lister *et al.*, 1990). Particularly significant amongst the fish are records of burbot (*Lota lota*) and carp (*Cyprinus carpio*), the latter being the first recorded from the British Pleistocene. In the area of Newhouse Farm (Fig. 5.11) the channel sediments include a thin bed of coarse, shelly red-orange sand containing abundant reworked Red Crag Mollusca as well as indigenous species. The sand itself resembles the Red Crag, which, since it underlies parts of the channel, is probably its direct source. Sandy and pebbly horizons within the silts indicate occasional higher energy flood events. These were found particularly beneath the eastern end of the village, including the area of the GCR site (Bridgland *et al.*, 1990).

The fluviatile Oakley Gravel and Little Oakley Silts and Sands are capped by a complex, poorly bedded unit of variable thickness. This unit, which predominantly comprises silty or clayey sand with pebbles and calcareous nodules, thickening downslope, has been attributed to solifluction (Bridgland *et al.*, 1990). The sequence at Little Oakley can thus be summarized as follows (for thicknesses, see Fig. 5.11):

3. Colluvium

2. Little Oakley Silts and Sands

1. Oakley Gravel

Pre-Pleistocene strata: London Clay and Waltonian Red Crag

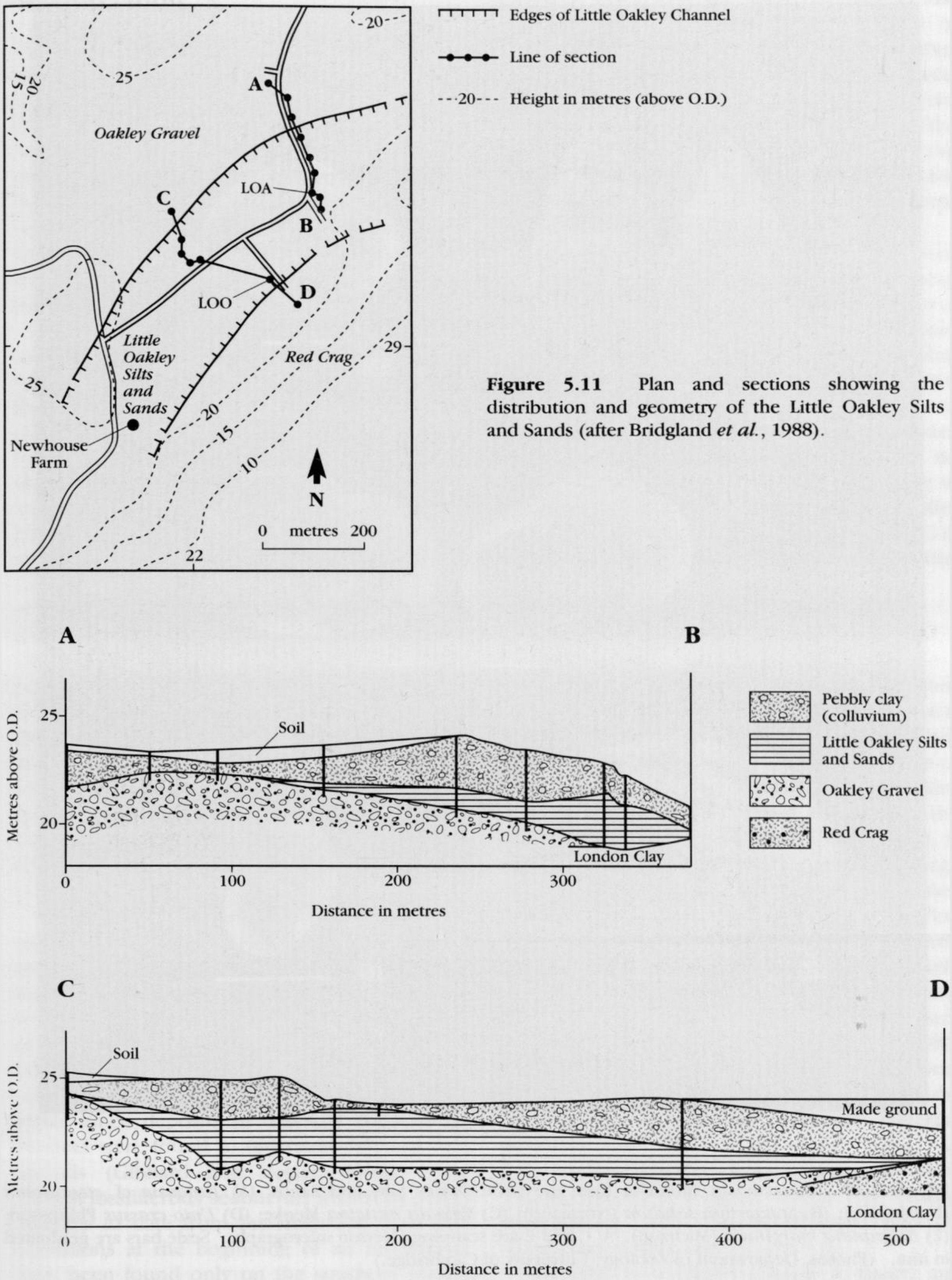


Figure 5.11 Plan and sections showing the distribution and geometry of the Little Oakley Silts and Sands (after Bridgland *et al.*, 1988).

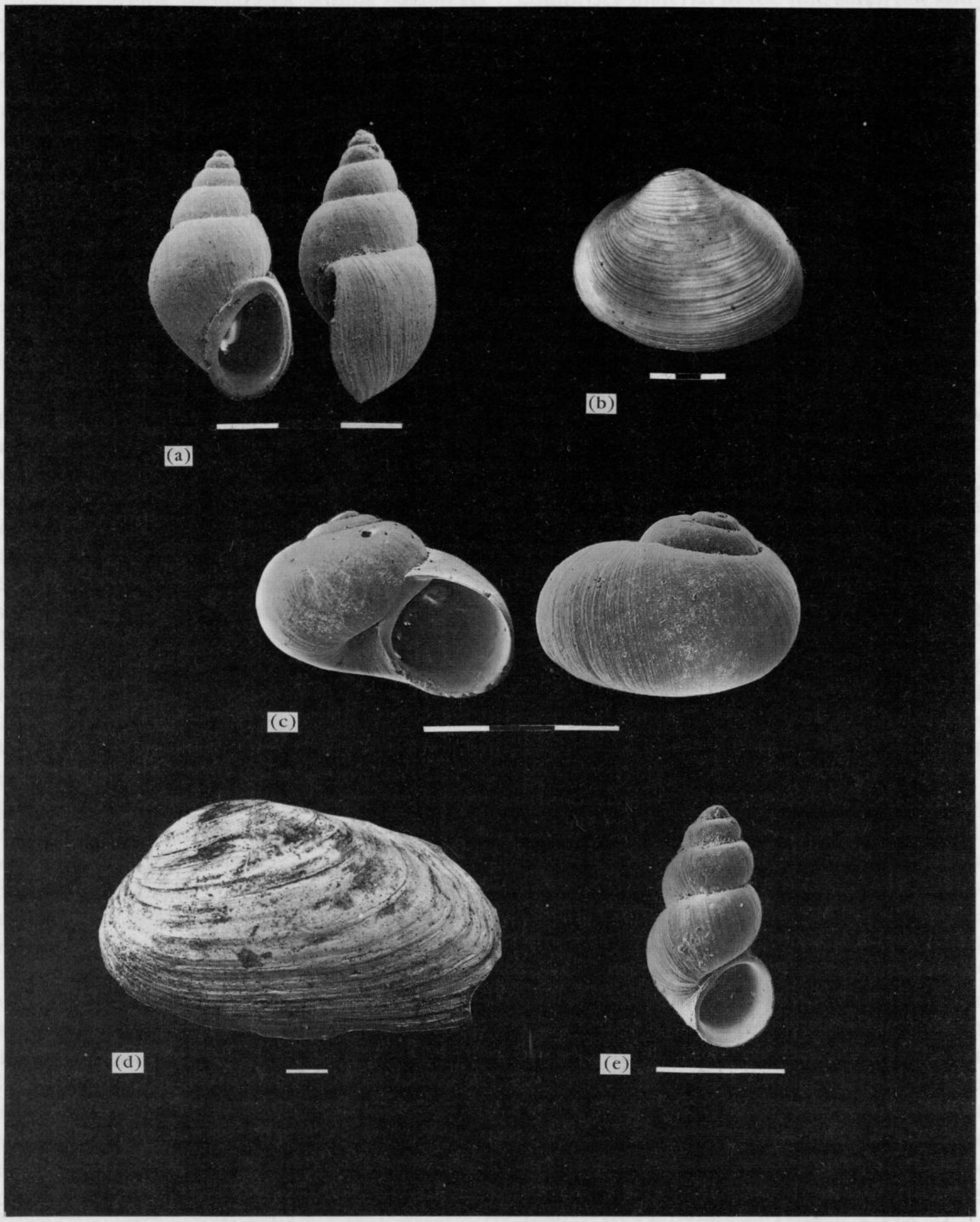


Figure 5.12 Characteristic Mollusca from the Little Oakley Silts and Sands. (A) *Tanousia* cf. *stenostoma* (Nordmann); (B) *Sphaerium solidum* (Normand); (C) *Valvata naticina* Menke; (D) *Unio crassus* Philipsson; (E) *Belgrandia marginata* (Michaud). A, C and E are scanning electron micrographs. Scale bars are graduated in mm. (Photos: Department of Zoology, University of Cambridge.)

Interpretation

The Little Oakley site, after several decades of neglect, has benefited recently from a multidisciplinary appraisal using modern techniques. The sedimentological interpretation has been restricted, however, by the lack of exposure; the reconstruction of the three-dimensional form of the sediment body has relied primarily on augering and occasional temporary excavations. The best evidence for palaeoenvironmental conditions has therefore come from studies of the palaeontology.

The Little Oakley Silts and Sands contain rich assemblages of freshwater molluscs and ostracods, comprising taxa indicative of deposition in the lower reaches of a large, well-oxygenated, calcareous river, upstream from any tidal influence (Preece, 1990b; Robinson, 1990). Terrestrial mollusca are also present, which testifies that the river had wide, open floodplains with fringing marsh habitats (indicated, for example, by *Vertigo antivertigo* (Draparnaud) and *Zonitoides nitidus* (Müller)) and extensive areas of dry, calcareous grassland (indicated by *Trochoidea geyeri* (Soos) and *Truncatellina cylindrica* (Férussac)) (Preece, 1990b). Pollen analyses have confirmed the presence of grassland, but have suggested that woodland also existed in the catchment during most of the time represented (Gibbard and Peglar, 1990). The vertebrate assemblage includes species typical of fluviatile, marsh, grassland and woodland environments (Lister *et al.*, 1990), supporting the evidence from the pollen and molluscs.

A more detailed assessment of the palynology (Gibbard and Peglar, 1990) reveals that early herb-dominated vegetation gave way to boreal forest, with birch and pine dominant, and then to deciduous forest in which oak and particularly elm were major constituents. This vegetational history was reconstructed from the palynological records of several separate boreholes, since deposits in different parts of the channel were found to represent different time periods (Gibbard and Peglar, 1990). The earliest fossiliferous sediments, shown by pollen analyses to date from the transition from cold conditions at the beginning of an interglacial, have been found only on the southern margin of the channel; the basal channel sediments become progressively younger northwards (Gibbard and Peglar, 1990). The Mollusca from borehole LOO, near the southern edge of the channel, record a progressive replacement of aquatic taxa by marsh snails (as above), thus indicating a shallowing sequence (Preece, 1990b). This suggests that this part of the feature was filled as the active channel shifted northwards. The precise width of the active channel must therefore have been somewhat less than the maximum width of the Little Oakley Silts and Sands sediment body.

The vertebrate assemblages from the channel deposits are fully temperate in character. Knowledge of the modern breeding requirements of certain fish species (Cyprinidae and Percidae) recovered from Little Oakley suggests that during the summer months (May–August) water temperatures must have reached a minimum of 15°C and a maximum of 22°C, whereas in winter (December–March) they must have fallen no lower than 0.6°C. Moreover, the occurrence of the pond tortoise (*Emys orbicularis*) implies mean July temperatures well in excess of 18°C if, as seems likely, this represents a breeding population (Lister *et al.*, 1990).

Palaeogeography

Little Oakley lies in an area that is highly important for the study of Pleistocene geology, since it is one in which the Thames and East Anglian stratigraphies can be compared. The results of clast-lithological analysis indicate that the Oakley Gravel, the terrace formation into which the Little Oakley Silts and Sands are channelled, is part of the pre-diversion Thames drainage system (Bridgland, 1988a; see above). Detailed clast compositional data from the Tendring Plateau (Table 5.2) indicates that the early Thames was joined, as it flowed north-eastwards, by an important tributary draining northwards from the Weald, the direct ancestor of the modern River Medway (Bridgland, 1980, 1983a, 1988a; Fig. 5.4). This ancient fluvial confluence is recognized in the gravels of the area by an increase in southern material, predominantly Lower Greensand chert, an important component of Medway gravels. Thus Thames gravels of Kesgrave Group type change downstream into Thames-Medway deposits (Bridgland, 1988a; Figs 5.2 and 5.4).

The ratio of southern material to quartz and quartzites has been employed to demonstrate the change in clast composition resulting from the confluence between the Kesgrave Thames and the Medway (Bridgland, 1988a; Bridgland *et al.*, 1990). In the gravels upstream from the confluence, this ratio is relatively low, ranging from 0.02 to 0.10. A ratio of approximately 0.10 is considered to represent the upstream limit of Medway influence, this being the highest ratio encountered in Kesgrave Group gravels further upstream. Ratios generally increase downstream from this westward limit to 0.50 and above (Bridgland, 1988a; Bridgland *et al.*, 1990; Table 5.2). A gradual compositional change is observed, a phenomenon for which several causes can be envisaged. Firstly, full mixing of the gravel loads of the two rivers may not have occurred for a considerable distance downstream from the confluence. Secondly, the general distribution of gravel deposits in Essex indicates a progressive southward migration of the Thames and an eastward migration of the Medway. This means that the Thames, on its southern flank, would have been reworking west-bank terrace deposits of the Medway, causing an increase in southern material in its bedload gravel several kilometres above the actual confluence.

The composition of the Oakley Gravel in the vicinity of Little Oakley shows it to fall within the Thames-Medway category; in particular, southern to quartz and quartzite ratios in excess of 0.10 were revealed (Table 5.2). However, the analysis of scattered gravel-sized clasts in the Little Oakley Silts and Sands has revealed equivalent ratios close to, but generally below 0.10 (Bridgland *et al.*, 1988, 1990; Table 5.2). There are two possible interpretations of this data. Firstly, the Little Oakley channel deposits may be the product of a tributary river that has reworked the Kesgrave gravels over a wide area, mixing material derived from further upstream, remote from the Medway confluence area, with that from the local Oakley Gravel. Alternatively, the Little Oakley Silts and Sands may have accumulated in the channel of the Thames, immediately upstream from its confluence with the contemporary Medway channel. Therefore the Little Oakley sediments, although attributed to the Thames, might be expected to show some Medway influence, because of reworking either from older Medway terraces (as described above) or from the underlying Oakley Gravel, which represents a wider gravel-covered Thames floodplain that had already coalesced with that of the Medway (Fig. 5.4). The palaeontological and sedimentological evidence for the presence of a large river at Little Oakley, combined with regional stratigraphical evidence indicating that the Thames occupied the area of the Tendring Plateau until the Anglian Stage, provides support for a Thames origin for the Little Oakley Silts and Sands (Bridgland *et al.*, 1988, 1990).

Biostratigraphy and correlation

The palaeontological evidence from the Little Oakley Silts and Sands not only enables detailed palaeoecological reconstructions, but also provides evidence for the relative age of the deposits. The pollen assemblages, from various profiles through the deposits, together represent the early part (biozones I and II) of an early Middle Pleistocene interglacial (Bridgland, 1990b; Gibbard and Peglar, 1990). Hornbeam (*Carpinus*) and 'Tertiary relics' (such as *Tsuga*, *Carya* or *Eucommia*) are absent, suggesting that the deposits are unlikely to be of pre-Cromerian age. A number of features of the pollen record are suggestive of a Cromerian (*sensu* West Runton) age: *Ulmus* (elm) expands early and becomes dominant, *Picea* (spruce) is present throughout, whereas *Quercus* (oak) expands late and is followed by *Corylus* (hazel). The similarity between this sequence of woodland development and that of the Cromerian stratotype at West Runton, Norfolk, has led to suggestions that the two sites may be correlatives (Bridgland *et al.*, 1988, 1990).

The vertebrate fauna is also suggestive of a broadly Cromerian age for the Little Oakley Silts and Sands (Lister *et al.*, 1990). The presence of the giant deer *Megaloceros verticornis* and *M. dawkinsi*, together with the vole *Mimomys savini*, strongly indicate deposition during the early Middle Pleistocene. In western Europe these two deer species are restricted to deposits of Cromerian and early Elsterian (Anglian) ages, whereas *M. savini* extends from the late Early Pleistocene to the type Cromerian, but is replaced in some late pre-Anglian ('late Cromerian') assemblages by its evolutionary descendant, *Arvicola cantiana* (see Chapter 1). The Little Oakley vertebrate fauna is fully temperate in character; it clearly represents an interglacial later than the Pastonian Stage but earlier than those 'late Cromerian' sites with *A. cantiana*, such as Westbury-sub-Mendip (Bishop, 1982).

The rich vertebrate fauna from the West Runton Freshwater Bed (biozones CrIb-IIb) shares with Little Oakley such characteristic extinct taxa as the water vole *Mimomys savini*, the pine vole *Pitymys gregaloides* (Hinton), the Etruscan rhinoceros *Dicerorhinus etruscus* and the giant deer *Megaloceros verticornis* (Stuart, 1975, 1981, 1982a). The much more limited fauna from Little Oakley compares closely with that of West Runton, although pond tortoise (*Emys orbicularis*) has not yet been recorded from the latter. Shrew remains from Little Oakley represent a potentially valuable means of comparison with the fauna from West Runton, in which *Sorex* species of three different sizes occur. There are indications from the collections accumulated to date from Little Oakley that a similar assemblage of shrews occurs, but further sampling is required in order to obtain crucial mandibular remains (Lister *et al.*, 1990).

The molluscan assemblage from Little Oakley includes *Tanousia*, a genus known only from the Cromerian in Britain. *Valvata naticina*, *Bithynia troscheli* and *Unio crassus* are unknown in Britain before this stage. The presence of *B. troscheli* to the exclusion of *Bithynia tentaculata* is a feature that characterizes most British Cromerian sites. These features of the assemblage are consistent with a broadly Cromerian age, although the same taxa are found in earlier sediments in The Netherlands and elsewhere (Preece, 1990b). Recent consideration of the molluscan assemblages from Cromerian (*sensu lato*) sites in Britain and north-west Europe (Meijer and Preece, in press) suggests that the Little Oakley fauna is peculiar, thus far, to this one locality. Meijer and Preece point to significant differences between molluscan faunas that can be regarded as 'early' and others that can be regarded as 'late' within the 'Cromerian Complex'. Significant taxa amongst the 'early' assemblages are *Valvata goldfussiana* and *Tanousia runtoniana*, extinct species that do not seem to survive into the 'late' faunas. The 'late' assemblages have *V. naticina*, *Belgrandia marginata* and *Bithynia tentaculata*, which have yet to be found in the 'early' faunas, and are indistinguishable, malacologically, from Hoxnian (Holsteinian) assemblages. The British sites at West Runton and Sugworth both have molluscan faunas that can be classified, according to these criteria, as 'early'. Other British Cromerian (*sensu lato*) sites such as Sidestrand and Trimmingham have yielded the 'late' type of molluscan assemblage. Little Oakley, uniquely, has a fauna that seems intermediate between these two categories. *Valvata goldfussiana*, an element of the 'early' fauna, is absent, whereas *Bithynia tentaculata* is present. The *Tanousia* from Little Oakley is a different species from that found at West Runton and is close to, but smaller than, *T. stenostoma* a species recognized in Denmark (Preece, 1990b). Meijer and Preece (in press) have suggested that the Little Oakley site represents a later temperate episode within the 'Cromerian Complex' than either West Runton or Sugworth.

Significant amongst the ostracod fauna from Little Oakley are *Candona tricicatricosa* (Diebel and Pietrzeniuk), *Ilyocypris quinculminata* (Sylvester and Bradley), *Sclerocypris clavata prisca* (Diebel and Pietrzeniuk) and *Scottia browniana*. None of these is restricted to the Cromerian, but they are unknown together in Britain after the Hoxnian, thus supporting a broadly Middle Pleistocene age (Robinson, 1990).

Bridgland *et al.* (1990) have cited amino acid ratios from shells from Little Oakley, analysed by two different laboratories. Specimens of both *Valvata piscinalis* and *V. naticina* were analysed in London (London Quaternary Centre; laboratory now relocated to the Institute of Earth Sciences, the University College of Wales, Aberystwyth), and ratios from *V. naticina* were also obtained in Colorado (INSTAAR Laboratory). The D : L ratios from *V. piscinalis* are somewhat higher than those from *V. naticina*, which may indicate that epimerization is faster in the former species. Comparison with *V. piscinalis* ratios from other Middle Pleistocene sites is informative, the following being listed by Bridgland *et al.* (1990) and/or Bowen *et al.* (1989):

Site	Mean D : L ratios		Laboratory
Hoxne	0.243 ± 0.023	(n=3)	INSTAAR
Hoxne	0.261 ± 0.01	(n=4)	London
Swanscombe	0.30 ± 0.016	(n=10)	London
Swanscombe	0.297 ± 0.009	(n=5)	INSTAAR
Clacton	0.299 ± 0.002	(n=3)	London
Little Oakley	0.324 ± 0.004	(n=2)	London
Little Oakley	0.336 ± 0.027	(n=4)	London
West Runton	0.348 ± 0.011	(n=5)	London

These ratios are consistent with a broad correlation between Little Oakley and West Runton and confirm that these sites are older than those at Hoxne, Swanscombe and Clacton, all attributed to the Hoxnian Stage (*sensu lato*). However, ratios from *V. goldfussiana* shells from Sugworth compare closely with those quoted above from Swanscombe and Clacton, despite the convincing biostratigraphical indications that this site is a broad correlative of Little Oakley and West Runton (see Chapter 2, Sugworth).

The stratigraphical record of the lower Middle Pleistocene in Britain, best represented on the Norfolk coast, is now known to be far from complete (Zalasiewicz and Gibbard, 1988). Comparison with the sequence in The Netherlands, in particular, shows that repeated climatic fluctuations occurred in the period following the Matuyama–Brunhes palaeomagnetic reversal and prior to the Elsterian (= Anglian) Stage; four warm/cold climatic cycles are recognized below Elsterian tills in The Netherlands and are collectively termed the 'Cromerian Complex', the magnetic reversal occurring between the peak of the earliest of the four temperate episodes and the trough of the succeeding glacial (Zagwijn *et al.*, 1971; de Jong, 1988; Chapter 1).

Exactly how the Little Oakley interglacial relates to the 'Cromerian Complex' of The Netherlands is difficult to determine, as the four interglacials comprising this complex were distinguished using palynology alone. Correlation with 'Cromerian Complex Interglacial I' (or earlier temperate intervals) is precluded by the absence of Tertiary relics such as *Eucommia* and *Tsuga* (Gibbard and Peglar, 1990). Similarly, the absence of *Taxus* and/or *Carpinus* in the early temperate substage (biozone II) differentiates the sequence in the Little Oakley Silts and Sands from 'Cromerian Complex Interglacials II and III'. There are similarities, however, between the palynology of Little Oakley and Noordbergum, a site in The Netherlands that has been assigned to 'Interglacial IV' (de Jong, 1988). Noordbergum has also been tentatively correlated with the Cromerian stratotype at West Runton (Zagwijn, 1985), a suggestion supported by amino acid ratios from Noordbergum (Miller and Mangerud, 1985). However, the recent recognition of *Arvicola cantiana* amongst collections from Noordbergum (von Kolfschoten, 1988) argues against these correlations, since the earlier vole *Mimomys savini* occurs at both West Runton and Little Oakley, rather than *A. cantiana* (Stuart, 1975, 1981, 1982a; Bridgland *et al.*, 1988). This has led to the suggestion that the Dutch sequence is itself incomplete, that the British Cromerian (*sensu stricto*) is missing in The Netherlands and that Little Oakley and West Runton are broadly of 'late Cromerian Complex' age (Bridgland *et al.*, 1990).

The Matuyama–Brunhes palaeomagnetic boundary is recognized as a highly significant stratigraphical marker within the Pleistocene, widely adopted as the base of the Middle Pleistocene (Richmond and Fullerton, 1986). Since this magnetic reversal approximately coincides, in the sedimentary record, with the end of 'Cromerian Complex Interglacial I' of the Dutch sequence, palaeomagnetic information is of considerable value in the study of sites of 'Cromerian Complex' age. The polarity of the Little Oakley Silts and Sands has been established as normal (Austin, in Bridgland *et al.*, 1990), indicating deposition after the Matuyama–Brunhes reversal and therefore after 'Cromerian Complex Interglacial I' of The Netherlands. This implies an age of somewhat less than 780,000 years BP, the approximate date of the magnetic reversal (Shackleton *et al.*, 1990).

Within the British sequence, the interglacial at Little Oakley has been interpreted as more recent than that at Ardleigh, since the Little Oakley Channel is cut through the local Oakley Gravel, the downstream equivalent of the Ardleigh Gravel (Gibbard, 1988b; Bridgland *et al.*, 1990). It is important to note, however, that the Little Oakley Silts and Sands occupy a position well below the original upper surface level of the Oakley Formation, in an area of considerable dissection (Fig. 5.3). The maximum thickness of the fossiliferous sediments is *c.* 4 m and they do not extend higher than *c.* 24 m O.D. (Fig. 5.11), whereas the Oakley Gravel terrace surface, prior to subsequent erosion, was probably aggraded to around 28–30 m O.D. It is therefore possible that a later aggradation of Oakley Gravel occurred, after the deposition of the Little Oakley Silts and Sands, and was removed by the erosion of the upper 4–5 m of the terrace deposits. Thus it is possible that the interglacials represented at Little Oakley and Ardleigh are one and the same. There is nothing in the palynological records from these two sites to disprove this alternative hypothesis (P.L. Gibbard, pers. comm.), but pollen is the only significant biostratigraphical evidence that the two localities both provide. If the terminology of the climatic model for terrace formation (presented in Chapter 1) is adopted, the two possible interpretations of the relation between the Ardleigh and Little Oakley sequences can be further examined. If the same interglacial is represented at both sites, the gravel into which the Little Oakley channel is incised must be the pre-interglacial (phase 2) part of the Ardleigh/Oakley Formation, with the post-interglacial (phase 4) gravel missing from the immediate area. A single cold-warm-cold cycle would thus be represented in the deposits of the Ardleigh/Oakley Formation. If different interglacials are represented, and the Little Oakley Silts and Sands were deposited by the Thames and not a later tributary, the implication would be that no rejuvenation occurred in this part of the Thames catchment during the cold episode represented by the Ardleigh Upper Gravel.

Conclusions

The Little Oakley interglacial site is clearly a critical locality for Pleistocene palaeontology and stratigraphy. The interglacial sediments, filling a channel cut through the local early Thames-Medway gravel (the Oakley Gravel), are richly fossiliferous, yielding pollen and the remains of molluscs, ostracods, mammals and fish. The combination of the various fossil types present indicates that the sediments represent a period of generally warm climate, comparable to that of the present day. The pollen provides a detailed record of climatic and vegetational change during the first half of an interglacial (temperate) period. The mammals include the extinct vole *Mimomys savini*, the Etruscan rhinoceros and the giant deer *Megaloceros verticornis*. These species, as well as certain extinct molluscs from Little Oakley, are characteristic of several temperate-climate episodes that, alternating with colder periods, preceded the major glaciation during which the Thames was diverted. This period of fluctuating climate, recognized in The Netherlands and called the 'Cromerian Complex', covers a long span of Pleistocene time, between around 750,000 and 450,000 years BP. The name derives from the Cromerian Stage, defined in north Norfolk, which is thought to coincide with part of the 'Cromerian Complex'. The significance of the Little Oakley interglacial deposits is heightened by the fact that they occur within the early terrace deposits of the Thames system. They therefore provide a means for dating the Thames terrace sequence and to enable improved correlation between the Thames Basin and Pleistocene sequences in other parts of Britain and western Europe.

WIVENHOE GRAVEL PIT (TM 005235)

D.R. Bridgland

Highlights

At Wivenhoe, periglacial Thames gravels both underlie and overlie an organic silty clay that contains the remains of temperate-climate plants and beetles. It is believed that this entire sequence pre-dates the Anglian glaciation, which would suggest that the temperate interval represented falls within the 'Cromerian Complex' as recognized in The Netherlands.

Introduction

Wivenhoe Gravel Pit is located near the southern edge of the Tendring Plateau, *c*. 2 km from the estuary of the River Colne. Deposits classified as part of the Kesgrave Sands and Gravels (Rose *et al.*, 1976) have been exploited here for many years, old workings covering around half a square kilometre. The site is now regarded as the type locality for the Wivenhoe Gravel, which is chronologically the third of the four terrace formations (Figs 5.2 and 5.3) that constitute the Low-level Kesgrave Subgroup (Bridgland, 1988a; see above, Introduction to Part 1).

Recent appraisal of the site has revealed fossiliferous sediments apparently interbedded with the Wivenhoe Gravel (Bridgland *et al.*, 1988; Fig. 5.13). These sediments have yielded pollen from temperate-climate trees, together with other plant fossils and beetle remains. The biostratigraphical evidence is as yet insufficiently distinctive to identify any particular temperate episode.

The stratigraphical position of the fossiliferous sediments at Wivenhoe is highly significant. They occur within a terrace formation (the Wivenhoe/Cooks Green Gravel) that is stratigraphically younger than the Ardleigh/Oakley Gravel, the formation that includes the Cromerian deposits at Little Oakley, and stratigraphically older than the St Osyth/Holland Formation, which is correlated with the Anglian Stage glacial (Bridgland, 1988a; Bridgland *et al.*, 1988; Fig. 5.3; see also Little Oakley, and St Osyth and Holland-on-Sea). This makes the Wivenhoe deposits strong candidates for correlation with 'late Cromerian' sites recognized elsewhere in Britain and in north-west Europe. There is controversy at present over whether such sites represent the latter part of the Cromerian Stage (*sensu* West Runton) or an additional temperate episode between the type Cromerian interglacial and the Anglian glacial (see Chapter 1). Further research is required, however, to establish the age of the Wivenhoe deposits satisfactorily.

Description

Peaty deposits containing beetles were first reported from the Wivenhoe pit by McKeown and Samuel (1985), who provided a photographic record of a section showing organic sediments above gravel. These authors suggested that the peaty deposits were of Cromerian age, but cited no supporting evidence. Later investigations at the present GCR site revealed that deposits rich in plant material occur near the top of the Wivenhoe Gravel in a restricted area around TM 050236 (Bridgland *et al.*, 1988). The GCR section at Wivenhoe reveals the following sequence (Fig. 5.13):

			Thickness
4.	Silty clay, locally ?organic, cryoturbated		*c.* 1.5 m
3.	Gravel and sand, horizontally bedded	(Wivenhoe Upper Gravel)	1.5 m
2.	Organic silty clay with scattered pebbles and plant remains, brecciated		*c.* 1 m
1.	Medium-coarse sandy gravel interbedded with sand	(Wivenhoe Lower Gravel)	*c.* 5 m

The sequence is disrupted by frost cracks and ice-wedge pseudomorphs. Most of these appear to emanate from various levels within the upper gravel (member 3), but there are clearly some that formed in the sediments below prior to the deposition of this member (Fig. 5.13). These features indicate that the upper gravel was laid down during a periglacial episode that followed the temperate period represented by the organic clay (member 2). Analysis of the clast content of the gravels below and above the organic clay has indicated that they have close similarities and that both are typical of the Low-level Kesgrave Subgroup (Bridgland, 1988a; Bridgland *et al.*, 1988; Table 5.2).

The organic silty clay contains pollen, plant macrofossils and insect remains. A pollen sequence has been determined (Gibbard, in Bridgland *et al.*, 1988), its arboreal component dominated by birch, pine, spruce and alder, with smaller quantities of, for example, silver fir, elm, oak, hornbeam, hazel and willow. A 500 gm sample from this unit has yielded a limited flora, comprising fruits of *Schoenoplectus lacustris* (L.) Palla, trigonal nutlets of *Carex* spp. and seeds of *Menyanthus trifoliata* L. (M.H. Field, pers. comm.). Two flint flakes, evidently formed by percussion, were recovered from the organic silty clay (Fig. 5.13). Their interpretation as Palaeolithic artefacts, claimed by Bridgland *et al.* (1988), remains equivocal (see below).

Thin, involuted lenses of dark grey, possibly organic clay occur at higher levels in the sequence, within the cryoturbated upper part of the upper gravel (Fig. 5.13). No pollen or other fossil material has been recovered from these levels (P.L. Gibbard, pers. comm.), which may represent reworking of organic material from the underlying silty clay.

Interpretation

This site is an important source of evidence for the reconstruction of Thames drainage evolution in the early Middle Pleistocene, shortly before the diversion of the river during the Anglian Stage. Prior to the discovery of various pre-Anglian interglacial sites within the Low-level Kesgrave Subgroup deposits of Essex (Bridgland *et al.*, 1988; see above, Ardleigh and Little Oakley), little was known about this time period. It had been widely accepted that all of

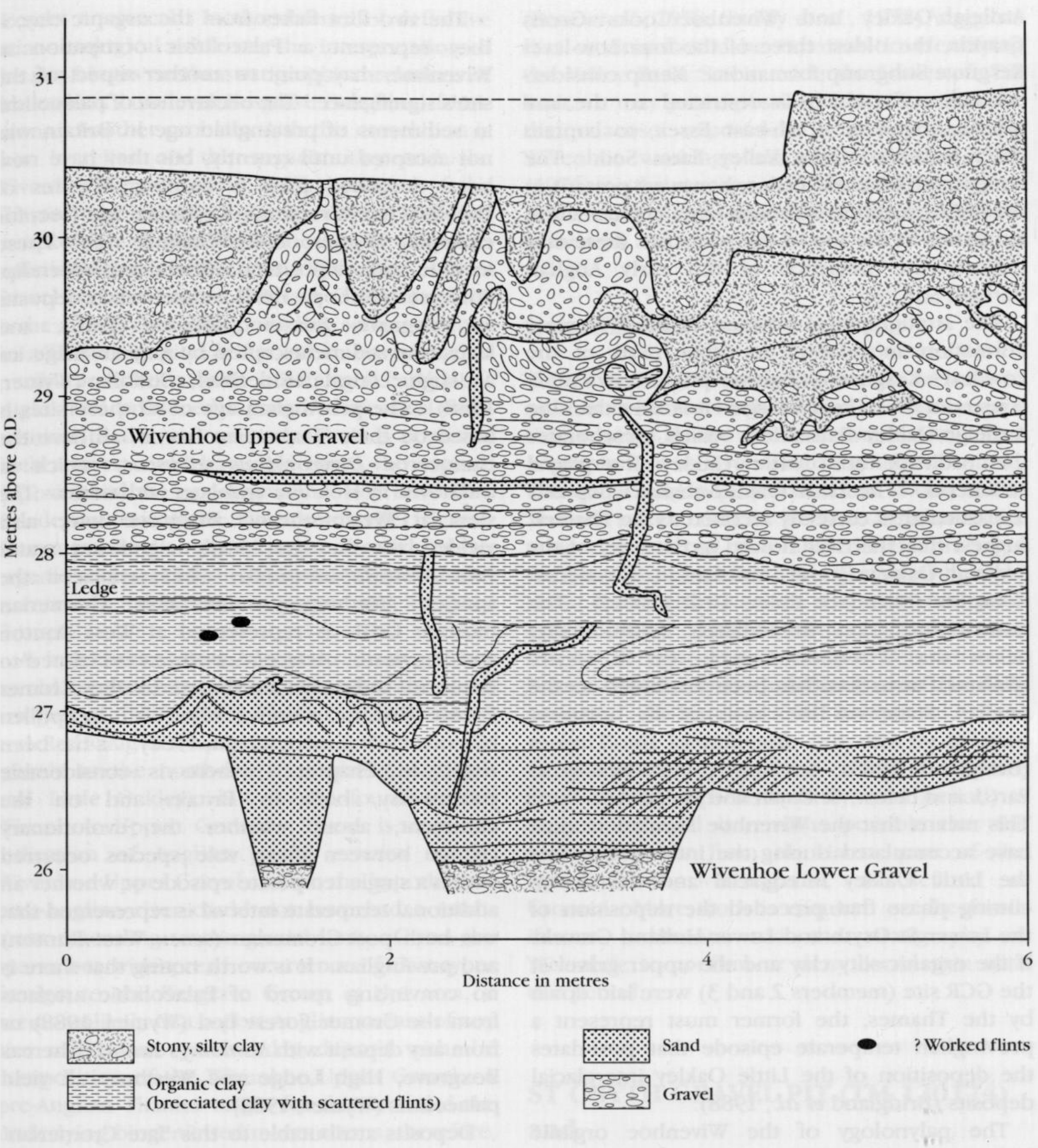


Figure 5.13 Section at Wivenhoe, showing the organic clay (modified from Bridgland *et al.*, 1988)

the Kesgrave Sands and Gravels were aggraded during the Beestonian Stage (Rose *et al.*, 1976; Rose and Allen, 1977), but later studies revealed that a series of distinct terrace formations is represented and that deposition of these early Thames gravels spanned a large proportion of Pleistocene time (Rose, 1983a; Kemp, 1985a; Rose *et al.*, 1985b; see above, Introduction to Part 1).

