Lion Pit Tramway Cutting (West Thurrock)

[TQ 598 783]

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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 (Figure 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 trickearths'. These were: (1) the Tunnel Cement Works (first described by Abbott, 1890), at the extreme western end of the brickearth outcrop [TQ 575 777]; (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 (Figure 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 — (Figure 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 (Figure 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 590 780], provided sections through a very similar sequence, again banked against Chalk on the southern side of the Purfleet Anticline (Figure 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 (Figure 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, (Figure 4.26), (Figure 4.27) and (Figure 4.28)) was located at the northern limit of the 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 (Figure 4.27) and (Figure 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 (Figure 4.27) and (Figure 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 (Figure 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 (Figure 4.26) and (Figure 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 (Figure 4.29) yields a large amount of worked flint, including characteristic Levallois artefacts of the type described by Warren (see below; (Figure 4.30)). Several of the pieces collected in 1984 have been found to refit together (Figure 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. (Figure 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 (Figure 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 (Figure 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 (Figure 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 (Figure 4.27)).

Two smaller sections (sections 2 and 3) further south revealed a sequence similar to that observed in the road cutting (Figure 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 recovered. 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* (Willer), *Hippeutis complanatus* (L.), *Lymnaea truncatula* (Willer), *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 (Figure 4.25). In section 2 of the tramway cutting the gravel, less than 2 m thick, was cryoturbated into the top of the brickearth (Figure 4.26). Although not present at section 1, this gravel represents part of the waterlain succession at West Thurrock and has 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 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; (Figure 4.27)) was excavated under controlled archaeological conditions and yielded 87 flakes and four cores (Figure 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 (Figure 4.27). The material includes a number of flakes that can be refitted on to one another or on to cores (Figure 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 (Figure 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 (Figure 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 517 758] and Rutter's Pit [TQ 514 765], 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).

