Aveley, Sandy Lane Quarry

[TQ 551 808]

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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 (Figure 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 (Figure 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 (Blez-ard, 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 brickmaking (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 560 808] 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 (Figure

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 (calcare■ ous) 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 London Clay	*c.* 3.0 m

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. (Figure 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 an even thicker sequence). Many of the beds are, therefore, of variable thickness, thinning against the London Clay 'cliff to the east (Figure 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; 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; (Figure 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; (Figure 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 (Figure 4.33)).

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; (Figure 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 (Figure 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 446 868] to [TQ 447 865]) 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 (Figure 4.33). His section showed a distinct rise in the gravel surface (beneath overlying brickearth) at about [TQ 446 867]. 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 (Figure 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 (Figure 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 (Figure 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 453 872] 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 (Figure 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.

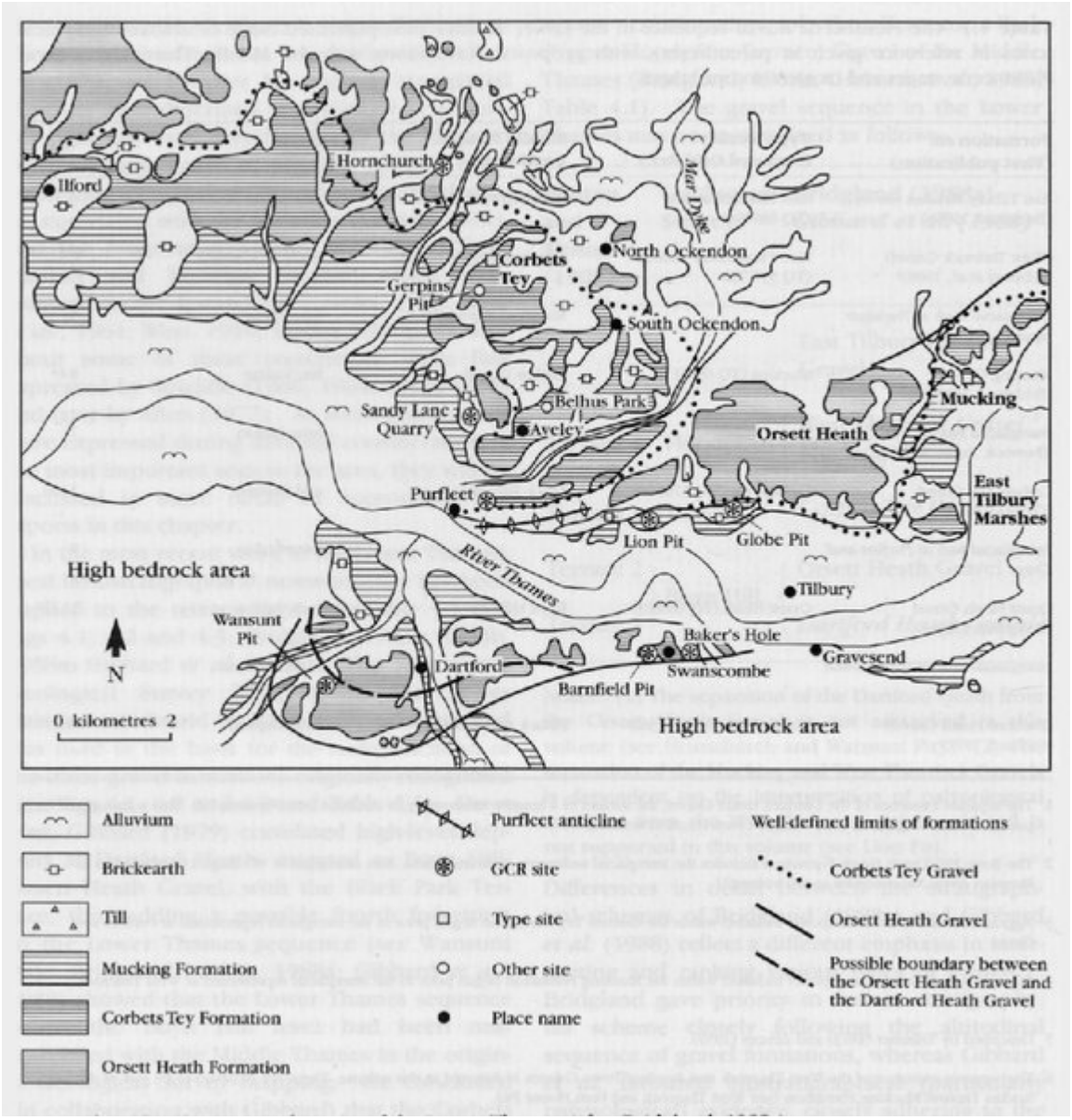
However, an amino acid ratio of 0.23 ± 0.02 from *B. tentaculata* from Ilford (Bowen *et al.,* 1989) indicates a greater antiquity than the Aveley sediments, raising doubts about the correlation of these two sites. Bowen *et al.* ascribed these specimens to the 'shelly bed' at Ilford, which suggests 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); (Figure 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).