The temperate-climate Valley Farm Soil and the (superimposed) periglacial Barham Soil were both identified at Wivenhoe by Rose *et al.* (1976), although the stratigraphical control of overlying Anglian glacial sediments is lacking at this site, which lies outside the maximum ice limit (Fig. 5.4F). Kemp (1985a) observed that the Soil Survey of England and Wales had mapped a stagnogleyic palaeo-argillic brown earth soil (their Tendring Association) on undissected remnants of the Waldringfield, Ardleigh/Oakley and Wivenhoe/Cooks Green Gravels, the oldest three of the four Low-level Kesgrave Subgroup formations. Kemp considered this soil, which is restricted to the unglaciated area of north-east Essex, to contain relict features of the Valley Farm Soil. The temperate palaeosol is not, however, present in the GCR section, although the cryoturbation structures at the top of the sequence there may indicate the presence of the early Anglian Barham Soil.

The stratigraphical position of the Wivenhoe Formation in relation to other parts of the Low-level Kesgrave Subgroup puts considerable constraint on its relative age. It is later than the Ardleigh/Oakley Formation, which incorporates the Ardleigh and Little Oakley interglacial sediments. The Little Oakley channel deposits in particular, if correctly ascribed to the Thames, suggest that the river flowed at the level of the Ardleigh/Oakley Gravel until late in 'Cromerian Complex' times (see above, Little Oakley). The terrace formation immediately (altitudinally) below the Wivenhoe Gravel, the St Osyth/Holland Formation, has been attributed to the Anglian Stage on the basis of its apparent correlation with the diversion of the Thames (Bridgland, 1988a; see above, Introduction to Part 1 and below, St Osyth and Holland-on-Sea). This means that the Wivenhoe Formation must have accumulated during the interval between the Little Oakley interglacial and the down-cutting phase that preceded the deposition of the Lower St Osyth and Lower Holland Gravels. If the organic silty clay and the upper gravel at the GCR site (members 2 and 3) were laid down by the Thames, the former must represent a pre-Anglian temperate episode that post-dates the deposition of the Little Oakley interglacial deposits (Bridgland *et al.*, 1988).

The palynology of the Wivenhoe organic sediments is not stratigraphically diagnostic. It merely provides a record of boreal forest vegetation of a type found in many interglacial and interstadial sequences (P.L. Gibbard, pers. comm.). The plant macrofossils are equally undiagnostic. They indicate the presence of a marshy area adjacent to a water body, but the three species listed above occur in cold- and warm-climate sediments throughout the British Pleistocene (M.H. Field, pers. comm.). It is hoped that further details of the palaeontology, when available, will provide information of stratigraphical significance.

The two flint flakes from the organic clay, if they represent a Palaeolithic occupation at Wivenhoe, may point to another aspect of the site's significance. The occurrence of palaeoliths in sediments of pre-Anglian age in Britain was not accepted until recently, but they have now been described from a number of sites of probable late 'Cromerian Complex' age (see, for example, Wymer, 1988; Chapter 1). These include cave deposits at Westbury-sub-Mendip, Somerset (Bishop, 1982), raised-beach deposits at Boxgrove, Sussex (Roberts, 1986), and lacustrine sediments rafted by Anglian Stage ice at High Lodge, Mildenhall, Suffolk (Wymer, 1988). The pre-Anglian age of all these sites is based on their mammalian faunas; all have the rhinoceros *Dicerorhinus etruscus*, which is unknown in Hoxnian and later sediments. The sites at Westbury and Boxgrove have also yielded the stratigraphically significant water vole *Arvicola cantiana*, which replaced the species *Mimomys savini* after Cromerian biozone CrIII, as represented at West Runton and Sugworth. *Arvicola cantiana* is claimed to occur in sediments attributed to the Cromer Forest Bed at Ostend, Norfolk, in pollen biozone CrIV (Stuart, 1982a, 1988). As has been noted in Chapter 1, there is considerable controversy, both in Britain and on the continent, about whether the evolutionary change between these vole species occurred within a single temperate episode or whether an additional temperate interval is represented that was both post-Cromerian (*sensu* West Runton) and pre-Anglian. It is worth noting that there is no convincing record of Palaeolithic artefacts from the Cromer Forest Bed (Wymer, 1988) or from any deposit with *Mimomys savini*, whereas Boxgrove, High Lodge and Westbury all yield palaeoliths (Wymer, 1988).

Deposits attributable to this 'late Cromerian' interval (characterized by *A. cantiana*) have yet to be identified in association with the Thames sequence. They would be anticipated in a stratigraphical position within the terrace sequence between Cromerian *sensu lato* sites that have *Mimomys savini*, such as Little Oakley, and the Anglian Stage St Osyth/Holland Formation. As the Wivenhoe Formation occupies exactly this position, the Wivenhoe organic deposit is a prime candidate for the first record of the Westbury temperate interval in the Thames system.

However, the evidence for assigning the Wivenhoe organic deposit to this interval is at present equivocal. In the absence of definitive palaeontological evidence, the interpretation of the site hinges on the stratigraphical relations of the various Low-level Kesgrave Subgroup formations. Another problem with this correlation is that it relies on the organic clay and the Wivenhoe Upper Gravel being products of the Thames and not of a tributary river. The clast composition of the Wivenhoe Upper Gravel is indistinguishable from the Wivenhoe Lower Gravel and from other Kesgrave Group deposits in the area (Table 5.2), providing some evidence for a Thames origin. It is possible, however, that a tributary stream with a localized catchment might have produced a gravel of identical composition to the various early Thames deposits. Such a river could have laid down the organic deposits and the upper gravel at any time after the deposition of the Wivenhoe Lower Gravel. Thus a pre-Anglian age is only indicated for the organic sediments if the Wivenhoe Upper Gravel is correctly interpreted as part of the Kesgrave Group.

A hypothetical post-Anglian tributary stream would have to have been confined to the western part of the Tendring Plateau, since Medway- and Red Crag-derived material is present in the gravels to the north-east (see above, Ardleigh and Little Oakley), but is not found in the Wivenhoe Upper Gravel. There is also no indication of Anglian glacial erratics in the Wivenhoe Upper Gravel, and so the hypothetical post-Anglian river could not have had a catchment extending to the glacial limit. Given the sparse but widespread occurrence of clast types foreign to the Kesgrave Group in the area, it seems unlikely that a post-Anglian stream of any size could have produced a deposit with the composition of the Wivenhoe Upper Gravel. A pre-Anglian Thames origin for this unit and the underlying biogenic sediments seems, therefore, to be indicated.

Supporting evidence for the occurrence of a further temperate interval between the Little Oakley interglacial and the Anglian Stage is provided by the identification of relict elements of the Valley Farm Soil in the upper levels of the Wivenhoe/Cooks Green Formation (Rose *et al.*, 1976; Kemp, 1985a). In the unglaciated area of north-east Essex, the soil is only present in relict form and there is no upper stratigraphical control on its age. The occurrence of rubified soils similar to the pre-Anglian Valley Farm Soil on post-Anglian deposits in the Chelmsford area (Rose *et al.*, 1978; Sturdy *et al.*, 1978), suggests that caution should be exercised in identifying the Valley Farm Soil outside the Lowestoft Till limit. It may prove possible, however, to relate the palaeosol exposed in other parts of the Wivenhoe workings, recorded by Rose *et al.* (1976), to the stratigraphical level of the organic clay member; an assessment of this relationship is awaited.

Conclusions

The GCR site at Wivenhoe provides sections in sediments formed by the early River Thames at a time when it flowed north-eastwards across East Anglia, before its diversion to its modern course. This is the only locality discovered to date in the Thames system that is likely to represent the temperate interval that immediately preceded the (Anglian) glaciation (this glaciation brought about the river's diversion about 450,000 years ago). Much work is required before this interval, recognized in recent years elsewhere in Britain but as yet undefined, can be fully evaluated. Its status as a full interglacial has yet to be firmly established; it could be that an interstadial (a short-lived temperate-climate event during a predominantly cold period) is represented and it remains possible that the sediments date from the latter part of the type-Cromerian interglacial, as defined at Cromer. More work is required on the fossiliferous sediments and the stratigraphy at Wivenhoe to confirm or deny correlation with this period.

ST OSYTH GRAVEL PIT (TM 120174) and HOLLAND-ON-SEA CLIFF (TM 211166)

D.R. Bridgland

Highlights

Sediments at these two sites record the events immediately prior to and during the glaciation of the Thames valley, leading up to the diversion of the river. At both sites, gravels of the pre-diversion (Kesgrave Group) are overlain by sediments rich in outwash from the ice sheet that blocked the course of the river in central Essex and the Vale of St Albans. At St Osyth the sediments were laid down immediately upstream from the Medway confluence, whereas the gravels at Holland-on-Sea are of Thames-Medway type. The upper gravel at Holland-on-Sea demonstrates that the Medway was unaffected by the glaciation that blocked the Thames.

Introduction

The St Osyth and Holland-on-Sea GCR sites are situated near the southern edge of the Tendring Plateau, in the vicinity of Clacton-on-Sea (Fig. 5.2). The St Osyth pit lies 6 km west of the coast, whereas the Holland cliffs are near the northern end of a 6 km length of erstwhile coastal exposure running north-eastwards from the West Cliff at Clacton, itself part of another GCR site (see Part 2 of this chapter). The St Osyth and Holland sections are both in the lowest of the four Low-level Kesgrave Subgroup formations recognized on the Tendring Plateau (Bridgland, 1988a; Fig. 5.2; see above, Introduction to Part 1). St Osyth lies upstream from the contemporary confluence between the Thames and the Medway, whereas Holland lies within the confluence area (Bridgland *et al.*, 1988, 1990; Fig. 5.4E).

The sites at St Osyth and Holland-on-Sea provide complementary evidence enabling the reconstruction of events in the lower part of the Thames basin during the Anglian glaciation, when the diversion of the river took place. At both sites deposits typical of the Kesgrave Group are overlain by later gravels, believed to have been laid down at the time of the Lowestoft glaciation (Bridgland, 1980, 1983a, 1988a; Bridgland *et al.*, 1988). Considered together, the sites are of considerable stratigraphical significance, since they provide a basis for correlating the terrace sequence in southern East Anglia with the succession in the Middle Thames and the Vale of St Albans, which can also be related to the Anglian glaciation (Table 1.1 and Fig. 1.3).

Description

There have been relatively few descriptions of the Pleistocene deposits in this area, with the notable exception of the Clacton interglacial sediments. Wood (1866b) attributed gravels underlying the coastal district, between St Osyth and Clacton, to his 'East Essex Gravel', equating them with deposits south of the Blackwater estuary (see Part 2 of this chapter). The only available geology map (Old Series, Sheet 48) shows the Tendring Plateau largely covered by 'Glacial Gravel' and 'Glacial Loam', but with the patches of 'Post Glacial' drift fringing the valleys of the Colne and Stour and in the extreme south-east of the area, between St Osyth and the coast. The 'loam' comprises post-Anglian loess mixed with stones from the underlying gravels (Eden, 1980). Misinterpretation of this material has led to the unfounded suggestion that till occurs on the Tendring peninsula (Geological Survey, 1:625,000 Quaternary sheet).

The St Osyth site falls within an outcrop mapped as 'Glacial Gravel', separated from deposits to the east, which were mapped as 'Post Glacial', by the valley of a stream flowing into the St Osyth Creek. The 'Post Glacial' deposits extend to the coast, where they are synonymous with the 'Holland Gravel' of Warren (1923a; 1955). However, it is apparent from clast-lithological studies that the gravels on either side of the above-mentioned stream were formerly continuous (Bridgland, 1983a; Bridgland *et al.*, 1988), despite the fact that they were classified differently by the Geological Survey. Indeed, Oakley and Leakey (1937, fig. 10) classified the St Osyth deposits, in common with all the gravels east of a line from Brightlingsea to Great Oakley, as fluviatile.

Warren (1923a, 1924b, 1933) had already interpreted the gravels of the Tendring Plateau as fluvial deposits and attributed them to the Thames, although at that time he was not aware of their considerable antiquity. The discovery of the Cromerian channel-fill at Little Oakley (see above, Little Oakley) led Warren (1940, 1955, 1957) to realize that these gravels were the products of Thames drainage prior to the diversion of the river into its modern valley. This anticipated the inclusion of these deposits by Rose *et al.* (1976) in the newly-defined Kesgrave Sands and Gravels, which they attributed to the pre-diversion Thames.

There are, in fact, significant differences between the Kesgrave Group deposits at St Osyth and Holland-on-Sea, but these represent downstream compositional changes within a single gravel formation. These early Thames terrace deposits are locally overlain by later gravels of a different type, which prove to be of considerable stratigraphical significance.

St Osyth Gravel Pit

Various commercial workings have exploited the spread of gravel to the north-west of St Osyth over the past few decades. The full thickness of the aggradational sequence is only preserved in a small part of the area, the upper horizons having been widely denuded as a result of later dissection. The GCR site occupies approximately the highest point on the outcrop and appears to preserve the most complete sequence. The lower and major part of the sediments here comprise up to 10 m of typical coarse, predominantly matrix-supported gravels of Kesgrave type. Palaeocurrent data from cross-bedded sandy intercalations indicate flow to the south-east, in keeping with the interpretation of the sediments as products of the early Thames, which flowed from the Colchester area towards Clacton (Bridgland, 1980, 1983a). This, the Lower St Osyth Gravel, is overlain by up to 3 m of sand, into which is channelled 1–2 m of gravel of a quite different character, the Upper St Osyth Gravel (Fig. 5.14). The latter comprises fine gravel material scattered in a matrix of coarse sand. It contains a higher proportion of flint than the lower gravel, but a much smaller proportion of rounded pebbles reworked from the Palaeogene. Furthermore, the Upper St

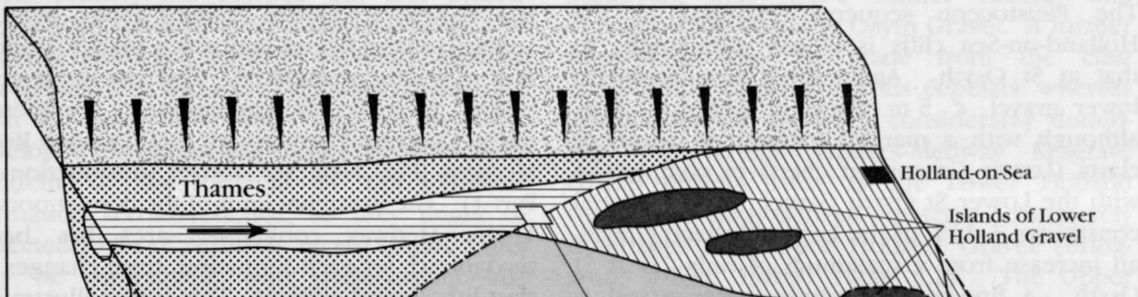


Figure 5.14 Stylized block diagram showing the stratigraphical relations of the Lower and Upper St Osyth and Holland Gravels.

Osyth Gravel contains fewer exotic rock-types than Kesgrave Group gravels (including the Lower St Osyth Gravel) and those present show greater affinities to Anglian glacial gravels than to the underlying Kesgrave Thames deposits. In particular, the exotic suite in the Upper St Osyth Gravel includes *Rhaxella* chert, a rock derived from the Oxfordian of north Yorkshire that, in the London Basin and southern East Anglia (outside the Crag Basin), is present only in Anglian glacial deposits or, reworked, in post-Anglian sediments (Bridgland, 1983a, 1986b). It is uncertain at present whether the intermediate sand has closer affinities with the upper or lower gravel. It is hoped that an analysis of heavy minerals, presently being undertaken, will answer this particular question.

Holland-on-Sea Cliff

The Pleistocene sequence exposed in the Holland-on-Sea cliffs is closely comparable to that at St Osyth. Again there is a dominant lower gravel, *c.* 5 m thick, of Kesgrave type, although with a marked increase in southern clasts (Lower Greensand chert) in comparison with the Lower St Osyth Gravel. Such material constitutes 3–11% of the Lower Holland Gravel, an increase from a maximum of only 2% at St Osyth. A fine-grained, sandy upper gravel is again recognized, separated from the underlying coarser gravel by sands. However, this separation is less well-marked, with alternations of sand and gravel, of which the lower horizons have clast compositions transitional between the Lower and Upper Holland Gravels (Bridgland *et al.*, 1988; Table 5.2, sample 2B), possibly reflecting reworking of the former. The Upper Holland Gravel has been sampled over a wide area inland, as well as at the type section. At some localities it contains large proportions of southern lithologies, one analysis yielding nearly 32% of such material (Bridgland, 1983a; see below). The deposit is otherwise similar in composition and sedimentary characteristics to the Upper St Osyth Gravel.

Interpretation

The principal scientific interest at the St Osyth and Holland-on-Sea GCR sites is stratigraphical. Each is the type site of two lithostratigraphical units: St Osyth pit is the type locality for the Lower St Osyth Gravel and the Upper St Osyth Gravel, whereas Holland Cliffs provide the type section for the Lower Holland Gravel and the Upper Holland Gravel. The interrelations between these deposits and the palaeogeographical interpretation that has been determined from their clast composition provide an illustration, in north-east Essex, of the glacial interruption of Thames drainage that occurred, further upstream, during the Anglian Stage. This provides an important means of correlation with the sequence in the Vale of St Albans (see Fig. 1.3).

The Lower St Osyth and Lower Holland Gravels together represent the lowest (and therefore the youngest) formation within the Kesgrave Group (Bridgland, 1983a, 1988a; Fig. 5.2). They are separately named because they differ from one another in clast-lithological composition; the Lower St Osyth Gravel is a typical Kesgrave Group Thames gravel, but the Lower Holland Gravel contains a higher proportion of southern material. This change is considered to reflect the contemporary confluence of the Kesgrave Thames with the extended River Medway (Fig. 5.4E; see above, Introduction to Part 1). The upstream limit of the contemporary Thames-Medway confluence area has been recognized, for each formation, from changes in clast-lithological content. This is best illustrated by differences in the ratio of southern material to quartz and quartzites (Bridgland *et al.*, 1988, 1990; see above, Little Oakley). Kesgrave Thames gravels upstream from the Medway confluence are characterized by values for this ratio below 0.10, whereas the ratio increases progressively eastwards from the upstream edge of the confluence area (Bridgland *et al.*, 1988; Table 5.2). The Lower St Osyth/Lower Holland Gravel has been sampled at various points between Fingringhoe (TM 042202) and Holland-on-Sea, enabling a more detailed appraisal of these compositional changes than has been possible so far in any of the higher-level formations (Bridgland *et al.*, 1990). This has shown the change from Lower St Osyth to Lower Holland Gravel to occur within the eastern extension of the St Osyth pit (TM 120170; Fig. 5.14), less than 0.5 km to the east of the GCR site (Bridgland *et al.*, 1988).

The fact that the Lower St Osyth/Lower Holland Gravel is the lowest of the pre-diversion (Low-level Kesgrave) Thames formations suggests that its deposition closely preceded the diversion of the river, particularly since temperate sediments of 'Cromerian Complex' age are recognized within higher formations in the area. This led Bridgland (1983a, 1988a) to ascribe this formation to the Anglian Stage and propose a correlation with the Winter Hill Gravel of the Middle Thames. It may be significant that the 'Tendring Association', the soil unit believed to contain relict elements of the Valley Farm Soil (see above, Wivenhoe), has not been mapped on the St Osyth/Holland Formation (Kemp, 1985a), nor were the Valley Farm or Barham Soils recognized in exposures recorded at St Osyth by Rose *et al.* (1976). This may indicate that no temperate-climate interval separated the aggradation of the Lower St Osyth/Lower Holland Gravel and the Anglian glaciation, as is implied by the ascription of the former to the Anglian Stage. However, J. Rose (pers. comm.) has pointed out that palaeoargillic soils are developed at the land surface on both the Lower and Upper St Osyth and Holland Gravels and that these are difficult to distinguish from the Valley Farm Soil. They are, however, developed on dissection slopes and are independent of the original St Osyth/Holland Formation terrace surface, so they might be expected to be of relatively recent origin. They may be comparable with palaeoargillic and rubified soils developed on the Anglian till of central Essex (Rose *et al.*, 1978; Sturdy *et al.*, 1978).

There is strong stratigraphical support for the correlation of the St Osyth and Holland Gravel with the Winter Hill/Westmill Gravel of the Middle Thames from the interpretation of the two upper units at St Osyth and Holland-on-Sea. The Upper St Osyth Gravel, recognized at the type site and at Fingringhoe, is a fine sandy gravel with closer compositional affinities to Anglian glacial gravel than to Kesgrave Group Thames deposits. In particular, it is characterized by a low Palaeogene (rounded) flint content, a relatively large non-quartzose exotic component and the occurrence of *Rhaxella* chert, all features that typify Anglian outwash gravels but would be unusual in the Kesgrave Group (*Rhaxella* chert is found consistently in Kesgrave Group deposits only within the Crag Basin, where the lithology has been reworked from the Crag). The deposit lacks the non-durable, calcareous component of ice-proximal gravels associated with the Lowestoft Till; calcareous clasts would probably not have survived fluvial transport from the ice front, which lay *c.* 20 km west of St Osyth (Fig. 5.4F). The Upper St Osyth Member is therefore interpreted as a distal outwash gravel.

East of St Osyth, in the former Thames-Medway confluence area, the Lower Holland Gravel is overlain by another fine-grained gravel, similar to that at St Osyth in that it is relatively poor in Palaeogene flint and quartzose exotics. However, this Upper Holland Gravel contains large amounts of southern material (Bridgland, 1983a; Bridgland *et al.*, 1988). In fact, the deposit contains as much Lower Greensand chert as the early Medway gravels to the south of the Blackwater estuary (Tables 5.3 and 5.5; see Part 2 of this chapter). The favoured interpretation of the Upper Holland Gravel is that it represents the confluence of the Medway, not with the Thames, but with the outwash stream, occupying that river's former course, that deposited the Upper St Osyth Gravel. A further observation can be made from the clast composition of these various deposits: whereas Thames-derived sediment considerably dominates the various Thames-Medway Kesgrave Group gravels, such as the Lower Holland Gravel, Medway-derived material completely dominates the Upper Holland Gravel (Bridgland, 1983a, 1988a; Table 5.2). The Upper Holland Gravel has been sampled over a wide area between the St Osyth pits and the type section. Its southern component generally increases in size downstream, although the highest figure, 31.4%, was encountered in a sample from Burrs Road (TM 193173), 2.5 km to the north-west of the Holland-on-Sea GCR site (Table 5.2). The Upper Holland Gravel appears to be much more widely distributed than the Upper St Osyth Gravel, the occurrence of which is extremely localized. This again suggests that the outwash stream responsible for the Upper St Osyth Gravel was much smaller than the contemporary River Medway, into which it flowed to the east of St Osyth.

The Upper St Osyth Gravel, even as far upstream as Fingringhoe, also contains a significant southern component (Table 5.2). This is unexpected in what is believed to be the product of an outwash stream that issued from the Anglian ice sheet. Anglian Stage glacial deposits in Essex generally contain such material in small quantities, reworked from earlier sediments such as the Kesgrave Sands and Gravels, in which Greensand chert has been traced as far

Table 5.5 Clast-lithological composition of gravels described in Chapter 5, Parts 2 and 3.

			Flint			Southern			Exotics								
Gravel	**Site**	**Sample**	**Tertiary**	**Nodular**	**Total**	**Gnsd chert**	**Hastings Beds**	**Total**	**Quartz**	**Quartzite**	**Carb chert**	**Rhax chert**	**Total**	**Ratio (sthrn: q/qtzt)**	**Ratio (qtz:qtzt)**	**Total count**	**National Grid Reference**
Tributary gravels																	
Blackwater	Gt Totham	1	31.7	10.0	80.5	0.2		0.2	8.7	7.2	2.0	0.5	19.0	0.01	1.20	609	TL 865091
Terrace 2	*11.2-16*	*1*	*28.4*	*5.7*	*78.1*	*1.1*		*1.1*	*9.8*	*6.4*	*2.7*	*0.2*	*20.5*	*0.07*	*1.53*	*1092*	
gravel		2	41.2	9.8	78.6				11.2	8.5	0.8	0.6	21.2		1.32	481.0	TL 865091
	11.2-16	*2*	*34.3*	*5.2*	*77.8*	*0.4*		*0.4*	*11.8*	*6.8*	*1.6*	*0.4*	*21.8*	*0.02*	*1.72*	*834*	
E. Mersea	Restrnt site	1	35.4	12.7	85.2	7.4		7.6	4.6	2.0	0.3	0.3	7.1	1.07	2.25	393	TM 0526 1362
Restaurant	*11.2-16*	*1*	*41.5*	*4.2*	*83.1*	*8.3*		*8.4*	*4.3*	*2.3*	*1.0*	*0.1*	*8.4*	*1.26*	*1.86*	*1197*	
Gravel	Hippo site	1	42.2	12.9	83.7	6.2		6.2	4.0	4.0	1.1	0.2	10.2	0.78	1.00	630	TM 0653 1434
Tollesbury	Garlands Fm	1A	37.8	12.9	83.6				9.4	3.5	1.1	0.1	16.2		2.71	805	TL 9467 1059
Gravel		1B	40.4	•	82.6	0.1		0.1	11.6	3.9	0.4		17.3	0.01	3.00	987	
	11.2-16	*1B*	*33.9*	*8.6*	*77.5*	*0.5*		*0.5*	*14.7*	*3.1*	*1.8*		*22.0*	*0.03*	*4.72*	*1475*	
Gravel above	Maldon	1	32.1	18.2	78.8				7.3	8.5	1.2		21.2		0.86	411	TL 8417 0670
Maldon Till	*11.2-16*	*1*	*28.2*	*8.0*	*65.0*	*1.2*		*1.5*	*18.4*	*7.4*	*1.8*	*0.3*	*33.1*	*0.06*	*2.50*	*326*	
	11.2-16	*3*	*25.5*	*7.3*	*74.2*	*0.4*		*0.4*	*11.3*	*8.0*	*1.8*		*25.1*	*0.02*	*1.41*	*275*	
Anglian	Ugley	1	41.9	23.7	87.9				3.5	0.8	1.5	0.4	11.9		0.22	520	TL 516278
glacial		2	3.6	37.6	87.1				2.6	1.7	2.1	1.7	12.6		0.64	420	
gravels (1)																	
Brightlingsea	Bghtlngsea	1	26.4	12.9	80.5	0.3		0.3	11.0	8.2	1.9		21.4	0.01	1.33	364	TM 1282 3125
Gravel	*11.2-16*	*2*	*27.8*	*73.0*	*0.9*			*0.9*	*15.3*	*7.0*	*2.5*	*0.4*	*26.1*	*0.04*	*2.18*	*800*	
East Mersea Hippo site, gravel in brickearth		1	44.4	12.5	84.7	11.6		11.6	1.6	1.9		0.3	3.8	3.36	0.83	320	TM 0652 1434
Low-level East Essex Gravel																	
Barling/Dam-	D. Wick	1	52.0	14.5	88.3	10.6		10.9	0.4	0.4			0.8	14.00	1.00	256	TQ 9614 9268
mer Wick	*11.2-16*	*1*	*46.9*	*2.4*	*87.8*	*9.8*		*10.0*	*0.9*	*0.4*	*0.5*	*0.4*	*2.3*	*7.50*	*2.33*	*752*	
Gravel	Barling	1	33.7	•	80.4	18.6		18.6	1.0				1.0	19.00		306	TQ 9318 9018
Mersea	West Mersea	1	38.6	•	82.4	14.0	0.2	14.2	1.9	0.9		0.3	3.5	5.13	2.20	578	TM 0134 1361
Island		2	44.8	7.9	87.7	9.5		10.0	1.2	0.2	0.5		2.3	7.17	5.00	431	TM 0144 1373
Gravel	Fen Farm	1	47.6	•	87.2	10.7		10.7	1.5	0.4	0.2		2.2	5.50	4.00	553	TM 0590 1444
		2	52.3	2.9	90.0	7.6		7.6	1.2	0.6	0.2	0.4	2.3	4.33	2.00	512	TM 0583 1437
	11.2-16	*2*	*47.5*	*2.9*	*88.2*	*8.7*		*8.7*	*1.7*	*0.5*	*0.4*	*0.1*	*3.1*	*3.86*	*3.38*	*1573*	
	Cudmore Grove	1	47.1	11.6	89.9	6.7		6.8	1.1	1.5	0.3	0.2	3.3	2.57	0.75	1061	TM 0667 1451
		2	45.3	8.8	85.0	11.5		11.6	1.4	1.0	0.7		3.4	4.88	1.29	671	TM 0676 1458
	Point Clear	1	33.1	•	77.3	19.9	0.2	20.1	0.9		0.7	0.4	2.6	22.80		568	TM 1023 1480
Cudmore Grove	Channel	1	40.2	11.6	85.0	14.0		14.0	0.7	0.3			1.0	14.00	2.00	301	TM 0664 1447
lag gravel (2)	*11.2-16*	*1*	*48.1*	*4.1*	*86.9*	*9.9*	*0.6*	*10.8*	*1.3*	*0.7*	*0.4*		*2.4*	*5.50*	*1.80*	*715*	
Wigborough	Wigborough	1A	42.9	•	85.0	4.1	0.3	4.4	5.9	3.4	0.3		10.1	0.53	1.75	387	TM 1176 1447
Gravel	Wick	1B	40.4	8.0	79.7	6.7	0.2	7.1	8.0	3.5	0.5		13.1	0.62	2.25	565	
	Jaywick	1	51.0	4.3	81.3	4.8		4.8	7.0	5.3	0.2		13.7	0.39	1.32	416	TM 1502 1419
	11.2-16	*1*	*42.1*	*4.1*	*82.4*	*6.0*		*6.0*	*7.3*	*2.0*	*0.7*	*0.2*	*11.6*	*0.65*	*3.69*	*813*	
Upper gravel	Clacton	4A	45.0	10.5	89.1	8.1		8.1	0.8	0.9	0.9		2.8	4.62	0.86	742	TM 1739 1433
at West Cliff	cliffs	4B	41.0	8.1	83.8	13.4		13.4	0.4	0.9	1.3		2.9	10.17	0.50	456	
	11.2-16	*4B*	*51.4*	*4.6*	*86.6*	*8.9*		*9.0*	*2.7*	*1.4*	*0.2*	*0.2*	*4.4*	*2.18*	*1.94*	*1217*	
Clacton	Lion Point	1	28.2	•	79.2	17.8		17.8	1.2	1.5	0.3		3.1	6.57	0.75	259	TM 1445 1274
Channel		2	42.3	9.8	86.9	8.9	0.3	9.2	2.6	0.7	0.3		3.9	2.80	4.00	305	TM 1445 1274
Gravel	*11.2-16*	*2*	*46.5*	*5.6*	*88.9*	*6.1*		*6.1*	*2.2*	*0.7*	*0.7*	*0.4*	*4.9*	*2.10*	*3.20*	*721*	
	Butlins	1	46.0	9.3	90.1	7.2		7.2	1.5	0.3	0.6		2.4	4.00	4.00	335	TM 1546 1382
	11.2-16	*1*	*39.8*	*4.9*	*85.9*	*8.0*	*0.1*	*8.2*	*2.2*	*2.3*	*0.4*	*0.4*	*5.7*	*1.86*	*0.95*	*973*	
Southchurch	Southend	1	33.6	•	76.2	20.9		21.2	0.7	0.2	0.5	1.1	2.6	26.00	4.00	613	TQ 8962 8750
/Asheldham	Goldsands	1A	41.6	•	84.0	12.8		13.5	0.9		0.5	0.9	2.3	15.00		445	TQ 9609 9901
Gravel	Pit	1B(3)	51.7	•	88.8	9.50	0.2	9.9	0.4	0.4	0.5	0.1	1.4	14.17	1.00	862	
		2(3)	41.3	11.9	88.0	10.0		10.2	1.1	0.4	0.2	0.1	1.8	7.08	3.00	834	TQ 9608 9897

Gravel	Site	Sample	Flint: Tertiary	Flint: Nodular	Flint: Total	Southern: Gnsd chert	Southern: Hastings Beds	Southern: Total	Exotics: Quartz	Exotics: Quartzite	Exotics: Carb chert	Exotics: Rhax chert	Exotics: Total	Ratio (sthrn: q/qtzt)	Ratio (qtz:qtzt)	Total count	National Grid Reference
High-level East Essex Gravel																	
Chalkwell	Caidge Fm	1	44.7	10.3	74.6	23.7	1.3	25.2	0.3				0.3	98.00		389	TQ 9471 9940
/Caidge	*11.2-16*	*1*	*38.4*	*5.9*	*69.1*	*29.4*	*1.2*	*30.9*								*524*	
Gravel	Chalkwell Pk	1	58.9	2.4	55.1	15.2					0.2		0.2			494	TQ 8579 8636
Canewdon/St	St Law.	1	11.2	*	36.3	62.6		63.2		0.2	0.2		0.4	289.00		457	TQ 9677 0408
Lawrence	*11.2-16*	*1*(4)	*9.8*	*1.9*	*34.6*	*65.1*		*65.4*								*1069*	
Gravel	Canewdon	1B	45.5	9.8	73.0	26.2	0.5	26.9		0.2			0.2	167.00		622	TQ 8973 9468
Belfairs	Bovill Uplands	1A	60.3	*	85.5	14.0	0.3	14.2		0.3			0.3	54.00		380	TQ 9252 9998
/Mayland		1C	46.6	13.3	74.4	24.1	0.6	25.6								324	
Gravel	*11.2-16*	*1C*	*50.3*	*3.7*	*72.8*	*25.6*	*1.1*	*27.0*								*644*	
	Belfairs Pk	1	39.5	8.4	65.2	34.1	0.3	34.5			0.3		0.3			299	TQ 8336 8764
Ashingdon	Mount View	1	43.2	*	80.3	19.7		19.7								620	TQ 8545 9339
Gravel	*11.2-16*	*1*	*46.2*	*3.3*	*75.2*	*23.9*	*0.1*	*24.3*		*0.1*			*0.3*	*184.00*		*757*	
Oakwood	Oakwood	1	62.9	6.8	73.1	26.7	0.2	26.9								558	TQ 8234 8839
Gravel	*11.2-16*	*1*	*44.6*	*3.1*	*69.0*	*30.2*	*0.4*	*30.9*			*0.2*		*0.2*			*1099*	
Daws Heath	Daws Heath	1	63.5	8.3	86.1	13.2	0.3	13.7			0.2		0.2			613	TQ 8068 8887
Gravel	*11.2-16*	*1*	*52.3*	*2.5*	*76.5*	*22.4*	*0.6*	*23.3*			*0.2*		*0.2*			*1200*	
Claydons	Claydons	1	72.7	2.7	89.9	9.6	0.2	10.0								553	TQ 8017 8896
Gravel	*11.2-16*	*1*	*61.2*	*2.0*	*83.9*	*15.8*		*16.0*	*0.1*				*0.1*	*112.00*		*701*	

* Not separately recorded

(1) For comparison only - non-durables excluded

(2) Feather edge

(3) From the lower gravel at the GCR site

(4) Subsample

See also notes to Table 4.2, page 181

north as Norfolk (Hey, 1980). However, other features of the clast composition of the Upper St Osyth Gravel (the paucity of reworked Palaeogene flint pebbles, for instance) imply that reworking of material from the Kesgrave Group has been insufficient to account for the high southern count. This is an obvious fact, since the amount of southern material is higher in the Upper St Osyth Gravel than in any Kesgrave Group formation upstream from the Medway confluence. The provenance of this extra southern material was probably the area to the south of Colchester, which, in the Middle Pleistocene, would probably have been covered by high-level left-bank terraces of the early Medway. Work in south-eastern Essex and north Kent has indicated that the Medway is a river of considerable antiquity and that throughout its early course from the Medway Towns to the Blackwater estuary it was progressively migrating eastwards (Bridgland, 1980, 1983a, 1988a; Bridgland and Harding, 1985). It is therefore likely that an extensive terrace system existed to the west of the Anglian course of the Medway, which is depicted in Fig. 5.4 (E and F). It is possible that a small river system drained northwards from this area into the old Thames valley. Its contribution would have been insignificant whilst the Thames continued to supply huge quantities of gravel to the area, but, as with the Medway in the case of the Upper Holland Gravel, this contribution made a significant difference to the gravel load of the Upper St Osyth Gravel outwash stream.

Detailed analysis of the clast composition of these various gravels in north-eastern Essex therefore shows that the Thames was replaced, in Upper St Osyth/Upper Holland Gravel times, by an outwash stream. The explanation of this remarkable change lies in events during the Anglian glaciation of the northern London Basin. Gibbard (1977, 1979) showed that, during this glaciation, ice blocked the early Thames course through the Vale of St Albans, leading to the diversion of the river into its modern valley through London (see Chapter 3). The Upper St Osyth and Upper Holland gravels have been interpreted as deposits laid down during this period when the Thames valley was blocked and the river was not reaching the Tendring Plateau. The Medway, however, was unaffected and continued to flow to Clacton and beyond without hindrance from the glaciation, receiving the Upper St Osyth Gravel outwash stream as a west-bank tributary (Fig. 5.4F).

This interpretation of the sequences at St Osyth and Holland-on-Sea is strengthened by the identification of the next (and final) aggradation in the terrace succession of the Tendring Plateau as the product of the post-diversion Thames-Medway (Fig. 5.5B; see Part 2 of this chapter). The Upper St Osyth/Upper Holland Gravel can be correlated with deposits in other parts of the Thames drainage system that were affected by the (Anglian) glacial diversion of the river. It has been considered (Bridgland *et al.*, 1988) to be a time-equivalent of the (lacustrine) Moor Mill Laminated Clay and the (deltaic) Winter Hill Upper Gravel, both laid down in a proglacial lake that formed when the Thames was blocked, immediately prior to its diversion (Gibbard, 1977; see Chapter 3, Moor Mill). It is probable that the time interval during which the Moor Mill lake existed was relatively brief, perhaps only a few centuries (Bridgland *et al.*, 1988). The reinterpretation of events during the glaciation of the Vale of St Albans, by Cheshire (1981, 1986a), suggests that the Thames was diverted following the formation of the Watton Road Lake, near Hertford, rather than at Moor Mill (see Chapter 3, Part 2). This would indicate precise correlation between the Watton Road lacustrine sediments and the Upper St Osyth/Upper Holland Gravel, making the latter slightly older than is indicated by the correlation with the Moor Mill lake beds. Whichever of these two correlations is correct, the Upper St Osyth/Upper Holland Gravel is clearly one of the most closely datable gravel units in the Thames basin.