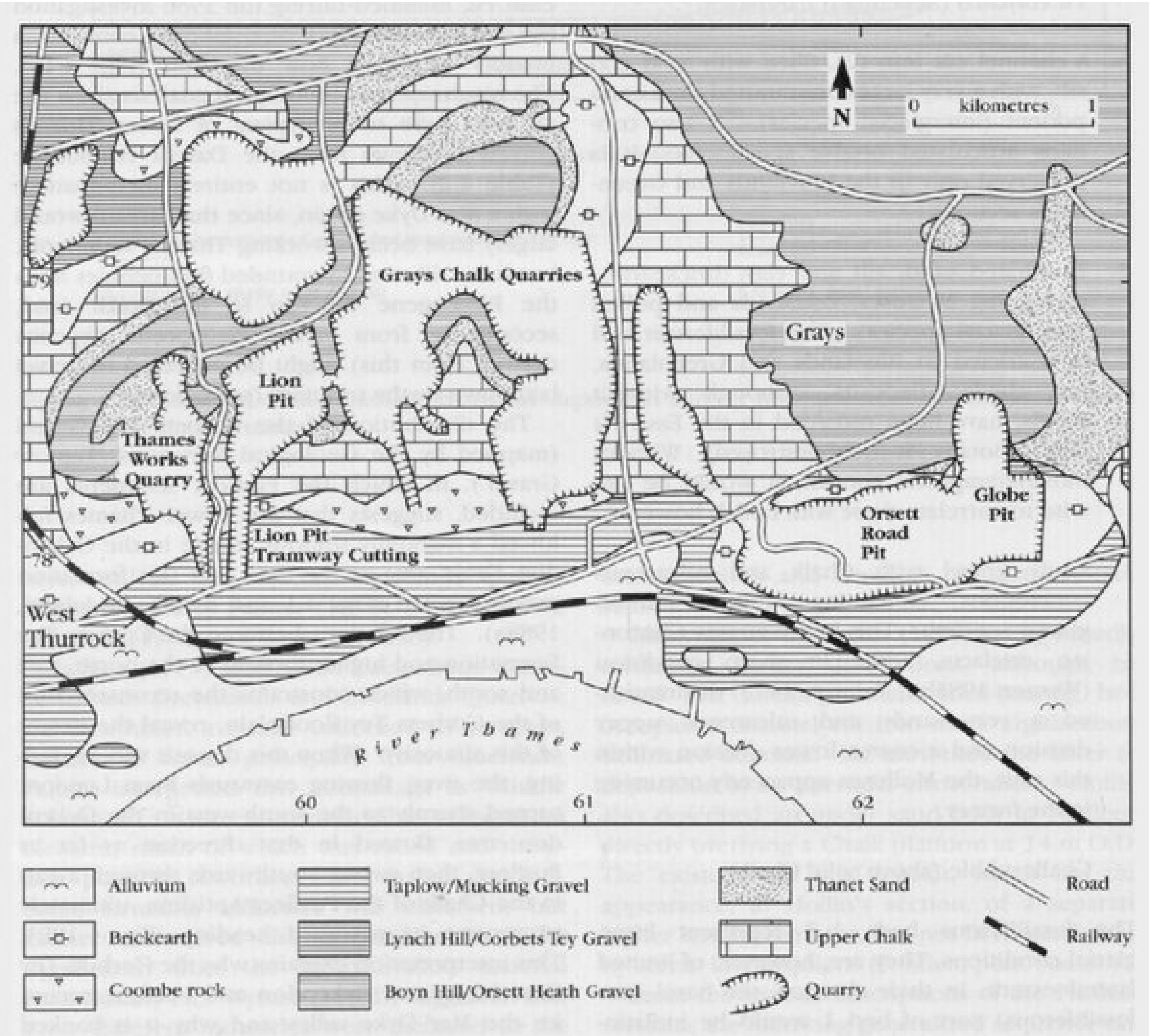
Conclusions

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

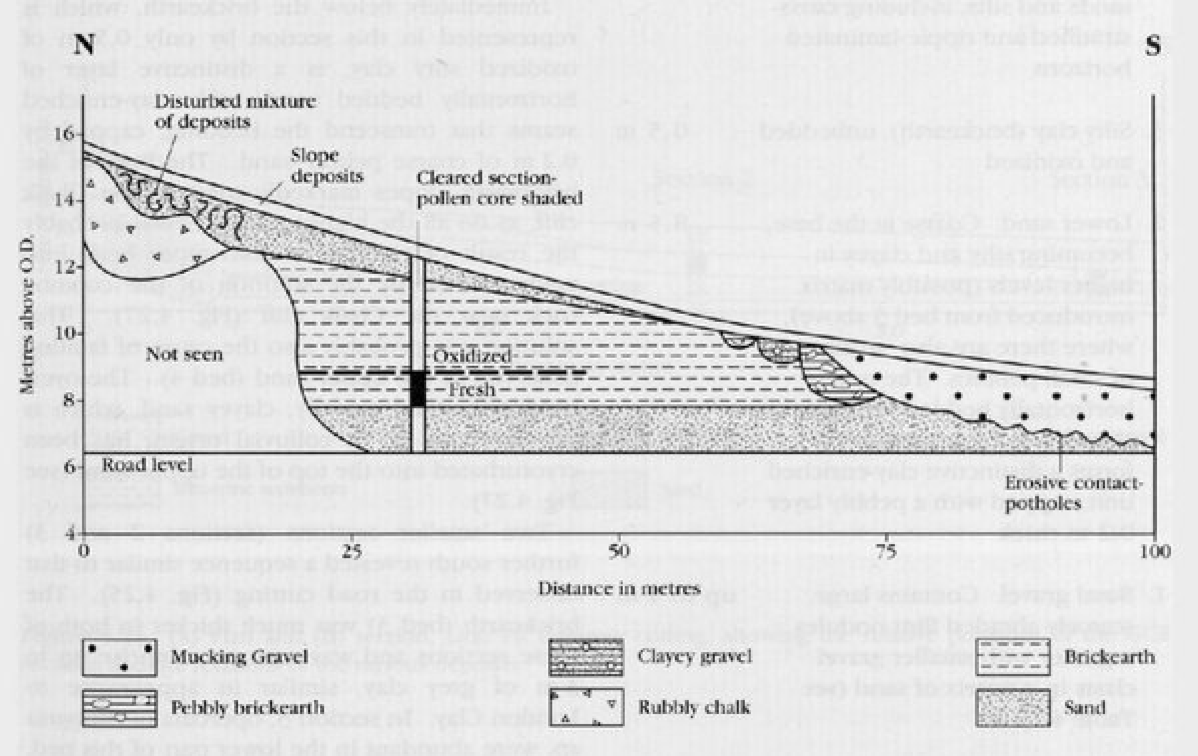
Gravel of the Lower Thames — the lowest of the three terraces recognized above the modern floodplain in this area. The basal deposit at West Thurrock is a mass of redeposited Chalk ('coombe rock') that has accumulated beneath the cliff, probably under cold conditions. Several further lenses of similar 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 trickearth'. 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.