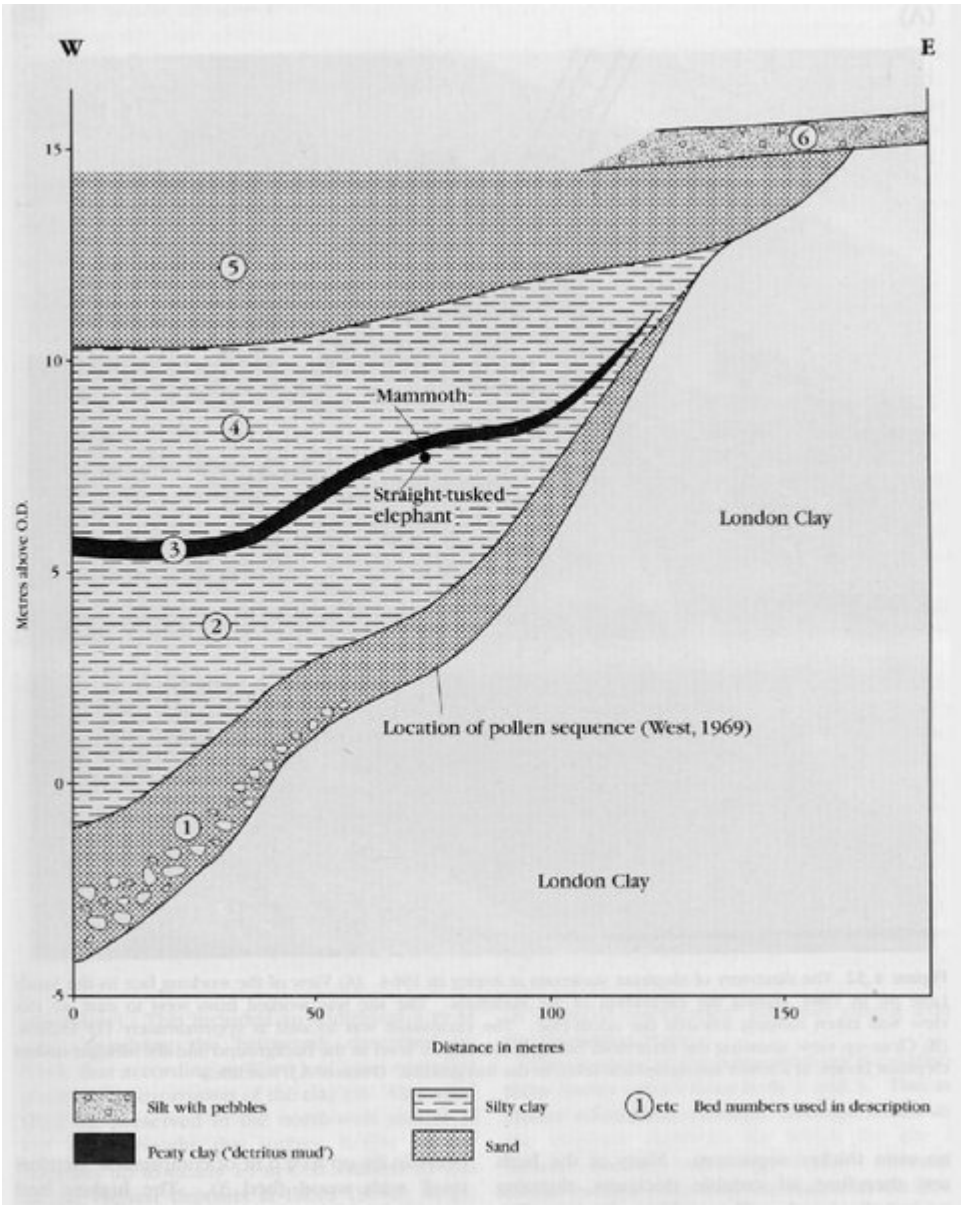
Conclusions

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.