Summary

At St Osyth, an important section reveals the lowest Kesgrave Thames formation, the Lower St Osyth Gravel, overlain by fine-grained sandy gravel (Upper St Osyth Gravel), interpreted as distal outwash laid down while the Thames was blocked further upstream. The palaeogeographical interpretation of this sequence cannot be made without reference to the evidence further downstream in the area of the contemporary Thames-Medway confluence. The sequence there is revealed in equally important cliff sections at Holland-on-Sea, where a comparable sequence to that at St Osyth is exposed, with equivalent Lower Holland Gravel overlain by Upper Holland Gravel. The composition of the former is typical of the Kesgrave Sands and Gravels, but the latter is dominated by Medway-derived material. The only way that gravel so closely resembling the Medway deposits further south could have been deposited at Holland, which was clearly within the contemporary Thames-Medway valley, is for there to have been no contribution from the Thames. The only time when the Thames and Medway have not joined, either before or after the diversion of the former, was during the brief period when the Thames was blocked by the Lowestoft Till ice sheet (immediately prior to its diversion). The Upper Holland Gravel, and its upstream equivalent the Upper St Osyth Gravel, are therefore correlated with this glacial event. These deposits thus provide a key stratigraphical marker within the terrace sequence of north-east Essex, one that assists correlation within the Thames system as a whole and with the Pleistocene sequence in other areas.

Conclusions

Using only the evidence of the rock-types present in the gravels at St Osyth and Holland-on-Sea, it is possible to demonstrate the rapid and catastrophic changes that affected the Thames as a result of the most extensive Pleistocene glaciation, during the Anglian Stage (around 450,000 years ago). Comparison of the gravels at these two sites reveals that the north-eastward-flowing Thames abruptly ceased to reach this area, because it was blocked by ice upstream, in what is now Hertfordshire and central Essex. The lower gravel at St Osyth is a typical pre-diversion Thames deposit. The Holland-on-Sea section is downstream of the contemporary confluence with the Medway, so that the Lower Gravel there is a Thames-Medway deposit, although much dominated by Thames material. The upper (later) gravels at both sites are significantly different. In particular, they contain material carried by meltwater streams from the Anglian ice sheet. The River Medway, lying beyond the direct influence of the ice, continued to flow northwards. This is demonstrated by the composition of the upper gravel at Holland-on-Sea, which is very much dominated by Medway material, in marked contrast to the lower gravel. The implication of this is that the Medway was very much larger than the meltwater river that replaced the Thames at that time. After it was diverted into its modern course, the Thames joined with the Medway in the Southend area, approximately at the location where the estuaries of the two rivers join today.

Part 2:

EASTERN ESSEX

D.R. Bridgland

Introduction

The second part of this chapter deals with sites associated with the sequence of terrace deposits classified as 'East Essex Gravel' by Wood (1866b). These deposits primarily occupy the coastal district of Essex between the estuaries of the Thames and Blackwater, although they are also represented on Mersea Island and in the south-eastern corner of the Tendring Plateau (Fig. 5.1). Bisected by the Crouch estuary, this region is characterized by a series of gravel terraces descending south-eastwards, towards the North Sea (see Figs 5.15 and 5.16). These give way inland to higher, isolated hills capped by Bagshot Beds, Claygate Beds and, frequently, high-level gravel remnants (still part of the East Essex Gravel), the highest of which are found on the Rayleigh Hills, up to a maximum height of 76 m O.D. at Hadleigh. The northward extension of part of this sequence to the Clacton area provides a direct link with the stratigraphical sequence on the Tendring Plateau, described in Part 1 of this chapter.

Wood (1866b) believed the East Essex Gravel to be a dissected spread of marine shingle formed in an embayment of the North Sea. Whitaker (1889) interpreted the deposits as a continuation of the gravels of the Lower Thames valley, laid down by a united Thames-Medway river. Holmes (1896), Gregory (1922) and Coles (1934) all attempted the reconstruction of former fluvial courses across this area, the first proposing a route trending east-north-eastwards to the north of the Langdon and Rayleigh Hills, his 'Romford River'. Of these three early workers, Gregory paid most attention to the deposits, noting abundant material from Kent in the composition of the East Essex Gravel. He envisaged these deposits as accumulations, of considerable antiquity, on the northern slope of an extended Weald, pre-dating the excavation of the modern Thames valley.

Work in the late 1960s by Gruhn *et al.* (1974) demonstrated that the gravels of this area represent the left-bank terrace deposits of a fluvial valley system whose eastern side has been lost to the North Sea. In an early application of clast-lithological analysis, they recognized an abundance of Lower Greensand material in the gravels, combined with a paucity of quartz and other 'exotic' lithologies from the north and west. They therefore attributed the bulk of the gravel to the Medway, although noting (after Whitaker, 1889) that the Thames was probably confluent with the Medway at that time. They suggested that the Medway, with a steeper gradient and a more proximal supply of gravel-forming source materials, provided the major part of the gravel load of the Thames-Medway system.

The work of Gruhn *et al.* pre-dated the publication of New Series geological maps of the area (Sheets 241 and 258/9; Bristow, 1985; Lake *et al.*, 1986; also maps in Hollyer and Simmons, 1978, and Simmons, 1978). The East Essex Gravel is divided on these maps into 'Sand and Gravel of Unknown Age' (high-level deposits south of the Crouch) and four terraces, designated 'Crouch Terraces 1–4', the nomenclature reflecting their distribution either side of the modern Crouch estuary rather than implying deposition by that river. A number of buried channels were recognized beneath these terrace gravels and were attributed to subglacial or partly subglacial streams associated with a hitherto unrecognized ice lobe occupying the southern North Sea (Lake *et al.*, 1977). These authors also suggested that the fourth terrace was formed at approximately the same time, as a kame terrace system at the margin of this ice lobe.

More recent appraisal of these deposits has augmented the Geological Survey mapping, using a lithostratigraphical approach based on detailed analysis of clast types and frequencies (Bridgland, 1980, 1983a, 1983b, 1986a, 1986b, 1988a). Two broad types of gravel have been recognized within Wood's East Essex Gravel, differentiated on both clast lithology (Table 5.5) and altitudinal distribution. They comprise an earlier 'High-level East Essex Gravel', composed almost exclusively of local and southern rocks, and a later type, the 'Low-level East Essex Gravel', containing similar materials but with the important addition of a significant suite of exotic rocks derived from the north and west. Within each of these two types of gravel, a number of separate terrace formations can be distinguished on the basis of geological mapping (Table 5.6); the High- and Low-level East Essex Gravels are therefore classified as subgroups.

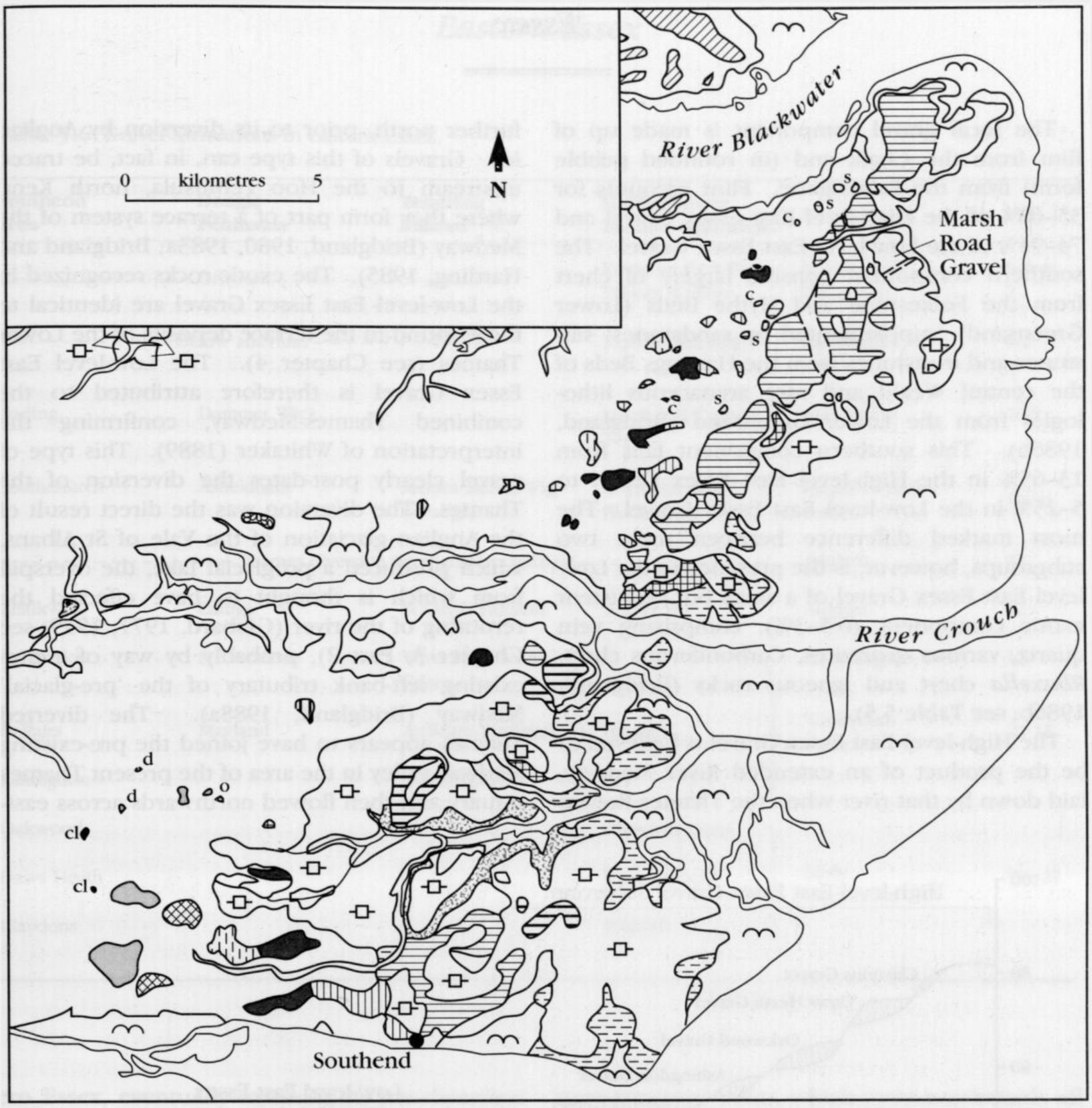


Figure 5.15 The gravels of eastern Essex (after Bridgland, 1988a).

The local gravel component is made up of flint from the Chalk and (in rounded pebble form) from the Palaeogene. Flint accounts for 35–68% of the High-level East Essex Gravel and 74–94% of the Low-level East Essex Gravel. The southern component consists largely of chert from the Folkestone and Hythe Beds (Lower Greensand), supplemented by sandstones, siltstones and ironstones from the Hastings Beds of the central Weald and rare arenaceous lithologies from the Lower Greensand (Bridgland, 1986b). This southern component falls from 13–65% in the High-level East Essex Gravel to 5–25% in the Low-level East Essex Gravel. The most marked difference between these two subgroups, however, is the presence in the Low-level East Essex Gravel of a small but consistent exotic component (0.5–3%), comprising vein quartz, various quartzites, Carboniferous chert, *Rhaxella* chert and igneous rocks (Bridgland, 1986b; see Table 5.5).

The High-level East Essex Gravel is believed to be the product of an extended River Medway, laid down by that river when the Thames flowed further north, prior to its diversion by Anglian ice. Gravels of this type can, in fact, be traced upstream to the Hoo Peninsula, north Kent, where they form part of a terrace system of the Medway (Bridgland, 1980, 1983a; Bridgland and Harding, 1985). The exotic rocks recognized in the Low-level East Essex Gravel are identical to those found in the terrace deposits of the Lower Thames (see Chapter 4). The Low-level East Essex Gravel is therefore attributed to the combined Thames-Medway, confirming the interpretation of Whitaker (1889). This type of gravel clearly post-dates the diversion of the Thames. The diversion was the direct result of the Anglian glaciation of the Vale of St Albans, which produced a proglacial lake, the overspill from which is thought to have effected the rerouting of the river (Gibbard, 1977, 1979; see Chapter 3, Part 2), probably by way of a pre-existing left-bank tributary of the 'pre-glacial' Medway (Bridgland, 1988a). The diverted Thames appears to have joined the pre-existing Medway valley in the area of the present Thames estuary and then flowed northwards across east-

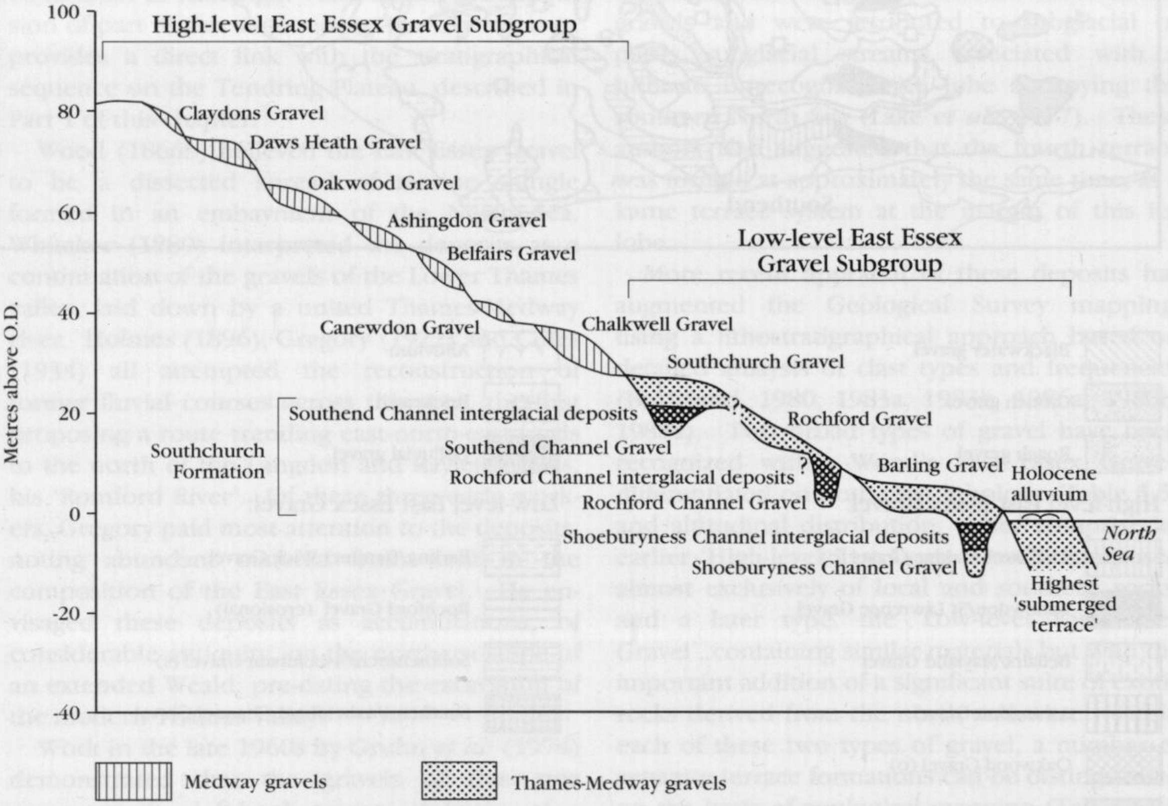


Figure 5.16 Idealized transverse section through the gravels of the Southend area (modified from Bridgland, 1988a).

Table 5.6 Gravel formations in eastern Essex.

Southend area	**Dengie Peninsula**	**Tendring Plateau**	**Middle/Lower Thames equivalent**	**Stage**	**^{18}O**
– – – – – – – – – Offshore – – – – – – – – –			Kempton Park/East Tilbury Marshes	late Saalian - Devensian	6-4 or 2
– – – – – – – – – Below alluvium – – – – – – – – –			Taplow/Mucking	late Saalian	8-6
Barling	Dammer Wick		Lynch Hill/Corbets Tey	mid-Saalian	10-8
Southchurch	Asheldham	Mersea Island/Wigborough	Boyn Hill (and Black Park)	Anglian - early Saalian	12-10
– – – – – – – – – Thames diversion (stratigraphic marker) – – – – – – – – –				Anglian	12
Chalkwell	Caidge	St Osyth/Holland	Winter Hill	Anglian	12
Canewdon	St Lawrence	Wivenhoe/Cooks Green		early Anglian	12
Belfairs	Mayland	Ardleigh/Oakleigh	?Rassler	'Cromerian Complex'	21-13
Ashingdon		Waldringfield			
Oakwood			?Gerrards Cross		
Daws Heath			?Beaconsfield	Early Pleistocene	Pre-21
Claydons			?Satwell		

ern Essex, eventually rejoining its pre-diversion course in the Clacton area (Bridgland, 1980, 1983a, 1983b, 1988a; Fig. 5.5).

This new route is exemplified by the distribution of the Southchurch Gravel of the Southend area and its downstream equivalents, the Asheldham Gravel of the Dengie Peninsula, the Mersea Island Gravel and the Wigborough Gravel of the Clacton area (see Figs 5.2, 5.5 and 5.15). The northern part of the old Medway course across eastern Essex was abandoned following the deposition of the Southchurch/Asheldham Gravel, the river subsequently turning eastwards towards the North Sea Basin in the region of the modern Crouch estuary (Fig. 5.5). Later gravels in this northern part of the area are products of tributary rivers such as the Chelmer and Blackwater (see Part 3 of this chapter). The Thames-Medway course across the coastal fringe of Essex is reflected by evidence offshore of the submerged (pre-Holocene transgression) valley, which turns northwards off Southend to run parallel to the coastline as far north as the Crouch estuary (Fig. 5.5F), from which a substantial submerged tributary valley emerges (D'Olier, 1975; Bridgland and D'Olier, 1989). The East Essex Gravels essentially form left-bank terraces of this continuation of the Thames-Medway valley, the axis of which is now submerged.

The abrupt compositional change between the High-level and Low-level East Essex Gravels provides an important stratigraphical marker, of great assistance to correlation both within eastern Essex and, thanks to its causal link with the Anglian glaciation and the associated diversion of the Thames, with other areas. Furthermore, the highest of the Low-level East Essex Gravel formations, the Southchurch/Asheldham Gravel, can be traced as far north as Clacton (Fig. 5.5B), thus linking with the Kesgrave Group sequence in southern East Anglia

(Bridgland, 1980, 1983a, 1988a). This stratigraphical marker is the basis for correlation of the lowest three High-level East Essex Gravel Medway formations with the lowest three Kesgrave Group formations on the Tendring Plateau, where the pre-diversion confluence between the two rivers has been recognized (Fig. 5.4; see Part 1 of this chapter).

Since it was the glacial diversion of the Thames that brought the river into its modern lower valley and effected the change to Thames-Medway drainage in eastern Essex, the terrace gravels of the Lower Thames (see Chapter 4) and the Low-level East Essex Gravel must be lateral equivalents. Correlation between the two areas has proved difficult, largely because of a lengthy downstream gap in the terrace record between Stanford-le-Hope and Southend, where the Pleistocene gravels are cut out by the extensive Holocene alluvium of Fobbing Marshes and Canvey Island. Previous correlations have relied primarily on the downstream projection of gravel bodies, although with some palaeontological and archaeological support (Bridgland, 1983a, 1988a). Recently it has become apparent, partly from offshore evidence, that a revision of the correlation scheme suggested by Bridgland (1988a) is necessary (Bridgland *et al.*, 1993; Table 1.1 and Fig. 1.3; Table 5.6). Further discussion of this correlation will appear in the three site reports below.

The buried channels first recognized by Lake *et al.* (1977), and attributed by them to glaciofluvial processes, have been reinterpreted as integral parts of the fluvial stratigraphy of the Low-level East Essex Gravel sequence (Bridgland, 1980, 1983a, 1988a; Bridgland *et al.*, 1993). These channels cover a range of altitudes, a possible reason for the original glaciofluvial interpretation. Bridgland (1983a, 1988a) believed that three separate downcutting events were represented, associated with three Low-level East Essex Gravel formations, his Southchurch, Rochford and Barling Gravels (Fig. 5.15). Each of the channels contains basal gravels overlain by probable interglacial sediments, usually of apparent estuarine character, but these have only been recorded from boreholes and have yet to be described in detail (new work on these channel-fills has been carried out recently by H.M. Roe). They are generally capped by the deposits mapped as terrace gravels, thus showing tripartite sequences that correspond to phases 2, 3 and 4 of the climatic model for terrace formation (see Chapter 1). The oldest of these channels is believed to represent an upstream continuation of the Clacton Channel, traditionally assigned to the Hoxnian (Warren, 1955; Fig. 5.5A; see below, Clacton). It is also thought to be preserved at Cudmore Grove, East Mersea (see Cudmore Grove).

Eastern Essex is an important area for research on the British Pleistocene, because it lies directly between the Lower Thames valley and East Anglia, both of which have well-documented and detailed stratigraphical records. The area is also of considerable significance for studies of the southern North Sea, since many of the deposits in eastern Essex can be traced offshore (Bridgland and D'Olier, 1989). Because it lies at the edge of the North Sea Basin, the gravel sequence in eastern Essex is interbedded with estuarine channel-fills related to high sea-level events. The sequence in this area, although poorly documented through lack of exposure, promises to be more complete than elsewhere in the Thames system and will probably be the source of valuable future contributions to the Pleistocene record. As much of the evidence from this area lies deep below ground level, the coverage of GCR sites is limited. The Low-level East Essex Gravel is represented, however, in GCR sites at Clacton, Cudmore Grove (East Mersea) and Southminster. The Clacton and Cudmore Grove sites include important interglacial sequences; the former is also the internationally recognized type locality for the Clactonian Palaeolithic Industry. It is possible that future research in this area will result in other important sites being recognized and added to this coverage.

CLACTON (CLIFFS, FORESHORE AND GOLF COURSE)

D.R. Bridgland

Highlights

A key locality for studies of Pleistocene stratigraphy and palaeontology, the complex site at Clacton reveals a channel-fill traditionally assigned to the Hoxnian Stage. This series of deposits, attributed to the Thames-Medway, contains faunal and floral remains indicative of temperate-climate conditions. In addition to the considerable stratigraphical, palaeontological and palaeoenvironmental significance of the site, it is famous as the type locality for the Clactonian Palaeolithic Industry. The location of the Clacton deposits is such that a stratigraphical link between the Thames system and the East Anglian Pleistocene succession is provided, making this one of the most important Pleistocene sites in southern Britain. The palaeogeographical position of the site in relation to the regional Thames terrace sequence, together with the stratigraphical evidence it provides, indicates a Hoxnian (*sensu* Swanscombe) age for the interglacial sediments here, immediately postdating the Anglian diversion of the Thames.

Introduction

The cliffs, foreshore and immediate inland area at Clacton-on-Sea together constitute a complex Pleistocene site of international significance. Clacton lies in the south-eastern corner of the Tendring Plateau. Recent work has shown that the gravels in this area belong mainly to the pre-diversion Thames system (Rose *et al.*, 1976; Bridgland, 1980, 1988a; Green *et al.*, 1982; Bridgland *et al.*, 1988, 1990; Part 1 of this chapter). At Clacton, fossiliferous Pleistocene channel deposits are preserved in an arcuate area to the south of the town centre (Fig. 5.17), intersecting with the present coastline at Lion Point, Jaywick (western end) and to the south of the pier (eastern end). These sediments have yielded many Palaeolithic artefacts, which form a characteristic assemblage of flakes and cores, with no formal tools such as hand-axes (Warren, 1912, 1922, 1933, 1958). Clacton is the type locality of this particular Palaeolithic industry, to which the name Clactonian was first applied by Warren (1926; see below).

Although they were discovered and extensively described in the last century (Brown, 1838,

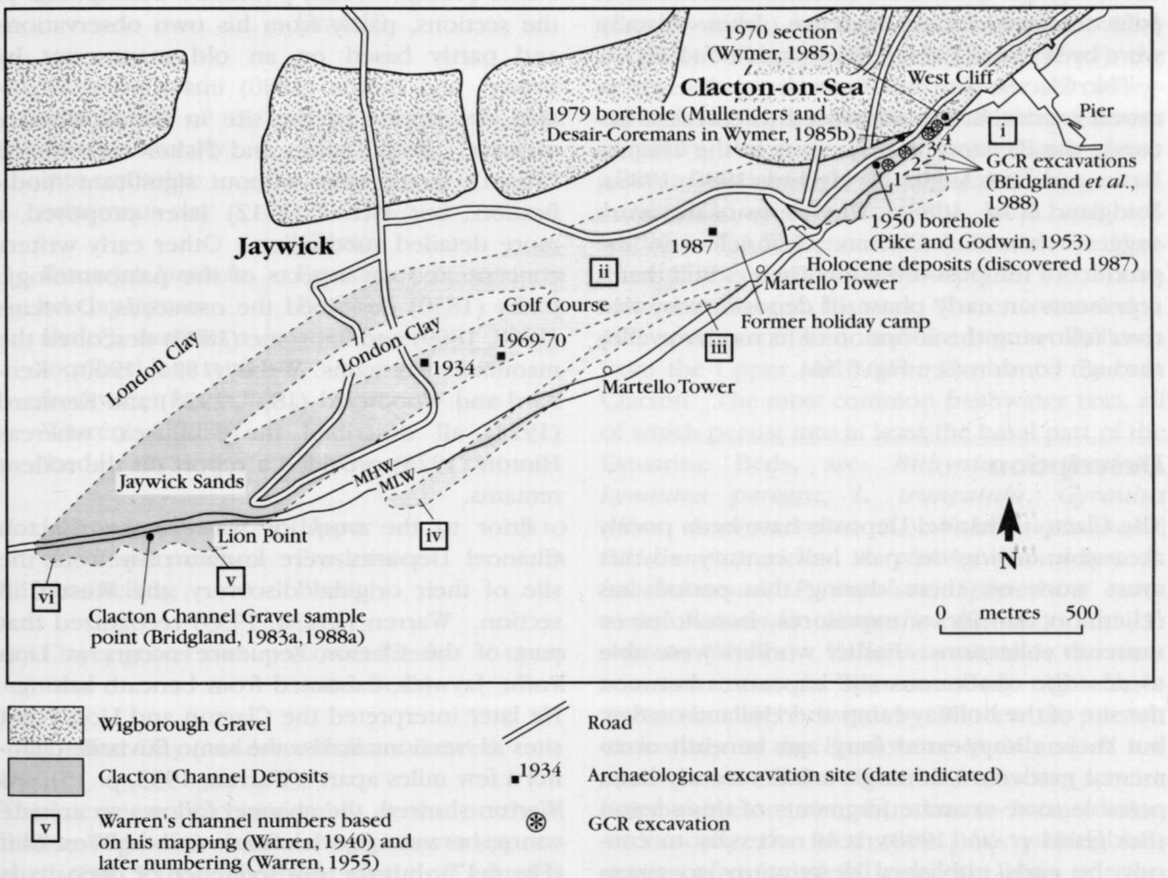


Figure 5.17 Map showing the distribution of Pleistocene deposits in the region of Clacton and the location of the various sites mentioned in the text.

1840, 1841; Fisher, 1868a; Dalton, 1880), much of our present knowledge of the Clacton Channel Deposits can be credited to S.H. Warren, who devoted a considerable proportion of his life's work to the deposits at Clacton and the Clactonian Industry (Warren, 1922, 1923a, 1924b, 1933, 1940, 1951, 1955, 1958). Pollen from these sediments was used to construct one of the first British interglacial pollen diagrams (Pike and Godwin, 1953), subsequently the basis for their ascription to the Hoxnian Stage (West, 1956, 1963; Turner, 1973). The deposits have been widely regarded as downstream correlatives of those at Swanscombe in the Lower Thames (Chapter 4), the two sites having been correlated by a comparison of their molluscan faunas (Kerney, 1971; Turner and Kerney, 1971). Two full-scale archaeological excavations have taken place on the golf course (Oakley and Leakey, 1937; Singer *et al.*, 1973) and a further investigation, as yet unpublished, was recently undertaken of exposures created during the redevelopment of the holiday camp (Wymer, 1988; Fig. 5.17). The most recent summaries of palaeoenvironmental evidence from Clacton were by Wymer (1974, 1985b) and Roe (1981).

The Clacton site has figured prominently in recent work that has attempted to correlate between the Pleistocene sequences in the Thames Basin and East Anglia (Bridgland, 1980, 1988a; Bridgland *et al.*, 1988). The results of this work suggest that the Clacton Channel was the product of the post-diversion Thames and that it represents an early phase of deposition by that river following the adoption of its modern valley through London (see Fig. 5.5A).

Description

The Clacton Channel Deposits have been poorly accessible during the past half century, so that most work on them during this period has relied on temporary exposures, boreholes or museum collections. Earlier workers were able to describe continuous cliff exposures between the site of the holiday camp and Holland-on-Sea, but these disappeared long ago beneath ornamental gardens. Although it has recently been possible to re-excavate fragments of this section (Bridgland *et al.*, 1988), it is necessary to consult the early published descriptions to assess the characteristics and extent of the Clacton sediments.

The deposits were discovered in the late 1830s by John Brown of Stanway, who wrote a number of short papers describing them and their fossil content (Brown, 1838, 1839, 1840, 1841, 1845, 1857). Brown (1840, 1841) noted the occurrence of both marine and freshwater molluscs at Clacton and that only the latter type occurred in the lowest stratum, which also yielded mammalian remains. He divided the sequence into seven separate beds, broadly reflecting a change from a freshwater/lacustrine environment to 'fluvio-marine' (estuarine) conditions. He also recorded a bed with freshwater shells near the top, possibly an early reference to Warren's (1923a, 1955) 'bed l' (see below).

References to the fossiliferous beds at Clacton also appeared in a number of other early publications, notably those of Owen (1846), Wood (1848), who suggested that the 'lacustrine' deposit might be the freshwater equivalent of the Red Crag, and his son (Wood, 1866b), in his original description of the East Essex Gravel (see above, Introduction to Part 2). In addition, Fisher (1868a, 1868b) published descriptions of the sections, partly from his own observations and partly based on an old manuscript by Brown, and Dalton (1880) included an illustrated description of the site in the Colchester memoir. Both Dalton and Fisher reproduced Brown's stratigraphy without significant modification, but Picton (1912) later proposed a more detailed subdivision. Other early writers concentrated on aspects of the palaeontology: Jones (1850) described the ostracods, Dawkins (1868, 1869) and Ransome (1890) described the mammalian remains, Webb (1894, 1900), Kennard and Woodward (1897, 1923) and Kennard (1924) all described the Mollusca, whereas Hinton (1923) provided a report on the rodent remains.

Prior to the work of Warren, the Clacton Channel Deposits were known only from the site of their original discovery, the West Cliff section. Warren (1923a, 1933) recognized that part of the Clacton sequence occurs at Lion Point, Jaywick, exhumed from beneath saltings. He later interpreted the Clacton and Lion Point sites as 'sections across the same fluviatile channel a few miles apart' (Warren, 1933, p. 15). As Warren showed, the channel follows an arcuate course between Jaywick Sands and the West Cliff (Fig. 5.17), but the full sequence of deposits is only preserved at the latter (eastern) end. The channel is excavated in London Clay, but in the cliffs it can also be observed to dissect the Lower Holland Gravel (Fig. 5.18). Its base is reputed to decline to at least 6 m below O.D. (Warren, 1955).

The most complete succession of Clacton Channel Deposits is preserved at the West Cliff locality, where a sequence of fluvial beds overlain by estuarine sediments occurs. Warren (1923a, figs 1 and 2; p. 611) originally proposed a complex subdivision of the sediments here, with an upper series of estuarine clays and sands and a lower series of freshwater gravel, loam and clay. He subsequently found that many of his earlier subdivisions could not be followed laterally for any great distance and adopted the following more generalized sequence for what is widely regarded as the definitive description of the channel deposits (Warren, 1955; Fig. 5.19):

		Thickness
6. Surface soil and colluvium		1–3 m
5. Upper bedded gravel	(Mersea Island/ Wigborough Gravel?)	*c.* 2 m
4. Estuarine sand with shells, passing laterally into estuarine calcareous clay	(Clacton Estuarine Beds)	up to 4 m
3. Estuarine laminated clay ('peaty shale'); contains a localized lens with freshwater fauna, Warren's (1923a) 'bed l'		up to 5 m
2. Loamy sands and clays, with much channelling	(Upper Freshwater Beds)	up to 4 m
1. Clayey gravel and sand	(Lower Freshwater Beds)	up to 7 m
London Clay (or Lower Holland Gravel)		

Thicknesses vary considerably as the northern feather-edge of the channel sequence is approached (Fig. 5.18). The basal sand and gravel is typically *c.* 1 m thick, the minimum thickness of the Clacton Freshwater Beds (beds 1 and 2 combined) being just over 2 m. The overlying Estuarine Beds (beds 3 and 4) continue the sequence up to *c.* 10 m O.D. (Figs 5.18 and 5.19). Within the Estuarine Beds, Warren (1923a) recorded a thin (0.3 m) and discontinuous bed ('bed l') containing only non-marine fauna. Molluscs, ostracods, plant macrofossils and pollen have been obtained from both the Freshwater and Estuarine Beds, except where the latter are oxidized, near the modern land surface. The Freshwater Beds have also yielded a rich mammalian fauna and large collections of Clactonian artefacts; the richest concentrations were in the upper part of the Lower Freshwater Beds (Warren, 1923a, 1955). Unfortunately most of the early collections from the different beds have been combined and it is also possible that material from the Lion Point foreshore locality may have been grouped with that from the West Cliff section (Wymer, 1985b).

According to the summary by Wymer (1985b), the mammalian assemblage from the natural exposures includes beaver (*Castor fiber*), the voles *Arvicola cantiana* and *Microtus agrestis*, lion (*Panthera leo*), straight-tusked elephant (*Palaeoloxodon antiquus*), horse (*Equus ferus*), the extinct rhinoceroses *Dicerorhinus kirchbergensis* and *D. hemitoechus*, red deer (*Cervus elaphus*), the large fallow deer *Dama dama clactoniana* and boar (*Sus scrofa*).

Assimilating data from the work and collections of A.S. Kennard, A.G. Davis, the Museum of the Geological Survey and the British Museum (Natural History), Warren recorded *c.* 100 species of land and freshwater Mollusca from the Upper and Lower Freshwater Beds at Clacton. The most common freshwater taxa, all of which persist into at least the basal part of the Estuarine Beds, are: *Bithynia tentaculata*, *Lymnaea peregra*, *L. truncatula*, *Gyraulus albus*, *Armiger crista* (L.), *Valvata piscinalis*, *Pisidium amnicum*, *P. clessini* (Neumayr), *P. henslowanum*, *P. nitidum*, *Sphaerium corneum*, *Potamida littoralis* (Cuvier) and *V. cristata* (Müller). *Vallonia costata* is the most common terrestrial species. Only eight freshwater taxa were listed by Warren as present exclusively in the Freshwater Beds and all are uncommon. All the common freshwater species listed above are also abundant at Swanscombe. Additionally, the Freshwater Beds yielded four species of ostracod, all currently living in rivers or lakes in Europe (Withers, in Warren, 1923a).

The Clacton Estuarine Beds contain a number

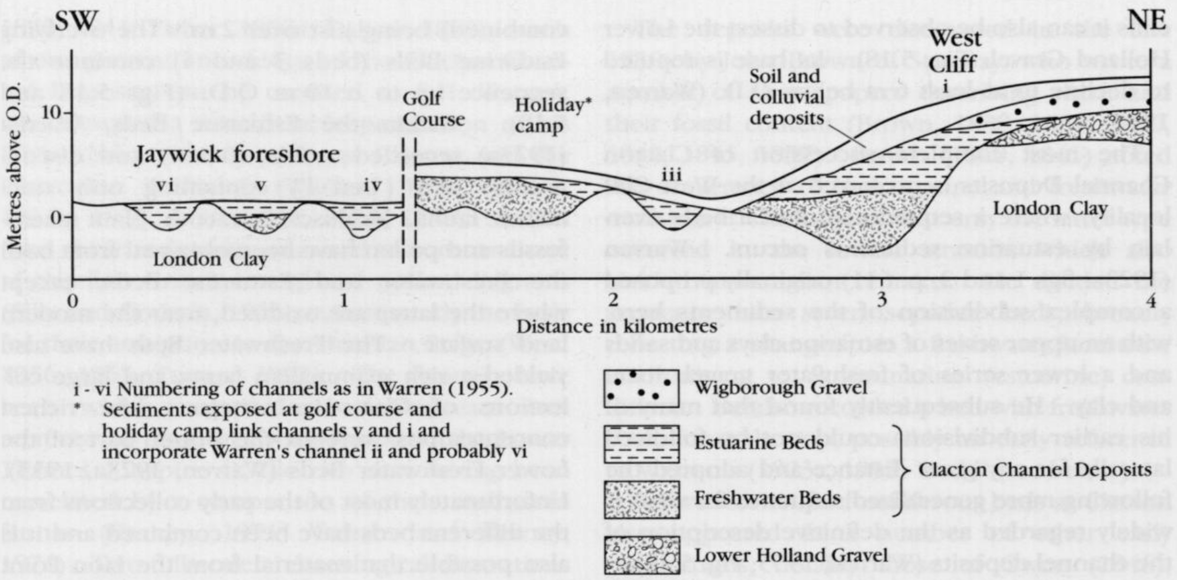


Figure 5.18 Section through the Clacton area, showing the various Clacton Channel occurrences (modified from Warren, 1955).

of freshwater mollusc species that are absent in the Freshwater Beds; for example, Kennard and Woodward (1923) listed *Paladilhia radigueli* (Bourguignat), *Viviparus diluvianus* and *Corbicula fluminalis*. Of these, *P. radigueli*, which is probably part of the *Hydrobia ventrosa* complex (R.C. Preece, pers. comm.), was abundant. Warren (1955) subsequently recorded small numbers of this snail in the Freshwater Beds from the cliff-top borehole and from Jaywick. It is nowadays, however, regarded as a probable brackish-water species (R.C. Preece, pers. comm.). *Paladilhia radigueli* and *V. diluvianus* are also present in small quantities in Warren's (freshwater) 'bed l', which occurs within the Estuarine Beds (see above and Fig. 5.19). Marine species from the Estuarine Beds included *Cerastoderma edule* L., *Hydrobia ulvae* (Pennant), *Littorina littoralis* (L.), *Mytilus edulis* (L.), *Scrobicularia plana* (da Costa), *Macoma balthica* (L.) and *Turritella communis* Risso (Brown, 1841; Dalton, 1880; Baden-Powell, 1955). This assemblage comprises estuarine taxa characteristic of a sandy mud substrate (R.C. Preece, pers. comm.). Other taxa were recorded by Baden-Powell (1955) from estuarine deposits filling Warren's channels iii-iv; these channels should probably be treated separately, as their relation to the main Clacton Channel requires further investigation (see below). A number of species of foraminifera have also been recorded from the Estuarine Beds, the dominant taxon being *Nonion depressula* Walker and Jacob (Ovey, in Warren, 1955; van Voorthuysen, in Baden-Powell, 1955).