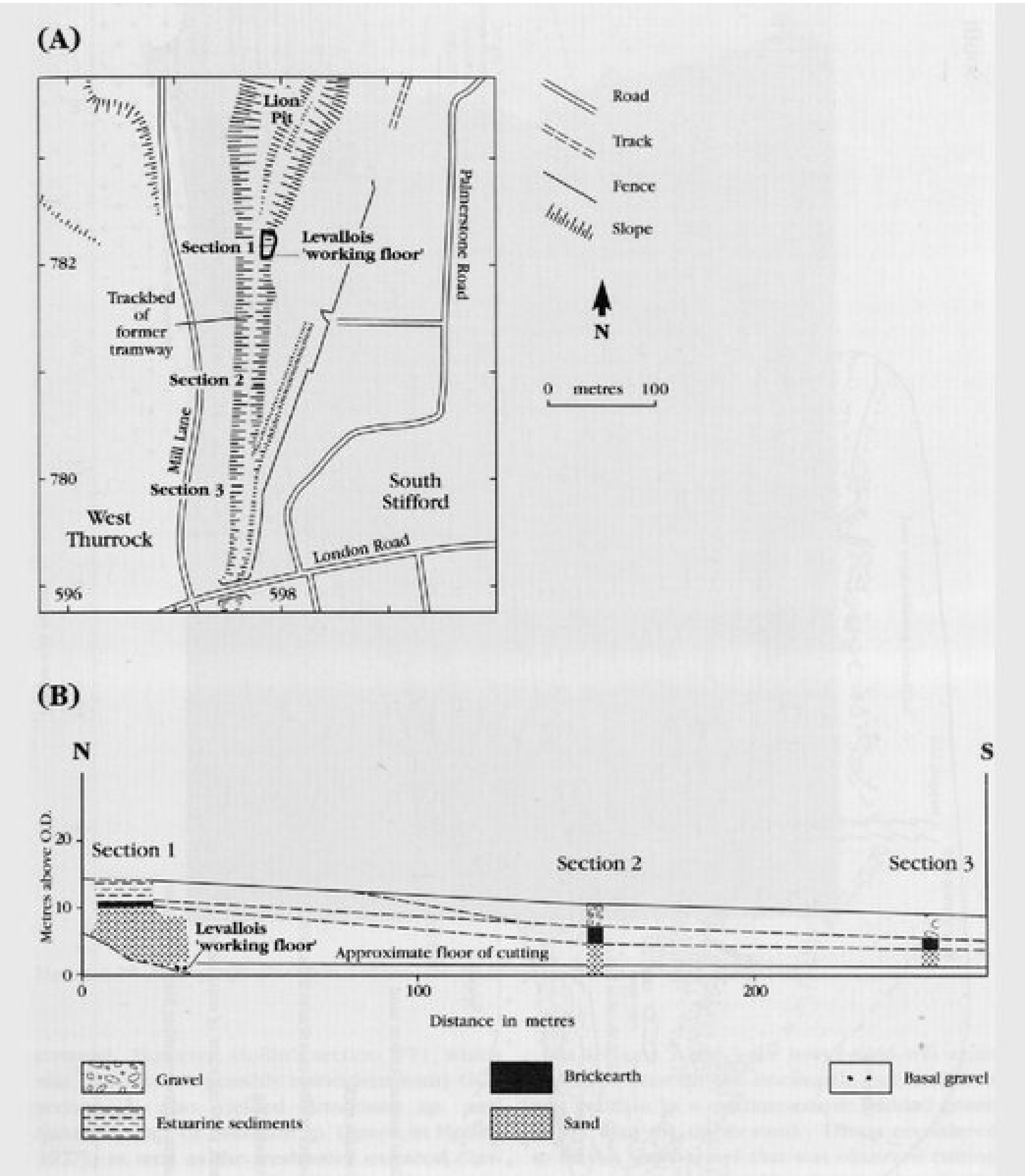
References



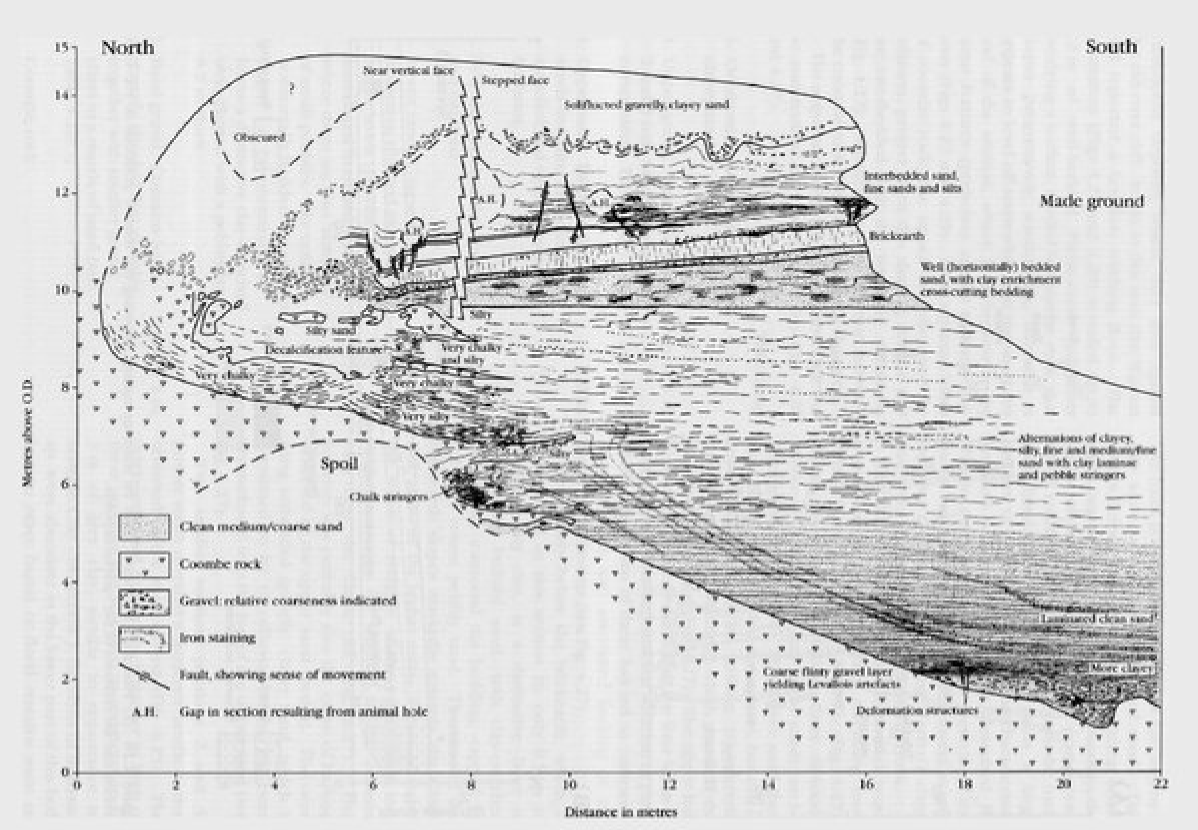
(Figure 4.21) Map showing the various sites in the Thurrock-Grays area.



