Quaternary of the Thames

D.R. Bridgland
Bridgland Earth Science Consultancy,
Darlington, UK.

Scientific Editor: D. Q. Bowen
GCR Editor: W. A. Wimbledon

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Chapter 4

The Lower Thames

Introduction

The previous two chapters have covered the upper part of the Thames catchment, upstream from the London Basin (Chapter 2), and then the middle part of its course, the area in which the longest record of the river's depositional history is preserved and where detailed evidence for its glacial diversion can be observed (Chapter 3). This chapter is concerned with the valley of the Lower Thames, which contains a complex sequence of Middle and Upper Pleistocene deposits laid down under a variety of climatic conditions in both fluvial and estuarine environments.

The division between the Middle and Lower Thames, a purely arbitrary boundary, is conventionally placed in central London. Application of the term Lower Thames to the valley downstream from the Colne confluence at Staines, which has only existed as a Thames course since the glacial diversion, would perhaps provide a more meaningful geographical and geological division. Any problems of definition are largely academic, however, since most of the scientific interest and all of the GCR sites in the post-diversion valley fall either within or downstream from Greater London.

Despite an abundance of important palaeontological and archaeological localities and a long history of research, the succession in the Lower Thames has been poorly understood and a satisfactory correlation with the terraces of the classic Middle Thames region has been demonstrated only recently (Gibbard, 1985; Bridgland, 1988a; Gibbard *et al.*, 1988).

Research history

The first detailed appraisal of the Lower Thames sequence was by Hinton and Kennard (1900, 1905, 1907), who identified (1905) four gravel terraces numbered in declining sequence. The mapping of the three named 'valley gravel' terraces (Boyn Hill, Taplow and Floodplain), established in the Middle Thames (Chapter 3), was extended into the Lower Thames by the Geological Survey on its 'New Series' maps (Sheets 257 and 271; Dewey *et al.*, 1924; Dines and Edmunds, 1925). This mapping did not distinguish between Hinton and Kennard's 1st and 2nd terraces, both of which were classified as 'Boyn Hill Gravel'. King and Oakley (1936) concluded that a simple altitudinal sequence was not applicable to the Lower Thames because, in that part of the valley, repeated rejuvenations and aggradations had resulted in deposits of various ages being laid down at similar elevations. They described a complex sequence of downcutting and depositional phases, the evidence for which was largely archaeological or palaeontological. For example, sediments at different levels were considered to have been laid down sequentially, on account of their having similar assemblages of Palaeolithic artefacts; conversely, deposits beneath single terrace surfaces were sometimes attributed to depositional events widely separated in time, on the grounds of archaeological differences. King and Oakley's sequence offered little hope for the classification of the more widespread unfossiliferous gravels that make up the bulk of the Pleistocene record in the Lower Thames and contain only mixed assemblages of abraded artefacts. Their scheme did, however, gain widespread acceptance, a possible reason for the paucity of subsequent work on terrace stratigraphy in the area, although the rich Palaeolithic and palaeontological sites continued to receive much attention.

The post-war years saw a number of additions made to the original tripartite sequence in the Middle Thames, notably the Lynch Hill Terrace (between the Boyn Hill and the Taplow) and various pre-Boyn Hill aggradations, from the Black Park Terrace upwards (see Chapter 1; Chapter 3 and Fig. 3.2). Few attempts were made to trace these into the Lower Thames, although Wooldridge and Linton (1955) suggested that the Lynch Hill Terrace was probably represented within the belts of gravel to the east of London mapped as Boyn Hill and Taplow. Wooldridge and Linton provided a description of the terraces in the eastern part of the Lower Thames area in which they adhered closely to the Geological Survey's sequence. However, Evans (1971) returned to a complex scheme in his pioneering attempt to correlate the Thames terrace sequence with the deep-sea record (see Chapter 1). There were considerable similarities between his model and that of King and Oakley, but Evans took the radical step of allocating the various aggradations in the Lower Thames to seven separate warm periods. With the exception of Evans's model, the interpretation of the Lower Thames terrace sequence has, over the past two to three decades, generally followed the conventional Middle and Upper Pleistocene chronological scheme, as set out by Mitchell *et al.* (1973; see Chapter 1). Various interglacial deposits were described at a number of important sites and were correlated with the Hoxnian or Ipswichian Stages of the East Anglian sequence: examples include the Swanscombe deposits, correlated with the Hoxnian (Kerney, 1971), and the biogenic sediments at Aveley, Ilford, Purfleet and Trafalgar Square, which were assigned to the Ipswichian (Franks, 1960; West *et al.*, 1964; West, 1969; Hollin, 1977). Doubts about some of these correlations were first expressed by Sutcliffe (1960, 1964, 1975, 1976) and later by Allen (1977). As these reservations were expressed during detailed consideration of the most important sites in the area, they will be discussed in more detail in appropriate site reports in this chapter.

In the most recent work in the Lower Thames, local lithostratigraphical nomenclature has been applied to the terrace deposits (Table 4.1 and Figs 4.1, 4.2 and 4.3; Bridgland, 1983a, 1983b, 1988a; Gibbard *et al.*, 1988). The New Series Geological Survey mapping of the Lower Thames was found to be broadly accurate and was used as the basis for the reclassification of the three gravel formations originally recognized (see Figs 4.1, 4.2 and 4.3 and Table 4.1). However, Gibbard (1979) correlated high-level deposits at Dartford Heath, mapped as Boyn Hill/Orsett Heath Gravel, with the Black Park Terrace, thus adding a possible fourth formation to the Lower Thames sequence (see Wansunt Pit). Bridgland (1983a, 1988a; Gibbard *et al.*, 1988) showed that the Lower Thames sequence below the Boyn Hill level had been miscorrelated with the Middle Thames in the original Geological Survey mapping. He concluded (in collaboration with Gibbard) that the Corbets Tey Gravel of the Lower Thames correlates with the Lynch Hill Gravel of the Middle Thames (Table 4.1), not recognized in the original tripartite classification of the terraces in the latter area. This formation appears on the geological maps of the Lower Thames as Taplow, but the true correlative of the Taplow Gravel of the Middle Thames type area is the Mucking Gravel, which was mapped east of London as Floodplain Gravel.

Beneath the alluvium of the modern floodplain, Bridgland (1983a, 1988a) recognized a further gravel formation, the East Tilbury Marshes Gravel, which is interpreted as a downstream continuation of the Kempton Park (Upper Floodplain Terrace) Gravel of the Middle Thames (Bridgland, 1988a; Gibbard *et al.*, 1988; Table 4.1). The gravel sequence in the Lower Thames may be summarized as follows:

Hinton and Kennard (1905)	**Geological Survey**	**Bridgland (1988a)** ***Gibbard et al. (1988)***
		East Tilbury Marshes Gravel
Terrace 4	Floodplain	*West Thurrock Gravel* [2] Mucking Gravel
Terrace 3	Taplow	Corbets Tey Gravel
Terrace 2 Terrace 1	Boyn Hill	Orsett Heath Gravel *Dartford Heath Gravel* [1]

Notes: (1) The separation of the Dartford Heath from the Orsett Heath Gravel is not advocated in this volume (see Hornchurch and Wansunt Pit). (2) The separation of the Mucking and West Thurrock Gravels is dependent on the interpretation of palynological evidence from the West Thurrock brickearth and is not supported in this volume (see Lion Pit).

Differences in detail between the stratigraphical schemes of Bridgland (1988a) and Gibbard *et al.* (1988) reflect a different emphasis in interpreting and ranking various types of evidence. Bridgland gave priority to terrace stratigraphy, his scheme closely following the altitudinal sequence of gravel formations, whereas Gibbard *et al.* favoured biostratigraphical (particularly palynological) evidence, closely adhering to the post-Anglian chronology of Mitchell *et al.* (1973). This has led to important differences in the interpretation of sites such as Purfleet, Globe Pit (Little Thurrock) and the Lion Pit tramway cutting (West Thurrock); these differences are discussed below (see appropriate reports).

An alternative dating model for the Lower Thames terrace succession is proposed in this chapter, based on the stratigraphical relations between the bedded, largely unfossiliferous gravels, ascribed to periglacial episodes, and the interglacial sediments that occur at various sites. This model, which adheres closely to that

Table 4.1 The Pleistocene fluvial sequence in the Lower Thames (first published usage of lithostratigraphical terms in reference given in parentheses), with proposed correlations with the Middle Thames sequence, Pleistocene stages and oxygen isotope stages.

Formation ***etc*** **(First publication)**	**Type locality (National Grid Ref.)**	**Middle Thames equivalent**	**Stage**	**^{18}O**
East Tilbury Marshes Gravel (Bridgland, 1983b)	East Tilbury Marshes (TQ 688784)	Kempton Park Gravel	mid to late Devensian	6-2[7]
(West Thurrock Gravel) (Gibbard *et al*., 1988)[6]	Lion Pit tramway cutting (TQ 597779)	(Reading Town Gravel)[6]	(early Devensian)	(?5d)
Interglacial Beds at Trafalgar Square		Brentford deposits[5]	Ipswichian	5e
Mucking Gravel (Bridgland, 1983b)	Mucking (TQ 689815)	Taplow Gravel	late Saalian	8-6[4]
Interglacial beds at West Thurrock, Aveley etc.			Intra-Saalian	7
Corbets Tey Gravel (Gibbard, 1985)	Corbets Tey (TQ 570844)	Lynch Hill Gravel	mid-Saalian	10-8[3]
Interglacial beds at Purfleet and Grays			Intra-Saalian	9
Orsett Heath Gravel (Bridgland, 1983b)	Orsett Heath (TQ 668803)	Boyn Hill Gravel	early Saalian	12-10[2]
Interglacial beds at Swanscombe			Hoxnian *sensu* Swanscombe	11[2]
(Dartford Heath Gravel) (Gibbard, 1979)[1]	Wansunt Pit (TQ 5147360)	(?Black Park Gravel)	(late Anglian)	(12)

1 The separate existence of the Dartford Heath Gravel, the subject of a lengthy controversy, is doubtful (see Wansunt Pit). This is thought to be part of the late Anglian to early Saalian Orsett Heath Formation.

2 The Boyn Hill/Orsett Heath Formation includes the interglacial sediments at Swanscombe, here attributed to ^{18}O Stage 11 (referred to as Hoxnian *sensu* Swanscombe in this volume).

3 Aggradation of the terrace deposits included within the Corbets Tey Formation began prior to the interglacial represented at Purfleet and Grays.

4 Aggradation of the terrace deposits included within the Mucking Formation began prior to the interglacial represented at West Thurrock, Aveley etc.

5 Described by Trimmer (1813) and Zeuner (1959).

6 The separate existence of the West Thurrock and Reading Town Gravels is disputed in this volume. These are believed to be part of the late Saalian Taplow/Mucking Formation (see West Thurrock and Fern House Pit).

7 The Ipswichian sediments at Trafalgar Square and Brentford are regarded here as part of the Kempton Park Formation (see Chapter 3, Fern House Pit). This formation is considered to represent aggradation from the end of Stage 6 (gravel underlying the Trafalgar Square sediments, the Spring Gardens Gravel of Gibbard, 1985) to the mid-Devensian.

outlined by Bridgland (1988a), recognizes two additional fully temperate episodes within the sequence, between the conventional Hoxnian (*sensu* Swanscombe) and Ipswichian (*sensu* Trafalgar Square) Stages (Fig. 4.3; Table 4.1). It forms the principal basis for the stratigraphical scheme for the Thames catchment as a whole and for the climatic model for terrace formation, both of which were put forward in Chapter 1. If the Anglian Stage, during which modern Lower Thames drainage was initiated, is correlated with Stage 12 of the oxygen isotope chronology (Bowen *et al.*, 1986b) and the last interglacial (Ipswichian *sensu* Trafalgar Square) with Sub-stage 5e (Gascoyne *et al.*, 1981; Shotton, 1983), three earlier post-Anglian interglacial episodes remain to be identified on land. Bowen *et al.* (1989) have recently published

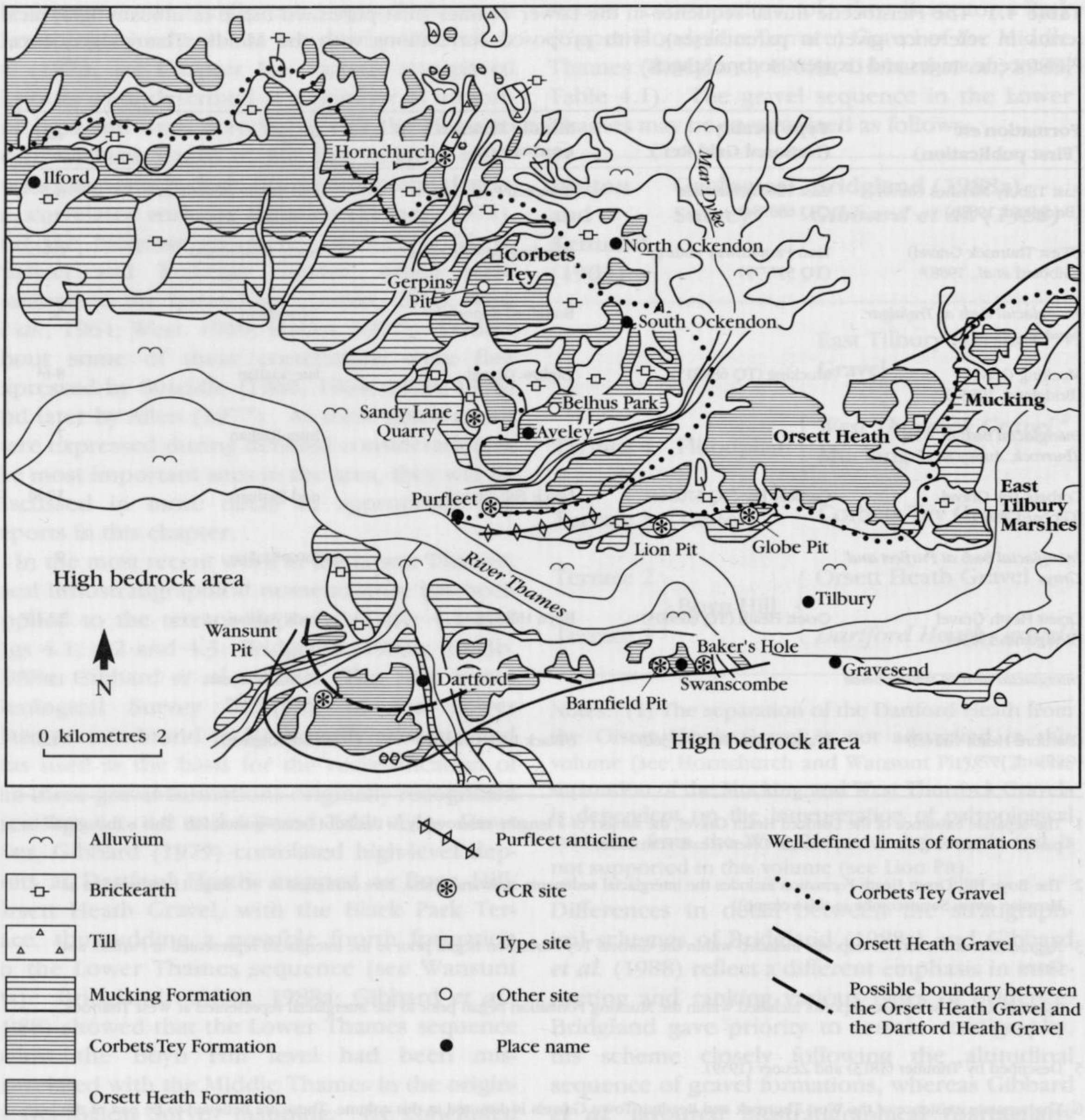


Figure 4.1 The Pleistocene deposits of the Lower Thames (after Bridgland, 1988a).

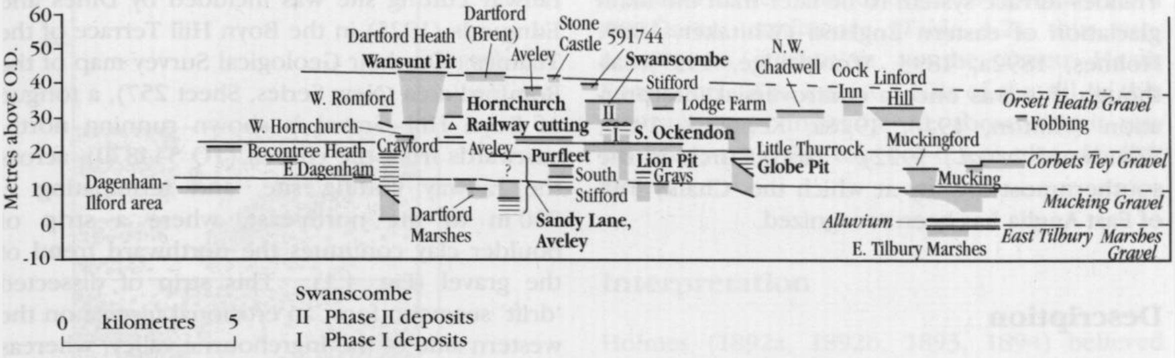
amino acid ratios from various post-Anglian sediments and suggested that these can be divided into four groupings, equating with the four major post-Anglian temperate episodes, Oxygen Isotope stages 11, 9, 7 and 5. The same number of temperate episodes is now recognized in the Lower Thames sequence; on this basis correlations with the deep-sea record are suggested in Table 4.1. Details of the evidence from which this model has been assembled are given in the various site descriptions in this chapter.

HORNCHURCH RAILWAY CUTTING (TQ 547874)

D.R. Bridgland

Highlights

This locality demonstrates the maximum southern limit of the Anglian ice sheets. At Hornchurch a remnant of Anglian till is overlain by a post-diversion Thames gravel. This gravel is part



Stipple indicates gravels and sands, horizontal ornament indicates fine-grained deposits.

Figure 4.2 Longitudinal profiles of terrace deposits in the Lower Thames.

of the highest terrace of the Lower Thames, a fact that implies that the terrace sequence in this part of the valley is entirely of post-diversion (late Anglian/post-Anglian) age.

Introduction

Sections at Hornchurch showing chalky till overlain by Thames terrace gravel have been famous since the last century, when the original descriptions were written (Holmes, 1892a, 1892b, 1892c). The stratigraphical importance of these sections, created during construction of the Romford to Upminster railway line, has long been recognized. The sequence in the Hornchurch–Romford district is unique, in the Lower Thames valley, in that terrace deposits there are in contact with Anglian glacigenic sediments. The superposition of the Boyn Hill/Orsett Heath Gravel above till at Hornchurch has formed a principal basis for considering the entire Lower

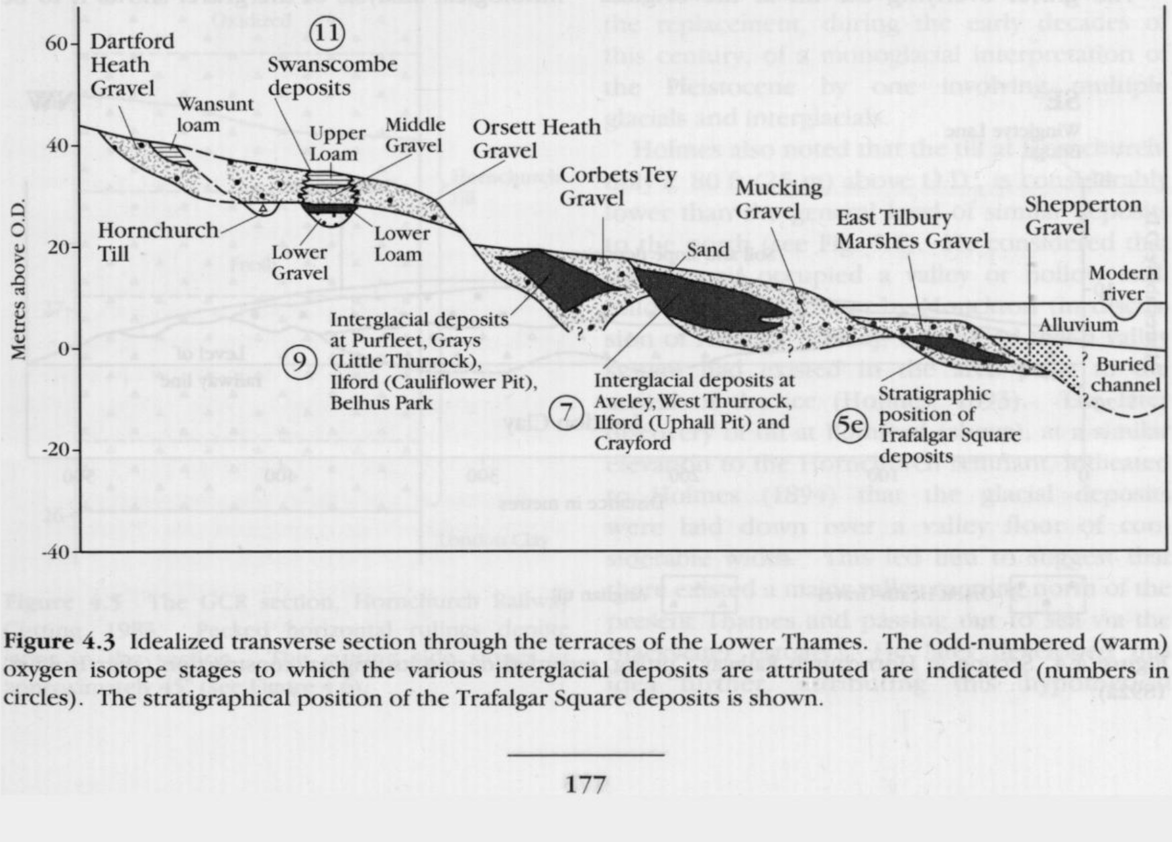


Figure 4.3 Idealized transverse section through the terraces of the Lower Thames. The odd-numbered (warm) oxygen isotope stages to which the various interglacial deposits are attributed are indicated (numbers in circles). The stratigraphical position of the Trafalgar Square deposits is shown.

Thames terrace system to be later than the main glaciation of eastern England (Whitaker, 1889; Holmes, 1892a, 1893; Wooldridge, 1957), although this was once a controversial interpretation (Hinton, 1910, 1926a; Kennard, 1916; Woodward *et al.*, 1922). Hornchurch is the southernmost locality at which the 'Chalky Till' of East Anglia has been recognized.

Description

The GCR site is part of a railway cutting excavated in the 1890s through a ridge of gravel-capped land running north-eastwards from the parish church at Hornchurch. When newly excavated, a section here (TQ 547874), up to 8 m deep and 600 m long, showed *c.* 5 m of till overlain by sand and gravel (Fig. 4.4). The till was observed over a distance of *c.* 300 m in the central part of the cutting; it appeared to occupy a depression in the London Clay, as the sand and gravel directly overlay London Clay to the north-west and south-east of the till outcrop (Holmes, 1892a, 1892b, 1892c, 1893, 1894; Fig. 4.4). At the Romford end of the same railway line a second cutting (TQ 525887) also showed till between the London Clay and Thames gravel, in this case associated with 'dark silt' deposits, interbedded with sand and pebbles (Holmes, 1894).

The gravel overlying the till at the original railway cutting site was included by Dines and Edmunds (1925) in the Boyn Hill Terrace of the Thames. On their Geological Survey map of the Romford area (New Series, Sheet 257), a tongue of Boyn Hill Gravel is shown running north-eastwards from the church (TQ 544870), across the railway cutting site, and terminating *c.* 200 m to the north-east, where a strip of boulder clay continues the northward trend of the gravel (Fig. 4.1). This strip of dissected 'drift' seems to form an erosional terrace on the western side of the Ingrebourne valley, whereas the 'boulder clay' and brickearth of the Upminster district form a complementary feature on the eastern side of the valley (Pocock, 1903; New Series Sheet 257; Fig. 4.1).

Attempts to locate till beneath the thickest part of the Orsett Heath Gravel at Hornchurch, exposed in a pit near the church (TQ 544868), revealed only London Clay bedrock, although chalky till was reported when an electricity substation was built in part of this pit (Anon., 1982b). A section was therefore cleared in the railway cutting in 1983 (Anon., 1984a), revealing the sequence illustrated in Figs 4.5 and 4.6. The land surface at this, the GCR site (*c.* 33 m above O.D.), is clearly erosional, so that the full thickness of the Orsett Heath Gravel is not preserved. However, 4 m of bedded gravel, considerably disturbed by an ice-wedge cast, was exposed above 3 m of till (Figs 4.5 and 4.6). Clast-lithological analysis of the gravel shows it to be

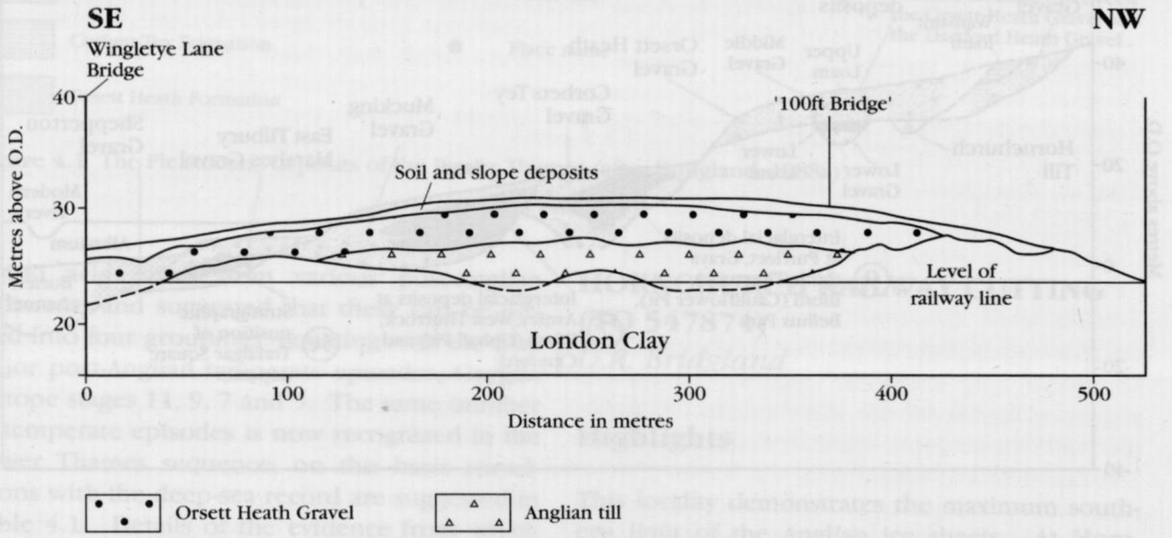


Figure 4.4 Section in Hornchurch Railway Cutting, recorded during its original construction (after Holmes, 1892a).

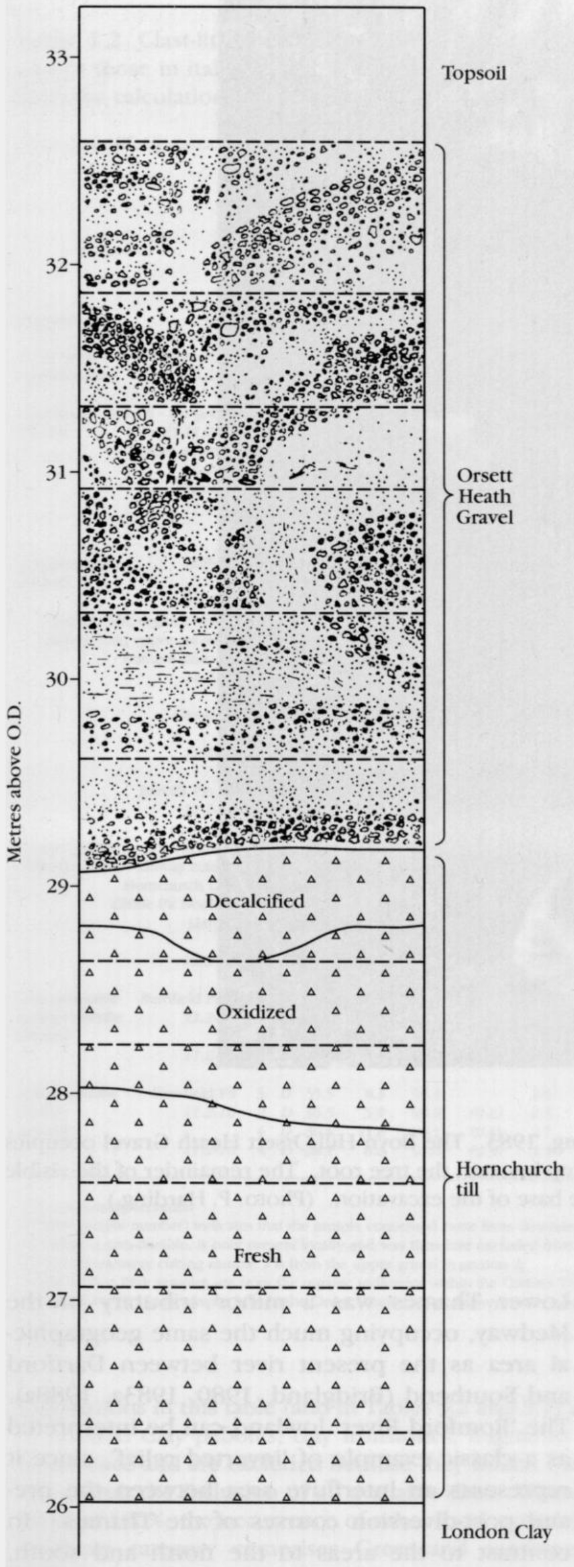


Figure 4.5 The GCR section, Hornchurch Railway Cutting, 1983. Pecked horizontal rulings denote steps in the section. The cutting side slopes at approximately 45° (see Figure 4.6).

typical of Lower Thames deposits upstream from the Darent confluence (Table 4.2), thus supporting its attribution to the Orsett Heath Formation. The lowest 1.5 m of the till in this exposure was unweathered; above this it was oxidized, with the top 0.1–0.3 m also decalcified.

Interpretation

Holmes (1892a, 1892b, 1893, 1894) believed that the gravel overlying the till at Hornchurch belonged to the oldest terrace of the Lower Thames valley. He therefore concluded that the fluvial drifts of the area were entirely 'post-glacial'. This interpretation was generally accepted, although some workers preferred to place the 'Chalky Boulder Clay' of south-eastern Britain later than the 'High Terrace' of the Thames (Hinton, 1910, 1926a; Kennard, 1916; Woodward *et al.*, 1922). Kennard (1916) was perhaps the staunchest opponent of Holmes's interpretation. He believed the Lower Thames and its tributaries to be of 'pre-glacial' age and considered the gravel above the Hornchurch till to be the product of 'a tributary stream, possibly the Ingrebourne, or ... not a river gravel at all' (Kennard, 1916, p. 264). According to Preece (1990a), Kennard's view reflected his strong monoglacialist convictions; the evidence from Hornchurch was of fundamental importance in the replacement, during the early decades of this century, of a monoglacial interpretation of the Pleistocene by one involving multiple glacials and interglacials.

Holmes also noted that the till at Hornchurch, only *c.* 80 ft (25 m) above O.D., is considerably lower than the general level of similar deposits to the north (see Fig. 5.1). He considered that the deposit occupied a valley or hollow and, following a suggestion by Monckton (in discussion of Holmes, 1892a), concluded that a valley system had existed in the area prior to the arrival of the ice (Holmes, 1893). The later discovery of till at Romford (above), at a similar elevation to the Hornchurch remnant, indicated to Holmes (1894) that the glacial deposits were laid down over a valley floor of considerable width. This led him to suggest that there existed a major valley running north of the present Thames and passing out to sea via the Blackwater estuary. He later developed this idea further, attributing this hypothetical

Figure 4.6 The GCR section, Hornchurch Railway Cutting, 1983. The Boyn Hill/Orsett Heath Gravel occupies the upper part of the section, its base occurring on the step beneath the tree root. The remainder of the visible section is in till, although London Clay was reached in the base of the excavation. (Photo: P. Harding.)

valley to a 'Romford River' (Holmes, 1896).

This hypothetical phase of fluvial development, presumed to pre-date the deposition of any of the terrace gravels of the Lower Thames, became widely accepted by later writers as an early course of the river (Saner and Wooldridge, 1929; Baker and Jones, 1980; Baker, 1983), but recent work in the area through which it was thought to have passed has yielded no evidence for drainage by the Thames or any other river (Bridgland, 1986c). On the contrary, studies of the fluvial deposits of eastern and southern Essex suggest that any precursor of the modern Lower Thames was a minor tributary of the Medway, occupying much the same geographical area as the present river between Dartford and Southend (Bridgland, 1980, 1983a, 1988a). The 'Romford River' lowland can be interpreted as a classic example of 'inverted relief', since it represents an interfluve area between the pre- and post-diversion courses of the Thames. In contrast to the areas to the north and south, there were no early gravels on this interfluve, so the non-resistant London Clay was therefore afforded no protection from erosion during the latter part of the Pleistocene (Bridgland, 1986c).

Table 4.2 Clast-lithological data from the Lower Thames. All counts by the author, at 16–32 mm size range, except those in italics, which are 11.2–16 mm counts. Note that non-durables (including Chalk) are excluded from the calculations, but Chalk is shown in this table as a relative % of the total durables.

			Flint			Chalk	Southern		Exotics								
Gravel	**Site**	**Sample**	**Tertiary**	**Nodular**	**Total**	**Chalk (1)**	**Gnsd chert**	**Total**	**Quartz**	**Quartzite**	**Carb chert**	**Rhax chert**	**Igneous**	**Total**	**Ratio (qtz:qtzt)**	**Total count**	**National Grid Reference**
East Tilbury	E.Tilbury Mshs	1 D	58.9	9.9	96.2		0.9	1.1	0.9	0.7	0.5	0.3	0.3	2.7	1.40	745	TQ 6880 7843
Marshes Gr.	*11.2-16*	1 D	49.5	6.6	92.2		1.5	1.6	3.2	1.4	0.6	0.2	0.1	6.1	2.21	979	
Mucking	Lion Pit - lwr gravel	1 D	47.8	35.9	97.5	(1.1)	0.7	0.7	0.7	1.1				1.8	0.67	276	TQ 5978 7821
Gravel	('floor') *11.2-16*	*1* D	*50.2*	*19.6*	*95.7*	*(0.3)*	*0.6*	*0.6*	*1.8*	*0.9*	*0.6*		*0.3*	*3.7*	*2.00*	*327*	
	upper gravel (2)	2 D	67.1	5.9	95.3		0.8	0.8		3.5				3.9		255	TQ 5978 7809
	11.2-16	*2* D	*59.4*	*3.2*	*94.2*		*1.1*	*1.1*	*1.9*	*1.5*	*0.4*	*0.4*		*4.7*	*1.29*	*465*	
	Mucking	1A D	64.0	9.3	97.0		1.1	1.1	0.9	0.6		0.1		1.8	1.50	708	TQ 6892 8154
	11.2-16	*1A* D	*57.7*	*4.9*	*92.1*		*1.9*	*1.9*	*3.1*	*1.2*	*1.1*	*0.2*	*0.1*	*6.0*	*2.55*	*901*	
		1B D	37.4	13.3	92.5		4.9	4.9	1.2	0.6	0.6	0.3		2.6	2.00	345	
Corbets Tey	Stifford	1A	51.6	8.4	94.0		0.4	0.4	2.9	1.2	0.6	0.1	0.4	5.5	2.33	730	TQ 5900 7908
Gravel		1B	52.5	*	92.9		0.9	1.0	3.5	1.4	0.5	0.1		5.9	2.46	918	
	11.2-16	*1B*	*39.2*	*8.3*	*88.3*		*1.1*	*1.4*	*6.0*	*2.6*	*1.1*	*0.2*	*0.1*	*10.3*	*2.30*	*1277*	
	Belhus Park, organic bed (3)	1	47.5	9.8	90.2	(0.3)	0.7	0.7	2.0	4.4	2.0	0.7		9.1	0.46	297	TQ 575811
	Belhus Park, upper gravel (3)	1	49.0	9.7	93.8				3.5	1.4	0.7		0.7	6.2	2.50	145	
	Purfleet, Esso Pit	1A	44.8	16.9	91.8		0.5	0.5	2.5	3.0	1.6			7.4	0.82	366	TQ 5607 7837
	11.2-16	*1A*	*36.3*	*7.6*	*86.6*		*1.0*	*1.1*	*3.9*	*3.7*	*3.1*	*0.5*	*0.2*	*11.7*	*1.04*	*618*	
		1B	47.7	18.1	95.0	(37.3)	1.5	1.5	0.8	1.5	0.8	0.4		3.5	0.50	260	
	Globe Pit	1 D	57.9	11.2	93.1		3.2	3.5	0.8	1.1	1.1	0.2		3.4	0.71	653	TQ 6251 7830
		2 D	50.2	10.5	93.2		3.1	3.1	1.3	0.7	0.7	0.8		3.7	2.00	617	TQ 6251 7828
	11.2-16	*2* D	*40.7*	*5.4*	*90.5*		*4.4*	*4.7*	*2.1*	*0.8*	*1.2*	*0.2*	*0.1*	*4.5*	*2.73*	*1456*	
		3 D	64.6	8.9	94.4		2.4	2.4	1.5	1.0	0.4			3.2	1.40	463	TQ 6251 7827
	Barvills Fm Pit	1 D	67.9	11.8	92.9		3.3	3.3	1.7	1.1	0.4	0.1		3.6	1.50	722	TQ 6811 7774
	11.2-16	*1* D	*55.6*	*5.6*	*91.8*		*2.7*	*2.9*	*2.2*	*1.1*	*1.1*	*0.3*	*0.3*	*5.3*	*2.08*	*1138*	
Orsett Heath	Hornchurch	1	41.8	0.7	92.6		2.3	2.3	2.0	1.4	0.6	0.6		5.1	1.17	352	TQ 5464 8739
Gravel	railway cutting	2	28.9	11.7	90.2		1.6	1.9	1.9	2.3	1.6	0.9	0.9	7.9	0.80	429	TQ 5464 8739
	Hornchurch Dell	1	54.0	7.7	91.7		1.5	1.5	2.1	2.8	1.2	0.4		6.7	0.78	676	TQ 5440 8675
	Globe Pit North (4)	1A D	41.4	9.0	90.4		4.1	4.4	0.6	1.4	1.6	0.3		5.2	0.40	365	TQ 6245 7855
	Linford	1 D	64.6	11.6	96.0		2.2	2.4	0.7		0.2		0.2	1.7		424	TQ 6681 8028
		2 D	84.2	4.0	95.7		1.4	1.6		0.5		0.2	1.2	2.7		625	TQ 6681 8028
	11.2-16	*2* D	*28.0*	*3.6*	*91.3*		*1.1*	*1.2*	*3.9*	*2.3*	*0.6*	*0.2*	*0.5*	*7.4*	*1.73*	*665*	
Swanscombe	Barnfield Pit 1	1 D	58.2	9.8	93.9		0.9	1.2	2.4	1.8	0.5			4.8	1.37	1081	TQ 5973 7430
Lower Middle	*11.2-16*	*1* D	*50.9*	*5.3*	*89.9*		*2.1*	*2.3*	*4.4*	*2.0*	*0.8*		*0.1*	*7.7*	*2.21*	*1703*	
Gravel		2 D	48.5	12.7	92.7		1.9	2.0	1.9	1.8	0.5	0.1	0.2	5.0	1.05	992	TQ 5973 7430
	11.2-16	*2* D	*41.6*	*5.5*	*89.7*		*3.0*	*3.1*	*3.5*	*1.5*	*0.5*	*0.2*	*0.2*	*6.8*	*2.42*	*1785*	
Swanscombe	Barnfield Pit	3 D	55.5	8.3	94.3		1.0	1.0	2.3	1.3	0.5	0.2	0.1	4.5	1.75	931	TQ 5974 7430
Lower	*11.2-16*	*3* D	*36.5*	*5.9*	*89.0*	*(0.1)*	*2.5*	*2.7*	*4.0*	*2.9*	*0.5*	*0.1*	*0.1*	*8.3*	*1.40*	*1391*	
Gravel		4 D	30.5	11.8	94.1	(0.4)	2.7	2.8	1.1	0.8	0.4	0.1		2.7	1.29	857	TQ 5974 7430
	11.2-16	*4* D	*28.1*	*8.8*	*90.6*	*(0.3)*	*3.5*	*3.8*	*2.7*	*1.5*	*0.9*	*0.2*		*5.6**	*1.74*	*1494*	

* Not separately recorded

D (after sample number) indicates that the sample concerned came from downstream of the contemporary Darent confluence.

(1) -Chalk, a non-durable, is only present locally and was therefore excluded from calculations, but shown instead as a % of the total durable material.

(2) Lion Pit tramway cutting sample 2 is from the upper gravel in section 2;

(3) The Belhus Park samples are from the organic sediments within the Corbets Tey Formation and from the gravel overlying the organic sediments;

(4) The Globe Pit North sample is from the Orsett Heath Gravel outcrop in the northern part of the old workings, outside the GCR site.

Calculations in this table (and in Tables 5.2 and 5.5) are based on the durable content only. Non-durables such as London Clay pebbles, clay ironstones, fragments of septaria and even Chalk, are highly localized in their occurrence and are excluded because they inhibit comparison of widespread gravel characteristics. Space does not permit the inclusion of all available data. Where the addition of the flint, southern and exotic totals falls short of 100%, the occurrence of other local material is indicated, predominantly sarsen. Extra material in the southern category comprises Greensand sandstones and (where not shown separately) Hastings Beds sandstones, siltstones and ironstones. Extra material in the exotic category comprises arkosic sandstones, unidentified cherts and (where not shown separately) igneous rocks. Note that: the Tertiary flint category comprises rounded pebbles (sometimes subsequently broken) reworked from the Palaeogene; Gnsd = Greensand; Carb chert = Carboniferous/Palaeozoic chert; Rhax = *Rhaxella*; the igneous category includes metamorphic rocks (very rarely encountered); the quartzite category includes durable sandstones.

By the beginning of the present century the Hornchurch cuttings were no longer available for study, but attention moved to the opposite side of the Ingrebourne valley when till was discovered beneath brickearth deposits near Upminster, *c.* 2 km to the north-east of the Hornchurch site (Pocock, 1903). The Upminster brickyards exposed over 7 m of horizontally bedded brickearth with occasional seams of gravel (Dalton, 1890; Pocock, 1903; Woodward, 1904). This deposit was laminated in its lower part, the laminations showing contortions, leading Pocock (1903, p. 200) to suggest that the sediment had been disturbed 'by ice-floes'. These contortions, and the association with till, suggested to Pocock that the brickearth was a glacial-lake deposit. Woodward went further and, believing that the ice had reached the Grays area and caused disturbances there in the Chalk, suggested that 'the waters of the Thames Valley were pounded up by an icy dam' (Woodward, 1904, pp. 483–484).

Warren (1912) supported theories of lake development in association with the glaciation of the Hornchurch area. He claimed that the Hornchurch-Romford till probably rested on an overdeepened lake bottom, since it was unlikely that the whole Thames valley had been excavated at that time to the depth of the Hornchurch deposits. The same author later recorded new sections near Hornchurch, opened up on either side of the Ingrebourne valley during the construction of the Southend Arterial Road (A127), showing till overlain by laminated silts that he interpreted as lacustrine (Warren, 1924a). In the eastern section (TQ 565890), Palaeolithic artefacts were found in gravel and sand interbedded with the silts (Dines and Edmunds, 1925; Dewey, 1930, 1932; Warren, 1942; Wymer, 1968, 1985b), interpreted by Warren (1942) as a product of the Ingrebourne. According to Dewey (1932), some of these artefacts suggested the use of the Levallois technique. There is little indication that artefacts have been recovered from the gravel overlying the till at Hornchurch (see, however, Wymer (1985b, p. 297)), although Palaeolithic material is widespread in the Boyn Hill/Orsett Heath Gravel. Dines and Edmunds (1925) described both of the Arterial Road sections in some detail, recording several steep-sided channels about 2 m deep filled with chalky till. They suggested (1925, p. 32) that these occurrences of till represented 'remnants of a spread which filled a valley now occupied by the Ingrebourne river', as previously envisaged by Woodward (1909; Woodward *et al.*, 1922).

Zeuner (1945, p. 155) claimed that the Hornchurch till lies on what he termed the 'Boyn Hill bench', meaning the erosion surface beneath the Boyn Hill/Orsett Heath Gravel (formed by the downcutting phase separating this from the preceding Black Park Formation). Zeuner recognized that the earliest occupation by the river of the Lower Thames valley coincided with his 'Kingston Leaf', later redefined as the Black Park Terrace (Wooldridge and Linton, 1955; Gibbard, 1979), and not with the Boyn Hill Terrace. His interpretation of the Hornchurch site therefore implied that the diversion of the Thames into its modern valley and the formation of the Kingston Leaf (Black Park) aggradation both pre-dated the Hornchurch glaciation. Zeuner, in fact, favoured river capture as the mechanism for the diversion of the Thames, not glacial intervention.

Wooldridge (1957) remapped the deposits of the Hornchurch area and concluded that the till was part of a dissected lobe that descends into the Ingrebourne valley from the plateau to the north, reflecting the former presence of a tongue of ice 'of glacier-like dimensions' (1957, p. 13). Wooldridge suggested a correlation between the till at Hornchurch and the Maldon Till of Clayton (1957), on the basis that both are confined to valley floors (see Chapter 5, Maldon). He suggested that these low-level tills could be equated with the Lowestoft Till of Suffolk, implying an Anglian age. Wooldridge considered that the major part of the excavation of the Lower Thames valley had occurred since the emplacement of the till, thus removing any evidence for the latter having extended further southwards. Wooldridge also suggested a correlation between the excavation of the valley in which the Hornchurch till was deposited and the erosion of the Clacton Channel. He followed King and Oakley (1936), however, in referring the erosion of the Clacton Channel to their 'Inter-Boyn Hill Erosion Stage'; he thus implied, indirectly, that the lowest 'Boyn Hill' deposits at Swanscombe were older than the till at Hornchurch, an interpretation that would seem to assign the Hornchurch glaciation to the mid-Hoxnian (interglacial) Stage – clearly an untenable view.

Ideas that a major valley system existed in the Lower Thames region prior to the Hornchurch glaciation, as implied by Zeuner (1945) and Wooldridge (1957), cast doubt on the theory that the diversion of the Thames was brought about by the glaciation of its former, more northerly route. In recent years, however, work in the Vale of St Albans has confirmed the role of Anglian Stage ice sheets in this diversion event (Gibbard, 1974, 1977, 1979; Chapter 3). Gibbard (1979) also demonstrated that the Black Park Gravel, which he assigned to the late Anglian, is the oldest Thames formation in the new valley through London. Later work has confirmed the Anglian age of the Black Park Formation and has suggested that it was emplaced, at least in part, while ice still occupied parts of the London Basin (Gibbard, 1983, 1985; Cheshire, 1986a; Chapter 3, Part 2).

The reopening of the section in the Hornchurch railway cutting, as part of the GCR programme (Anon., 1984a), allowed confirmation of the sequence described by Holmes and the application of modern analytical techniques to the deposits exposed. Sedimentological and chemical analyses of the till (C.A. Whiteman, pers. comm.) have shown that it comprises 65–77% clay (with subordinate silt), up to 25% sand and up to 10% gravel, the latter dominated by Chalk (40–65%) and flint (12–35%). Limestones, calcareous fossils and non-durable igneous rocks are also present. Fabric data show preferred east-west clast orientations, interpreted by Whiteman as transverse to ice flow, which he considered to be from the north. He interpreted similar fabrics in the lower till of the Chelmsford area in the same way. This fabric data, together with the colour and chemical composition of the deposit, led Whiteman to correlate the till at Hornchurch with his Newney Green Member of the Lowestoft Formation (Whiteman, 1990; Allen *et al.*, 1991; Chapter 5, Newney Green). Cheshire (1986a), however, correlated the till at Hornchurch with his Stortford Till, which was formed by the second of four separate ice advances into Hertfordshire and south Essex, all part of the Anglian (Lowestoft) glaciation (see Chapter 3 and Fig. 3.10E).

Analysis of the clast composition of the overlying gravel (Bridgland, 1988a) supports its interpretation as a main-stream Thames deposit (Table 4.2); it was included by Bridgland (1988a) and Gibbard *et al.* (1988) in the Orsett Heath Gravel. As the latter is correlated with the Boyn Hill Formation of the Middle Thames, this confirms the attribution of the gravel at Hornchurch to this terrace (the former 'High Terrace' of the Lower Thames). This is not the oldest terrace in the post-diversion Thames valley; as stated above, it has been demonstrated that the Black Park Gravel is the earliest post-diversion formation. The recognition of the Black Park Formation in the Lower Thames is, however, controversial (see below, Wansunt Pit).

Many previous authors have noted that the Hornchurch till lies significantly lower than the general level of the Anglian glacial sediments of southern East Anglia and, as stated, this led to suggestions that a valley system existed in the Hornchurch area prior to the glaciation (Holmes, 1892b, 1893; Woodward, 1909; Woodward *et al.*, 1922; Dines and Edmunds, 1925; Warren, 1942; Wooldridge, 1957). The low altitude of the Hornchurch till, overlying London Clay at 25 m O.D., poses problems for Lower Thames stratigraphy and for the reconstruction of chronological events following the diversion of the river. According to Gibbard (1979), the downstream correlative of the earliest post-diversion formation, the Black Park Gravel, has a base level of *c.* 38 m O.D. in the Dartford area (his Dartford Heath Gravel), which was at least 10 km downstream from Hornchurch along the route taken by the pre-Mucking Gravel Thames (see Fig. 4.1). The aggradation of this formation is considered to have been coeval, at least in part, with the continued glaciation of the Vale of St Albans (see Chapter 3, Part 2). However, the altitude of the till at Hornchurch suggests that the valley system there had already been excavated to over 12 m below the supposed Black Park base level (at Dartford) at the time of the ice advance (the Stortford Till advance of Cheshire, 1986a). This is difficult to reconcile with the correlation of the Black Park and Dartford Heath gravels, which has long been a subject of debate (see below, Wansunt Pit). It must be stated at this juncture that the elevation of glacial sediments is of no stratigraphical significance unless they are interbedded with fluviatile or marine deposits; glaciers can erode and infill closed hollows of very large dimensions, which can be well below the level of other contemporaneous sediments. It is therefore possible that the till at Hornchurch was deposited in an overdeepened hollow (as suggested by Warren (1917, 1924a)) or a 'tunnel-valley'. However, neither of these explanations seems likely given the location so close to the limit of what appears to have been a narrow lobe of ice. Moreover, there is further evidence that a valley system was deeply excavated in the Lower Thames by Late Anglian times, from projections of the Westmill Upper Gravel from the Vale of St Albans southwards down the Lea valley (Cheshire, 1983c, 1986a). This gravel, contemporaneous with the later part of the glaciation of the Hertford area and charged with its outwash (Chapter 3, Part 2), has a steep downstream gradient, indicating that its base level would have been as low as 35 m O.D. when it joined the Lower Thames valley and around 30 m O.D. by the Hornchurch area – 8 m below the base of the Dartford Heath Gravel some 10 km further downstream (see Fig. 4.7).