Although a wealth of plant remains had been recognized in the deposits several years previously (Reid and Chandler, 1923), it was with the development of pollen analysis that the biostratigraphical significance of the Clacton palaeobotany was first realized. The pioneering palynological study of the channel deposits by Pike and Godwin (1953) was based on a cliff-top borehole (see Figs 5.17 and 5.19). In this borehole, pollen-bearing clays and silts ascribed to the Estuarine Beds overlay organic silty sands with freshwater shells, also polleniferous, which were attributed by Warren (1955) to the Lower Freshwater Beds. The pollen sequence from this borehole showed that the freshwater sediments were laid down during a warm-temperate period, with deciduous woodland established in the region, whereas the overlying Estuarine Beds represent a period of declining warmth, in which coniferous forests became dominant (Pike and Godwin, 1953). The spectra from the Estuarine Beds, which record a marked increase in silver fir (*Abies*) pollen, have subsequently been assigned to biozone IIIb of the Hoxnian interglacial, whereas the underlying freshwater

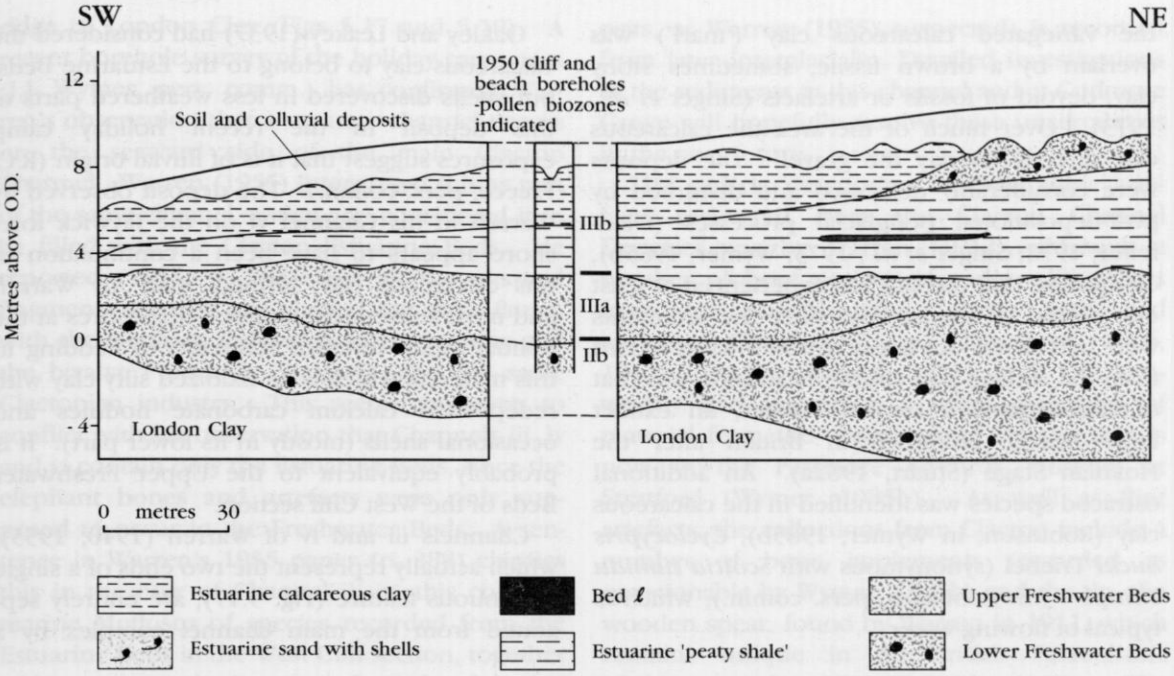


Figure 5.19 Section through the fill of the main Clacton Channel, as exposed at the West Cliff (modified from Warren, 1955).

sediments have been attributed to biozone HoIIIa (Turner and Kerney, 1971). Turner and Kerney (1971) also succeeded in extracting pollen from the Upper Freshwater Beds from a borehole through the modern beach (drilled in the 1950s but not analysed at that time). These sediments proved to contain high levels of oak and alder and were ascribed by Turner and Kerney to biozone Ho IIb, indicating that they pre-date the entire sequence in the cliff-top borehole. Warren's view that the Lower Freshwater Beds were represented in the Pike and Godwin pollen sequence was therefore refuted (Fig. 5.19).

Plant macrofossils, mostly seeds and fruits, were described from both boreholes by Turner and Kerney (1971). These authors broadly confirmed the earlier records of Reid and Chandler (1923), but were also able to relate the new material to the pollen biozones. Plant macrofossils appear to have been distributed throughout the deposits; Reid (in Reid and Chandler, 1923) considered there to be little difference between the assemblages from different beds. Reid and Chandler recorded 137 species, generally indicative of temperate, rather dry conditions. An important new record by Turner and Kerney was that of *Azolla filiculoides* (Lam.), a water fern that is no longer native to Britain and is thought to characterize the Hoxnian Stage.

Sections excavated on the golf course in the early 1930s, in the inland part of the outcrop of the Clacton Channel Deposits (Fig. 5.17), revealed the following sequence (Oakley and Leakey, 1937):

		Thickness
	Pale brown hillwash	0.3–0.6 m
Clacton Channel Deposits	Variegated silty clay ('loam')	0.3–0.6 m
	White or variegated calcareous clay	0.0–0.6 m
	Pebbly silver-sand, cross-bedded, with lenses of silty clay and local seams of calcareous clay ('marl')	0.6–1.2 m
	Red sandy gravel	>0.9 m

In a second excavation at the golf course, 300 m to the east of the first (Figs 5.17 and 5.20), a similar sequence was revealed, although the variegated calcareous clay ('marl') was overlain by a brown fissile, sometimes stony clay, devoid of fossils or artefacts (Singer *et al.*, 1973). Over much of the area the calcareous clay directly overlay the gravel. The deposits were considerably deformed and disturbed by post-depositional periglacial processes (Gladfelter, 1972; Singer *et al.*, 1973; Wymer, 1985b), confirming that the site has experienced at least one period of intense cold since the sediments were laid down. An important new fossil record from the second golf course excavation was that of ***Trogontherium cuvieri*** Fischer, an extinct large beaver unknown in Britain after the Hoxnian Stage (Stuart, 1982a). An additional ostracod species was identified in the calcareous clay (Robinson, in Wymer, 1985b), ***Cyclocypris hucki*** Triebel (synonymous with *Scottia tumida* Kempf – J.E. Robinson, pers. comm.), which is typical of flowing water.

Oakley and Leakey (1937) had considered the calcareous clay to belong to the Estuarine Beds, but shells discovered in less weathered parts of this deposit in the recent holiday camp exposures suggest that it is of fluvial origin (R.C. Preece, pers. comm.). The deposit observed by Warren in his Channel vi on the Jaywick foreshore appears to have been a continuation of this calcareous clay, termed 'marl' by Warren and most subsequent authors. Exposures at the holiday camp revealed remnants of bedding in this material, which is an oxidized silty clay with redeposited calcium carbonate nodules and occasional shells (mostly in its lower part). It is probably equivalent to the Upper Freshwater Beds of the West Cliff section.

Channels iii and iv of Warren (1940, 1955), which actually represent the two ends of a single continuous feature (Fig. 5.17), are entirely separated from the main channel complex by a

Figure 5.20 Photograph of the second archaeological excavation at Clacton, taken in 1970. The Clacton Channel Gravel is clearly seen, beneath calcareous silt (marl). London Clay forms the floor of the excavated area; careful removal of the overlying gravel has revealed undulations in its surface, probably scour features. (Photo: J.J. Wymer.)

ridge of London Clay (Figs 5.17 and 5.18). A recent borehole survey of the holiday camp area (J.J. Wymer, pers. comm.) has confirmed Warren's observation that a separate channel occurs on the seaward side of the main Clacton Channel. Warren (1955) interpreted this as part of the same channel system and considered it to be filled with the Clacton Estuarine Beds. He reported (1955, p. 284) that all the channel fragments seen by him yielded the same fauna, with the elephant *Palaeoloxodon antiquus* and the bivalve *Potamida littoralis*, and the same Clactonian industry. This seems, however, to conflict with his observation that Channels iii, iv and vi contain only the Estuarine Beds, since the elephant bones and artefacts were only supposed to occur in the Freshwater Beds. A sentence in Warren's 1955 paper (p. 288) clarifies this in the case of Channel iii–iv; this contains marine Mollusca of species recorded from the Estuarine Beds in the West Cliff section, together with occasional bones of *Palaeoloxodon antiquus*, but non-marine molluscs are absent. According to Warren's (1940) observations of the Jaywick foreshore and hinterland, the deposits of the main Clacton Channel are themselves divided into two parallel strips by a low ridge of London Clay, his (1955) Channels v and vi (see Figs 5.17 and 5.18). The recognition of estuarine sediments at foreshore level in Channel iii–iv (that on the seaward side of the main channel) raises a number of interesting possibilities, as they are significantly lower than the Estuarine Beds at the West Cliff locality (Fig. 5.19). This may indicate a period of erosion following the deposition of the Upper Freshwater Beds, an explanation that was apparently favoured by Warren (1955) – his 'minor non-sequence'? The recognition at Cudmore Grove, East Mersea (only 9 km upstream from Clacton), of a sequence, also ascribed to the Hoxnian Stage, in which estuarine sediments underlie fluviatile ones (Bridgland *et al.*, 1988), raises the possibility that these low-level estuarine sediments on the Jaywick–Clacton foreshore might pre-date the Freshwater Beds (see below). The possibility that the separate iii–iv channel-fill at Clacton is a later Colne deposit and totally unrelated to the Hoxnian sequence is another alternative that cannot be ruled out. The fauna recorded from this channel is not stratigraphically diagnostic; the marine molluscs are all species that are extant and straight-tusked elephant (even if not reworked into these deposits, as Warren (1955) suspected) is recorded from later interglacials. Detailed investigations of the sediments in this channel and at Cudmore Grove will hopefully resolve these uncertainties in the near future.

The earliest description of Palaeolithic artefacts recovered from the Clacton Channel Deposits was by Warren (1912), although a number of brief notices of earlier discoveries from (or possibly from) these beds had appeared (Evans, 1872, p. 521; Anon., 1906, 1911a, 1911b; Warren, 1911) and J.W. Kenworthy had assembled a small collection of material from the exposures at Clacton that is now in the Passmore Edwards Museum at Stratford (Wymer, 1985b). As well as flint artefacts, the collections from Clacton include a number of bone implements (regarded as questionable by Wymer, 1985b) and the tip of a wooden spear, found by Warren in 1911, which remains unique in the British Palaeolithic (Oakley *et al.*, 1977; McNabb, 1989). The artefacts come from the Lower and Upper Freshwater Beds, the richest concentrations occurring in the gravel of the former, whereas the fine-grained sediments of the Upper Freshwater Beds (including the calcareous clay at the golf course) have yielded the best preserved material, including the celebrated wooden spear.

Interpretation

The Clacton Channel Deposits provide a wealth of palaeontological evidence of considerable value for environmental reconstruction; in addition, some of the taxa recognized are of considerable biostratigraphical significance. The sediments also represent an important element within the sequence of Thames and Thames-Medway deposits that is now recognized in north-east Essex, the interpretation of which has significant implications for the Pleistocene evolution of Thames drainage. All of the above help to evaluate the palaeoenvironmental context of the type Clactonian Industry and to relate this to the British Pleistocene sequence.

The relation of the Clacton sediments to the Thames system has been established only in recent decades. Warren (1923a) originally attributed the Clacton Channel to a small local stream. Later, when he observed that the channel originally exposed in the West Cliff was one of several running side by side, he concluded that 'scoured-out deeps in the bed of a wide river' were represented (Warren, 1955, p. 284) and that the deposits were the product of the main Thames-Medway. Estimates of the age of the Clacton sediments, which were attributed to the 'Great Interglacial' (= Hoxnian) by Pike and Godwin (1953), implied that they belong to the post-diversion Thames system; the subsequent correlation of the Swanscombe and Clacton sediments on the basis of their molluscan faunas by Kerney (1971) reinforced this view. Although alternative interpretations have been proposed (Gladfelter, 1975), the post-diversion Thames origin of the Clacton Channel Deposits has been confirmed by recent work in eastern Essex (Bridgland, 1980, 1983a, 1988a; Fig. 5.5A).

Palaeontology

The wealth of palaeontological data from Clacton is important for both environmental reconstruction and relative dating. Most recent authors have agreed that the deposits accumulated under fully interglacial conditions during the Hoxnian. Many early descriptions included faunal lists, but the most detailed summaries of the palaeontology were by Warren (1923a, 1924b, 1955). Warren's final (1955) summary was revised in the light of Pike and Godwin's (1953) description of an interglacial pollen sequence, later assigned to the Hoxnian Stage (West, 1963; Turner, 1973) .

The molluscan faunas from the various deposits at Clacton are particularly informative. In addition to the most abundant taxa, listed above, there are certain species of biostratigraphical significance. Most notable amongst these are *Belgrandia marginata*, *Valvata piscinalis* forma *antiqua*, *Viviparus diluvianus* and *Corbicula fluminalis*, all of which first appear in the Estuarine Beds or very near the top of the Freshwater Beds (Warren, 1955; Kerney, 1971). These species are part of the so-called 'Rhenish fauna' recognized at Swanscombe, where they appear near the junction between the Lower Loam and the Lower Middle Gravel (Kennard, 1942; Kerney, 1971; see Chapter 4, Swanscombe). According to Kennard (1942), this assemblage was indicative of a connection between the Thames and Rhine at this time. The condition of specimens of *C. fluminalis*, *V. piscinalis* f. *antiqua* and *V. diluvianus* from Clacton suggests reworking from an older deposit (Kennard and Woodward, 1923), possibly a lower bed within the Clacton sequence that was destroyed by intraformational erosion. The appearance of these 'Rhenish' taxa, coupled with other similarities in the molluscan faunas, enabled Kerney (1971) to relate the interglacial pollen sequence recognized at Clacton to the succession at Swanscombe, which lacks a satisfactory palynological record (see Chapter 4, Swanscombe). The Mollusca also provide important palaeoenvironmental information; in particular, they allow the distinction of the freshwater and estuarine sediments at Clacton. Freshwater species dominate the assemblage from the Estuarine Beds, but they are accompanied by marine taxa (Warren, 1955). The most complete summary of the marine Mollusca from Clacton was by Baden-Powell (1955), who noted that the assemblage could not be distinguished from those found in Holocene deposits. His faunal list indicates in which of Warren's six channels the various taxa have been found.

The mammalian remains at Clacton were described in detail by Warren (1923a). He noted that the elephants were of the straight-tusked species (*Palaeoloxodon antiquus*) and that mammoth did not occur, a feature consistent with a Hoxnian age (Stuart, 1982a). The important observation that fallow deer remains from Clacton differ from living examples was made by Dawkins (1868) and Falconer (1868), who both (independently) identified them as a distinct (larger) species, although they are currently interpreted as a subspecies *Dama dama clactoniana* (Stuart, 1974, 1982a; Leonardi and Petronio, 1976; Lister, 1986). The Clacton fallow deer is thought to characterize Hoxnian deposits in Britain; it is an important component of the Swanscombe fauna (see Chapter 4, Swanscombe), supporting the proposed correlation of the two sites (Sutcliffe, 1964).

Two types of extinct rhinoceros occur in the Clacton Channel, *Dicerorhinus hemitoechus* and *D. kirchbergensis* (Sutcliffe, 1964). Rhinoceros teeth from the basal gravel (basal bed 1) were found to have fibrous vegetable matter lodged in crevices, which was interpreted as the remains of the animals' food (Pike and Godwin, 1953; Warren, 1955). This material yielded pollen taxa dominated by non-arboreal types, which led Pike and Godwin to suggest that it represented an earlier (pre-temperate) phase of the interglacial, earlier than any of the sediments encountered in their cliff-top borehole (see above). Warren, on the other hand, suggested that non-arboreal pollen from food remains might have mixed with tree pollen from the containing sediments to give the assemblages obtained. He thought that the remains might provide important evidence for the diet of these animals.

Occasional remains of small mammals have been known to occur in the Clacton Channel Deposits from the time of their earliest description, Brown (1840) having recorded water rat from his original section (see, however, Hinton, 1923). Unfortunately, the assemblage of small vertebrates remains sparse, particularly in comparison with possible correlative sites such as Cudmore Grove and Little Thurrock (Stuart, 1974; Sutcliffe and Kowalski, 1976; Wymer, 1985b; Bridgland *et al.*, 1988; see below, Cudmore Grove). This is despite the careful sieving of the sediments exposed in the second golf course excavation (Singer *et al.*, 1973; Wymer, 1985b), which added only the vole *Clethrionomys* sp. and giant beaver to the assemblage.

Analyses of samples from the cliff-top borehole (see above), as well as older samples collected by Warren, formed the basis for the Clacton pollen diagram published by Pike and Godwin (1953). This has the following characteristics: abundant (but generally declining) alder; oak and elm relatively abundant in the lower part of the sequence; hazel declining throughout the sequence; pine consistently important throughout; and silver fir becoming dominant towards the top. A comparison with other British and continental sites suggested a correlation with the 'Penultimate Interglacial' (Pike and Godwin, 1953), which was later redefined as the Hoxnian (West, 1963; Turner, 1973). Turner and Kerney (1971) subsequently confirmed this interpretation. These authors worked additionally on samples, obtained from the borehole at beach level (see above), of earlier sediments within the Upper Freshwater Beds than those analysed by Pike and Godwin. These sediments, which they attributed to biozone HoIIb, yielded the biostratigraphically significant unnamed palynomorph known as 'Type X', which is thought to be characteristic of the Hoxnian Stage in Britain (Turner and Kerney, 1971).

Wymer (1974) reported that pollen analysis of the calcareous clay ('marl') at the golf course site had revealed spectra dominated by pine, birch and grasses. These spectra, obtained using heavy liquid flotation techniques, were attributed by Mullenders and Desair-Coremans (in Wymer, 1974; preliminary interpretation in Singer *et al.*, 1973) to the early Hoxnian Stage (biozone HoI). This interpretation led to the conclusion that the golf course sequence was older than that at the West Cliff, in which biozones HoIIb, IIIa and IIIb have been identified (Wymer, 1974, 1981, 1985b; Gladfelter, 1975; Fig. 5.19). Supporting evidence for differentiating the sediments at the golf course from those in the West Cliff has been claimed from the recognition of periglacial structures in the basal gravel that pre-date the accumulation of the overlying calcareous clay (Gladfelter, 1972; Singer *et al.*, 1973; Wymer, 1985b). On the basis of this evidence, Wymer (1985b) suggested that the earliest human occupation of the site, represented by abraded artefacts in the gravel (see below), occurred in a pre-Hoxnian (*sensu* Clacton) temperate interval. This interpretation was disputed by West (in Wymer, 1985b), who considered all the cryoturbation structures observed in the golf course sections to have formed after deposition of the calcareous clay. It is possible that some deformation of the gravel prior to burial by the calcareous clay might have been caused by some other process, perhaps related to waterlogging.

The palynological basis for regarding the golf course sediments as earlier than those at the West Cliff has also been challenged. Turner (1975, 1985) has seriously questioned the reliability of the pollen assemblages from the golf course site, because of the very low pollen concentrations in these sediments. He argued that the observed concentration of pine and birch had occurred as a result of the destruction of less durable grains during the weathering to which these oxidized sediments have clearly been subjected. Indeed, it was pointed out by Turner (1985) that the occasional grains of hazel, oak and alder pollen identified by Mullenders and Desair-Coremans imply that these taxa, which are highly susceptible to weathering, were once considerably more common. These deciduous species are not characteristic of the early parts of interglacials; their presence in the calcareous clay suggests instead that it accumulated during biozone II or III (Turner, 1985). It is therefore likely that the golf course sequence is entirely comparable to that in the

West Cliff sections, with the Lower and Upper Freshwater Beds represented, the former by the gravel and the latter by the weathered calcareous clay. The Estuarine Beds are apparently missing at the golf course; in fact the westernmost feather-edge of the outcrop of these beds has been observed recently at the holiday camp (Fig. 5.18). Warren's (1955) observations suggest that these or other estuarine deposits may be present on the foreshore at Jaywick, however (see Fig. 5.18).

Geochronological evidence

Szabo and Collins (1975) obtained a radiometric (uranium-thorium) date of 245,000 (+35,000/-25,000) years BP from a bone sample from the 1969 excavations at the golf course. As noted by Wymer (1985b), this is considerably younger than many predictions for the Hoxnian, based on an age for the preceding Anglian glaciation of between 400,000 and 470,000 years, as suggested by Kukla (1977).

The most recent evidence, independent of stratigraphy, for the age of the Clacton deposits has come from amino acid analyses (see Chapter 1 for explanation). Early work in this field by Miller *et al.* (1979), using shells of *Corbicula fluminalis*, grouped Clacton with sites in the Lower Thames such as Crayford and Aveley, which are attributed in this volume to Oxygen Isotope Stage 7 (see Chapter 4). However, in more recent analyses using a modified technique, Bowen *et al.* (1989) have obtained higher ratios, indicative of a greater age, using specimens of *Pisidium* (0.305 ± 0.001 (n = 2)) and *Valvata* (0.299 ± 0.002 (n = 3)) from Clacton. These ratios are comparable with results (mainly using different species) from Swanscombe, which Bowen *et al.* correlated with Oxygen Isotope Stage 11. Since the Anglian Stage is considered to correlate with Oxygen Isotope Stage 12 (see Chapter 1), a Stage 11 age for Clacton would conform with the widely held view that the site represents an immediately post-Anglian (post-diversion) Thames-Medway channel, an interpretation that has been reaffirmed by palaeogeographical reconstructions, based on terrace stratigraphy, of the sequence in eastern Essex (Bridgland, 1988a; Fig. 5.5). The biostratigraphical correlation of the sequences at Clacton and Swanscombe is also upheld by the conclusions of Bowen *et al.*, but the ascription to the Hoxnian interglacial is questioned, since amino acid ratios obtained from shells from the Hoxne type locality are lower and were considered to be indicative of Stage 9 (see Chapter 1). The term Hoxnian, as applied here to the Clacton sequence, should therefore be taken to mean Hoxnian *sensu* Swanscombe, pending confirmation (or otherwise) that the Hoxne sediments represent the same time interval as those at Swanscombe and Clacton.

Evidence for sea levels and possible subsidence

The Clacton site provides important evidence for Hoxnian sea levels, since part of the sequence is of estuarine origin. Palynological studies have revealed that the change from freshwater to estuarine conditions at Clacton occurred in the late-temperate phase of the interglacial, biozone HoIII (see above). There is evidence for a minor non-sequence at this point in the succession, with erosion to the lower levels occupied by the estuarine deposits at Lion Point (see Fig. 5.18; see above). However, the pollen record (Pike and Godwin, 1953) shows little evidence for a lengthy break in deposition. Warren (1955) noted that the estuarine deposits overlap the Freshwater Beds, but considered this to be exactly what would be expected as a result of a marine transgression. There are several reasons for concluding that this transgression did not extend upstream far beyond Clacton and that sea level may have generally declined during the interval represented by the Estuarine Beds. Firstly, Warren (1955, p. 287) noted that land and freshwater taxa greatly predominate over marine species throughout the lower part of the Estuarine Beds, except at their extreme base. Secondly, the occurrence of the freshwater lens, Warren's 'bed l' (see above; Fig. 5.19), suggests that there was a brief break in estuarine conditions, although this may simply represent the transport of fluvial sediment into the estuarine environment during a flood event. Finally, the palaeobotanical record shows that deciduous forest was replaced by coniferous woodland during the deposition of the Estuarine Beds, suggesting a deterioration of climate that might be expected to have been accompanied by a fall in sea level.

A problem encountered in attempts to

determine contemporary sea levels from the Clacton Estuarine Beds is that many workers have considered the area of the southern North Sea coast to have been significantly lowered by subsidence during the late Pleistocene (West, 1963, 1972; Evans, 1971; Kerney, 1971). This interpretation appears to be based largely on the views of Wooldridge (1927b, 1928; Wooldridge and Henderson, 1955), who defined a precise western limit to such downwarping, his 'Braintree line', and the widespread acceptance of a Hoxnian sea-level maximum at *c.* 32 m O.D. (Zeuner, 1945, 1959; West, 1963, 1972), much higher than the Clacton Estuarine Beds. Both these bases have been challenged in recent years. The bulk of the evidence for subsidence of the edge of the North Sea Basin is for differential movement during the Holocene, which has been demonstrated by various authors (Rossiter, 1972; D'Olier, 1975; Devoy, 1977, 1979; Greensmith and Tucker, 1980). The measured rates of differential warping during the Holocene are sufficiently high to have lowered the coastal area of Essex by many metres if this relative movement had occurred continuously throughout the Middle and Late Pleistocene. Differential warping on this scale would have lowered all the Middle Pleistocene terrace deposits in eastern Essex to below modern sea level, so it is apparent that the process could only have operated during a small proportion of this time, perhaps during high sea-level phases when sedimentation was occurring in the present offshore areas (Bridgland, 1983a, 1988a). The association of a 32 m sea level with the Hoxnian interglacial is traditionally based on extrapolation from Mediterranean areas by Zeuner (1945, 1959) and the occurrence of Hoxnian deposits at this elevation in the 'Goodwood raised beach' of West Sussex and at Swanscombe. The Goodwood raised beach deposit has recently been thoroughly reinvestigated at Boxgrove and appears to be pre-Hoxnian (Roberts, 1986), whereas Swanscombe is clearly a fluvial site, with no direct relevance to contemporary sea level. Moreover, the height difference between the deposits at Swanscombe and Clacton, a fall of around 27 m over a distance of approximately 110 km (along the course reconstructed in Fig. 5.5A), implies a downstream gradient of *c.* 1:4000, which is within the range of gradients observed amongst the fluvial terraces of the Middle and Lower Thames. This important fact, which was noticed by a number of previous workers, including Zeuner (1945), Singer *et al.* (1973) and Clayton (1977), allows the reconstruction of a Thames and Thames-Medway course for the Hoxnian Stage (*sensu* Swanscombe) in which the Clacton and Swanscombe sediments are shown to be broadly contemporaneous deposits of the same river system (Bridgland, 1980, 1983a, 1988a; Fig. 5.5A). The problems of reconciling the various evidence for sea levels during the Hoxnian Stage will be further discussed below (see Cudmore Grove).

Palaeolithic evidence

Warren (1912, 1922) was the first to recognize that the flint artefacts from Clacton, a mixture of thick stone-struck flakes and relatively crude cores, did not belong either to the Acheulian Industry, since there were no hand-axes, or the Mousterian Industry, which is characterized by more advanced preparation of cores (Levallois technique; see Chapter 1) than is seen in the Clacton material. The assemblage was initially defined as Mesvinian by Breuil and a detailed description was published under this title by Warren (1922). However, Breuil (in Warren, 1926) subsequently recognized earlier and later divisions of the Mesvinian Industry and recommended confining the term Mesvinian to the later division. Warren (1926) noted that the Clacton assemblage belonged to the earlier of these divisions and was therefore pre-Mesvinian; he proposed the term Clactonian for this industry.

At about the same time, a comparable Clactonian industry was identified in the Lower Gravel at Swanscombe (Chandler, 1930, 1931; see Chapter 4). A detailed description of the Clactonian artefacts from both these sites was published by Breuil (1932b), who considered (in agreement with Chandler) that the artefacts from the Swanscombe Lower Gravel were generally older than those from Clacton. This view, supported by Warren (1933), was probably influential in the formulation of King and Oakley's (1936) model for Lower Thames evolution, in which the Clacton sequence was correlated with a hiatus between the Lower Loam and Lower Middle Gravel at Swanscombe (see Chapter 4, Swanscombe and Globe Pit).

In 1934 the first of two archaeological

excavations was carried out at the Jaywick golf course, from which 190 artefacts were recovered (Oakley and Leakey, 1937). This material was not restricted to definite levels, nor was there any correlation between differences in typology and stratigraphical position. The unabraded condition of many of the artefacts led Oakley and Leakey to suggest the proximity of a working floor. The second series of excavations at the golf course (in 1969 and 1970) yielded over 1200 artefacts (Wymer and Singer, 1970; Singer et al., 1973; Wymer, 1985b; Fig. 5.20). These were most common in the basal gravel, occurring throughout the deposit, but with a slight concentration near its southern edge. The condition of the material varied from mint to very rolled, the former becoming increasingly common towards the top of the gravel. The industry continues sporadically in the overlying calcareous clay, which produced low numbers of well-preserved artefacts. Certain flakes have been refitted on to cores or other flakes, including two examples from the calcareous clay fitting on to pieces from the gravel/clay interface (Wymer, 1985b). The majority of conjoinable material occurred at the latter interface, in an 'accumulation of discarded flint work and broken bones' resting on the gravel (Wymer, 1985b, p. 283). Wymer claimed the mint and conjoinable material from the top of the gravel to represent the debris of human occupation in primary context, a view apparently supported by the successful identification of microwear characteristics on the edges of some artefacts, indicating the type of usage to which they had been put (Keeley, in Roe, 1981; in Wymer, 1985b). Mint artefacts occurred frequently in the upper part of the gravel, whereas abraded ones were evenly distributed throughout the deposit. Wymer regarded the former as part of the primary context debitage that had been incorporated into the gravel from above, perhaps by trampling while the deposit was waterlogged; he considered the abraded material to have been derived from an earlier occupation, pre-dating the deposition of the gravel. A minimum age in the late Anglian or very early Hoxnian Stage is implied for this early occupation. Wymer (1974, 1985b) was inclined to attribute this assemblage to a pre-Hoxnian (*sensu* Clacton) 'mild phase', but this interpretation relied heavily on the pollen evidence from the golf course site, now regarded as unreliable (see above).

A later artefact assemblage, again in derived condition, occurred in a small gravel fan overlying the calcareous clay at the golf course, attributed by Wymer (1985b) to solifluction in a periglacial climate. Wymer considered this deposit, which also contains bone fragments, to pre-date the Freshwater Beds of the West Cliff section. It seems more likely, however, that the calcareous clay is itself part of the Freshwater Beds (see above) and that the gravel fan, if it is really of periglacial origin, is of post-Hoxnian age and incorporates material reworked from the Clacton Channel Deposits.

Until recently the Clactonian Industry was regarded as stratigraphically older in Britain than the earliest appearance of the Acheulian, a view based largely on the sequence at Swanscombe and the absence of hand-axes in the Clactonian gravels at Swanscombe, Clacton and Little Thurrock (Wymer, 1974; Gladfelter and Singer, 1975; see Chapter 1). Flaws in this argument have long been apparent; later Clactonian industries were noted, for example, in the Lynch Hill Gravel of the Reading area (Wymer, 1968), with which the Little Thurrock site would be correlated according to the interpretation presented in Chapter 4 (see Globe Pit). There are also a few records of hand-axes or of evidence for their manufacture from Clacton and the Swanscombe Lower Gravel. Breuil (1932a) intimated that derived 'Chellean' (= Abbevillian or Early Acheulian) implements occurred at the base of the Swanscombe succession, mixed with the indigenous Clactonian material. A hand-axe was apparently recovered from the Lower Gravel during the Waechter excavations (Ohel, 1979; Newcomer, in Ohel, 1979). Wymer (1985b) pointed out that a number of hand-axes had been found on the foreshore at Lion Point and Clacton, but none was located *in situ* in the channel deposits. Furthermore, Singer *et al.* (1973) discovered three possible hand-axe finishing flakes in the 1970 Clacton excavations, all in derived condition. There is now abundant stratigraphical evidence that hand-axes were made in Britain prior to the deposition of the Clacton Channel sediments (see Chapter 1). Industries comprising only primitive hand-axes, classified as Early Acheulian, have also been described in likely pre-Hoxnian gravels at Farnham, Surrey and Fordwich, Kent (Roe, 1964, 1968a, 1975); they are presumably contemporary with or earlier than the Clactonian industries of both Clacton and Swanscombe. Hand-axes have been found in gravels of the Thames system that are now attributed to the late Anglian (see Chapter 3, Highlands Farm Pit and Hamstead Marshall) and in conjunction with a Cromerian mammalian fauna at Boxgrove, West Sussex (Roberts, 1986; Chapter 1). Thus there is no reason why derived hand-axes or characteristic flakes from their manufacture should not occur in the Clacton Channel Deposits, although it is clear that the important industry in the immediate area, which apparently persisted from late Anglian to mid-Hoxnian times, involved no hand-axe manufacture.

Various authors have proposed chronological divisions of the Clactonian Industry over the years, generally based on typology and/or condition, together with stratigraphical considerations (Breuil, 1932b; Warren, 1958; Collins, 1969; for summary, see Roe, 1981). Wymer (1968) argued that such divisions were unjustified and subsequent stratigraphical revisions have revealed that there is little basis for them. Following a recent re-evaluation of the industry, J. McNabb (pers. comm.) found no typological or technological grounds for separating the assemblages from Clactonian sites at Barnham, Suffolk (see Wymer, 1985b), Little Thurrock and Swanscombe in the Lower Thames (see Chapter 4) and Clacton itself. He also considered the essential characteristics of the Clactonian to be present within an assemblage of apparently pre-Anglian artefacts from High Lodge, near Mildenhall, Suffolk (see Wymer, 1985b, 1988; Chapter 1), implying that the industry was practised in Britain before the Anglian Stage.

The occurrence of Palaeolithic assemblages lacking both hand-axes and evidence for the refined flaking techniques employed in the Mousterian industries has puzzled archaeologists since they were first recognized. Warren (1951) compared cores from Clactonian sites to the early pebble and flake tool industries of Africa and Asia, considering the Clactonian to be an offshoot of the tradition of these primitive industries, an idea first mooted by Oakley (1949). In this industry flint working was carried out using bold strokes with a hard (stone) hammer, producing characteristically pronounced bulbs of percussion (Baden-Powell, 1949). Wymer (1985b) has emphasized, however, that there is no such thing as a 'typical Clactonian flake'; hard-hammer flakes of the type making up the bulk of Clactonian assemblages are also found in other industries, including post-Palaeolithic ones, although in these they tend to represent a smaller proportion of the total material. This fact has led to the suggestion that the Clactonian is merely a 'facies' of the Acheulian, assemblages without hand-axes (Clactonian) representing debitage from locations where preliminary working of raw material took place, with tool manufacture occurring elsewhere (Ohel, 1977, 1979). This suggestion scarcely seems feasible, as hand-axe manufacture is not a lengthy process; it is inconceivable, if the Clactonian knappers were hand-axe makers, that no evidence of this would be found amongst many thousands of artefacts at a site such as Clacton (excepting the three questionable and abraded finishing flakes from the Singer/Wymer excavation – see above). The above suggestion also fails to explain the geographical distribution of flake and hand-axe industries. Clacton lies at the western extremity of a 'province' of flake-core industries, which dominate the eastern European and Asian Palaeolithic, whereas hand-axe industries are dominant in the south-western and southern part of Europe (see Roe, 1981). Britain lies, according to some authorities, on the frontier between these two 'provinces', in an area where both Clactonian and hand-axe industries are found, possibly resulting from separate cultural groupings.

Stratigraphical relations of the Clacton deposits

Doubt has existed for many years about the precise stratigraphical relations between the Clacton Channel Deposits and the Pleistocene gravels of the Clacton area. The early descriptions and illustrations of the cliff sections at Clacton (Brown, 1840; Wood, 1866b; Fisher, 1868a; Dalton, 1880; Prestwich, 1890b) indicate that the channel deposits cut through earlier stratified gravel, which was later termed the Holland Gravel (Warren, 1923a; 1955). Fisher (1868a) claimed (in the caption to an illustration of the cliff section) that the channel deposits and the Holland Gravel were both overlain by an 'obliquely bedded gravel of unascertained relation', newer than the channel deposits but older than the overlying colluvial 'trail' (Fisher, 1868a, p. 214). Fisher's figure shows what appears to be cross-bedding, inclined towards the northern end of the section. Most later descriptions either ignored any gravel overlying the channel deposits or described it as a poorly bedded unit that might have resulted from solifluction. Fisher's claim, coupled with Warren's consistent caution regarding the matter (Warren never saw the critical area exposed), led to controversy over the relation between the channel deposits and the Holland Gravel (summarized by Wymer (1985b)). Clarification of this relationship has only been achieved by recent trial excavations in the West Cliff (Bridgland *et al.*, 1988; see below).