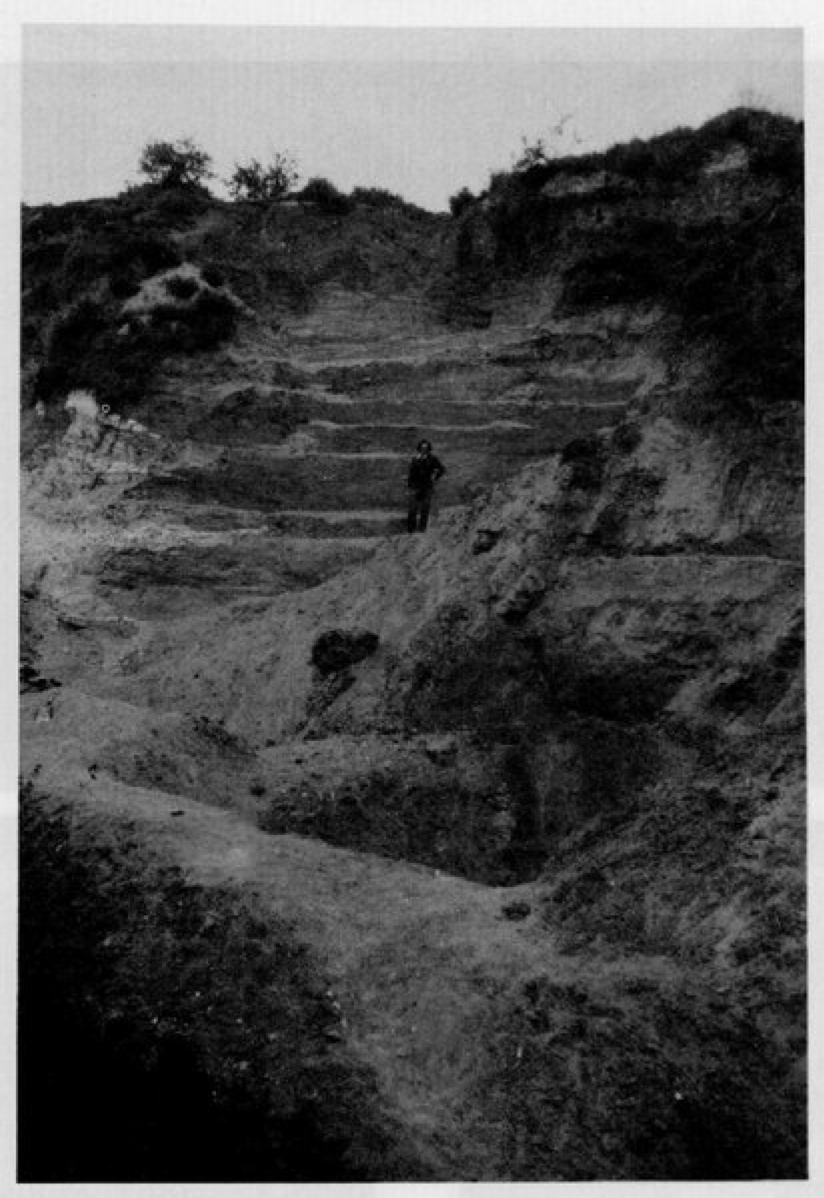
(Figure 4.25) Section through the deposits of the Mucking Formation revealed in a road cutting in 1983–4.



(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.



(Figure 4.27) Lion Pit tramway cutting [no caption]



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

(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.)

				Flint		Chalk	Southern		Exotics								
Gravel	Site	Sample	Tertiary	Nodular	Total	[1]Chalk	Gnsd chert	Total	Quartz	Quartzite	Carb chert	Rhax chert	Igneous	Total	Ratio (qz:qzt)	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*	
	Bellhus 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
	Bellhus 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 7857
	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.