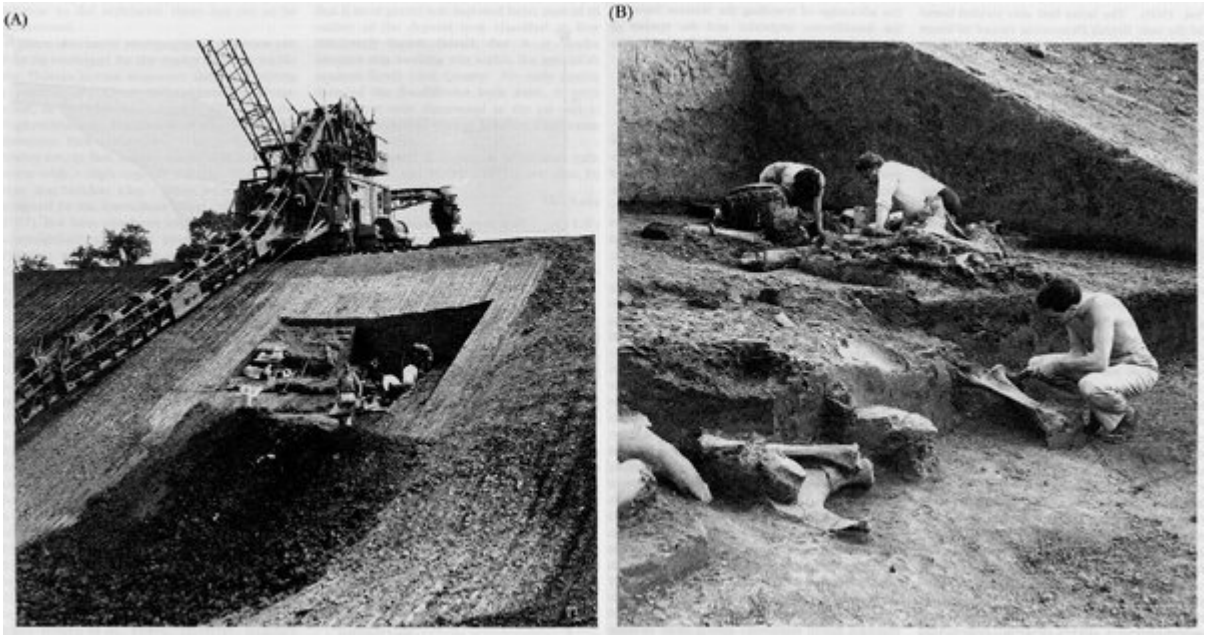
References



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

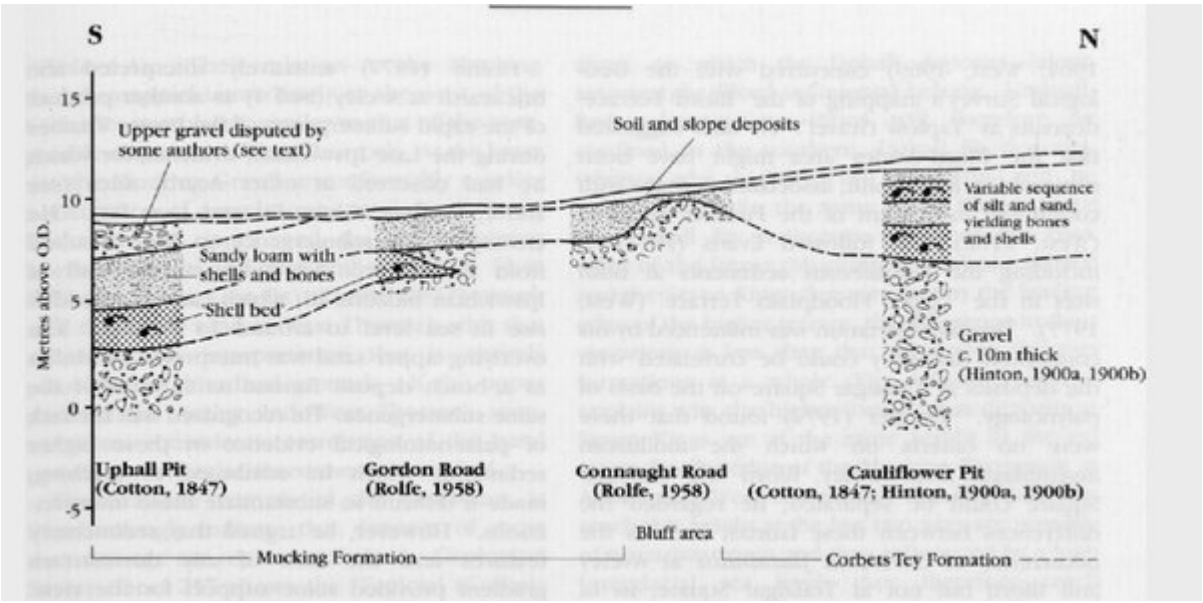


(Figure 4.31) Section through the deposits of the Mucking Formation at Sandy Lane Quarry, Aveley (modified from Hollin, 1977).



(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 552 808]. (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.)