Most early workers considered the Holland Gravel to belong to the 'Glacial Series' of Wood and Harmer (1868), but Warren (1923a, 1924b, 1933) recognized that the gravels covering the Tendring Plateau, including that in the Clacton district, were terrace deposits of the Thames. In these early papers he suggested a correlation of these gravels with the Boyn Hill Terrace, regarding the Clacton Channel Deposits as a possible equivalent, laid down by a smaller stream, of the Taplow aggradation of the Thames. Subsequently, Warren (1951) cited the opinion of Solomon (in Oakley and Leakey, 1937), that the Holland Gravel was not of Thames but of Colne origin. He later changed his opinion again, realizing that the channel deposits were the product of a river of sufficient size to be the main Thames, and suggested that the Holland Gravel was a pre-diversion Thames deposit (Warren, 1955), a view that has been confirmed by recent work (Rose *et al.*, 1976; Bridgland, 1983a, 1988a).

A number of separate deposits have recently been identified within what was formerly classified as Holland Gravel. Within the main sheet of Holland Gravel, which stretches from the cliffs at Clacton and Holland to the St Osyth gravel pits, lower and upper divisions have been recognized (see above, St Osyth and Holland-on-Sea). On the basis of clast composition, it has been demonstrated that the Lower Holland Gravel is a pre-diversion Thames-Medway deposit, whereas the Upper Holland Gravel, overlying and apparently channelled into the top of the Lower Holland Gravel, appears to date from the brief period during the Anglian glaciation when the Thames was blocked by ice and no longer reached the Clacton area (Bridgland, 1983a, 1988a; Bridgland *et al.*, 1988, 1990). This interpretation is again based on the clast content of the Upper Holland Gravel, which is predominantly indicative of a Medway provenance, supplemented by small amounts of the type of material introduced by the Anglian glaciation. On the basis of these observations, the Holland Gravel Formation has been ascribed to the Anglian Stage and correlated with the Winter Hill Formation of the Middle Thames (Table 1.1 and Fig. 1.2; Table 5.3 and see above, St Osyth and Holland-on-Sea). Thus the Clacton Channel Deposits cut through and overlie the downstream equivalent of the Winter Hill Gravel, the last Thames formation to be aggraded prior to the diversion of the river.

A later gravel formation, the Mersea Island/Wigborough Gravel, has also been recognized in the Clacton area within the broad definition of the Holland Gravel applied by earlier workers (Bridgland, 1983a, 1988a; Bridgland *et al.*, 1990). This deposit is represented by a string of remnants along the southern fringe of the Tendring Plateau, running from Point Clear to Jaywick. These appear, from their distribution and altitude, to be a continuation of the gravels of Mersea Island (Figs 5.2 and 5.5B). This has been confirmed by clast-lithological analysis (Table 5.5), which indicates that the deposits are part of the Low-level East Essex Gravel Subgroup, interpreted as the product of the post-diversion Thames-Medway (Bridgland, 1980, 1983a, 1988a; Bridgland *et al.*, 1988; see above, Introduction to Part 2). The Mersea Island Gravel (Fig. 5.2) contains only a few percent of quartzose exotic clasts, in contrast to the 12–20% present in pre-diversion Thames-Medway gravels, and also contains significantly more Greensand chert from the Medway catchment (Table 5.5). However, between Point Clear and Jaywick the clast content of this formation changes markedly over a short lateral (downstream) distance. In this transition, from gravel of Mersea Island to Wigborough type, quartzose exotics become more important at the expense of Greensand chert, so that the deposit closely resembles the Lower Holland Gravel. A possible explanation for this change is an influx of material reworked from the pre-diversion gravels covering the Tendring Plateau, possibly as a result of a confluence between the Thames-Medway and an early River Colne, which would have formed in the eastern end of the abandoned pre-diversion Thames valley (Fig. 5.5B). It is possible that the upper gravel in the West

Cliff at Clacton, illustrated by Fisher (1868a), represents a downstream continuation of this post-diversion formation (see below).

Analysis of the clast content of the Clacton Channel Gravel (basal Lower Freshwater Beds) indicates that it too is the product of the post-diversion Thames-Medway (Bridgland, 1980, 1983a, 1988a; Bridgland *et al.*, 1988; Table 5.5). However, the relation between the Clacton Channel Gravel and the Wigborough Gravel is unclear from the mapped distribution of these deposits. The former is benched into the London Clay at the extreme south-eastern edge of the Tendring Plateau, at a height of *c.* -6 m O.D., and was aggraded to at least +10 m O.D. (Fig. 5.18), whereas the latter has a surface level falling from 15 m O.D. at Point Clear to 11 m O.D. at Jaywick. In the latter area the London Clay rises to the land surface between the outcrops of the Wigborough Gravel and the Clacton Channel Deposits (Fig. 5.2). The geomorphology would therefore seem to suggest that the excavation of the Clacton Channel resulted from post-Wigborough Gravel rejuvenation. It has been suggested, however, that the Wigborough Gravel formerly extended further south, covering the channel deposits (Bridgland, 1988a; Bridgland *et al.*, 1988). Only a single post-diversion Thames-Medway terrace formation has been recognized north of the Crouch, the Asheldham Gravel/Mersea Island/Wigborough Gravel (Bridgland, 1983a, 1988a; Fig. 5.5B). On the Dengie Peninsula (between the Crouch and Blackwater estuaries), this formation fills and overlies a buried channel, the Asheldham Channel (see below, Southminster and Fig. 5.28). An upstream equivalent of this channel has been identified south of the Crouch, the Southend Channel (Fig. 5.5A), and it has been suggested that the Swanscombe Lower Gravel channel is its correlative (Bridgland, 1980, 1983a, 1988a). Downstream the same channel is believed to continue across Mersea Island, where it contains estuarine and fluvial deposits that are exposed, beneath the Mersea Island Gravel, at Cudmore Grove (Bridgland *et al.*, 1988; Fig. 5.5A). This has been interpreted as an upstream equivalent of the Clacton Channel (Bridgland, 1980, 1983a, 1988a). According to this regional interpretation, the Wigborough Gravel must once have covered the Clacton Channel Deposits, but has since been removed by erosion, except for the series of remnants between Point Clear and Jaywick.

In order to clarify the relations between the gravels of the Clacton cliffs and the Clacton Channel Deposits, temporary sections were excavated at four points along the West Cliff during April 1987 by P. Harding and the author. The first three sections were entirely within the Clacton Estuarine Beds, although augering at the base of section 3 may have reached London Clay. The fourth section was of considerable interest, however, in that it revealed the feather-edge of the interglacial beds, in the form of a blue-grey clay, interstratified between bedded gravels (Bridgland *et al.*, 1988). A large flake was discovered ***in situ*** at the intersection between the top of the lower gravel and the base of this clay (Fig. 5.21); a small flake was also found in the upper gravel. The lower deposit is considered to be the Lower Holland Gravel, the last terrace formation of the pre-diversion Thames-Medway. The gravel above the channel deposits, presumably that observed by Brown and illustrated by Fisher, is clearly a bedded fluvial deposit, albeit with a rather high silt/clay content and perhaps somewhat disturbed (both of which could be the result of proximity to the land surface, within the zone of cryoturbation and pedogenesis). This upper gravel has a clast-content similar to the Mersea Island and Clacton Channel Gravels, suggesting that it too represents the post-diversion Thames-Medway (Low-level East Essex Gravel Subgroup). There is a surprising similarity in clast composition between the Clacton Channel Gravel and the upper gravel in the West Cliff section, on the one hand, and the Mersea Island Gravel, on the other (Table 5.5). The Clacton site is well downstream of the supposed confluence with the Colne, so reworked quartzose material from the pre-diversion gravels, as seen in the Wigborough Gravel at Jaywick, should be present there. An eastward projection of the series of Wigborough Gravel remnants indicates that the formation should intersect with the present coast in the area of the West Cliff section. This poses a problem of interpretation, in that the characteristics of the gravel above the channel deposits do not support its identification as part of the Wigborough Gravel, although it occupies the geographical and stratigraphical position in which that formation would be expected. A possible explanation is that the upper gravel in the cliffs is more closely allied to the channel deposits than to the Wigborough Gravel, which is assumed to represent

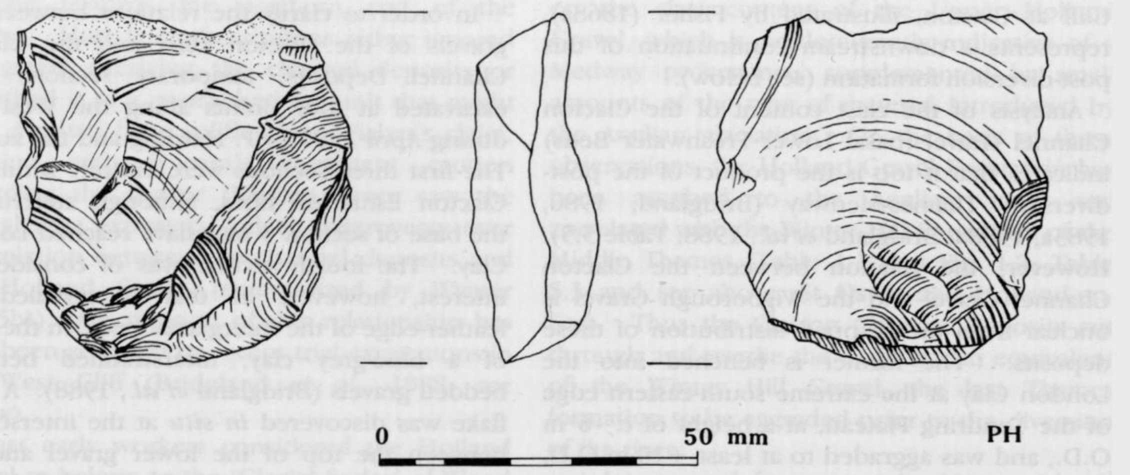


Figure 5.21 Flint flake from the West Cliff at Clacton, found *in situ* in GCR Section 4 in April 1987, at *c.* 9.9 m O.D. This flake was lying immediately below the wedge of blue-grey clay, interpreted as the feather-edge of the Clacton Channel Deposits. This is probably the highest point at which an artefact has been found in the Clacton deposits, although stratigraphically it was at the same level as the earlier Palaeolithic finds. (Drawing by P. Harding.)

a later cold episode. The Colne tributary may not have operated as a major source of gravel (reworked from the Kesgrave Group deposits to the north and west) until after the Hoxnian Stage (*sensu* Clacton). Alternatively, mixing of Thames-Medway- and Colne-derived gravel may have been incomplete, allowing deposits of Mersea Island Gravel affinities to be deposited downstream from the confluence with the Colne.

The possibility that the regional sequence is more complex than has yet been established, and that the Clacton Channel post-dates the Wigborough Gravel, cannot be ruled out however, since no gravel of Wigborough type has yet been found overlying the channel deposits. Indeed, since the Wigborough Gravel and the Lower Holland Gravel are very difficult to separate on the basis of clast-lithological content (see Tables 5.2 and 5.5), it is possible that the gravel underlying the channel deposits in the cliff section could be the Wigborough Gravel, rather than the Lower Holland Gravel. At present the interpretation of this cliff section still relies heavily on the regional stratigraphical framework derived from studies of the terrace sequence in eastern Essex as a whole. Further consideration will be given to this question below, in the report on the closely related site at Cudmore Grove, East Mersea.

The correlation of the Clacton Channel Deposits with the lower part of the Swanscombe sequence (Table 1.1 and Fig. 1.2), implied by the above interpretation, confirms many previously published opinions, notably those of Singer *et al.* (1973), on the basis of the Palaeolithic industries at the two sites. In fact a small collection of Clactonian artefacts has also been obtained from equivalent deposits (Asheldham Channel Gravel) at Burnham-on-Crouch (TQ 945972), further establishing a link between this particular phase of Thames evolution and the Clactonian Industry (Bridgland, 1988a). Bridgland (1980, 1983a, 1988a) suggested a correlation between these early post-diversion deposits and both the Black Park and Boyn Hill Gravels of the Middle Thames. He believed that the steeper Black Park aggradation had fallen below the level of the Boyn Hill in eastern Essex, so that the Black Park Gravel is represented within the lower part of the Boyn Hill/Mersea Island/Wigborough Formation (no rejuvenation can be recognized between the Black Park and Boyn Hill Formations downstream from London). This implies that the erosion of the Clacton Channel, prior to its infilling during the Hoxnian Stage, may have resulted from downcutting associated with the pre-Black Park rejuvenation; this incision has been directly attributed elsewhere in this volume to the diversion of the Thames (see Chapters 1, 3 and 4). It is also possible that any basal, pre-Hoxnian sediments in the Clacton Channel may equate with the Black Park Formation of the Middle Thames.

Summary

The complex GCR site at Clacton has been shown to be a Pleistocene locality of international significance. It provides evidence from many of the various disciplines involved in Quaternary studies, in particular from Palaeolithic archaeology and palaeontology. The site has yielded a range of faunal material seldom bettered in others of this age, including highly significant large-mammal and mollusc faunas. It is extremely likely that modern sampling of the freshwater beds at the West Cliff site, which have not been exposed for many years, would produce an assemblage of smaller vertebrates to match those from other sites more recently investigated. The site also has a particularly rich palaeobotanical record.

The wealth of palaeontological information from Clacton is of increased value since the site can be directly related to the Thames terrace sequence. This is not the case with the Hoxnian type site, which represents a lacustrine infill and is therefore more difficult to relate to an integrated regional stratigraphy. Swanscombe, the only other well-known Hoxnian site within the Thames system, lacks a convincing palaeobotanical record; indeed, the Clacton sequence has been used to calibrate that at Swanscombe, by a comparison of their molluscan faunas.

Conclusions

The Clacton locality, with its complex fossil record and stratigraphy, has been central to the debate about the interglacial (temperate-climate) period immediately following the glaciation that brought about the diversion of the Thames. The site is internationally famous for the occurrence there, in channel deposits of the early Thames-Medway, of abundant Palaeolithic (early Stone Age) artefacts. There are no recognizable tools amongst these artefacts; instead the 'industry' comprises a characteristic mixture of crudely worked flint. Clacton was established as the type locality for this particular type of industry in 1926. The Clacton sections also yield the remains of terrestrial, fluvial and marine faunas and floras. These illustrate life in and around the river during the early part of this temperate interval and, higher in the sequence, an influx of marine species marks a change to estuarine conditions as the sea level rose. The Thames at this time flowed in its modern valley, through what is now London, but turned northwards to rejoin its old pre-diversion valley just upstream from Clacton. There is widespread agreement that the Clacton sequence can be correlated with sediments at Swanscombe, in the Lower Thames valley, both being attributed to the interglacial (around 400,000 years BP) that immediately followed the major glaciation during the Anglian Stage. The Clacton sediments have also been equated, on the basis of similarities in pollen content, with lake sediments at Hoxne in Suffolk, the type locality for the Hoxnian interglacial.

CUDMORE GROVE (EAST MERSEA) CLIFFS AND FORESHORE (TM 068146)

D.R. Bridgland

Highlights

A highly fossiliferous Middle Pleistocene channel-fill, underlying gravels of post-diversion Thames-Medway origin, has been revealed here in recent years by coastal erosion. The deposits at Cudmore Grove include estuarine and freshwater beds. They are probably equivalent in age to the fossiliferous deposits at Clacton and Swanscombe, which have been interpreted as part of the same interglacial Thames channel-fill. The tracing of this channel from the Lower Thames valley through eastern Essex charts the course of the Thames during the period that followed the Anglian glaciation. The Cudmore Grove site has produced the most extensive small-vertebrate fauna from the British Pleistocene.

Introduction

The Pleistocene interest of Mersea Island has long been overshadowed by the richly fossiliferous Middle Pleistocene channel deposits at

Clacton-on-Sea, situated only 9 km to the east. However, the gravels covering parts of the island were the subject of discussion by early workers (Wood, 1866b; Dalton, 1908; Anon., 1913). Furthermore, records of Pleistocene fossils discovered at East Mersea can be traced back for at least 80 years (Dalton, 1908; Warren, 1917, 1924b, 1933; Cornwall, 1958; Zeuner, 1958; Sutcliffe, 1964; Spencer, 1966). Today three separate Pleistocene localities are recognized here (Bridgland *et al.*, 1988) within a single, complex GCR site. Pleistocene channel-fills occur at all three sites (Figs 5.22, 5.23 and 5.24), exposed by present-day marine erosion. At Cudmore Grove two channels of different ages are recognized, the Cudmore Grove Channel, which is attributed to the Thames-Medway and is the subject of the present report, and a later feature, the sediments in which yield hippopotamus. The latter, at the Cudmore Grove Hippopotamus Site, is closely associated with the third East Mersea locality, the Restaurant Site, 1 km to the west. The sediments at the Hippopotamus Site and the Restaurant Site are attributed to a later tributary river, rather than the main Thames-Medway, and are thus described below in Part 3 of this chapter.

Most early records of fossils from East Mersea seem to be related to the later tributary deposits, but there is one probable reference to the Cudmore Grove Thames-Medway sediments. A Pleistocene estuarine deposit with shells of *Cerastoderma* and *Scrobicularia* was encountered in 1906 in an excavation for a well in a small pit 'one mile east by north of East Mersea church' (Dalton, 1908, p. 136).

At that time there was, to the south of Cudmore Grove, a tract of well-established salt-marsh, still remembered by local inhabitants, between the high, gravel-covered land and the sea. Subsequent destruction of the salt-marsh has led to the formation of cliffs at the edge of the higher land. These had reached a height of just over 3 m in 1971, when they were described by Tucker and Greensmith (1973). Greatly accelerated erosion in recent years has doubled their height and given rise to fine cliff and foreshore exposures in the fossiliferous deposits and the overlying gravel. It seems likely that the pit referred to by Dalton was situated within the present Country Park at Cudmore Grove, where there is a small overgrown hollow (TM 065148). This lies *c.* 300 m from the present cliffs, so, if the channel deposits are continuous between the two, they are of considerable extent.

Description

The cliffs at Cudmore Grove expose fossiliferous estuarine deposits beneath up to 4 m of

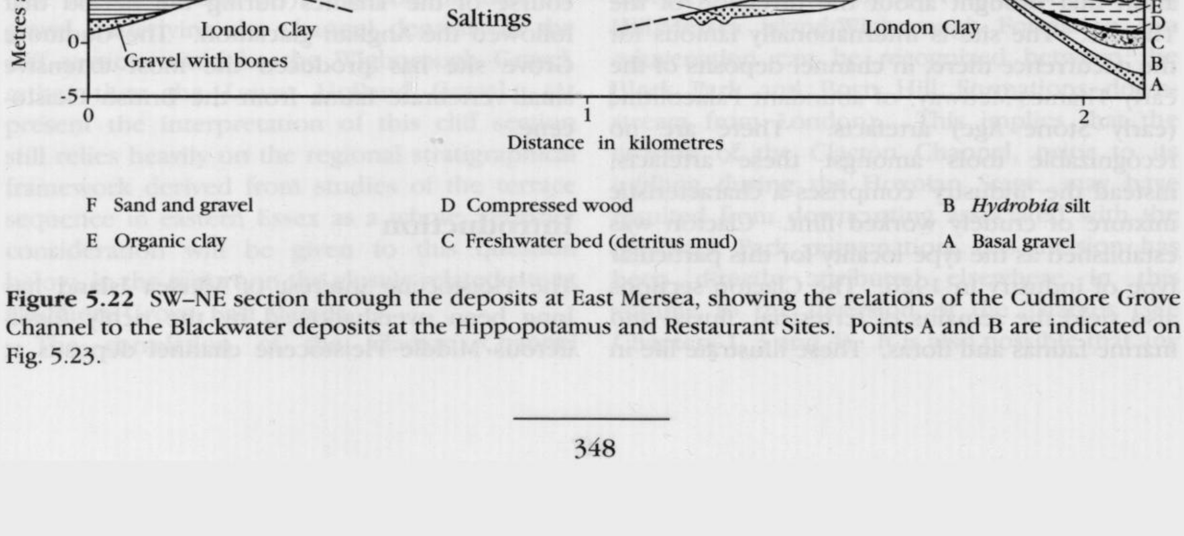


Figure 5.22 SW–NE section through the deposits at East Mersea, showing the relations of the Cudmore Grove Channel to the Blackwater deposits at the Hippopotamus and Restaurant Sites. Points A and B are indicated on Fig. 5.23.

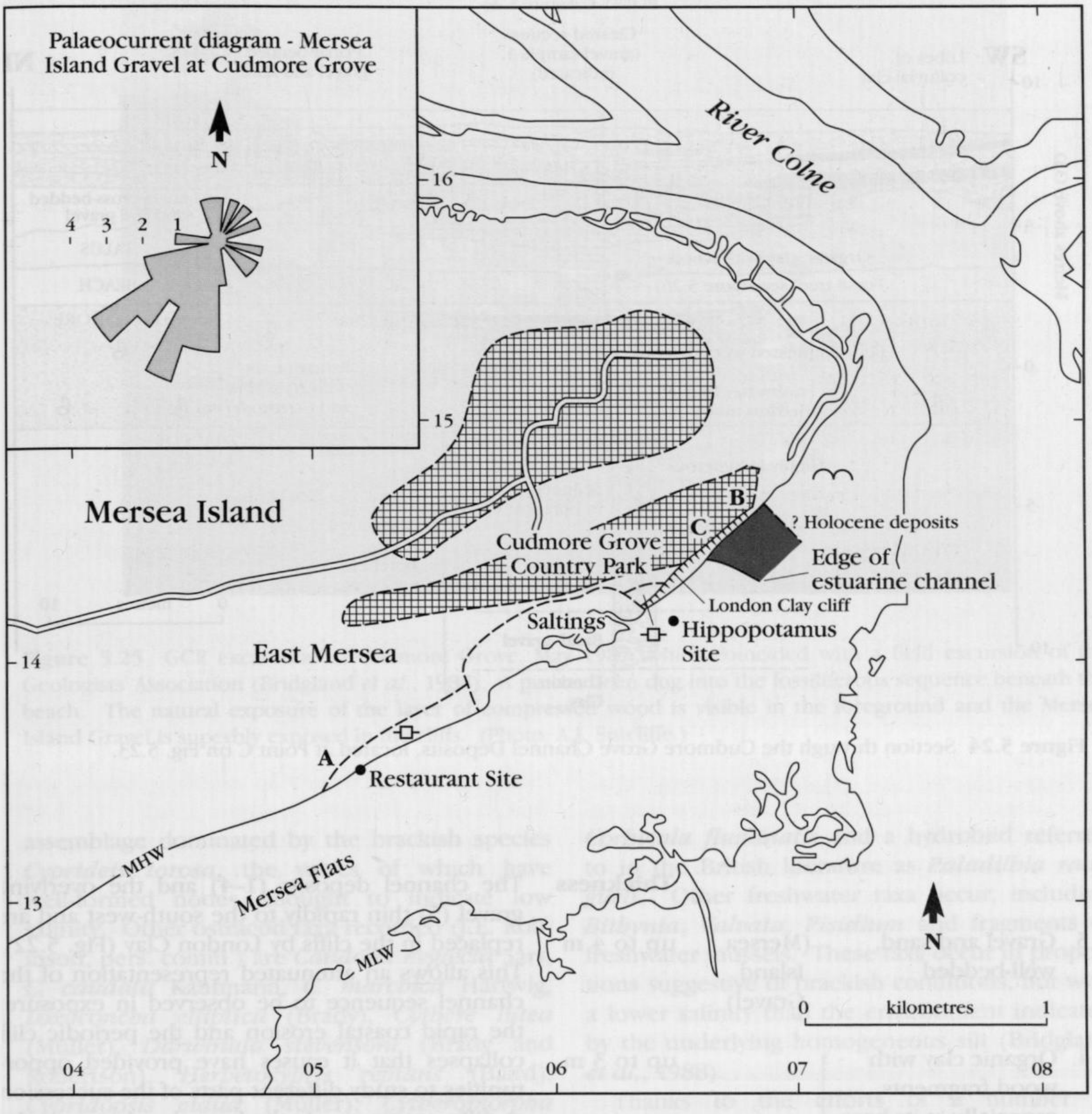


Figure 5.23 Map showing the Pleistocene deposits of East Mersea (after Bridgland *et al.*, 1988). The points A and B refer to the ends of the section in Fig. 5.22. Point C is the location of the section in Fig. 5.24.

well-bedded gravel and sand (Fig. 5.24). These deposits occupy a channel deeply excavated into the London Clay, the southern edge of which can be traced across the foreshore (Fig. 5.23). The base of the channel has been reached in a borehole in the central part of the outcrop at -11 m O.D., where some 3 m of gravel underlie the fossiliferous sediments (Roe, in Bridgland *et al.*, 1988). The sequence can be summarized as follows:

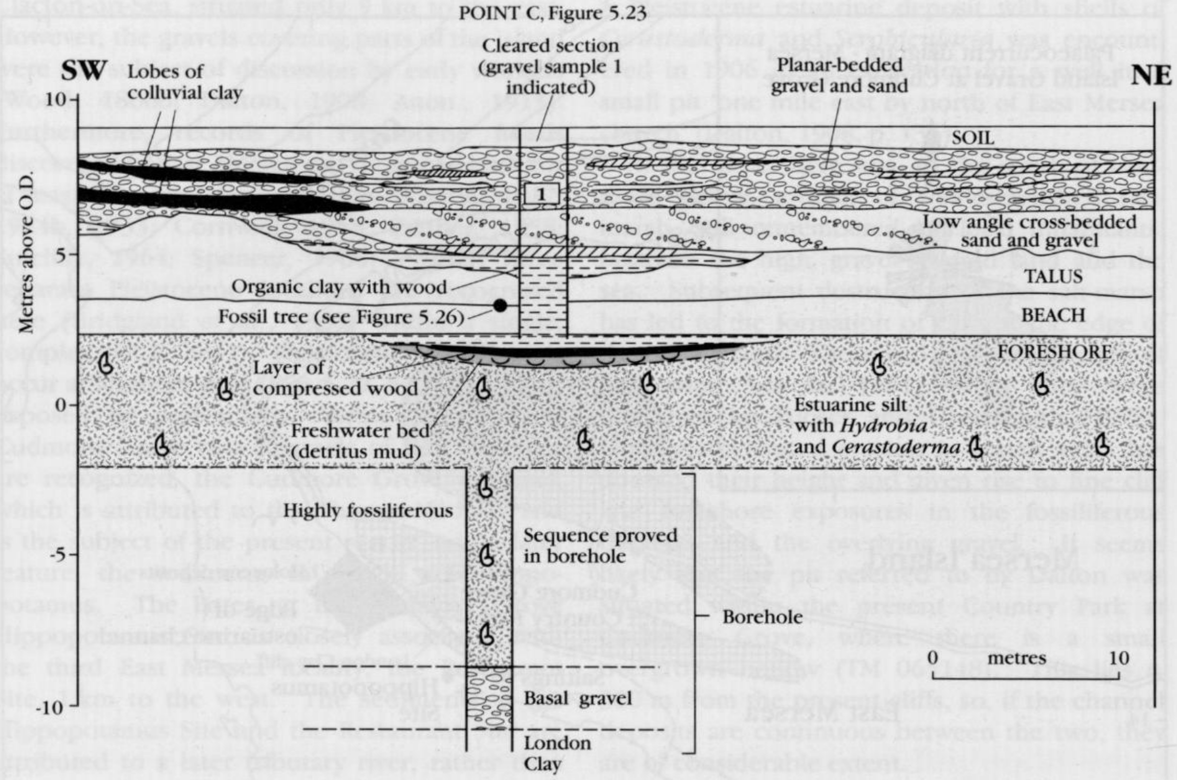


Figure 5.24 Section through the Cudmore Grove Channel Deposits, located at Point C on Fig. 5.23.

		Thickness
5. Gravel and sand, well-bedded	(Mersea Island Gravel)	up to 4 m
4. Organic clay with wood fragments, especially at its base	(Cudmore Grove Channel Deposits)	up to 3 m
3. Shelly 'detritus mud', richly fossiliferous		0–0.3 m
2. Homogeneous clayey silt with estuarine Mollusca		up to 10 m
1. Gravel	(Cudmore Grove Channel Gravel)	3 m
London Clay		

The channel deposits (1–4) and the overlying gravel (5) thin rapidly to the south-west and are replaced in the cliffs by London Clay (Fig. 5.22). This allows an attenuated representation of the channel sequence to be observed in exposure; the rapid coastal erosion and the periodic cliff collapses that it causes have provided opportunities to study different parts of the succession at different times. At the boundary between the channel deposits and the London Clay is a 'lag gravel', only 0.2–0.3 m thick, composed largely of rounded London Clay pebbles set in a clay matrix. Scattered durable clasts also occur, however, which resemble the material in the gravel overlying the channel sequence (Table 5.5). A Palaeolithic flake in very fresh condition has been recovered from this basal deposit (Bridgland *et al.*, 1988; see below).

The homogeneous clayey silt (bed 2) constitutes the bulk of the channel-fill (Fig. 5.24). It contains abundant molluscs, mostly hydrobiids and *Cerastoderma*, indicative of brackish or intertidal conditions. From its 'feather-edge', in the cliffs, this bed yields a rich ostracod

Figure 5.25 GCR excavation at Cudmore Grove, May 1987, which coincided with a field excursion of the Geologists' Association (Bridgland *et al.*, 1988). A pit has been dug into the fossiliferous sequence beneath the beach. The natural exposure of the layer of compressed wood is visible in the foreground and the Mersea Island Gravel is superbly exposed in the cliffs. (Photo: A.J. Sutcliffe.)

assemblage dominated by the brackish species *Cyprideis torosa*, the valves of which have well-formed nodes, thought to indicate low salinity. Other ostracod taxa recorded (J.E. Robinson, pers. comm.) are *Candona neglecta* Sars, *C. caudata* Kaufmann, *C. marchica* Hartwig, *Loxoconcha elliptica* (Brady), *Cythere lutea* (Müller), *Darwinula stevensoni* (Brady and Robertson), *Herpetocypris reptans* (Baird), *Cypridopsis vidua* (Müller), *Cytheromorpha fuscata* (Brady), *Ilyocypris gibba* (Ramdohr) and *Limnocythere inopinata* (Baird). The majority of the above are freshwater species, but *L. elliptica*, *C. lutea* and *C. fuscata* live in marine or brackish conditions. The deposit also contains pollen from trees such as oak, elm and hazel, implying fully temperate conditions (Roe, in Bridgland *et al.*, 1988).

Above the estuarine silt, but apparently of restricted lateral extent, occurs the most richly fossiliferous of the Cudmore Grove deposits, the shelly 'detritus mud' (bed 3). This bed is usually only *c.* 0.3 m thick, but it is packed with shell fragments and is very rich in small vertebrate remains. The molluscan fauna is dominated by *Corbicula fluminalis* and a hydrobiid referred to in the British literature as *Paladilhia radigueli*. Other freshwater taxa occur, including *Bithynia*, *Valvata*, *Pisidium* and fragments of freshwater mussels. These taxa occur in proportions suggestive of brackish conditions, but with a lower salinity than the environment indicated by the underlying homogeneous silt (Bridgland *et al.*, 1988).

Thanks to the efforts of a number of collectors (notably J.D. Clayden, D. Harrison, M. Warren and R. Wrayton), who have sieved huge volumes of sediment from the foreshore exposures, bed 3 has produced a wealth of small vertebrate remains that is unparalleled in the British Middle Pleistocene. The rodents include *Apodemus sylvaticus* (L.) (wood mouse), *Clethrionomys glareolus* (bank vole) and *Microtus agrestis* (short-tailed field vole); the insectivores *Neomys fodiens* (water shrew) and *Crocidura* sp. (white-toothed shrew) are also present, the former in some abundance. Larger mammals include quite common remains of *Castor fiber* (beaver), much rarer *Ursus* sp. (bear), and a tooth of *Macaca sylvanus* (macaque), a species

Figure 5.26 Part of a fossil tree protrudes from beneath the beach at Cudmore Grove. An interesting analogue is provided by the modern tree, which has fallen over the cliffs from the rapidly diminishing grove, a victim of the rapid coastal erosion. (Photo: A.J. Sutcliffe.)

known only from pre-Ipswichian interglacial deposits in Britain. Other vertebrate remains discovered in this bed include *Emys orbicularis* (pond tortoise), *Bufo bufo* (L.) (toad), *Rana* sp. (frog), *Eptesicus* sp. (bat) and several species of birds and fish. Several elements of the herpetofauna are new to the British Pleistocene (Holman *et al.*, 1990). The palynological sequence from the site places this bed in the late temperate phase of the interglacial; it has been attributed to Hoxnian biozone HoIIIb (Roe, in Holman *et al.*, 1990).

The overlying organic clay (bed 4) lacks calcareous fossils, but contains, except in the oxidized upper few centimetres, abundant wood fragments and well-preserved pollen. The latter is similar to that in the homogeneous silt (bed 2), with the addition of substantial hornbeam and alder, small amounts of silver fir (*Abies*) and occasional records of the palynomorph 'Type X' (Roe, in Bridgland *et al.*, 1988). At the base of this bed is a layer of compressed wood (Figs 5.24 and 5.25) that includes large fragments. Two tree-trunks, one with roots attached, have been observed at different times protruding from this bed and forming prominent features on the modern beach and foreshore (Fig. 5.26).

The gravel that overlies the channel deposits contains a mixture of local, southern and exotic clasts similar to those in the Clacton Channel Gravel and in the Low-level East Essex Gravel south of the Blackwater (Bridgland, 1980, 1983a, 1983b, 1988a; Bridgland *et al.*, 1988; Table 5.5). Excellent exposures in this deposit are provided by the cliffs at Cudmore Grove, allowing sedimentary and post-depositional structures to be observed. At the western end of its exposure in the cliffs, as it thins against rising London Clay bedrock, the gravel is interbedded with steeply dipping beds of redeposited clay (Fig. 5.24), thought to represent lobes of colluvial material at the edge of the contemporary floodplain. Towards the opposite end of the exposure, the gravel is disrupted by numerous near-vertical structures resembling ice-wedge casts, but often with a slight downthrow on their eastern side. The underlying organic clay is diapirically uplifted beneath a number of these features, which might result from cambering rather than (or as well as) ground-ice development (Bridgland *et al.*, 1988).

Interpretation

Although research on the Cudmore Grove site is still in progress, sufficient information has already come to light to indicate that this is an extremely important Middle Pleistocene locality. Much of the site's significance results from its exceptional wealth of faunal evidence, the interest of which is enhanced (as at Clacton) by the fact that the deposits are a component part of the Thames-Medway terrace sequence.

The palaeontology of the channel deposits provides information about the palaeoenvironment as well as evidence for relative dating and correlation with other sites. The sequence records a change from a fluvial channel-fill, as evidenced by the thick basal gravel, to an estuarine environment, indicated by the characteristics and faunal content of the homogeneous silt (bed 2). Later deposits suggest a tendency towards marine regression, with a decrease in salinity indicated by the fauna of the 'detritus mud'. The overlying gravel (bed 5) presumably marks a return to a fluvial environment, very possibly coupled with a climatic deterioration, major gravel units normally being regarded as cold-climate deposits (see Chapter 1). However, there is nothing to suggest a lengthy hiatus between the organic clay and the overlying gravel. In fact the lower part of the gravel comprises a series of low-angle cross sets (Fig. 5.24), dipping south-eastwards, that may represent deltaic progradation over the estuarine sequence, perhaps in response to an increased supply of sediment, prior to any major fall in sea level (Whiteman, in Bridgland *et al.*, 1988).

The channel sediments above the basal gravel are of clear interglacial character. The rodent assemblage in the 'detritus mud' (bed 3), for example, is typical of the temperate woodland phases of the Middle and Late Pleistocene (Currant, 1986; Bridgland *et al.*, 1988). The pollen and fossil wood further indicate that deciduous woodland was established in the region. The fact that sea level was sufficiently high to allow estuarine deposition within the present land area is also indicative of an interglacial, as sea levels during cold episodes were many metres below that at the present time.

The overlying Mersea Island Gravel is of sedimentological interest, comprising a varied sequence displaying a number of different types of bedding structure. These range from small-scale cross-stratification to the large foresets mentioned above. Several of the sandier horizons show evidence of penecontemporaneous deformation, suggesting that they were highly saturated when the overlying beds were laid down above them. Palaeocurrent measurements from small-scale foresets are widely distributed (Fig. 5.23, inset), giving rise to a radial distribution that is somewhat difficult to interpret. A south-south-east mean direction can be calculated, if the largest gap in the distribution is taken as a 'false origin', but this is of dubious value. It fails to take into account the strong double-peaked concentration of dips to the south-west. Double peaks of this type are typical in braided river gravels, in which they are believed to represent deposition on either side of lozenge-shaped bars (see Reading, 1978). These peaks appear to indicate that a river flowing towards the south-west deposited at least some parts of the gravel sequence.

The Mersea Island Gravel was excluded by Wood (1866b) from his original definition of the East Essex Gravel and was mapped as 'Glacial' by the early officers of the Geological Survey (Old Series, Sheet 48SW). However, Dalton (1908) decided that the gravel must be 'Post-glacial', following the discovery of fossiliferous deposits beneath it (see above), and it was subsequently described as a Thames-Medway deposit (Anon., 1913). Wooldridge (1927b), perhaps swayed by the Geological Survey mapping, interpreted the gravel as glacial outwash. The palaeocurrent evidence, which suggests that all or part of the gravel sequence at Cudmore Grove represents a braided river floodplain trending towards the south or south-west, would appear to support its interpretation as outwash. The composition of the gravel, however, provides important evidence precluding a provenance from the north. The deposit bears no resemblance to outwash, even of distal type, and it contains little of the quartzose exotic material that a river from the north or north-east would have reworked from the pre-diversion

Thames gravels of the Tendring Plateau (Bridgland *et al.*, 1988; Table 5.2). Instead, its clast composition implies parity with the Low-level East Essex Gravel deposits to the south of the Blackwater estuary (Table 5.5), which are interpreted as the products of the post-diversion Thames-Medway. Thus the south-westward palaeocurrents from the Cudmore Grove cliffs, if correctly interpreted, must be a localized trend, possibly representative of a braided floodplain that followed a sinuous course across the area of Mersea Island. The gravel is considered to be part of a single, thick aggradational unit, the Mersea Island Gravel, that also includes the much higher remnants at West Mersea and on the eastern side of the Colne estuary at Point Clear (Bridgland, 1983a, 1988a; Figs 5.2 and 5.27).