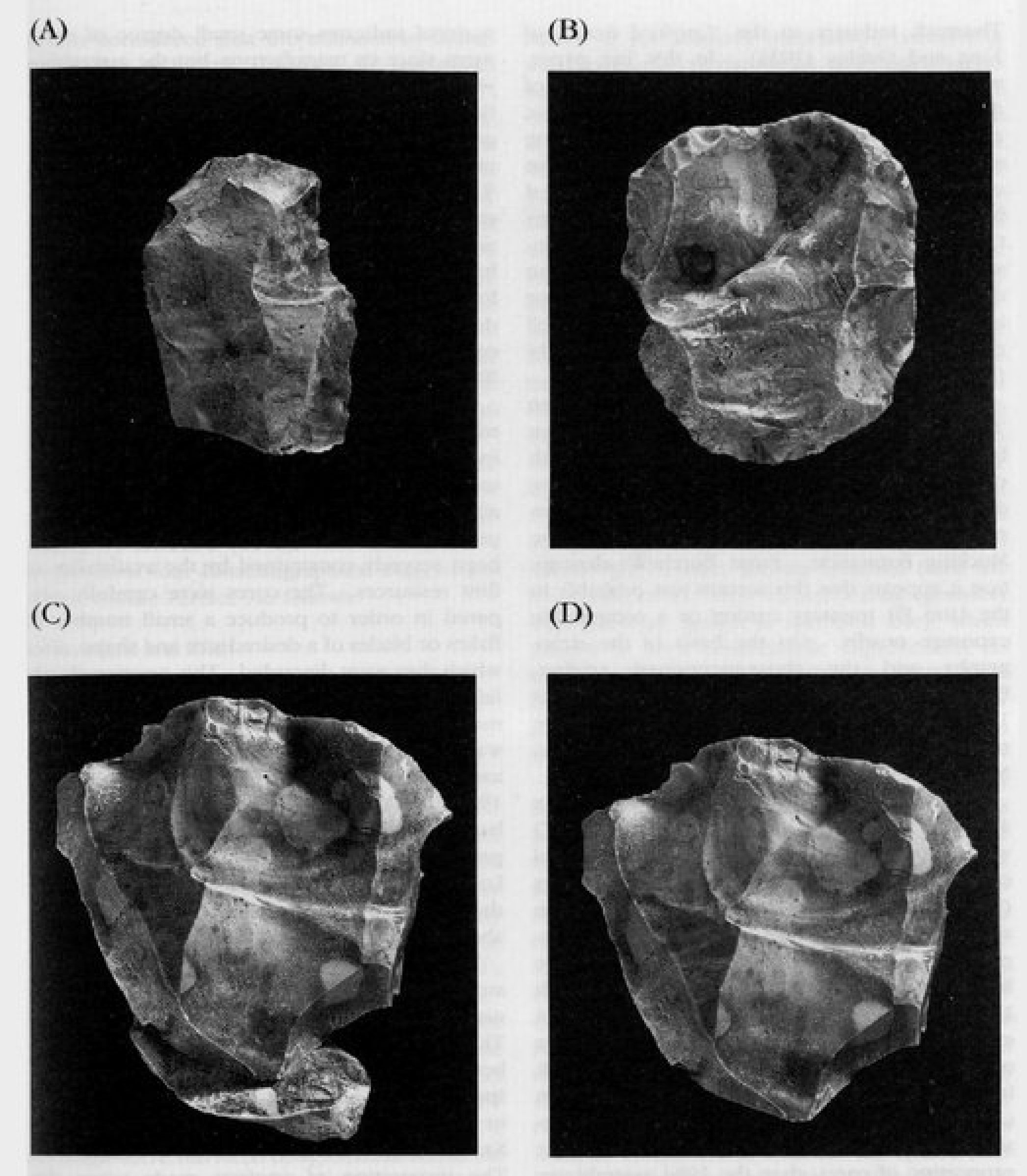
[1] -Chalk, a non-durable, is only present locally and was therefore excluded from calculations, but shown instead as a % of the total durable material.