(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.

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.

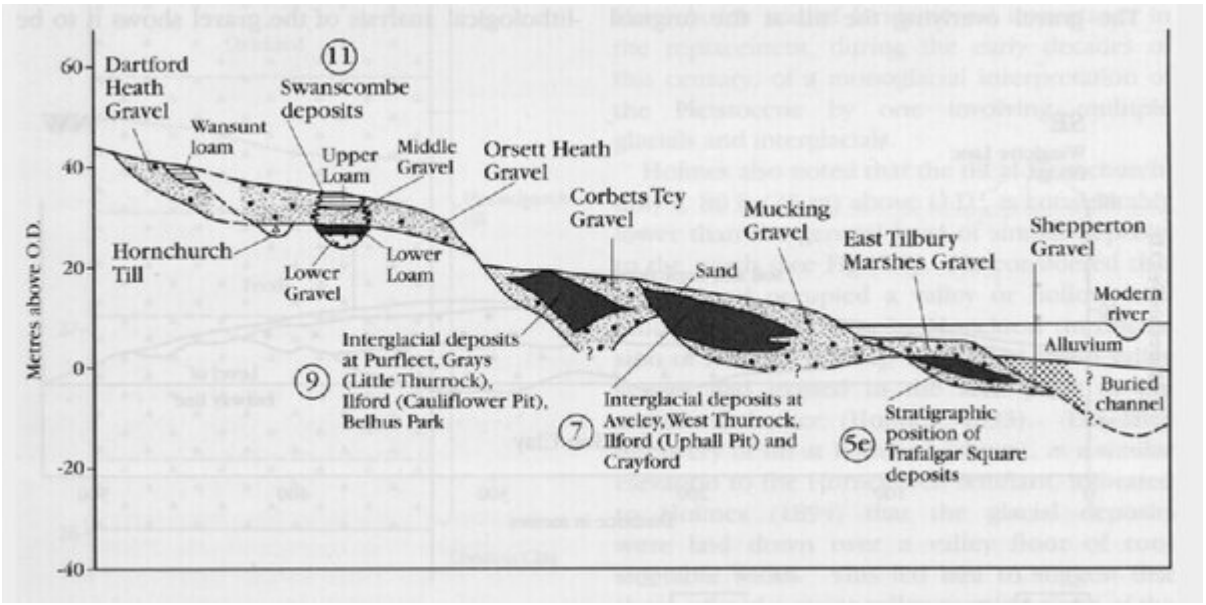
4 Aggradation of the terrace deposits included within the Mucking Formation began prior to the interglacial represented at West Thurrock, Aveley etc.