Correlation

In what appears to be the first record of their existence, Dalton (1908, pp 136–7) compared the Cudmore Grove deposits with those at Clacton: 'the silt much resembles the unweathered condition of the Clacton Postglacial deposit, as found below the beach; it is there full of land and freshwater shells and plant remains, though of estuarine character at a higher level, as seen in the cliffs. Possibly a similar sequence obtains in East Mersea, the estuarine passing down into a lacustrine deposit'.

Dalton's suggestion, made before the complexity of climatic fluctuations during the Pleistocene was widely accepted and based largely on the character of the sediments, is supported by much of the scientific evidence gathered in recent years. Most palaeontological indications of the age of the deposits suggest that they, like the Clacton Channel sequence, are of Hoxnian (*sensu* Swanscombe) age. Amongst the rich vertebrate fauna from Cudmore Grove, the vole ***Arvicola cantiana*** has a restricted occurrence within the Pleistocene between the late 'Cromerian Complex', where it

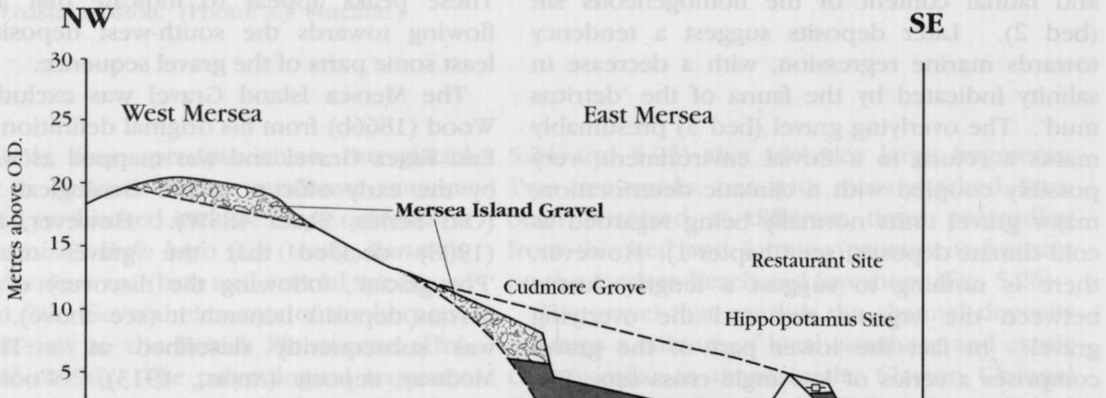


Figure 5.27 Idealized transverse section through Mersea Island (after Bridgland *et al.*, 1988).

replaces the earlier form *Mimomys savini* (see Chapter 1), and the Ipswichian (*sensu* Trafalgar Square), in which it in turn is replaced by the modern water vole *Arvicola terrestris* (Hinton) (Sutcliffe and Kowalski, 1976).

The pollen record from the Cudmore Grove channel sequence is also of particular value for relative dating, in that it resembles those from Hoxnian sites in the general area, such as Marks Tey (Turner, 1970) and Clacton (Pike and Godwin, 1953; Turner and Kerney, 1971; see above, Clacton). The detailed analysis of pollen and spores from Cudmore Grove is as yet unpublished, but preliminary observations have already proved informative (Roe, in Bridgland *et al.*, 1988; in Holman *et al.*, 1990). Of considerable significance is the occurrence of 'Type X', which is generally regarded as an indicator of the Hoxnian Stage (see above, Clacton). Correlation of the Cudmore Grove sequence with the Hoxnian (*sensu* Swanscombe) would support recent palaeogeographical reconstructions of the various Pleistocene deposits in eastern Essex, based on terrace stratigraphy (Bridgland, 1988a; Figs 5.5A and 5.5B). This reconstruction involves a correlation of the Cudmore Grove and the Clacton channels. There are, however, a number of uncertainties to overcome before detailed correlation between the sequences at the two sites can be established.

The estuarine character of the deposits at Cudmore Grove would seem to indicate that they post-date the most fossiliferous part of the Clacton sequence, which is of freshwater origin (see above, Clacton). The Clacton Estuarine Beds were regarded by Warren (1955) as representing a period of declining sea level following a marine transgression. The palynological record from Clacton places this transgression between biozones HoIIIa and IIIb, the Estuarine Beds being ascribed to IIIb (see above, Clacton and Fig. 5.19). The fossiliferous sequence at Cudmore Grove also appears to record a period of declining sea level, as suggested by the molluscan fauna of the detritus mud. The pollen from Cudmore Grove indicates that biozone HoIIIb is also represented there. The fact that deposits of this age occur at a lower elevation at Cudmore Grove than at the Clacton West Cliff site (the transgression is represented at *c.* 3 m in the West Cliff section – see Fig. 5.19) lends support to the suggestion that there was a period of erosion between the deposition of the Freshwater and Estuarine Beds at Clacton (see above, Clacton). Thus the lower part of the estuarine sequence at Cudmore Grove probably has no equivalent in the Clacton West Cliff section, but may correlate with the lower-level estuarine deposits in other parts of the Clacton site, such as Warren's Channel vi at Lion Point (Fig. 5.18).

The basal gravel and the peripheral 'lag' gravel at Cudmore Grove are probably fluviatile, but these have yet to yield any palaeontological evidence and therefore cannot be related to the standard Hoxnian pollen sequence. The flake found in the 'lag gravel' may, however, indicate an upstream continuation of the industry at Clacton, where artefacts are concentrated in the Freshwater Beds. The flake was found *in situ* during sampling for clast-lithological analysis; this involved removing only a very small volume of the deposit, so a rich Palaeolithic content may be indicated. Wymer (1985b) recorded an earlier discovery of a flake at the site. This was found in 1978 'in the top of an orange clay with large flint pebbles', at TM 067144 (Vincent and George, in Wymer, 1985b, p. 258). The grid reference closely coincides with the outcrop of the 'lag gravel' at the western edge of the channel and the description also suggests that this artefact (now in the Passmore Edwards Museum) came from this deposit. Two further flakes, again in fresh condition, have been found on the beach in close proximity to the exposure of the 'lag gravel'. It is likely that these specimens, one found by D. Maddy during the Geologists' Association excursion to East Mersea in May 1987 and the other by P. Spencer in February 1989, were derived from the Cudmore Grove deposits, possibly the basal gravel. Unfortunately, because of the location of these deposits, at (and below) foreshore level beneath actively eroding cliffs, it will be difficult to verify that an important Palaeolithic industry is present.

The reconstruction of post-Anglian palaeodrainage in eastern Essex (Bridgland, 1980, 1983a, 1983b, 1988a; Fig. 5.5A and 5.5B) also supports the correlation of the Cudmore Grove and Clacton sediments. This reconstruction, based on terrace stratigraphy and aided by gravel clast analyses, suggests that the Thames-Medway river only flowed as far north as Mersea Island and Clacton for the period of a single terrace cycle, that during which the Asheldham/Mersea Island/Wigborough Formation was deposited (see Fig. 5.5). Subsequent formations are only found to the south of the Blackwater, their distribution reflecting the progressive south-eastward migration of the river. The ages attributed to these various formations (Tables 1.1 and 5.3) imply that the course across Mersea Island to Clacton persisted, following the Anglian Stage diversion of the Thames, until Oxygen Isotope Stage 10. During the latter stage, rejuvenation to the Barling Formation level coincided with a southward shift in the course of the Thames-Medway. This means that, unless this interpretation is incorrect, all interglacial deposits of post-diversion Thames-Medway origin to the north of the Dengie Peninsula must date from Oxygen Isotope Stage 11. Such deposits, which include the sediments filling parts of the Southend/Asheldham Channel (Fig. 5.5A) as well as those at Cudmore Grove and Clacton, are therefore seen as downstream equivalents of the deposits at Swanscombe (Bridgland, 1983a, 1988a; see Chapter 4).

A view contradictory to this interpretation has, however, been expressed by Currant (1989), in an appraisal of small-mammal faunas in Britain. Currant noted that there are many similarities between the rich assemblage of small mammals at Cudmore Grove and that from Grays in the Lower Thames (see Chapter 4, Globe Pit). The shrew *Crocidura*, several specimens of which have been recovered from the 'detritus mud' (bed 3) at Cudmore Grove, is a very rare element of the British Pleistocene mammalian fauna, but it has also been recorded from the Orsett Road section at Grays (Hinton, 1901; Bridgland *et al.*, 1988). An abundance of water shrew (*Neomys fodiens*) is another rare phenomenon, but this species is also well-represented at Grays (Hinton, 1911). Currant placed both Cudmore Grove and Grays within his Group 2 assemblages, along with Aveley (see Chapter 4). He regarded this group as intermediate in age between Hoxnian stage assemblages (his 'Group 3'), in which he included Swanscombe and Clacton, and the last interglacial '*Hippopotamus* fauna', his 'Group 1'. There is a recognizable weakness in Currant's groupings, however; this stems from the fact that the assemblages he discusses have very different levels of richness. Thus the Grays and Cudmore Grove faunas are both from prolific sites that have yielded large numbers of specimens. The assemblages from Clacton and Swanscombe, differentiated from Cudmore Grove by Currant, are sparse by comparison. It is possible, therefore, that the strong similarities between the Grays and Cudmore Grove assemblages, and their distinction from Currant's 'Group 3 assemblages', merely result from the relative richness of these two faunas and are of no stratigraphical significance.

The interpretation of the Lower Thames sequence proposed in this volume (Chapter 4) also fails to conform with Currant's groupings. Sites from two aggradational formations (the Corbets Tey and Mucking Formations) appear within his Group 2 assemblages, representing, according to the evidence presented in Chapter 4, warm Oxygen Isotope stages 9 and 7. This suggests that evidence from small-mammal assemblages (in common with other biostratigraphical evidence – see Chapter 4) does not allow at present a distinction to be made between faunas from Stages 9 and 7. It therefore seems wise to give precedence to the evidence from terrace stratigraphy and palaeodrainage reconstruction, which provide the most reliable framework for interpreting the fluvial record in the lower reaches of the Thames Basin and for correlation with the deep-sea record (see Chapter 1 and Table 1.1). In the absence, thus far, of a complete analysis of the Mollusca and pollen from Cudmore Grove, or of amino acid ratios from the former, the principal evidence for correlation with other sites comes from the reconstruction of terrace formations in eastern Essex.

Conclusions

Evidence from the sequence at Cudmore Grove, only revealed by coastal erosion during the last decade, shows this to be an extremely important Pleistocene locality. The site yields a wealth of palaeontological information that is of great importance for reconstructing the contemporary environment and for dating the deposits. This evidence indicates warm (interglacial) conditions and a Middle Pleistocene age. The plant and animal remains in the Cudmore Grove channel sediments provide a picture of life during this interglacial period. A huge range of fossils are included – molluscs, ostracods (microscopic crustaceans), pollen, other plant fossils, mammals (including monkey, beaver, bear, bat and extinct voles), reptiles, birds, amphibians and fish. In fact the fauna of small vertebrates is considered to be the richest ever found in Britain.

Pollen preserved in the fine-grained sediments suggests a correlation with the nearby (Hoxnian Stage) fossiliferous sediments at Clacton. The latter suggestion conforms with reconstructions of the course taken by the Thames-Medway after the Thames was diverted by ice during the most severe Middle Pleistocene glaciation. This course took the river through both East Mersea and Clacton. The Cudmore Grove sediments are thus interpreted as part of an interglacial channel-fill that can be recognized widely within the lower reaches of the Thames system. This channel-fill, which includes the well-known fossiliferous and artefact-bearing deposits at Swanscombe as well as at Clacton, is believed to have been laid down during Oxygen Isotope Stage 11 (Hoxnian *sensu* Swanscombe), *c.* 400,000 years ago.

SOUTHMINSTER, GOLDSANDS ROAD PIT (TQ 961991)

D.R. Bridgland

Highlights

This pit exposes typical gravel of the post-diversion Thames-Medway, deposited by the Thames, downstream from its confluence with the Medway, as it flowed north-eastwards across this part of Essex. This stretch of the river's course was formerly part of the Medway valley but was adopted by the Thames upon its diversion. The Asheldham Gravel at Southminster is believed to equate with both the Black Park Gravel and the Boyn Hill Gravel of the Middle Thames (the former underlying the latter in the Southminster area), the first two formations to be deposited by the river after its diversion during the Anglian Stage.

Introduction

Exposures at Goldsands Road Pit, Southminster, reveal the Asheldham Gravel, the highest and oldest formation of the Low-level East Essex Gravel Subgroup, which is attributed to the post-diversion Thames-Medway (Bridgland, 1983a, 1983b, 1988a; Figs 5.5B and 5.15). This formation is broadly equivalent to both the Southminster and Asheldham Terrace gravels of Gruhn *et al.* (1974) and to the '3rd Terrace' of the Geological Survey (Lake *et al.*, 1977, 1986).

Southminster lies in the south-eastern corner of the Dengie Peninsula, which separates the Crouch and Blackwater estuaries. The Asheldham Gravel is the most extensively preserved terrace formation on this peninsula, largely because later Thames-Medway deposition seems to have been confined, onshore, to the area further south. Higher deposits to the west belong to the High-level East Essex Gravel Subgroup, the product of the tributary Medway system (Figs 5.15 and 5.16; see above, Introduction to Part 2). The Asheldham Gravel forms an almost continuous sheet, averaging approximately 1 km in width, between Burnham-on-Crouch and Bradwell, dissected only by small streams flowing eastwards into the North Sea (Fig. 5.15). Geological Survey borehole data and subdrift contour mapping (Lake *et al.*, 1977; Simmons, 1978) show that over much of the area the Asheldham Gravel overlies a substantial buried channel, the Asheldham Channel (Fig. 5.28). Boreholes have revealed that this channel contains localized fossiliferous sediments, but scientific evaluation of these has only recently been undertaken (H.M. Roe, pers. comm.) and results have yet to be published.

Description

The exposures in the Goldsands Road Pit show mainly matrix-supported, massive and cross-stratified sandy gravel, interbedded with sands and clayey sands (Fig. 5.29). These sediments essentially comprise upper and lower gravel units, separated by ripple-drift-laminated and cross-bedded sands (Bridgland, 1983a, 1983b). Palaeocurrent measurements from the sands indicate flow to the east-north-east. In a large part of the pit the sands and gravels are overlain by 1.5 m of silty clay (brickearth), containing scattered pebbles. This may be either a flood-plain (overbank) deposit or a colluvial accumulation and, except for the pebbles, has an appearance similar to weathered London Clay. These deposits, with the exception of the clay, are typical of the products of a braided-river environment (Miall, 1977), the range of sediment types suggesting deposition on

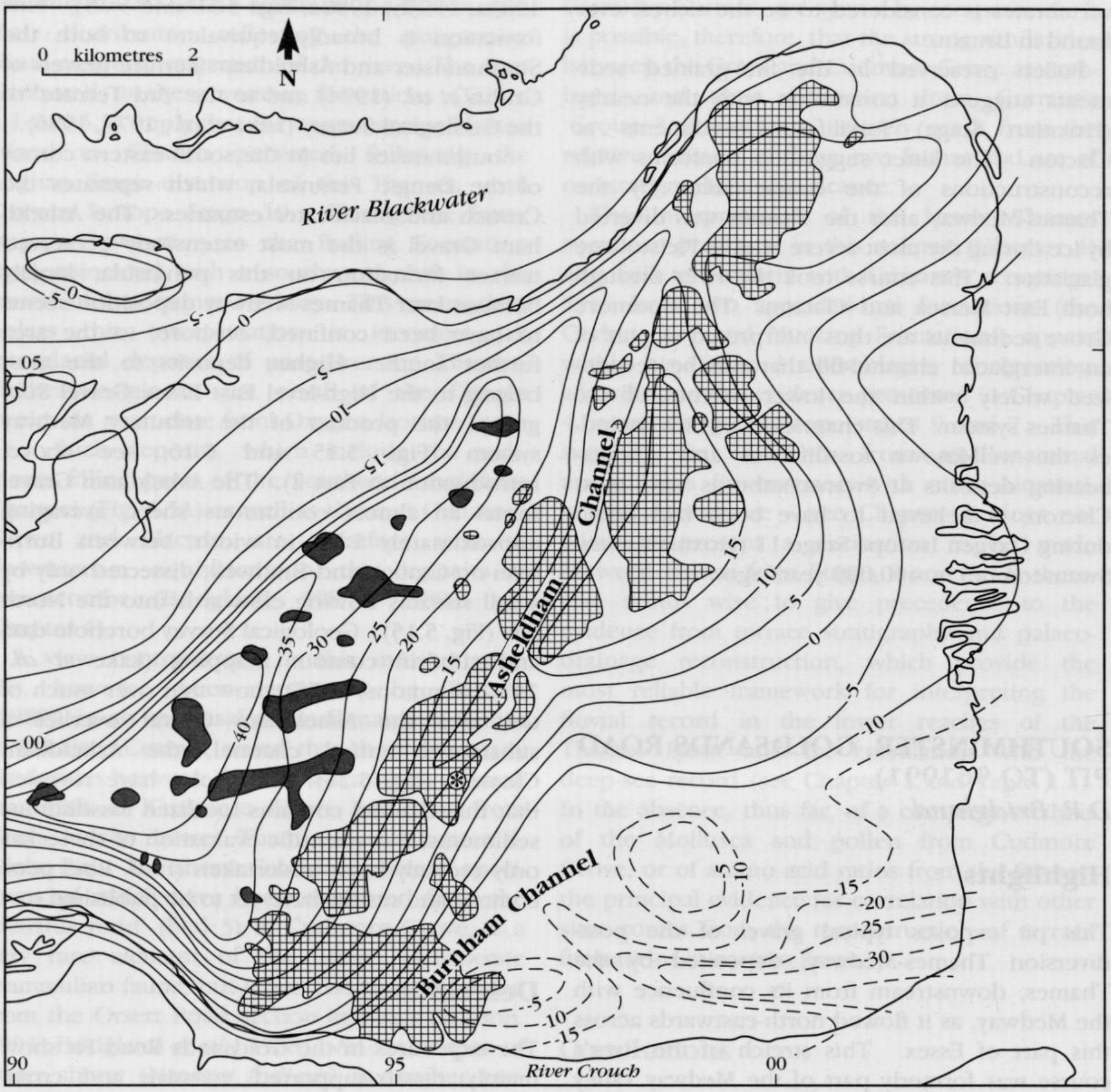


Figure 5.28 Map showing the outcrop of the Asheldham Gravel and bedrock surface contours, revealing the form of the Asheldham Channel (modified from Lake *et al.*, 1977).

longitudinal and linguoid bars. The original land surface in the vicinity of the pit was probably between 20 m and 21 m O.D., rising north-westwards to 25 m O.D. in the middle of Southminster (TQ 956998), well within the mapped range of the Asheldham Gravel.

A total thickness of over 4.5 m of Pleistocene sediments overlies London Clay at 15.5 m O.D. in the GCR site. Gruhn and Bryan, who worked here at a time of more extensive quarrying, reported a sloping 'bench' beneath the gravel of the area, ranging between 9.7 and 10.7 m O.D.,

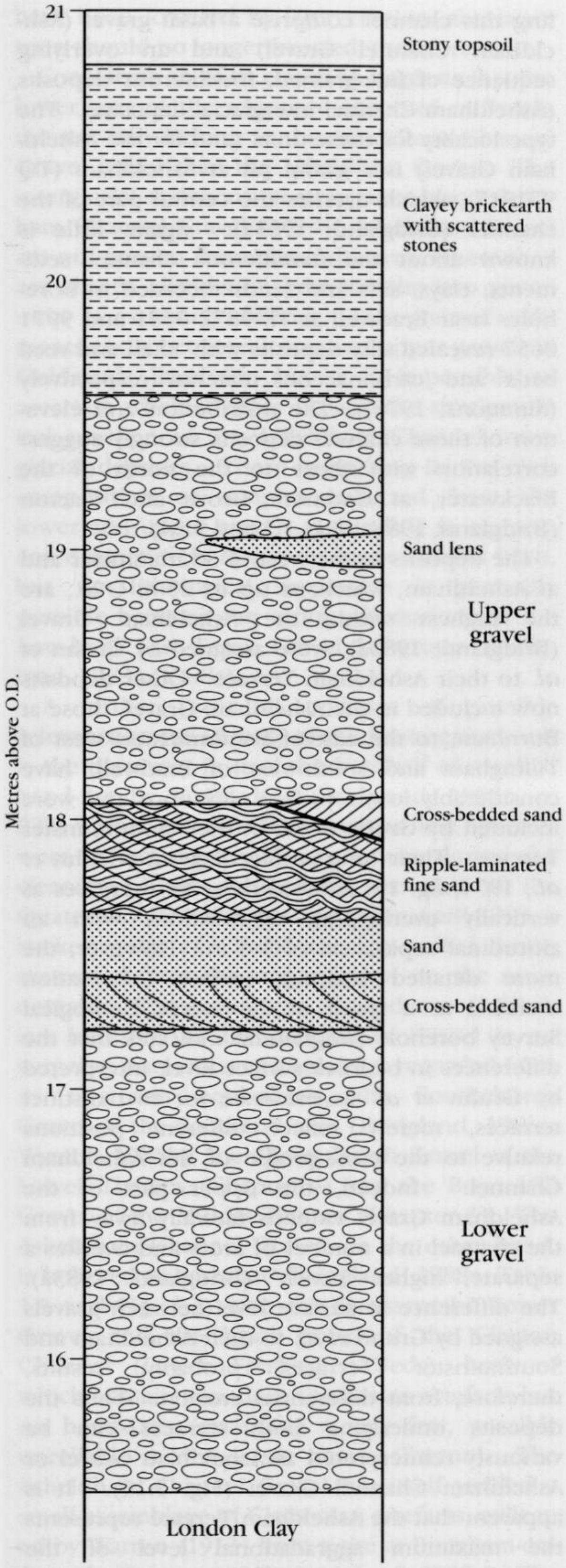


Figure 5.29 Section at Goldsands Pit. This shows the division into upper and lower gravels, separated by cross-bedded and ripple-laminated sands.

with the highest bedrock level in the north-east (Gruhn *et al.*, 1974, unpublished appendix). Three Geological Survey boreholes in the vicinity add to the general picture of variable relief. A borehole to the north-west of Goldsands Road Pit showed 3.8 m of sandy, silty clay and soil, overlying 2.4 m of gravel, the London Clay being reached at 14.4 m O.D. Another, 350–400 m to the south-west, showed only 3 m of Pleistocene sediments overlying the London Clay at 16.3 m O.D. The third borehole, near Newmoor (TL 9964 0035), to the north of Southminster, revealed 10.5 m of gravel overlying the London Clay at 10.8 m O.D. (Simmons, 1978). This bedrock surface information suggests that the deposits fill a channel eroded into the London Clay, the eastern side of which appears to be preserved beneath the eastern edge of the Asheldham Gravel outcrop (Fig. 5.28). This contradicts the subdrift contour maps published by the Geological Survey (Lake *et al.*, 1977; Simmons, 1978), which suggest that the eastern side of the channel has been removed by later erosion.

Interpretation

Clast-lithological analysis of the Asheldham Gravel at Southminster reveals the combination of local, southern and exotic lithologies that characterizes the Low-level East Essex Gravel Subgroup (Bridgland, 1983a, 1983b, 1988a; Table 5.5). In comparison with the High-level East Essex Gravel deposits, which lie to the west and at a greater elevation, the Asheldham Gravel contains rather more local material (84–91%) and significantly less southern material (7.8–13.5%). The occurrence of a number of pebbles of Ightham Stone and Hastings Beds lithologies (Bridgland, 1983a, 1986b) indicates a continued Medway influence, these being derived from north Kent and the central Weald respectively. Most significant, however, is the appearance of an exotic component (1.4–2.25%) in the Asheldham Gravel, including all the types characteristic of the Lower Thames gravels of the Tilbury area (see Chapter 4): predominantly quartz, quartzites, Carboniferous chert and *Rhaxella* chert. The appearance of this characteristic exotic suite in the Asheldham Gravel marks the initiation of Thames drainage in this part of eastern Essex, which resulted from the Anglian diversion of the river (see above, Introduction to Part 2).

The buried channel underlying the Asheldham Gravel, revealed by various bedrock surface data, is part of a complex feature recognized by Lake *et al.* (1977) as their 'Burnham Buried Channel'. However, the feature they described incorporates a deep channel, eroded to well below ordnance datum, beneath 'First Crouch Terrace' (Barling/Dammer Wick Gravel) deposits in the Burnham-on-Crouch area (see Figs 5.15 and 5.28). This deep channel is here attributed to later incision, which has partly dissected the earlier deposits. Although the name Burnham Channel has previously been used for the older channel beneath the Asheldham Gravel (Bridgland, 1983a, 1983b), it is now restricted to the later, deeply incised feature. The Burnham Channel has been interpreted as a downstream continuation of the Shoeburyness Channel of the Southend area (Bridgland, 1988a; Fig. 5.5C). Little is known of the sediments filling this feature, but the bivalve *Corbicula fluminalis* is known both from Shoeburyness (Whitaker, 1889; Kennard and Woodward, 1907) and from a borehole at East Wick, Burnham-on-Crouch (Warren, 1951), possibly from the channel(s) in question. The occurrence of this bivalve might be an indication of deposition in a temperate episode pre-dating the Ipswichian Stage (*sensu* Trafalgar Square); in other words, pre-Oxygen Isotope Stage 5 (see Chapter 2, Stanton Harcourt and Magdalen Grove). A correlation between the Shoeburyness/Burnham Channel Deposits and the Mucking Formation of the Lower Thames was suggested by Bridgland (1988a). However, following a recent revision of terrace correlation between the Lower Thames and the Southend area (Bridgland *et al.*, 1993), the Shoeburyness/Burnham Channel is thought to be a downstream equivalent of the interglacial Thames channel recognized within the Corbets Tey Formation in the Ockendon–Purfleet area, which suggests correlation with the Oxygen Isotope Stage 9 temperate episode (see Chapter 4, Purfleet; Tables 1.1 and 4.1).

The older channel, underlying the Asheldham Gravel, has been redefined as the Asheldham Channel (Bridgland, 1988a). The deposits filling this channel comprise a basal gravel (Asheldham Channel Gravel) and an overlying sequence of fine-grained, fossiliferous deposits (Asheldham Channel interglacial deposits). The type locality for these units (and for the Asheldham Gravel) is a gravel pit at Asheldham (TQ 971917), which overlies the central part of the channel (Bridgland, 1983a). Again, little is known about the fossiliferous channel sediments; clays, silts and sands recorded in boreholes near Bradwell at TL 9872 0581 and 9971 0657 revealed silty deposits with 'shell and reed beds' and 'carbonaceous material' respectively (Simmons, 1978). The distribution and elevation of these channel deposits strongly suggest correlation with those to the north of the Blackwater, at Cudmore Grove and Clacton (Bridgland, 1988a; Figs 1.3 and 5.5A).

The deposits to the west of Southminster and at Asheldham, which, at up to 25 m O.D., are the highest within the Asheldham Gravel (Bridgland, 1983a), were assigned by Gruhn *et al.* to their Asheldham Terrace. Other deposits now included in the Asheldham Gravel, those at Burnham, to the east of Southminster, west of Tillingham and south-west of Bradwell, have considerably lower surface elevations and were included by Gruhn *et al.* in their Southminster Terrace. Their long-profile diagram (Gruhn *et al.*, 1974, fig. 10) showed these two terraces as vertically overlapping aggradations with an altitudinal separation of 3–5 m. However, the more detailed bedrock surface information available as a result of the recent Geological Survey borehole programme indicates that the differences in bedrock surface level, interpreted by Gruhn *et al.* as evidence for two distinct terraces, merely reflect different positions relative to the cross-profile of the Asheldham Channel. Indeed, the upper part of the Asheldham Gravel extends laterally away from the channel in a number of areas and overlies a separate, higher 'bench' (Bridgland, 1983a). The difference in surface level between gravels assigned by Gruhn *et al.* to their Asheldham and Southminster Terraces probably results, therefore, from differential erosion. Thus the deposits underlying both terraces can be variously reinterpreted as Asheldham Gravel or Asheldham Channel Gravel (Fig. 5.15). It is apparent that the Asheldham Terrace represents the maximum aggradational level of the Asheldham Formation, whereas areas attributed by Gruhn *et al.* to their Southminster Terrace have been lowered by later erosion; the latter term should no longer be used, therefore.

Consideration of its elevation suggests that the lower part of the sequence observed at Southminster may belong to the Asheldham Channel Gravel rather than the Asheldham Gravel. The interglacial sediments that separate the Asheldham Channel Gravel and the Asheldham Gravel are not present throughout the area; where they are absent, distinction between the two gravel units is extremely difficult. Fine-grained sediments occur between lower and upper gravels at Goldsands Road Pit, but it is impossible to ascertain whether these occupy the stratigraphical position of the Asheldham Channel interglacial deposits. There is nothing in the clast composition of samples collected from the lower and upper gravels (Table 5.5) to support any distinction between the units on this basis, but no lithological separation is generally possible between the various formations of the Low-level East Essex Gravel Subgroup (Bridgland, 1983a, 1988a).

A further piece of evidence of possible relevance to the identity of the lower gravel unit is the discovery in it of the butt-half of a rolled hand-axe by P. Harding (Bridgland, 1983a, p. 227; Wymer, 1985b). Two such broken artefacts were in fact discovered at the site during the cleaning of the sections for the visit of the Quaternary Research Association in April 1983, a broken point of a hand-axe, less rolled, being recovered from the upper gravel on the same occasion. The occurrence of hand-axes (Acheulian Industry) in the Asheldham Gravel is no surprise; numerous examples are recorded from its upstream equivalents, the Southchurch Gravel of the Southend area (Bridgland, 1983a; Wymer, 1985b), the Orsett Heath Gravel of the Lower Thames (Chapter 4) and the Boyn Hill Gravel of the Middle Thames (Chapter 3). The Asheldham Channel Gravel, on the other hand, is believed to correlate (Bridgland, 1988a; Table 1.1 and Fig. 1.3) with the Swanscombe Lower Gravel and the basal gravel of the Clacton Channel (Lower Freshwater Beds), both of which contain abundant Clactonian artefacts but no hand-axes (excluding a very few, possibly unreliable records – see above, Clacton). The Asheldham Channel Gravel has itself yielded a small assemblage of Clactonian artefacts, collected by Warren (1933) from a site at Burnham-on-Crouch (Wymer, 1985b; Bridgland, 1988a). The apparent association of Clactonian material with the pre-interglacial and early interglacial parts of the Asheldham Formation (phase 2 and early phase 3 of the climatic terrace model – see Chapter 1) may indicate that the lower gravel at Southminster, which has yielded a hand-axe, post-dates the interglacial. However, there is good evidence to suggest that hand-axe makers occupied the Thames valley prior to the Clactonian occupation represented by the Swanscombe and Clacton industries, as has been discussed above (see Clacton). Three rolled, probable hand-axe finishing flakes were, in fact, found amongst the material collected in the second golf course excavation at Clacton (Singer *et al.*, 1973; Wymer, 1985b), implying that derived Acheulian material is to be expected in the Asheldham/Clacton Channel Gravel. The hand-axes from Southminster may therefore have no stratigraphical significance, other than indicating that the gravel post-dates the earliest occupation of southern Britain by Palaeolithic Man.

The correlations proposed in this volume, based on terrace stratigraphy, imply that aggradation of the Asheldham Formation spanned the period from the late Anglian (late Oxygen Isotope Stage 12) to early Oxygen Isotope Stage 10, when rejuvenation to the level of the Barling Formation occurred (Chapter 1). The Asheldham Formation and its upstream correlative in the Lower Thames, the Orsett Heath Formation, are considered to correlate with the Boyn Hill Formation of the Middle Thames (see Chapter 4). They are also believed to incorporate, in their lower parts, downstream equivalents of the late Anglian Black Park Gravel of the Middle Thames, the earliest post-diversion formation, which appears to have been graded to a very low base level (see Chapter 4, Wansunt Pit). It must be emphasized that the degree of complexity implied by this interpretation is indicated by regional stratigraphical evidence (summarized in Table 1.1) and cannot, as yet, be determined from the sediments of the Asheldham Formation at Southminster or elsewhere.

Conclusions

Fluvial gravels occurring at this locality contain a mixture of rocks from Kent, to the south, and from the north-west, carried down the main Thames valley. This is because they were deposited by the combined Thames-Medway river, formed by the confluence of the Medway and the Thames in the area south of Southend. Older deposits in the Southminster area show that this part of Essex was formerly in the Medway valley, at a time when that river extended from Kent to the Clacton area, where it joined the old (pre-diversion) Thames. When diverted, the Thames adopted the old Medway valley between Southend and Clacton, depositing gravels of the type found at Southminster. The GCR site at Goldsands Road Pit provides exposures in the Asheldham Gravel and, possibly, in the Asheldham Channel Gravel. The study of these deposits is of considerable importance in reconstructing the evolution of the river system in this area during the Middle Pleistocene. This area of eastern Essex provides an important link between the Lower Thames sequence, with its abundance of fossiliferous and Palaeolithic sites, and the Tendring Plateau, where a comparable wealth of information also exists.

Part 3:

DEPOSITS OF LOCAL RIVERS
D.R. Bridgland

Introduction

It has been shown earlier in this chapter that a large part of Essex was, at different times during the Early and Middle Pleistocene, drained by the lower reaches of the Thames. In the Early Pleistocene the Thames flowed across the north-western part of the county towards Suffolk, and much of Essex was drained northwards towards it (although not necessarily directly into it), the main north-flowing river being the Medway. By the Middle Pleistocene the south-eastward migration of the Thames, possibly aided by diversion or capture by a Medway tributary (Bridgland, 1988a), had resulted in a north-eastward course for the river across Essex to the Tendring Plateau, where it was joined by the Medway (see Part 1 of this chapter). During the Anglian Stage the Thames was diverted, by way of its present valley through London, into the Medway, thus bringing into being the Thames drainage of south-western and eastern Essex. Subsequent migration caused the river to abandon the north-eastern part of this course, although the northward trend is still represented in the offshore continuation of the Late Pleistocene Thames-Medway valley (D'Olier, 1975; Bridgland and D'Olier, 1989; Fig. 5.5F).

In the latter part of the Pleistocene, as the Thames moved further towards the south and east, new tributary streams were initiated, draining the areas once occupied by the main river. In particular, the Colne appears to have formed in the old beheaded valley of the Kesgrave (Lower St Osyth Gravel) Thames; this former river is presumably the 'misfit' remnant of the pre-diversion Thames itself (see Fig. 5.5B). The Chelmer and Blackwater also appear to drain parts of the old Thames valley in central Essex (Fig. 5.4E), the latter flowing in the opposite direction to the Thames. This part of the old valley was apparently modified by glacial activity between its occupation by the Thames and by the later rivers, since considerable thicknesses of till occur in overdeepened sections of it (Bristow, 1985).

The tributary rivers of the northern and western parts of Essex thus appear to have been initiated immediately following the Anglian glaciation. It is therefore not surprising that they have extensive terrace systems of their own (see Geological Survey Sheet 241, Chelmsford), although these have received comparatively little attention from geologists. A number of important Pleistocene sites have come to light within these terrace systems over the years, but it has not always been easy to distinguish the deposits of these rivers from those of the Thames; there has, for example, been uncertainty about whether the deposits in the Clacton area are the products of the Thames or the local River Colne (see above, Clacton). The richest source of hand-axes in Essex, a gravel at Upper Dovercourt (TM 240313) (Underwood, 1913; Warren, 1933; Wymer, 1985b), appears to be a Stour terrace deposit banked against the much earlier Oakley Gravel, of (pre-diversion) Thames-Medway origin (Bridgland *et al.*, 1990). Most of the Palaeolithic discoveries in the Chelmsford, Maldon and Colchester areas, carefully catalogued by Wymer (1985b), are probably from the terraces of the Chelmer, Blackwater and Colne. Occasionally collections of mammalian bones have also been made from these deposits (Wymer, 1985b). There are a few sites in areas where the gravels are generally believed to be pre-diversion (Kesgrave Group) Thames deposits, but where important fossil or Palaeolithic discoveries raise doubts about this interpretation. One such is near Thorpe-le-Soken (Daking's Pit – TM 155233), where a rich assemblage of artefacts has been recovered from deposits mapped as part of the Cooks Green Gravel (Warren, 1933; Oakley and Leakey, 1937; Wymer, 1985b). A recent reinvestigation has confirmed the presence of abundant worked flakes, but has also shown the gravel to be perceptibly different to the local Cooks Green Formation. In particular, it contains *Rhaxella* chert, which is very rare in the Kesgrave Group gravels upstream of the Crag basin (see Part 1 of this chapter), but is present in the Red Crag and in Anglian Stage glacial deposits. This site lies in the valley of the Holland Brook, which suggests that the gravel may be a post-Anglian deposit laid down by that river.

Three GCR sites are included in this part of the chapter, covering very different areas of interest, although all three are associated with the River Blackwater. The first, Maldon Railway Cutting, is an important site for stratigraphical evaluation of the deposits of the Anglian glaciation, since it is the type locality of the controversial Maldon Till. The other two sites are of Late Pleistocene age, dating from the last interglacial/glacial cycle; they therefore represent a part of the Pleistocene for which no Thames deposits are known in Essex (if the various Lower Thames interglacial sites are correctly interpreted as pre-Ipswichian in Chapter 4). The Ipswichian Stage (*sensu* Trafalgar Square) is represented by hippopotamus-bearing deposits at East Mersea, while a site in a low terrace of the Blackwater at Great Totham has yielded an abundance of palaeontological data that suggests deposition during the Devensian Stage.