Bridgland (1980, 1983a) suggested a revised Lower Thames stratigraphy, in which the surface overlain by the Hornchurch till was correlated with the Black Park 'bench', the erosion surface beneath the Black Park Gravel. This surface, equivalent to that underlying Zeuner's Kingston Leaf, appears to fall below the level of the Boyn Hill Gravel east of London (Evans, 1971; Bridgland, 1980). It was probably formed as a result of rapid downcutting by the newly diverted Thames along its adopted course. This interpretation allows the reconciliation of an Anglian age for the till at Hornchurch with the evidence for diversion of the Thames from the Vale of St Albans during the same glacial period. According to Cheshire (1986a), the Thames was diverted by the first of the four ice advances into the Vale of St Albans, whereas the till at Hornchurch represents the second advance. Thus by the time the ice reached Hornchurch, the Thames had already excavated its newly adopted valley to the base level of the Hornchurch till.

There remains a significant difficulty, however. This arises from the fact that Anglian glacial deposits and Hoxnian fluvial sediments apparently overlie the same erosion surface, 26 m above O.D. at Hornchurch and *c.* 23 m O.D. at Swanscombe; yet the accepted terrace stratigraphy of the Lower Thames requires the (Late Anglian) Black Park/Dartford Heath Gravel to have been aggraded to over 40 m O.D. (Fig. 4.3) between the deposition of these two sets of sediments. This problem (discussed below – see Wansunt Pit) raises serious doubts about the correlation of the gravel at Dartford Heath with the Black Park Formation.

The Hornchurch railway cutting GCR site contains an important stratigraphical reference section, illustrating the relations between Anglian till and one of the oldest gravels of the Lower Thames terrace sequence. The details of the initiation and evolution of the Thames valley through London, during and following the glaciation, are at present uncertain. Further studies are required of deposits in the critical areas on the northern side of the present valley, where glacial sediments are preserved beneath fluvial (Thames) deposits. In particular, knowledge of the precise geometry of the till remnants would be useful, as would further information about the possible lacustrine sediments at Upminster. The reference section at Hornchurch will be a starting point for further work on the Anglian glacial deposits and palaeogeography of the Lower Thames region.

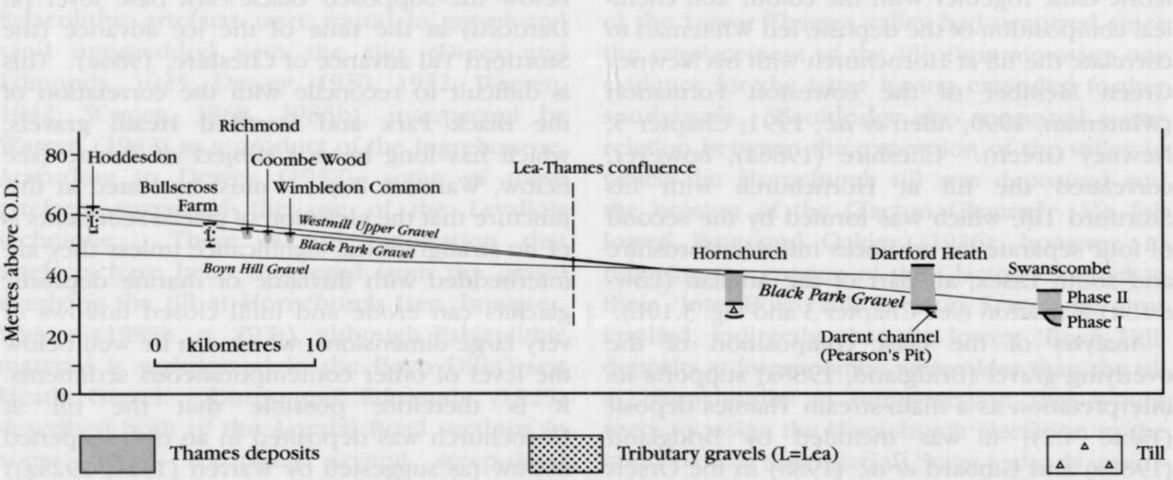


Figure 4.7 Long profile projections of the Black Park and Boyn Hill Formations between the Middle and Lower Thames. The correlation with the Westmill Upper Gravel of the Lea basin is also shown.

Conclusions

This locality is a unique reference site, providing important evidence that the glaciation of the North London area by East Anglian ice (during the Anglian Stage, around 450,000 years BP) occurred before the deposition of the highest terrace gravel of the Lower Thames. During this glaciation, ice sheets repeatedly invaded the old Thames valley across Hertfordshire and central Essex. Hornchurch is the most southerly point known to have been reached by these ice sheets. A narrow lobe of till (boulder clay), directly deposited by the ice, now occupies the Ingrebourne valley to the north of Hornchurch, as was first discovered when the railway was constructed. The till at Hornchurch is overlain by gravel of the Boyn Hill Terrace. This juxtaposition underlines the fact that the Lower Thames came into existence only after the Anglian ice sheets blocked the old route of the river, diverting it into its modern valley through London.

WANSUNT PIT, DARTFORD HEATH (TQ 515738)

D.R. Bridgland

Highlights

Controversial Thames gravels, variously correlated with the Black Park or Boyn Hill Formations, are overlain at this site by palaeolith-bearing fine-grained sediments.

Introduction

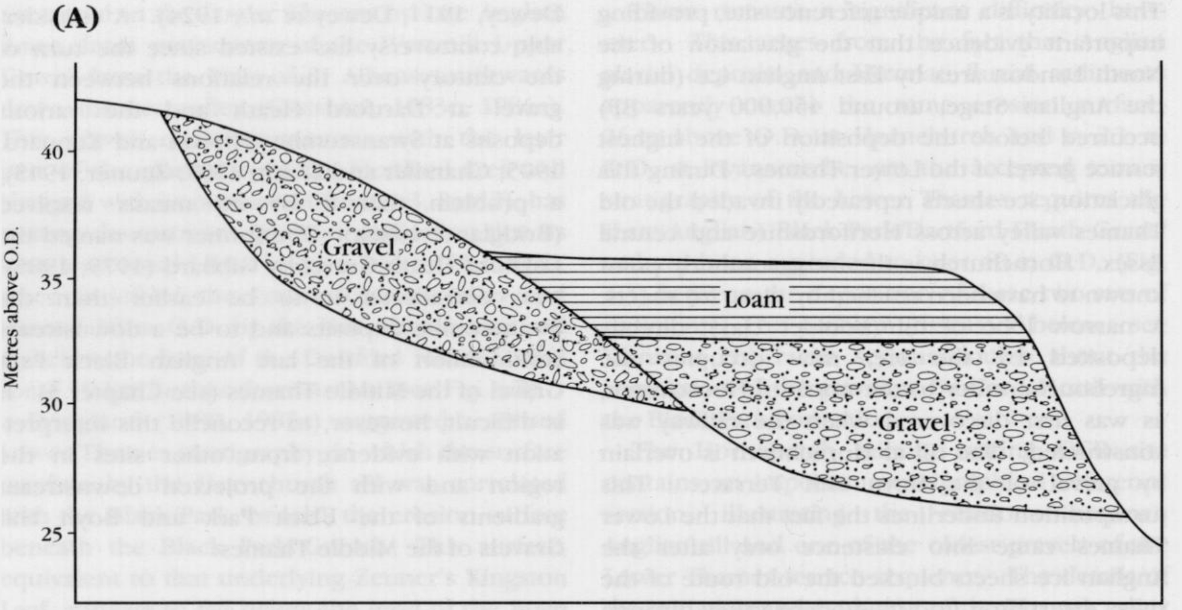
Wansunt Pit is one of many old workings that once exploited the Pleistocene gravels and the underlying Thanet Sand of Dartford Heath. Although most have been infilled, the floor of Wansunt Pit has become a factory site and steep faces on its south-eastern side are still available for study. There is a long history of interest in the Dartford Heath deposits, which have been correlated by some workers with the famous Palaeolithic fossiliferous sediments at Swanscombe, a few kilometres to the east (Chandler and Leach, 1911, 1912; Leach, 1913; Smith and Dewey, 1914; Dewey *et al.*, 1924). A considerable controversy has existed since the turn of the century over the relations between the gravel at Dartford Heath and the various deposits at Swanscombe (Hinton and Kennard, 1905; Chandler and Leach, 1907; Zeuner, 1945), a problem that is by no means resolved (Bridgland, 1988a). The former was named the Dartford Heath Gravel by Gibbard (1979, 1985), who considered it to be earlier than the Swanscombe deposits and to be a downstream continuation of the late Anglian Black Park Gravel of the Middle Thames (see Chapter 3). It is difficult, however, to reconcile this interpretation with evidence from other sites in the region and with the projected downstream gradients of the Black Park and Boyn Hill Gravels of the Middle Thames.

Description

Wansunt Pit lies on the western side of Dartford Heath, excavated into the edge of the largely gravel-covered 'plateau'. The thickest depth of gravel recorded from any Thames valley site was once exposed here, almost 20 m in all (Smith and Dewey, 1914). Few detailed descriptions of exposures in the gravel exist. There has been speculation, however, that two separate aggradations were represented, one banked against the other (Cornwall, 1950; Fig. 4.8A). No observations of two gravel bodies with such a relation have ever been made, however; published descriptions of pits on Dartford Heath all suggest that a single aggradation was represented (Chandler and Leach, 1911, 1912; Smith and Dewey, 1914; Dewey *et al.*, 1924; Dewey, 1959).

Chandler and Leach (1912) reported that up to 13 m of gravel was exposed in Wansunt Pit, the upper 4 m loamy and the remainder cross-bedded and sandy (Fig. 4.8B). They believed that most of the non-local gravel clasts occurred in the lower sandy gravel, which suggests that the upper 4 m may have represented locally-derived, possibly colluvial material. The lower sandy gravel also yielded mammalian remains, the most exhaustive list being provided by Leach (1913). He recorded *Palaeoloxodon antiquus*, *Cervus elaphus*, *Cervus* sp., *Bos* or *Bison* sp., *Equus caballus* and indeterminate rhinoceros.

Over part of the site the gravel was cut out by



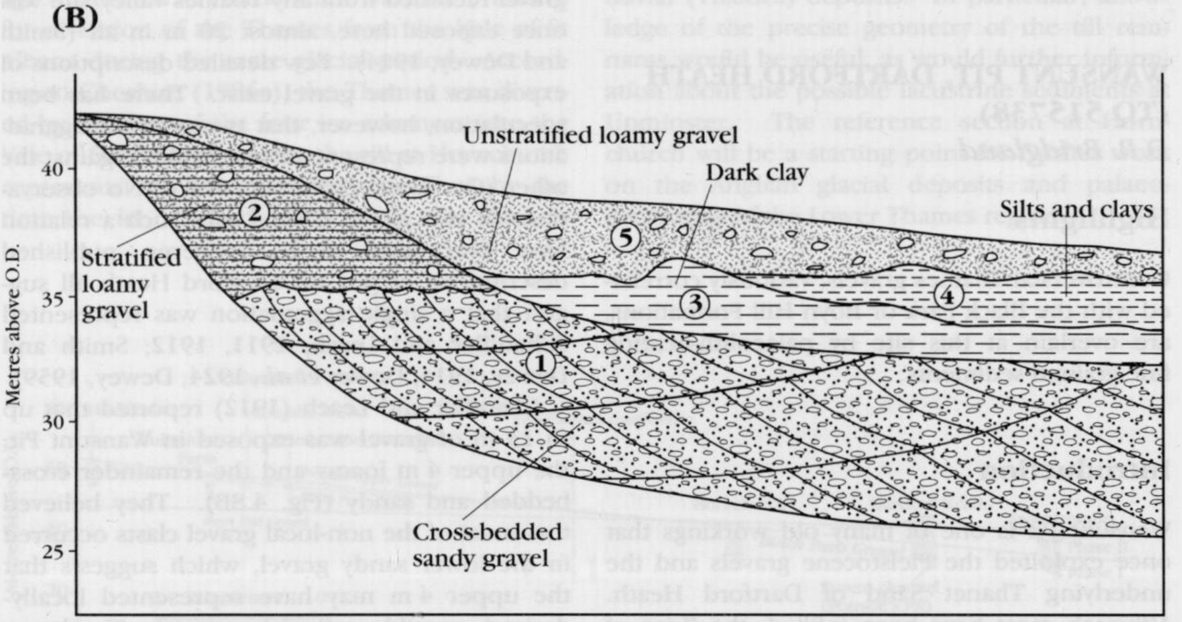


Figure 4.8 Contrasting interpretations of the sediments at Dartford Heath: (A) hypothetical and idealized section, after Cornwall (1950); (B) a composite section based on observations of exposures in Wansunt Pit (after Chandler and Leach, 1912). Bed numbers used in the description section are indicated.

overlying fine-grained deposits ('Wansunt loam') from which Palaeolithic artefacts were obtained (Chandler and Leach, 1911, 1912; Smith and Dewey, 1914). The sequence therefore comprised (see also Fig. 4.8B):

		Thickness
5. Unstratified, loamy gravel	(?colluvium)	uncertain
4. Stratified silts and clays	'Wansunt loam'	0–3 m
3. Dark clay		
2. Loamy gravel, planar-bedded	Dartford Heath Gravel	4 m
1. Sandy gravel, cross-bedded		up to 11 m

Smith and Dewey (1914) recorded a greater thickness for bed 2 (over 6 m) and reported that another 3 m of clayey gravel occurred beneath the floor of the pit, bringing the total thickness of Pleistocene deposits to nearly 20 m.

The stratified silts and clays (bed 4) yielded most of the flakes and implements, as well as fragments of mammal teeth (*Equus caballus* and *Bos* sp.), although the dark clay (3) contained a few flakes. Beds 3 and 4 were interpreted by Chandler and Leach as the fill of a small stream channel ('Wansunt loam' – see below). The uppermost unstratified gravel (5) was interpreted as slope wash from the higher part of the heath to the south (see Fig. 4.8B; Chandler and Leach, 1912).

A number of reviews and catalogues of the archaeology of Wansunt Pit have appeared since the initial discoveries, notably those of Clinch (1908), Smith (1926), Anon. (1931) and Wymer (1968).

Interpretation

Wansunt Pit provides valuable exposures in what many have regarded as the oldest gravel deposited by the Thames in its post-diversion valley. It is the type locality of the Dartford Heath Gravel (Gibbard, 1979), the name given to this high-level deposit in the Lower Thames. Part of the scientific importance of this site arises from the long-standing controversy over the age of the gravel and its relation to other deposits in the Middle and Lower Thames. For this reason, a detailed examination of past references to this and other Dartford Heath localities will be included here, to illustrate the development of the controversy.

Probably the earliest description of the Dartford Heath Gravel was by Trimmer (1853), who noted its continuation on the eastern side of the Darent valley as far as Greenhithe. Trimmer also traced his 'Dartford Gravel' southwards up the Darent valley to Sutton-at-Hone, but later mapping by the Geological Survey has shown the latter to be a more recent deposit (New Series, Sheet 271). Trimmer recorded 15 ft (4.5 m) of gravel exposed in a pit at Wilmington, on the south-eastern side of the heath. He described at length the composition of the gravel in the Dartford area, recording the presence of flints, southern lithologies from the Weald and quartzite pebbles from the Midlands. He noted that the spreads of gravel at Dartford Heath and Dartford Brent (on the opposite side of the Darent) coincide with the former confluence of the rivers Darent and Thames.

Evans (1872) figured a hand-axe found by F.C.J. Spurrell some 8 ft (2.5 m) beneath the surface of the Dartford Heath Gravel. He considered this gravel to be 'that of the upper level of Dartford Heath' (Evans, 1872, p. 532) and attributed it to the Thames rather than the Darent or the Cray. The above quotation from Evans is of interest, since it suggests that he may have observed more than one gravel unit at Dartford Heath, many years before the controversy over the terrace sequence in the Dartford area was initiated. The comment may simply mean, however, that Evans attributed the Dartford Heath deposits to a higher rather than a lower terrace. A second implement was found nearby in 1879 (Spurrell, 1880; Evans, 1897). Spurrell (1880) remarked that the 'Dartford Gravel' extended for many miles on either side of the present River Thames and that it contained Palaeolithic implements. He later illustrated a section at Dartford Heath, showing brickearth channelled into the edge of the gravel (Spurrell, 1886, plate 1). As no details of location or orientation were given, it is impossible to judge whether this might be an early reference to the 'Wansunt loam', although Spurrell (1886, p. 102) attributed it to the 'uppermost layers at Crayford' (for summary of Crayford deposits see below, Lion Pit).

Prestwich (1891) correlated the Dartford Heath aggradation with his 'Upper Valley Gravels' of the Darent, which he traced from the modern Darent–Eden watershed at Limpsfield, where palaeoliths were recovered. No artefacts or fossils were recorded at Dartford by Prestwich in this paper; a reference to this author, without date or source, by Chandler and Leach (1912), attributing rhinoceros, mammoth and *Corbicula fluminalis* to the Dartford Heath Gravel, remains a mystery. According to Newton (1895), however, Spurrell had found bones of mammoth, rhinoceros, ox, horse and deer in pits at Northfleet and Dartford Brent and, at the latter (probable location TQ 555743), had also found the shells of *C. fluminalis, Bithynia tentaculata* (L.), *Valvata piscinalis* and *Pisidium fontinale*. This fauna indicates that temperate-climate sediments are (or were) included within the deposits covering Dartford Heath and Dartford Brent. Spurrell himself recorded finds of mammoth and rhinoceros from the Dartford Heath gravels, in a brief report of a Geologists' Association excursion that visited Wansunt Pit (Spurrell, 1893). In another excursion report, Salter (1903) noted that sections 54 ft (16.5 m) deep were observed.

Spurrell (1886) and Salter (1903) both associated the Dartford Heath deposits with the high-level gravels of Kingston Hill and Wimbledon Common, which later appeared as 'Glacial Gravel' rather than terrace gravel on the New Series Geological Survey map (1921, Sheet 270). Spurrell's and Salter's views thus pre-empted the controversy that followed. This began, however, with the first real dissension from the view that the Dartford Heath and Swanscombe gravels were part of the same 'High Terrace' sheet, by Hinton and Kennard (1905). They believed that the Dartford Heath Gravel represented the earliest Lower Thames terrace (their 1st Terrace), aggraded to 136 ft (41.5 m) O.D., whereas the Swanscombe deposits, which reach only 100 ft (30.5 m) O.D., were assigned to their 2nd Terrace.

Chandler and Leach (1907, 1911, 1912) described more than 12 m of cross-bedded sands and gravels at Wansunt Pit, resting on Thanet Sand at 90 ft (27.5 m) O.D., and took these to be 'fluviatile drifts lying at the same level as the Swanscombe and Galley Hill gravel spreads; contemporaneous and, arguably, continuous with them, but now separated from them by the subsequent erosion of the Darent valley' (1907, p. 122). In this series of papers they consistently refuted the idea that the gravel at Dartford Heath was the result of an earlier, higher-level aggradation. They noted, with the collaboration of E.T. Newton, the admixture in the gravels of the characteristic suite of 'exotic' lithologies, which occurs throughout the Thames Basin, and southern rocks from the Darent catchment. Their observation of *Rhaxella* chert was the earliest record in the Thames valley of this important rock-type, attributed at that time to the Arngrove Stone of Oxfordshire and Buckinghamshire (Newton, 1907). Recent studies have shown that most, if not all, of the *Rhaxella* chert in the Pleistocene of the London Basin was derived from North Yorkshire during the Anglian glaciation (Bridgland, 1980, 1986b). Its presence in Pleistocene deposits in south-east England is therefore important evidence for an age contemporary with, or later than, this glacial event.

The interpretation of the Dartford Heath deposits promoted by Chandler and Leach was supported by Burchell (1933), King and Oakley (1936) and Marston (1937). The fluctuation of opinion concerning these deposits is reflected in the various Geological Survey memoirs describing the area. In the earliest of these volumes, Whitaker (1884, 1889) listed exposures at Dartford Heath and Dartford Brent and grouped the deposits there with gravels extending further eastwards to Swanscombe, considering them all to represent a dissected 'high terrace'. In the first edition of *The Geology of the London District*, Woodward (1909) reproduced Hinton and Kennard's classification of the Thames terraces, distinguishing the gravels of Dartford and Swanscombe as 1st and 2nd Terraces respectively. In the second edition of this memoir (Woodward *et al.*, 1922), the distinction was dropped and both Dartford Heath and Swanscombe were again included in the 'High Terrace'. Following a resurvey of the London district, undertaken before the First World War, the geomorphological feature and associated deposits formerly referred to as the 'High' or '100 ft' terrace were reclassified as 'Boyn Hill Terrace' (Bromehead, 1912; Dewey and Bromehead, 1915; Sherlock and Noble, 1922). On the New Series geological map of Dartford (Sheet 271), the Dartford Heath deposits, in common with patches of gravel east of the Darent from Dartford to Northfleet, duly appeared as Boyn Hill Gravel. In the accompanying memoir, Dewey *et al.* (1924) remarked that a number of exposures between Dartford and Northfleet indicated that the Boyn Hill Gravel occupies and overlies a channel running west to east; the base of the deposits thus rises to the south and to the north, where their lower levels are separated from the modern river by a buried ridge of bedrock. Rapid rises in the bedrock surface towards the edges of a large trough-feature of this kind may explain the variations in bedrock surface level beneath different parts of the Dartford Heath deposits that are apparent from published descriptions over the years.

The controversy initiated by Hinton and Kennard (1905) was rekindled by Zeuner (1945), who returned to a model in which the Dartford Heath Gravel was classified with the high-level deposits of Kingston and Wimbledon. Zeuner believed that all these deposits were related to the recently described Winter Hill Terrace of the Middle Thames (see Chapter 3). He considered that the 'bench' of the Winter Hill Terrace (the base of the terrace deposits) divided near the Thames–Colne confluence and that the higher of the two 'benches' so produced passed through the Finchley Depression, following Wooldridge's (1938) intermediate course to Essex (Chapter 3 and Fig. 3.4), whereas the lower 'bench' followed the modern course of the river. Zeuner named the deposits overlying these two erosional features the 'Finchley Leaf' and 'Kingston Leaf' respectively. The Kingston and Wimbledon gravels had previously been assigned to the Winter Hill Terrace by Saner and Wooldridge (1929). Zeuner (1945) traced his Kingston Leaf 'bench' from Burnham Beeches (67 m O.D.) downstream to Hillingdon (55 m O.D.), Kingston and Richmond Hills (46 m O.D.) and Dartford Heath (27.5–30.5 m O.D.), therefore correlating the Dartford Heath Gravel with the lower division of the Winter Hill Terrace. He believed the Dartford Heath deposits to be older than those at Swanscombe, which overlie his 'Boyn Hill bench' at 75 ft (23 m) O.D., and that the formation of the two 'benches' was separated by the glaciation of the London area (see above, Hornchurch). In reintroducing the idea that the Dartford Heath deposits were distinct from the Boyn Hill Formation, as represented elsewhere in the Lower Thames, Zeuner perpetuated a controversy that has considerable significance for the classification and dating of the Lower Thames succession and its correlation with sequences elsewhere. Later contributions to this debate will be considered below, in the section on correlation.

Other important Dartford Heath sites

Following the early descriptions of Wansunt Pit, most work on the Dartford Heath deposits has taken place at other sites. Newton (1930) described gravels penetrated by curious cones of sandy clay (loam) in Pearson's Pit (TQ 533737), on the eastern side of the Heath. These features may have been similar to the 'pipes' that disrupt the Lynch Hill Gravel at Furze Platt, which are thought to result from Chalk solution (see Chapter 3, Cannoncourt Farm Pit). Pearson's Pit also produced implements from the body of the Dartford Heath Gravel (Marston, 1937; Dewey, 1959; Wymer, 1968). Marston concluded from these discoveries that the gravel represented 'a later stage of the Barnfield later Middle Gravels and Sands' (Marston, 1937, p. 351) and was of later age than the Swanscombe Lower and Lower Middle Gravels. This was in general agreement with King and Oakley (1936), who placed the Dartford Heath Gravel in their 'Middle Barnfield', or 'Late Boyn Hill Stage'. Wymer (1968) suggested that the implements may have come from the overlying 'loam', but Dewey (1959) clearly reported that some of Mr Pearson's personal collection of hand-axes had been derived from the lowest part of the gravel, the base of which was about 33.5 m above O.D.

A third important quarry that exploited the Dartford Heath Gravel was Bowman's Lodge Pit (TQ 518738), a short distance to the east of the Wansunt Pit. Opened after the Second World War, the excavation of this pit was closely monitored by the archaeologist, P.J. Tester, who described Palaeolithic artefacts obtained from the surface of the gravel, beneath an overlying brickearth that he interpreted as a continuation of the 'Wansunt loam' (Tester, 1951, 1975). Cornwall (1950) described Bowman's Lodge Pit, noting that the base of the gravel rose eastwards from 26 m O.D. to 29 m O.D. in only a few hundred metres along the northern side of the pit, the gravel correspondingly thinning from 7.5 to 6 m. This appears to represent the eastern edge of gravel deposition on Dartford Heath.

Excavations in 1952 on the eastern fringe of Dartford Heath yielded Acheulian implements from fluviatile sands and loams overlying Chalk at 26.5 m O.D. (Tester, 1953). Tester concluded that these were typologically similar to the Middle Barnfield industry of Swanscombe; strong evidence, he considered, for the Boyn Hill age of at least the eastern portion of the Dartford Heath Gravel.

The 'Wansunt loam' and its Palaeolithic industry

Chandler and Leach (1911) were the first to observe the clays and silts ('Wansunt loam'), cut into the Dartford Heath Gravel, that yielded Palaeolithic artefacts and mammal teeth (see above, Description). They later described in detail how the gravel was truncated by a steep slope, in the north-eastern corner of Wansunt Pit, against which the silts and clays were banked (Chandler and Leach, 1912; Fig. 4.8B). They interpreted this feature as the edge of a channel cut into the Dartford Heath Gravel, probably formed by a tributary stream and of significantly younger age (Chandler and Leach, 1911, 1912). Leach (1913) described a further, lower channel in Wansunt Pit, filled with hillwash and loam and containing charcoal and occasional palaeoliths. Chandler and Leach (1912) also recorded occasional finds of artefacts in the Dartford Heath Gravel itself, from Wansunt Pit and other sites, mainly in the upper loamy gravel, but including a rolled example from the cross-bedded gravel.

In 1913 Smith and Dewey (1914) conducted excavations for the British Museum at Wansunt Pit. Various cuttings were made in and to the north-east of the pit, in order to test the interpretation by Chandler and Leach of the clayey and silty deposits as the channel-fill of a minor tributary, a hypothesis put forward without the northern side of the inferred channel having been observed. The results of this work revealed that no northern side is preserved and that the clays and silts extend to the front edge of the terrace remnant at Dartford Heath, where they are truncated by the slope to the modern Thames floodplain. It was concluded, therefore, that the fine-grained sediments were emplaced above and against the gravel by the Thames itself, possibly near the end of 100 ft (Boyn Hill) Terrace times (Smith and Dewey, 1914; Dewey *et al.*, 1924; Smith, 1926). These authors recorded many Acheulian implements from the clays and loams and a few from the Dartford Heath Gravel itself. Following Smith's and Dewey's work, the deposits formerly attributed to the 'Wansunt Channel' have been generally referred to as the 'Wansunt loam'.

The artefacts collected from the 'Wansunt loam' were in an excellent state of preservation and included several sets of conjoinable flakes, suggesting the close proximity of a working floor. Indeed, Chandler and Leach (1912, p. 108) reported that 'At least one 'nest' of flakes was found such as would result from flaking on the spot'. Finished tools were also found, dominantly cordate and ovate hand-axes, although side- and end-scrapers were also identified (Wymer, 1968). Occasional flakes have been interpreted as showing evidence of Levallois technique (Chandler and Leach, 1912; Wymer, 1968), although Roe (1968b) listed no Levallois material from the site.

The Bowmans Lodge industry, from a supposed continuation of the 'Wansunt loam', is similar to that from the original site, mainly comprising typical Acheulian material, but with the important addition of a collection of small 'chopper-cores' (Tester, 1951, 1975; Wymer, 1968). The occurrence together of 'chopper-cores' and hand-axes in similar states of preservation, as they are in the Bowmans Lodge collection, is extremely rare in the Thames valley (Wymer, 1968). As at Wansunt Pit, occasional evidence of Levallois technique has been claimed (Tester, 1951, 1975; Wymer, 1968; Roe, 1981, p. 228). The Bowmans Lodge assemblage was used by Roe (1964, 1968a, 1981) in his statistical analysis of the typology of British Lower and Middle Palaeolithic hand-axe assemblages. Roe was impressed by the undisturbed nature of this material, which fell within his Group VI (ovate tradition, more pointed types), as did the assemblage from the Swanscombe Upper Loam, whereas the industry in the Middle Gravels at Swanscombe fell within his Group II (pointed tradition with some ovates). Roe's analyses, based on measurements of breadth and thickness, add support to the suggestion that the 'Wansunt loam' post-dates much of the Swanscombe sequence, although this is based largely on the superposition of Roe's Group VI over Group II at Swanscombe itself. It is clear, however, that the Swanscombe situation, with 'pointed' industries preceding 'ovate' ones, does not hold good for Britain as a whole (Roe, 1981, pp. 302–3). What remains uncertain is whether this model is stratigraphically valid for the immediate Swanscombe-Dartford area.

A hand-annotated 1:10,560 map of the

Wansunt Pit site formerly belonging to A.L. Leach, a copy of which was supplied to the Nature Conservancy Council by J.N. Carreck, clarifies a number of questions about site locations in the vicinity of Wansunt Pit. Wymer (1968) suggested that the 'Wansunt loam' was first discovered in Martin's Pit; the above-mentioned map, however, shows Martin's Pit to have been to the south of Wansunt Pit, quite remote from the edge of the loam. The annotated map suggests that the southern edge of the 'Wansunt loam' passes through the northern part of the present GCR site.

Correlation with the Lower Thames sequence

The continuing controversy over the correlation between the Dartford Heath deposits and the Swanscombe sediments has hampered the integration of these terrace remnants in north Kent with the established Thames sequence.

Cornwall (1950) noted that there was no evidence for a protracted period of subaerial weathering of the Dartford Heath Gravel surface prior to the deposition of the 'Wansunt loam', a fact that suggested to him that the two deposits were not separated by any lengthy interval of time. He claimed, however, that the industry from the surface of the gravel appears, on typological grounds, to be slightly later than the 'Middle Barnfield Stage' at Swanscombe. These conclusions argue against the Hinton and Kennard model of the Dartford Heath Gravel as a separate, pre-Boyn Hill aggradation, especially if Smith and Dewey (1914) were correct in attributing the 'Wansunt loam' to the Thames. It is difficult to envisage the Thames depositing the latter sediments above the Dartford Heath Gravel after rejuvenation had taken the river on to a lower terrace level, yet Cornwall considered the 'Wansunt loam' to be of 'late Boyn Hill' age (therefore post-dating a supposed rejuvenation from the Dartford Heath to the Boyn Hill level). This would appear to favour the interpretation promoted by Chandler and Leach, in which the Dartford Heath deposits are seen as the culmination of the Boyn Hill Gravel aggradation. In an attempt to find a compromise between the two theories, Cornwall suggested that the highest parts of the heath might represent an earlier terrace, against which the Boyn Hill Gravel has been banked (Fig. 4.8A), although he presented no field evidence in support of this idea; a similar suggestion had been made by Zeuner (1945, p. 120), in a footnote. If this was the case, the higher of the two units would be the Dartford Heath Gravel and the lower would be attributable to the Orsett Heath Gravel (Bridgland, 1988a; see Introduction to this chapter).

Dewey (1959) reviewed this continuing controversy, as well as making a number of important observations and describing sites about which little or nothing has been published. He noted that at Pearson's Pit (TQ 530733) the Dartford Heath Gravel overlay a buried channel, some 2.5 m deep and 30 m wide, cut into the Thanet Sand. He attributed this feature to a tributary flowing across the area to join the main valley and correlated it with the Lower Gravel and Lower Loam channel at Barnfield Pit, with which it is altitudinally comparable, concluding that the excavation of the latter pre-dated the deposition of the Dartford Heath Gravel. This interpretation implies that the Dartford Heath Gravel is part of the same terrace aggradation as the upper part of the sequence at Swanscombe, reaffirming the views of Chandler and Leach (1907, 1911, 1912).

The controversy was further intensified by Evans (1971). According to Evans, the first three terraces to be formed in the modern Thames valley had progressively shallower downstream gradients, indicating that base level rose between each, rather than falling (as would be expected in a terrace sequence – see Chapter 1). These three terraces were the Kingston Leaf, Black Park and Boyn Hill aggradations, for which Evans estimated contemporary sea levels of 27 m, 29 m and 32 m respectively. Wooldridge and Linton (1955) had attributed Zeuner's 'Kingston Leaf' at Wimbledon and Kingston to the Black Park Terrace (as defined by Hare, 1947), but Evans did not accept this correlation, regarding the Kingston deposits as the result of a separate, higher-level aggradation, somewhat earlier than the Black Park Terrace. Evans's hypothesis implied that the Kingston Leaf and Black Park gravels, because of their steeper downstream gradients, should fall below the Boyn Hill Terrace surface somewhere in the London area, so that the products of the three aggradations are superimposed in the Lower Thames. Therefore (according to Evans), the deposits at Dartford, which are aggraded to the highest level of any Lower Thames gravels, would represent the latest of these three aggradations, that of the Boyn Hill Terrace. The Black Park Gravel, if represented at all at Dartford, would fall within the lower part of the sedimentary sequence there, beneath the Boyn Hill deposits.

However, P.L. Gibbard (pers. comm.) has refuted Evans's idea of a separate Kingston Leaf; he has pointed out that the Kingston Hill deposits are higher than the main Black Park Gravel because they represent the equivalent terrace of the tributary River Wey. Gibbard (1979) reaffirmed the conclusions of Hinton and Kennard (1905) and Zeuner (1945) by correlating the Dartford Heath Gravel with the Black Park Gravel of the Middle Thames, citing the similarity in gravel composition between Dartford Heath and Richmond in support of this argument. He later reiterated this view and suggested that a downstream continuation of the Dartford Heath Gravel could be recognized in Essex, at Orsett (TQ 655811; Gibbard *et al.*, 1988). However, Bridgland (1980) followed Evans (1971) in concluding that the Black Park Gravel falls below the Boyn Hill aggradation in the London area. He suggested that the Swanscombe Lower Gravel and Loam might represent part of the Black Park aggradation, but that the Swanscombe Lower Middle and Upper Middle Gravels and the Dartford Heath deposits represent the Boyn Hill Gravel. Projection of the Black Park and Boyn Hill Gravels downstream from the Middle Thames, using data presented by Gibbard (1985) in the latter area, indicates that they should intersect between London and Dartford (Fig. 4.7). The Black Park surface would therefore be expected to be lower, not higher, than the Boyn Hill surface in the Dartford area, as Evans predicted. However, the elevation of the upper surface of the Dartford Heath Gravel, 41.5 m O.D., is *c.* 7 m higher than the general level of the Boyn Hill Terrace surface in this area.

Other explanations of the anomalously high level of part of the Dartford Heath spread must be considered, therefore. It is difficult to envisage a mechanism that could result in the localized accumulation of fluviatile deposits so high above the normal floodplain level. The location of the Dartford Heath deposits at the back edge of the terrace, at the apex of a major bend in the floodplain at that time and in the region of the multiple Darent/Cray/Thames confluence (Fig. 4.1), may be of relevance. Dewey *et al.* (1924, p. 90) opened their account of the Boyn Hill (100 ft) Terrace of the Dartford area by noting that: 'the gravel spreads are, in part, of the nature of deltas at the confluence of the tributaries with the main river'. The Orsett remnant, claimed by Gibbard *et al.* (1988) as a downstream correlative of the Dartford Heath Gravel, is only 2–3 m higher than the Boyn Hill/Orsett Heath Gravel at the Orsett Heath type locality, nearby. Its extra elevation may well reflect its position at the back-edge of an Orsett Heath Gravel terrace remnant.

Records of buried channels beneath the terrace sediments of the Dartford area (Dewey *et al.*, 1924; Dewey, 1959) may be of some significance to this discussion. Bridgland (1980, 1983a, 1983b, 1988a) described a major buried channel system underlying the downstream continuation of the Boyn Hill/Orsett Heath Gravel across eastern Essex, which he correlated with the Lower Gravel Channel at Swanscombe and the Clacton Channel (see Chapter 5). The terrace gravels overlying this channel system, the highest post-diversion Thames deposits recognized in eastern Essex by Bridgland, were correlated with the Boyn Hill/Orsett Heath Gravel, no continuation of the Black Park Gravel apparently being represented. This supports the view, first suggested by Evans (1971), that the Black Park Terrace passes beneath the later Boyn Hill aggradation east of London; the former aggradation is probably represented within the channel deposits that underlie the latter in this area (Bridgland, 1980, 1988a; Fig. 1.3). This interpretation gains further support from the low height of the till at Hornchurch (see above, Hornchurch) and the gradient of the earliest River Lea deposit, the Westmill Upper Gravel (Cheshire, 1983c, 1986a; Chapter 3, Part 2; Fig. 4.7), both of which imply that the Lower Thames valley was excavated to below 30 m O.D. by the late Anglian, the recognized age of the Black Park Gravel.

The balance of evidence, therefore, appears to favour the interpretation of the Dartford Heath Gravel as part of the Boyn Hill/Orsett Heath Formation. The most significant points are: (1) the recorded thickness of the gravel at Dartford Heath, which implies a single aggradation up to 20 m thick; (2) the record, by Dewey *et al.* (1924), of a major channel beneath the mapped spreads of gravel east of Dartford Heath, apparently equivalent to that beneath the Boyn Hill/Orsett Heath Gravel of the Swanscombe area; (3) Dewey's (1959) observation of a tributary channel, cut to the base level of the Swanscombe Lower Gravel, beneath the Dartford Heath Gravel at Pearson's Pit (which reinforces 2); (4) the fact that the Black Park Formation, with its steep long-profile, appears likely to fall below the Boyn Hill level upstream of Dartford, therefore precluding correlation with the Dartford Heath Gravel (Fig. 4.7); and (5) evidence from the glacial history of the area to the north-west, which indicates that the Lower Thames valley system was excavated to below the level of the Dartford Heath Gravel by late Anglian times. These points combine to provide a strong case for assigning the entire Dartford Heath sequence to the Boyn Hill/Orsett Heath Formation.

The interpretation of the Dartford Heath Gravel and associated deposits by Gibbard (1979; Gibbard *et al.*, 1988), and that favoured in this report, are clearly incompatible. These different views represent the latest episode in a long-standing controversy regarding the interpretation and wider correlation of the Lower Thames sequence. The resolution of this controversy is a task requiring urgent attention. The last remaining exposures of this deposit, at Wansunt Pit, will be of prime importance for future work on the gravel. The possibility that part of the 'Wansunt loam' remains *in situ* at the site heightens its scientific importance. Future work may determine whether a surviving remnant of the loam is indeed present and provide new information about the origin and age of both the loam and the underlying gravel.

Conclusions

Wansunt Pit provides exposures in the Dartford Heath Gravel, the highest-level terrace deposit in the Lower Thames. Controversy has continued throughout this century over the relation of this deposit to others in the terrace 'staircase' in this part of the valley, particularly the famous Swanscombe skull site. Some workers have regarded the gravel at Wansunt Pit as a remnant of a very early terrace, one that is not preserved downstream. Others have regarded it as merely an unusually high 'feather-edge' remnant of a high-level terrace that is widely recognized elsewhere in the valley, including Swanscombe – the view favoured in this volume. The resolution of this dispute is of considerable urgency, as it has implications for the dating of the Pleistocene terrace sequence in the Lower Thames and for relating it to the original formation of this part of the valley, following the river's diversion by ice around 450,000 years ago. An important aspect of the geological interest at Wansunt Pit is the occurrence there, in a loam deposit overlying the gravel, of a rich assemblage of well-preserved Palaeolithic artefacts.

SWANSCOMBE (BARNFIELD PIT – SKULL SITE NNR AND ALKERDEN LANE ALLOTMENTS SSSI)

D.R. Bridgland

Highlights

A sequence of gravels, sands and loams at Swanscombe has yielded important assemblages of interglacial mammals and molluscs. The sediments also contain a wealth of Palaeolithic artefacts, demonstrating the rare superposition of different industries – Acheulian above Clactonian. The site is famous for the discovery, in association with Acheulian artefacts, of a human skull, intermediate in form between *Homo erectus* and Neanderthal Man. The site has long been regarded as Hoxnian, but this has recently become the subject of controversy, although it is clear that the first post-Anglian interglacial is represented.

Introduction

Barnfield Pit, now the 'Swanscombe skull site' NNR, is probably the most famous Pleistocene locality in Britain and is certainly the best known in the Thames valley. The site became the first geological NNR (National Nature Reserve) when it was donated to the nation by the former owners, the Associated Portland Cement Company Ltd, in 1954. In fact two old pits, the original Barnfield Pit and Colyer's Pit, were amalgamated during the early decades of this century to form the site later known as Barnfield Pit or, sometimes, as Milton Street Pit (Wymer, 1968). The Swanscombe site is of international renown as a result of the discovery there, *in situ* in an old

Thames gravel, of the fragmentary skull of an early human. Remarkably, three pieces of the same skull were found on separate occasions, in 1935, 1936 and 1955, from the same sedimentary unit (Marston, 1937; Wymer, 1955, 1964b). Together they form the back half of the skull of a young adult, possibly a woman (Stringer, 1985).

Quite apart from the discovery of 'Swanscombe Man', Barnfield Pit is an extremely important Pleistocene stratigraphical site. Products of two fluvial aggradations occur in superposition, separated by a soil horizon and overlain by overbank ('floodloam') and slope deposits (Wymer, 1968; Conway and Waechter, 1977; Bridgland *et al.*, 1985). All these sediments contain Palaeolithic artefacts, three distinct assemblages being represented in stratigraphical sequence (Wymer, 1968; Roe, 1981). In fact, the Swanscombe district has produced more palaeoliths than any other in Britain (Wymer, 1968). Many of the sediments are also fossiliferous, with mammals (Sutcliffe, 1964) and molluscs (Kerney, 1971) providing the most significant environmental and biostratigraphical evidence. In recent years there has been general agreement that these indicate a Hoxnian age, but current uncertainty about the correlation between terrestrial stratigraphies and the marine oxygen isotope sequence (Bowen *et al.*, 1989; Chapter 1), together with a controversial pollen record from Swanscombe suggesting a complex succession of climatic fluctuations (Hubbard, 1982; Turner, 1985), have raised new doubts about this interpretation.

Sections in the south-western part of the skull site were opened in 1977 for a visit by INQUA (International Union for Quaternary Research; Conway and Waechter, 1977) and reopened in 1985 for a celebration of the 50th anniversary of the discovery of 'Swanscombe Man' (Duff, 1985). Further research excavations have taken place at Swanscombe under the auspices of the Geological Conservation Review. Firstly, in 1982, the full sequence was uncovered in the north-west corner of the site (Figs 4.9, 4.10, 4.11 and 4.12) for geological appraisal and sampling, including the collection of material for thermoluminescence dating (Bridgland *et al.*, 1985) and, in particular, for the detailed examination of the weathering horizon at the top of the Lower Loam (Kemp, 1985b). Secondly, in 1986, the Lower Gravel and Lower Loam were re-exposed to allow sampling of the former for sieving in search of small vertebrates, and to collect calcite coatings from pebbles in the Lower Gravel in order to obtain a uranium-series date (results of the latter are not yet available). The upper part of the Swanscombe sequence has been quarried away from the area of Barnfield Pit, now the NNR. However, sections in the full sequence, which is preserved *in situ* in the Alkerden Lane Allotments SSSI, are available at the western margin of the old pit (Figs 4.9 and 4.11).

Within the confines of the present volume, a comprehensive review of the literature and research on the Swanscombe site is not possible. In addition to over a hundred specialist reports dealing with various different aspects of the scientific interest, two major symposium volumes exist that are devoted to Swanscombe (Swanscombe Committee, 1938; Ovey, 1964). Swanscombe is also the most frequently cited Thames (Pleistocene) site, there being innumerable passing references to it in the geological, palaeontological and archaeological literature. An archaeological excavation had already taken place at Barnfield Pit prior to the discovery of the Swanscombe skull (Smith and Dewey, 1914), underlining the importance of the site as a Palaeolithic locality, irrespective of its anthropological significance. Several further excavations have been carried out since the discovery, of which two were major undertakings (Wymer, 1964b; Waechter, 1969, 1970, 1971, 1972). Comprehensive, multi-disciplinary reviews of the site and its importance (with extensive bibliographies) were produced by Oakley (1952) and Wymer (1968). The most recent archaeological excavations, which were confined to the lower part of the sequence (Waechter, 1969, 1970, 1971, 1972), have yet to be published in detail. Meanwhile Roe (1981) has provided the most recent detailed review of the archaeological significance of the Swanscombe skull site and associated localities.

Important reviews of the palaeontology have appeared from time to time, the most recent being by Sutcliffe (1964) and Stuart (1982a) on the mammals and by Kerney (1971) on the molluscs. The present report will concentrate on developments over the past two decades and on the significance of Swanscombe in respect to the current interpretation of the Thames sequence and the British Pleistocene as a whole.

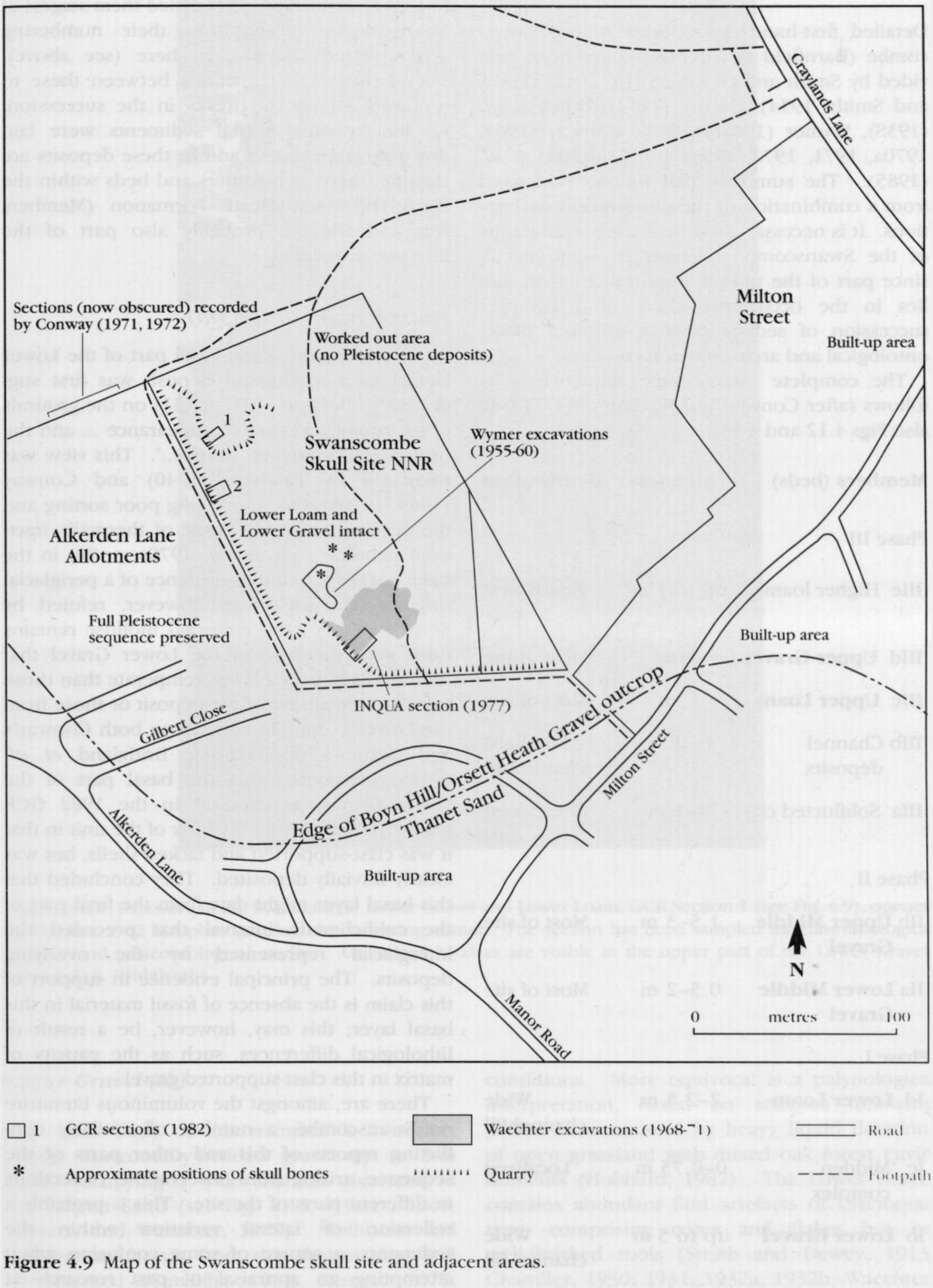


Figure 4.9 Map of the Swanscombe skull site and adjacent areas.

Description

Detailed first-hand descriptions of the Swanscombe (Barnfield Pit) deposits have been provided by Smith and Dewey (1913, 1914; Dewey and Smith, 1914), Dewey (1932), Dines *et al.* (1938), Wymer (1964b, 1968), Conway (1969, 1970a, 1971, 1972, 1985) and Bridgland *et al.* (1985). The summary that follows is derived from a combination of the more recent descriptions. It is necessary to describe the stratigraphy of the Swanscombe deposits in some detail, since part of the unique importance of the site lies in the occurrence there of a complex succession of sediments with different palaeontological and archaeological contents.

The complete Swanscombe sequence is as follows (after Conway and Waechter, 1977) (see also Figs 4.12 and 4.13):

Members (beds)	**Thickness**	**Distribution**
Phase III		
IIIe Higher loams	up to 1 m	South-west only
IIId **Upper Gravel**	2 m	Most of site
IIIc **Upper Loam**	1 m	Most of site
IIIb Channel deposits	0–2 m	Localized channel-fill
IIIa Soliflucted clay	0–1 m	South-west only
Phase II		
IIb **Upper Middle Gravel**	1.5–3 m	Most of site
IIa **Lower Middle Gravel**	0.5–2 m	Most of site
Phase I		
Id **Lower Loam**	2–2.5 m	Wide channel-fill
Ic 'Midden' complex	0–0.75 m	Localized
Ib **Lower Gravel**	up to 5 m	Wide channel-fill
Ia Basal gravel	0–0.5 m	Localized

Conway and Waechter (1977) recognized three phases of deposition (they called them stages) at Swanscombe, reflected in their numbering system, which is adopted here (see above). They believed the junctions between these to represent significant breaks in the succession. All the principal fluvial sediments were laid down during Phases I and II; these deposits are classified here as members and beds within the Boyn Hill/Orsett Heath Formation (Members IIIb and IIIc are probably also part of the fluviatile sequence).

Phase I: Basal Gravel (Ia)

An interpretation of the basal part of the Lower Gravel as a solifluction deposit was first suggested by Marston (1937, p. 31) on the grounds of its 'rough and tumble appearance ... and the presence of scratched flakes ...'. This view was reiterated by Paterson (1940) and Conway (1969, 1970a), the latter citing poor sorting and the occurrence of '... 'nests' of thermally fractured pebbles ...' (Conway, 1970a, p. 90) in the basal part of the unit as evidence of a periglacial origin. The idea was, however, refuted by Kerney (1971), who recorded mollusc remains from near the base of the Lower Gravel that indicated a climate no less temperate than those from the remainder of the deposit or those from the Lower Loam. In contrast to both Conway's and Kerney's observations, Bridgland *et al.* (1985) considered that the basal part of the Lower Gravel, as exposed in the 1982 GCR section, differed from the bulk of the unit in that it was clast-supported and lacked shells, but was clearly fluvially deposited. They concluded that this basal layer might date from the final part of the cold-climatic interval that preceded the interglacial represented by the overlying deposits. The principal evidence in support of this claim is the absence of fossil material in this basal layer; this may, however, be a result of lithological differences, such as the paucity of matrix in this clast-supported gravel.