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.

(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.



(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.

Age (in thousands of years)	Upper Thames	Middle Thames	Lower Thames	Essex	Stage	^{18}O
10	Recent floodplain and channel deposits: Holocene alluvium of floodplain and coast				Holocene	1
71	Northmoor Gravel	Shepperton Gravel	Submerged	Submerged	late Devensian	2-4
		Temperate climate deposits at South Kensington (Imperial centre), Isleworth and Kempton Park	Submerged	Submerged	early-mid-Devensian? interstadial(s)	3a & /or 3c?
122	Cold climate gravels above Tyrrhurn Gravel	Reading area: Upper levels of Taplow Gravel	Slough area: Kempton Park Gravel	East Tilbury Marshes Gravel	Submerged	early-mid-Devensian	5d-2
128	Tyrrhurn Gravel	Within Taplow Formation	Trafalgar Square and Brentford deposits	Below floodplain	Submerged	Ipswichian (across Trafalgar Square)	5e
186	Stanton Harcourt Gravel	Taplow Gravel	Basal Kempton Pk Gravel - incl. Spring Gardens Gravel of Gibbard (1985)	Basal East Tilbury Marshes Gravel	Submerged	late Saalian	6
		Taplow Gravel	Mucking Gravel				
245	Stanton Harcourt Channel Deposits, interglacial Magdalen Grove, Summertown etc.	Interglacial deposits at Redlands Pit, Reading	Interglacial deposits at Arches, Ilford (Uphall Pit), West Thurrock, Grayford and Northfleet	Submerged	Intra-Saalian temperate episode	7
	Basal Summertown-Radley Formation at some sites?	Basal Taplow Gravel?	Basal Mucking Gravel	Submerged		
					mid-Saalian	8
303	Wolvercote Gravel at some sites?	Lynch Hill Gravel	Corbets Tey Gravel	Barling Gravel		
339	Wolvercote Channel Deposits		Interglacial deposits at Ilford (Cauliflower Pit), Belhus Park, Purfleet and Grays	Shoeburyness Channel interglacial deposits	Intra-Saalian temperate episode	9
	Basal Wolvercote Gravel	Basal Lynch Hill Gravel?	Basal Corbets Tey Gravel	Shoeburyness Channel - basal gravel		
					early Saalian	10
	* Moreton Drift (Arkell, 1947a)					
	Harborough Gravel	Boyn Hill Gravel	Orsett Heath Gravel	Southchurch/Asheldham/ Mersea Island/Wigborough Gravel		
425	Reworked mammalian fauna in Harborough Gravel		Swanscombe deposits	Southend/Asheldham/ Cudmore Grove/Clacton Channel Deposits	Hoxnian (across Swanscombe)	11
	Basal Harborough Gravel?	Basal Boyn Hill Gravel?	Basal Orsett Heath Gravel (incl. Basal Gravel at Swanscombe)	Southend/Asheldham/ Cudmore Grove/Clacton Channel - basal gravel		
	Rejuvenation event					
	Preclard Formation	Black Park gravel			Anglian	12
	Moreton Drift?	Anglian glacial deposits	Hornchurch Till	U St Osyth/U. Holland Gravel		
478	Preclard Formation	Winter Hill/Westmill Gravel	Valley did not exist as a Thames course prior to this	St Osyth/Holland Formation		
	Sugworth Channel Deposits	Basket Gravel?		Wivenhoe/Cooks Green Pit Ardleigh/St Osyth Formation Wolsingfield Gravel	Cromerian Complex	13-15
	Combe Formation	Germans Cross Gravel		Boyes Gravel*	Early Pleistocene	pre-13
	Higher divisions of the Northern Drift Group	Beaconsfield Gravel Satwell Gravel Gravel at Cholsey wood Westland Green Gravels Stoke Row Gravel Nettlebed Gravel Nettlebed interglacial deposits		Mersea Gravel* Stubbing Gravel*		

* Nomenclature for High level Kesgrave Subgroup in Essex follows Whiteman (1990).

(Table 1.1) Correlation of Quaternary deposits within the Thames system. Rejuvenations that have occurred since the Anglian glaciation are indicated.