MALDON RAILWAY CUTTING (TQ 842067)

D.R. Bridgland

Highlights

This is the type locality of the Maldon Till, deposited here during the Anglian Stage at a position close to the maximum extent of Lowestoft glaciation. The till at Maldon has previously been interpreted as stratigraphically earlier than the main Lowestoft Till, separated from the latter by an intermediate glacial gravel. Gravels overlying the till at Maldon were hitherto regarded as part of this intermediate deposit, but are now interpreted as fluvial terrace sediments. These are taken to be the product of the Blackwater–Chelmer river system, which came into being, following the Anglian glaciation, as the new drainage of the area once occupied by the Thames.

Introduction

Maldon Railway Cutting is of importance to Pleistocene studies as the type locality of the Maldon Till, which has been claimed to represent an early ice advance into southern East Anglia. It was formerly held that this represented the second of three separate glacial advances into the Chelmsford area (Clayton, 1957, 1960). However, following the recognition that glaciation occurred in Essex only during the Anglian Stage (Turner, 1970; Baker, 1971; Bristow and Cox, 1973; Perrin *et al.*, 1973), the Maldon Till was later attributed to the earlier of two advances of the Lowestoft Till ice into the region (Baker, 1971, 1983; Ambrose, 1973; Baker and Jones, 1980; Bristow, 1985). These various interpretations of the evidence at Maldon were based largely on the original description of the railway cutting sections by Whitaker (1889), the exposures having been obscured since that date. However, till was mapped at the locality in the late 1960s by the Geological Survey (Ambrose, 1973; Sheet 241).

A recent re-excavation of the site, soon to be part of the Maldon by-pass road scheme (the railway closed many years ago), confirmed the presence of till beneath coarse gravel. However, analysis of the clast composition of the gravel (Table 5.5) and the discovery of a hand-axe, apparently from the deposit, suggest that it is not glacial outwash, as was previously assumed. This reappraisal has undermined previous interpretations of Anglian glacial stratigraphy, which held the Maldon Till to be earlier than the main Anglian ice advance into the region. The till at Maldon has subsequently been interpreted as an isolated outlier of the widespread sheet of Lowestoft Till that covers much of central and north-western Essex (Whiteman, 1987; in Allen *et al.*, 1991). The Maldon outlier, in fact, falls marginally outside most published reconstructions of the Anglian ice limit (see, for example, Rose, 1983b; Bowen *et al.*, 1986a). It is one of several small till remnants along the line of the Danbury–Tiptree Ridge, regarded by many authors as the maximum south-eastward extent of the Lowestoft Till (see Geological Survey, New Series Sheet 241; Bristow, 1985).

Description

Whitaker (1889) described sections created in August 1887 at Maldon, during the construction of the railway to Wickford. Whitaker recorded detailed variations that he observed at various points along the cutting. He also listed the following generalized succession (Whitaker, 1889, p. 317):

(e) 'Gravel. ?At one place becoming a gravelly loam. Overlying, or ?locally replaced by

(d) Brown bedded loam and sand, with gravelly layers, beneath which there occurs, also locally

(c) Bedded gravel and loam.

(b) Grey boulder clay, or stony loam, with, at the base,

(a) Irregular gravelly bed.'

London Clay was exposed beneath the glacial deposits and also occurred as a lenticular mass up to 2.5 m thick within the Pleistocene sequence. Whitaker regarded the latter as a 'boulder', although emplacement as a result of diapirism or glaciotectonic deformation may also be envisaged.

In March 1984 two small sections were reopened (as part of the Geological Conservation Review) in the side of the disused cutting by P. Allen, C.A. Whiteman and the author, located in the steep face of an old landslip-scar. The sections broadly confirmed Whitaker's observations, revealing the following sequence (see Fig. 5.30):

	Thickness
4. Sand and silt, poorly exposed, to land surface (39 m O.D.)	4.0 m
3. Sandy silt, with gravel stringers and sand lenses	1.0 m
2. Gravel, silty and poorly bedded	2.3 m
1. Chalky till, sandy, fresh grey (weathered brown near top)	>1.0 m
London Clay (seen lower on the cutting side)	

The basal gravel described by Whitaker (see above, a) was not seen; this does not necessarily indicate its absence, since the base of the till could not be exposed because of waterlogging. The till itself contains conspicuous Chalk clasts, ensuring that it is readily distinguished from the London Clay bedrock. The deposit appeared unusually well-bedded in the GCR section, but was otherwise of typical Lowestoft Till appearance (Whiteman, 1990).

The gravel (bed 2) was found to be similar, in terms of clast composition (Table 5.5), to the Kesgrave Group Thames deposits that cover much of central Essex (see Part 1 of this chapter and Table 5.2). Material of the type associated with Anglian glacial deposits, such as *Rhaxella* chert (Bridgland, 1986b), is only present in small quantities. The deposit comprises only durable clasts, indicating that it is not an ice-proximal outwash gravel. A hand-axe was discovered whilst removing talus from the section. This is a rolled and patinated specimen (Fig. 5.31), which, judging from its condition and its location in pebbly talus, almost certainly came from the gravel.

The uppermost 4 m of the sequence (bed 4) was observed in a narrow trench cut in the sloping cutting-side above the face illustrated in Fig. 5.30. This sandy silty deposit, which has a reddish brown colour, may equate with Whitaker's brown loam and sand (above, d), which he described as locally replacing the upper part of the gravel.

Interpretation

The interpretation of the till at Maldon as a 'lower boulder clay' dates back to the original description by Whitaker, who suggested that it correlated with similar deposits occurring beneath 'glacial gravel' in Suffolk and Norfolk (Whitaker, 1889, pp. 299 and 316). The site achieved the status of a type section three-quarters of a century later, as a result of the work of Clayton (1957, 1960, 1964), despite having been obscured by talus and vegetation throughout the intervening period. Clayton (1957) recognized three separate tills in central Essex, (1) an older, dissected 'Hanningfield Till', confined to high ground, (2) a lower till within a 'sandwich' of deposits filling valleys, his 'Maldon Till' and (3) a later 'Springfield Till', forming the upper leaf of the sequence in the valleys and separated from the Maldon Till by gravel. This last deposit, which he termed the 'Chelmsford Gravels', was interpreted as glacial outwash. Clayton (1957) suggested a correlation between the Hanningfield Till and the continental Elsterian (= Anglian) glaciation and between the later tripartite sequence (Maldon Till, Chelmsford Gravels and Springfield Till) and the Saalian Stage. Within a few years Clayton had modified his views, suggesting that the Hanningfield and Maldon Tills were both Anglian, with the Chelmsford Gravels representing the Hoxnian and the Springfield Till representing the Saalian (Clayton, 1960).

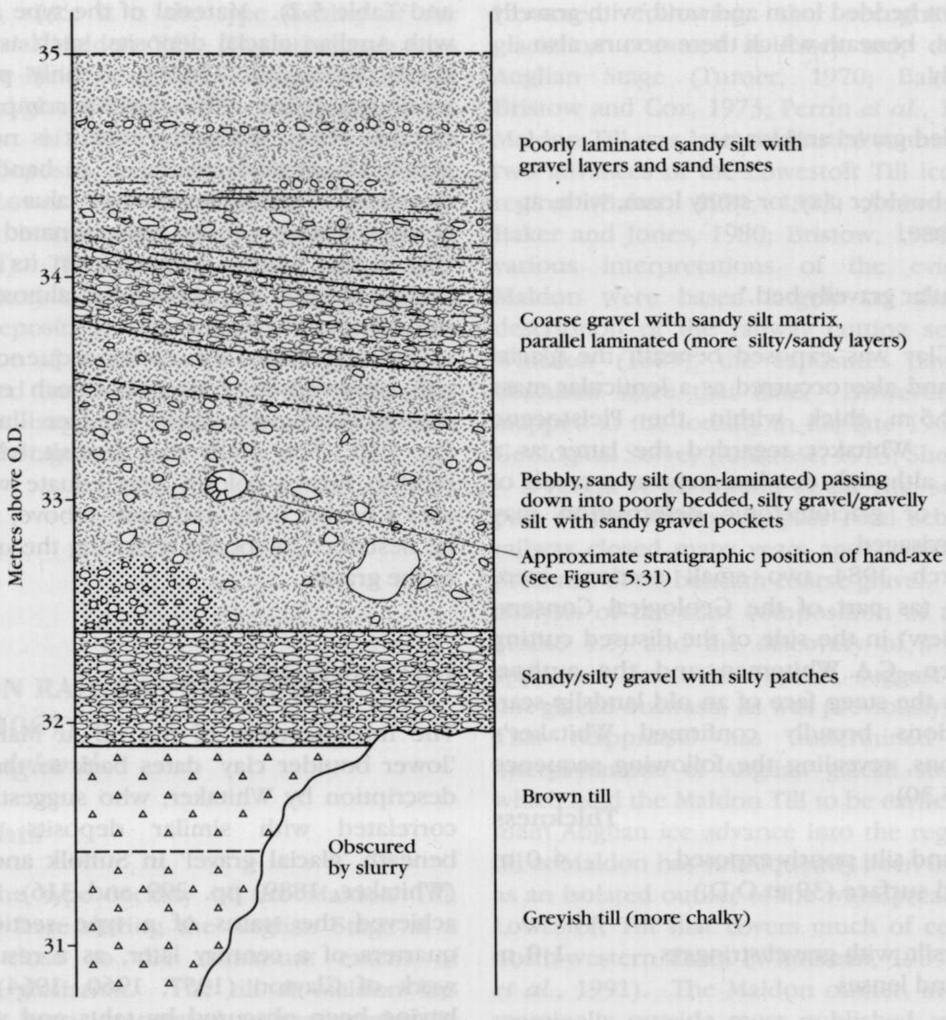


Figure 5.30 Section excavated at the Maldon GCR site in March 1984. Beds 1–3 are illustrated (see Description).

Later workers demonstrated that no distinction could be made between the till occurring on plateaux and that in valleys, leading to the conclusion that only a single glaciation has occurred in southern East Anglia (Turner, 1970; Baker, 1971; Bristow and Cox, 1973; Perrin *et al.*, 1973), during the Anglian Stage (Turner, 1973). The Maldon Till was therefore attributed to an early advance of the Anglian ice and the Chelmsford Gravels were, once again, regarded as outwash (Baker and Jones, 1980; Baker, 1983).

Bristow (1985) expressed doubt as to whether the till described at Maldon was an *in situ* glacial deposit, observing that other records of a lower till in the Chelmsford area could instead be interpreted as London Clay, glacial lake deposits or colluvium. A lower till was found during recent Geological Survey mapping, however, in the Witham area (Bristow, 1985). The name Maldon Till was applied to this deposit, despite reservations about the type locality, which had not been seen in section since the construction of the railway.

Wooldridge (1957) had suggested a correlation between the Maldon Till of Clayton and the till at Hornchurch, which he believed to represent the glaciation that diverted the Thames into its modern valley (see Chapter 4, Hornchurch). This correlation was later supported by Clayton (1960, 1964). A summary of the progression of views on the glacial history of southern Essex was provided by Baker and Jones (1980). They suggested that the Maldon

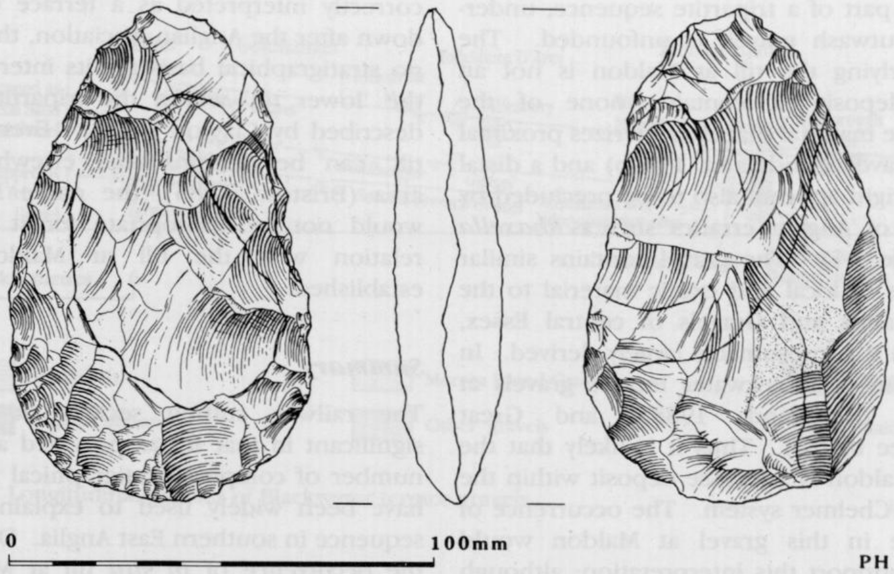


Figure 5.31 Flint hand-axe from Maldon Railway Cutting, found during the GCR excavations. The artefact is a cordate hand-axe of Wymer's (1968) type J, having a symmetrical shape with a cutting edge around the entire circumference. The implement has a white surface patina and is slightly rolled, although with rather more severe damage of the edges. Both sides show a network of incipient thermal fractures. (Drawing and description by P. Harding).

Till could also be correlated with the Ware Till of the Vale of St Albans (see Chapter 3) and that the early Anglian glacial advance responsible for this deposit was also responsible for the diversion of the Thames from its valley across central Essex. They envisaged that a temporary route was used by the river, carrying it from the Vale of St Albans by way of the modern Lower Lea valley into its modern course downstream of London (see Chapter 3, Part 2), a hypothesis supported by Cheshire (1981) and Baker (1983). Baker and Jones (1980) cited evidence from proglacial lake deposits in the Newport area of north-west Essex for the duration of the interval between lower and upper Anglian tills. In that area they recognized a lower, Quendon Till, separated from the main Lowestoft Till sheet. They correlated this lower till with the Maldon Till of south-east Essex and the Ware Till of Hertfordshire. The counting of supposed annual varves in the above-mentioned lacustrine deposits suggested to Baker and Jones that the Quendon/Maldon Till ice advance and the readvance that resulted in the accumulation of the main Lowestoft Till were separated by an interval of 5400 years. During this interval the ice-front apparently stabilized just to the north of Newport.

The most recent re-evaluation of the till at Maldon is that by Whiteman (in Allen *et al.*, 1991), who, following the 1984 re-excavation, equated it with his Newney Green Member of the Lowestoft Till Formation. Although the Newney Green Member is the lower of two divisions of the Lowestoft Till recognized by Whiteman in central Essex, he considered it to be part of the single till sheet that covers southern East Anglia. Whiteman found no evidence in central Essex for the tripartite sequence (Maldon Till–Chelmsford Gravels–Springfield Till) proposed by Clayton. He pointed out that in many instances the deposits ascribed to the middle part of this sequence, the Chelmsford Gravels, are in fact occurrences of Kesgrave Sands and Gravels and therefore pre-date the glacial sequence altogether (Whiteman, in Allen *et al.*, 1991). Whiteman's work supports the correlation between the tills at Maldon and Hornchurch, since he also assigned the latter to his Newney Green Member. Cheshire (1986a) suggested that the till exposed in 1984 at Maldon might have been gelifluncted, which could account for its stratified appearance.

The recent reinvestigation of the Maldon site shows that the interpretation of the till there as the lowest part of a tripartite sequence, underlying an outwash gravel, is unfounded. The gravel overlying the till at Maldon is not an outwash deposit; it contains none of the non-durable material that characterizes proximal outwash gravels (Bridgland, 1986b) and a distal outwash origin appears also to be precluded by the paucity of 'Anglian erratics' such as *Rhaxella* chert (Table 5.5). The gravel contains similar proportions of local and exotic material to the Kesgrave Sands and Gravels of central Essex, from which it is presumably largely derived. In this it resembles Blackwater terrace gravels at Tollesbury (Bridgland, 1983a) and Great Totham (see below). Thus it is likely that the gravel at Maldon is a terrace deposit within the Blackwater/Chelmer system. The occurrence of a hand-axe in this gravel at Maldon would appear to support this interpretation; although such palaeoliths are no longer regarded as indicative of a post-Anglian age (see Chapters 1 and 3), they are unknown from outwash gravels in this area.

The elevation of the gravel at Maldon, with a base level of 32 m and a maximum surface height of 39 m O.D. (the upper part is replaced by sands and silts in the section recorded here), suggests a correlation with the Tollesbury Gravel (type locality: TL 947106) of Bridgland (1983a). The latter formation, aggraded to *c.* 26 m O.D. in its type area, was correlated by Bridgland with the Mersea Island Gravel, implying a further correlation with the earliest post-diversion formation of the Thames-Medway in eastern Essex and with the Boyn Hill Gravel of the Thames system (see Part 2 of this chapter). This aggradation is believed to have been initiated late in the Anglian Stage and to have been completed in the early Saalian (Bridgland, 1988a; Table 5.6). If the gradient required to trace the Tollesbury Gravel downstream into the Mersea Island Gravel, *c.* 0.7 m per kilometre, is projected upstream to Maldon it would take the top of the formation to *c.* 35 m O.D. Allowing for a slight upstream increase in gradient, this strongly supports the correlation of the Maldon and Tollesbury aggradations (Fig. 5.5B and 5.32). The Maldon deposit can therefore be regarded as an upstream outlier of the Tollesbury Gravel. Its geographical location suggests that it may have been deposited by the Chelmer, the southern branch of the Blackwater system (see Fig. 5.1).

If the gravel overlying the till at Maldon is correctly interpreted as a terrace deposit laid down after the Anglian glaciation, there remains no stratigraphical basis for its interpretation as the 'lower till' within the tripartite sequence described by Clayton (1957). Even if a 'lower till' can be demonstrated elsewhere in the area (Bristow, 1985), the name Maldon Till would not be appropriate for it unless correlation with the till at Maldon can be established.

Summary

The railway cutting section at Maldon is significant in that it has provided a basis for a number of complex stratigraphical models that have been widely used to explain the glacial sequence in southern East Anglia. Doubts about the occurrence of *in situ* till at Maldon have been allayed by a recent reinvestigation, but this has itself raised doubts about the status of the deposit as an early 'lower till' within the glacial sequence. This status depends upon gravel overlying the till being a glacial outwash deposit, part of a tripartite sequence with a later 'upper till' (not present in the Maldon area). The discovery that the gravel at Maldon is probably a terrace deposit of the Blackwater/Chelmer system means that the underlying till can no longer be placed at the base of the tripartite sequence of Clayton (1957) and may question the validity of that sequence.

Conclusions

The historic section at Maldon, showing glacial sediments (Maldon Till) overlain by water-lain gravels, has previously been cited as evidence for of a complex regional story of alternating deposition by ice sheets and meltwater streams. The Maldon Till has been widely interpreted as the lower element in a three-part sequence of till, glacial gravel and till, the gravel at Maldon being regarded as the intermediate meltwater deposit. The recognition, presented here for the first time, that this gravel is the product of the Blackwater/Chelmer river system, casts doubt upon the validity of the three-part sequence. The Maldon section is now more simply interpreted as showing till, deposited by East Anglian ice around 450,000 years ago, overlain by river gravels deposited subsequent to the Anglian glaciation.

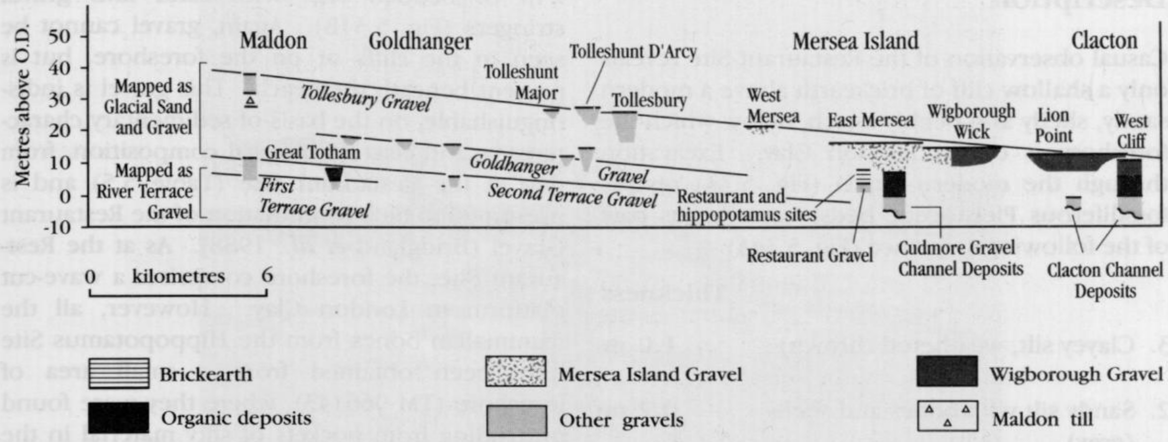


Figure 5.32 Longitudinal profiles of Blackwater terrace gravels.

EAST MERSEA RESTAURANT SITE (TM 053136) and HIPPOPOTAMUS SITE (TM 065142)

D.R. Bridgland

Highlights

Fossiliferous sediments here appear to provide a rare record of the Ipswichian Stage in fluvial deposits within the Thames catchment downstream from London. The site has one of the richest interglacial bone-beds in southern Britain, deposited by an erstwhile Thames tributary, the Essex Blackwater.

Introduction

The East Mersea Restaurant Site and Hippopotamus Site both reveal Late Pleistocene fossiliferous deposits attributed to the River Blackwater. They are of considerable stratigraphical importance because of their close proximity to the Middle Pleistocene Thames-Medway locality at Cudmore Grove (see Part 2 of this chapter). The three sites collectively constitute a single large and complex GCR site, which also includes an area of cryoturbated London Clay between the two sets of Pleistocene deposits (see Figs 5.22 and 5.23).

The Restaurant Site, *c.* 1.5 km to the south-west of Cudmore Grove, appears to coincide with most if not all the early records of fossil bone-bearing deposits at East Mersea (Warren, 1917, 1924b, 1933; Cornwall, 1958; Zeuner, 1958). The sequence at the Restaurant Site has produced Mollusca and ostracods, as well as abundant mammalian remains. Warren (1933) considered it the richest bone-bed he had seen. The occurrence of hippopotamus suggests deposition during the Ipswichian Stage (*sensu* Trafalgar Square) (Sutcliffe, 1964; see Chapter 1).

There is a further occurrence of hippopotamus-bearing sediments at East Mersea, at the Hippopotamus Site, which lies between the Restaurant Site and the outcrop of the Cudmore Grove Channel (Fig. 5.23). The Hippopotamus Site was discovered more recently and has so far only produced a small assemblage of mammalian bones, found on the foreshore in pockets of Pleistocene sediment in the surface of a London Clay platform. Pleistocene deposits that presumably have been stripped from this platform by recent marine erosion are exposed in the nearby cliffs. This fauna consists entirely of taxa already known from the Restaurant Site. Similar sequences of deposits are found at both localities, comprising a basal gravel overlain by finer grained sediments. The (basal) gravel is quite different to that overlying the Cudmore Grove estuarine deposits and provides the basis for attributing these Upper Pleistocene sediments to the River Blackwater.

Description

Casual observation of the Restaurant Site reveals only a shallow cliff of brickearth above a modern sandy, shelly and pebbly beach, below which the foreshore is cut in London Clay. Excavation through the modern beach (Fig. 5.33) reveals fossiliferous Pleistocene beds, however, as part of the following sequence (Fig. 5.34A):

	Thickness
3. Clayey silt, weathered (brown)	1.0 m
2. Sandy silt with bones and shells (grey)	0.2 m
1. Gravel with mammal bones	0.4 m
London Clay	

This sequence appears to fill a channel excavated in London Clay, the latter rising to cut out the later deposits beneath the eastern end of the beach. The gravel contains considerably more quartzose exotic material than the Mersea Island Gravel, but also includes a large proportion of southern rocks (predominantly Greensand chert) of the type characteristic of the East Essex Gravels (Table 5.5 and see Part 2 of this Chapter). It has been termed the (East Mersea) Restaurant Gravel (Bridgland *et al.*, 1988).

Better exposures of the sequence were available in the early post-war years, when the Restaurant Gravel was preserved at the landward edge of the foreshore (Cornwall, 1958). Cornwall interpreted this deposit as filling the channel of a 'considerable stream', trending towards 110° east of north. He interpreted the overlying sequence as a 'floodloam' overlain by marine silt and considered there to be a buried soil at the top of the floodloam. In addition to the published descriptions, the Restaurant Site was excavated in 1934 by D. Bate and J. Reach (MS notes in the Natural History Museum) and in the late 1960s by R. Gruhn and A.L. Bryan (MS notes in the Institute of Archaeology, London University) and H.E.P. Spencer. The mammalian remains from those excavations are preserved in the Natural History Museum, except for Spencer's collection, which is in the Ipswich Museum.

The Hippopotamus Site is broadly similar to the Restaurant Site, but the cliff section at the former is considerably higher and exposes over 2 m of bedded silts with sand and gravel stringers (Fig. 5.34B). Again, gravel cannot be seen in the cliffs or on the foreshore, but is present beneath the beach. This gravel is indistinguishable, on the basis of sedimentary characteristics and clast-lithological composition, from that at the Restaurant Site (Table 5.5) and is presumed to be a continuation of the Restaurant Gravel (Bridgland *et al.*, 1988). As at the Restaurant Site, the foreshore comprises a wave-cut platform in London Clay. However, all the mammalian bones from the Hippopotamus Site have been obtained from a small area of foreshore (TM 066143), where they were found protruding from pockets of silty material in the bedrock surface (Fig. 5.35). These probably represent scour hollows at the base of the Restaurant Gravel. The Pleistocene deposits at the Hippopotamus Site are separated from the Cudmore Grove Channel by London Clay, which rises to the full height of the cliffs between the two Pleistocene channels (Figs 5.22 and 5.23).

The Restaurant Site has yielded a mammalian fauna of ten species (Bridgland *et al.*, 1988): in addition to the important indicator species *Hippopotamus amphibius*, the assemblage includes *Palaeoloxodon antiquus* (straight-tusked elephant), *Dicerorhinus hemitoechus* (narrow-nosed rhinoceros), *Bison priscus*, *Megaloceros giganteus* (giant deer) and *Crocuta crocuta* (Enxleben) (spotted hyaena). Another species of stratigraphical significance to occur is the modern water vole *Arvicola terrestris*, which is known only from the Late Pleistocene (Sutcliffe and Kowalski, 1976). As the bulk of the collections is from early investigations, no attempt has been made to separate assemblages from the gravel and silt (beds 1 and 2). The Hippopotamus Site has produced, in addition to hippopotamus, only giant deer and indeterminate bovine and elephant bones (Bridgland *et al.*, 1988).

The molluscan fauna, which occurs only in the sandy silt (bed 2) at the Restaurant Site, is dominated by freshwater bivalves, including *Pisidium supinum* and *P. moitessierianum*, which suggest deposition in a sizeable stream. Of particular interest is the occurrence of *Sphaerium rivicola* (Lamarck), which is rare in the British Pleistocene (Bridgland *et al.*, 1988). Five ostracod taxa have also been recovered from this same deposit: *Candona neglecta*, *Ilyocypris bradyi*, *I. schwarzbachi* Kempf, *Herpetocypris* sp. and *Cyprideis torosa*. The

Figure 5.33 Excavations at the East Mersea Restaurant Site. This view, looking north-east, shows bones being collected from the channel deposits temporarily exposed in a trench dug through the beach. Only London Clay is exposed on the foreshore. (Photo: A.J. Sutcliffe.)

first two, which dominate the fauna, require a low-energy freshwater environment, but *C. torosa* is a brackish water species. However, only a few specimens of the last-mentioned species were encountered, the poor preservation of which may suggest derivation from an earlier estuarine deposit, such as that at Cudmore Grove, in which the species is common (see above).

Interpretation

Warren (1917, 1924b, 1933) was the first to recognize an 'elephant bed' at East Mersea and suggested that it was equivalent to the Clacton Channel Deposits, which also yield elephant remains (at both sites all identifiable elephant remains are attributable to *Palaeoloxodon antiquus*). The Clacton deposits were sub-

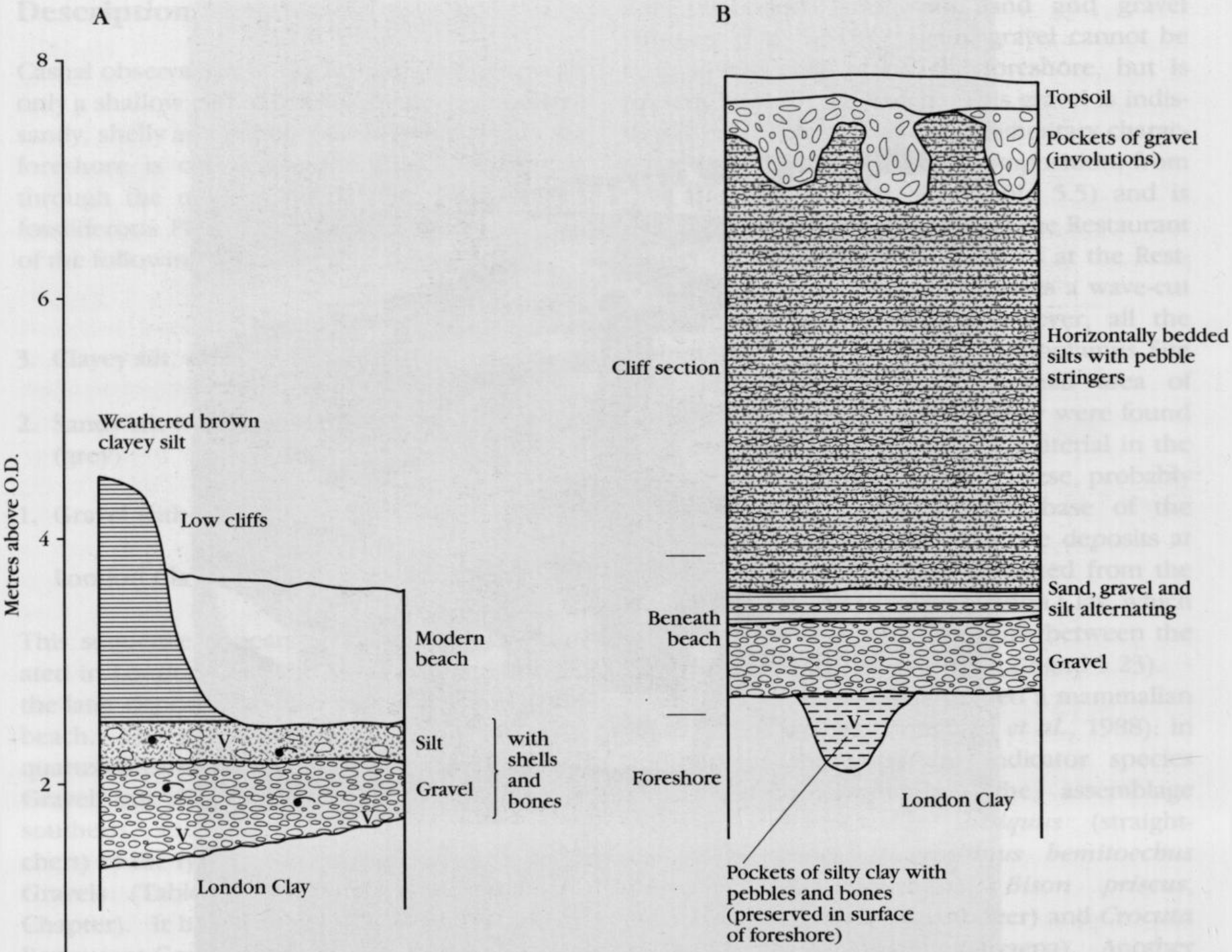


Figure 5.34 Sections at: (A) the East Mersea Restaurant Site; and (B) the Cudmore Grove Hippopotamus Site.

sequently assigned to the 'Great Interglacial' (Hoxnian Stage) (Pike and Godwin, 1953), which led to a similar interpretation of the sediments at East Mersea (Cornwall, 1958; Zeuner, 1958; Spencer, 1966). However, *Hippopotamus* is prominent amongst collections from East Mersea and, since this species is believed to have been absent from Britain during the Hoxnian, the site had been attributed to the Ipswichian Stage (*sensu* Trafalgar Square) (Sutcliffe, 1964) well in advance of the recent investigations, which have confirmed that it is quite unrelated to the Clacton deposits (Bridgland *et al.*, 1988).

The Restaurant and Hippopotamus Sites have closely similar sedimentary sequences at comparable elevations, the clast-lithological composition of the gravel at both sites matches (Table 5.5), and the limited fauna from the Hippopotamus Site is entirely coincident with taxa within the assemblage from the Restaurant Site. All these factors lead to the conclusion that a single set of deposits is represented at the two sites. These deposits are not, however, continuous between the two outcrops, but are cut out by Holocene saltings (Fig. 5.23).

The most important biostratigraphical evidence from this sequence derives from the mammalian fauna. This is of fully interglacial character and, unlike that from the Clacton and Cudmore Grove channels, includes hippopotamus. It also includes straight-tusked

Figure 5.35 East Mersea Hippopotamus Site: an elephant tooth is shown protruding from a silty pocket in the London Clay foreshore. All the faunal remains from this site have been recovered from similar situations, thought to represent pockets at the base of the Restaurant Gravel (see text). (Photo: A.J. Sutcliffe.)

elephant and narrow-nosed rhinoceros, but lacks horse. Its closest match is with mammalian assemblages from Joint Mitnor Cave (Devon), Trafalgar Square (London), Barrington (Cambridgeshire) and Victoria Cave (North Yorkshire), all ascribed to the Ipswichian Stage. The last of these has yielded a uranium-series date of *c.* 120,000 years BP, confirming a last interglacial age (Gascoyne *et al.*, 1981). There is little in the molluscan or ostracod faunas to confirm or deny the correlation of the deposits at East Mersea with the Ipswichian, although they do imply temperate conditions, and the two dominant ostracod species (*C. neglecta* and *I. bradyi*) survive in the Holocene. *Ilyocypris schwarzbachi*, however, was first described from a Holsteinian interglacial site at Karlich, near Koblenz.

If the fossiliferous deposits are of Ipswichian age, it is likely that the overlying unfossiliferous bedded silts and sands at the Hippopotamus Site represent aggradation under cold conditions during the Devensian Stage. These contain 'stringers' of gravel, the contents of which were analysed along with the underlying Restaurant Gravel (Table 5.5). The clast composition of the Restaurant Gravel is of considerable significance to palaeogeographical reconstruction. It differs in this respect from the Mersea Island Gravel (see above, Cudmore Grove) in that it contains a higher exotic fraction, dominated by the quartzose lithologies that characterize the gravels of the pre-diversion Thames. This composition is consistent with a Blackwater origin, in which case this exotic material is presumed to have been reworked from Kesgrave Group deposits in central Essex. Other exotic lithologies, in particular *Rhaxella* chert, are probably derived from Anglian Stage glacial deposits in the same area, although they could have been reworked from older Blackwater terrace gravels or from the Mersea Island Gravel. The latter has probably contributed much of the Greensand chert, but the High- and Low-level East Essex Gravels to the south of the Blackwater are also likely to have provided this rock type (see Part 2 of this chapter). The gravel stringers within the bedded silts and sands at the Hippopotamus Site contain fewer exotic rocks and more Greensand chert, having a composition intermediate between that of the Restaurant Gravel and the Mersea Island Gravel, although closer to the latter (Table 5.5). This suggests that much of the material was derived from the immediate valley side, from the Mersea Island Gravel (Bridgland *et al.*, 1988). Such a process might be considered more likely under cold-climate conditions, thus supporting the interpretation of these upper deposits as of Devensian age.

The conclusion that the fluvial sequence at the Restaurant and Hippopotamus Sites is the product of the River Blackwater and not the Thames-Medway is fully consistent with its apparent Ipswichian age. It is thought that the Thames-Medway had migrated a considerable distance to the south of Mersea Island by the Ipswichian, leaving the area to be drained by the Blackwater (Bridgland, 1988a; Fig. 5.5). The plotting of long-profiles of River Blackwater gravel formations (Fig. 5.32) suggests that the Restaurant Gravel lies higher in the sequence than the mapped terraces in the Maldon area (Geological Survey, New Series, Sheet 241). To the north of the terrace gravels, however, a belt of 'Glacial Sand and Gravel' has been mapped, extending from Great Totham to Tollesbury. These have been identified as older terrace gravels of the Blackwater system (Bridgland, 1983a; Bridgland *et al.*, 1990). Two formations can be recognized within these higher terrace deposits, the Tollesbury Gravel, already mentioned (see above, Maldon), and the Goldhanger Gravel, which is well-represented around the village of Goldhanger (TL 905090). The gradient of the Goldhanger Gravel suggests possible correlation with the Restaurant Gravel (Fig. 5.32). This would imply that all the mapped terrace deposits of the Maldon area are later in age than the Ipswichian Stage (*sensu* Trafalgar Square) and, conversely, that the deposits mapped as 'Glacial Sand and Gravel' account for all Blackwater deposition between the Anglian Stage (when the river was formed – see Maldon) and the Late Pleistocene. Comparison with the fluvial record in the Lower Thames valley (Chapter 4), in which four formations are recognized representing this time interval, suggests that the sequence thus far established in the Blackwater is unlikely to be complete.

The London Clay exposures between the Cudmore Grove Channel–Mersea Island Gravel section and the silts (brickearth) at the Hippopotamus Site show evidence of severe and repeated periglacial activity. Involutions, filled with gravel similar to that above the Cudmore Grove Channel, have been observed in the upper levels of the cliff and extend into the upper part of the silt sequence above the Restaurant Gravel near its eastern edge. Further west, the height of the cliffs declines and the uppermost, cryoturbated silts have probably been removed by erosion. Immediately east of the Blackwater sequence at the Hippopotamus Site, two sets of gravel-filled involutions occur at the top of the London Clay cliffs (Fig. 5.22). The lower of these, which is formed in the top of the London Clay, is overlain by a sheet of redeposited (colluvial) clay, indistinguishable from the bedrock and probably derived directly from it. The higher set of involutions is developed in this remobilized clay. Also of interest are large dislocated pockets of gravel that occur in the London Clay between the silts and Mersea Island Gravel exposures. These apparently comprise relatively undisturbed Mersea Island Gravel, so much so that palaeocurrent measurements have been obtained from foresets in one of them. The latter are inclined directly towards the near-vertical wall of London Clay at the edge of the pocket, suggesting that the contact is not erosional, but has been produced by post-depositional deformation. The clay itself is highly fissile and appears to have been subjected to considerable disturbance. It seems likely that the gravel pockets represent the feather-edge of the Mersea Island Gravel, perhaps higher parts of the unit than are now preserved, which have been let down undisturbed into the London Clay, probably when the latter was itself highly mobile and rising diapirically around the gravel pockets. Such processes are likely to have operated during periods of summer melting in a periglacial environment. Since the Restaurant Gravel is attributed to the Ipswichian, the periglacial episode during which this occurred must belong within the Devensian Stage.