There are, amongst the voluminous literature on Swanscombe, a number of similarly conflicting reports of this and other parts of the sequence, arising from observations of sections in different parts of the site. This is probably a reflection of lateral variation within the sediments, a source of some confusion when attempting an appraisal of past research at Swanscombe.

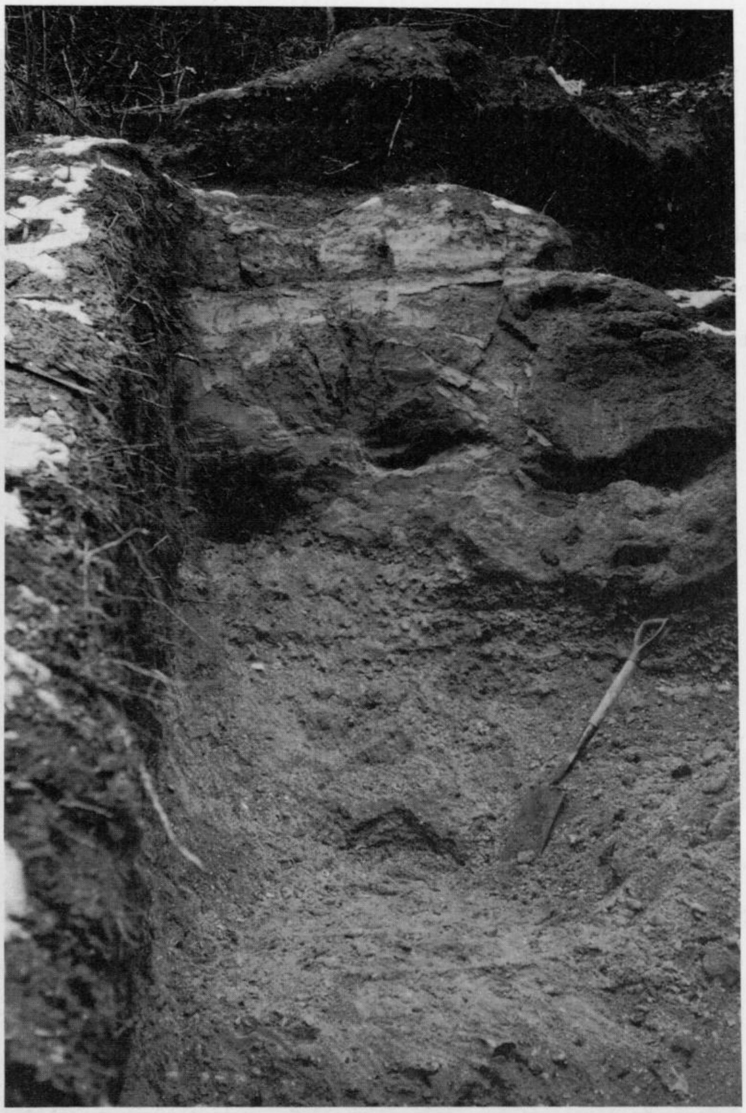


Figure 4.10 Exposure in the Swanscombe Lower Gravel and Lower Loam, GCR Section 1 (see Fig. 4.9), opened in October 1982 but photographed the following winter. The section has been sampled for clast-lithological analysis and palaeontological studies. Articulated bivalves are visible in the upper part of the Lower Gravel. (Photo: D.R. Bridgland.)

Lower Gravel (Ib)

The main body of this member is a coarse, sandy, horizontally-bedded gravel up to 5 m thick, occupying a wide channel excavated in the Thanet Sand (see Fig. 4.13; Wymer, 1968; Conway and Waechter, 1977). Molluscan and mammalian faunas from this deposit are well documented (Sutcliffe, 1964; Kerney, 1971; Stuart, 1982a) and point to fully temperate conditions. More equivocal is a palynological interpretation, based on analyses following pollen concentration by heavy liquid flotation, of open grassland with mixed oak forest environments (Hubbard, 1982). The Lower Gravel contains abundant flint artefacts of Clactonian type, comprising cores and flakes but no well-finished tools (Smith and Dewey, 1913; Chandler, 1930, 1931, 1932a, 1932b; Waechter, 1969, 1970, 1971, 1972).

Figure 4.11 Exposure in the Swanscombe Lower Loam, Lower Middle Gravel, Upper Middle Gravel and Upper Loam, GCR Section 2 (see Fig. 4.9), October 1982. The Lower Loam, exposed in a pit (see Fig. 4.15) at the base of the main section, has been sampled for studies of micromorphology. The shovel is standing on the top of the Lower Middle Gravel (see also Fig. 4.12). (Photo: P. Harding.)

'Midden' complex (Ic)

This localized bed is channelled into the upper part of the Lower Gravel to a depth of 0.75 m. It comprises thin alternations of silt, sand and fine gravel and contains important concentrations of mammalian remains and Clactonian artefacts in very fresh condition, possibly indicating a primary context (Conway, 1970a, 1971, 1972; Waechter, 1970, 1971, 1972; Conway and Waechter, 1977). It was originally described as part of the Lower Loam (Conway, 1970a; Waechter, 1970), but Conway (1971, p. 60) later recognized a 'distinct stratigraphic break' between the 'midden' deposits and the Lower Loam. The 'Midden' complex has been associated with the Lower Gravel in subsequent publications. The level of concentration of

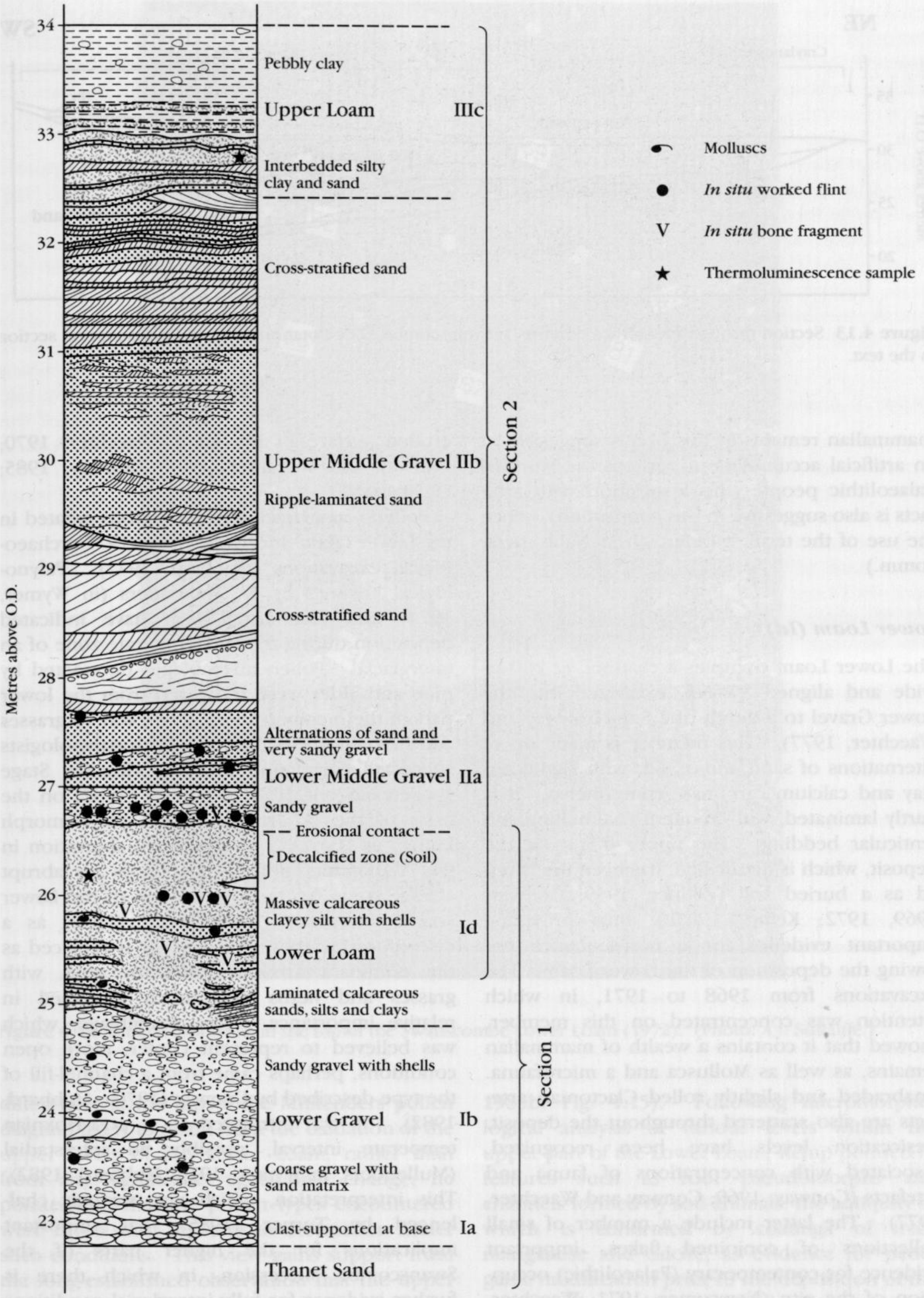


Figure 4.12 The sequence at Swanscombe, based on the exposures excavated by the GCR Unit in 1982 (after Bridgland *et al.*, 1985).

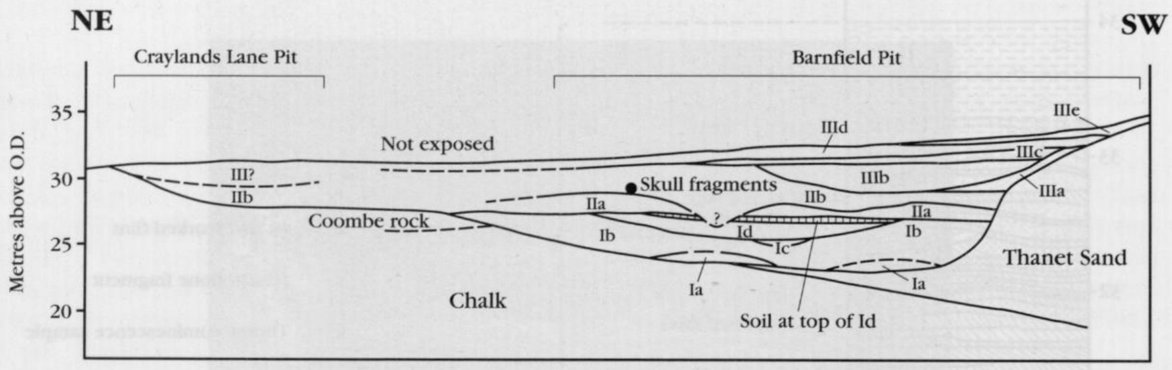


Figure 4.13 Section through the terrace deposits at Swanscombe. The notation follows the description section in the text.

mammalian remains in this bed is suggestive of an artificial accumulation, perhaps the work of Palaeolithic people (the association with artefacts is also suggestive in this connection), hence the use of the term 'midden' (J. McNabb, pers. comm.)

Lower Loam (Id)

The Lower Loam occupies a channel, *c.* 200 m wide and aligned SW–NE, excavated into the Lower Gravel to a depth of 2.5 m (Conway and Waechter, 1977). This member is made up of alternations of sand and/or silt, with significant clay and calcium carbonate components. It is partly laminated, with frequent channelling and lenticular bedding. The upper 0.5 m of the deposit, which is decalcified, has been interpreted as a buried soil (Zeuner, 1959; Conway, 1969, 1972; Kemp, 1985b), thus providing important evidence for a non-sequence following the deposition of the Lower Loam. The excavations from 1968 to 1971, in which attention was concentrated on this member, showed that it contains a wealth of mammalian remains, as well as Mollusca and a microfauna. Unabraded and slightly rolled Clactonian artefacts are also scattered throughout the deposit. Desiccation levels have been recognized, associated with concentrations of fauna and artefacts (Conway, 1969; Conway and Waechter, 1977). The latter include a number of small collections of conjoined flakes, important evidence for contemporary (Palaeolithic) occupation of the site (Newcomer, 1971; Waechter, 1971). Animal footprints (fallow deer and ox) have been exhumed at these levels and on the eroded surface of the loam (Waechter, 1970; Conway and Waechter, 1977; Conway, 1985; Fig. 4.14).

Pollen was extracted from sections created in the Lower Loam during the 1968–1971 archaeological excavations (Hubbard, 1972). Palynological analyses by W. Mullenders (in Wymer, 1974) and Hubbard (1982) have indicated deposition during the late-temperate zone of an interglacial. Pollen assemblages dominated by pine and alder were recovered from the lower part of the member, these giving way to grasses and herbs towards the top. Both palynologists suggested correlation with the Hoxnian Stage (pollen biozone HoII), Hubbard (1982) on the basis of the occurrence of the palynomorph known as 'Type X'. A significant aberration in the Mullenders pollen diagram is an abrupt change some 0.6 m from the top of the Lower Loam, interpreted by Hubbard (1982) as a disconformity, above which alder is replaced as the dominant arboreal taxon by pine, with grasses and herbs also much increased in relative importance. This assemblage, which was believed to represent cooler, more open conditions, perhaps came from a channel-fill of the type described by Conway (1970a; Hubbard, 1982). It was attributed to a post-Hoxnian temperate interval, possibly an interstadial (Mullenders, in Wymer, 1974; Hubbard, 1982). This interpretation, which was strongly challenged by Turner (1985), has important implications for the higher parts of the Swanscombe succession, in which there is further evidence for fully interglacial conditions (see below).

Turner (1985) considered the palynological

Figure 4.14 Animal footprints in the top of the Swanscombe Lower Loam (1972). (Photo: A.J. Sutcliffe.)

differences at the top of the Mullenders pollen diagram likely to result from the oxidation of the upper levels of the Lower Loam, rather than from any significant vegetational change; he pointed out that the pollen types encountered were those most resistant to destruction under such conditions. This view gains support from the long-established observation that the upper metre or so of the loam is weathered and decalcified, and from the recent confirmation that a buried soil is present at this level (Kemp, 1985b; Fig. 4.15). Following micromorphological analysis of various levels within the upper part of the Lower Loam, Kemp pointed to features such as root pseudomorphs and channels formed by soil animals, the antiquity of which is confirmed by coatings of iron, manganese and calcite, as evidence for pedogenic modification prior to the deposition of the overlying Lower Middle Gravel. The survival of these features indicated to Kemp that they were formed after the decalcification of the upper levels of the loam, since this produced a thorough reorganization of the microscopic structure of the material, with redeposition of calcium carbonate in lower parts of the profile. He was therefore able to argue strongly that the decalcification occurred as a result of pedogenesis while the loam was at the land surface, not as a result of leaching by groundwater percolating through the later sediments, as was suggested by Kerney (1971). Kemp thought it possible that this soil formed during part of a single temperate episode, presumably that represented by the interglacial fauna from the Phase I and II deposits at Swanscombe.

Phase II: Lower Middle Gravel (IIa)

The second phase of fluvial deposition at Swanscombe commenced with the aggradation of the Lower Middle Gravel, which took place over a wider area than is covered by any of the earlier sediments (see Fig. 4.13). A 'lag' deposit at the base of this member comprises coarse flints with occasional bone fragments (Conway and Waechter, 1977; Bridgland *et al.*, 1985). This member, which consists of loose sandy gravel interbedded with minor layers of sand, represents the only true gravel amongst the Phase II deposits. It varies from 0.5 to 2 m in thickness, largely as a result of erosion prior to deposition of the Upper Middle Gravel. According to some descriptions, the Lower Middle Gravel is in some areas completely cut out as a result of this erosion (Marston, 1937; Wymer, 1968), but recent reinterpretation has favoured collapse in response to the solution of the underlying Chalk as the reason for its absence from parts of the site (Conway, 1972). The Lower Middle Gravel is the oldest of the Swanscombe deposits to contain (Acheulian) hand-axes, which are extremely abundant, the member probably having yielded several thousand (Wymer, 1968). These finished tools are vastly outnumbered by flakes; section cleaning and sampling in 1982 yielded 25 flakes from the Lower Middle Gravel (from a section 3 m wide, in which the member was just over 1 m thick), although no hand-axes were found (Bridgland *et al.*, 1985). Sandy horizons within the Lower Middle Gravel have yielded molluscan remains, a number of species appearing at Swanscombe for the first time at this level, including taxa once believed to be indicative of a connection with the Rhine system (Kennard, 1938; below). The land snails present in the Lower Middle Gravel indicate that woodland was more firmly established during its deposition than at any other time during the aggradation of the Swanscombe sequence (Kerney, 1971).

Mammalian remains are common, but poorly preserved. Many come from the basal 'lag' horizon. Poor recording and labelling makes it difficult to separate material collected from the two members representing Phase II of the Swanscombe sequence (Sutcliffe, 1964). Hence Wymer (1974) was prepared to list only *Palaeoloxodon antiquus* and *Bos primigenius* from the Lower Middle Gravel (both of which also occur in the overlying Upper Middle Gravel). It seems likely that the bulk of the collections from the undifferentiated Middle Gravel came from the Upper Middle Gravel, especially as they suggest a change to more open conditions (Sutcliffe, 1964), which is consistent with other environmental evidence from the Upper Middle Gravel.

Upper Middle Gravel (IIb)

The term Upper Middle Gravel has been applied to a series of cross-bedded and ripple-laminated beds, predominantly of sand, but with subordinate silt and gravel horizons. It was from one such bed that three pieces of human skull were found (Marston, 1937; Wymer, 1955, 1964b; Stringer, 1985). In the only extensive excavation of the Phase II deposits, Wymer (1964b) found that certain beds within the Upper Middle Gravel contained concentrations of mammalian remains and Palaeolithic material. In this same excavation, silt horizons in this part of the sequence were found to contain specks of organic matter that may represent burnt vegetable material, possibly resulting from man-made fires (Oakley, 1964; Wymer, 1968). Mollusca are rare in this member, the assemblage generally resembling that from the Lower Middle Gravel. Mammalian remains are abundant, the commonest being horse and giant ox, but with important records of wolf, lion, the Clacton fallow deer, giant deer and a number of rodents (Sutcliffe, 1964). The latter include Norway lemming, which, coupled with a terrestrial molluscan fauna indicative of damp, open conditions, implies a climatic cooling (Kerney, 1971).

In the 1982 sections it was observed that the

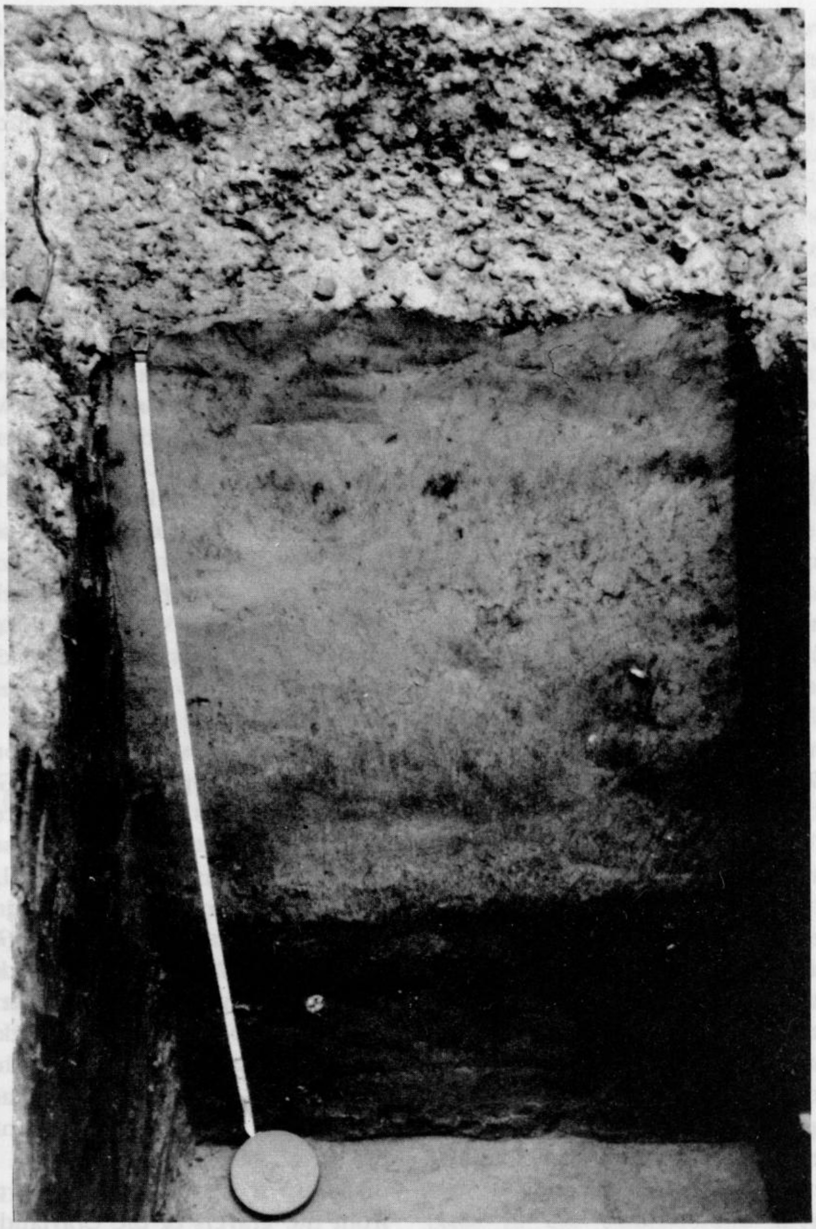


Figure 4.15 Photograph of buried soil in the upper part of the Swanscombe Lower Loam. (Photo: D.R. Bridgland.)

cross-stratified sands comprising the highest part of the Upper Middle Gravel were interbedded with brown silty clay laminae. The latter became progressively thicker until they predominated, the sands finally dying out at *c.* 33 m O.D. This was interpreted as a transition between Upper Middle Gravel and Upper Loam facies (Bridgland *et al.*, 1985). A similar description of this part of the sequence was given by Dines *et al.* (1938). This observation is in conflict, however, with several other previous records, which suggest that an unconformity separates these two members, citing evidence for erosion, for the periglacial disturbance of the surface of the Upper Middle Gravel and for the emplacement of a lobe of colluvial gravel at this level (Marston, 1937; Paterson, 1940; Wymer, 1968; Conway and Waechter, 1977; Hubbard, 1982).

Deposits above the Upper Middle Gravel have therefore been assigned to a separate phase, Phase III of the Swanscombe succession (Conway and Waechter, 1977). There is, however, some support for interpretation of the Upper Middle Gravel/Upper Loam boundary as gradational, in the description by Conway (1971) of his Section G, cut in the northern edge of the Alkerden Lane Allotments. Given the location of the 1982 sections (Fig. 4.9), it seems that there may be no significant (visible) break in the sequence at this level in the northern part of the site.

Phase III: Solifluected clay (IIIa)

A wedge of soliflucted material (clayey diamicton) was recognized between the Upper Middle Gravel and the Upper Loam near the back edge of the Swanscombe terrace remnant by Dines *et al.* (1938). This has recently been interpreted as the first of a series of cold-climate deposits marking the beginning of Phase III of the Swanscombe succession (Conway and Waechter, 1977). As stated above, other observations suggest little evidence for a major break at this level. The significance of such wedges of colluvial material adjacent to a former valley side, in terms of the length of time or severity of climate represented, is uncertain. A sequence of sands and silts at West Thurrock, thought to represent an estuarine accumulation, is punctuated by several wedges of unbedded chalky material that are not considered to represent major breaks in the succession (see below, Lion Pit); the interpretation of the West Thurrock sediments as estuarine implies a high sea level and, therefore, a temperate climate.

Channel deposits (IIIb)

More convincing evidence for cold-climatic conditions is provided by a channel *c.* 2 m deep, cut into the Upper Middle Gravel and infilled with horizontally-bedded, fine loamy sands with thin seams of silty clay. The occurrence in these sediments of ice-wedge casts, cryoturbation structures and microfaulting, together with an absence of pollen, has led to their attribution to a period of severely cold climate (Conway and Waechter, 1977; Hubbard, 1982; Conway, 1985). No fauna or archaeological material has been found in these sediments, which occur only beneath the north-western part of the Alkerden Lane Allotments site (Conway, 1972). However, they are of importance in providing evidence for a cold interval separating the deposition of the Upper Middle Gravel and the Upper Loam.

Upper Loam (IIIc)

According to Conway and Waechter (1977), the channel-fill sands (IIIb) pass upwards conformably into the Upper Loam. As noted above, in other parts of the site there appears to be little evidence for a major break between the Upper Middle Gravel and the Upper Loam. The latter is a poorly bedded to massive silty clay, brown or red-brown, with scattered flints. It has usually been interpreted as an overbank (floodplain) deposit, an interpretation supported by occasional reports of current bedding (Chandler, 1930). Dines *et al.* (1938) believed that the deposit may have been decalcified. They considered it to mark the final phase of Boyn Hill Terrace aggradation.

A further possible indication of a hiatus between the Upper Middle Gravel and the Upper Loam is the occurrence of patinated artefacts from the extreme base of the latter (Dewey, 1919, 1930; Burchell, 1931), comprising an assemblage quite distinct from that in the Middle Gravels (Wymer, 1968; Conway and Waechter, 1977). A further industry has been recovered from the upper part of the Upper Loam, made up of unabraded flint-knapping debris and white patinated hand-axes of twisted ovate type (Conway and Waechter, 1977). Ovates are unknown from Barnfield Pit below the level of the Upper Loam, although they make up a significant part of the assemblage from the gravels of the Craylands Lane Pit (TQ 604746; Dewey and Smith, 1914; Smith and Dewey, 1914; Dewey, 1932; Wymer, 1968). Wymer (1968) considered the implements from that site to be derived from the same stratigraphical horizon as the base of the Upper Loam in Barnfield Pit.

The Upper Loam has yielded no faunal remains, but sparse pollen spectra obtained by sieving large samples of the deposit have been considered indicative of temperate woodland conditions, resembling the middle part of an interglacial (Conway and Waechter, 1977; Hubbard, 1982). Hubbard (1982) tentatively correlated the deposit with the Ipswichian Stage on the basis of palynology. However, the validity of the palynological record from Swanscombe has been severely questioned (Turner, 1985; below).

Upper Gravel (IIId)

This member is a poorly sorted mixture of clay, sand and coarse, angular gravel, up to 2 m thick, with little sign of bedding. It has been universally interpreted as a solifluction deposit, an interpretation supported by evidence that periglaciation affected the surface of the Upper Loam before the gravel was deposited (principally from ice-wedge casts originating from the junction between the two members). The Upper Gravel has yielded several patinated twisted-ovate hand-axes, thought to have been reworked from the Upper Loam (Wymer, 1968; Conway and Waechter, 1977). The only faunal remains from the unit are *Ovibos* (musk ox) from near the base (Conway and Waechter, 1977), a further indication of intensely cold conditions.

Higher loams (IIIe)

Minor accumulations of loamy sand are recorded from above the Upper Gravel in the south-western part of the site (Conway and Waechter, 1977). These deposits have probably been washed or soliflucted over the bluff at the edge of the former floodplain. They extend the sequence up to nearly 35 m O.D., but appear to be of little significance to the fluvial record at the site.

Interpretation

The unique importance of the Swanscombe (Barnfield Pit) site is readily apparent. It has yielded the oldest fossil hominid remains in Britain and the only unequivocal Lower Palaeolithic human bones in England (there is a second British site with Lower Palaeolithic human fossils, of more recent age than the Swanscombe skull, at Pontnewydd, in North Wales (Green *et al.*, 1984)). The site is also unique in that three separate Palaeolithic industries occur there in stratigraphical superposition. The fact that all these discoveries are associated with a complex succession of gravels, sands and silts that contain abundant faunal remains and form part of the terrace record of Britain's major river, the Thames, is extremely fortuitous. This allows the anthropological and archaeological information from Swanscombe to be assimilated into the context of Pleistocene chronology and palaeogeography. Unfortunately, the Pleistocene evolution of the Thames system and its relation to the sequence of Middle Pleistocene climatic fluctuations are the subjects of controversy. The information from Swanscombe plays an important part in the investigation of these problems.

The Swanscombe skull

The interpretation of the fragmentary human skull from Swanscombe has involved a good deal of controversy, the absence of frontal bones preventing clear comparison with other, more complete finds from elsewhere. Thus the Swanscombe skull has been attributed by different authors to an early form of modern man (*Homo sapiens*) (Morant, 1938; Keith, 1939; Vallois, 1954, 1958; Montagu, 1960; Leakey, 1972), to Neanderthal Man (*Homo neanderthalensis*), again an early form (Weidenreich, 1940, 1943; Breitinger, 1952, 1955, 1964; Howell, 1960), to a late form of *Homo erectus* (Wolpoff, 1971) or to a Neanderthaloid 'early *sapiens*' form (Clark, 1955). Even the often quoted female sex of the individual is open to question; although most authors have adhered to this interpretation, Keith (1939) considered the individual to have been a male and Weiner and Campbell (1964) cited statistical analyses of detailed measurements of this and other human skulls in support of this latter view. There have even been attempts to erect new species on the basis of the Swanscombe specimen, namely *Homo marstoni* (Paterson, 1940) and *Homo swanscombensis* (Kennard, 1942).

Most authorities have considered the nearest match to the Swanscombe specimen to be a more complete skull from Steinheim, near Stuttgart, Germany (Berckhemer, 1933), recovered from gravels believed to date from the Holsteinian Stage (widely regarded as equivalent to the Hoxnian Interglacial – see Chapter 1). This specimen retains its frontal parts, which display prominent brow-ridges, a characteristic archaic feature. The consensus view at present holds that the Swanscombe and Steinheim skulls both belong in the early part of the Neanderthal lineage, ancestral to classic Neanderthal Man, who flourished during the last glaciation, but not necessarily an ancestor of modern man (Howell, 1960; Stringer, 1974, 1978, 1983, 1985, 1986; Stringer *et al.*, 1984; for summaries see Day, 1977; Cook *et al.*, 1982).

The Palaeolithic record at Swanscombe

Swanscombe is one of very few British localities to yield distinct Palaeolithic industries from different stratigraphical levels (in superposition). At Barnfield Pit the association of the Phase I sediments with Clactonian material and of Phases II and III with Acheulian artefacts was established at an early date (Smith and Dewey, 1913; Chandler, 1930, 1931; Marston, 1937; Wymer, 1968; Roe, 1981). There is also a typological distinction between the hand-axe assemblages from the Phase II and Phase III deposits, ovate forms being confined to the latter (see above; Roe, 1968a, 1981; Wymer, 1968). In the Lower Thames a stratified sequence of different artefact types has also been claimed by Wymer (1985b) at Bluelands Quarry, Purfleet (see below, Purfleet). Whether the stratigraphical relations between the particular Palaeolithic industries demonstrated at Swanscombe are of more than local significance is, at present, uncertain. Further information is required about British Palaeolithic development before this question can be answered.

Swanscombe is also of major importance as one of only three British Clactonian sites with material preserved in primary context, the others being Barnham, Suffolk, and Clacton (Wymer, 1985b). During 1970, excavations in the Swanscombe Lower Loam uncovered a thin horizon within the deposit, thought to represent a former subaerial surface, in which lay scatters of conjoinable flint flakes (Newcomer, 1971; Waechter, 1971). These have been interpreted as the debris of knapping activity that took place on site during breaks in the deposition of the Lower Loam. This interpretation is strongly supported by the discovery of small secondary broken pieces, formed as accidents of flaking, that can be fitted back on to the larger flakes (Newcomer, 1971). Newcomer was able to partly reconstruct the shapes of the cores from which some of these flakes were struck, even though the cores themselves were not present amongst the debris. These collections comprise the best-preserved archaeological material to have been discovered to date from any part of the Swanscombe sequence. All the other levels, many of which produce artefacts in much greater abundance, contain only allochthonous material washed together by the river and included in its deposits. This is true of the skull level in the Upper Middle Gravel, the skull itself representing part of the fluvial sediment-load. The discovery of these occupation horizons in the Lower Loam is ironic, since most earlier workers had considered this member to be practically sterile, with only Marston (1937) claiming to have found material in it, which he attributed to a Clactonian industry. Wymer (1968) concurred with Marston's interpretation, on the basis of a number of mint or near mint chopper-cores and flakes in the British Museum (Kennard Collection). However, Waechter (in Ohel, 1979) was not prepared to accept the material collected in 1970 from the Lower Loam as unequivocally Clactonian. He considered the size of the assemblage to be too small to allow 'firm "cultural" designation' (Waechter in Roe, 1981, p. 72). Newcomer (in Ohel, 1979) shared these doubts. Despite this caution, there are two lines of evidence suggesting that the material from the Lower Loam represents a continuation of the Clactonian industry from the underlying Lower Gravel: firstly, no hand-axes or hand-axe finishing flakes have been recovered from the Lower Loam; secondly, geological and palaeontological evidence indicates that the Lower Gravel and Lower Loam represent a separate phase of aggradation (Phase I), earlier than the hand-axe-bearing Phase II and III deposits at Swanscombe. In addition, recent reappraisal of the 1970 collections from the Lower Loam (J. McNabb, pers. comm.) indicates that the material can be considered technologically identical to the industry from the Lower Gravel.

The Acheulian assemblage from the Lower and Upper Middle gravels (IIa and IIb) is dominated by pointed hand-axes (Wymer, 1964b, 1968; Roe, 1968a, 1981), which, according to Roe (1981), account for almost 80% of the total. Roe (1968b) reported that at least 625 hand-axes were known to have come from these deposits. Although both these Phase II members contain artefacts, most authors have considered the two together and much of the material in the various collections is simply marked 'Middle Gravel' (Roe, 1968a; Wymer, 1968). There is little or no apparent difference between the material that can be precisely attributed to each of the two individual members (Roe, 1968a; Wymer, 1968).

This assemblage of predominantly pointed implements contrasts with the collections from the Upper Loam and Upper Gravel, which contain much higher proportions of cordate or ovate forms and are dominated by well-made flat ovates (Wymer, 1964b, 1968; Roe, 1968a, 1981; Waechter, 1973). Some of the latter material came from the base of the Upper Loam, lying on the surface of the Upper Middle Gravel. Here, and at various horizons within the Upper Loam, working floors were reported by Marston (1937, 1942), but there are no well-documented records of excavations demonstrating these. Some of the surviving material from these Phase III deposits, despite a white patina, is in extremely fresh condition (Wymer, 1968), which lends some support to Marston's claims. However, many such finds were recovered from the Upper Gravel, having presumably been reworked from the subjacent loam.

The possible stratigraphical significance of the superposition of these three separate industries at Swanscombe is considered below.

Palaeontological evidence from Swanscombe

The mammalian fauna from Swanscombe (from the Phase I and II deposits) forms an important part of the British Middle Pleistocene record (Sutcliffe, 1964; Stuart, 1982a). In addition to the more common species, which generally assist environmental interpretation and correlation with other sites, there are a number of records of very rare taxa. In particular, the cave bear *Ursus spelaeus* (Rosenmüller and Heintoth), discovered in the Lower Gravel (Kurtén, 1959; Sutcliffe, 1964), is possibly the earliest from western Europe. Sutcliffe (1964, p. 91) suggested that this species was present in Britain only during the early Hoxnian, all later British bears being assigned to the brown bear species (*Ursus arctos* (L.)). He listed the following features of the Swanscombe faunas that he considered to be significantly similar to other Hoxnian assemblages (such as that from Clacton – see Chapter 5) and significantly different to fossiliferous deposits from later temperate phases:

1. The rhinoceroses *Dicerorhinus kirchbergensis* (Jäger) and *D. hemitoechus* are both present (the former in units Ib-d and IIa and IIb, the latter in Ib).
2. The fallow deer is of a large race, *Dama dama clactoniana* (Falconer) (units Ib-Id, IIa and IIb).
3. Horse is present (units Ib-Id, IIa and IIb – becoming increasingly abundant in higher units).
4. Hippopotamus is absent.
5. Hyaena is absent.

Lister (1986) has recently discussed the characteristics and significance of fossil deer from Swanscombe. He emphasized that the occurrence of fallow deer in each of the main fluviatile levels (see 2, above) implies that these all reflect deposition under temperate conditions. The attribution of fallow deer remains from Swanscombe to *Dama dama clactoniana*, a large form restricted in its occurrence to post-Cromerian/pre-Ipswichian (*sensu* Trafalgar Square) sediments, could be unequivocally demonstrated only for specimens from the Phase I deposits, since only those had yielded antlers sufficiently well-preserved for determination. Lister also observed that antler fragments of *Megaloceros giganteus* (Blumenbach) from Swanscombe (admittedly only three in number) share morphological characteristics with specimens from Steinheim, the German site that has also yielded hominid remains closely comparable with those from Swanscombe (see above). The antlers from these sites have widths at the extreme upper limit of the variation seen in Devensian examples from Ireland, suggesting that this may be a feature of early *M. giganteus* populations (the occurrence of this species extends from the Anglian to the Late Devensian).

Relatively little has been published on small mammals from Swanscombe, although the occurrence of lemming in the Upper Middle Gravel (IIb) has been cited frequently as evidence for climatic cooling (Kerney, 1971; Sutcliffe and Kowalski, 1976; see above). Rodent remains have been recorded from the Phase I deposits at Barnfield Pit (Carreck in Kerney, 1959a; Sutcliffe and Kowalski, 1976) and from a silt bed within the Upper Middle Gravel (IIb), slightly higher than the level from which the skull fragments were obtained (Schreuder, 1950). Sutcliffe and Kowalski (1976) noted similarities between the rodent assemblage from Swanscombe and that from the Cromerian stratotype (the Upper Freshwater Bed of West Runton), particularly the occurrence in both of *Microtus arvalinus, M. ratticepoides* Hinton and *Pitymys arvaloides* (Hinton). Conversely, the vole *Mimomys savini*, which occurs at West Runton, is replaced by *Arvicola cantiana* at Swanscombe; at one time this was considered to provide strong support for a Hoxnian age for the Swanscombe deposits (Sutcliffe, 1964), but the recent recognition that a number of 'late Cromerian' faunas contain *A. cantiana* (Bishop, 1982; Stuart, 1982a, 1988; Currant in Roberts, 1986; Chapter 1) appears to negate this evidence.

The molluscan fauna from Swanscombe has provided the strongest evidence for correlating the sequence with the established Pleistocene chronostratigraphy (Castell, 1964; Kerney, 1971). The malacological collections from the various pits are amongst the richest from the British Middle Pleistocene, with several species unique to Swanscombe. Of particular importance is the so-called 'Rhenish suite', recognized by Kennard (1938), which first appears in the Phase II deposits. This comprises an assemblage of predominantly southern species, including *Corbicula fluminalis, Viviparus diluvianus* (Kunth) and *Theodoxus serratiliniformis* (Geyer), several of which have been claimed to be characteristic of Rhine deposits. According to Castell (1964), *T. serratiliniformis* is characteristic of the 'Great Interglacial' (Hoxnian Stage), when it was restricted to the Rhine-Thames basin. The record of this species from Swanscombe (Fig. 4.16) is the only one from Britain. The only other British occurrence of *Viviparus diluvianus* (Fig. 4.16) is in the Clacton Estuarine Beds. Kennard (1938) interpreted the appearance of these 'Rhenish' Mollusca as evidence that the Thames and Rhine systems became linked after deposition of the Lower Loam (Id).

By comparing the molluscan faunas from Swanscombe and Clacton, Kerney (1971) was able to suggest correlations between the various fossiliferous parts of the Swanscombe sequence and the Hoxnian pollen biozones established at Hoxne (West, 1956) and recognized at Clacton (Turner and Kerney, 1971). He attributed the Phase I deposits at Swanscombe to biozone HoII and the basal Phase II deposits to subzone HoIIIb, considering the transition between biozones II and III to be missing from the sedimentary record at Swanscombe, lost in the hiatus (marked by the period of soil formation) at the top of the Lower Loam.

Thus the sediments at Swanscombe were correlated with the Hoxnian Stage interglacial, which was originally defined palynologically, despite the absence of a pollen sequence from this site. Pollen assemblages have since been obtained from much of the Swanscombe sequence (Mullenders in Wymer, 1974; Hubbard, 1982; see above, Description). Interpretation of these assemblages has led to suggestions of considerable stratigraphical complexity, with two or even three climatic cycles being recognized (Hubbard, 1982). However, this interpretation has failed to gain wide acceptance; the validity of palynological studies of deposits with such low pollen concentrations has been questioned (Bridgland *et al.*, 1985; Turner, 1985). Turner considered it likely that various types of contamination have an important influence on palynological assemblages from sediments with a pollen-yield as poor as those at Swanscombe. Contamination could occur by the reworking of older pollen, by later pollen being introduced from percolating groundwater or by airborne modern grains being introduced during sampling and laboratory preparation. Turner also pointed out that sediments in which pollen preservation has been poor frequently contain only the more robust grains, leading to concentrations of certain taxa that result from diagenetic rather than vegetational factors; assemblages from such deposits need very careful interpretation, therefore. These points appear to seriously undermine the palaeoenvironmental and stratigraphical determinations based on pollen from this site, where none of the sediments yield abundant well-preserved pollen. Thus the pollen assemblages from Swanscombe should be interpreted with caution; where the palynological interpretation of the sediments contradicts evidence from other sources, the former should probably be disregarded.

Palaeoenvironmental and palaeogeographical significance of the Swanscombe sequence

A wealth of palaeoenvironmental information has been obtained from studies of the fossil

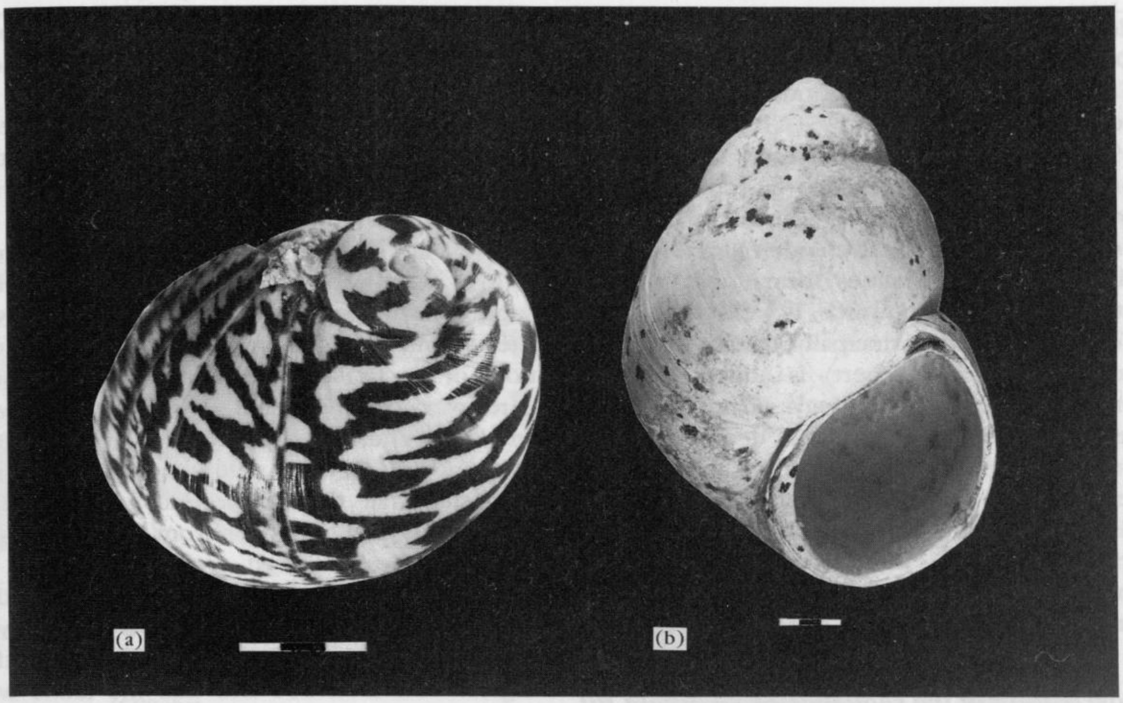


Figure 4.16 The two most characteristic molluscan species of the so-called 'Rhenish' fauna from Swanscombe: (A) *Theodoxus serratiliniformis* (Geyer); (B) *Viviparus diluvianus* (Kunth). Scale bars graduated in mm. (Photos: Department of Zoology, University of Cambridge).

content of the Swanscombe sediments. In particular, the prevailing climate and vegetation at the time of deposition of the individual units has been reconstructed, principally from the molluscan faunas, but also from mammal remains and, controversially, from pollen (see description of individual members and beds, above).

The environment of deposition represented by the various units can be determined from their sedimentological characteristics, although little appears to have been published on this subject. Bridgland *et al.* (1985) discussed the various depositional environments represented by the sequence exposed in 1982. They noted the progressive decline in fluvial energy in the Phase I sequence, from an actively aggrading gravel-bed river in the basal gravel (Ia), possibly representing the end of a cold period, through the increasingly sandy Lower Gravel (Ib), into the sandy basal parts of the Lower Loam (Id) and culminating in the siltier upper horizons of this member. The upward decrease in grain size in the Lower Loam was considered to represent a transition from channel-fill to overbank (floodplain) deposits, an interpretation supported by the molluscan fauna. The Phase II sequence again commences with high-energy deposits in the form of the Lower Middle Gravel (IIb), alternations of sand and gravel reflecting considerable current variability. The overlying Upper Middle Gravel (IIb) reflects continued fluctuations of current strength, but with a general decrease in energy indicated by the progression from planar cross-bedded to ripple-laminated sands. The interdigitation of silty horizons near the top of the 1982 section appears to indicate the further reduction in flow energy. This was thought to reflect a transition into the Upper Loam (IIIc), which has usually been interpreted as an overbank deposit. Palaeocurrent measurements have seldom been recorded from Swanscombe, although Bridgland *et al.* (1985) presented evidence, from foreset orientations in the Upper Middle Gravel (IIb), for flow towards the south-south-east. Interestingly, Wymer (1964b) estimated the same flow direction, based on gross sediment geometry, from his studies of the Upper Middle Gravel in connection with the skull discovery.

There has recently been a suggestion by Wymer (1985b, p. 321) that the Swanscombe deposits might be the product of the River Darent rather than the mainstream Thames. The composition of the various gravels at Swanscombe (Baden-Powell, 1951; Bridgland *et al.*, 1985) points strongly, however, to a Thames origin. The suite of 'exotic' (far-travelled) rock-types (Bridgland, 1986b), which can be traced downstream from the Evenlode valley and which characterizes all Thames formations from the Stoke Row Gravel onwards, is well represented. To this material (principally quartz, quartzites and Carboniferous chert) is added a further important 'exotic' lithology, *Rhaxella* chert, reworked from Anglian glacial deposits (above; Bridgland, 1986b). The predominance of these 'exotic' rocks over southern lithologies such as Greensand chert, which characterize south-bank tributaries such as the Darent, provides seemingly unequivocal evidence for the Thames origin of the Swanscombe deposits.

Correlation of the sequence at Barnfield Pit with other nearby sites in the Thames system

The initial task in correlating the sequence at Barnfield Pit with the Pleistocene record elsewhere is to determine its relation to the various other sites in the immediate neighbourhood of north Kent. These range from the other fossiliferous and Palaeolithic localities at Swanscombe to other sites in the terrace deposits on the south side of the Lower Thames, some of which (such as those at Dartford Heath) are also within the 'Boyn Hill Gravel' as mapped by the Geological Survey (see above, Wansunt Pit).

The most important of the other Swanscombe localities is probably the Ingress Vale site, or Dierden's Pit (TQ 595748; Fig. 4.17), separated from Barnfield Pit by a dry valley (the Ingress Vale). The former pit (now defunct) produced a wealth of faunal material and a confusing archaeological assemblage, but lacked the stratigraphical complexity of the skull site. It was so rich in molluscan remains that it was frequently referred to as the 'shell pit'. These came from a sandy 'shell bed' that also yielded a large collection of mammalian remains (Sutcliffe, 1964, Appendix; Wymer, 1968). There has, unfortunately, been considerable uncertainty about the correlation of these deposits with the sequence at Barnfield Pit. The earliest discoveries of palaeoliths in Dierden's Pit were well-made, sharp, patinated hand-axes found around the turn of the century, apparently in the shell bed (Stopes, 1900, 1903; Newton, 1901; Kerney, 1959b; Wymer, 1968). These discoveries led to detailed investigations, which produced collections of faunal remains and artefacts from the shell bed that were considered comparable with material from the Lower Gravel at Barnfield Pit (Dewey and Smith, 1914; Smith and Dewey, 1914), pointing to a correlation that is also supported by the altitudinal relations of the two sites (Wymer, 1968). In particular, large collections of Clactonian flakes and several chopper-cores were obtained from the deposit by Dewey and Smith and, more recently, by P.J. Tester and J.N. Carreck (Wymer, 1968). Wymer (1968) suggested that the earlier finds of Acheulian implements may have been from loamy deposits overlying the shell bed and was inclined to support the correlation of the latter with the Lower Gravel. However, Kennard (1916) was adamant that Acheulian material occurred in the Ingress Vale shell bed and that the fauna was contemporary with this industry. This controversy appears to have been resolved by Kerney (1959b, 1971, in Sutcliffe, 1964), who recorded the discovery of an Acheulian industry in the shelly deposits at Dierden's Pit, from what was apparently the reopening of the sections studied by Dewey and Smith. Kerney's material was entirely made up of flakes, including many of Clactonian type. Some, however, were distinctive hand-axe finishing flakes (Kerney, 1959b). The assemblage was studied by Marston (in Kerney, 1959b), in whose opinion the objects were unequivocally Acheulian and closely comparable to a series in his possession from the Upper Middle Gravel (IIb) of Barnfield Pit.