The deposits at these two localities are therefore interpreted as products of an Ipswichian to early Devensian Blackwater aggradation, laid down long after the Thames-Medway had ceased to flow further north (within the present land area of south-eastern Essex) than the immediate vicinity of its present estuary (Bridgland, 1988a; Fig. 5.5).

Relation to the regional sequence

The Restaurant and Hippopotamus Sites at East Mersea, together with Cudmore Grove, form a highly significant locality spanning a large part of the Middle and Late Pleistocene. Whereas the Cudmore Grove site exposes a succession ascribed to the Hoxnian (*sensu* Swanscombe), the Restaurant and Hippopotamus Sites represent the Ipswichian (*sensu* Trafalgar Square) and Devensian Stages, the last interglacial and glacial episodes. The sediments at the Restaurant and Hippopotamus Sites are contained in the later and smaller of two juxtaposed channels (Fig. 5.27), attributed in this case to the River Blackwater, whereas the earlier, deeper channel at Cudmore Grove represents the Thames-Medway. The coastal sections at East Mersea thus reveal sediments from both of the post-Anglian interglacials defined by Mitchell *et al.* (1973). However, evidence from other parts of the Thames Basin now suggests that this sequence is an oversimplification, so the preservation at this locality of sediments representing the Hoxnian and Ipswichian Stages is regarded as coincidental; there were two further post-Anglian temperate intervals that are not represented at East Mersea, but which occurred between the deposition there of the Thames-Medway (Cudmore Grove Channel) and Blackwater (Restaurant Gravel) deposits. It is clear that major changes in palaeogeography took place between the emplacement of the two sets of deposits. The Thames-Medway, represented at Cudmore Grove, had migrated a considerable distance to the south by the Ipswichian, leaving the Blackwater as the main drainage line in the area of Mersea Island (as it is today).

The Blackwater deposits at the East Mersea Restaurant and Hippopotamus Sites are therefore of considerable stratigraphical significance. Notwithstanding this, they are also of importance as a source of palaeoenvironmental evidence for the Ipswichian Stage. If the various Corbets Tey and Mucking Formation sites in the Lower Thames are correctly interpreted as of pre-Ipswichian (*sensu* Trafalgar Square) age (see Chapter 4), East Mersea is the only true 'last interglacial' site within the Thames system downstream of London. The fact that it represents a tributary is no accident. It is apparent from the elevation of the Trafalgar Square site that the projected Ipswichian thalweg level of the main river falls below the valley floor in the Lower Thames and probably below ordnance datum before the modern coast is reached. Therefore Thames-Medway Ipswichian deposits are more likely to be found offshore from the Essex coast or beneath coastal alluvium than within the onshore terrace system. Whether this is because of post-Ipswichian subsidence or whether it indicates that Ipswichian sea level was much lower than is generally believed is at present uncertain.

Conclusions

These two related localities provide exposures in fluvial sediments containing an assemblage of mammal remains typical of the last Pleistocene interglacial episode (the Ipswichian). These include such characteristic elements as hippopotamus, hyaena and straight-tusked elephant. The remains of molluscs and ostracods (small crustaceans) are also found at the Restaurant Site. During the last interglacial, the main channel of the Thames, downstream from London, lay well below the level of the present river floodplain, below modern sea level. It is because the interglacial sediments at East Mersea were deposited in a former tributary of the Thames, the Blackwater, that they lie at a sufficiently high level to be studied at the surface – the steeper upstream gradient of the Blackwater brings its last interglacial floodplain level above modern sea level at East Mersea. Because of this, the two East Mersea localities expose the only unequivocal last interglacial (Ipswichian) deposits (dated at around 125,000 years BP) yet recognized in the Thames catchment downstream from London. They are therefore comparable to the famous but inaccessible fossiliferous site at Trafalgar Square.

GREAT TOTHAM (LOFTS FARM PIT; TL 866092)

D.R. Bridgland, T. Allen, G.R. Coope, P.L. Gibbard and R. Wrayton

Highlights

A view, rare in the Thames catchment, of presumed Devensian fossiliferous sediments is here afforded by a section in a gravel terrace of the River Blackwater, a former tributary of the Thames. These deposits contain a typical cold-climate mammalian fauna, with reindeer, woolly mammoth, woolly rhinoceros and hyaena. They also contain pollen and the remains of insects and ostracods.

Introduction

A gravel pit in the 2nd Terrace of the Blackwater at Great Totham exploited what appear to be the most recent sediments included within the GCR Thames coverage. This site is located 2 km NNE of Maldon, on the northern side of the River Blackwater, at the upstream limit of its present-day estuary (Fig. 5.1). Organic sediments interbedded with the gravel near Lofts Farm have yielded a large collection of mammalian bones, as well as pollen, other plant remains, insects and ostracods. The deposits are believed to represent the Devensian Stage, on the bases both of their faunal contents and of regional terrace stratigraphy.

Devensian sediments are relatively common in the valley bottom (floodplain) gravels of the Thames upstream from London and in many of its tributaries (Coope and Angus, 1975; Sutcliffe and Kowalski, 1976; Gibbard *et al.*, 1982; Kerney *et al.*, 1982; Gibbard, 1985). In these situations, however, they invariably lie below the water table and are difficult to study except where accessible in active gravel pits or temporary exposures. Downstream from London, Holocene subsidence of the North Sea Basin, coupled with the low Devensian base level, ensures that sediments dating from the last glacial are well below floodplain level, within the buried channel. In Essex such sediments, like the Ipswichian deposits at East Mersea (see above), can therefore be studied only in the valleys of minor rivers such as the Blackwater, where steeper upstream gradients bring them more rapidly above floodplain level than is the case with the Thames (Bridgland, 1988a).

At present the Blackwater flows out to sea east of Maldon, but offshore bedrock surface contour mapping indicates that before the Holocene marine transgression it flowed into the now submerged valley of the Thames-Medway, *c.* 20 km to the south of Clacton (D'Olier, 1975; Bridgland and D'Olier, 1989; Fig. 5.5F). The Blackwater may therefore be regarded as a tributary of the Thames-Medway system.

The Great Totham locality has not been described hitherto, so the present report is the first documentation of evidence collected at the site. An excavation was carried out at Lofts Farm Pit by the GCR Unit in the autumn of 1985, when the organic sediments were sampled in detail. Analyses of the samples collected on this occasion are still incomplete.

Description

The former gravel workings at Great Totham exposed deposits attributed by the Geological Survey (Sheet 241) to the 2nd Terrace of the Blackwater-Chelmer system, immediately downstream of the confluence between these two rivers (Fig. 5.1). In a small area to the north-west of Lofts Farm (TL 866092) the following section was recorded:

	Thickness
Surface stripped prior to quarrying (the original surface level was *c.* 9 m O.D.)	
3. Disturbed clayey gravel occurs within ice-wedge casts and involutions in (2)	*c.* 3 m
2. Organic clays and silts, oxidized near top	2.6 m
1. Gravel, horizontally bedded	*c.* 2 m
London Clay	

Involutions and ice-wedge pseudomorphs, which occur in the upper part of the sequence, indicate that permafrost conditions have prevailed at Great Totham at some time since the deposition of the fossiliferous sediments. Clast-lithological analysis of the gravel (bed 1) reveals a close similarity to other deposits attributed to deposition by the River Blackwater (Table 5.5).

The most spectacular discoveries at Great Totham were a collection of vertebrate bones (Fig. 5.36) amassed by R. Wrayton, who visited the site frequently while it was in operation (1982–4) and discovered the organic sediments. The mammalian assemblage consists of *Canis lupus* (wolf), *Crocuta crocuta* (spotted hyaena), *Rangifer tarandus* L. (reindeer), *Megaloceros* sp. (giant deer), *Bison* and/or *Bos* (bovid), *Coelodonta antiquitatis* (woolly rhinoceros), *Equus ferus* (horse) and *Mammuthus primigenius* (woolly mammoth). Freshwater fish and Amphibia are also represented, namely *Perca fluviatilis* L. (perch), *Esox lucius* L. (pike), *Gasterosteus aculeatus* L. (three-spined stickleback), a cyprinid (carp family), frog (*Rana* sp.) and indeterminate newt (Fig. 5.37). The bones are well preserved, although many show evidence of damage during transport by the river. The remains of small mammals have been discovered but have yet to be identified. During the 1985 excavation an ulna of woolly mammoth was discovered *in situ* in the organic silty clay, the only addition to the assemblage of large bones. The organic deposits also contain pollen and the remains of plants, insects and ostracods.

The majority of the insect remains recovered at Great Totham came from a bulk sample from bed 2, the organic clays and silts. These were supplemented by a similar but smaller assemblage from a sample collected in 1984, which has not been related to the stratigraphical sequence described above, but which can be assumed to come from bed 2. Altogether 45 taxa of Coleoptera were recorded, of which 37 could be identified to species or species group. Six are no longer living in Britain and are distinguished by an asterisk in the following list:

Carabidae	
Notiophilus aquaticus (L.)	23
**Diacheila polita* (Fald.)	3
Elaphrus cupreus Duft.	1
Loricera pilicornis (F.)	1
Clivina fossor (L.)	2
Dyschirius globosus (Hbst.)	2
Trechus secalis (Payk.)	1
Bembidion (Metallina) properans (Steph.)	3
Bembidion (Princidium) bipunctatum (L.)	6
Bembidion (Notaphus) obliquum Sturm	1
Bembidion (Blepharoplataphus) virens Gyll.	1
Bembidion (Plataphodes) sp.	1
**Bembidion (Plataphus) hasti* Sahlb.	1
Bembidion (Philochthus) aeneum Germ.	4
Pterostichus strenuus (Panz.)	1
Pterostichus melanarius (Ill.)	1
Calathus melanocephalus (L.)	1
Agonum ericeti (Panz.)	1
**Amara municipalis* (Duft.)	5
**Amara torrida* (Panz.)	2
Dytiscidae	
Ilybius sp.	1
Gyrinidae	
Gyrinius aeratus Steph.	1
Hydraenidae	
Helophorus aquaticus (L.) type	1
Hydrophilidae	
Cercyon melanocephalus (L.)	2
Cercyon tristis (Ill.)	1
Cercyon analis (Payk.)	2
Cryptopleurum minutum (F.)	1
Hydrobius fuscipes (L.)	1
Silphidae	
Thanatophilus dispar (Hbst.)	1
Liodidae	
Agathidium marginatum Sturm	1
Staphylinidae	
Stenus sp.	1
Xantholinus sp.	1
Tachyporus sp.	1
Tachinus sp.	1
Scarabaeidae	
Aegialia sabuleti (Panz.)	3
Aphodius fimetarius (L.)	5
Aphodius sp.	27
Chrysomelidae	
**Phaedon segnis* Weise	1
Curculionidae	
Apion sp.	2
Otiorhynchus fuscipes (Ol.)	7
Otiorhynchus arcticus (F.)	3
Otiorhynchus ligneus (Ol.)	3
Otiorhynchus rugifrons (Gyll.)	5
Notaris aethiops (F.)	3
Alophus triguttatus (F.)	12

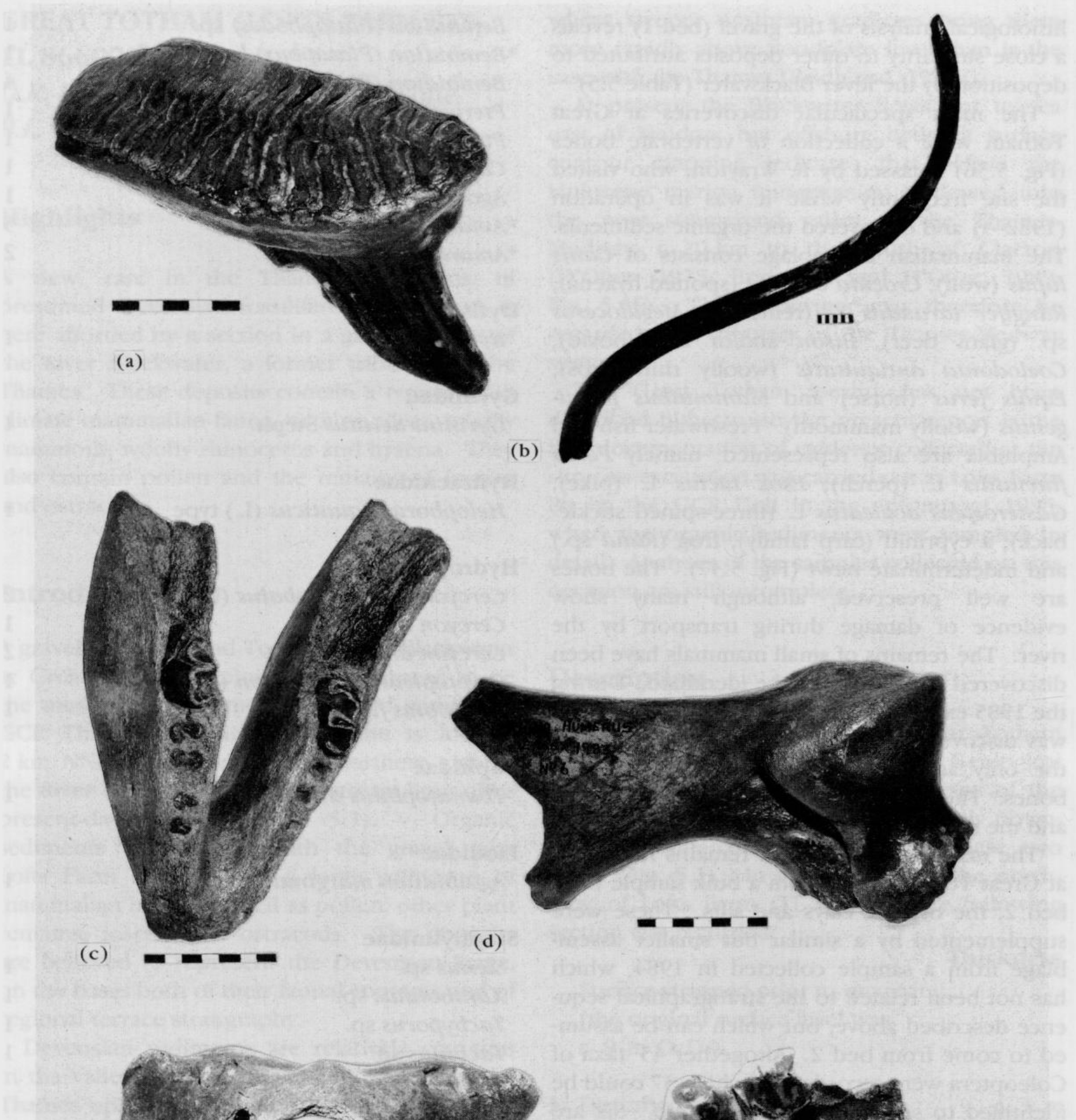


Figure 5.36 Mammalian bones from Great Totham (R. Wrayton collection). (A) Molar tooth of mammoth (*Mammuthus primigenius*). (B) Tusk of mammoth (*Mammuthus primigenius*). (C) Lower jaw of woolly rhinoceros (*Coelodonta antiquitatis*). (D) Humerus of woolly rhinoceros (*Coelodonta antiquitatis*). (E) Vertebra of horse (*Equus ferus*). (F) Fragment of jaw of spotted hyaena (*Crocuta crocuta*). Scale bars are graduated in cm. (Photos: R. Wrayton).

In this faunal list the nomenclature follows that of Lucht (1987). The number opposite each taxon indicates the minimum number of individuals present in the sample.

During the period when R. Wrayton was collecting fossil bones from the Great Totham site, he also sieved a large amount of the biogenic sediment of bed 2 and found it to contain a rich fossil fauna and flora. At this time a number of broken valves of the bivalve *Pisidium* sp. and an apex of the gastropod *Bithynia tentaculata* were recovered. These remain the only Mollusca recorded from the site. Also collected at this time (1984) was the preliminary sample from bed 2 that produced significant numbers of beetles and ostracods; it was the assessment of this preliminary sample that prompted the more detailed investigation of the site that was undertaken by the GCR Unit the following year.

A study has been made of the cladoceran and ostracod remains from five serial bulk samples that were taken from the lower 0.9 m of bed 2 during the 1985 GCR excavation. The uppermost of these samples was barren, but the other four, from the lowest 0.70 m of bed 2, all contained small crustacea (Table 5.7). Between 0.15 and 0.50 m from the base of the unit, cladoceran ephippia and ostracod valves were present in profusion, particularly in the 0.15–0.30 m sample. As a similar assemblage of small crustacea was present in all four fossiliferous samples, the 0.15–0.30 m sample can be regarded as representative of the bed 2 fauna at its optimum. In this sample, cladoceran ephippia, the saddle-shaped coverings of 'winter' or 'resting' eggs, were common. Both the elongate ephippia of the *Daphnia magna* group and more triangulate ephippia belonging to the *D. pulex* or *D. longispina* groups were

Figure 5.37 Small vertebrate remains from Great Totham. The identifiable species represented are pike (*Esox lucius*), perch (*Perca fluviatilis*), stickleback (*Gasterosteus aculeatus*) and frog (*Rana* sp.; probably *R. temporaria*, common frog). Remains of a cyprinid fish (carp family) and indeterminate newt are also present. Identifications by B. Clarke (Amphibia) and A. Wheeler (fish) of the Natural History Museum. Scale bar is graduated in mm, numbered in cm. (Photo: Paul Douthwaite.)

Table 5.7 Ostracods from Great Totham (identifications by T. Allen).

		Height (cm) above base of organic clays and silts				
Species	**Group**	**0 - 15**	**15 - 30**	**30 - 50**	**50 - 70**	**70 - 90**
Cyclocypris serena (Koch)	1	-	Common	Very rare	-	-
Candona candida (Müller)	2	Very rare	Common	Common	Very rare	-
Candona neglecta Sars	2	Very rare	Abundant	Abundant	Very rare	-
Ilyocypris bradyi Sars	2	-	Common	Common	-	-
Cypria ophthalmica (Jurine)	3	-	Common	Very rare	-	-
Ilyocypris gibba (Ramdohr)	4	Very rare	Very common	Common	-	-
Eucypris zenkeri (Chyzer)	4	-	Rare	-	-	-
Limnocythere inopinata (Baird)	4	-	Rare	Very rare	-	-
Herpetocypris sp.	?	-	Rare	Very rare	-	-
Potamocypris sp.	?	-	Very rare	Very rare	-	-
Overall frequency		**Very rare**	**Very common**	**Common**	**Very rare**	**Absent**

present in equal quantities. Ten species of ostracods were recorded from this sample (Table 5.7). The most abundant species was *Candona neglecta*, which was represented by many adult male and female valves and large numbers of instars. Valves of *Ilyocypris gibba*, often strongly tuberculate, were also very common (Table 5.7). Four other species were found in significant numbers: *Candona candida*, *Cyclocypris serena*, *Cypria ophthalmica* and *Ilyocypris bradyi*. Adult valves and instars of the remaining species (Table 5.7) were present only in small numbers. Single valves of *Candona protzi* Hartwig and *Candona weltneri* Hartwig were found in the 1984 preliminary sample, but no examples of these species were encountered in the material collected from the 1985 GCR excavation.

Only a preliminary assessment of the palaeobotany of the organic deposits can be given here. Three samples from bed 2 have been analysed, from 2 m, 2.5 m and 3 m (approximately) above the London Clay. The second of these was from a particularly fossiliferous level, rich in macroscopic plant remains and ostracods (although collected from an earlier exposure, this was probably broadly equivalent to the richest ostracod-bearing levels sampled in 1985 – see above). All three samples yielded a similar pollen assemblage, dominated by herbs, grasses and sedges (Fig. 5.38). The plant macrofossil counts from the three levels are also closely comparable (Table 5.8).

Interpretation

The organic sediments (bed 2) at Great Totham have provided considerable palaeontological evidence, but this is predominantly of value to environmental reconstruction rather than stratigraphy. Although further assessment of the flora and fauna is in progress, the fossil assemblage recognized thus far is not stratigraphically diagnostic. It is necessary to look to the terrace record of the River Blackwater, and to the

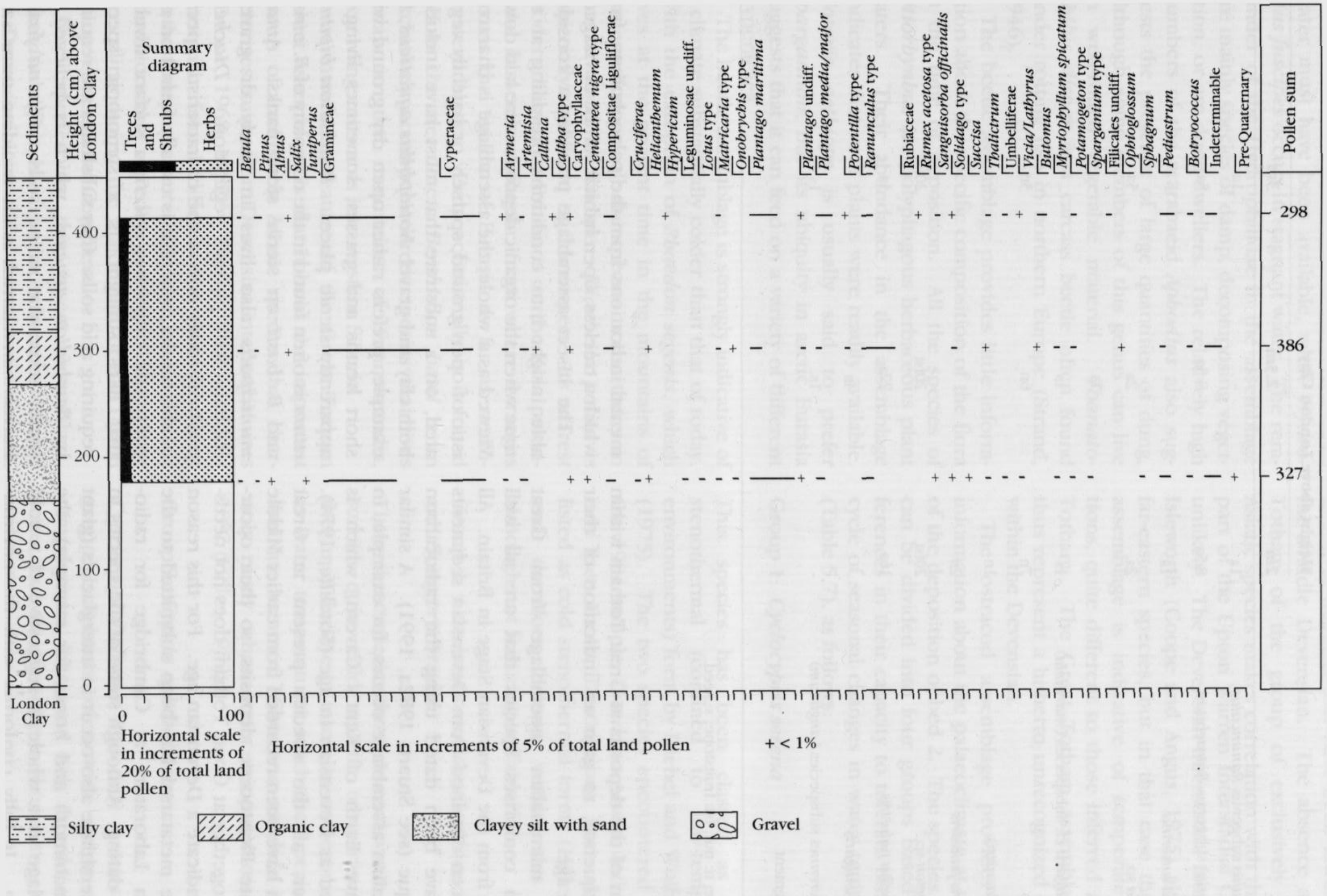


Figure 5.38 Pollen from the organic deposits at Great Totham.

Table 5.8 Plant macrofossils from Lofts Farm Pit, Great Totham (identifications by M. Pettit).

	Height above London Clay		
	2m	**2.5m**	**3m**
Ranunculus subgenus *Ranunculus*	1a	-	1a
Ranunculus subgenus *Batrachium*	8.5a	9.5a	5a
Potentilla anserina	1a	-	-
Potentilla sp.	2a	2a	5a
Viola sp.	-	1s	-
Silene vulgaris cf. subspecies (*maritima*)	1s	1s	-
Carex sp.	7n	6n	3n
Scirpus lacustris	1n	-	-
Eleocharis palustris	2n	-	-
Potamegeton sp.	20fst	20fst	20fst
Zannichellia palustris	16a	22a	3a
Hippuris vulgaris	-	4a	-
Linum perennes subspecies (*anglicum*)	-	1s	1s
Moss fragment	-	+	-

a: achene; n: nut; fst: fruitstone; s: seed.

position of the deposits at Great Totham within that sequence, to gain an indication of their relative age.

The mammalian assemblage from Great Totham comprises species that are all well known from the Devensian Stage in Britain. All have been obtained from Devensian sediments that have been dated using the radiocarbon technique (see Stuart, 1982a, 1991). A similar mammalian assemblage occurs, for example, in the Cave Earth of Kent's Cavern, which is regarded as Devensian in age (Sutcliffe, 1974). However, all the species present at Great Totham have been recorded from earlier Middle and Late Pleistocene deposits, so their occurrence together at Great Totham does not necessarily indicate a Devensian age. For this reason a horse metatarsal has been submitted to the Godwin Laboratory at Cambridge for radiocarbon dating. Although some of the species in this assemblage also occur in interglacials (giant deer, mammoth and horse, for example), the assemblage as a whole is suggestive of a cold episode. It fully conforms with the environmental indications from the palaeobotany, from which a treeless, open habitat can be envisaged.

The insect assemblage provides a considerable insight into conditions prevailing at the time when the organic deposits were laid down. Viewed as a whole, the assemblage is characteristic of open ground, sparsely or patchily vegetated, on a substrate that must have included both clay and gravel. *Notiophilus aquaticus*, for example, prefers rather open dry ground with short heaths and grasses, sometimes living in apparently sterile places. *Bembidion bipunctatum* is often found in the company of *B. virens* and *B. hasti* on sterile stony banks. *Amara municipalis* also lives in sandy or gravelly habitats with sparse vegetation. *Diacheila polita* is today one of the characteristic species of the tundra, where it is usually found on dry peaty soil. *Agonum ericeti*, a surface dweller that likes sunlight, is a stenotopic species requiring acid soils. Clay substrates are required by *Bembidion aeneum*, which is believed to prefer somewhat saline soils. *Clivina fossor* burrows in clayrich soils, avoiding pure sand

(Lindroth, 1985).

There are very few Coleoptera present that require fully aquatic habitats. Single specimens of *Ilybius* and *Gyrinus* indicate that some open water must have been available, while *Hydrobius fuscipes* occurs in stagnant water. The remainder of the Hydrophilidae in the assemblage are mainly species of damp, decomposing vegetation, or are dung-dwellers. The relatively high numbers of the scarabaeid *Aphodius* also suggests the presence of large quantities of dung, although some members of this genus can live in well-rotted vegetable material. *Thanatophilus dispar* is a carcass beetle often found under rotting fish in northern Europe (Strand, 1946).

The beetle assemblage provides little information about the specific composition of the flora at the time of deposition. All the species of *Otiorhynhus* are polyphagous herbaceous plant eaters. Their abundance in the assemblage indicates that such plants were readily available. *Notaris aethiops* is usually said to prefer *Sparganium*, but its ubiquity in arctic Eurasia suggests that it can feed on a variety of different Cyperacaea.

The beetle assemblage is strongly indicative of a climate substantially colder than that of today. With the exception of *Phaedon segenis*, which lives at the present time in the mountains of eastern Europe, all the species occur today in the far north of Europe. *Diacheila polita* is especially significant in this respect. Its nearest modern habitat to Britain is on the Kola peninsula, in northern Russia, from where it ranges across the tundra of Eurasia as far as north-western Alaska. Only occasionally is it found below the tree line. *Bembidion hasti* is an exclusively north-palaeoarctic species that lives today in the mountains of Fennoscandia, extending eastwards into western Siberia.

An interesting feature of the Great Totham insect assemblage is that it lacks the important group of exclusively Asiatic species that characterizes faunas from Devensian interstadial sites (Coope, 1968, 1987). The implication of this particular faunal difference is that the Great Totham deposits were laid down under climatic conditions that were less continental than those prevailing during the major part of the Upton Warren Interstadial Complex.

One species in this insect assemblage, *Phaedon segnis*, has up to now been found only in Devensian interstadial contexts in Britain. This was found (incorrectly recorded under the name *P. pyritosus*) at Upton Warren (Coope *et al.*, 1961) and at Marlow (Coope, in Gibbard, 1985), in deposits that have been attributed to the Middle Devensian. The absence at Great Totham of the group of exclusively eastern Asiatic species makes correlation with the major part of the Upton Warren Interstadial Complex unlikely. The Devensian interstadial fauna from Isleworth (Coope and Angus, 1975) also lacks far-eastern species, but in that case the insect assemblage is indicative of temperate conditions, quite different to those inferred at Great Totham. The Great Totham assemblage may thus represent a hitherto unrecognized episode within the Devensian.

The ostracod assemblage provides further information about the palaeoclimate at the time of the deposition of bed 2. The species present can be divided into four groups based on differences in their capacity to tolerate the annual cycle of seasonal changes in water temperature (Table 5.7), as follows:

Group 1: *Cyclocypris serena*

This species has been classed as a cold stenothermal (confined to low-temperature environments) form by Diebel and Wolfschläger (1975). The two species encountered only in the 1984 sample, *Candona protzi* and *C. weltneri* (see above, Description), have also been listed as cold stenothermal forms (Hiller, 1972) and therefore belong within this group, although not featuring in Table 5.7.

Group 2: *Candona candida, Candona neglecta* and *Ilyocypris bradyi*

These three species thrive in cool water and can survive quite cold aquatic temperatures, but they may decline in numbers or become absent as water temperatures reach their peak in mid- and late summer. *Candona candida* is found only rarely when water temperatures exceed 18°C (Hiller, 1972).

Group 3: *Cypria ophthalmica*

Cypria ophthalmica, the only species in this group, is tolerant of a wide range of water temperatures, living not only in cold and cool water, but also thriving in the warmer water of summer.

Group 4: *Ilyocypris gibba*, *Eucypris zenkeri* and *Limnocythere inopinata*

These species flourish in the warm aquatic conditions of the summer months and, while able to tolerate the cooler water temperatures of spring and autumn, they would be absent during the coldest winter months.

Overall the ostracod assemblage contains a preponderance of species adapted to cool water conditions. As aquatic temperatures started to rise in late spring to early summer, the cold stenothermal forms (Group 1) would have become scarce and then failed, leaving the cool water ostracods (Group 2) to dominate the assemblage. A subsidiary fauna of summer species (Group 4) would have begun to appear at this time, becoming increasingly important as temperatures increased during the early summer. By mid- to late summer the Group 4 species would have formed a substantial part of the ostracod fauna, perhaps even achieving a short period of dominance if water temperature peaked at above 18–20°C. As aquatic temperature decreased with the onset of autumn, the summer species would have declined, leaving the cool-water species again predominant. *Cypria ophthalmica*, the single Group 3 species, would have been a constant member of the fauna throughout the year.

This ostracod assemblage lived in a permanent body of fresh or oligohaline (slightly brackish) moving water with at least moderate summer weed growth. *Eucypris zenkeri*, in particular, is characteristic of slowly moving, shallow, plant-rich waters (Klie, 1938). The assemblage is similar to faunas described from the Devensian interstadial sites at Fladbury, Isleworth and Upton Warren (Siddiqui, 1971). The presence of numerous Daphniidae ephippia, such as are found in the silts and clays at Great Totham, may be an indication of seasonality, as these egg covers are produced to enable the survival of periods of inhospitable conditions; however, the climatic significance of these is limited, as ephippia are produced by the Daphniidae at the present time over a wide range of latitudes, from arctic to subtropical (Shotton and Osborne, 1965).

The preliminary pollen analysis of the organic sediments (Fig. 5.38) indicates that vegetation was sparse at the time of deposition. Tree and shrub pollen are so rare as to preclude the growth of such plants locally, the small quantities present probably resulting from either long-distance transport or reworking. Amongst the herb pollen, several distinct plant communities are indicated. It is clear that the channel and adjacent wet ground supported communities of the aquatics *Thalictrum*, *Myriophylum spicatum* L., *Sparganium* and *Butomus*. The abundance of grass pollen, together with a range of dry-ground herbs, points to the occurrence of grassland further away from the depositional site. The pollen of Compositae (Liguliflorae), *Artemisia*, *Plantago majorimedia*, Umbelliferae, Caryophyllaceae, *Helianthenmum*, *Centaurea nigra*, *Vicia/Lathyrus* and *Matricaria* type were all probably derived from this habitat. Damp grassland and meadow environments also occurred in the vicinity, to judge by the abundance of pollen from Cyperaceae, *Sanguisorba officinalis* L. and *Caltha* type.

Of particular interest is the repeated occurrence of the pollen of halophytic plants such as *Plantago maritima* L. and *Armeria*. These records, reinforced by the finds of *Silene vulgaris maritima* (Withering) (A. and D. Löve) in the plant macrofossil assemblage (see below), are indicative of high soil salinity. This phenomenon has been frequently attributed to high evaporation rates under cold-climate conditions (West, 1988).

The limited plant macrofossil assemblage (Table 5.8) compares closely with that of the pollen. It is dominated by the remains of aquatics such as *Potamogeton* spp., *Hippuris vulgaris* (L.), *Ranunculus* (*Batrachium*), *Myriophyllum* cf. *spicatum* and *Zannichelia palustris* (L.). Marsh plants (*Eleocharis palustris* (L.) Roemer and Schultes, *Potentilla* sp.) and dry grassland taxa (*Linum perenne anglicum* Ockendon, *Viola* sp. and *Ranunculus* (*Ranunculus*)) occur in all three samples (Table 5.8), confirming that similar conditions prevailed throughout the period of the deposition of the organic clays and silts. The palaeobotanical evidence is typical of cold episodes during the Middle and Late Pleistocene, intervals that are often termed 'full-glacial'. Such floras recur repeatedly and are not therefore characteristic of any particular period.

As indicated above, the terrace record of the Blackwater provides some stratigraphical indication of the likely age of the Great Totham deposits. The long-profiles of the terraces in both branches of the Blackwater system, the Blackwater itself and the River Chelmer, have been illustrated by Bristow (1985). In the Maldon area and further downstream, Bristow recognized no well-marked formations above the 2nd Terrace. A minor spread, mapped as 3rd Terrace, to the north of Chigborough Farm (around TL 878091) appears to be poorly differentiated from the 2nd Terrace (Bristow, 1985, figure 21). In the present volume the deposits on the northern side of the Blackwater estuary, which were mapped as 'Glacial Sand and Gravel', are recognized as higher, older terraces of the Blackwater system (see above, Maldon and East Mersea). Figure 5.32 shows projections of the long-profiles of the terrace gravels of the Blackwater system downstream from Maldon. The downstream gradient of the 2nd Terrace indicates that it falls below ordnance datum between Tollesbury and Mersea Island. As has been noted previously, this places the 2nd Terrace lower in the Blackwater terrace sequence than the fossiliferous deposits at the East Mersea Restaurant and Hippopotamus sites (Fig. 5.32). Since the latter have been attributed to the Ipswichian Stage, this would appear to provide important confirmatory evidence for the Devensian age of the 2nd Terrace and, therefore, the deposits at Great Totham.

In terms of the scheme for Thames terrace stratigraphy promoted in this volume, however, the occurrence of Ipswichian and Devensian deposits in different terraces of the Blackwater system is somewhat surprising. In the London area Ipswichian sediments and deposits dating from the mid-Devensian Upton Warren Interstadial both occur within the Kempton Park Formation of the Thames (see Chapter 3, Fern House Pit). No terrace rejuvenation appears to separate the Ipswichian and the Middle Devensian in this area, the downcutting to the Shepperton Gravel level occurring in the Late Devensian (Gibbard, 1985). It is possible that a rejuvenation occurred in the early Devensian in the Upper Thames, however; recent indications from a site in the Northmoor Formation at Cassington (see Chapter 2, Stanton Harcourt and Magdalen Grove) suggest that sediments of Chelford Interstadial or Upton Warren Interstadial age occur there (D. Maddy, pers. comm.), which would require there to have been a downcutting event soon after the deposition of the Ipswichian Eynsham Gravel at the Summertown-Radley Terrace level.

Conclusions

The Great Totham site provides a rare opportunity for the study of last-glacial fossiliferous sediments in the lower reaches of the Thames system, in this case situated in the valley of the River Blackwater (a former Thames tributary). Organic sediments here have yielded an impressive assemblage of large mammal remains, as well as smaller vertebrates, pollen, other plant remains, insects and ostracods. The mammal fauna has many of the elements regarded as typical of cold climatic episodes: wolf, giant deer, reindeer, woolly rhinoceros and mammoth are all represented. A rich assemblage of fossil beetles has been collected from the organic sediments. It too points to conditions much colder than today, with several species present that now live in the far north of Europe and/or Eurasia. The last glacial (Devensian) age cannot be ascertained with certainty from the palaeontology, however. It is necessary to compare the height of the Great Totham sediments within the sequence of Blackwater terraces with that of the last interglacial site at East Mersea, which appears to be in a higher (and therefore older) terrace, implying that the Great Totham terrace post-dates the last interglacial.