Kerney also reassessed the molluscan and vertebrate faunas from Dierden's Pit. He noted the presence of the characteristic 'Rhenish' molluscan suite and concluded that the Ingress Vale deposits belonged to the 'late temperate substage' of the interglacial, placing them above the Lower Loam of Barnfield Pit but earlier than the bulk of the Middle Gravel. The faunal assemblage from Dierden's Pit is indicative of temperate woodland, thus contrasting with the open-habitat fauna from the Upper Middle Gravel (Sutcliffe, 1964; Kerney, 1971). Kerney considered the latter assemblage to post-date that from Dierden's Pit and to imply climatic deterioration later in the interglacial. However, the presence of ovate hand-axes in the collections from the Dierden's Pit shell bed

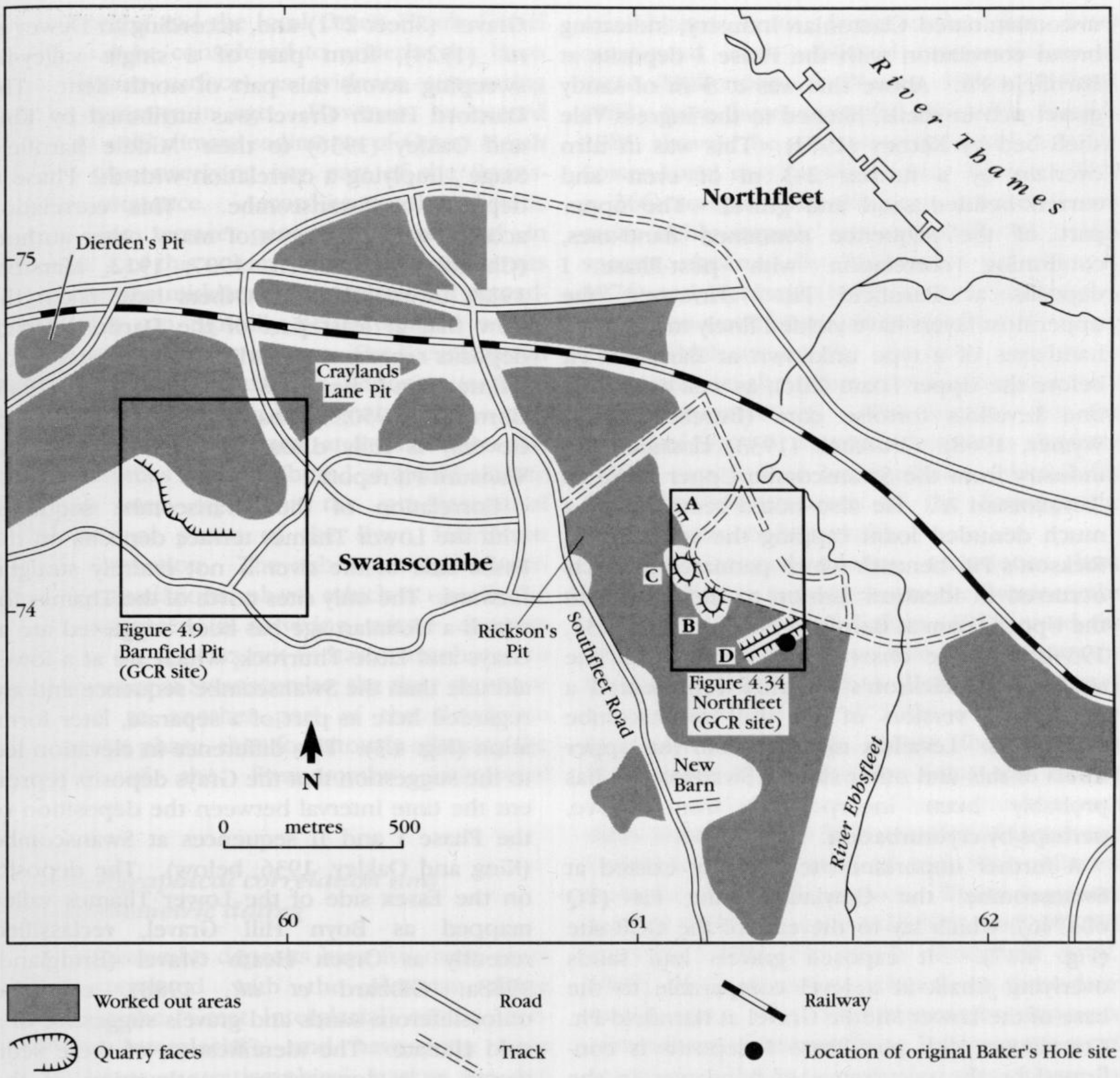


Figure 4.17 Map of the Swanscombe–Northfleet area, showing the locations of the various Pleistocene localities.

(Stopes, 1903) may indicate an age slightly younger than the Upper Middle Gravel, comparable perhaps with the higher deposits at Rickson's Pit (Kerney, 1959b; below). A unique find from Dierden's Pit is a vertebra of bottle-nosed dolphin (*Tursiops truncatus* (Montague)) in the Hinton collection (Sutcliffe, 1964), the presence of which has sometimes been claimed as evidence of proximity to the contemporary coast (Kerney, 1971). However, Stuart's (1982a) suggestion, that this represents an individual that swam up the river and became stranded, seems more plausible, considering the paucity of other indications of a marine influence at Swanscombe.

Another important site at Swanscombe was Rickson's Pit (TQ 608743; Fig. 4.17), now entirely quarried away (Tester, 1955), which shared with Barnfield Pit the important stratigraphical superposition of Acheulian above Clactonian industries. The succession at Rickson's Pit was less complex than that at Barnfield Pit, however, comprising a sequence of gravels and sands, and generally lacking the well-defined loams of the latter site (Dewey, 1932, 1934; Wymer, 1968; Waechter, 1973; Roe, 1981). The lowest gravel, 1 m thick and conspicuously coarser than any above, contained an uncontaminated Clactonian industry, indicating broad correlation with the Phase I deposits at Barnfield Pit. Above this was *c.* 3 m of sandy gravel rich in shells, likened to the Ingress Vale shell bed by Kerney (1971). This was in turn overlain by a further 2–3 m of even- and current-bedded sand and gravel. The upper part of the sequence contained hand-axes, confirming correlation with post-Phase I deposits at Barnfield Pit. However, the uppermost layers have yielded finely made ovate hand-axes of a type unknown at Barnfield Pit before the Upper Loam (IIIc), as well as at least one Levallois tortoise core (Burchell, 1931; Wymer, 1968). Burchell (1933) classified the industry from the Swanscombe Upper Loam as 'Levalloisian A'. He also noted remnants of a much denuded loam capping the sequence at Rickson's Pit, beneath which patinated artefacts occurred in identical fashion to those beneath the Upper Loam at Barnfield Pit (Burchell, 1931, 1934b). These observations suggest that the sequence at Rickson's Pit once represented a condensed version of the full Swanscombe succession. Levallois material from the upper levels of this and other sites at Swanscombe has probably been incorporated from above, perhaps by cryoturbation.

A further important site formerly existed at Swanscombe, the Craylands Lane Pit (TQ 604746), which lay to the east of the GCR site (Fig. 4.17). It exposed gravels and sands overlying Chalk at a level comparable to the base of the Lower Middle Gravel at Barnfield Pit. Correlation with post-Phase I deposits is confirmed by the occurrence of hand-axes in the gravels at Craylands Lane. As with Rickson's Pit, ovate hand-axes and Levalloisian material were recovered (Dewey and Smith, 1914; Smith and Dewey, 1914), indicating that sediments equivalent to the Phase III deposits of Barnfield Pit were present (Wymer, 1968; Waechter, 1973). Other nearby sites, of less significance, were documented by Wymer (1968).

The relations between the Swanscombe sequence and the gravels and 'loams' covering Dartford Heath, 7 km to the west, has been the subject of much debate (see above, Wansunt Pit). The deposits at the latter locality are aggraded to *c.* 42 m O.D., at least 8 m higher than the fluvial part of the Swanscombe sequence (Phases I and II). However, the deposits at both sites were mapped by the Geological Survey as part of their 'Boyn Hill Gravel' (Sheet 271) and, according to Dewey *et al.* (1924), form part of a single valley-fill sweeping across this part of north Kent. The Dartford Heath Gravel was attributed by King and Oakley (1936) to their 'Middle Barnfield Stage', implying a correlation with the Phase II deposits at Swanscombe. This correlation accords with the views of many other authors (Chandler and Leach, 1907, 1912; Marston, 1937; Dewey, 1959). Others have taken the view that at least part of the Dartford Heath deposits represent an earlier terrace aggradation (Hinton and Kennard, 1905; Zeuner, 1945; Cornwall, 1950; Gibbard, 1979). This controversy is fully discussed below and in the Wansunt Pit report.

Correlation of the Swanscombe sequence with the Lower Thames terrace deposits on the Essex side of the river is not entirely straightforward. The only sites north of the Thames for which a Hoxnian age has been suggested are at Grays and Little Thurrock, which are at a lower altitude than the Swanscombe sequence and are regarded here as part of a separate, later formation (Fig. 4.3). This difference in elevation led to the suggestion that the Grays deposits represent the time interval between the deposition of the Phase I and II sequences at Swanscombe (King and Oakley, 1936; below). The deposits on the Essex side of the Lower Thames valley mapped as Boyn Hill Gravel, reclassified recently as Orsett Heath Gravel (Bridgland, 1988a; Gibbard *et al.*, 1988), comprise unfossiliferous sands and gravels suggestive of a cold climate. The identification of these sediments as a downstream continuation of the Boyn Hill Gravel of the Middle Thames has recently been upheld (Bridgland, 1988a; Gibbard *et al.*, 1988). The Boyn Hill/Orsett Heath Gravel is interpreted as a periglacial braided-river deposit and has been attributed by Gibbard (1985) to the early Saalian Stage (Wolstonian). This dating is, in fact, largely based on the interpretation of the stratigraphical relations between the Boyn Hill/Orsett Heath Gravel and the Swanscombe sequence (Gibbard, 1985, pp. 136–137). Gibbard considered the palaeontological evidence for climatic cooling in the higher levels of the Swanscombe sequence (above the Lower Middle Gravel – IIa) to reflect a transition from the Hoxnian Stage interglacial to the glacial conditions of the early Saalian (Wolstonian) Stage. He pointed to the similarity in elevation between the top of the sequence at

Swanscombe and the local Orsett Heath Gravel (both may be considered to underlie the Boyn Hill Terrace surface) as evidence supporting their proximity in age. However, no record exists of cold-climate sediments of Orsett Heath Gravel type overlying any part of the Swanscombe sequence. According to the climatic model for terrace generation presented in Chapter 1 of this volume, interglacial sediments represent the middle of three phases of aggradation that can typically be recognized within individual terrace formations. The accumulation of such temperate-climate deposits is both preceded and followed by aggradation in a cold climate. The Basal Gravel at Swanscombe (Ia) has sometimes been attributed to a cold climate and so may represent the pre-interglacial aggradational phase of the Boyn Hill/Orsett Heath Formation. The subsequent post-interglacial aggradational phase, which is usually the best-represented in surviving terrace deposits (Chapter 1), appears not to have contributed to the sequence at Swanscombe; the river may have migrated to another part of the floodplain during this phase, thus fortuitously allowing the survival of the Swanscombe interglacial sediments.

Biostratigraphical correlation and geochronometric dating

The Swanscombe deposits have for many years been correlated with the Hoxnian Stage (formerly the 'Great Interglacial' or the 'Penultimate Interglacial'), and have long been regarded as a stratigraphical marker for that interval in the Thames valley (King and Oakley, 1936; Castell, 1964; Sutcliffe, 1964; Kerney, 1971). However, this may be in need of reappraisal in the light of evidence that the record of climatic fluctuation during the Middle and Late Pleistocene is more complex than was thought hitherto (see Chapter 1).

To date, the most convincing biostratigraphical argument for the Hoxnian age of the Swanscombe sediments has being derived from the molluscan record and its comparison with that from Clacton (Kerney, 1971). The record of the palynomorph 'Type X' in the Lower Gravel and Lower Loam (Hubbard, 1982) appears to add weight to the argument, since this grain is considered to be characteristic of Hoxnian pollen assemblages (Turner, 1970; Phillips, 1976). Although the validity of pollen assemblages from Swanscombe has been questioned, and published interpretations of these (Mullenders, *in* Wymer, 1974; Hubbard, 1982) have been strongly criticized (Turner, 1985; above), the palynological record from the Lower Loam may be significant. Turner (1985, p. 366) accepted that this deposit was formerly more richly organic and regarded the pollen spectra obtained by Mullenders (*in* Wymer, 1974) and Hubbard (1982) as 'residual temperate pollen assemblages dominated by *Alnus* and *Pinus* which are on the one hand resistant to decay and on the other easy to recognize in a mutilated condition'. This implies that the record of 'Type X' from this deposit by Hubbard (1982) may indeed be significant, even if his elaborate interpretation of the Swanscombe sequence cannot be upheld.

Geochronometric dating techniques have been applied in recent years to the Swanscombe sequence. Szabo and Collins (1975) used the uranium-series method to date a bone from the basal Lower Middle Gravel (IIa). This indicated a minimum age of 272,000 years for the specimen, supporting claims for a Middle Pleistocene (Hoxnian *sensu lato*) age for the Upper Middle Gravel. Thermoluminescence dates were obtained from samples of Lower and Upper Loam (members Id and IIIc) collected from the 1982 GCR sections. These suggested ages of 228,800 years (±23,300) and 202,000 years (±15,200) respectively (Bridgland *et al.*, 1985). As these authors pointed out, these dates would place the full Swanscombe sequence within Oxygen Isotope Stage 7. Given the stratigraphical evidence presented in this volume for correlation of the Swanscombe deposits with an earlier temperate episode (probably Stage 11), together with uncertainties about the validity of early (pre-late Devensian) thermoluminescence dates (see, for example, Parks and Rendell, 1988), it seems likely that the dates from the Swanscombe loams are underestimates.

Recently, Bowen *et al.* (1989) have attempted to relate elements of the British terrestrial sequence to the oceanic (oxygen isotope) record, on the basis of amino acid analyses of mollusc shells. Amongst results from interglacial molluscan species from post-Anglian sediments, these authors recognized four groups of ratios that, they suggested, represent four separate temperate intervals. They correlated these with Oxygen Isotope Stages 11, 9, 7 and 5(e) (see Chapter 1). This technique has been applied to shells from all four main fluviatile members at Barnfield Pit (Ib, Id, IIa and IIb), as well as from the Ingress Vale shell bed (Bowen *et al.*, 1989). Results have been obtained from four different species. The D-alloisoleucine : L-isoleucine (D : L) ratios from Swanscombe are closely clustered around 0.3, the small range providing support for the view that the entire aggradation occurred during a single temperate episode. These results confirm the findings of early amino acid analyses of shells from Dierden's Pit (Ingress Vale) by Miller *et al.* (1979). However, ratios obtained from the Hoxnian stratotype are lower, indicating to Bowen *et al.* (1989) that the type-Hoxnian sequence relates to a later episode, which they correlated with Oxygen Isotope Stage 9. For this reason Bowen *et al.* suggested that Swanscombe should be regarded as the 'stratotype' for a previously undefined post-Cromerian/pre-Hoxnian temperate episode, equivalent to Oxygen Isotope Stage 11. This interpretation implies that there were two separate temperate intervals during the late Middle Pleistocene during which vegetation developed in Britain in similar ways; sediments that accumulated during both episodes have yielded pollen spectra that have been attributed to the Hoxnian interglacial. The strongest evidence for assigning the Swanscombe sediments to the Hoxnian Stage is probably the correlation with the palynologically dated Hoxnian sequence at Clacton (Kerney, 1971). The revised chronostratigraphical scheme of Bowen *et al.* (1989) upholds this correlation, since shells from the Clacton deposits also yield amino acid ratios suggestive of Stage 11 (Chapter 5), implying that they too may be pre-Hoxnian (*sensu* Hoxne). Because of the problems that exist in reconciling biostratigraphy with geochronology in this part of the British Pleistocene, the term Hoxnian Stage *sensu* Swanscombe is used to refer to the Stage 11 interglacial episode in this volume (Chapter 1).

The significance of the Swanscombe deposits within the Thames terrace sequence

For many years the association of the Swanscombe deposits with the Hoxnian Stage (formerly the 'Great Interglacial') was a key factor in dating the Boyn Hill Terrace and, therefore, the Thames terrace system as a whole. The evidence for a Hoxnian age for the Swanscombe sequence, chiefly from mammalian and molluscan faunas (see above), was reinforced by Baden-Powell (1951). He claimed to have recognized clast-types in the gravels at Swanscombe that were characteristic of the Lowestoft (Anglian) glaciation, but none that were characteristic of the later (post-Hoxnian) 'Gipping glaciation'. Since no post-Hoxnian glaciation is now recognized in southern East Anglia (Chapter 5), this evidence can no longer be accepted. However, the occurrence in the Swanscombe gravels of *Rhaxella* chert, a lithology first introduced into the London Basin in quantity by the Anglian (Lowestoft) glaciation (Bridgland, 1986b), was confirmed by Bridgland *et al.* (1985; see Table 4.2). These authors also recorded non-durable Jurassic clasts, including fragments of *Gryphaea* sp., in the Lower Gravel. They suggested that this material was secondarily derived from Anglian glacial deposits, the nearest representatives of which are at Hornchurch (see Fig. 4.1 and above, Hornchurch).

The established view of the Swanscombe sediments as evidence for a Hoxnian age for the Boyn Hill Terrace throughout the Thames system has been superseded in recent years, although it is still to be found in many texts. Gibbard (1985) demonstrated that the Boyn Hill Gravel (the deposit normally underlying this terrace) is, in common with most Thames terrace deposits, a cold-climate accumulation formed in a periglacial braided-river environment (see Chapter 3). Although the Swanscombe deposits do not therefore represent the Boyn Hill Gravel in its typical form, they may be considered as part of the Boyn Hill Formation, which, according to the stratigraphical scheme proposed in Chapter 1 of this volume, includes cold-climate deposits both pre-dating and post-dating the Swanscombe sediments (see Table 1.1).

There is, furthermore, a significant body of opinion that holds that the sequence at Swanscombe may represent sedimentation during more than a single temperate interval. The view that the sequence is of considerable complexity was first stated by King and Oakley (1936). These authors outlined a stratigraphical scheme for the Lower Thames terraces in which the deposition of the Swanscombe Phase I deposits (their 'Lower Barnfield Stage') was followed by major incision to a much lower base level. Aggradation at this lower level followed, represented by the Clacton Channel sediments and deposits containing Clactonian artefacts and faunal remains at Little Thurrock and Grays (their 'Clacton-on-Sea Stage'; see below, Globe Pit; Chapter 5, Clacton). This aggradation continued to the full height of the Boyn Hill Terrace surface as mapped by the Geological Survey (over 40 m O.D. at Dartford Heath), the Phase II sediments at Swanscombe representing part of this process (their 'Middle Barnfield Stage'). The bases for King and Oakley's reconstruction were (1) the archaeological record from the three Clactonian sites (Swanscombe, Little Thurrock and Clacton) and (2) the occurrence at Grays of a mammalian fauna that was believed to be of similar age to that from the Swanscombe deposits. This scheme was widely accepted for many years, although Marston (in Bull, 1942) made clear his scepticism about the downcutting phase between the Phase I and II deposits of the Swanscombe sequence.

Despite the complexity implied by their interpretation, King and Oakley attributed the entire fluvial succession at Swanscombe to the 'Great Interglacial' (Hoxnian). It is difficult to reconcile the implied chronostratigraphical position of the hiatus between the Lower Loam and the Lower Middle Gravel, in the mid-Hoxnian, with the incision event envisaged by King and Oakley at this stratigraphical level; the former would seem to indicate a high interglacial sea level, whereas the latter would suggest a marked lowering of sea level. However, there appears to be supporting evidence for a low sea-level event at this time from the molluscan faunas. Kennard (1938) considered the occurrence of the characteristic suite of 'Rhenish' molluscs in the Phase II deposits at Swanscombe to indicate that the Thames and Rhine became joined after the deposition of the Lower Loam. Such a connection would appear to require a low sea-level phase at precisely the time postulated by King and Oakley. However, Kerney (1971) was not convinced by the evidence for a major hiatus above the Lower Loam, coinciding with the linking of the Thames and Rhine. He pointed out that the first traces of the 'Rhenish' faunas appeared near the top of the Lower Loam (after Davis, 1953) and that the molluscan record showed no indication of a significant hiatus at the base of the Lower Middle Gravel. He also suggested a diagenetic origin for the weathered zone at the top of the loam, which had been widely regarded hitherto as evidence for a period of prolonged subaerial exposure. This horizon has now been confirmed as a buried soil (Kemp, 1985b; see above), but its characteristics suggest formation under temperate-climate conditions during a relatively brief period, so again no indication of a major break in the interglacial succession is provided.

Evans (1971) presented another complex interpretation of the Swanscombe sequence in his pioneering attempt to relate the Thames terraces to the global marine (oxygen isotope) record. He correlated the Lower Gravel and Lower Loam at Swanscombe with the Kingston Leaf aggradation of Zeuner (1945), attributing both to his half-cycle 8w (equivalent to Oxygen Isotope Stage 15 of Shackleton and Opdyke, 1973, 1976). Evans correlated the Swanscombe Lower Middle Gravel with the Black Park Gravel of the Middle Thames, which he attributed to his half-cycle 7w (Stage 13), and saw only the Upper Middle Gravel as a true Boyn Hill deposit, dating from the next warm half-cycle (6w = Stage 11). Evans believed that the two earlier aggradations were represented within the lower parts of the sequence at Swanscombe, rather than as higher terrace remnants on the valley side, because their steeper downstream gradients had taken them below the Boyn Hill Terrace level in the London area (see above, Wansunt Pit). This interpretation argues for two major breaks in the succession at Swanscombe, each equivalent to a cold event in the oxygen isotope record (Stages 14 and 12). The boundary between the Lower Loam and Lower Middle Gravel was already well-established as a non-sequence, with evidence for subaerial weathering (see above), and had been correlated by King and Oakley (1936) with erosion elsewhere in the valley. The later hiatus envisaged by Evans, between the Lower and Upper Middle Gravels, was less well-established, although Marston (1937) had reported evidence for major erosion at this level in the sequence. As stated above, Conway (1972) questioned the evidence for this erosive phase, suggesting that features previously interpreted as channels may have been produced by solution of the underlying Chalk. In addition to Conway's suggestion, the continuity of the mammalian, molluscan and Palaeolithic (Acheulian) assemblages between the Lower and Upper Middle Gravels argues against Evans's interpretation.

Reappraisal, in the area west of London, of the late Anglian Black Park Gravel has indicated that Zeuner's (1945) Kingston Leaf is a correlative of this formation (Gibbard, 1979; see above, Wansunt Pit), rather than representing a separate, older aggradation as suggested by Evans (1971). As a result, Bridgland (1980) proposed a modified version of Evans's interpretation of the Swanscombe sequence, in which Boyn Hill deposits were considered to overlie Black Park deposits, rather than the tripartite sequence favoured by Evans. Bridgland suggested that the Lower Gravel channel was a product of pre-Black Park Formation downcutting, thus agreeing with Zeuner (1945) that the Clacton Channel was excavated at this time, rather than after deposition of the Lower Loam. In fact, Bridgland (1980, 1983a, 1983b, 1988a) traced an equivalent channel across eastern Essex between Southend and Mersea Island, suggesting a direct link between the Lower Gravel channel at Swanscombe and the Clacton Channel (see Chapter 5). He recognized that much of the Lower Gravel and Lower Loam and the Clacton sequences are of interglacial origin and therefore post-date the late Anglian Black Park Gravel, the aggradation of which began while ice still occupied parts of the old Thames valley in Hertfordshire (see Chapter 3). He suggested, however, that the basal deposits at the two sites, already claimed as late Anglian by previous authors (above; Chapter 5, Clacton), may be equivalent to the Black Park Gravel of the Middle Thames.

A problem exists in reconciling the different interpretations of this part of the Lower Thames sequence proposed by Gibbard (1979) and by Bridgland (1980, 1988a). This problem, which has already been discussed above (see Hornchurch and Wansunt Pit), hinges on whether the Lower Thames valley was deeply excavated in Black Park times (late Anglian), as the elevation of the Hornchurch till remnant suggests, or whether the valley floor was much higher; *c.* 37 m O.D. was suggested by Gibbard (1979) as the base of his Dartford Heath Gravel, which he correlated with the Black Park Gravel. However, the correlation of the Dartford Heath and Black Park Gravels has been rejected earlier in this volume (see above, Hornchurch and Wansunt Pit), on the grounds that the downstream projection of the Black Park Formation confirms Evans's suggestion that this deposit falls below the level of the Boyn Hill Terrace east of London. It therefore passes well below the level of the Dartford Heath outlier and supports the evidence from the till at Hornchurch for deep excavation of the valley by the late Anglian (Fig. 4.7). The Black Park Formation of the Middle Thames can, according to this reinterpretation, be correlated with the basal deposits of the Swanscombe Lower Gravel channel. At Swanscombe, however, little of this late Anglian gravel is preserved; it has been replaced by a Hoxnian temperate sequence. Aggradation continued to the Boyn Hill Terrace level, the river occupying this, its highest floodplain level in the Lower Thames, in the early part of the subsequent cold interval (the early Saalian).

The rejuvenation that separated the Boyn Hill floodplain from that on which the Black Park Gravel was deposited cannot, therefore, be recognized downstream from London. This event, which presumably occurred before the end of the Anglian Stage, may have had little effect in this area, where sediments equivalent to the Black Park Formation of the Middle Thames are thought to be directly overlain by gravels of the Boyn Hill Formation. It is difficult to determine whether any significant downcutting occurred in the valley downstream from London at this time, as any evidence would have been buried by the subsequent aggradation of the Boyn Hill Gravel to over 40 m O.D. Further upstream this rejuvenation is of considerable importance; for example, it coincided with the abandonment of the 'Ancient Channel' between Caversham and Henley (Chapter 3, Highlands Farm Pit). It has already been noted (Chapters 1 and 3) that the initiation of Black Park Gravel deposition was intimately related to the glaciation of the London Basin and the resultant diversion of the Thames; special circumstances therefore controlled the formation of this terrace, which was not generated by climatic fluctuation in the way that most other Thames terraces have been (see Chapter 1 – climatic model for terrace generation). It may be that the diversion of the Thames pre-empted the climatically induced rejuvenation event that was due to occur towards the end of the Anglian cold episode, causing the incision from the Winter Hill to the Black Park level. The time interval represented by the Black Park Gravel was evidently short; it was insufficient for a separate terrace feature to become established throughout the catchment, since the Black Park

Formation can be shown to converge upstream with the earlier Winter Hill Formation (see Chapter 1 and Fig. 1.3). The subsequent incision to the Boyn Hill level may have occurred in response to isostatic uplift following the disappearance of the Anglian ice sheets from Hertfordshire. Certainly the evolution of the terrace system at this time reflects the disruption and instability brought about by the Anglian glaciation and cannot be explained solely by the climatic model applied to other parts of the sequence.

In the revised stratigraphical scheme for the Thames terraces presented in Chapter 1 of this volume, the Swanscombe sediments provide important evidence for allocating the Hanborough/Boyn Hill/Orsett Heath Formation to Oxygen Isotope Stages 12–10, by indicating a Stage 11 age for the interglacial phase (phase 3 of the climatic model) that separates the two cold-climate phases of aggradation recognized within this formation (Table 1.1). The post-interglacial aggradational phase (phase 4) appears to totally dominate the formation, possibly because of the disruption to the normal cycle caused by the glaciation of the London Basin, discussed above. Thus palaeontological evidence for the Stage 11 temperate episode has rarely been preserved; it is recognized in reworked mammal bones in the (phase 4) Hanborough Gravel of the Upper Thames (Chapter 2), but Swanscombe is the only locality in the present valley where *in situ* Stage 11 sediments are well-documented. The recorded occurrence of temperate-climate Mollusca at Dartford suggests that a further, smaller remnant may have existed there (see above, Wansunt Pit), but other surviving sediments of this age all lie downstream in Essex, in the former continuation of the Thames (Thames-Medway) course (see below, Chapter 5).

Final commentary

The Swanscombe (Barnfield Pit) site is one of the most important British Pleistocene localities. The wealth of information that has been gleaned from this site is apparent from the vast literature that exists. There is, however, considerable potential for gaining new information from the Swanscombe sequence. This is particularly the case at a time when the established terrestrial Pleistocene record is receiving such a critical re-examination. Swanscombe provides one of the foundations of this record and any re-appraisal will have to take account of the evidence from this site.

The Swanscombe record has a major shortcoming: despite the efforts of Mullenders (in Wymer, 1974) and Hubbard (1982), it lacks a convincing palynological sequence to compare with the established pollen-based biostratigraphy of the major British interglacials. Palynological studies have provided the basis for the identification of temperate intervals in the Pleistocene sequence both in Britain and western Europe (West, 1963; Mitchell *et al.*, 1973; de Jong, 1988), based on differences in vegetational development between different stages. Further work may enhance what has been achieved in this field at Swanscombe already, but the nature of the sediments probably precludes the preservation of a continuous record of vegetational change through the interglacial. However, other methods may supersede palynology as the principal technique for stratigraphical comparison in the British Pleistocene, particularly if mounting evidence that different temperate intervals can have nearly identical pollen records is substantiated.

There is some indication that faunal remains in the remaining Phase I deposits within the Swanscombe nature reserve have deteriorated since the higher parts of the sequence were removed, particularly the mammal bones. The third skull fragment was itself considerably weathered in comparison to the two previous finds (Wymer, 1964b), perhaps reflecting weathering during the intervening 19 years. If this is the case it is doubtful whether any similar material in the remaining sediments will have survived the further four decades of weathering that have followed the 1955 discovery. Further evidence that weathering is damaging the faunal remains in these deposits is provided by the poor state of the bones recovered from the Lower Loam in the 1982 investigation and the near absence of small vertebrate remains in the sieved samples from 1986 (A.P. Currant, pers. comm.). This emphasizes the critical importance of the Alkerden Lane Allotments SSSI, where the full Swanscombe sequence is preserved. In this area the survival of the higher layers, particularly the clayey slope and overbank deposits that cap the sequence, will hopefully have protected the faunal content of the lower material from weathering.

Conclusions

Swanscombe is probably the most famous British Pleistocene site; it is of international renown because of the discovery there of the fragmentary skull of an early Stone Age woman. Even without this find, the site would be of enormous importance. It combines a complex record of deposition by the Thames during a temperate (interglacial) episode, when the river laid down a series of gravels and loams containing abundant mammalian and molluscan fossils, with a rare occurrence of different Stone Age industries one above the other. In the first of these, confined to the lower part of the sequence, only flint flakes and 'cores' (blocks from which flakes have been removed) are found. The later industry, from the higher part of the sequence (including the level at which the skull was found), includes deliberately shaped tools called hand-axes, many hundreds of which have been found at Swanscombe. At the level within the sequence at which this change in the artefacts occurs, there are also important changes in the molluscan content of the sediments. In particular, a number of new species appear for the first time, including extremely rare forms known only from this locality in Britain. There is important evidence for a break in the sedimentary sequence of this same level, in the form of a soil that is developed in the top of the Swanscombe Lower Loam.

This combination of complex sedimentary, archaeological and faunal records makes Swanscombe a key reference site for other localities in Britain and western Europe. It is clear, from the position of the site within the 'staircase' of Lower Thames terraces, that the interglacial represented at Swanscombe is that which followed the Anglian Stage, when the Lower Thames drainage was initiated by the glacial diversion of the river. This would indicate deposition of the Swanscombe sequence at around 400,000 years before present. Hitherto, the Swanscombe sediments have generally been attributed to the Hoxnian Stage, named after a series of lake beds at Hoxne in Suffolk. However, it has recently been suggested that these lake beds relate to a more recent warm episode and that the Swanscombe section should be regarded as the type locality for the first post-Anglian interglacial, which is correlated with Stage 11 of the deep-sea record. This view contradicts the well-established intercorrelation between the Swanscombe deposits and the Hoxne lake beds by way of the important Thames site at Clacton. The Swanscombe and Clacton sequences are closely correlated on the basis of their molluscan faunas, whereas Clacton and Hoxne have been correlated using pollen analysis. The Swanscombe sequence is certain to be central to future research aimed at resolving this controversy. It is fortunate that the full sequence is preserved intact beneath the Alkerden Lane Allotments SSSI, adjacent to the partly worked-out Swanscombe Skull Site NNR.

PURFLEET – BLUELANDS, GREENLANDS, ESSO AND BOTANY PITS

D.R. Bridgland

Highlights

Adjacent quarries at Purfleet afford an unrivalled opportunity for the study of lateral variations in the deposits of a single Thames terrace. This complex site reveals interglacial sediments sandwiched between cold-climate gravels. The interglacial sediments have yielded an important molluscan fauna, while the gravels have been found to contain artefacts from several different Palaeolithic industries. The interglacial represented at Purfleet is believed to fall within the complex Saalian Stage, probably equating with Stage 9 of the oxygen isotope record.

Introduction

Four adjacent quarries are included in the Purfleet GCR site (Fig. 4.18), three of which are chalk pits revealing important sections in overlying Pleistocene deposits. These are, from north-east to south-west, Bluelands Quarry, Greenlands Quarry and Botany Pit. Between Botany Pit and Greenlands Quarry is a smaller gravel working, now within the confines of an oil storage depot, known as the Esso Pit. The Pleistocene sediments exposed in these pits are part of a spread of gravel, 'brickearth' and 'coombe deposits' that abuts against the northern side of the Purfleet Anticline, an

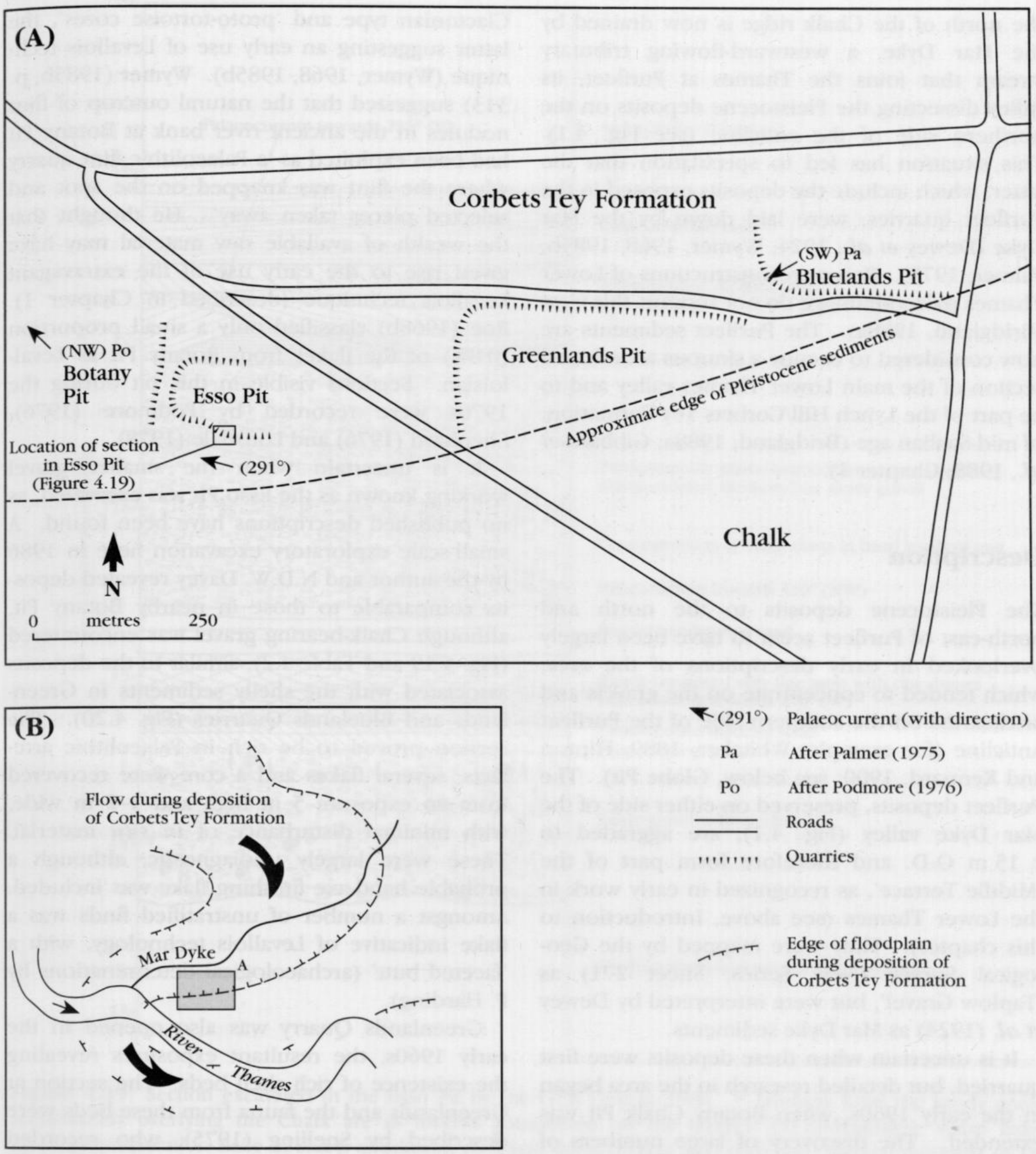


Figure 4.18 (A) Map showing the location of the various exposures at Purfleet; (B) the extent of the Thames floodplain in the Purfleet area during the deposition of the Corbets Tey Gravel. Note that where the floodplain passed through the Chalk outcrop of the Purfleet Anticline it was considerably restricted.

east-west trending structure that causes the Upper Chalk to outcrop in a ridge between Purfleet and Grays (Geological Survey, New Series, Sheet 271; Fig. 4.1). The deposits contain important assemblages of Palaeolithic artefacts and Mollusca (Wymer, 1968, 1985b; Palmer, 1975; Snelling, 1975; Allen, 1977; Hollin, 1977) and have also yielded pollen (Hollin, 1977).

Thames terrace deposits have been widely recognized to the south of the Purfleet Anticline, similarly banked against the Chalk. The area to the north of the Chalk ridge is now drained by the Mar Dyke, a westward-flowing tributary stream that joins the Thames at Purfleet, its valley dissecting the Pleistocene deposits on the northern side of the anticline (see Fig. 4.1). This situation has led to speculation that the latter, which include the deposits exposed in the Purfleet quarries, were laid down by the Mar Dyke (Dewey *et al.*, 1924; Wymer, 1968, 1985b; Palmer, 1975). Recent reconstructions of Lower Thames palaeodrainage do not support this view (Bridgland, 1988a). The Purfleet sediments are now considered to occupy a sinuous abandoned section of the main Lower Thames valley and to be part of the Lynch Hill/Corbets Tey Formation, of mid-Saalian age (Bridgland, 1988a; Gibbard *et al.*, 1988; Chapter 1).

Description

The Pleistocene deposits to the north and north-east of Purfleet seem to have been largely overlooked in early descriptions of the area, which tended to concentrate on the gravels and brickearths on the southern side of the Purfleet Anticline (for example, Whitaker, 1889; Hinton and Kennard, 1900; see below, Globe Pit). The Purfleet deposits, preserved on either side of the Mar Dyke valley (Fig. 4.1), are aggraded to *c.* 15 m O.D. and therefore form part of the 'Middle Terrace', as recognized in early work in the Lower Thames (see above, Introduction to this chapter). They were mapped by the Geological Survey (New Series, Sheet 271) as 'Taplow Gravel', but were interpreted by Dewey *et al.* (1924) as Mar Dyke sediments.

It is uncertain when these deposits were first quarried, but detailed research in the area began in the early 1960s, when Botany Chalk Pit was extended. The discovery of large numbers of flint artefacts in the overlying sand and gravel led to the publication of a description by Wymer (1968). He noted that the gravel was current-bedded and that it passed laterally into 'coombe rock' in the southern part of the pit. In the eastern face, now graded, the gravel could be seen banked against Chalk containing bands of flint nodules. The gravel immediately adjacent to this rising bank of Chalk contains one of the richest concentrations of worked flint in the British Palaeolithic (Wymer, 1968; A.J.R. Snelling, pers. comm.). The assemblage from Botany Pit includes hand-axes, chopper-cores of Clactonian type and 'proto-tortoise cores', the latter suggesting an early use of Levallois technique (Wymer, 1968, 1985b). Wymer (1985b, p. 313) suggested that the natural outcrop of flint nodules in the ancient river bank at Botany Pit had been exploited as 'a Palaeolithic flint quarry where the flint was knapped on the spot and selected pieces taken away'. He thought that the wealth of available raw material may have given rise to the early use of the extravagant Levallois technique (described in Chapter 1). Roe (1968b) classified only a small proportion (0.8%) of the flakes from Botany Pit as Levalloisian. Sections visible in this pit during the 1970s were recorded by Podmore (1976), Shephard (1976) and Lonsdale (1978).

It is uncertain when the smaller gravel working known as the Esso Pit was excavated, as no published descriptions have been found. A small-scale exploratory excavation here in 1986 by the author and N.D.W. Davey revealed deposits comparable to those in nearby Botany Pit, although Chalk-bearing gravel was encountered (Fig. 4.19 and Table 4.2), similar to the deposits associated with the shelly sediments in Greenlands and Bluelands Quarries (Fig. 4.20). The section proved to be rich in Palaeolithic artefacts; several flakes and a core were recovered from an exposure 5 m high and 1–2 m wide, with minimal disturbance of ***in situ*** material. These were largely undiagnostic, although a probable hand-axe finishing flake was included. Amongst a number of unstratified finds was a flake indicative of Levallois technology, with a 'faceted butt' (archaeological determinations by P. Harding).

Greenlands Quarry was also opened in the early 1960s, the resultant exposures revealing the existence of rich shell beds. The section at Greenlands and the fauna from these beds were described by Snelling (1975), who recorded over 25 ft (7.5 m) of Pleistocene deposits overlying Chalk and Chalk rubble in the north face (Fig. 4.20). The lower 4 m of these sediments are dominated, above a basal gravel (0.5 m), by shelly clays and sands, the best-preserved molluscan remains coming from the upper, more sandy half of these lower beds. Above the shelly beds, alternating gravels and clays form the remainder of the sequence. Snelling listed 27 molluscan species from the Greenlands shell beds (all but seven of them aquatic), together with mammal bones and teeth, including straight-tusked elephant (*Palaeoloxodon*

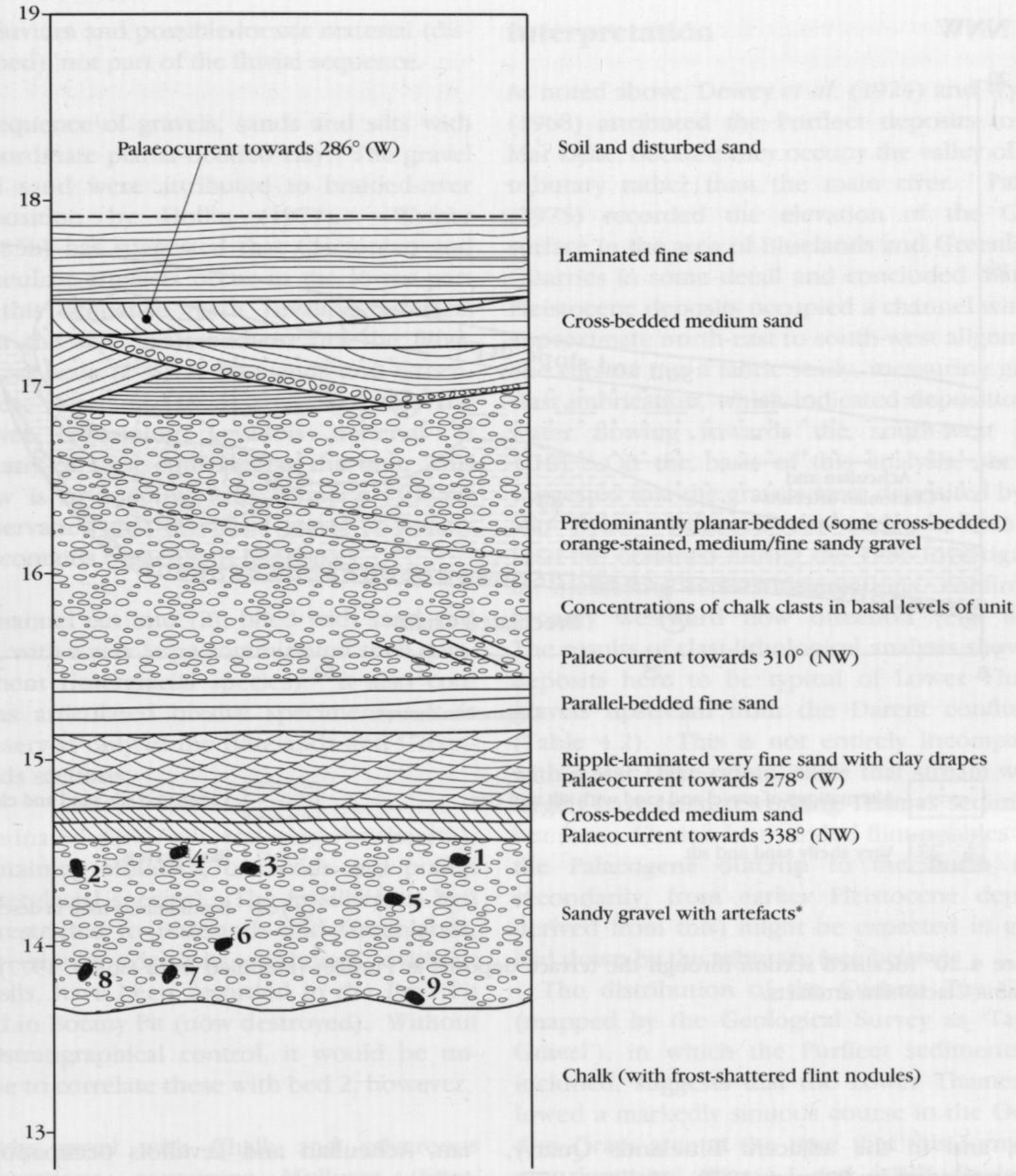


Figure 4.19 Section excavated in the Esso Pit by the GCR Unit in 1986. * Artefacts from the sandy gravel immediately overlying the Chalk are as follows (numbered on the figure): (1) undiagnostic sharp flake; (2) large preparation flake in sharp condition; (3) small cortical flake that may have formed naturally in the river's bed load; (4) undiagnostic hard-hammer flake in slightly rolled condition; (5) broken flake (the break probably occurred at the time of knapping); (6) broken unstained flake that may have formed naturally in the river's bed load; (7) core, utilizing a broken nodule – approximately four flakes have been removed by alternate flaking; (8) small sharp flake that may have formed naturally in the river's bed load; (9) a sharp flake, thick in section (particularly towards the distal end), with semi-converging scars on the dorsal surface – flakes of this type are produced during the shaping of hand-axes. Other material was found elsewhere at the site. The collection has been lodged with the British Museum. Archaeological determinations by P. Harding.

antiquus), bison and indeterminate small rodents. The molluscan assemblage includes the aquatic snail *Belgrandia marginata* (Michard) in great abundance; *Bithynia tentaculata* is also common, as are the bivalves *Pisidium amnicum* (Müller), *P. supinum, P. henslowanum* (Sheppard) and *Corbicula fluminalis*. Later descriptions of the sediments

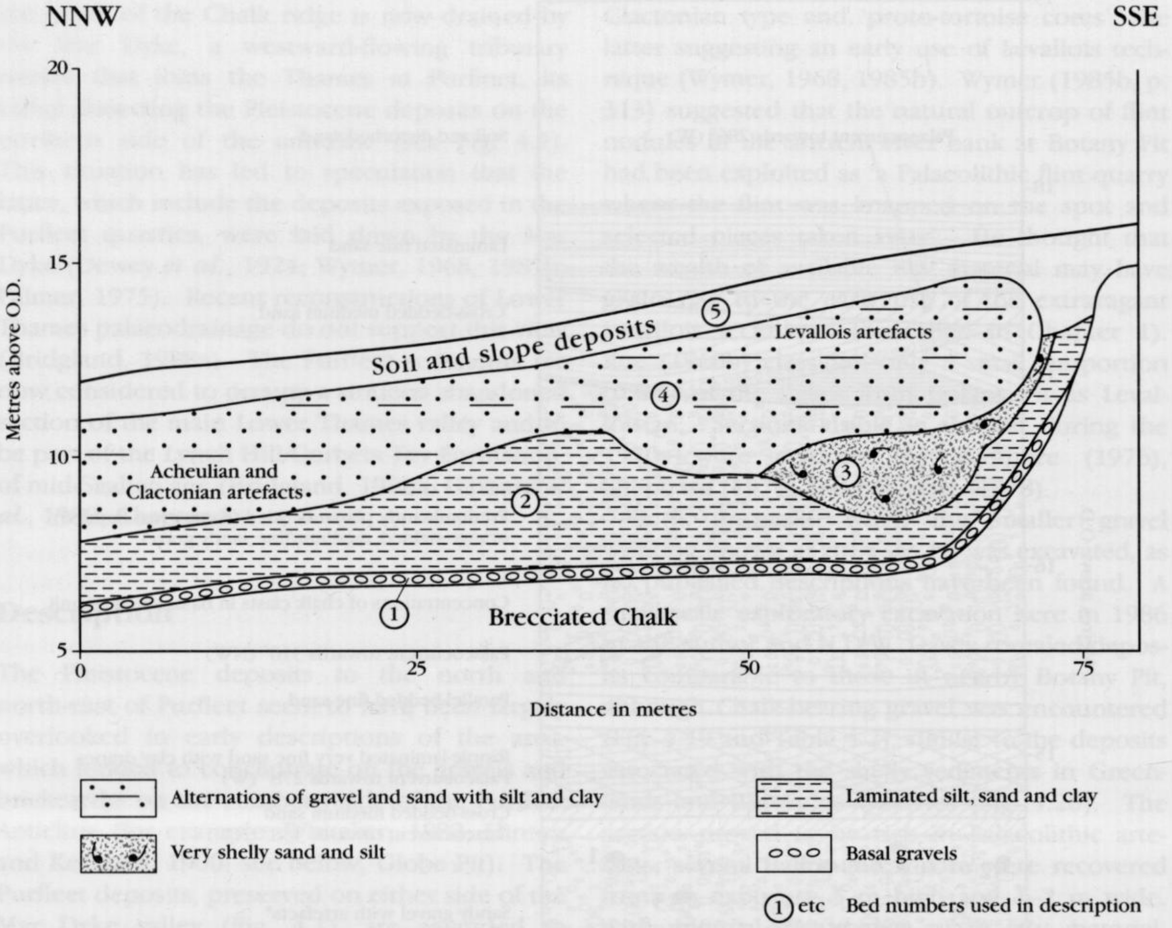


Figure 4.20 Idealized section through the terrace deposits at Purfleet (modified from Hollin, 1977). Bed 1 contains Clactonian artefacts.

here, and in the adjacent Bluelands Quarry, were provided by Palmer (1975), Hollin (1977), Lonsdale (1978) and Wymer (1985b).

Palmer (1975) discovered Palaeolithic material in both Greenlands and Bluelands Quarries; she assembled a mixed collection of scrapers, flakes and cores, principally from Bluelands. Palmer interpreted this assemblage as 'Middle Acheulian', with a considerable Clactonian element, much of which was rolled and therefore possibly reworked from earlier deposits. Some Levallois influence was observed, but Palmer considered the assemblage to differ significantly from the proto-Levallois material from Botany Pit. Wymer (1985b) suggested that three different industries were included in the collections assembled by Palmer, possibly reflecting a stratigraphical sequence of Clactonian, Acheulian and Levallois occupations (see below).

Observations by Hollin (1971, 1977) broadly confirmed earlier descriptions, although he noted that Snelling's main shell-bearing bed occupies a channel cut into more argillaceous, laminated deposits. He attributed the latter to deposition in an intertidal environment. Hollin also described an upper sand body at Purfleet, directly overlying a Chalk platform at 14 m O.D. The existence of this deposit, which has the appearance, in Hollin's section, of a separate higher terrace remnant, has not been confirmed by recent investigations (P. Allen, pers. comm.).

From the various descriptions of the Purfleet sections, the following generalized sequence can be reconstructed (see also Fig. 4.20, which indicates approximate thicknesses):

5. Colluvium and possible loessic material (disturbed), not part of the fluvial sequence.

4. A sequence of gravels, sands and silts with subordinate planar-bedded clay. The gravel and sand were attributed to braided-river deposition by Hollin (1977). Wymer (1985b) has suggested that Clactonian and Acheulian artefacts occur in the lower part of this sequence, with Levallois artefacts near the top. This bed overlies the interglacial beds (1–3) at Bluelands and Greenlands. Snelling (1975) suggested that the gravel containing Levallois material at Botany Pit is the equivalent of this unit. This view is in keeping with Wymer's (1985b) observation that the basal gravel at Botany Pit contains (Acheulian) hand-axes.

3. A channel cut into (2), filled with sand and silt, with a very large comminuted shell component (interglacial species). It also contains articulated bivalve specimens. It is preserved only in the Bluelands and Greenlands sections.

2. Laminated sand, silt and clay (brickearth), containing Mollusca, ostracods and pollen (interglacial species). The fossiliferous bed is restricted to Bluelands and Greenlands, but similar deposits, although without fossils, have been recorded in the Esso Pit and in Botany Pit (now destroyed). Without biostratigraphical control, it would be unwise to correlate these with bed 2, however.

1. Sandy gravel with Chalk and calcareous concretions, containing Mollusca (interglacial species). This bed contains Clactonian artefacts, some in sharp condition (Wymer, 1985b). Palmer (1975) distinguished a very sandy and calcareous upper division and a coarse lower division within this unit, the Mollusca apparently occurring in the former.

Chalk rubble (above solid Chalk).

The fossiliferous beds 1–3 represent interglacial conditions. They are, however, of limited lateral extent; in their absence, the basal (unfossiliferous) part of bed 1 would be indistinguishable from bed 4 (except, perhaps, from their Palaeolithic contents).

Interpretation

As noted above, Dewey *et al.* (1924) and Wymer (1968) attributed the Purfleet deposits to the Mar Dyke, because they occupy the valley of that tributary rather than the main river. Palmer (1975) recorded the elevation of the Chalk surface in the area of Bluelands and Greenlands Quarries in some detail and concluded that the Pleistocene deposits occupied a channel with an approximate north-east to south-west alignment. She carried out a fabric study, measuring gravel clast imbrication, which indicated deposition by water flowing towards the south-west (Fig. 4.18). On the basis of this analysis, she too suggested that the gravels were deposited by the Mar Dyke. Palaeocurrent evidence from the Esso Pit, obtained during the 1986 investigation by measuring foreset orientations, confirms a broadly westward flow direction (Fig. 4.18). The results of clast-lithological analysis show the deposits here to be typical of Lower Thames gravels upstream from the Darent confluence (Table 4.2). This is not entirely incompatible with a Mar Dyke origin, since that stream would largely have been reworking Thames sediments, but some dilution by rounded flint pebbles from the Palaeogene outcrop to the north (and, secondarily, from earlier Pleistocene deposits derived from this) might be expected in gravel laid down by the tributary (see below).

The distribution of the Corbets Tey Gravel (mapped by the Geological Survey as 'Taplow Gravel'), in which the Purfleet sediments are included, suggests that the Lower Thames followed a markedly sinuous course in the Ockendon–Grays area at the time that this formation was deposited (Figs 4.1 and 4.18B; Bridgland, 1988a). The relations between the Corbets Tey Formation and higher ground to the north, east and south, which constrains the reconstruction of the Corbets Tey floodplain, reveal the extent of this sinuosity. When this deposit was aggrading, the river, flowing eastwards from London, turned sharply to the south-west in the Ockendon area, flowed in that direction as far as Purfleet, then swung southwards through a gap in the Chalk of the Purfleet Anticline, ultimately to resume its eastward heading (Fig. 4.18B). This interpretation explains why the Corbets Tey Gravel between Ockendon and Purfleet occupies the Mar Dyke valley and why it is banked against the northern side of the Chalk ridge at Purfleet: it is apparent that the Mar Dyke tributary has adopted this abandoned part of the early, sinuous Thames valley. An explanation is also provided for the palaeocurrent data from Purfleet, which records the westward flow between the two 180° bends in the valley (Fig. 4.18). In support of this interpretation is the fact that the wide and almost continuous belt of Corbets Tey Gravel between Ilford and Ockendon, clearly forming a terrace of the Thames, cannot be traced eastwards beyond Ockendon, as a higher area of bedrock stands in the way. Furthermore, the Mar Dyke valley upstream from the Corbets Tey Gravel outcrop is entirely devoid of gravel; there is nothing to indicate that this stream is of sufficient antiquity to have deposited any part of the Purfleet sequence and no evidence that it ever laid down substantial pre-Holocene sediments.

Deposits ascribed to a north-bank tributary of the Thames, perhaps ancestral to the Mar Dyke, were described by Hinton and Kennard (1900); this description probably pertains to the deposits located at around TQ 610790 (Fig. 4.21). These deposits occupy a 'col' to the north of Grays that separates two spreads of Orsett Heath Gravel capping the ridge formed by the Purfleet Anticline. Brickearth has been mapped here (Geological Survey, Sheet 271; Fig. 4.21), presumably corresponding to loams and clays described in the upper part of the Hinton

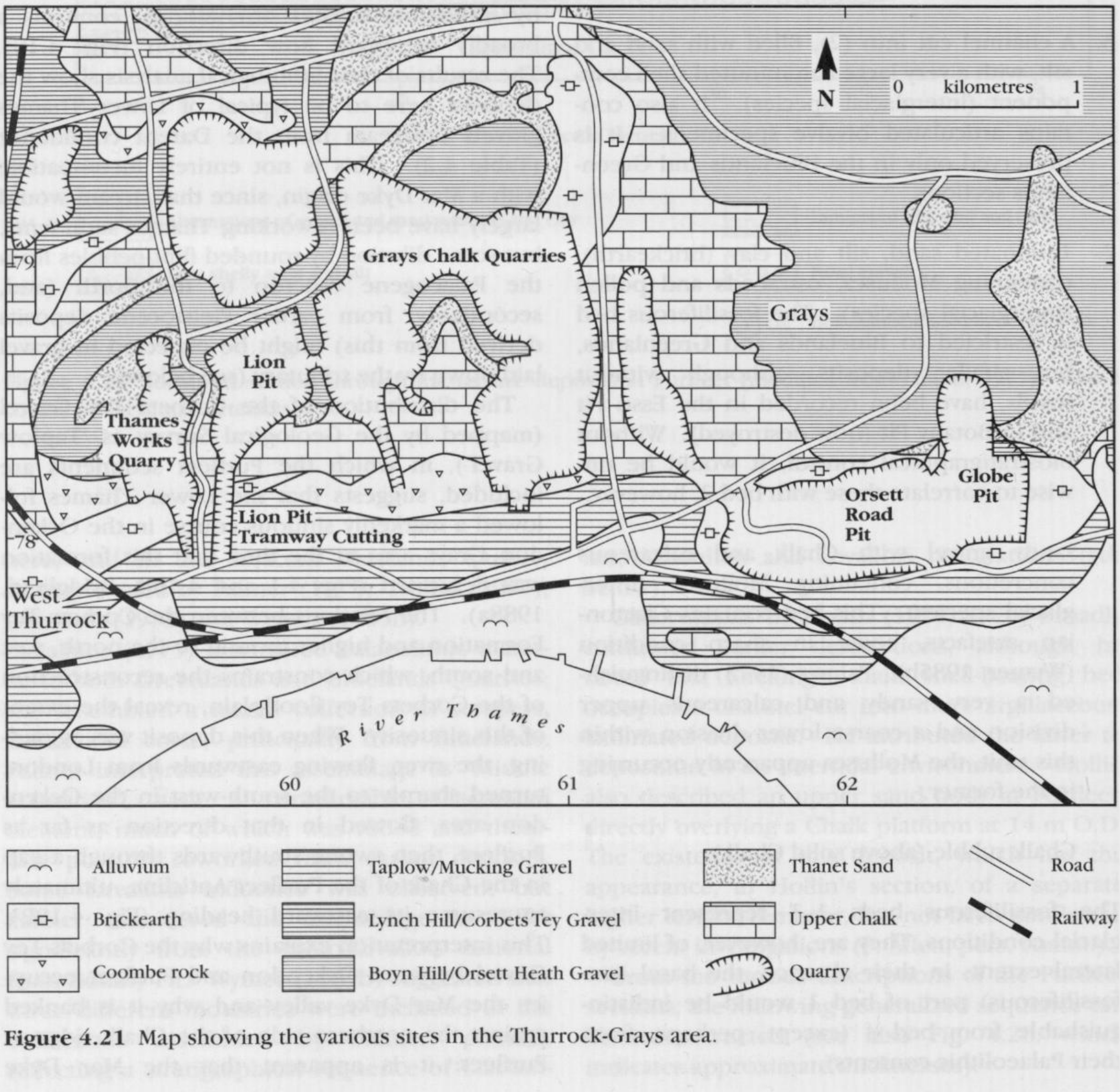


Figure 4.21 Map showing the various sites in the Thurrock-Grays area.

and Kennard section. Beneath this material was up to 2 m of gravel, largely composed of rounded flint pebbles (from the Palaeogene), but with some subangular flint. Rocks foreign to the area, of the type that characterize the Lower Thames gravels, were conspicuously scarce. The sequence fills a north–south-trending channel cut into the Thanet Sand (Hinton and Kennard, 1900). These deposits, of uncertain age, are clearly very different to the gravels (including those at Purfleet) that occupy the sinuous Thames course described above; this fact lends support to the argument that the Purfleet deposits are products of the main river.

Hollin (1971, 1977) ascribed laminated silts in the lower part of the Greenlands succession (bed 2) to an intertidal environment, suggesting that this part of the Lower Thames was within the estuarine zone at the time of their deposition. However, Robinson (in Hollin, 1977) recorded various freshwater ostracods from these laminated deposits, although specimens of *Cyprideis torosa* (Jones) from the later shelly channel-fill (bed 3) show the tuberculate ornament that this species develops in brackish conditions. Allen (1977) recorded further evidence for deposition in a slightly brackish environment, in the form of ostracods and foraminifera from a shelly seam within the laminated beds at Greenlands Quarry (bed 2). This seam also yielded the remains of insectivores, rodents, amphibians and fish (Palmer, 1975; Allen, 1977). A herpetofauna from the site has been recorded recently by Holman and Clayden (1988).

Stratigraphy and correlation

Very different stratigraphical interpretations of the Purfleet locality have been put forward, depending on whether terrace stratigraphy, archaeology or palaeontology have been given priority as evidence for relative dating. From the molluscan evidence, Snelling (1975) concluded that the interglacial deposits at Greenlands were of Hoxnian age. This view was based principally on the occurrence of the freshwater snail *Valvata antiqua* (Morris), not known from post-Hoxnian sediments (Castell, in Snelling, 1975). However, he observed that the deposits appeared to belong to the same terrace as the gravel at Botany Pit, which had yielded an abundant Proto-Levallois industry that he was reluctant to accept as of Hoxnian age. He therefore suggested that the upper (post-interglacial) part of the Greenlands sequence and the Palaeolithic gravel at Botany Pit were lateral equivalents and that they were of post-Hoxnian age.

Palmer (1975) likened the Palaeolithic assemblage from Bluelands Quarry to the Acheulian industry in the Middle Gravel at Swanscombe, thus supporting correlation with the Hoxnian. In a reappraisal of Palmer's findings, Wymer (1985b) concluded that three separate Palaeolithic industries were represented amongst her collection. He recognized Clactonian elements, generally somewhat abraded, from within and immediately above the shelly deposits (in beds 1–3 and in the lower part of 4). In the latter context (lower bed 4), he also recognized abraded Acheulian material. A Levallois flake was attributed to the highest gravel layer (upper bed 4) (Fig. 4.20). In a similar reappraisal of the records of finds in Botany Pit, Wymer (1985b) noted that sharp hand-axes occurred at the base of the gravel there, immediately above the Chalk. He suggested that these pre-date the Levalloisian material from the site. Thus there is archaeological support for the correlation of the gravel at Botany Pit with bed 4 of the general Purfleet sequence, in which Levallois artefacts also appear in the upper levels. This concurs with Snelling's (1975) suggestion that the Levallois material post-dates the interglacial beds. The implication that Palaeolithic assemblages may occur in a meaningful stratigraphical sequence in the Corbets Tey Gravel is potentially of great significance (see below, Globe Pit).

Hollin (in Palmer, 1975; Hollin, 1977) collected pollen samples from the laminated deposits (bed 2) in Greenlands Quarry, but obtained well-preserved material at only four levels. Analysis of these pointed to pollen biozone II of an interglacial, but the assemblage was insufficiently distinctive to allow correlation with either of the two post-Anglian temperate stages recognized in Britain at that time, the Hoxnian and the Ipswichian. However, Allen (in Hollin, 1977) considered that the occurrence, at Purfleet, of the bivalves *Unio* sp. and *Corbicula fluminalis* so early in an interglacial (biozone II) was suggestive of the Ipswichian rather than the Hoxnian. Hollin was inclined to accept this view rather than Castell's interpretation of the assemblage as Hoxnian (see above). Hollin suggested that the laminated deposits represented an estuarine phase resulting from a rapid rise in sea level in response to an Antarctic ice surge during the Ipswichian Stage.

Allen (1977) recognized that problems exist in ascribing the Purfleet sediments to either the Hoxnian or the Ipswichian Stage. He observed that if the deposits were Hoxnian, the Mollusca would indicate a late part of the interglacial (largely on the basis of a comparison with Swanscombe, where *Corbicula fluminalis* is absent from the early part of the sequence – see above, Swanscombe); this is contrary to the palynological evidence, which implies that biozone II, the early temperate phase, is represented. Conversely, Allen regarded the elevation of the deposits as too high, in comparison with Ipswichian sites elsewhere in the Lower Thames, for correlation with that stage. He suggested that 'the deposits aggraded during another interglacial between the Hoxnian and the Ipswichian' (Allen, 1977, p. 3).

Preece (1988) has contributed recently to this debate. He noted the occurrence at Greenlands of the large freshwater mussel *Margaritifera auricularia* (Spengler), which is only recorded from one other British interglacial site, namely the well-known Ipswichian deposits of Trafalgar Square. Despite this and other similarities, he pointed out that the molluscan faunas of Trafalgar Square and Purfleet show 'some striking differences' (Preece, 1988, p. 51). Preece cited, as an example, the absence of *C. fluminalis* at Trafalgar Square, in sediments that appear to derive from a similar depositional environment to that represented at Purfleet, where the species is abundant. The potential stratigraphical significance of this species, and in particular the theory that it was absent from Britain during the Ipswichian Stage (*sensu* Trafalgar Square), has been discussed in Chapter 2 (see Stanton Harcourt and Magdalen Grove).

Bridgland (1983a, 1988a) offered a reappraisal of Lower Thames terrace stratigraphy based on the traditional method of recognizing the products of the various individual terrace aggradations from their distribution and elevation. He correlated the deposits at Purfleet with the Lynch Hill/Corbets Tey Formation of the Thames and demonstrated that they were laid down by the main river, not the Mar Dyke tributary (see above). This correlation implies a mid-Saalian age (Tables 4.1 and 1.1). Despite this, Gibbard *et al.* (1988) preferred to assign the Purfleet sediments to the Mar Dyke, believing them to relate to the infilling of this tributary valley during an Ipswichian high sea-level phase. In this difference of opinions, palaeogeographical reconstructions and age determinations are closely interrelated. Bridgland (1983a, 1988a) showed that the Thames, after depositing the Taplow/Corbets Tey Gravel in what is now the Mar Dyke valley, had abandoned this course by the late Saalian Stage, when the Mucking Gravel was laid down. Therefore, if the Purfleet interglacial deposits are Ipswichian, they must be the product of the Mar Dyke and not the Thames; conversely, if they were deposited by the Thames, they must be pre-Ipswichian. Comparison with the north-bank tributary gravels that were described by Hinton and Kennard (1900; see above), strongly suggests that the Purfleet deposits are of Thames origin, which, as pointed out above, carries the implication of a pre-Ipswichian age for the interglacial beds at Bluelands and Greenlands Quarries.

A further indication of the age of the Purfleet deposits has been obtained by the amino acid analysis of shells from the locality. The results of preliminary work of this type suggested that specimens of *C. fluminalis* from Purfleet (which gave D-alloisoleucine : L-isoleucine ratios of between 0.33 and 0.39) were the oldest of any from the Lower Thames, including examples from the Swanscombe Middle Gravel and from Stoke Newington (Miller *et al.*, 1979). These findings have been broadly confirmed by Bowen *et al.* (1989), who published a ratio of 0.34 (± 0.24) based on two *Bithynia* shells from Purfleet. The large standard deviation of the latter ratio, however, suggests that it could be imprecise. Bowen *et al.* also published an updated *Corbicula* ratio of 0.38 (± 0.07) from the shelly gravel at Greenlands and Bluelands. These ratios are comparable with results from sites attributed to the Cromerian Stage (Bowen *et al.*, 1989). These data must be misleading, since the deposits cannot pre-date the diversion of the Thames into the valley through London (and Purfleet) during the Anglian Stage. These high amino acid ratios may, however, lend support to the view that the Purfleet deposits are of pre-Ipswichian age, since shells from sites attributed to that stage (Trafalgar Square and Bobbitshole, for example) have given uniformly low ratios, in the range 0.09 to 0.13 (Bowen *et al.*, 1989).

From an examination of the various published descriptions and discussions of the Purfleet sediments, it is apparent that they have been correlated with practically every other interglacial site in the Lower Thames at one time or another. Those who favoured an older, Hoxnian age have suggested correlation with the Swanscombe Middle Gravel (Palmer, 1975), but those favouring an Ipswichian age have broadly linked the site with Ilford, Aveley, West Thurrock, Crayford and even Trafalgar Square (Hollin, 1977; Gibbard *et al.*, 1988), despite the fact that the Purfleet deposits form part of a different, higher terrace to all of these (Fig. 4.3).

There are, however, other interglacial sediments associated with the Corbets Tey Gravel, at Grays and Little Thurrock (see below, Globe Pit), at Belhus Park (Wymer, 1985b) and near the type locality at Corbets Tey (Ward, 1984). It is also likely that the complex of sites at Stoke Newington, discovered in the last century (Smith, 1883, 1894; Wymer, 1968; Kerney, 1971; Harding and Gibbard, 1984), belong to the Lynch Hill/Corbets Tey Formation. Amino acid ratios from specimens of *Corbicula* from Stoke Newington and Hackney support a correlation with Grays (Miller *et al.*, 1979), although similar ratios were also obtained from Swanscombe, considered here to be older. All the above sites, perhaps significantly, have yielded *Corbicula fluminalis*.

A borehole at Corbets Tey (TQ 550850) produced a very similar molluscan fauna to that from Greenlands, as well as plant, ostracod, small vertebrate and insect remains (Ward, 1984). The presence of the gastropod *Hydrobia* cf. *ventrosa* (Montagu) and the ostracod *Cyprideis torosa* provides evidence for estuarine or brackish conditions (Ward, 1984). Old records (in Wymer, 1985b) of a gravel pit at Gerpins (TQ 555840), 1 km to the south-west, appear to describe organic deposits containing wood beneath 8 m of sand belonging to the Corbets Tey Formation. A correlation of these deposits with that at Belhus Park, 3.5 km further to the south-east, was suggested by Wymer (1985b). Eight hand-axes are recorded from Gerpins Pit (Wymer, 1985b), possibly representing a lateral equivalent of the assemblage from Purfleet. The Corbets Tey, Gerpins Pit and Belhus Park sites are associated with a major channel feature within the Corbets Tey Gravel outcrop, revealed by borehole data (P.L. Gibbard, pers. comm.). According to Gibbard, this channel is excavated through the Corbets Tey Gravel and was filled during the Ipswichian Stage by Mar Dyke deposits. However, at Belhus Park the interglacial sediments were seen to be sandwiched between gravels, both apparently of Corbets Tey type. The upper gravel, in addition to containing a full suite of Thames far-travelled lithologies (Table 4.2), also yielded a number of Palaeolithic artefacts, some in very sharp condition (Wymer, 1985b). According to Wymer, these artefacts, Acheulian hand-axes and cleavers, 'cannot have been derived from any earlier deposit and must be contemporary with the aggradation that produced the gravel overlying the organic deposit' (1985b, p. 314). Artefacts of this type would be out of place in a post-Ipswichian context (see Wymer, 1988). It is therefore considered likely that the interglacial sediments at Belhus Park are pre-Ipswichian Thames deposits. Further evidence in support of this view has recently come to light, from amino acid analyses of shells from the Belhus Park interglacial deposits (Bowen, 1991; see below).

In the revised stratigraphical scheme for the Thames terrace system presented in Chapter 1, the interglacial represented within the Lynch Hill/Corbets Tey Formation is correlated with Oxygen Isotope Stage 9 (Table 1.1). The Purfleet sediments provide important evidence with regard to this interpretation. Despite many suggestions that they are Hoxnian, they have been differentiated from that stage, as represented at Swanscombe, on the basis of differences in the molluscan faunas from the two sites and their comparison with the record for vegetational history during the Hoxnian, derived from the Clacton sequence (Allen, 1977; see above, Swanscombe). An Ipswichian (*sensu* Trafalgar Square) age, still favoured by some authors (Gibbard *et al.*, 1988), may be ruled out by the presence of *Corbicula fluminalis*, which appears to have been absent from the Thames valley during that stage (Chapter 2, Stanton Harcourt and Magdalen Grove). Notwithstanding these biostratigraphical arguments, sediments that are attributed to these two established stages form part of different terrace formations to that (the Wolvercote/Lynch Hill/Corbets Tey Formation) recognized at Purfleet (Table 1.1). Terrace stratigraphy, taken in isolation, suggests correlation of the Purfleet interglacial sediments with those at Wolvercote, Stoke Newington, and Grays and Little Thurrock (Table 1.1). The same line of evidence suggests that all these were laid down during the second of four post-Anglian interglacials (Fig. 4.3); the correlation of the Anglian with Oxygen Isotope Stage 12 therefore points to a Stage 9 age for the Purfleet deposits and their correlatives (see Chapter 1 and Table 1.1). Recently, amino acid ratios have been obtained from shells from the interglacial deposits at Belhus Park, described above. These ratios (0.26) support the correlation with Stage 9 (Bowen, 1991). The corroboration (or otherwise) of the above correlations, on biostratigraphical grounds or from additional amino acid analyses, must await further research on these various deposits.

Summary

The complex of pits at Purfleet together constitute one of the most important localities for the reconstruction of Thames drainage development. They provide evidence from every discipline of relevance to Pleistocene stratigraphy. In particular, important Palaeolithic and molluscan assemblages from different parts of the composite site provide significant stratigraphical and palaeoenvironmental evidence. The site has long been recognized as possibly representative of an undefined and unnamed temperate interval between the Hoxnian and Ipswichian. There is still considerable controversy about whether the sediments at Purfleet, which belong to the Lynch Hill/Corbets Tey Formation, represent a post-Hoxnian/pre-Ipswichian temperate episode or a partly estuarine valley-fill of Ipswichian age. There is also a closely related dispute as to whether the deposits are the product of the Thames or of the tributary Mar Dyke stream. In fact, several lines of evidence combine to suggest that the temperate deposits at Purfleet correlate with Oxygen Isotope Stage 9. Phases 3 (interglacial) and 4 (post-interglacial) of the model for terrace formation (proposed in Chapter 1) are clearly well-represented at Purfleet, by the various fossiliferous sediments and the overlying gravels of bed 4 (respectively). It seems likely that the unfossiliferous lower division of bed 1, recorded by Palmer (1975), represents phase 2 of the model, therefore dating from the end of Stage 10 (the same age as the gravel at the Globe Pit site – see below). The importance of the fossiliferous beds at Purfleet is heightened by the destruction of the last remaining exposures of the Grays brickearth (see below, Globe Pit), which is also considered to have accumulated during Oxygen Isotope Stage 9.

Conclusions

The various sections at Purfleet can be pieced together to provide a detailed record of the sediments that make up the Corbets Tey Gravel, which forms the second of the three terraces preserved on the Essex side of the Lower Thames valley. The picture that emerges is one of widespread cold-climate gravel aggradation, following the more localized deposition of fossiliferous sediments during an interglacial. The gravels contain Lower Palaeolithic (early Stone Age) flint artefacts – these are particularly abundant at the Botany and Esso Pits. The lowest gravels, beneath and/or part of the interglacial beds, contain artefacts belonging to the early and rather primitive Clactonian industry, whereas the later gravels contain the important addition of later types, including material flaked using the 'Levallois technique' (a distinctive method of flint working that produced artefacts of characteristic types). This appearance of Levallois material, implying the first use of this technique after the interglacial represented at Purfleet, is the earliest in the Lower Thames sequence and is of considerable stratigraphical importance.

The age of the interglacial at Purfleet is controversial. On the basis of rather meagre pollen evidence it has been correlated with the last interglacial, only 120,000 years BP. This view is contradicted by the rich molluscan assemblage from Bluelands and Greenlands Quarries, which indicates that the sediments are older than the accepted last interglacial site at Trafalgar Square. The relations of this site to the terrace sequence in the Lower Thames suggests that the second of four post-Anglian interglacials is represented at Purfleet, implying correlation with Stage 9 of the deep-sea record and an age of around 300,000 years BP.

GLOBE PIT, LITTLE THURROCK (TQ 625783)

D.R. Bridgland

Highlights

Globe Pit provides important evidence that contributes to the stratigraphical record of the Lower Thames terrace sequence and, in particular, to the parallel record of Palaeolithic occupation in southern Britain. A gravel here, the feather-edge of the Lynch Hill/Corbets Tey Formation, yields a prolific Clactonian industry. The occurrence of this industry, which has been regarded as 'early' within the Lower Palaeolithic, within deposits formerly ascribed to the 'Middle Terrace', has long been regarded as anomalous. The fact that hand-axes occur at higher-level sites such as Swanscombe has given rise to interpretations of the Lower Thames sequence involving complex fluctuations of base level. Consideration of the relations between these artefact-bearing deposits and fossiliferous sediments elsewhere in this and other terrace aggradations suggests that the gravel at Globe Pit is indeed slightly later than the Swanscombe sequence, probably dating from the latter part of Oxygen Isotope Stage 10 (early Saalian).

Introduction

Globe Pit is the first of two sites in the Grays area, a district famous for the fossiliferous Pleistocene brickearth (a mixture of silts, sands and clays) that was exploited there until early in the present century. Two main spreads of brickearth appear on the Geological Survey map (Sheet 271) in the vicinity of Grays, one at West Thurrock and the other at Little Thurrock (Fig. 4.1). A third spread to the north of Grays (around TQ 611793; Fig. 4.21) is not part of the fossiliferous Thames brickearth, but overlies north-bank tributary gravels (Hinton and Kennard, 1900; see above, Purfleet) and has itself been attributed to an ancestral Mar Dyke (Dewey *et al.*, 1924). The Chalk quarry at Globe Pit was an extension of early workings in the Little Thurrock brickearth spread.

The brickearth of the Grays area has generally been associated with the 'Middle Terrace' of the Lower Thames, mapped by the Geological Survey as 'Taplow Gravel', but now recognized as Corbets Tey Gravel and correlated with the Lynch Hill Formation of the Middle Thames (Bridgland, 1988a; Gibbard *et al.*, 1988). The term brickearth is in this instance applied to well-bedded, often laminated, fluviatile silts and fine sands with subordinate clay (West, 1969; Hollin, 1977).

The brickearth and associated gravels at Grays (Little Thurrock) have been studied by numerous workers over more than one and a half centuries. Early contributions included those of Morris (1836), Wood (1848), Jones (1850), Wood Jun. (1866a, 1867, 1868, 1872), Dawkins (1867), Tylor (1869), Hughes (in Whitaker, 1889, p. 420), Woodward (1890), Reid (1897), Hinton and Kennard (1900) and Dewey *et al.* (1924). A full list of previous literature describing the area was given by Hinton and Kennard (1900), much of which refers to faunal remains found in the brickearth. Of particular importance were sections in a pit south of Orsett Road, in which a highly fossiliferous lenticular bed of fine sand yielded abundant remains of molluscs and small vertebrates (Hinton and Kennard, 1900; Hinton, 1901). According to Sutcliffe and Kowalski (1976), this pit was *c.* 650 m to the west of the GCR site. It was certainly within the same terrace remnant (Fig. 4.21), suggesting that records from Grays and Little Thurrock can be considered together.

Elsewhere the Grays and Little Thurrock brickearth has yielded vertebrate remains, molluscs, ostracods, plant remains, pollen and, less frequently, Palaeolithic artefacts (Hinton and Kennard, 1900; Wymer, 1968, 1985b; West, 1969; Hollin, 1977). The principal source of palaeoliths has been Globe Pit, situated at the extreme eastern end of the brickearth spread, where a rich Clactonian industry has been recognized (King and Oakley, 1936; Wymer, 1957). The artefacts occur principally in gravels underlying the brickearth, but have also been reworked into the latter deposit (Wymer, 1957, 1968, 1985b; Snelling, 1964). The artefact-bearing gravel is believed to be part of the Lynch Hill/Corbets Tey Formation, of mid-Saalian age (Bridgland, 1988a; see above, Introduction and Purfleet). The recovery of a large Clactonian assemblage from the mid-Saalian Corbets Tey Gravel is somewhat problematic, as this industry has normally been associated with late Anglian or Hoxnian sediments, such as the Lower Gravel at Swanscombe and the Clacton Channel Deposits (Wymer, 1974; see above, Swanscombe; Chapter 5, Clacton). This has led to suggestions that the deposits at Little Thurrock are older than their position within the terrace sequence suggests (King and Oakley, 1936; Wymer, 1968).

Description

The surviving Pleistocene sediments in Globe Pit are concentrated in two areas. At the northern

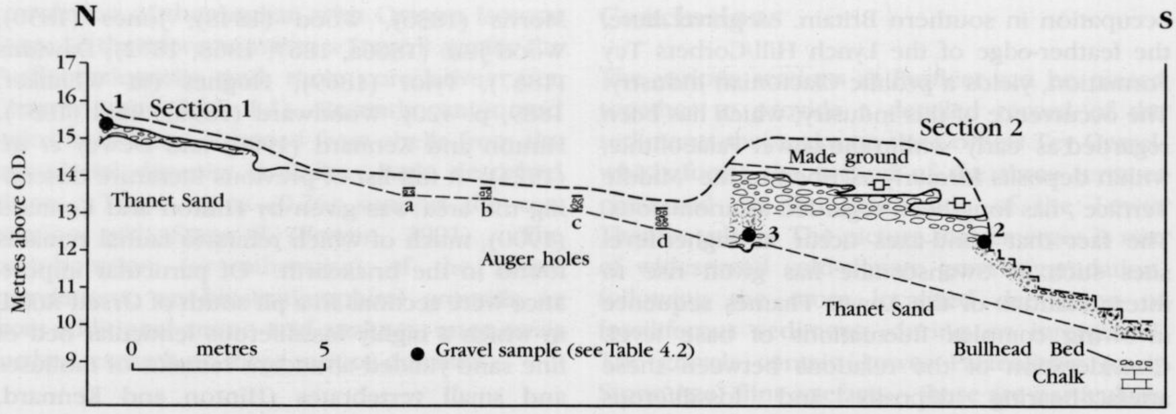


Figure 4.22 The GCR sections at Globe Pit.

edge of the site, in a small area occupied by allotments, a deposit mapped as Boyn Hill Gravel overlies Thanet Sand at 20.5 m O.D. (see Fig. 4.22). There are no clear records of artefacts from this deposit (Wymer, 1968, 1985b), which has been confirmed recently as part of the Boyn Hill/Orsett Heath Gravel Formation (Bridgland, 1988a). The Globe Pit GCR site is limited to an elevated area on the north-eastern side of a large Chalk quarry, behind the gardens on the south side of Overcliff Road, where a surviving remnant of Corbets Tey Gravel is located. In this area the Pleistocene deposits, which thin rapidly northwards, are banked against Palaeogene Thanet Sand (Fig. 4.22). The area has been partly excavated for gravel and it is difficult to ascertain how much of the original land surface remains. The gravel is overlain in the southern part of the site by a wedge of unbedded clayey sand, probably the feather-edge of the Grays brickearth (Fig. 4.22). Published descriptions of the site by West (1969) and Hollin (1977) indicate that *in situ* deposits formerly extended further south, where brickearth containing Mollusca and pollen of temperate-climate affinities occurred. Lamentably, despite the site having SSSI status since the 1950s, this fossiliferous material was entirely quarried away by 1980.

The earliest detailed description of exposures in the Pleistocene deposits at Little Thurrock was by Morris (1836), who recorded laminated beds with comminuted shell debris amongst various sediments occupying a 'valley' between the higher ground to the north (formed by the Chalk of the Purfleet Anticline) and a much lower 'ridge' of Chalk to the south. The latter was clarified by Dewey *et al.* (1924), who noted that the channel filled with brickearth is separated on its southern side from the alluvium of the modern valley by a low gravel-covered ridge of Chalk. This gravel, which was described by Tylor (1869), may form part of the Taplow/Mucking Formation (see Introduction to this chapter; Fig. 4.23).

The first published illustration of a section in Globe Pit was by Hinton and Kennard (1900, p. 364). This showed gravel and brickearth of their 'Middle Terrace Series' overlying material that, in the caption to the illustration, they termed 'Gravel and Sand washed down from [the] valley to the north (High Terrace Series derived)'. This last bed, which formed the northern edge of the Pleistocene deposits in Hinton and Kennard's section, was probably the equivalent of the gravel at the GCR site. Descriptions of the site have been provided in recent years by Wymer (1957, 1968, 1985b), Snelling (1964), West (1969) and Hollin (1977). The most detailed section through the sequence, most of which is now quarried away, was illustrated by Wymer (1985b). This showed brickearth above a lower gravel resting on Chalk at 6 m O.D. and overlain by a later gravel (Fig. 4.23). The lower gravel is shown to extend higher up the valley-side than the later sediments, where it overlies a narrow, higher 'bench' cut in Thanet Sand at 15 m O.D. Wymer (1957, 1968, 1985b) considered the gravel on this higher bench to be older than that at 6 m O.D. and regarded the deposits covering the slope between the two as of colluvial origin.

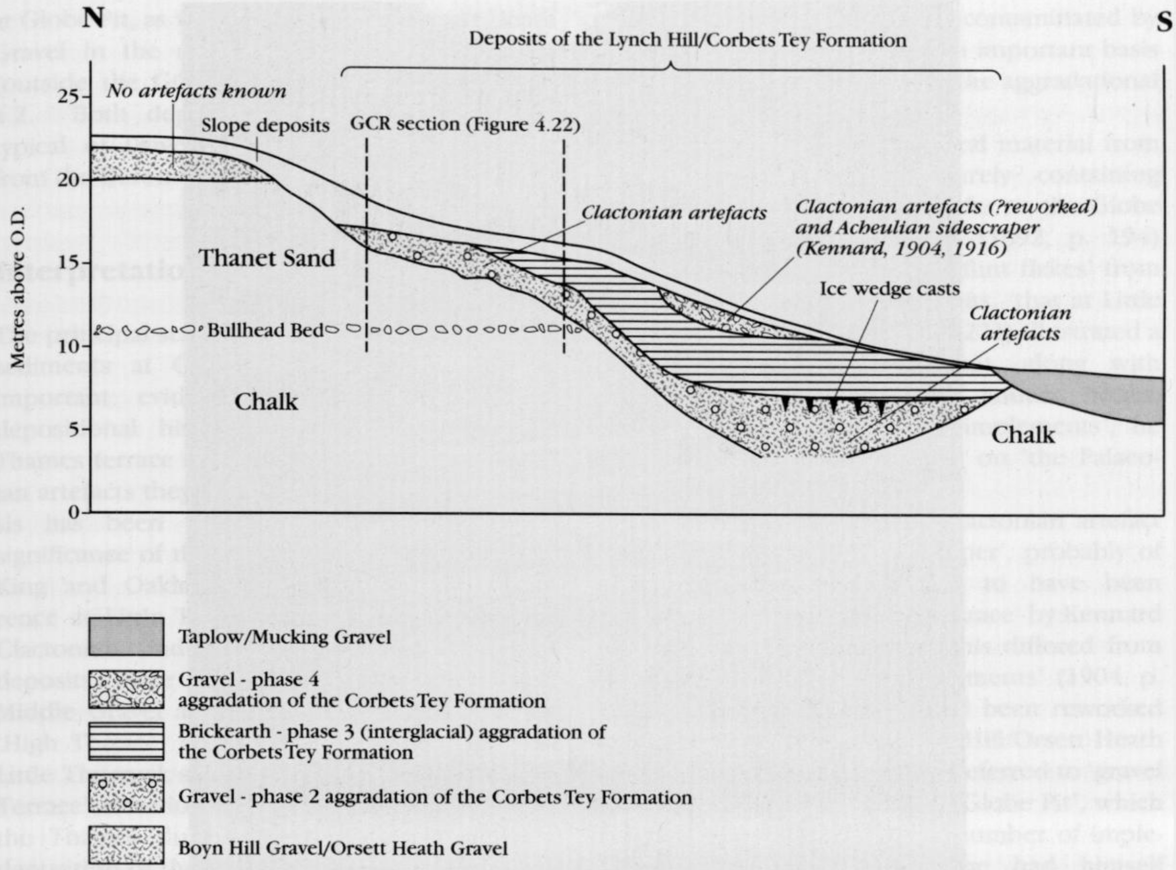


Figure 4.23 Section through the Pleistocene deposits in the area of Globe Pit (after Wymer, 1985b).

This interpretation, which was supported by West (1969) and Evans (1971), would appear to link back to the above quotation from Hinton and Kennard, who were presumably describing the same sloping gravel body.

Reappraisal of the site in 1983, as part of the Geological Conservation Review (Anon., 1984b), has raised serious doubts about this interpretation. Sections cut in the remaining deposits indicated that fluvially bedded sand and gravel, albeit with penecontemporaneous deformation structures, can be traced to below 10 m O.D. (Figs 4.22 and 4.24). Although the deposits further south, which extended down to 6 m O.D. (and, according to Tylor (1869), to well below ordnance datum), have now been quarried away, the GCR section extended well into the material interpreted by Wymer as a slope deposit. The recognition that *in situ* fluvial sediments extend to below 10 m O.D. leads to the suggestion that the 15 m 'bench' described by Wymer is simply the feather-edge of a much thicker aggradational sequence, that represented by the Corbets Tey Formation as a whole (see Fig. 4.23).

Wherever the Thanet Sand surface was uncovered at Globe Pit in the 1983 excavations, it proved to be extremely uneven, with what appeared to be 'potholes' in the old river bed at the base of the gravel. However, in a larger area of Thanet Sand surface that was uncovered in 1984 (section 1; Fig. 4.22), there were indications of a linear trend to the undulations. The largest of these features, at the southern end of section 1, appears to be coincident with the 'step' in the bedrock surface observed by Wymer (1957). This feature has been undercut on its northern side. Few previous descriptions of the form of bedrock surfaces beneath Pleistocene gravels have been published (see, however, Chapter 2, Wolvercote). Harding and Gibbard (1984) provided a record of similar features at

Figure 4.24 GCR Section 2 at Globe Pit, showing bedded gravel extending to below 10 m O.D. (looking north). The surveying staff rests on the exhumed Thanet Sand surface. (Photo: P. Harding.)

Stoke Newington; as at Globe Pit, these features, which otherwise resembled potholes, had a linear trend and showed undercutting. They were attributed by Harding and Gibbard to fluvial erosion of the London Clay. A similar explanation can therefore be offered for the features at Globe Pit. A summary of the tripartite sequence formerly exposed in this part of Globe Pit can therefore be given, as follows:

3. Upper gravel (now removed)
2. Fossiliferous brickearth (now removed)
1. Lower Gravel, containing Clactonian artefacts (feather-edge survives).

This sequence is assigned here to the Lynch Hill/Corbets Tey Formation. The clast-lithological contents of the basal Corbets Tey Gravel at Globe Pit, as well as those of the Orsett Heath Gravel in the northern part of the workings (outside the GCR site), are recorded in Table 4.2. Both deposits have clast compositions typical of Lower Thames gravels downstream from the Darent confluence.

Interpretation

The principal scientific interest in the remaining sediments at Globe Pit, in addition to the important evidence they provide for the depositional history and stratigraphy of the Thames terrace system, arises from the Clactonian artefacts they contain. Considerable emphasis has been placed on the stratigraphical significance of this assemblage by past workers. King and Oakley (1936) regarded the occurrence at Little Thurrock of an uncontaminated Clactonian industry as evidence that the deposits there were older than the Lower Middle Gravel at Swanscombe, which is at the 'High Terrace' level. They concluded that the Little Thurrock sediments, although at a 'Middle Terrace' elevation, filled a channel excavated by the Thames during the interval between the deposition of the Swanscombe Lower Loam and Lower Middle Gravel, during which time the upper surface of the Lower Loam was subjected to subaerial weathering (see above, Swanscombe). The well-known channel deposits at Clacton, containing the type-Clactonian industry, were attributed to the same time interval, their 'Clacton-on-Sea Stage'. This model, although rejected by Marston (in Bull, 1942), was supported by Oakley and Leakey (1937) and Warren (1955). It implied (1) that much of the 'High Terrace' (now recognized as Boyn Hill/Orsett Heath Gravel), which contains Acheulian hand-axes, was younger than the 'Middle Terrace' deposits at Little Thurrock; (2) that aggradation had been continuous, following deposition of the Little Thurrock deposits, until reaching the highest level of the 'High Terrace', at *c.* 42 m O.D. at Dartford Heath; and (3) that the geomorphological 'Middle Terrace' feature had resulted from a combination of erosion and deposition, as the river subsequently incised its valley for a second time to the 'Middle Terrace' level. The Clactonian industry was, until recently, considered to appear earlier in Britain than the Acheulian (see Wymer, 1974), so its presence at Little Thurrock, uncontaminated by Acheulian material, provided an important basis for the above interpretation of the aggradational sequence.

Early records of archaeological material from Little Thurrock, although rarely containing details of location, probably refer to the Globe Pit or sites nearby. Spurrell (1892, p. 194) described 'numerous "waster" flint flakes' from the easternmost of the Grays pits, 'that at Little Thurrock', and Smith (1894, p. 271) illustrated a 'worked' red deer antler that, along with numerous other fragments of antlers, bones, tusks, and 'keen flakes and implements', he claimed to have found *in situ* on 'the Palaeolithic floor at Little Thurrock'.

The only record of a non-Clactonian artefact from the site is of a 'side scraper', probably of Acheulian affinities, reported to have been found *in situ* in the 'Middle Terrace' by Kennard (1904). He recognized that this differed from 'the true Middle Terrace implements' (1904, p. 112) and suggested that it had been reworked from the 'High Terrace' (Boyn Hill/Orsett Heath Gravel). Kennard (1916) later referred to 'gravel overlying the brickearth at the Globe Pit', which he claimed to have yielded a number of implements, including the one he had himself described in 1904. This presumably refers to the upper gravel figured by Wymer (1985b; Fig. 4.23), a record based largely on unpublished observations in the mid-1960s by B.W. Conway. This is an important record, as it indicates that the non-Clactonian artefact was from a different gravel to that which has yielded the extensive Clactonian assemblage (see below).

King and Oakley's (1936) correlation of the Little Thurrock sediments, and the artefacts they contain, with those at Clacton was reaffirmed by Warren (1942, 1955), who further suggested (1947) that the incision event represented by the channels at Grays and Clacton also preceded the aggradation of his 'Furze Platt Stage' deposits in the Maidenhead area. This is an interesting suggestion, since both the Furze Platt deposits (see Chapter 3, Cannoncourt Farm Pit) and the artefact-bearing gravel at Globe Pit are now believed to be part of the Lynch Hill/Corbets Tey Formation (Table 1.1).

Wymer (1957) pinpointed the source of Clactonian artefacts at Little Thurrock to a small remnant of gravel overlying a 'bench' at 49 ft (15 m O.D.) in the north-eastern corner of

Globe Pit (approximately coinciding with the GCR site). He collected 289 flakes and five 'chopper-cores' from this gravel. Many of the former show secondary working and over half are in mint or fairly sharp condition, indicating minimal transport prior to incorporation in the gravel (Wymer, 1957, 1968). No Acheulian implements or finishing flakes were encountered, leading Wymer to conclude that the collection represents a single industry, with no admixture of material from any other. Wymer's sections were reopened and extended in 1961 by Snelling (1964), when some 280 worked flints were obtained, including two hammerstones, two waste cores and very occasional core-tools similar to those described by Wymer.

Hart (1960), who also described the deposits at Globe Pit, recorded a sequence of brickearth with gravelly partings, with Clactonian artefacts occurring in the latter. In an undated, unpublished report on file with English Nature, Hart recorded gravel containing Clactonian artefacts and mammalian remains occupying a channel with a base level of 6.5 m O.D., well below the level of the 'bench' described by Wymer (1957). The former existence at this level of deposits yielding (mainly sharp) Clactonian material has been confirmed recently by Wymer (1985b; Fig. 4.23).

Biostratigraphy and correlation

Even before the discovery of a Clactonian industry at Little Thurrock, a number of authors had concluded from its mammalian fauna that the Grays brickearth was of a greater age than had usually been attributed to deposits of the 'Middle Terrace' (Hinton, 1910, 1926a, 1926b; Kennard, 1916; Warren, 1923a). Hinton (1910, 1926a, 1926b) placed considerable emphasis on evidence from small mammals in support of this conclusion. This view was perpetuated in the stratigraphical model of the Lower Thames terraces proposed by King and Oakley (1936), who correlated the Little Thurrock deposits with the hiatus between the Lower Loam and Lower Middle Gravel at Swanscombe (see above). Since the Swanscombe sequence has been almost universally ascribed to the Hoxnian Stage (Sutcliffe, 1964; Kerney, 1971), a Hoxnian age for the Little Thurrock deposits is implied by this interpretation. Kerney (1959b) also considered a Hoxnian age to be likely on the basis of similarities between the molluscan fauna at Grays and that in the Swanscombe Middle Gravels. Many elements of the characteristic assemblage from the Middle Gravels at Swanscombe (see above) also occur in the Grays collections; an example is the woodland snail *Macrogastra ventricosa* (Draparnaud), which is restricted, within the Thames system, to these two localities.

The western tract of brickearth in the Grays district was considered by some early workers to be of a later age than that at Little Thurrock, as it yielded different mammalian species (particularly voles) and was associated, at West Thurrock, with a Levallois industry (Kennard, 1916; Warren, 1923a, 1923b; see below, Lion Pit). Both sets of deposits have, however, been attributed in recent years to the Ipswichian Stage, principally on the basis of palynology (West, 1969; Hollin, 1977; Gibbard *et al.*, 1988). West (1969) obtained pollen from the brickearth at Globe Pit (now destroyed), which was banked against the gravel that yields Clactonian artefacts (Fig. 4.23). He recorded a section similar to that described by Hart, with a base level of 9 m O.D., comprising up to 0.5 m of gravel, overlain by 3 m of brown silt and sand (brickearth) containing *Corbicula fluminalis*. The pollen showed the brickearth to have accumulated under interglacial conditions, but was insufficiently diagnostic to distinguish between the Hoxnian and Ipswichian Stages, both possible interpretations on the basis of the molluscan evidence. However, since brickearth at comparable elevations at Aveley and Ilford, respectively 8 km and 19 km upstream, had yielded Ipswichian pollen sequences (West *et al.*, 1964; West, 1969), West favoured a similar age for the Little Thurrock deposit. This suggestion was disputed by Conway (1970b), who regarded the Clactonian artefacts, found throughout the lower gravel and in the brickearth (Fig. 4.23), as evidence for a Hoxnian age, as originally implied by King and Oakley.

The rich mammalian fauna from the Grays and Little Thurrock brickearth, although much celebrated by early collectors (lists were supplied by Whitaker (1889), Hinton and Kennard (1900) and Hinton (1926b)), has failed to provide clear biostratigraphical evidence for the age of the deposits. It has therefore been possible to reconcile the assemblage with attributions to both the Hoxnian and Ipswichian stages. The view that this eastern spread of brickearth is older than that to the west of Grays (Kennard, 1916; see below, Lion Pit) has, however, persisted (see Wymer, 1985b). The record of hippopotamus from Little Thurrock is of considerable significance, as it would seem to indicate correlation with the Ipswichian Stage (*sensu* Trafalgar Square); however, the record of horse from the same deposit appears to be contradictory, since that animal is believed to have been absent during the Ipswichian – as was the bivalve *Corbicula fluminalis*, also present at Little Thurrock (Chapter 1; Chapter 2, Stanton Harcourt and Magdalen Grove). Wymer (1985b) noted that there are many difficulties in assessing the early faunal collections from the Grays district, as the precise provenance of many specimens is unknown. He was therefore inclined to dismiss the record of hippopotamus from the Little Thurrock brickearth. There is considerable justification for this revision: Abbott (1890) had recorded hippopotamus remains from West Thurrock (although this record must also be regarded as doubtful – see below, Lion Pit) and Hinton and Kennard's (1900) faunal assemblage for the Grays deposits, the basis of most later lists, was an amalgamation of records from West Thurrock and Grays and Little Thurrock. Only later did these authors realize that the brickearths to the west and east of Grays were of different ages (Kennard, 1916; above). In fact, hippopotamus appears in faunal lists from most fossiliferous sites in the Lower Thames, including Swanscombe, where the record was based on a single fragment (subsequently discredited by the analysis of its fluorine content (Oakley and Gardiner, 1964; Sutcliffe, 1964)). Thus Hinton (1926a, p. 339), referring to two of the rare exceptions, was able to state that 'Hippopotamus ..., so characteristic of the earlier Thames horizons, [has] not been found at Crayford or Erith'. The opposite view would now be taken; hippopotamus is currently regarded as present only in the latest of the Thames interglacial deposits (Chapter 1).

Hollin (1971, 1977), who obtained further supplementary pollen samples from Globe Pit and elsewhere in the Grays brickearth (*sensu lato*), considered their high pine and low birch frequencies to support West's correlation of the deposits with the Ipswichian Stage. He interpreted the brickearth as a tidal deposit and suggested that, as at Purfleet (see above), it recorded estuarine aggradation to 14 m O.D. in response to a rise in sea level brought about by an Antarctic ice surge during the Ipswichian. The interpretation of this and other sites as representing the infilling of the Lower Thames valley during an Ipswichian sea level rise has recently been supported by Gibbard *et al.* (1988).

The correlation of the Grays and Little Thurrock sediments with the Ipswichian Stage is not supported by amino acid ratios from shells from the early collections (Miller *et al.*, 1979; Bowen *et al.*, 1989). Both sets of authors obtained D : L ratios of around 0.29 (using the genera *Corbicula* and *Bithynia*) and both grouped the site with Swanscombe, which, according to the interpretation of Bowen *et al.* would imply correlation with Oxygen Isotope Stage 11 (see above, Swanscombe; Chapter 1).

Terrace stratigraphy

Bridgland (1983a) considered the Little Thurrock sequence to fall within his Barvills Gravel, which was later reclassified as Corbetts Tey Gravel (Bridgland, 1988a; Gibbard *et al.*, 1988). This formation was correlated by Bridgland (1988a) with the Rochford Gravel of the Southend area, implying correlation of the basal gravel and interglacial sediments (brickearth) at Little Thurrock with the Rochford Channel Gravel and Rochford Channel interglacial deposits respectively. This correlation has recently been retracted, the Corbets Tey Gravel now being regarded as equivalent to the Barling Gravel of the Southend area (Bridgland *et al.*, 1993; see Chapter 5, Part 2). The channel at Grays, recognized by early workers such as Morris (1836), Tylor (1869) and Dewey *et al.* (1924), is thus regarded as an upstream equivalent of the Shoeburyness Channel. Since the Corbets Tey Gravel is correlated with the mid-Saalian Lynch Hill Formation of the Middle Thames (Bridgland, 1988a), this interpretation provides a stratigraphical argument for an intra-Saalian age for the Grays interglacial (Table 1.1).

The above correlations provide the basis for part of the revised stratigraphical scheme for the Thames terrace sequence presented in Chapter 1. Besides the Shoeburyness Channel Deposits, which have been investigated in detail only very recently (H.M. Roe, pers. comm.), the Little

Thurrock interglacial sediments are considered, according to this scheme, to correlate with temperate-climate deposits at Stoke Newington, Corbets Tey, Belhus Park and Purfleet, all of which have yielded comparable molluscan faunas with *C. fluminalis* (see above, Purfleet; Table 1.1).

The Globe Pit GCR site, however, retains little if any evidence to bear on the age of the Grays interglacial. Its main importance, as stated above, stems from the Clactonian artefacts that occur in the gravel underlying the interglacial beds. This gravel (bed 1, above) is presumed to represent the pre-interglacial aggradational phase (phase 2) of the Lynch Hill/Corbets Tey Formation, according to the climatic model for terrace formation presented in Chapter 1. The equivalence of the gravel underlying the brick-earth and that from which Wymer (1957) and Snelling (1964) obtained Clactonian artefacts was demonstrated by the GCR excavations. The gravel that was observed above the brickearth (Kennard, 1916; Wymer, 1985b; Fig. 4.23) is assumed to represent the post-interglacial (phase 4) part of the formation (and is therefore equivalent to the upper gravel at Belhus Park – see above, Purfleet). According to the strati-graphical scheme favoured here, this later gravel dates from Oxygen Isotope Stage 8, whereas the gravel with Clactonian artefacts dates from Stage 10; the interglacial beds are attributed to Stage 9 (Fig. 4.3).

The interpretation outlined above clearly implies that the Clactonian artefact-bearing gravel (bed 1) at the GCR site post-dates the higher-level Orsett Heath Gravel, which contains hand-axes, thus refuting the stratigraphical significance of the former industry. Of probable relevance to this argument is the recovery of two possible hand-axe finishing flakes in abraded condition from the GCR excavations (Bridgland and Harding, in press), which appears to confirm that the Little Thurrock gravel post-dates hand-axe manufacture in the area. However, the question remains as to whether the Clactonian industry at Globe Pit is contemporaneous with the Corbets Tey Gravel or whether it is derived from an older deposit, of similar age to the Swanscombe Phase I sediments. The balance of evidence suggests that the Globe Pit assemblage results from the accumulation, in the feather-edge of the Corbets Tey Gravel, of a vast amount of material from a nearby Clactonian working site. The Corbets Tey Formation would be expected to contain reworked Palaeolithic material from the higher Orsett Heath Gravel, which may be represented by the hand-axe finishing flakes. The relation between the age of the Clactonian working site and the age of the gravel cannot be determined. The archaeological material may have been preserved for a considerable time in an earlier deposit in the vicinity and then reworked into the Corbets Tey Gravel. The largely unabraded condition of the artefacts implies minimal transport by the Thames, which is in tune with their apparent concentration at the edge of the channel (whether they are contemporaneous or reworked).

Abraded Clactonian material has also been recognized within a mixed assemblage of artefacts from interglacial and post-interglacial deposits of the Corbets Tey Formation (phases 3 and 4) at Purfleet (Palmer, 1975; Wymer, 1985b; see above, Purfleet) and from the upstream correlative of this aggradation, the Lynch Hill Gravel of the Middle Thames (Wymer, 1988). Wymer (1988, p. 89) suggested that 'a Clactonian Industry of crude chopper-cores and flakes, without hand-axes, is present in the Lynch Hill Gravels, as several such artefacts came from this gravel at Deep Lane, Burnham'. There is mounting evidence, therefore, that the use of the Clactonian knapping technique persisted after deposition of the Swanscombe Phase I deposits. If fresh Clactonian material is restricted, in the Lynch Hill/Corbets Tey Formation, to the pre-interglacial (phase 2) deposits, the implication is that the industry persisted into the next oxygen isotope stage after that represented at Swanscombe, Oxygen Isotope Stage 10 (Table 1.1), to be replaced by Levalloisian knapping practices in Stage 8 (see above, Purfleet). The possibility that this is the case requires further stratigraphical investigation, however.

Summary

This review of previous descriptions and interpretations of the Little Thurrock site reveals that, despite considerable attention from geologists and archaeologists, the age of the deposits and their position within the Lower Thames terrace succession remains controversial. The role of Palaeolithic archaeology as a potential source of stratigraphical and relative dating evidence is currently under review. The Globe Pit industry provided an important foundation for past stratigraphical reconstructions of the Lower Thames sequence. The deposits were held to be older than their position in the 'Middle Terrace' (Corbets Tey Gravel) suggests and were frequently attributed to the Hoxnian Stage. Other workers, influenced by the relatively low elevation of the site, favoured an Ipswichian age. Interpretations of the archaeological and palaeontological evidence from these deposits have been revised in recent years and it now appears that some, perhaps all, of the early views were erroneous.

In current attempts at correlation between the Thames sequence and the deep-sea (oxygen isotope) record (Chapter 1), evidence from Globe Pit continues to be of considerable importance. In particular, the site complements the palaeontological evidence from Purfleet, which is considered to be its broad correlative. The two provide a picture of Lower Thames development during the aggradation of the Lynch Hill/Corbets Tey Gravel Formation, which appears to have occurred between Oxygen Isotope Stages 10 and 8 (inclusive).

Conclusions

The remaining deposits at Globe Pit provide an important reserve of gravel rich in Lower Palaeolithic (early Stone Age) flint artefacts of Clactonian type (named after another GCR Thames site, at Clacton in Essex). These comprise flakes and 'cores' (pieces of flint from which flakes have been removed), rather than the crafted tools that appeared in more advanced industries. The occurrence of these primitive artefacts at this site has been the subject of considerable interest for many years. The gravel here represents the middle of three terraces recognized on the north side of the Lower Thames valley, which would normally suggest that it was intermediate in age between the higher (older) terrace and the lower terrace. However, the high terrace at Swanscombe yields numerous hand-axes, part of an industry that is traditionally regarded as advanced and later than that found at Globe Pit. This led many workers to devise complex explanations of how the deposits here, at Little Thurrock, could be older than their position in the terrace sequence would seem to suggest. Reconsideration of the Lower Thames terrace sequence and the fossiliferous sediments within it, as well as the archaeological evidence from the gravels in the Lower and Middle Thames, leads to the conclusion that the gravel and the Palaeolithic industry at Globe Pit are indeed younger than the entire Swanscombe sequence. It is suggested here that they date from early in the Saalian, at around 350,000 years BP.

LION PIT TRAMWAY CUTTING (WEST THURROCK; TQ 598783)

D.R. Bridgland and P. Harding

Highlights

A spectacular Pleistocene section occurs at this site, showing interglacial deposits sandwiched between Thames terrace gravels, all banked against a fossil Chalk cliff. The entire sequence belongs to the Taplow/Mucking Gravel Formation, dating from the mid to late Saalian. The lower gravel, which is believed to date from Oxygen Isotope Stage 8, contains the slightly disturbed debris of a Levallois (Palaeolithic) working floor. The interglacial beds are attributed to Stage 7, but this is controversial, some workers regarding them as Ipswichian (Substage 5e) in age.

Introduction

This site, the second associated with the brickearth deposits of the Grays district (Fig. 4.21), is part of an old tramway cutting leading into one of the many Chalk quarries in the area. This cutting provides sections through Pleistocene deposits banked against a fossil Chalk cliff at the northern end of the site. These deposits comprise a sequence of silts and sands, possibly of intertidal origin, with an intervening bed of silty clay, thought to represent the fossiliferous West Thurrock brickearth described at the end of the last century (Whitaker, 1889; Abbott, 1890). The latter has yielded mammalian, molluscan and pollen assemblages indicative of an interglacial environment (Abbott, 1890; Hinton and Kennard, 1900; Carreck, 1976; Hollin, 1977; Gibbard *et al.*, 1988). Beneath this sequence is a basal gravel that contains, near the fossil river cliff, abundant Levallois knapping debris in a near-primary context (Warren, 1923a, 1923b, 1942). At the southern end of the cutting the above sequence is overlain by a later gravel, the stratigraphical interpretation of which is disputed (Bridgland, 1988a; Gibbard *et al.*, 1988), although it is here assigned to the Taplow/Mucking Formation.

A number of similar and, presumably, broadly equivalent sections have been described, mainly before the First World War (Whitaker, 1889; Abbott, 1890; Hinton and Kennard, 1900), although in the early 1980s a new road cutting, 0.9 km to the west of the GCR site, provided a further opportunity to study the West Thurrock sequence. Important differences between the faunal and archaeological evidence from West Thurrock and that from Grays and Little Thurrock were recognized at an early date, leading to the conclusion that the deposits at West Thurrock are the younger (Kennard, 1916; Warren, 1923a). However, following the establishment of the pollen-based stratigraphical scheme for the British Pleistocene (West, 1963, 1968; Mitchell *et al.*, 1973), many recent authors have interpreted the deposits both to the west and to the east of Grays as part of a 'Middle Terrace' Ipswichian aggradation (Carreck, 1972; Hollin, 1977; Gibbard *et al.*, 1988). Others have continued to regard the Grays and Little Thurrock deposits as older, probably of Hoxnian age (see above, Globe Pit), but the dating of the West Thurrock brickearth as Ipswichian has been widely accepted. Only with the realization that there were more temperate intervals in the Middle and Late Pleistocene than had been hitherto recognized (Chapter 1) has it been suggested that sediments such as those at West Thurrock might represent additional, unidentified interglacial episodes.

Description

The West Thurrock sequence has been exposed at a number of different locations, mainly as a result of Chalk quarrying activities (the extent of which is readily apparent on the Geological Survey map – New Series, Sheet 271), but also in railway (Holmes, 1890) and road cuttings. As with the deposits at Grays and Little Thurrock (see above), there is an extensive history of research on the West Thurrock brickearth sections. Whitaker (1889) described Pleistocene beds overlying and banked against the Chalk at several sites, including the tramway cutting at the Lion Cement Works Pit (this appears to be the earliest reference to the GCR site).

Abbott (1890) published a description of a section at the West Thurrock Tunnel Cement Works, further to the west than the sites described by Whitaker. His section showed a lower gravel overlain by thick, partly cross-bedded sands with clay seams, overlain in turn by coarse gravel. The sand was reclassified as brickearth by Dines (in Dewey *et al.*, 1924). Abbott claimed to have noticed flint artefacts (flakes) in the lower gravel and also recorded mammalian fossils from the section. These were *Palaeoloxodon antiquus*, *Mammuthus primigenius*, *Bos primigenius*, *Cervus elaphus*, *Bison*? sp., *Hippopotamus amphibius*, *Dicerorhinus kirchbergensis*, *D. hemitoechus* and *Coelodonta antiquitatis*. Abbott also described several species of mollusc from this section (see below). In recent years Abbott's faunal collection has been located and reassessed (Carreck, 1972; below). This record is of particular importance, as it is one of very few from the heyday of fossil mammal collection in the Grays area in which the West Thurrock and Little Thurrock brickearths are clearly distinguished. As noted above (see Globe Pit), most early faunal lists are amalgamations of collections from these two deposits, which were only later discovered to be of different ages. To Abbott's mammalian assemblage from the Tunnel Cement Works can be added horse, identified from the brickearth at the Thames Works Quarry (Hinton, 1901).

Hinton and Kennard (1900) described a number of sections in the western development of the Grays 'brickearths'. These were: (1) the Tunnel Cement Works (first described by Abbott, 1890), at the extreme western end of the brickearth outcrop (TQ 575777); (2) a pit west of Milwood (now Mill) Lane, first described by Whitaker (1889) and probably the pit known later as the Thames Works Quarry (Fig. 4.21); (3) the tramway cutting leading to the Lion Cement Works (the GCR site); (4) another similar section at the Grays Portland Cement Works (now within the large area of the Grays Chalk Quarries – Fig. 4.21); and lastly (5) a new excavation at the Lion Works, south of the road (and therefore, south of the GCR site), where 4 m of coarse, poorly stratified gravel was observed. This gravel was presumed to overlie the brickearth exposed in the Lion tramway cutting, a relationship that was confirmed in the recent road cutting (see Fig. 4.25; below).

The accuracy of these early descriptions has been largely confirmed by recent studies. Hollin (1977) excavated three profiles in the overgrown sides of the Lion Pit tramway cutting. He illustrated a section showing a Chalk cliff rising from 6 to 16 m O.D., the Chalk apparently shelving to below ordnance datum beneath the terrace deposits to the south. According to Hollin, the latter comprise (near the cliff) 9 m of sand, which is overlain further south by 2 m of clayey brickearth, in turn overlain by an upper sand, which reaches 15 m O.D. These horizons were seen to rise gently towards the cliff, with the entire section capped by 'trail' (colluvial deposits). Hollin recorded freshwater molluscs and ostracods from the base of the brickearth, although higher layers proved sterile. Attempts at obtaining pollen spectra met with little success, although a single countable sample yielded an assemblage rich in *Carpinus*, which Hollin attributed to biozone III of the Ipswichian interglacial.

In 1983/4 a new road cutting, 0.9 km to the west of the GCR site (TQ 590780), provided sections through a very similar sequence, again banked against Chalk on the southern side of the Purfleet Anticline (Fig. 4.25). This enabled the observation of large-scale sediment geometry and stratigraphical relations over the full north-south extent of the surviving interglacial sequence. The deposits here comprise *c.* 2.5 m of grey silty clay (brickearth), its upper two-thirds oxidized to brown. This overlies a massive bed of sand that was proved from 6.5 m O.D. (road level) to 7.9 m O.D. (base of the brickearth). Above the brickearth is a further sand bed, which is in turn overlain by unbedded gravelly, clayey sand of probable colluvial origin. The unoxidized part of the brickearth yields pollen spectra of Ipswichian affinities (P.L. Gibbard, pers. comm.). These deposits are unconformably overlain to the south by a well-bedded, medium to coarse sandy gravel (Fig. 4.25). The similarity of these deposits to those in the Lion Pit tramway cutting was confirmed in April 1984 by excavations at the latter site by the GCR Unit.

The main section excavated in the tramway cutting in 1984 (section 1, Figs 4.26, 4.27 and 4.28) was located at the northern limit of the

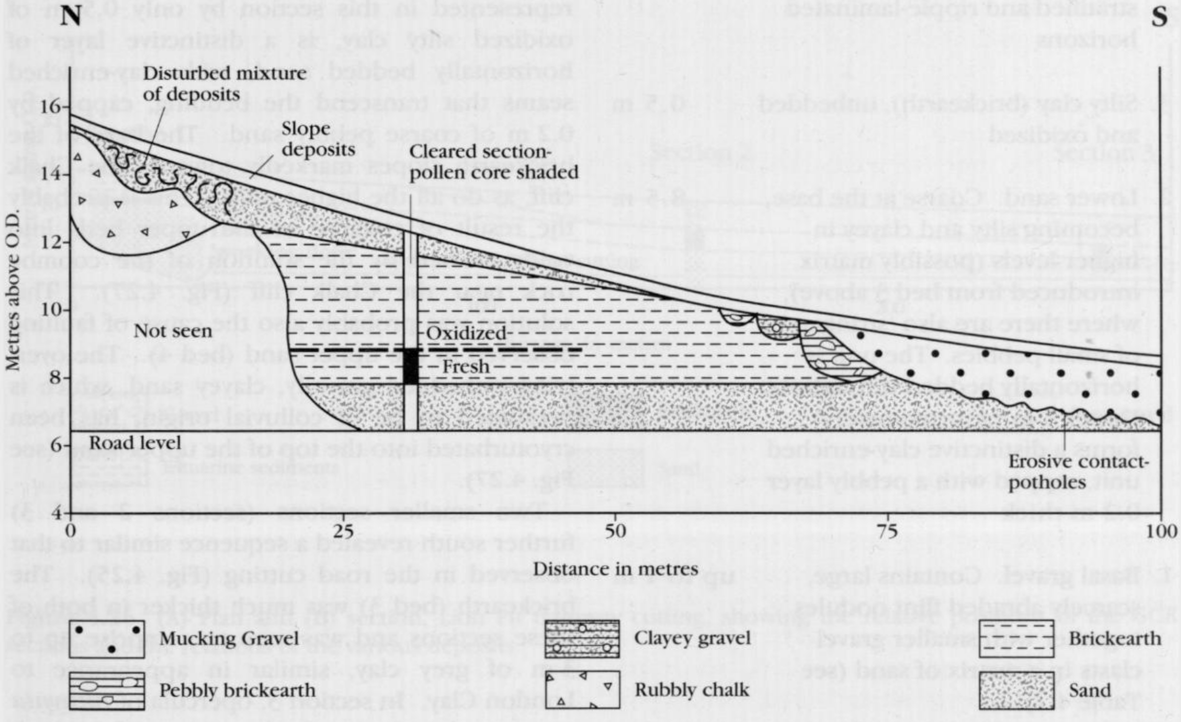


Figure 4.25 Section through the deposits of the Mucking Formation revealed in a road cutting in 1983–4.

Pleistocene deposits, where they abut against the old river cliff. It was in this area that Warren had reported a Levallois working floor. The excavation (Figs 4.27 and 4.28) revealed up to 12 m of well-bedded Pleistocene sediments overlying a surface, eroded in coombe rock, that slopes progressively southwards, although it appears to level off somewhat near the southern end of the section, where it is broken up by scour features (potholes) and/or solution hollows (Figs 4.27 and 4.29). Four separate lobes of coombe rock, the upper two disrupted by solution, project from this sloping surface and are interbedded with the waterlain sediments (Fig. 4.27). Nowhere was the junction between the coombe rock and the solid Chalk observed.

The sequence overlying the coombe rock can be summarized as follows (see also Figs 4.26 and 4.27):

	Thickness
6. Overburden: unbedded gravelly, clayey sand	
5. Upper gravel. Present in sections 2 and 3 only (see below and, for composition, Table 4.2)	up to 3 m
4. Upper sand. Interbedded fine sands and silts, including cross-stratified and ripple-laminated horizons	2.0 m
3. Silty clay (brickearth), unbedded and oxidized	0.5 m
2. Lower sand. Coarse at the base, becoming silty and clayey in higher levels (possibly matrix introduced from bed 3 above), where there are also 'stringers' of small pebbles. The unit is horizontally bedded throughout. Upper 1 m (approximately) forms a distinctive clay-enriched unit, capped with a pebbly layer 0.2 m thick	8.5 m
1. Basal gravel. Contains large, scarcely abraded flint nodules together with smaller gravel clasts in a matrix of sand (see Table 4.2).	up to 1 m
Coombe rock	

The basal gravel (bed 1) is divided into two by a thin seam of horizontally bedded sand. This shows deformation structures, including small-scale normal and reverse faults, possibly the result of settling in response to post-depositional solution of the underlying coombe rock. This basal gravel (Fig. 4.29) yields a large amount of worked flint, including characteristic Levallois artefacts of the type described by Warren (see below; Fig. 4.30). Several of the pieces collected in 1984 have been found to refit together (Fig. 4.30), supporting Warren's claim that a working site existed at West Thurrock.

The basal gravel is overlain by a thick sequence of sands, silts and clays, extending from 2 m O.D. to just over 13 m O.D. (Fig. 4.27). Within this sequence, Hollin's three divisions (lower sand, brickearth and upper sand) can be distinguished (beds 2–4). The lower sand (bed 2) is horizontally bedded throughout, but this is superficially masked by striking post-depositional ferruginous staining, which parallels the coombe rock surface (Fig. 4.27). The upper half of this bed is interbedded with the four lobes of coombe rock. Post-depositional solution of parts of the upper two of these has led to compensatory collapse and associated faulting of the overlying sediments (see Fig. 4.27).

Immediately below the brickearth, which is represented in this section by only 0.5 m of oxidized silty clay, is a distinctive layer of horizontally bedded sand, with clay-enriched seams that transcend the bedding, capped by 0.2 m of coarse pebbly sand. The base of the brickearth slopes markedly towards the Chalk cliff, as do all the higher units. This is probably the result of collapse of the upper beds into voids created by the solution of the coombe rock near the Chalk cliff (Fig. 4.27). This solution was probably also the cause of faulting observed in the upper sand (bed 4). The overlying unbedded gravelly, clayey sand, which is presumed to be of colluvial origin, has been cryoturbated into the top of the upper sand (see Fig. 4.27).

Two smaller sections (sections 2 and 3) further south revealed a sequence similar to that observed in the road cutting (Fig. 4.25). The brickearth (bed 3) was much thicker in both of these sections and was seen to comprise up to 3 m of grey clay, similar in appearance to London Clay. In section 3, opercula of *Bithynia* sp. were abundant in the lower part of this bed, but no other faunal or floral remains were re-

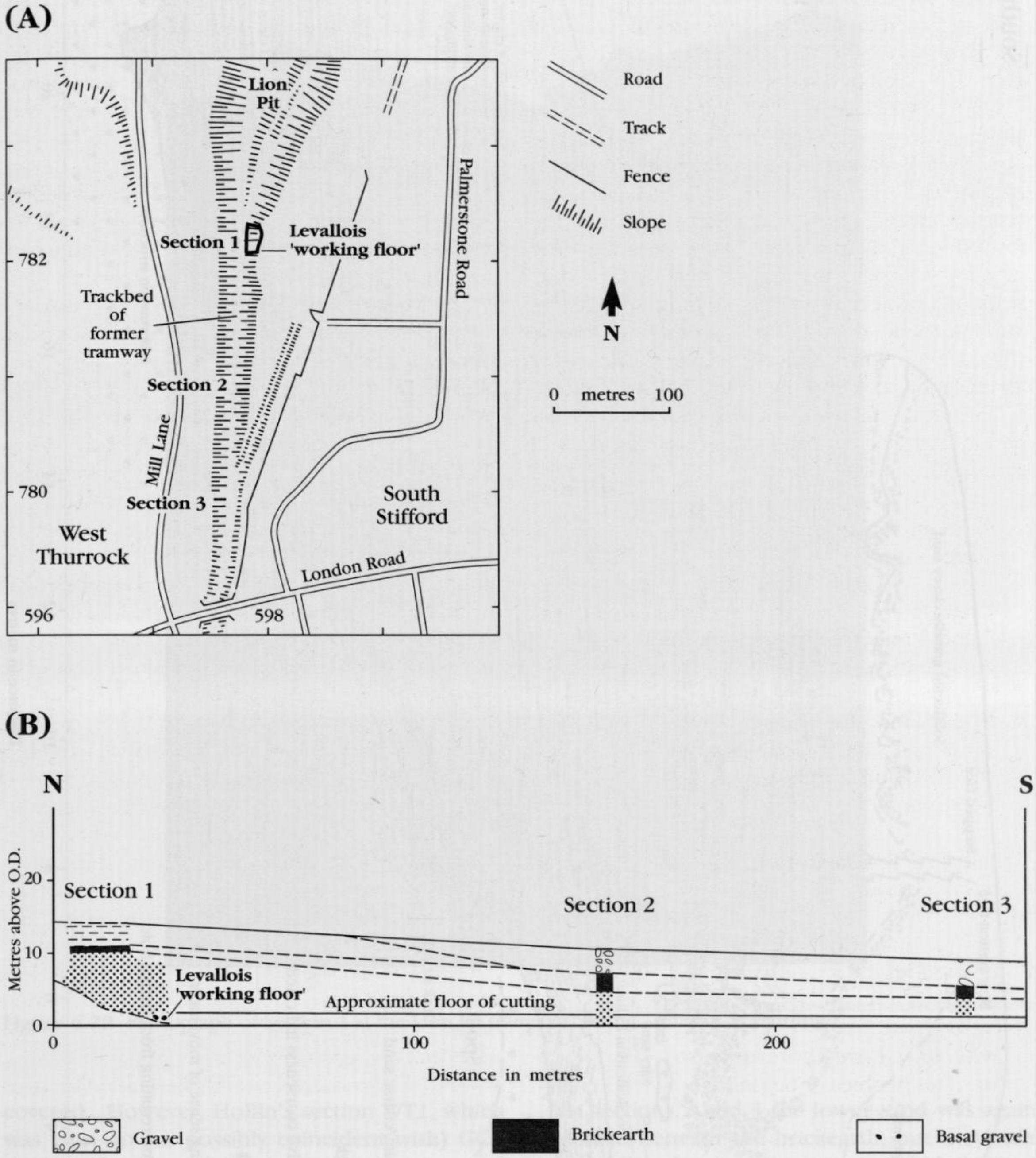
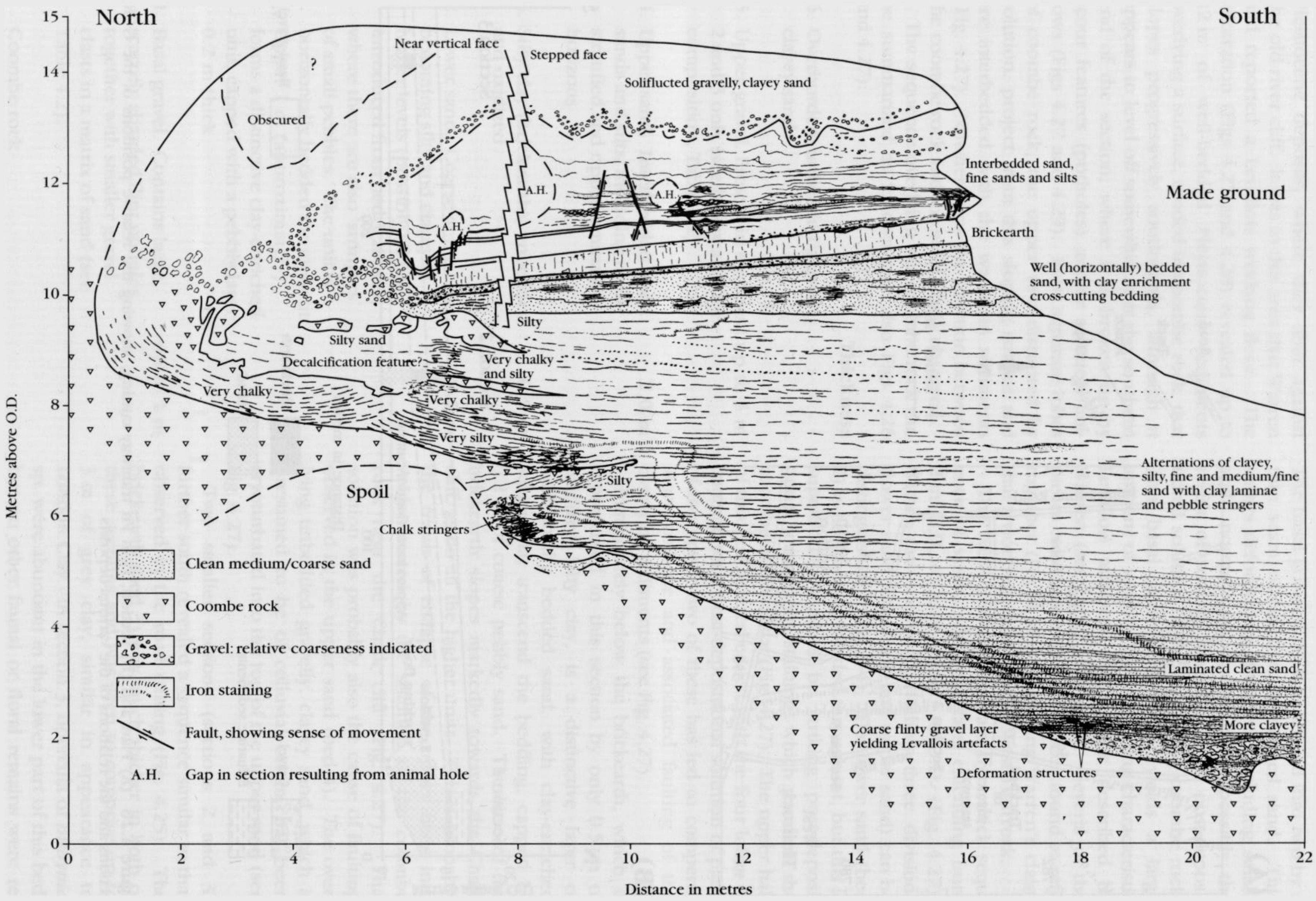


Figure 4.26 (A) Plan and (B) section, Lion Pit tramway cutting, showing the relative positions of the GCR sections and the relations of the various deposits.


North
South
Made ground
Near vertical face
Stepped face
Solifluctedgravelly, clayey sand
Obscured
?
Interbedded sand, fine sands and silts
A.H.
Brickearth
Well (horizontally) bedded sand, with clay enrichment cross-cutting bedding
Silty
Silty sand
Decalcification feature?
Very chalky and silty
Very chalky
Very silty
Silty
Spoil
Chalk stringers
Alternations of clayey, silty, fine and medium/fine sand with clay laminae and pebble stringers
Laminated clean sand
More clayey
Coarse flinty gravel layer yielding Levallois artefacts
Deformation structures
Clean medium/coarse sand
Coombe rock
Gravel: relative coarseness indicated
Iron staining
Fault, showing sense of movement
A.H. Gap in section resulting from animal hole
Metres above O.D.
Distance in metres
0
2
4
6
8
10
12
14
15
16
18
20
22

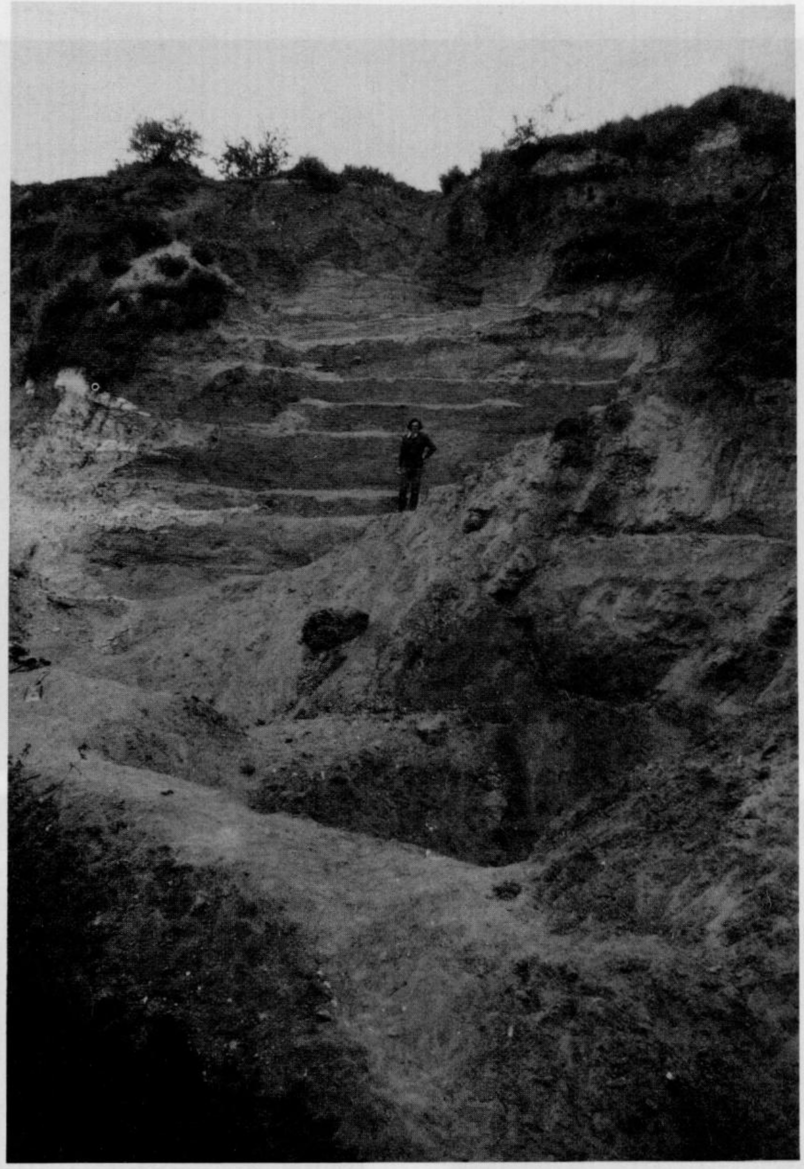


Figure 4.28 Photograph of Section 1 at the Lion Pit tramway cutting. (Photo: P. Harding.)

covered. However, Hollin's section WT1, which was close to (or possibly coincident with) GCR section 3, also yielded *Anodonta* sp. and *Sphaerium* sp. or *Pisidium* sp. (Evans, in Hollin, 1977), as well as the freshwater ostracod *Candona* (Robinson, in Hollin, 1977). The gastropods *Bithynia tentaculata*, *Valvata piscinalis*, *Planorbarius corneus* (L.), *Gyraulus albus* (Müller), *Hippeutis complanatus* (L.), *Lymnaea truncatula* (Müller), *L. peregra* (Müller) and *Pupilla muscorum* are also listed amongst the early collections from the West Thurrock brickearth (Woodward, 1890; Carreck, 1972).

In sections 2 and 3 the lower sand was again observed beneath the brickearth, but the latter was overlain by a medium-coarse bedded gravel rather than the upper sand. This is considered to be the same gravel that was observed cutting out the sand and brickearth sequence in the southern part of the 1983/4 road cutting exposure (Fig. 4.25). In section 2 of the tramway cutting the gravel, less than 2 m thick, was cryoturbated into the top of the brickearth (Fig. 4.26). Although not present at section 1, this gravel represents part of the waterlain succession at West Thurrock and has

Figure 4.29 Excavations at the base of Section 1, Lion Pit tramway cutting. The two layers of coarse flint near the base of the fluviatile deposits are clearly seen, above a potholed surface cut in coombe rock. The Lion Pit Palaeolithic industry occurs in these coarse layers. The material in the top right of the view is made ground. (Photo: P. Harding.)

therefore been added as bed 5 to the sequence described above.

Interpretation

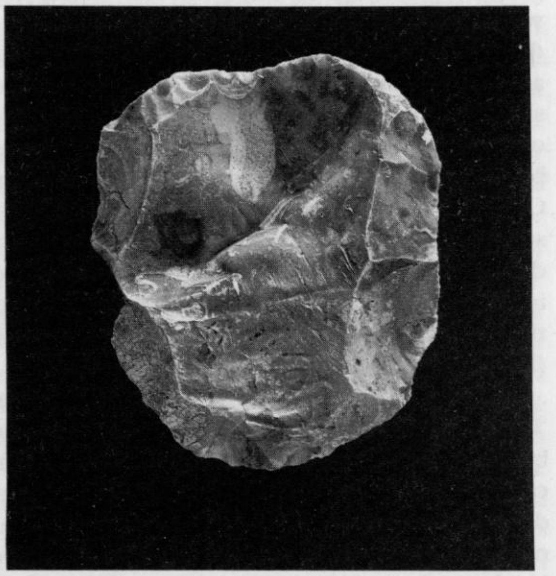
The Lion Pit tramway cutting GCR site combines extensive sections in the stratigraphically significant West Thurrock Pleistocene beds with an important Palaeolithic locality. The archaeological interest here is poorly documented, but the recent reinvestigation by the GCR Unit has shown that it is of considerable importance, probably representing an inundated 'working floor'.

Hinton and Kennard (1900) claimed that several Palaeolithic flakes had been found in this pit, but Kennard (in Dibley and Kennard, 1916) was the first to record Levallois material. According to Kennard, a number of Levallois flakes were found near the base of the old buried cliff. Although he referred to it as the 'Wouldham Cement Company's quarry at Grays', the site visited by Kennard was probably the Lion Pit, which has also been called the 'Wouldham Cement Works' (Hollin, 1977).

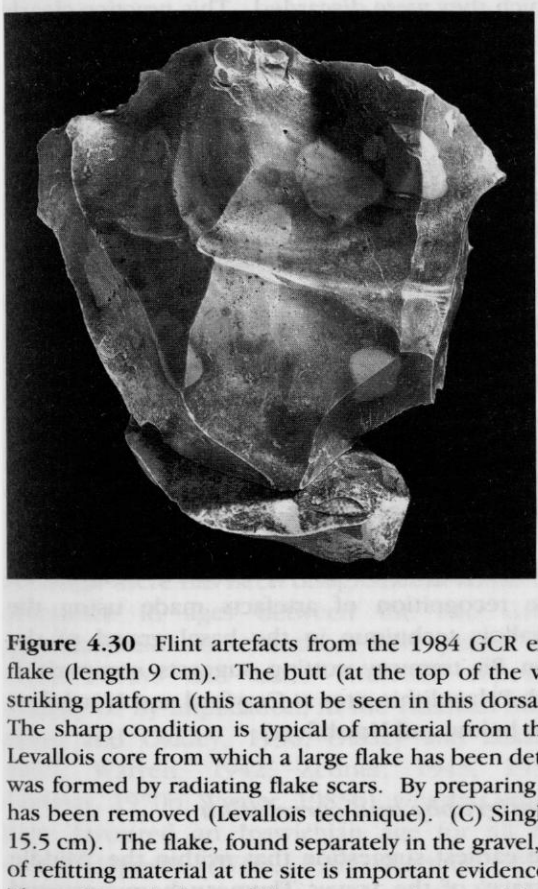
During a Geologists' Association excursion visit to the cutting, Warren (1923b) demonstrated the results of subsoil pressure on flint nodules at the base of the Pleistocene gravel, which had produced eolith-like objects by natural flaking. He pointed out that natural flakes, the production of which provide important evidence against the human origin of eoliths, were mingled here with the genuine artefacts of the proto-Mousterian (Levalloisian) industry discovered some years earlier by Kennard. In the same year, Warren (1923a, p. 607) made another passing reference to the 'proto-Mousterian' industry at West Thurrock, stating that it was 'characterized by the familiar 'tortoise-cores' and Levallois flakes' and overlain by beds containing *Mammuthus primigenius*. Warren (1942) subsequently referred the West

(A)

(B)



(C)



(D)

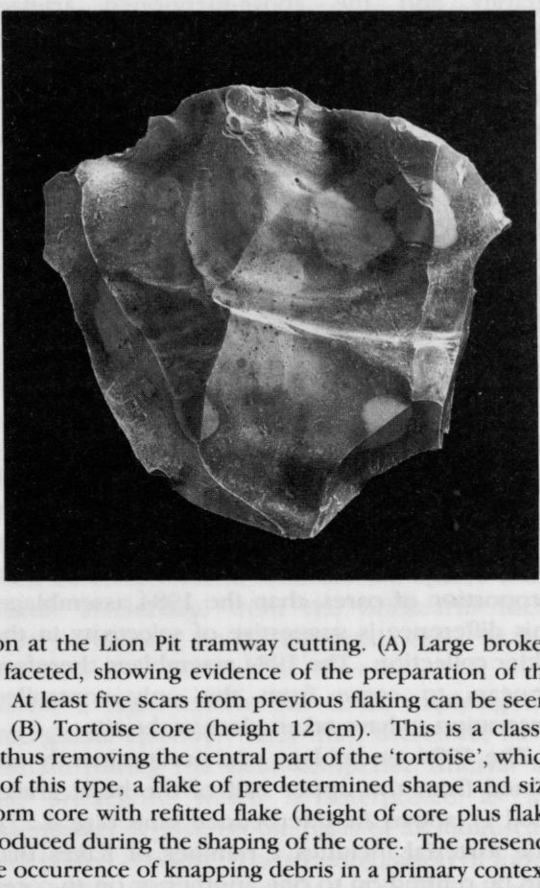


Figure 4.30 Flint artefacts from the 1984 GCR excavation at the Lion Pit tramway cutting. (A) Large broken flake (length 9 cm). The butt (at the top of the view) is faceted, showing evidence of the preparation of the striking platform (this cannot be seen in this dorsal view). At least five scars from previous flaking can be seen. The sharp condition is typical of material from the site. (B) Tortoise core (height 12 cm). This is a classic Levallois core from which a large flake has been detached, thus removing the central part of the 'tortoise', which was formed by radiating flake scars. By preparing a core of this type, a flake of predetermined shape and size has been removed (Levallois technique). (C) Single platform core with refitted flake (height of core plus flake 15.5 cm). The flake, found separately in the gravel, was produced during the shaping of the core. The presence of refitting material at the site is important evidence for the occurrence of knapping debris in a primary context. The striking platform of the core is at the top of the view. (D) The same core as in C, without the refitted flake (height 14 cm). (Photos by Elaine A. Wakefield.)

Thurrock industry to the 'Crayford Stage' of King and Oakley (1936). In this last paper, which included his most detailed description of the locality, Warren interpreted the Palaeolithic artefacts as representing a mid-Levallois working site on an old foreshore, inclined from the foot of the buried cliff towards the river, and covered by fluvial deposits to a height of 50 ft (15 m) O.D. In correspondence with the Nature Conservancy (pers. comm. to W.A. Macfadyen), he described the exact location of the working floor in the tramway cutting, information that enabled the re-exposure of the Levallois level in 1984 (Bridgland, 1985a).

Burchell (1933) recorded the discovery of an 'Upper Mousterian/Aurignacian' flake from loam banked against coombe rock in a cutting south of Belmont Castle, Grays. He noted that these deposits underlay the gravel of the '25 ft Terrace', which would now be referred to as the Mucking Formation. From Burchell's description it appears that this section was probably in the Lion Pit tramway cutting or a comparable exposure nearby. On the basis of the stratigraphy and the above-mentioned artefact, Burchell suggested that the deposits at West Thurrock and the sediments overlying coombe rock at his Northfleet site (see below, Northfleet) were closely related.

In 1984, at the GCR site, a narrow strip (1 m x 4 m) of basal gravel (bed 1, section 1; Fig. 4.27) was excavated under controlled archaeological conditions and yielded 87 flakes and four cores (Fig. 4.29). This more than doubled the known assemblage from the site, which previously comprised 73 flakes, seven cores and one hand-axe located in the Warren Collection at the British Museum. Both the material from the 1984 excavation and the Warren Collection include a number of flakes that are considered to result from natural processes, as described by Warren (1923b, 1923c). The Warren Collection generally comprises larger material, with a higher proportion of cores, than the 1984 assemblage; this difference is suggestive of selectivity in the older collection. The 1984 assemblage therefore appears to come from the only controlled excavation to have taken place at the site.

The 1984 assemblage was predominantly obtained from the upper half of the basal gravel (bed 1), above the interbedded sand (Fig. 4.27). The material includes a number of flakes that can be refitted on to one another or on to cores (Fig. 4.30). The distribution of such conjoinable material indicates some small degree of movement since its manufacture, but the assemblage clearly represents knapping debris that suffered little disturbance during incorporation into the gravel. The condition of the material – 91% was mint or sharp, according to the definition of Wymer (1968) – is consistent with abrasion by suspended particles washing over it, but there is nothing to suggest that the artefacts themselves have been transported. The assemblage is therefore interpreted as a collection of knapping debris that has been preserved in a near primary context following burial by later sediments. Warren's 'working floor' is thus confirmed.

The Palaeolithic material from the Lion Pit tramway cutting is principally a flake and blade industry, some of which has been produced using the Levallois technique. Levallois points and retouched flake tools are also present. The use of this extravagant technique must have been severely constrained by the availability of flint resources. The cores were carefully prepared in order to produce a small number of flakes or blades of a desired size and shape, after which they were discarded. This practice clearly failed to make optimum use of the available raw material. It is therefore likely that the technique was only employed when good quality flint was available in abundance (see, for example, Roe, 1981, p. 81). In the Lion Pit tramway cutting the basal gravel includes a considerably larger proportion of nodular flint than is typical in Lower Thames deposits (Table 4.2), confirming that the supply of fresh flint was indeed abundant at this locality.

The Lion Pit industry may be of considerable stratigraphical significance. The Levallois technique appears to have been first used in the Thames valley at some time during the interval between the Swanscombe interglacial and the Ipswichian Stage (*sensu* Trafalgar Square), within the period referred in this volume to the Saalian Stage (see above, Purfleet; Chapter 1). The recognition of artefacts made using the Levallois technique in the basal gravel of the Lion Pit tramway cutting suggests comparison with Palaeolithic sites at Crayford and Northfleet (see below and Northfleet).

Stratigraphy and correlation

The earliest suggestion that, within the 'Middle Terrace' of the Lower Thames, there occurred deposits of different ages was by Hinton (1910).

Hinton considered that the mammalian faunas from Grays and Little Thurrock did not match those from elsewhere in the 'Middle Terrace', particularly those from Crayford and Erith. The deposits at Grays (at sites such as the Orsett Road and Globe Pits – see above and Fig. 4.21) yielded an assemblage that includes the early vole species, *Arvicola cantiana*. Hinton noted that all the species recognized at Grays were absent from the deposits at Crayford and Erith, believing them to have been replaced in these sediments by a 'later' assemblage. Sutcliffe and Kowalski (1976), however, have pointed out that the Crayford and Erith rodent fauna has cold affinities and so is not directly comparable with that from Grays.

Hinton concluded that the Grays and Little Thurrock deposits were amongst the earliest within the 'Middle Terrace'. This view was supported by Kennard (1916), who established a sequence of four biostratigraphical stages within the 'Middle Terrace', as follows:

4. Crayford and Erith

3. Ilford (Cauliflower Pit)

2. Ilford (Uphall Pit)

1. Grays–Thurrock

Discussing the Grays area, Kennard (1916, p.255) assigned what he called 'the new brickearth to be seen in the various tramway cuttings' to stage 4. This description clearly appertains to the West Thurrock deposits, placing them, along with Crayford, in Kennard's most recent division of the 'Middle Terrace'. Later work, particularly the discovery of the Clactonian industry at Little Thurrock and of the more advanced Levallois industry at West Thurrock, served to consolidate this view (Warren, 1923a; Oakley and Leakey, 1937), although there has been disagreement about the difference in ages between the two Grays aggradations. Some authors have placed the earlier Grays and Little Thurrock deposits, directly or by implication, in the Hoxnian Stage (King and Oakley, 1936; Oakley and Leakey, 1937; Warren, 1942; Zeuner, 1945, 1959; Conway, 1970b; Wymer, 1985b), whereas others have favoured an Ipswichian age for all the Grays deposits (West, 1969; Carreck, 1972, 1976; Hollin, 1971, 1977; see above, Globe Pit).

Carreck (1972, 1976) conducted an extensive review of the available information concerning the Pleistocene of the Grays area, aided in his later work by the rediscovery in 1974 of Abbott's collection of mammalian fossils from West Thurrock. Carreck concluded that the West Thurrock deposits were of late Ipswichian age. Hollin (1977) cited the Levallois industry at the base of the section and the high incidence of *Carpinus* pollen in samples collected from the brickearth in support of an Ipswichian age (biozone III) for the West Thurrock brickearth. He suggested that the transition from the coarse lower sand (bed 2) to the finer-grained laminated sediments (bed 4) might represent a change from fluvial to estuarine conditions. He envisaged that this change resulted from a sudden rise in sea level, caused by an Antarctic ice surge during the mid-Ipswichian, that he had recognized at a number of Lower Thames sites (Hollin, 1971, 1977; see above, Purfleet and Globe Pit). Pollen spectra obtained from the brickearth in the 1983/4 road cutting (probably equivalent to bed 3 at the GCR site), which proved to be a considerable improvement on the material collected by Hollin, also point to an Ipswichian age (P.L. Gibbard, pers. comm.); the publication of a pollen diagram is anticipated in the near future.

Hollin's interpretation of the horizontally bedded sands as intertidal or estuarine deposits is supported by observations of the sequence exposed in GCR section 1 (Fig. 4.27). The thick (>7 m) horizontally bedded sand (bed 2) beneath the brickearth and the thinner sequence of interbedded sands and silts above the brickearth (bed 4) are both sedimentologically consistent with an intertidal depositional environment. In particular, the laminae of bed 4 resemble the closely interlayered bedding that is common in the sediments of intertidal flats (Reineck and Singh, 1975). Neither bed 4 nor bed 2, however, has yielded faunal evidence for such an environment, whereas the sparse molluscan assemblage from the brickearth itself clearly indicates freshwater conditions. If the unfossiliferous beds are of estuarine origin, they reflect a high relative sea level, implying an interglacial episode. They may, therefore, have formed during the same temperate interval as the brickearth, which is interpreted as an interglacial deposit on the basis of its molluscan and pollen content. The interdigitation of lobes of coombe rock into the edge of the lower sand appears to refute this suggestion, as such material (poorly sorted chalky debris) is generally attributed to periglacial slope processes, such as solifluction. The formation of minor lobes of material like those observed at Lion Pit may not require periglacial conditions, however; mudflows and slope failures, such as occur at the present time in Britain, are capable of producing similar deposits.

Given the doubts that have been expressed about the distinction of different late Middle and Late Pleistocene temperate episodes using palynology (Sutcliffe, 1960, 1964, 1975, 1976; Sutcliffe and Kowalski, 1976), the record of hippopotamus from West Thurrock (Abbott, 1890) would appear to be important in establishing an Ipswichian (*sensu* Trafalgar Square) age, since this animal is widely regarded as a reliable indicator of that stage in Britain (see Chapter 1). However, hippopotamus was not amongst the material described by Carreck (1976) in the rediscovered Abbott collection and it is possible that the record of this species at West Thurrock was based on a misidentification (A.P. Currant, pers. comm.).

The position of the interglacial beds at West Thurrock in relation to the Lower Thames terrace sequence is of some stratigraphical significance. The gravel that overlies these beds in both the road and tramway cuttings, mapped as 'Floodplain Gravel' by the Geological Survey (Sheet 271), was reclassified by Bridgland (1983a, 1988a) as the Mucking Gravel and equated with the late Saalian Taplow Formation of the Middle Thames (Bridgland, 1988a). This interpretation, which precludes an Ipswichian age for the West Thurrock brickearth, has proved controversial. Gibbard *et al.* (1988) considered the palynological evidence for an Ipswichian age for the West Thurrock brickearth to be sufficiently persuasive to indicate that the overlying gravel represents an early Devensian aggradation, hitherto unrecognized in the Lower Thames. They named this deposit, which has a composition and altitudinal distribution indistinguishable from the Mucking Gravel, the 'West Thurrock Gravel', citing the Lion Pit tramway cutting as the type section. Gibbard *et al.* (1988) suggested that this deposit could be correlated with the Reading Town Gravel of the Middle Thames, also attributed to the early Devensian (Gibbard, 1985). No equivalent unit has been recognized elsewhere in the Thames valley, however, and the separate existence of the Reading Town Gravel has been challenged earlier in this volume, where it has been reinterpreted as part of the late Saalian Taplow Formation (see Chapter 1; Chapter 2, Fern House Pit).

The pollen-based interpretation of the West Thurrock sequence can be challenged on a number of counts. Without the palynological evidence, the upper gravel (bed 5) would be assigned to the Taplow/Mucking Formation. Nearby sites within that formation, at Aveley and Ilford, have yielded similar pollen spectra to the West Thurrock brickearth, yet they have been assigned on other evidence (biostratigraphy, amino acid geochronology and terrace mapping) to a post-Hoxnian/pre-Ipswichian temperate episode (see below, Aveley). A straightforward interpretation of the regional stratigraphy in the Grays area is therefore favoured here and the West Thurrock sequence is attributed, in its entirety, to the late Saalian Mucking Formation. According to the climatic model for terrace formation (Chapter 1), the basal gravel (bed 1) would appear to represent the 'phase 2' (pre-interglacial) aggradation, whereas the interglacial beds (beds 2–4) and the upper gravel (bed 5) correspond to aggradational phases 3 and 4 respectively.

The above interpretation rejects the dating of the West Thurrock interglacial beds as Ipswichian. These sediments appear, however, to represent a later temperate episode than the Grays and Little Thurrock brickearth, since the two deposits are separated by both the post-interglacial (phase 4) gravel aggradation of the Lynch Hill/Corbets Tey Formation (see above, Globe Pit) and the subsequent downcutting that preceded the formation of the Lion Pit coombe rock and overlying basal gravel. As the interglacial sediments at Grays (and elsewhere within the Corbets Tey Formation) are attributed to Oxygen Isotope Stage 9 (see above, Globe Pit and Purfleet), and the Ipswichian Stage (*sensu* Trafalgar Square) is generally considered to correlate with Oxygen Isotope Substage 5e (Chapter 1), a correlation of the temperate episode represented at West Thurrock with Oxygen Isotope Stage 7 is suggested. The post-interglacial (phase 4) part of the Corbets Tey Gravel and the basal gravel at Lion Pit are both attributed, according to the above interpretation, to Oxygen Isotope Stage 8 (Table 1.1). There is archaeological support for the close association of these two gravel aggradations, despite their occupation of different terrace levels; both have yielded artefacts that show evidence of the use of the Levallois technique (see above, Purfleet and Globe Pit).

The altitude and stratigraphical position of the Ipswichian deposits at Trafalgar Square (Franks *et al.*, 1958; Gibbard, 1985) lend further support to the above interpretation. These deposits lie 30 km upstream from the Grays area, yet they are close to ordnance datum, nearly 10 m below the level of the West Thurrock brickearth. Furthermore, they represent the phase 3 (interglacial) part of the Kempton Park Formation, since they are underlain by a periglacial gravel sequence (the Spring Gardens Gravel Member of Gibbard (1985)), which represents the phase 2 aggradation of the Kempton Park Formation (see Table 1.1), and overlain by the Kempton Park Gravel as defined by Gibbard (1985). The Ipswichian (*sensu* Trafalgar Square) sediments therefore fall within a lower terrace than those at West Thurrock (Table 1.1). The altitude of the former deposits indicates that the Lower Thames valley was excavated to well below the level of the West Thurrock gravel by the beginning of the Ipswichian Stage. Indeed, it is clear that the Kempton Park Formation is aggraded to a much lower base level; it is correlated with the East Tilbury Marshes Gravel, which underlies the floodplain of the Lower Thames in the Tilbury area, where its upper surface is close to ordnance datum (Bridgland, 1983a, 1988a). Thus, if any sediments dating from the Ipswichian Stage (*sensu* Trafalgar Square) are preserved in the Grays area, they would be expected to be close to, or below, ordnance datum and to be represented within the 'Buried Channel' (Bridgland, 1988a; Table 1.1).

Relation to other sites in the Mucking Formation

The attribution of the interglacial sediments at West Thurrock to Oxygen Isotope Stage 7 implies correlation with other sites within the Thames system that have been attributed to that stage. In particular, sediments at Aveley (see below) and Stanton Harcourt (Chapter 2) have been important in the recognition and identification of this intra-Saalian temperate interval in Britain (Shotton, 1983; Bowen *et al.*, 1989; Chapter 1). The stratigraphical scheme for the Thames terraces established in this volume suggests that interglacial sediments at Ilford, Crayford and Northfleet also correlate with those at West Thurrock. There is some support for these correlations from both mammalian and molluscan faunas. Where temperate mammalian assemblages are recorded from the above sites, they resemble the fauna, which includes mammoth, straight-tusked elephant and horse, that is believed to characterize Oxygen Isotope Stage 7 (Shotton, 1983; see below, Aveley). In addition, *Corbicula fluminalis*, a bivalve that is characteristic of pre-Ipswichian temperate episodes but was probably absent from Britain during the Ipswichian Stage (*sensu* Trafalgar Square), occurs at all these sites. It has not, however, been recorded from the West Thurrock site, where its absence may be a reflection of the fact that molluscs in general (and bivalves in particular) do not appear to be well-preserved in the sediments there.

Where pollen has been obtained from the above sites, it has proved indistinguishable from assemblages from the Ipswichian Stage (*sensu* Trafalgar Square) and many palynologists are still of the opinion that all these localities represent the last interglacial (Ipswichian). Thus Ipswichian pollen sequences have been described from Aveley (West, 1969) and Ilford (West *et al.*, 1964), as well as West Thurrock (Gibbard *et al.*, 1988). Correlation of other sites in the Lower Thames with the Ipswichian Stage has been based on their stratigraphical relations to these polleniferous sites (Hollin, 1977; Stuart, 1982a).

The sites at Aveley, Ilford and Northfleet will be described below (see Aveley and Northfleet). At Crayford, areas of *in situ* deposits have been identified and it is hoped that temporary exposures will be investigated in the near future. No conservable remnants of these sediments remain, however. Nevertheless, a brief summary of the evidence from this important locality will be given here, as it seems likely to be a close correlative of the West Thurrock site. The Pleistocene deposits at Crayford (and Erith) are better known than their supposed correlatives at West Thurrock. Various pits in the Crayford area have yielded rich assemblages of molluscs, mammals and Palaeolithic artefacts, some of the latter in primary context (for summaries, see Kennard, 1944; Wymer, 1968; Roe, 1981). The Crayford sequence comprises brickearth above gravel, the latter descending to well below ordnance datum. The brickearth can be divided into lower fluviatile and upper colluvial elements, the former, which yielded the important faunal assemblages, extending to *c.* 11 m O.D. Palaeolithic artefacts occur in the gravel, between the gravel and the brickearth, and at several levels within the brickearth. Levalloisian working floors were reported from the base of the brickearth in two of the Crayford pits, Stoneham's Pit (TQ 517758) and Rutter's Pit (TQ 514765), both yielding conjoinable material (Spurrell, 1880; Chandler, 1916). The fluvial brickearth has frequently been ascribed to the Ipswichian Stage in recent years (Stuart, 1974, 1976, 1982a; Hollin, 1977; Roe, 1981; Gibbard *et al.*, 1988), but it has yielded both horse and *Corbicula fluminalis*, species believed by some workers (Chapter 1) to have been absent in Britain during that stage. Hippopotamus, regarded widely as indicative of the Ipswichian Stage (*sensu* Trafalgar Square) in Britain, has not been found at Crayford; indeed, the site has been interpreted, on the basis of its mammalian assemblage (which incorporates both temperate and cold elements), as intra-Saalian (Sutcliffe and Kowalski, 1976). Unfortunately, only the upper colluvial brickearth has been exposed in recent years. A large spread of 'Floodplain Gravel' appears on the Geological Survey map (Sheet 271) to the east of the brickearth outcrop at Crayford. In all records of the Crayford sites that refer to this gravel, it has been regarded as continuous with that underlying the brickearth (see Chandler, 1914; Kennard, 1944). This would therefore appear to represent the phase 2 aggradation of the Mucking Formation, with the Crayford interglacial sediments representing phase 3. The post-interglacial phase (phase 4) of Mucking Gravel aggradation may be represented within the outcrop to the east, but has not been recorded from above the brickearth. The biostratigraphy appears to indicate that the interglacial sediments accumulated during Oxygen Isotope Stage 7, as with other temperate-climate deposits within the Mucking Formation. Strong parallels can be recognized between the Crayford sequence and that at the Lion Pit tramway cutting; both have fine-grained fluviatile sediments containing interglacial faunas suggestive of an intra-Saalian age and in both cases these overlie Levallois 'floors'. Both sequences can be assigned to the Mucking Formation.

As has been noted above, evidence for the use of the Levallois technique first appears within the Corbets Tey Gravel, probably in the post-interglacial (phase 4) part of that formation. This suggests that the technique was first employed during Oxygen Isotope Stage 8. The Levallois artefacts at Crayford, Northfleet and West Thurrock all occur within or above gravels that underlie the temperate (phase 3) part of the Taplow/Mucking Formation, implying that they too date from Oxygen Isotope Stage 8. At Crayford, further finds from within the fluvial brickearth suggest that humans using the Levallois technique continued to occupy the area into Stage 7, although the occurrence of cold as well as temperate faunas in this deposit raises some doubts about the stratigraphical level of the Stage 8–Stage 7 transition; this may be near the top of the fluviatile sequence, at the base of the '*Corbicula* bed'. There is, nevertheless, important evidence from these three sites that the Levallois technique may be of chronostratigraphical significance.

Recently, the application of amino acid analysis to mollusc shells from sites in the Mucking Formation has proved to be a valuable source of evidence for correlation. Amino acid ratios from West Thurrock are not yet available, but results from sites that may be correlatives, such as Aveley, Ilford and Crayford (see below, Aveley), strongly support the claim that a Stage 7 interglacial event is represented at this level within the Lower Thames sequence (Bowen *et al.*, 1989).

Conclusions

The spectacular section in the Lion Pit tramway cutting combines important evidence from sediments, fossils and archaeology. A thick sequence of deposits occurs here at the northern edge of the terrace formed by Taplow/Mucking Gravel of the Lower Thames – the lowest of the three terraces recognized above the modern floodplain in this area. The basal deposit at West Thurrock is a mass of redeposited Chalk ('coombe rock') that has accumulated beneath the cliff, probably under cold conditions. Several further lenses of similar material interdigitate with the edge of the later sediments, where they are banked against the cliff. The lowest Thames deposit is a coarse gravel, containing the debris of a flint-working site almost as it was left by ancient man on the river's shoreline. Several of the pieces of flaked flint, which has been worked using the distinctive 'Levallois technique', can be fitted back together, a phenomenon that only occurs when such debris is little disturbed. This gravel is overlain by a thick sequence of laminated sands and silts, within which is a thicker bed of silty clay or 'brickearth'. The brickearth is better represented in the southern part of the site, where it has produced pollen and molluscs and, when the cutting was originally excavated, an extensive collection of mammal bones. The sands and silts are of intertidal (estuarine) origin, implying a high sea level, which again indicates deposition during an interglacial (sea levels were low during glacials, because much sea-water was locked up in larger polar ice caps). A later gravel, assumed to be a cold-climate deposit, overlies the interglacial sediments at the southern end of the cutting.

The age of the West Thurrock sequence is controversial. A more extensive pollen record has been obtained from the same brickearth in a road cutting a short distance to the west, where it has been attributed to the last interglacial (120,000 years BP). The position of the site within the 'staircase' of Lower Thames terraces, on the other hand, leads to the conclusion that the sequence represents part of the Saalian Stage, with the interglacial equivalent to the third of four interglacials recognized in the post-diversion Thames valley. This would indicate deposition at around 200,000 years BP, in Oxygen Isotope Stage 7 of the oceanic record.

AVELEY, SANDY LANE QUARRY (TQ 551808)

D.R. Bridgland

Highlights

This site, famous for the discovery of two elephant skeletons in the mid-1960s, preserves an important Pleistocene sequence thought to represent an interglacial between the Hoxnian and Ipswichian Stages. This temperate event is believed to equate with Oxygen Isotope Stage 7 of the deep-sea record. This interpretation continues to be a matter of controversy, however, as the Aveley sediments have also been assigned to the Ipswichian Stage (Substage 5e) on the basis of pollen analysis.

Introduction

This GCR site is adjacent to the former Sandy Lane Quarry, a large gravel and clay pit that occupied almost a square kilometre of land to the north-west of the village of Aveley. In this area the Thames floodplain runs approximately NNW–SSE, by-passing the loop through South Ockendon and Stifford that it followed in Corbets Tey Gravel times (see above, Purfleet and Fig. 4.1). Of the Lower Thames terrace deposits, only the Mucking Formation (mapped by the Geological Survey as 'Floodplain Gravel') appears to follow this shorter route, although later editions of the Geological Survey map (Sheet 257) show patches of brickearth and 'Taplow Gravel' between the Mucking Gravel and an outlier of Boyn Hill/Orsett Heath Gravel to the east of the GCR site (Fig. 4.1). The Orsett Heath Gravel outlier represents a 'meander core', as recognized by Wooldridge and Linton (1955), formed when the sinuous Corbets Tey Gravel course was abandoned. The addition of the 'Taplow Gravel' and brickearth to the later maps was a direct result of important exposures created in Sandy Lane Quarry, in an area hitherto mapped as Palaeogene Thanet Sand.

The eastern end of Sandy Lane Quarry exploited the above-mentioned outlier of Orsett Heath Gravel. The deposits mapped (later editions only of Sheet 257) as 'Taplow Gravel' were seen in sections at the western end of the quarry. They comprise a number of highly fossiliferous beds, which have yielded important mollusc, mammal, insect and pollen assemblages, indicative of interglacial conditions (Blezard, 1966, 1973; West, 1969; Cooper, 1972; Stuart, 1976; Sutcliffe, 1976; Sutcliffe and Kowalski, 1976; Hollin, 1977; Holyoak, 1983). Entirely separate from other mapped occurrences of 'Taplow Gravel', which have been reclassified as Lynch Hill/Corbets Tey Gravel (see Introduction to this chapter), these sediments have also been attributed to the 'Upper Floodplain Terrace' (West, 1977). Although the Upper Floodplain Terrace of the Middle Thames is correlated with the Kempton Park Formation (Chapter 1), the deposit mapped as 'Floodplain Gravel' in the Lower Thames is now referred to the Taplow/Mucking Formation (Bridgland, 1988a; Gibbard *et al.*, 1988; Introduction to this chapter). 'Floodplain' (Mucking) Gravel is mapped immediately to the west of the Aveley pit (Sheet 257), but its relation to the sediments there has yet to be determined.

Three alternative stratigraphical positions can thus be envisaged for the Aveley deposits within the Thames terrace sequence: they may belong (1) within the Lynch Hill/Corbets Tey Formation, as the later maps suggest, (2) within the Taplow/Mucking Formation or (3) within the Kempton Park Formation. The sediments at Aveley are, in fact, mainly sands, silts and clays, some with a high organic content, channelled into the London Clay. They were originally assigned to the Ipswichian (West, 1969; Hollin, 1977), but have also been ascribed to a hitherto unrecognized temperate episode between the Hoxnian and Ipswichian Stages (Sutcliffe and Bowen, 1973; Sutcliffe, 1975, 1976; Sutcliffe and Kowalski, 1976; Shotton, 1983; Wymer, 1985b; Bowen *et al.*, 1989).

The site is likely, on the basis of its faunal content and altitude, to correlate with Pleistocene deposits formerly exposed in south-west Ilford (Uphall Pit), which produced a rich molluscan fauna and considerable numbers of mammal bones when exploited for brick-making (Cotton, 1847; Dawkins, 1867; Phillips, 1871; Woodward and Davies, 1874; Hinton, 1900a, 1900b; Johnson, 1901; Rolfe, 1958). The Ilford deposits, like those at Aveley, have been attributed both to the Ipswichian (West *et al.*, 1964; Stuart, 1976, 1982a; Gibbard *et al.*, 1988) and to a post-Hoxnian/pre-Ipswichian temperate episode (Sutcliffe and Bowen, 1973; Sutcliffe, 1975, 1976; Sutcliffe and Kowalski, 1976; Shotton, 1983; Wymer, 1985b). The name 'Ilfordian' has been applied to this undefined 'stage' (Bowen, 1978; Wymer, 1985b), which is thought to correlate with Oxygen Isotope Stage 7 (Shotton, 1983; Bowen *et al.*, 1989). However, localities in north Ilford were on higher level, older terrace deposits, a fact that has led to much biostratigraphical confusion (see below) and makes Ilford, where no exposures have been available in recent years, unsuitable as a type locality.

Description

Unlike the Ilford pits, with which it is frequently correlated, there is no large body of early literature on the Aveley locality. A pit near the road junction (TQ 560808) north-west of Aveley was recorded by Whitaker (1889). He reported that 6 m of gravel was exposed here, part of the outlier of the deposit now classified as Boyn Hill/Orsett Heath Gravel, but it is unclear whether this working was within the area of the modern Sandy Lane Quarry. No early descriptions of the fossiliferous beds exist; it seems these were only discovered as the pit was extended westwards during London Clay extraction in the 1960s.

The sequence at Aveley is as follows (after West (1969) and Hollin (1977); see also Fig. 4.31):

	Thickness
6. Silt, pale yellow, with sand and gravel at the base	*c.* 1.0 m
5. Sand, grey and silty in its lowest 1 m, yellow and with scattered gravel above	up to 5.0 m
4. Silty clay, orange-brown, massive (brickearth). Contains Mollusca in its basal (calcareous) part only	2.0–2.5 m
3. Peaty layer with compressed wood (detritus mud)	up to 0.6 m
2. Silts and clays, grey (yellow-brown near base), containing freshwater Mollusca and fish, small vertebrates, wood and pollen	up to 7.0 m
1. Basal gravel below dominant sand, the latter with brown clay layers	*c.* 3.0 m
London Clay	

The first detailed description of the sediments exposed in the western part of Sandy Lane Quarry was by West (1969), reporting on a programme of pollen analyses, a preliminary account of which had been given by Blezard (1966). West described a sequence of Pleistocene deposits occupying a channel cut into the London Clay to a base level of 1.8 m O.D. (Fig. 4.31). The later description by Hollin (1977) indicates that the deposits thicken westwards, as revealed by later quarrying, reaching -4.3 m O.D. (it is possible that further extension of the quarry in this direction, towards the mapped outcrop of Mucking Gravel, might have revealed

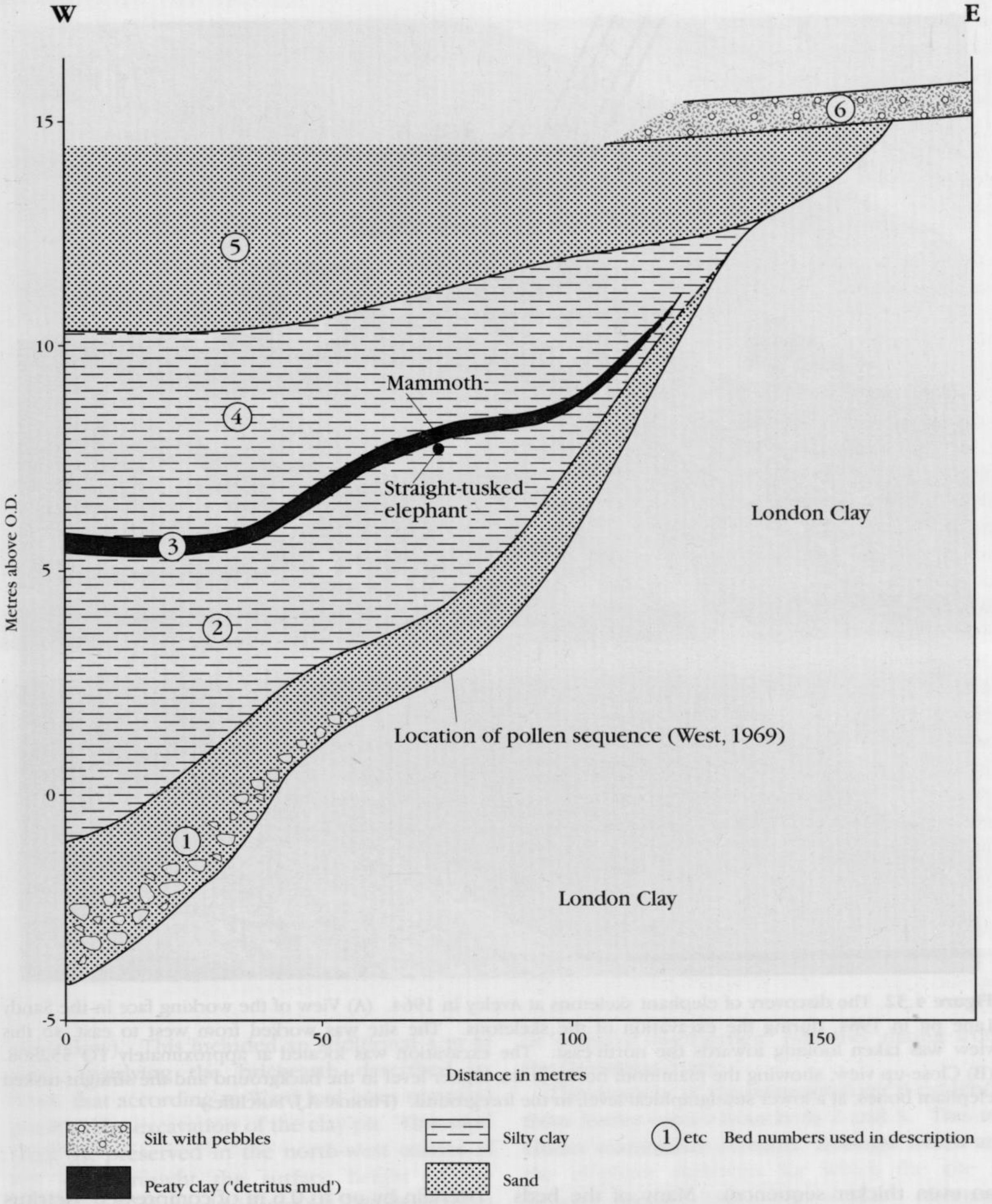


Figure 4.31 Section through the deposits of the Mucking Formation at Sandy Lane Quarry, Aveley (modified from Hollin, 1977).

(A)

Figure 4.32 The discovery of elephant skeletons at Aveley in 1964. (A) View of the working face in the Sandy Lane pit in 1964, during the excavation of the skeletons. The site was worked from west to east, so this view was taken looking towards the north-east. The excavation was located at approximately TQ 552808. (B) Close-up view, showing the mammoth bones at the higher level in the background and the straight-tusked elephant bones, at a lower stratigraphical level, in the foreground. (Photos: A.J. Sutcliffe.)

an even thicker sequence). Many of the beds are, therefore, of variable thickness, thinning against the London Clay 'cliff' to the east (Fig. 4.31). The lowest part of the channel infill (bed 1) comprises unfossiliferous silts, clays and thin sands above a basal gravel. These are overlain by organic silts and sands (bed 2), yielding freshwater shells and wood, that in turn are overlain by up to 0.6 m of compressed 'detritus mud' with wood (bed 3). The highest bed recorded by West was his brickearth, a stiff silty clay (bed 4).

Cooper (1972) provided detailed descriptions of the stratigraphy of the deposits based on a section drawn by G.R. Ward during the excavation of the elephant skeletons (Blezard, 1966;

(B)

see below). This included an additional 4 m of sand, overlying the brickearth described by West, that according to Ward had been removed prior to the excavation of the clay pit. This sand (bed 5), preserved in the north-west corner of the site, brought the surface height of the deposits up to nearly 15 m O.D., similar to that of the highest deposits at Ilford (Seven Kings; see below). Hollin (1971, 1977) noted that this upper sand extends eastwards beyond the limits of the fossiliferous channel-fill, where it directly overlies a steep London Clay surface. He also recorded a further bed above the sand, a pale yellow silt (bed 6) that he interpreted as aeolian or colluvial overburden, probably dating from the Devensian Stage.

The majority of the palaeontological evidence from Aveley comes from beds 2 and 3. This includes mammalian remains, amongst which are the elephant skeletons for which the site is famous (Anon., 1966; Fig. 4.32). Although found in close proximity, the skeletons are from different species; one is a straight-tusked elephant (*Palaeoloxodon antiquus*) and the other a woolly mammoth (*Mammuthus primigenius*). The former was in a silty clay at the top of bed 2 and the mammoth, only 0.3 m higher, was in the peaty 'detritus mud' of bed 3 (Anon., 1966;

West, 1969). The latter bed also yielded horse and the only British Pleistocene record of lesser white-toothed shrew (*Crocidura* cf. *suaveolens* (Pallas)) (Stuart, 1974, 1976, 1982a). Insect remains, primarily beetles, have also been recorded from these two beds (Coope, in Blezard, 1966; in Hollin, 1977; in Shotton, 1983), but they and their precise provenance have not been described in detail. Occasional ostracods were recovered from the same beds, while the brickearth (bed 4) produced an antler of red deer (Stuart, 1976). A second skeleton of straight-tusked elephant was excavated from the site, *c.* 25 m to the east of the first, by J.N. Carreck. This specimen, now in the Natural History Museum, was at the same stratigraphical level as the earlier *Palaeoloxodon* skeleton, beneath the detritus mud (A.J. Sutcliffe, pers. comm.).

Wiseman (1978) illustrated the exposures in the north face of Sandy Lane Quarry, from the Orsett Heath Gravel in the east to the fossiliferous deposits first described by West. His section traces the upper sand (bed 5) of the latter sequence to only 11 m O.D. and also shows a considerable amount of gravel within this bed. A separate development of sands and gravels occurred between 15 m and 20 m O.D. and was shown to be related to a minor geomorphological terrace feature visible in neighbouring unquarried land and on aerial photographs of the area taken prior to quarrying (Wiseman, 1978). These deposits, preserved primarily in pockets in the top of the London Clay, coincide with brickearth on later editions of the Geological Survey map (Sheet 257).

A temporary section in the eastern edge of the upper sand (bed 5) was observed by the present author in 1983. This showed cross-bedded sand banked against a steeply dipping London Clay surface (confirming Hollin's observation), presumed to be a channel edge or river cliff. The clay surface showed slickenside striations, however, suggesting relative movement between it and the sand. This might result from diapiric upwelling of the clay at the edge of the Pleistocene terrace, a phenomenon that appears commonly in the British Pleistocene (Allen, 1991), which would explain the extreme steepness of the observed London Clay surface.

Sandy Lane Quarry has now been infilled, but an unexcavated area immediately to the west has been identified as an alternative GCR site and it is hoped that the Aveley sequence will be exposed there in the near future. This may have the advantage of revealing the relation between the fossiliferous sequence and the spread of Mucking Gravel mapped immediately to the west of the pit.

Interpretation

The scientific importance of the Aveley site arises from its contribution to the palaeoenvironmental reconstruction and correlation of the Thames terrace sequence. The site is at the centre of the controversy over the stratigraphy and dating of post-Boyn Hill/Orsett Heath Gravel (= post-Oxygen Isotope Stage 10) interglacial sediments in the Lower Thames (see above, Purfleet, Globe Pit and Lion Pit).

Sandy Lane Quarry became well known as a result of the discovery there in 1964 of the two elephant skeletons, as described above (Anon., 1966; Blezard, 1966; Fig. 4.32). Straight-tusked elephant, represented by the lower of the two Aveley skeletons, is generally regarded as an interglacial animal, whereas mammoth (the upper specimen) is regarded as a cooler-climate species. The juxtaposition of these finds therefore presented a taphonomic problem. However, Blezard and Sutcliffe both pointed out that a considerable time gap could be represented by the vertical separation of the two skeletons, a view supported by the results of pollen analysis. A pollen diagram was produced by West (1969) from the fossiliferous sediments (beds 2 and 3). These yielded palynological spectra comparable to those previously obtained from Seven Kings, Ilford (West *et al.*, 1964), and were similarly attributed to the Ipswichian Stage (West, 1969). This analysis showed that the straight-tusked elephant lay in sediments dating from biozone IIb of the interglacial, whereas the mammoth lay in deposits of biozone III age. West (1969) discussed the possibility that the mammoth might date from after biozone III, considering that it may have been entombed in the older deposits while they were still soft. Sutcliffe (in West, 1969) reported that there was little sedimentological evidence to support such an interpretation. Correlation between the sites at Aveley and Ilford on the basis of their mammalian faunas has also been established (Sutcliffe and Bowen, 1973; Stuart, 1976; Sutcliffe, 1976), although there has been little recognition of the fact that two separate sets of deposits are present at Ilford (see below and Fig. 4.33).

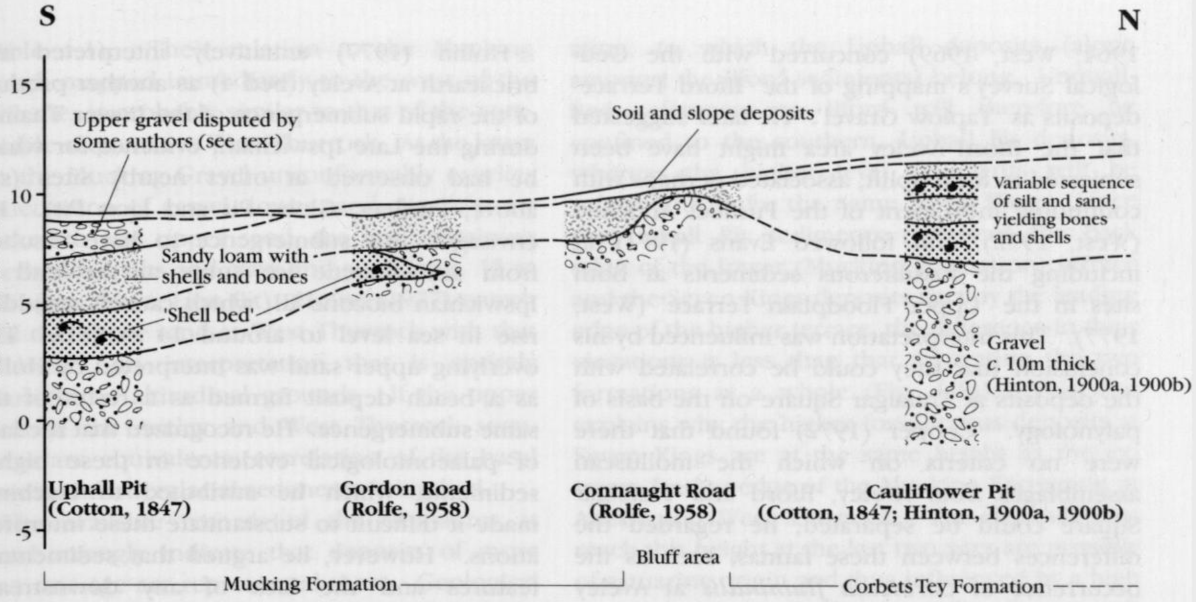


Figure 4.33 North–south section through the terrace deposits at Ilford. Compiled from published records, as shown. Note that information on the base levels of the Pleistocene deposits is generally lacking.

Correlation of the deposits at Ilford with the Ipswichian Stage (*sensu* Trafalgar Square) was the subject of controversy, however, even before the discovery of the elephant skeletons drew attention to the site at Aveley. The Aveley and Ilford sites both occur in association with deposits mapped as 'Taplow Gravel' by the Geological Survey. Sutcliffe (1960, 1964) considered the Ilford deposits to belong to a separate 'Ilford Terrace', intermediate in age between the Boyn Hill and 'Upper Floodplain' terraces. This view was based on differences in the interglacial mammalian assemblages from the deposits of the Boyn Hill/Orsett Heath Formation at Swanscombe, from the 'Ilford Terrace' and from the 'Upper Floodplain Terrace' at Trafalgar Square; it was also supported by the separate recognition of the terraces themselves. Sutcliffe made no distinction between the northern and southern pits at Ilford, which are here regarded as representing separate formations (the Lynch Hill/Corbets Tey Formation and the Taplow/Mucking Formation, respectively; Fig. 4.33, and see below). He noted that hippopotamus occurs only in the 'Upper Floodplain Terrace', as at Trafalgar Square, whereas horse and mammoth occur in the 'Ilford Terrace' but not the 'Upper Floodplain Terrace' (Sutcliffe, 1964, 1976; Sutcliffe and Bowen, 1973; Sutcliffe and Kowalski, 1976). Sutcliffe considered these assemblages to be so different that they could not be contemporaneous; they must either represent different parts of the same interglacial or two different interglacials. A considerable stratigraphical problem was therefore posed by the description of Ipswichian IIb pollen spectra in deposits of both the 'Ilford Terrace', at Ilford (Seven Kings) and Aveley (West *et al.*, 1964; West, 1969), and the 'Upper Floodplain Terrace' at Trafalgar Square (Franks, 1960). At Trafalgar Square the interglacial sediments lie slightly below ordnance datum, although the terrace surface is at 9 m O.D. The 'Ilford Terrace' (south Ilford deposits), on the other hand, is aggraded to above 10 m O.D. (the original terrace surface(s) in the Ilford area are degraded – see Fig. 4.33), some 15 km downstream from Trafalgar Square, with the biozone IIb deposits at 7 m O.D. (West *et al.*, 1964; Sutcliffe, 1976; Sutcliffe and Kowalski, 1976; see below). Sutcliffe attributed the Trafalgar Square deposits to the Ipswichian Stage, as represented at the Bobbitshole type locality in Suffolk, but considered the Aveley and Ilford deposits to have accumulated during an undefined post-Hoxnian/pre-Ipswichian temperate interval. The name 'Ilfordian' has subsequently been suggested for this episode (Bowen, 1978; Wymer, 1985b), but has not gained widespread recognition.

In his earlier papers, West (in West *et al.*, 1964; West, 1969) concurred with the Geological Survey's mapping of the 'Ilford Terrace' deposits as 'Taplow Gravel'. He later suggested that the Ilford–Aveley area might have been subjected to local uplift, associated perhaps with continuing movement of the Purfleet Anticline (West, 1972), and followed Evans (1971) in including the fossiliferous sediments at both sites in the 'Upper Floodplain Terrace' (West, 1977). This interpretation was influenced by his conclusion that they could be correlated with the deposits at Trafalgar Square on the basis of palynology. Cooper (1972) found that there were no criteria on which the molluscan assemblages from Aveley, Ilford and Trafalgar Square could be separated; he regarded the differences between these faunas, such as the occurrence of *Corbicula fluminalis* at Aveley and Ilford but not at Trafalgar Square, as of minor significance. Holyoak (1983) observed that the molluscan assemblage from Aveley consisted entirely of species known from Ipswichian sites; however, current opinion holds that many sites that have been attributed to that stage are, in fact, of intra-Saalian age, a view that originally derived from studies of mammalian faunas (Sutcliffe, 1960, 1964, 1975, 1976; see Chapter 1). It is suggested above that *C. fluminalis*, which Holyoak clearly regarded as present in British Ipswichian faunas, was in fact absent from this country during that stage (see Chapter 2, Stanton Harcourt and Magdalen Grove). Therefore molluscan evidence may support that from mammals in arguing for the distinction between the sediments at Aveley (and Ilford) and those at Trafalgar Square.

Stuart (1976) confirmed the distinction between the Ilford–Aveley and Trafalgar Square mammalian faunas, finding probable equivalents of both in deposits outside the Thames valley. However, he considered that the characteristics differentiating these assemblages could be related to pollen biozones within the Ipswichian. He noted that mammoth and horse were always absent from biozone II, even at Ilford and Aveley, whereas hippopotamus was recorded only from biozone II and the beginning of biozone III. He inferred that the Ilford fauna might in fact be later, not earlier, than the Trafalgar Square fauna and suggested that the Ilford and Aveley deposits were laid down in tributary valleys, therefore explaining their greater elevation than the sediments at Trafalgar Square.

Hollin (1977) tentatively interpreted the brickearth at Aveley (bed 4) as another product of the rapid submergence of the Lower Thames during the Late Ipswichian, evidence for which he had observed at other nearby sites (see above, Purfleet, Globe Pit and Lion Pit). He envisaged this submergence to have resulted from an Antarctic ice surge at the end of Ipswichian biozone III, which caused a sudden rise in sea level to around 14 m O.D. The overlying upper sand was interpreted by Hollin as a beach deposit formed as a result of the same submergence. He recognized that the lack of palaeontological evidence in these higher sediments, which he attributed to leaching, made it difficult to substantiate these interpretations. However, he argued that sedimentary features and the lack of any downstream gradient provided some support for the view. There appears to be little faunal evidence for a marine influence in the underlying fossiliferous deposits; ostracods from bed 2 were described as showing no sign of a marine influence (Robinson, in Hollin, 1977), although Cooper (1972) and Holyoak (1983) reported molluscan species that might indicate the proximity of the contemporary estuary. The particle-size distribution of the deposits at Aveley, evaluated by the plotting of standard deviation against the coarsest first percentile (after Friedman, 1967), is suggestive of a fluvial origin (Wiseman, 1978).

Correlation within the Lower Thames

The recent stratigraphical reappraisal of the Lower Thames terraces by Bridgland (1983a, 1988a) and Gibbard *et al.* (1988) allows further consideration of the relations of the interglacial deposits of the so-called 'Upper Floodplain' and 'Ilford' Terraces to one another and to the terrace sequence as a whole. The deposits mapped as 'Taplow Gravel' in the Lower Thames have now been reclassified as Corbets Tey Gravel and are correlated with the Lynch Hill Gravel of the Middle Thames (Bridgland, 1988a; Gibbard *et al.*, 1988). The deposits at Aveley, however, are not related to the Corbets Tey Formation, which follows a separate course to the east of the Orsett Heath Gravel outlier at Aveley (see above, Purfleet). They are more likely, on the grounds of their location and elevation, to represent part of the Mucking Formation, which is the true equivalent of the Taplow Formation of the Middle Thames

(Table 4.1). Their relation to the Mucking Gravel, mapped immediately to the west of the GCR site, is probably similar to that of the comparable sequence at West Thurrock. At the latter site the Mucking Gravel unconformably overlies a succession of gravel, lower sand, fossiliferous brickearth and upper sand, the last containing interbedded silts and clays and reaching *c.* 15 m O.D. (see above, Lion Pit). Hollin (1977) correlated the upper sand at West Thurrock with that at Aveley, an interpretation that is entirely plausible on altitudinal grounds. If the upper parts of the Aveley and West Thurrock sequences are equivalents, correlation of the basal gravels and interglacial sediments is implied.

The available records of the exposures at Ilford strongly indicate that deposits of more than one age are represented there. Geological Survey Sheet 257 shows the 'Taplow' (Corbets Tey Gravel) outcrop, beneath brickearth, projecting southwards to cover the whole of Ilford. However, Rolfe (1958) illustrated a north-south section through this area (from TQ 446868 to TQ 447865) that suggests that two separate terrace formations are represented at Ilford; the higher one relates to the Lynch Hill/Corbets Tey Formation and the lower one to the Taplow/Mucking Formation (Fig. 4.33). His section showed a distinct rise in the gravel surface (beneath overlying brickearth) at about TQ 446867. This suggests that the deposits to the south of this point are part of the Mucking Formation, the boundary between this and the Corbets Tey Gravel occurring further north than shown on the Geological Survey map. The southward extension of the Corbets Tey Gravel outcrop is therefore erroneous; the boundary between the two formations continues the trend followed both west and east of Ilford (Fig. 4.1).

The Uphall Pit, from which a large proportion of the mammalian and molluscan faunas was obtained, exploited the lower-level deposits of the Mucking Formation, whereas the other main Ilford site, the Cauliflower or High Road Pit, was on the higher Corbets Tey Formation. The latter site also produced molluscan and mammalian remains, notably the collection of Hinton (1900a, 1900b). Records from this and other sites from the higher terrace level at Ilford are not always easily distinguished from those from the Uphall Pit, but should not be included in consideration of the 'Ilford Terrace'; if the latter is taken to include the Aveley deposits, it is clearly synonymous with the Mucking Formation, to which the Uphall deposits (alone amongst the Ilford sediments) belong. Unqualified references to Ilford will therefore be confined to the southern, Uphall Pit deposits, whereas the higher level sediments will be referred to under the name Seven Kings. Since the Uphall Pit sediments represent the back edge of the lower (Mucking Formation) terrace and the Seven Kings deposits occupy the leading edge of the higher terrace, the difference in their elevations is less than that separating the two formations as a whole (Fig. 4.33). This also explains why the higher fossiliferous deposits at Seven Kings are at the same height as the extreme feather-edge of the Mucking Formation at Aveley and West Thurrock. The deposits that reach this height at the last two sites are possibly of estuarine origin and thus influenced by a high interglacial sea level; they therefore reach considerably higher elevations than the general level of the Mucking Formation. It should be noted that Kennard and Woodward (1900) suggested that deposits of different ages were represented by the two main Ilford sites, an opinion that seems to have been based purely on their elevation. Kennard (1916), however, considered that the lower (Uphall Pit) deposits were the younger of the two, the opposite to the opinion expressed here.

Records from the Uphall Pit indicate that a rich molluscan fauna, including the bivalve *Corbicula fluminalis*, was obtained there from a sand interbedded with the gravel of the Mucking Formation. Most of the mammalian fauna, however, was from brickearth overlying the shelly gravel (see Fig. 4.33). A section published by Wood (1866a) showed a further gravel overlying the fossiliferous brickearth in the Uphall Pit; this was presumably the deposit later mapped as 'Floodplain Gravel', which would appear to confirm that the sequence seen at the Uphall Pit is part of the Mucking Formation. According to West *et al.* (1964), Wood (in Woodward and Davies, 1874) subsequently retracted this observation, but this later statement by Wood merely expresses the opinion that the upper gravel at Ilford was not the same deposit that underlies the fossiliferous beds at Grays and Crayford. That Wood continued to recognize an upper gravel at Ilford is indicated by the reproduction of his Uphall Pit section by Woodward and Davies (1874, p. 394), in which the gravel bed above the brickearth is reclassified as 'newer gravel'. Phillips (1871, p. 470) also illustrated sand and gravel above the fossiliferous deposits in the Uphall Pit. Dines and Edmunds (1925) suggested that this upper gravel corresponds with that mapped as 'Floodplain Gravel' by the Geological Survey, thus pre-empting the conclusions outlined above.

Only part of the early fossil collections from Ilford appears, therefore, to come from the Taplow/Mucking Formation – that part that was collected from the Uphall Pit. Nevertheless, the mammalian and molluscan collections from that site are consistent with correlation with the Aveley deposits. The higher-level fossiliferous deposits at the Cauliflower Pit and Seven Kings appear to belong to the Lynch Hill/Corbets Tey Formation. They may represent a further occurrence of temperate-climate sediments similar to those recorded at Grays, Purfleet and Belhus Park, also from the Corbets Tey Formation (see above, Purfleet and Globe Pit). The pollen-bearing deposits described by West *et al.* (1964) at Seven Kings, a series of silts, clays and 'detritus muds', were from a site (TQ 453872) only 0.3 km to the east of the Cauliflower Pit. These sediments overlie the Corbets Tey Gravel, but were attributed by West *et al.* to a later tributary stream. They yielded a different molluscan fauna to that from the Mucking Formation at the Uphall Pit. The Seven Kings assemblage was dominated by *Bithynia tentaculata* and lacked *Corbicula fluminalis*. The relation of the fossiliferous sediments at the Seven Kings pollen site to the Corbets Tey Formation remains uncertain, since they are not covered by a further aggradation of Thames gravel. There is nothing to suggest, however, that they are in any way related to the fossiliferous sediments within the Mucking Formation at Ilford and Aveley.

The sequences at Aveley and West Thurrock, and at the Uphall Pit in south Ilford, can thus be assigned to the Mucking Formation. Their component beds can be interpreted according to the climatic model for terrace formation (Chapter 1): the basal gravels at each site represent the pre-interglacial aggradational phase (phase 2) of the Mucking Formation, whereas the interglacial deposits represent the mid-sequence temperate phase (phase 3). The main Mucking Gravel aggradation, that which appears on the Geological Survey maps as 'Floodplain Gravel' and which overlies the interglacial beds, represents the post-interglacial phase (phase 4) of the climatic model. These three elements of an essentially tripartite sequence are considered here to respectively date from Oxygen Isotope Stages 8, 7 and 6 (Fig. 4.3; Table 1.1).

Correlation with sediments outside the Lower Thames

The conclusion that the mammalian assemblages from Aveley and Ilford represent a distinctive fauna, which relates to an undefined post-Hoxnian/pre-Ipswichian temperate interval, has received support in recent years from the recognition of similar assemblages elsewhere (see Chapter 1). One site that has produced critical evidence is at Marsworth, Buckinghamshire, where a fossiliferous channelfill, producing a mammalian assemblage similar to that at Ilford and Aveley, occurs stratigraphically below another deposit containing hippopotamus. Periglacial colluvium separates the two fossiliferous deposits, indicating that different temperate episodes are represented (Currant and Wymer, in Shotton, 1983; Green *et al.*, 1984; Wymer, 1985b).

Further evidence for an intra-Saalian temperate episode comes from the Upper Thames, where sediments yielding a mammalian assemblage of the Ilford-Aveley type occur within the lower part of the Summertown-Radley Formation, whereas hippopotamus-bearing gravels, attributed to the Ipswichian Stage (*sensu* Trafalgar Square), occur in the upper part of the formation. There is abundant evidence from the intervening gravels that periglacial conditions prevailed between the accumulation of the two sets of temperate-climate sediments (see Chapter 2, Stanton Harcourt and Magdalen Grove). The post-interglacial (phase 4) aggradation of the Mucking Gravel, which overlies the interglacial sediments at West Thurrock, Ilford and (probably) Aveley, provides similar stratigraphical evidence for a cold-climate interval separating these from the Trafalgar Square deposits, although in the Lower Thames the stratigraphical evidence is complicated by the incision event between the Mucking and Kempton Park Formations. The Thames sites at Aveley, Ilford and Stanton Harcourt therefore provide fundamental evidence for the recognition of an additional temperate cycle separating the Hoxnian and Ipswichian interglacials as defined by Mitchell *et al.* (1973). This additional episode has been correlated with Oxygen Isotope Stage 7 of the deep-sea record

(Shotton, 1983; Wymer, 1985b; Bowen *et al.*, 1989; Chapter 1).

Recent analyses of beetle faunas from Aveley, Stanton Harcourt, Marsworth (upper channel) and a further site with similar affinities, at Stoke Goldington, Buckinghamshire, have provided supporting evidence for the correlation of these localities and their distinction from sediments ascribed to the Ipswichian Stage (*sensu* Trafalgar Square) (Coope, in Shotton, 1983). In particular, Coope cited the presence of a species now resident in the Caucasus, *Anotylus gibbulus*, as a dominant feature in the above four faunas. This species had not been recorded from Ipswichian sediments, although it is a minor component of the Devensian interstadial faunas at sites such as Upton Warren and Chelford. Coope suggested that the presence of *A. gibbulus* in abundance may be characteristic of deposits dating from Oxygen Isotope Stage 7. However, the recent discovery of this beetle in sediments at Coston, Norfolk, which also yield abundant hippopotamus and are therefore presumed to be of Ipswichian age (R.C. Preece, pers. comm.), appears to undermine its biostratigraphical value.

Geochronology

The chronostratigraphical interpretation of the Aveley site has been assisted by amino acid analyses of shells from the interglacial beds (see Chapter 1). Early work of this type by Miller *et al.* (1979) yielded amino acid ratios from *C. fluminalis* shells from various Lower Thames sites, including both Ilford and Aveley. From the latter site an average ratio of 0.19 ± 0.023 was obtained. Amino acid ratios from *Bithynia tentaculata* from Aveley, published recently by Bowen *et al.* (1989), suggest correlation with Stanton Harcourt and Crayford, both sites variously interpreted as Ipswichian or post-Hoxnian/pre-Ipswichian (see above, Lion Pit; Chapter 2, Stanton Harcourt). This species produced ratios of 0.170 ± 0.02 (Crayford), 0.154 ± 0.007 (Stanton Harcourt) and 0.148 ± 0.016 (Aveley). In contrast, the same species from the Bobbitshole Ipswichian type locality gave a ratio of 0.09 ± 0.015 and from Trafalgar Square gave 0.11 ± 0.005. These results strongly support the view, already argued on the basis of mammalian faunas (see above; Chapter 1), that the deposits at Aveley, Crayford and Stanton Harcourt are pre-Ipswichian. Bowen *et al.* (1989) regarded the amino acid ratios from these sites as indicative of correlation with Oxygen Isotope Stage 7.

However, an amino acid ratio of 0.23 ± 0.02 from *B. tentaculata* from Ilford (Bowen *et al.*, 1989) indicates a greater antiquity than the Aveley sediments, raising doubts about the correlation of these two sites. Bowen *et al.* ascribed these specimens to the 'shelly bed' at Ilford, which suggests that they came from collections from one of the early sites. *Bithynia tentaculata* was recorded from both the Cauliflower and Uphall pits and was also abundant at the Seven Kings pollen site (West *et al.*, 1964). The above ratio falls within the range interpreted by Bowen *et al.* as indicative of Oxygen Isotope Stage 9. This suggests that the specimens may have come from the Seven Kings deposits (Cauliflower Pit), as the interglacial sediments elsewhere within the Corbets Tey Formation have been attributed to Stage 9 (see Chapter 1 and Table 1.1; Fig. 4.3). The *Corbicula* shells analysed by Miller *et al.* (1979) were claimed to have come from the Uphall Pit. They yielded a mean ratio of 0.23 ± 0.038, identical to that obtained by Bowen *et al.* (1989) from *Bithynia*. Ratios from individual specimens were also published by Miller *et al.*, as follows: 0.19, 0.21, 0.21, 0.26, 0.28. It may be that two separate groupings can be recognized amongst these results, one at around 0.20 and the other from 0.26 to 0.28. The first of these would represent Stage 7 and the second group of higher ratios would represent Stage 9. This might indicate that the shells obtained by Miller *et al.* (from the Natural History Museum) were a mixture of specimens from the Uphall and Cauliflower pits. It is also possible that reworked shells from the older deposits were mixed with indigenous specimens in the sediments in the Uphall Pit. It must, however, be noted here that *Bithynia* shells from Little Thurrock and Purfleet, both of which are broadly correlated in this volume with the Cauliflower Pit sediments and attributed to the same interglacial episode, have given higher ratios than would be expected for Stage 9 (see above, Purfleet and Globe Pit).

Conclusions

The fossiliferous Pleistocene deposits at Aveley are of considerable importance both to the history of the Lower Thames and to British

Pleistocene stratigraphy as a whole. Their interpretation remains a subject of controversy, but most workers now regard this as a key site for the recognition of an additional interglacial between what used to be regarded as the next to last and the last interglacials – the Hoxnian and Ipswichian (respectively) of the established chronology of two decades ago. The controversy hinges on contradictory evidence from mammals and molluscs on the one hand and pollen on the other. It also involves consideration of an inaccessible site that is universally attributed to the last interglacial, at Trafalgar Square. Both sites have produced similar pollen sequences, leading to both being attributed on this basis to the last interglacial (Ipswichian Stage). However, there are marked differences between the mammal and mollusc faunas at the two sites: mammoth, for example, is present only at Aveley, whereas hippopotamus is present only at Trafalgar Square. This led to early suggestions that an older interglacial was represented at Aveley, intermediate in age between the Hoxnian and Ipswichian. In support of this view are two further pieces of evidence. Firstly, the Trafalgar Square sediments form part of a lower terrace, the downstream slope of which takes it below the level of the modern floodplain by the time the Aveley area is reached. Secondly, the analysis of amino acids in shells from the two sites confirms that Aveley is older than Trafalgar Square. Such evidence has led to the widespread recognition that the interglacial at Aveley represents the true penultimate interglacial, equivalent to Stage 7 of the deep-sea record, which occurred at around 200,000 years BP.

NORTHFLEET (EBBSFLEET VALLEY): BAKER'S HOLE COMPLEX

D.R. Bridgland

Highlights

This locality exposes a complex sequence of predominantly fine-grained sediments, probably representing a mixture of fluvial, colluvial and aeolian deposition in a tributary valley of the Lower Thames. The deposits have yielded sporadic mammalian and molluscan remains, mostly of species with cold affinities, but one level in particular suggests interglacial conditions. The rich 'Levallois industry' that occurs in the lower part of the sequence makes Northfleet the most significant Levallois site in Britain.

Introduction

Pleistocene deposits in the Northfleet district constitute the most famous and most prolific source of Levallois artefacts in Britain. These sediments are not of mainstream Thames origin, however, but belong to the tributary Ebbsfleet valley. For this reason, their relation to the Thames terrace system has been difficult to

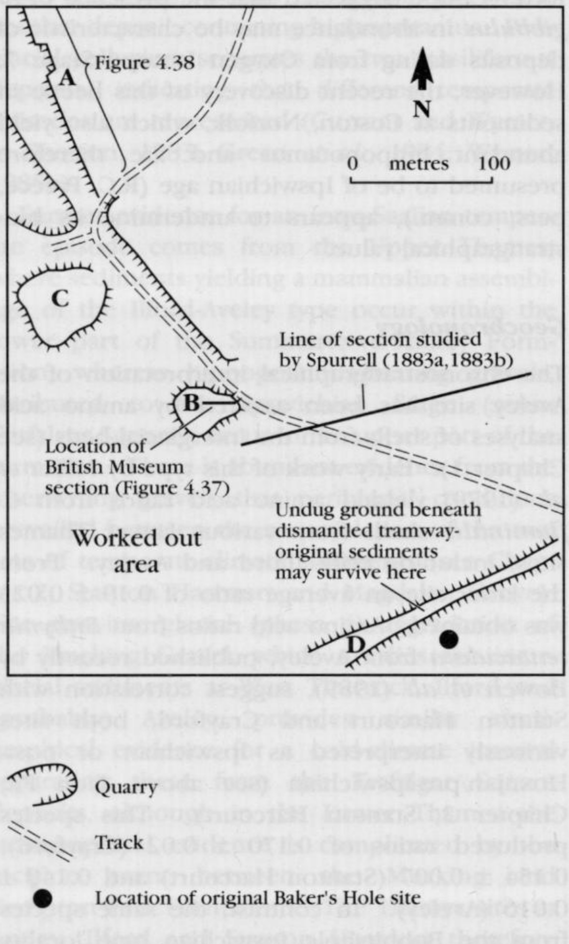


Figure 4.34 Plan of the surviving remnants of the Baker's Hole Complex, Northfleet. A–C are the three parts of the GCR site. Updated information regarding the location of the original Baker's Hole site (and the possibility that sediments related to this survive at D) has been supplied by F.F. Wenban-Smith (pers. comm.).

determine, despite the abundance of archaeological evidence they have yielded. The sediments, which comprise a series of gravels, sands and silts overlying a substantial sheet of soliflucted Chalk (coombe rock), have generally been correlated with the '50 ft' or 'Middle Terrace' of the main river (Smith, 1923; Burchell, 1933, 1934a, 1936a). The sediments above the coombe rock are often referred to as the 'Ebbsfleet Channel' deposits, a name first used by Burchell (1936a, 1936b). The fact that many of the huge numbers of Palaeolithic flakes from Northfleet were made using the Levallois technique (see Chapter 1) has long been recognized (Spurrell, 1883a; Smith, 1911; Dewey, 1932).

Three separate remnants of the Ebbsfleet deposits are included in the GCR site (Fig. 4.34). The stratigraphical relations of these to one another and to the earliest sections at Baker's Hole are imperfectly known. The Baker's Hole site, described in the early years of this century (Abbott, 1911; Smith, 1911), has only been relocated in recent years, having previously been regarded by many authors as entirely quarried away. Although never used by the owners of the site, the name Baker's Hole has consistently been cited in the archaeological and geological literature since 1911. A local legend attributes the name to a drunkard called Baker who perished by falling into the pit (Abbott, 1911). This name was applied by King and Oakley (1936) to the interval during which the periglacial deposits at the base of the Northfleet sequence were supposedly deposited, their 'Baker's Hole or Main Coombe Rock Stage'. The site has also been described under the names 'Southfleet Pit' and 'New Barn Pit'. Chalk extraction at Northfleet has now ceased and the surviving remnants of the Ebbsfleet sediments within the GCR site are to be incorporated in a large-scale restoration scheme in such a way that useful exposures and a reserve of deposits for future investigation both remain.

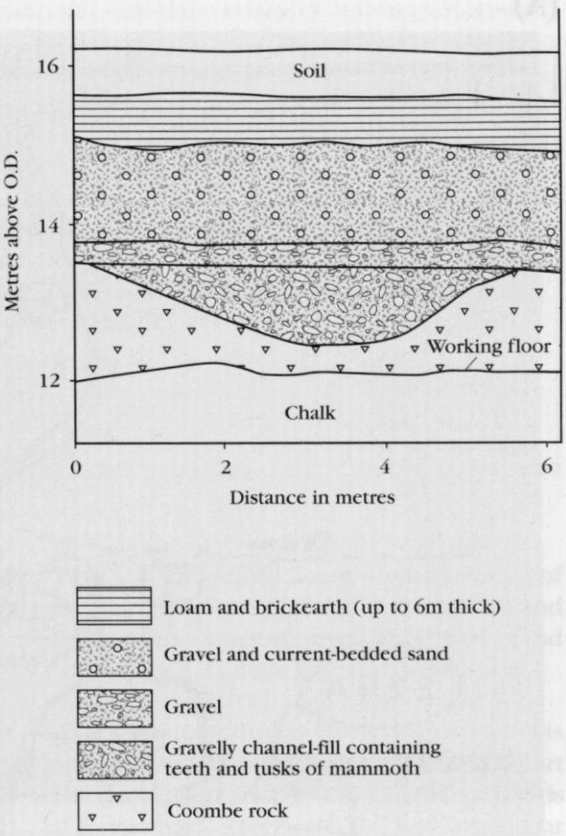


Figure 4.35 Section at the original Baker's Hole site (after Dewey, 1932).

Description

The occurrence of Palaeolithic artefacts in the Ebbsfleet valley at Northfleet was first reported by Spurrell (1883a, 1883b), although it is uncertain precisely where his observations were made. In the early years of this century new quarrying led to the discovery nearby of the celebrated Baker's Hole site, detailed descriptions being provided by Abbott (1911), Smith (1911) and Dewey (1932), the last including an illustration of the stratigraphy (see Figs 4.35 and 4.36). Smith (1911) described Palaeolithic implements and fossils from an accumulation of coombe rock likened, by Reid (in Smith, 1911), to that of the South Downs. The fossils included teeth and bones of elephant, horse, rhinoceros and deer. Few could be identified to species level because of their fragmentary nature and weathered state, but teeth of *Mammuthus primigenius* and *Dicerorhinus hemitoechus* were recognized, together with antler fragments of *Cervus elaphus*.

Dewey (1930, p. 148) described the Baker's Hole site as 'a working floor ... lying under masses of unassorted chalk and flint rubble'. He also observed that there were gravel and sand-filled channels cut into the upper surface of the coombe rock, in which mammoth tusks occurred (Dewey, 1930, 1932). These basal

(A)

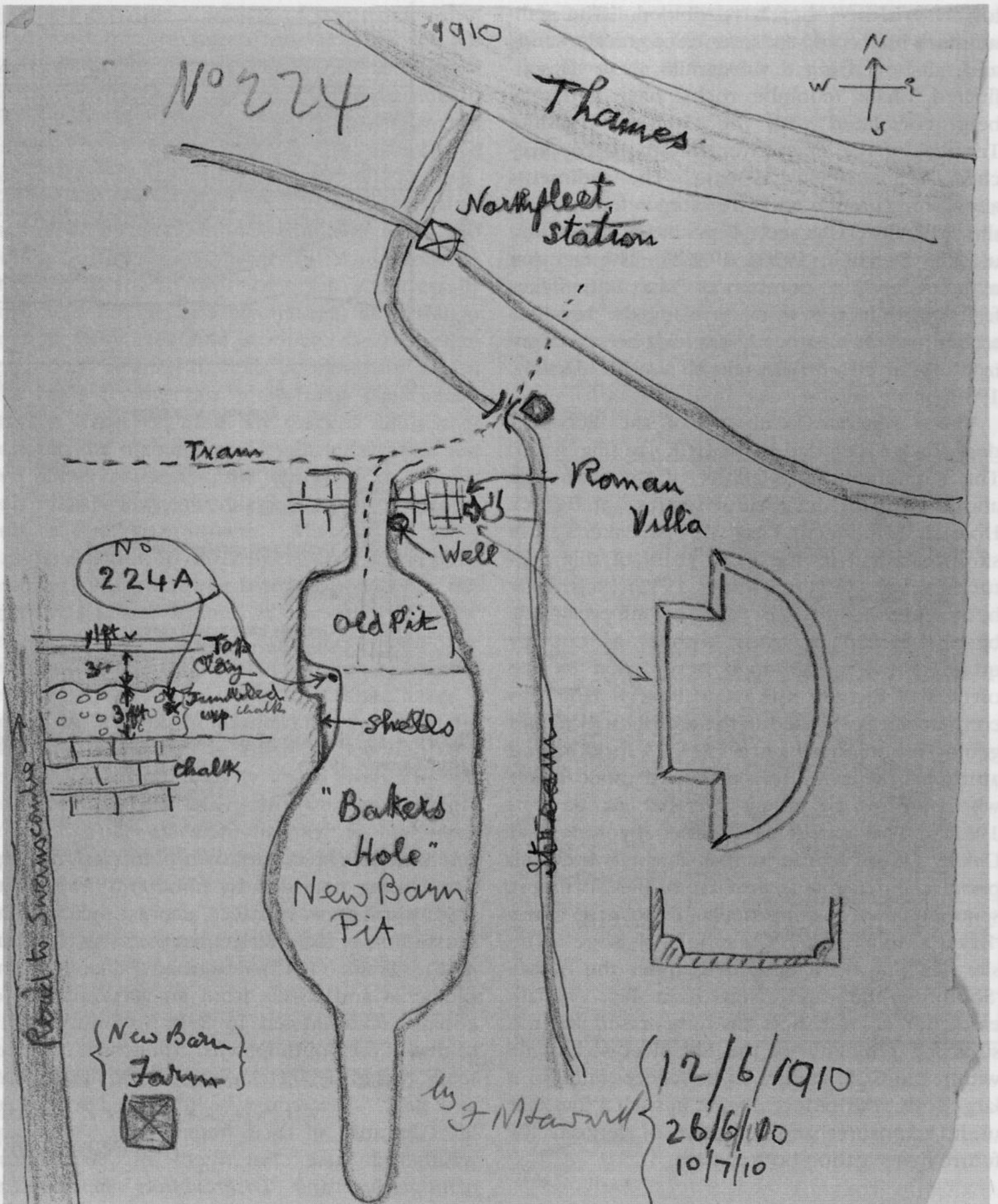
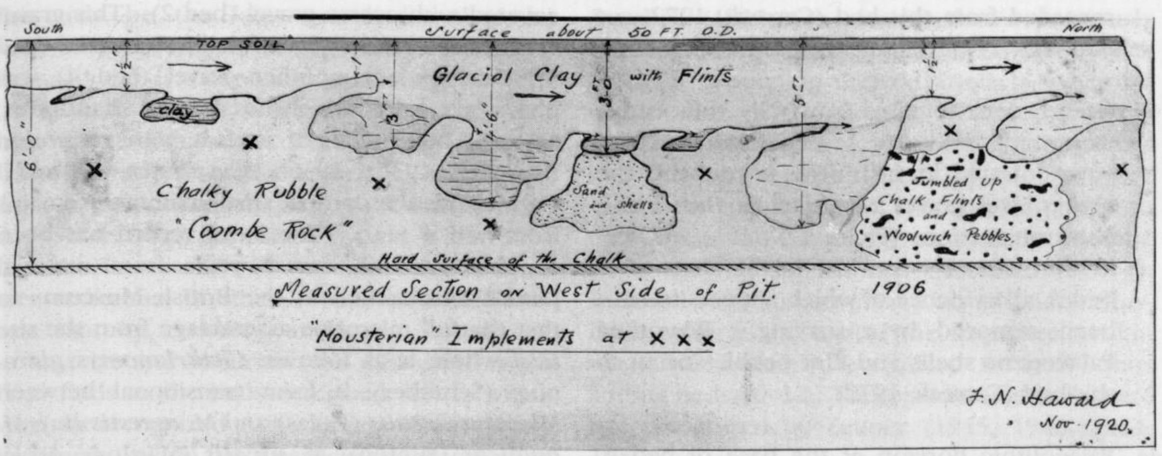


Figure 4.36 Early records from Northfleet, sketches of the original Baker's Hole site. (A) Map showing the location of the quarry known as 'Baker's Hole' and of the section there that yielded Palaeolithic artefacts, drawn by F.N. Haward in 1910. Reproduced by courtesy of the British Museum, London. (B) Measured drawing by F.N. Haward of the section on the west side of 'Newbarn Pit (Baker's Hole)' as seen in 1906, although the drawing is dated November 1920. The locations of artefact discoveries are indicated. (Reproduced by courtesy of the Natural History Museum, London). Thanks are due to F.F. Wenban-Smith, who drew the author's attention to the existence of these archival records, and S. Parfitt, who discovered the section drawing.

(B)



deposits were overlain by gravel and sand, the latter cross-bedded, then 'loam' and brickearth (Fig. 4.35). Spurrell (1883b), however, had referred to the artefacts lying on a 'kind of beach', which led Roe (1981) to question whether the industry might be associated with a fluvial deposit that pre-dates the coombe rock. It seems likely, however, that Spurrell's observations were made in the vicinity of the site later studied by Burchell (see below), so that the 'beach' to which he referred was probably a gravel forming part of the infill of the Ebbsfleet Channel.

Burchell (1933) described a series of gravels and 'brickearths' in the Ebbsfleet valley, overlying a 'bench' cut into the coombe rock and underlying Chalk at 7.5 m O.D. (Burchell, 1933; Fig. 4.37). The stratigraphical sequence here, equivalent to that represented in part of the GCR site, was pieced together over a lengthy period of observation (Burchell, 1933, 1935a, 1935b, 1936a, 1936b, 1936c, 1954, 1957; Boswell, 1940; Zeuner, 1945, 1946, 1954; Kerney and Sieveking, 1977). It can be summarized as follows (few indications of thickness have been recorded, perhaps because of variability in different parts of the channel; see Fig. 4.37):

12. 'Trail' – as bed 9 (formerly undifferentiated from 9).

11. Sandy 'fluvial brickearth'.

10. '*Cailloutis*' (thin gravel bed), yielding Levallois artefacts.

9. 'Trail': gravelly 'loam' with rafts of coombe rock. Published descriptions and illustrations suggest that this bed (and possibly bed 7) were cryoturbated.

8. Silt, aeolian/colluvial (brickearth). This yielded *Pupilla muscorum*. Its upper part was decalcified and devoid of shells. Bands of ferruginous staining were observed near the top.

7. Upper coombe rock, with derived artefacts and land snails.

6. Freshwater silt, fossiliferous (temperate-climate). This bed contains *Corbicula fluminalis* (see, however, below), amongst remains of 40 species of terrestrial, marsh and freshwater Mollusca (see below), as well as mammoth, giant deer, horse and indeterminate rhinoceros.

5a. Buried soil developed in the top of bed 5.

5. Silt (brickearth). This is interbedded with numerous minor lobes of 'coombe rock' and/or gravel. It contains *Pupilla muscorum*, *Vallonia costata* (Müller) and *Limax* sp., the last two from the lower part of the bed only. Descriptions and photographic records of sections excavated by the British Museum in 1969 reveal clear indications of aqueous bedding. These records also suggest interdigitation with (or incision through) beds 2 and 4. A total thickness of over 6 m is indicated (see Fig. 4.37). An

assemblage of small vertebrates is also recorded from this bed (Carreck, 1972; see below).

4. Gravel, with remains of woolly rhinoceros, mammoth and horse, together with artefacts (concentrated in 4a?). This is probably the higher-level gravel recorded in the British Museum sections (Fig. 4.37). If so, its separation from 2 is unclear in the absence of bed 3, all evidence of which appears to have been removed by quarrying. Reworked Palaeogene shells and flint pebbles occur in this bed (Carreck, 1972).

4a. Palaeolithic horizon at the base of bed 4, with a mixture of hand-axes, cores and flakes, including Clactonian and Levallois types (unabraded and unpatinated). These are accompanied by remains of mammoth, woolly rhinoceros and horse (Burchell, 1936a).

3. Sand, fossiliferous, yielding *Bithynia tentaculata*. Not seen in British Museum excavations? Carreck (1972), citing unpublished sources, also listed shells of *Arion* sp. and *Limax marginatus* (Müller), as well as giant deer and a number of small mammals. The latter were listed as *Arvicola abbotti*, *Microtus* sp. and *Clethrionomys* sp.

2. Coarse gravel, cryoturbated into or filling scour/solution hollows in the top of bed 1. Built up to >2 m at the edge of the channel, where it is interbedded with lenses of coombe rock and appears to interdigitate with the lower part of 5 (see Fig. 4.37).

1. Main Coombe Rock, thought to be equivalent to that at the Baker's Hole site. The working floor at Baker's Hole was at the base of this deposit (Fig. 4.35).

Frost-shattered Chalk.

In his early reports, Burchell took the gravel that appears above as bed 4 to mark the base of the Ebbsfleet sequence. Later excavations (Burchell, 1936a) revealed additional beds below this (2 and 3) and showed that the channel had been eroded prior to the deposition of the basal coombe rock (bed 1). The latter formerly occupied the channel, but was largely removed by erosion before its denuded remnant was covered with coarse gravel (bed 2). This gravel was in turn overlain by a fossiliferous sand (bed 3), above which another gravel (bed 4) was observed, from which unabraded hand-axes, amongst other types of artefact, were recovered (Burchell, 1936a, 1936b; see above). Burchell (1935a) also recorded small-mammal remains from bed 4 (4a?). The latter record has been supplemented in recent years from material placed by Burchell in the British Museum, so that the full microtine assemblage from the site as a whole is as follows: *Clethrionomys glareolus* (Schreber); a form transitional between *Microtus arvalis* (Pallas) and *M. agrestis* (L.); *M. anglicus* (Hinton); *M. nivalis* (Martins); *Arvicola cantiana* (Carreck, 1972; Sutcliffe and Kowalski, 1976). Whether all these taxa were present in bed 4/4a is uncertain; Burchell (1936a) also recorded a 'microtine fauna' from bed 3, but gave no details. Carreck (1972) recorded different elements from the above assemblage in beds 3, 4 and 5. Bed 4 also yielded a large Palaeolithic assemblage, listed by Burchell (1933) as: (1) much-rolled Clactonian and Acheulian artefacts, derived from earlier deposits, (2) less-abraded Levallois specimens, washed from the adjacent coombe rock, and (3) unrolled Levallois artefacts of a later type, some with marked Aurignacian (Upper Palaeolithic) characteristics.

Both Burchell and Zeuner interpreted the basal gravels and sands (beds 2–4) as fluviatile, but Kerney and Sieveking (1977) attributed them to solifluction. Detailed records and photographs of the British Museum sections show bedding structures in bed 5 that suggest the supply of silt from the valley side. Once in the channel this silt, of apparent loessic origin (see below), probably joined the sediment load of the Ebbsfleet, so that fluvial silt was deposited away from the margins of the channel. These records also raise questions about the stratigraphical significance of beds 1–4 and of Burchell's interpretation of the sequence of erosional and depositional events. It appears that the sections revealed the edge of a channel cut into frost shattered and soliflucted Chalk, filled by a gravel lag followed by fluviatile silts, the latter interdigitating with further lobes of gravel and coombe rock near the sides of the channel. A widening of the channel was followed by the formation of a later, more widespread gravel lag, which continues over the lower sequence in the deeper part of the channel. This may be the later gravel described by Burchell (bed 4). However, without the fossiliferous bed 3, it is impossible to distinguish beds 2 and 4 amongst a succession of gravels that interdigitate with the silt of bed 5 (Fig. 4.37).

The upper part of the sequence (beds 5 and above), predominantly silts (brickearth) with land snails, was deposited over a wider area than the lower channel deposits. From these later sediments Burchell (1933) obtained artefacts that he classified as Upper Mousterian, Aurignacian and Solutrian (it is difficult to relate these finds to the beds described above, which were not recognized at that time). The surviving brickearth (bed 5) has a particle-size distribution and mineralogical characteristics that suggest that it is predominantly of loessic origin, although with additional sand and gravel material (J.A. Catt and A.H. Weir, pers. comm.).

Continued excavations at Northfleet allowed Burchell (1935a) to observe that a previously unrecognized higher spread of coombe rock (bed 7), containing derived artefacts, occurred within this predominantly loessic (fluvially redeposited?) sequence. The recognition of this and other subordinate beds of coombe rock within the higher part of this succession led to the widespread use of the term 'Main Coombe Rock' for the deposit first described (bed 1). Burchell (1936c) recognized an additional fluviatile cycle at the top of the sequence, within what was formerly recognized as 'trail', thus adding beds 10–12. These additional beds were not recognized by Zeuner (1945, 1946, 1954, 1959).

Burchell originally recorded only the snail *Pupilla muscorum* from the brickearth sequence, which led him to conclude that a cold climate was represented (Burchell, 1935a).

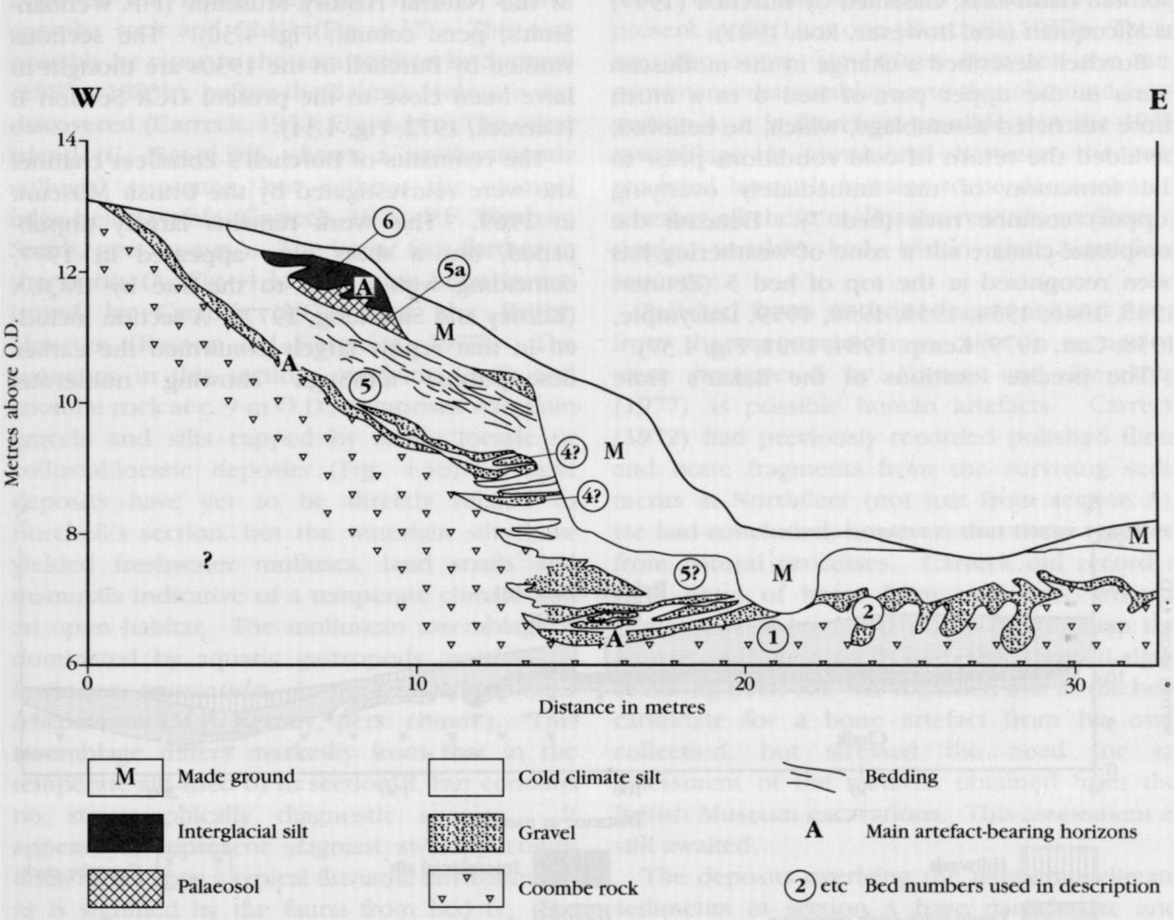


Figure 4.37 Section excavated at Northfleet (B, Fig. 4.34) by the British Museum (after Kerney and Sieveking, 1977). This is believed to coincide with Burchell's main 'Ebbsfleet Channel' section. Numbers refer to the description in the text.

However, later collecting revealed the presence of additional species within the silt (see above, bed 5) and, more importantly, led to the recognition of a temperate-climate bed (bed 6) (Zeuner, 1945, 1946, 1954, 1959; Burchell, 1954, 1957). This produced a rich molluscan fauna numbering some nine freshwater and 16 terrestrial species (Burchell, 1957); amongst the former *Corbicula fluminalis* and amongst the latter *Discus rotundatus* (Müller) were regarded by Burchell as particularly indicative of a climate at least as warm as at present. Carreck (1972) considered the record of *C. fluminalis* to be dubious. Another species listed by Burchell that is important as an interglacial indicator is *Azeca goodalli* (Férussac) (R.C. Preece, pers. comm.). Bed 6 also yielded bones and/or teeth of *Megaloceros giganteus* (giant deer), *Equus ferus* (horse), *Mammuthus primigenius* (mammoth) and rhinoceros, together with an assemblage of pointed hand-axes, classified by Burchell (1957) as Micoquian (see, however, Roe, 1981).

Burchell described a change in the molluscan fauna in the upper part of Bed 6 to a much more restricted assemblage, which, he believed, heralded the return of cold conditions prior to the formation of the immediately overlying (upper) coombe rock (bed 7). Beneath the temperate-climate silt a zone of weathering has been recognized at the top of bed 5 (Zeuner, 1945, 1946, 1954, 1955, 1958, 1959; Dalrymple, 1958; Catt, 1979; Kemp, 1984, 1991; Fig. 4.37).

The precise locations of the Baker's Hole section and of exposures studied at later dates have been subjects of considerable debate, largely because of the imperfect records made at the time. Wymer (1968) placed the original locality approximately 0.8 km to the south-east of the GCR site. Roe (1968b), on the other hand, cited a location 0.3 km to the west of the latter. Carreck (1972) considered Smith's Baker's Hole site to have been *c.* 200 m to the south-east of the surviving sections, at around TQ 614738. A recent detailed study of early publications and of notes and maps preserved with the Palaeolithic collections in the British Museum has led to the confirmation of Carreck's location (Wenban-Smith, 1990, and pers. comm.). It is possible that remnants of this important sequence survive beneath the bed of a disused tramway (Fig. 4.34), thought to be located within 20 m of the faces originally studied by Smith (1911), records of which have recently been discovered in the Natural History Museum (F.F. Wenban-Smith, pers. comm.; Fig. 4.36). The sections studied by Burchell in the 1930s are thought to have been close to the present GCR Section B (Carreck, 1972; Fig. 4.34).

The remnants of Burchell's Ebbsfleet channel site were reinvestigated by the British Museum in 1969. This work remains largely unpublished, but a short note appeared in 1977, coinciding with a visit to the site by INQUA (Kerney and Sieveking, 1977). A section included in that report largely confirmed the earlier descriptions, although showing numerous

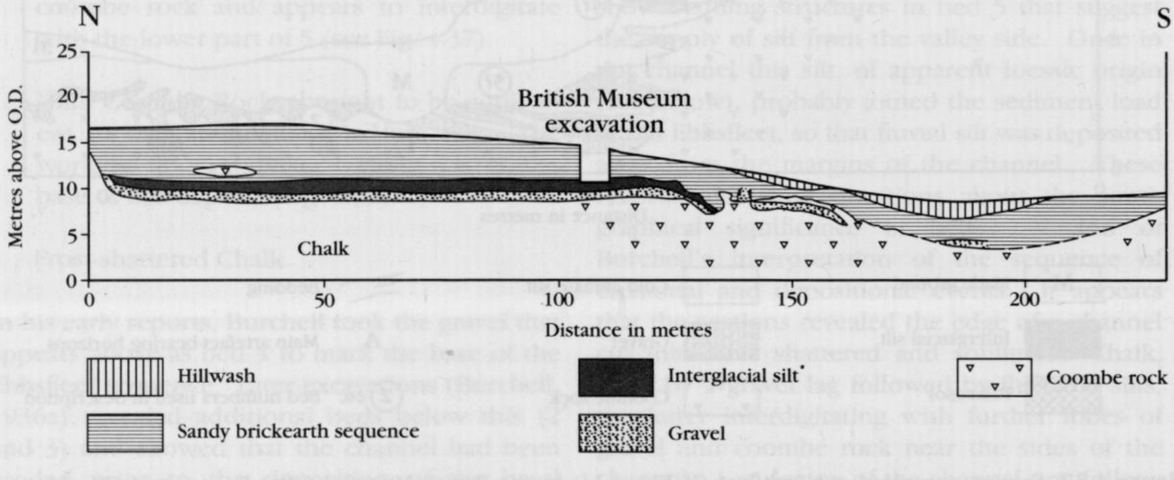


Figure 4.38 Section excavated at Northfleet (A, Fig. 4.34) by the British Museum (after Kerney and Sieveking, 1977).

interdigitations between the coombe rock and the Ebbsfleet loams (Fig. 4.37). The site had unfortunately been damaged by this time by the removal of the highest deposits (the top of bed 6 and all higher beds had been entirely quarried away by that time), and by tipping against the old faces. The occurrence of Levallois artefacts and a cold mammalian fauna in the basal gravels (bed 4?) was confirmed (Kerney and Sieveking, 1977), the palaeoliths corresponding typologically with Smith's (1911) Baker's Hole industry.

All that now remains of Burchell's Ebbsfleet valley locality are two residual islands and a linear face trending NNW–SSE (see Fig. 4.34). These show Chalk overlain by coombe rock, into which the Ebbsfleet deposits are channelled. One of the islands (B, Fig. 4.34) was excavated by the British Museum in the late 1960s (Kerney and Sieveking, 1977) and found to show the edge of the fluvial deposits, banked against coombe rock and Chalk (Fig. 4.37). This may possibly be close to the area studied by Spurrell (1883a, 1883b), before the Baker's Hole site was discovered (Carreck, 1972; Fig. 4.34). The other island (C, Fig. 4.34), shows a predominantly colluvial sequence, but without the channel edge being visible (Carreck, 1972; F.F. Wenban-Smith, pers. comm.). The linear face further to the north (A, Fig. 4.34) has also been investigated by Carreck (1972) and the British Museum (Kerney and Sieveking, 1977). The sequence in this section, overlying Chalk and coombe rock at *c.* 9 m O.D., comprises waterlain gravels and silts capped by sandy loessic or colluvial/loessic deposits (Fig. 4.38). These deposits have yet to be directly related to Burchell's section, but the waterlain silts have yielded freshwater molluscs, land snails and mammals indicative of a temperate climate and an open habitat. The molluscan assemblage is dominated by aquatic gastropods, particularly *Lymnaea truncatula*, *L. peregra* and *Anisus leucostoma* (M.P. Kerney, pers. comm.). This assemblage differs markedly from that in the temperate silt (bed 6) in section B, but contains no stratigraphically diagnostic species. It appears to represent stagnant swampy conditions rather than a typical fluviatile environment, as is signified by the fauna from bed 6. The contrast between the temperate-climate shelly beds in sections A and B may indicate a difference in facies rather than in age. The altitude of the two deposits is closely comparable (*c.* 11 m, section A; *c.* 12 m, section B), which suggests, if both can be confirmed as part of fluviatile sequences, that they may be of similar ages or even lateral equivalents. It is important to establish whether this is the case; if so, the deposits overlying the temperate-climate shelly silt in section A might equate with the higher part of Burchell's sequence, now removed by quarrying from the area of section B.

According to Carreck (1972), a record by Burchell (1935b, p. 330) of 25 molluscan taxa, from 'between Swanscombe and Northfleet', is an early reference to bed 6 in section B. Dominated by *Trichia hispida*, this assemblage was interpreted by Burchell as indicating a climate at least as warm as that at present. However, he provided no details of the location from which this fauna came and did not refer back to this earlier report in 1957. Furthermore, not all the species in the earlier list are present in the later one (Burchell, 1957). There are also some similarities between the unprovenanced assemblage and that obtained from section A; it is therefore possible that the 1935 assemblage is transitional between the two recorded later. It remains to be demonstrated whether all these molluscan records are from a single, variable bed within the Northfleet sequence.

Polished facets on bone fragments and flints from the temperate-climate silts in section A were interpreted by Kerney and Sieveking (1977) as possible human artefacts. Carreck (1972) had previously recorded polished flints and bone fragments from the surviving sediments at Northfleet (not just from section A). He had concluded, however, that these resulted from natural processes. Carreck did record a right ilium of horse from section A, from a stratigraphical level that places it later than the temperate-climate shelly bed, that showed signs of having been cut. He regarded this as the best candidate for a bone artefact from his own collection, but stressed the need for an assessment of the material obtained from the British Museum excavations. This assessment is still awaited.

The deposits overlying the temperate-climate sediments in section A have particle-size and mineralogical characteristics conforming with a loessic origin, but differ in their mineralogy from bed 5 in section B (J.A. Catt and A.H. Weir, pers. comm.; see below).

Interpretation

Abbott (1911) observed the association at Baker's Hole of a depression scoured into the Chalk with brecciation of the bedrock, festooning of the Pleistocene beds, deformation of these strata with slickensides along highly inclined slip-surfaces, together with a general mixing of fossils, archaeological relics and Pleistocene deposits. This led him to suggest that the movement of a heavy frozen mass passing from higher to lower ground had occurred. Of the various early explanations of coombe rock formation, this is one of the closest to the modern interpretation of such deposits as the result of mass-movement (solifluction).

Reid (in Smith, 1911) regarded the coombe rock at Baker's Hole as the product of rainwash derived from chalk slopes, the surfaces of which were partly frozen, during a period of intense cold. Bromehead (in Dewey *et al.*, 1924) suggested that the deposit was laid down by torrents of water produced by summer thaw, likening this to modern processes in Siberia. Similar ideas of torrential deposition of the Baker's Hole deposits were proposed by Jessop (1930). Dewey (1930) was the first to attribute the Main Coombe Rock to mass-movement associated with permafrost conditions, although he regarded the inundation of the working floor as a sudden and catastrophic event.

Interpretation of Palaeolithic assemblages

The importance of the Ebbsfleet valley as a source of unusual and distinctive Palaeolithic material was recognized at an early date. Spurrell (1883a, 1883b) noted the great variety of size, shape and freshness of artefacts from Northfleet and was clearly aware of the method of their manufacture (he gave (1883a) an accurate description of what was later to be termed the Levallois technique). Smith (1911) likened the industry at Baker's Hole to that from Le Moustier in the Dordogne but, although he mentioned that Levallois flakes occurred, the latter term was first applied to the assemblage as a whole by Dewey (1932).

Abbott (1911) repeatedly visited the site from 1892 and recovered implements and 'debitage' of the typical Northfleet type. Following an expansion of quarrying in 1907, large numbers of worked flints were collected by J. Cross; these formed the majority of the implements described by Abbott, who suggested the names 'Prestwichian' and 'Ebbsfleetian' to describe the industries represented at Baker's Hole, terms that did not receive widespread acceptance.

Smith (1911) considered that a small proportion of the Palaeolithic assemblage from Baker's Hole was derived from the earlier '100 ft Terrace' (Boyn Hill/Orsett Heath) deposits, through which the Ebbsfleet valley was eroded prior to the formation of the coombe rock. At least 99% of the palaeoliths were of a distinctive type, however, and were taken by Smith to represent the indigenous Baker's Hole industry. These consisted of flakes and cores, unrolled and usually unpatinated, which were classified by Smith as of 'Le Moustier' type. He concluded that this material represented the debris of a working floor that had been inundated by deposition of the coombe rock.

Burchell (1931) described the industry from the Baker's Hole working floor as Early Mousterian, with Levallois in parentheses. He later considered the unabraded Palaeolithic material collected from the gravels and silts overlying the coombe rock to represent a distinctive later industry, which he classified as 'Levallois D', recognizing certain Aurignacian (Upper Palaeolithic) characteristics in this assemblage (Burchell, 1933). In this paper (1933), he classified the industry from the Main Coombe Rock (bed 1) as 'Levallois B', believing it to post-date the industry from the Upper Loam at Swanscombe, which he classified as 'Levallois A' (see above, Swanscombe). Burchell believed there to be a typological succession of Levallois industries that could be related to terrace stratigraphy in the Lower Thames. He later described unrolled and unpatinated hand-axes from the junction between beds 3 and 4, regarding these as contemporaneous with the Levallois industry, a similar association having been recorded in the Somme valley (Burchell, 1936a, 1936b).

Correlation

The early workers were impressed by the similarity between the coombe rock at Baker's Hole and that on the Sussex coast (see Reid, in Smith, 1911). The occurrence of narrow-nosed rhinoceros *Dicerorhinus hemitoechus* at Baker's Hole was somewhat problematic, since the Sussex coombe rock, the palaeontology of which is otherwise similar, contains the woolly rhinoceros *Coelodonta antiquitatis*. Smith (1911) argued that the solitary tooth of *D. hemitoechus* on which the identification was based might have been derived from earlier deposits, along with a small proportion of the palaeoliths. This is certainly a possibility, since *D. hemitoechus* occurs in the Swanscombe sediments, which cap higher ground to the west of the Ebbsfleet valley (see above, Swanscombe).

Newton (in Smith, 1911) likened the restricted mammalian fauna at Baker's Hole to those from the 'Middle Terrace' of the Thames at Grays and Ilford (see above, Globe Pit and Aveley). Bromehead (in Dewey *et al.*, 1924) considered that the coombe rock (bed 1) had been deposited during the period of erosion that followed the deposition of the 'Middle (Taplow) Terrace' deposits of the Lower Thames, thus supporting Newton's correlation. Dewey (1932) correlated the cold period during which the coombe rock was deposited with the second of the two East Anglian glaciations recognized at that time, which would seem to imply a Saalian age. A similar correlation was proposed by Burchell (1931). Breuil (1932a, 1934) also assigned the Main Coombe Rock to the Riss (glacial) Stage (= Saalian) and interpreted the artefacts as 'early Levallois'. He regarded the deposits as earlier than, or contemporaneous with, the nearby Crayford sediments, now ascribed to the late Saalian Mucking Formation (see above, Lion Pit), which also yield Levallois artefacts.

Burchell (1933) disagreed with Bromehead's interpretation of the Main Coombe Rock as a post-'Taplow Terrace' accumulation, pointing out that coombe rock had never been found overlying this terrace; instead he suggested that the gravels and 'brickearths' that he had observed in the Ebbsfleet valley, cut into the Main Coombe Rock (Fig. 4.37), were probably of 'Taplow' ('50 ft Series') affinities. Burchell likened his 'Levallois D' artefact assemblage from the Ebbsfleet deposits to the industry at Crayford (see above, Lion Pit), thus concurring with Breuil, and claimed support for this view from the fact that both sets of deposits yield *Coelodonta antiquitatis*. He also considered that a comparable sequence of brickearth overlying coombe rock could be observed to the north of the Thames in the Grays area, an apparent reference to the sediments at West Thurrock (see above, Lion Pit).

In their well-known synthesis of Pleistocene deposits in the Thames valley, King and Oakley (1936) proposed two new stage names that relied heavily on evidence from the Northfleet area. The first was the ill-defined, possibly multiple, 'pre-Coombe Rock Erosion Stage(s)'. To this King and Oakley attributed the cutting of the various 'benches' recognized beneath Taplow terrace deposits in the Thames valley, the erosion and infilling of the Wansunt 'channel' (Dartford Heath – see above, Wansunt Pit) and the occupation of the Levallois working site at Baker's Hole. They also proposed a 'Baker's Hole or Main Coombe Rock Stage', which they correlated with the 'Little Eastern glaciation' (Saalian Stage). They believed that the coombe rock covering the Baker's Hole working floor was emplaced and subsequently dissected by the Ebbsfleet during this 'stage' and attributed the Ebbsfleet Channel deposits to the succeeding 'Taplow Stage', thus agreeing with Burchell rather than Bromehead. They also followed Burchell (1936c) in placing the uppermost part of the Ebbsfleet Channel sequence (beds 10 and 11) in their 'Ponders End or Upper Floodplain Terrace No 1 Stage', suggesting that the uppermost silt bed (11) had more the nature of hillwash than fluviatile alluvium. This last statement was disputed by Burchell (1936a), who claimed that, despite its steeply sloping base (from +15 m to -3 m O.D.), this bed contained sedimentary evidence for a fluvial origin.

Zeuner (1945), summarizing the Ebbsfleet sequence, interpreted the predominant silts as loessic deposits, citing the results of mechanical analyses. This view has received recent support from Catt (1977, 1978, pers. comm.; see below). Zeuner (1945, 1955) also described a weathering horizon at the top of bed 5, immediately beneath the temperate-climate silt (bed 6), that showed intense rubification, indicative of an interglacial climate. Catt (1979), however, observed that the reddened horizon contains less illuvial clay than would be expected in a typical interglacial soil. Kemp (1984, 1991) has recently confirmed Catt's observation; he noted that a number of pedogenic features can be recognized, not only in the reddened zone, but also more extensively within bed 5. Kemp considered the surviving material to represent only the basal part of a truncated soil profile, perhaps below the main levels of clay illuviation. He refuted Zeuner's claim that the Northfleet buried soil is strongly developed.

Zeuner (1945) correlated the aggradation (to *c.* 12 m O.D.) of the fluviatile temperate-climate deposits in Burchell's section with his 'Late Monastirian' sea level. He considered that this high-sea-level phase occurred around 125,000 years BP, which would imply correlation with the Ipswichian Stage (*sensu* Trafalgar Square). However, he noted that the sediments at the Baker's Hole site were aggraded to *c.* 16 m O.D., which he thought sufficient to suggest a correlation with the earlier 'Main Monastirian' sea level, which he dated at *c.* 150,000 years BP. He attributed both these high-sea-level phases to the 'last interglacial'; however, the last-mentioned date would now be considered to fall late within the Saalian Stage and to equate with the Oxygen Isotope Stage 6 cold episode (Table 1.1).

Examination by Oakley of the Palaeolithic assemblage collected by Spurrell from Northfleet led Oakley and King (1945) to express misgivings about their earlier correlation of the Baker's Hole coombe rock with the Saalian (King and Oakley, 1936). They decided, in collaboration with A.D. Lacaille, that the typology of the Baker's Hole assemblage placed it later within the 'Levalloisian' than had previously been thought. Oakley and King (1945) concluded that if the Baker's Hole industry, buried by the Main Coombe Rock, was 'late Levalloisian', the aforementioned bed must be post-Saalian. However, Breuil (1947) suggested that local variation in cultural development was responsible for this apparent anomaly and that the Baker's Hole industry, although similar to the 'Early Upper Levallois' in France, was in fact of 'Lower Levallois' (Saalian) age. He thought that a possible reason for such diachronism in the archaeological record was the southward migration of Palaeolithic Man from England in response to climatic deterioration, introducing more advanced techniques, developed in England, into the French sequence at higher stratigraphical levels.

Tester (1958) concurred with Breuil, pointing out that the Main Coombe Rock, if not Rissian (Saalian), would have to be considered of Würm (Devensian) age, which would imply a 'last glacial' age for the Taplow Terrace and leave a large hiatus between this and the (Hoxnian) Boyn Hill Terrace. Tester suggested that the character of the Baker's Hole industry resulted in part from the unusual abundance of excellent flint that was available following the pre-Main Coombe Rock downcutting. This allowed the extravagant Levallois technique to be used, there being no need to conserve raw material. This suggestion by Tester pre-empted modern interpretations, which recognize the availability of raw material as a major influence on the use of the Levallois technique and no longer consider it possible to recognize an evolutionary sequence within the Levallois assemblages from the Lower Thames (Roe, 1981).

In his later work, Burchell (1957) suggested a direct correlation between the temperate-climate silt (bed 6) in the Ebbsfleet succession and the similar '*Corbicula* bed' at Crayford (see above, Lion Pit). The temperate-climate sediments at Northfleet were attributed by Kerney and Sieveking (1977) to the Ipswichian Stage, mainly on the basis of their elevation, since they contain no pollen or stratigraphically significant fauna. However, Stuart (in Sutcliffe and Kowalski, 1976) noted that teeth of the vole *Arvicola cantiana* from the Burchell collection were of early type, implying (according to Sutcliffe and Kowalski) a pre-Ipswichian (*sensu* Trafalgar Square) age. The occurrence of *C. fluminalis* may provide support for this view, since this species is now regarded by some authorities as having been absent from Britain during the Ipswichian Stage (*sensu* Trafalgar Square) (see Chapter 2, Stanton Harcourt and Magdalen Grove). Note, however, that the occurrence of *C. fluminalis* at Northfleet requires confirmation. Carreck (1972) noted that reworked fragments of a Palaeogene *Corbicula* species are common in the Ebbsfleet sediments. Unfortunately, amino acid analyses of shells from Northfleet, which might provide a further indication of their age, have yet to be carried out (see, however, note at end of Interpretation section).

Care must be exercised in applying the new stratigraphical scheme for the Lower Thames terraces, presented in this volume, to the Ebbsfleet deposits, as they occur in a tributary valley, in which steeper gradients might be expected. However, the elevation of the water-lain sediments, between 7.5 m and 12 m O.D., suggests an association with the Taplow/Mucking Formation of the main river. This would confirm a correlation of the Northfleet sediments with the Taplow aggradation, as advocated by Burchell and others, but not with the deposits mapped as 'Taplow' in the Lower Thames (these are older; see above, Purfleet and Globe Pit), a fact that may have led to the dispute between Burchell and Bromehead (see above). This interpretation implies a correlation of the temperate-climate bed at Northfleet with the various interglacial deposits within the Mucking Formation of the main valley, such as those at Aveley and West Thurrock. Although regarded by many previous authors as being of Ipswichian age, these have been interpreted in this volume as representative of an undefined post-Hoxnian/pre-Ipswichian temperate interval, the equivalent of Oxygen Isotope Stage 7 (see above, Lion Pit and Aveley). The underlying fluviatile and aeolian beds at Northfleet can therefore be ascribed to Oxygen Isotope Stage 8, whereas the sediments above the temperate-climate silt probably date from Stage 6. This interpretation receives support from the association, at other sites in the Lower Thames, of sediments ascribed to Stage 8 with Levallois artefacts (see above, Purfleet and Lion Pit). The evidence from Northfleet may therefore help to reinforce the view that the recognition of this technique within the British Palaeolithic record may be of considerable stratigraphical significance.

The thermoluminescence dating technique has recently been applied to the Northfleet deposits (Parks and Rendell, 1988), sediments having been sampled from section A (H.M. Rendell, pers. comm.). These range between 149,200 and 115,600 years BP, results that would seem to point to a younger age than that suggested above. However, Parks and Rendell emphasized that, because of problems encountered in using this technique to date pre-Devensian sediments, these should be regarded as 'minimum age estimates' (the implications of these dates cannot in any case be determined until full stratigraphical details are published).

Mineralogical analyses of the loess-derived sediments exposed in both sections A and B (Figs 4.37 and 4.38) by J.A. Catt and A.H. Weir (pers. comm.) provide further clues to the possible age of the Northfleet sequence. By determining the relative proportions of non-opaque heavy-mineral species in the silt and fine-sand size ranges, it has been shown that Devensian loesses, which are common throughout southern and eastern Britain, have a characteristic suite of such minerals, strongly dominated by epidote (Catt *et al.*, 1971, 1974; Eden, 1980; Bridgland, 1983a). The fluvially bedded silt (bed 5) below the temperate-climate horizon in section B was found to have significantly different mineralogical characteristics; for example, it contains less epidote, amphiboles and rutile than typical Devensian loess, but more zircon, tourmaline and kyanite. Bed 5 also contains a rare brown and green spinel, which has not been reported in Devensian loessic deposits. Whether these differences result from genuine distinctions between loesses of different ages (which would be of considerable stratigraphical value), or whether they reflect the addition of silt-grade material from other sources into the Ebbsfleet deposits, remains uncertain. However, J.A. Catt and A.H. Weir (pers. comm.) have observed similar heavy-mineral distributions in pre-Eemian loess in Belgium. They have found that the Ebbsfleet silt (bed 5) also resembles this pre-Eemian loess in its clay mineralogy; both are composed mainly of smectite, illite and kaolinite. Devensian loess at Pegwell Bay, Kent (Weir *et al.*, 1971), has a quite different clay mineralogy in that it also contains significant proportions of vermiculite.

Catt and Weir have also found that the suite of heavy minerals in the temperate-climate sediments in section A at Northfleet resembles that in the pre-'*Corbicula* bed' silt (bed 5) in section B and in the Belgian pre-Eemian loess. The clay mineralogy confirms this affinity, which suggests that reworking of sediment from the underlying silt into the temperate-climate deposit has occurred. The brickearth that overlies the temperate-climate silts in section A has a similar clay mineralogy to the other sediments at Northfleet, but its heavy-mineral assemblage has considerably more epidote and less zircon. Although these differences mean that this upper brickearth has a mineral content closer to Devensian loess than any other bed at Northfleet, its composition remains transitional; in fact it resembles the pre-temperate silt (bed 5) more closely than it resembles Devensian loess. These results indicate that, if this upper brickearth is primarily of loessic origin (as its particle-size distribution suggests), either it too is of pre-Devensian age or it has largely been reworked from the older silt (bed 5).

Summary

The complex site at Northfleet is of considerable importance to British Quaternary stratigraphy. It represents the most significant occurrence of Palaeolithic material in Britain showing the use of the Levallois technique. Past researchers have probably read more into the Palaeolithic sequence at this site than can be supported by more rigorous assessment, but knowledge and understanding of the Levallois technique as represented in Britain is heavily dependent on evidence from this locality.

Important evidence for dating the industry and for reconstructing the palaeoenvironment that prevailed when the deposits were laid down is provided by the fossiliferous parts of the Northfleet sequence. The succession represents an important phase in the fluvial history of the Lower Thames region, one in which the presence of Palaeolithic Man was significant. It is probable that a previously unrecognized temperate episode, intermediate between the Hoxnian and Ipswichian Stages of the traditional chronology, is recorded by part of the Ebbsfleet sediments. These temperate-climate sediments have been widely attributed to the Ipswichian, but according to the new Lower Thames stratigraphical scheme, adopted in this volume, they are believed to correlate with Oxygen Isotope Stage 7 (intra-Saalian). This implies broad correlation with sediments of the main Lower Thames at Ilford (Uphall Pit), Aveley, West Thurrock and Crayford (Table 1.1).

Note: since writing this report, amino acid ratios have been obtained from shells of *Lymnaea peregra* from section A. Three sets of analyses yielded similar results, giving the following mean ratios: 0.177 ± 0.020 ($n = 5$); 0.188 ± 0.022 ($n = 5$); 0.169 ± 0.038 ($n = 8$) (D.Q. Bowen and F.F. Wenban-Smith, pers. comm.). These results strongly support the arguments given above for a Stage 7 age for the temperate-climate deposits at Northfleet.

Conclusions

The Northfleet site records the deposition of sediments in an old channel of the Ebbsfleet, a tributary of the main River Thames. The sequence here is largely of cold-climate origin, commencing with a basal 'coombe rock', a deposit formed by the accumulation of Chalk debris as a result of slope movement under periglacial conditions. At the bottom of this deposit, at the original Baker's Hole site, a Stone Age working area was discovered. The flint debris of this working site, some of which could be fitted back together, showed the use of a technique known as 'Levallois'. Indeed, Baker's Hole is the most important Levallois site in Britain. A complex sequence of gravel, sand and silt overlies the basal coombe rock and has produced further Levallois material, as well as occasional mammalian bones and teeth and snail shells, all suggestive of cold conditions. Other types of flint artefacts have also been recovered. Silty material at two locations (at least) within the Baker's Hole complex has yielded shells of temperate-climate molluscs, implying that a warm episode is represented within the predominantly cold Northfleet sequence. Traces of soil formation in the earlier sediments beneath this bed seem to confirm that temperate conditions prevailed and that there was a brief break in sedimentation at this time. This deposit was overlain by further cold-climate sediments, now mostly quarried away, which showed evidence of frost action during periods of intense cold.

There is little information from which to date either the temperate episode represented at Northfleet or the important artefact-bearing sediments that make up the lower part of the sequence. Comparison with the terrace sequence in the adjacent Lower Thames valley, however, suggests that the deposits are of mid- to late Saalian age and that the temperate episode probably equates with Stage 7 of the deep-sea record – about 200,000 years BP.