[2] Lion Pit tramway cutting sample 2 is from the upper gravel in section 2;

[3] The Bellhus 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.

(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.



(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.)

Age (in thousands of years)	Upper Thames	Middle Thames	Lower Thames	Essex	Stage	¹⁸O
10	Recent floodplain and channel deposits: Holocene alluvium of floodplain and coast				Holocene	1
	Northmoor Gravel	Shepperton Gravel	Submerged	Submerged	late Devensian	2-4
	Rejuvenation event					
71		Temperate climate deposits at South Kensington (Isleworth centre?), Isleworth and Kempton Park	Submerged	Submerged	early-mid Devensian? interstadial(s)	5a &/or 5c?
?	Cold climate gravels above Eynsham Gravel	**Reading area** U. levels of Taplow Gravel; **Slough area** Kempton Park Gravel	East Tilbury Marshes Gravel	Submerged	early-mid Devensian	5d-2
122	Eynsham Gravel	Within Taplow Formation; Trafalgar Square and Brentford deposits	Below floodplain	Submerged	Ipswichian (sensu Trafalgar Square)	5e
128	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
		Rejuvenation event				
		Taplow Gravel	Mucking Gravel			
186	Stanton Harcourt Channel Deposits, interglacial Magdalen Grove, Summertown etc.	Interglacial deposits at Redlands Pit, Reading	Interglacial deposits at Aveley, Ilford (Uphall Pit), West Thurrock, Crayford and Northfleet	Submerged	Intra-Saalian temperate episode	7
245	Basal Summertown-Radley Formation at some sites?	Basal Taplow Gravel?	Basal Mucking Gravel	Submerged		
	Rejuvenation event				mid-Saalian	8
	Wolvercote Gravel at some sites?	Lynch Hill Gravel	Corbets Tey Gravel	Barling Gravel		
303	Wolvercote Channel Deposits		Interglacial deposits at Ilford (Cauliflower Pit), Belhus Park, Purfleet and Grays	Shoeburyness Channel interglacial deposits	Intra-Saalian temperate episode	9
339	Basal Wolvercote Gravel	Basal Lynch Hill Gravel?	Basal Corbets Tey Gravel	Shoeburyness Channel - basal gravel		
	Rejuvenation event				early Saalian	10
	? Moreton Drift (Arkell, 1947a)					
	Hanborough Gravel	Boyn Hill Gravel	Orsett Heath Gravel	Southchurch/Asheldham/Mersea Island/Wigborough Gravel		
?	Reworked mammalian fauna in Hanborough Gravel		Swanscombe deposits	Southend/Asheldham/Cudmore Grove/Clacton Channel Deposits	Hoxnian (sensu Swanscombe)	11
423	Basal Hanborough Gravel? *Rejuvenation event*	Basal Boyn Hill Gravel?	Basal Orsett Heath Gravel (incl. Basal Gravel at Swanscombe)	Southend/Asheldham/Cudmore Grove/Clacton Channel - basal gravel		
	Freeland Formation	Black Park gravel				
	Moreton Drift?	Anglian glacial deposits	Hornchurch Till	U. St Osyth/U. Holland Gravel	Anglian	12
	Freeland Formation	Winter Hill/Westmill Gravel	Valley did not exist as a Thames course prior to this	St Osyth/Holland Formation		
478	Sugworth Channel Deposits	Rassler Gravel?		Wivenhoe/Cooks Green Pit Ardleigh/St Osyth Formation Waldringfield Gravel	Cromerian Complex	21-13
?	Combe Formation	Gerrards Cross Gravel		Bures Gravel*	Early Pleistocene	pre-21
	Higher divisions of the Northern Drift Group	Beaconsfield Gravel Satwell Gravel gravel at Chorleywood Westland Green Gravels Stoke Row Gravel Nettlebed Gravel Nettlebed interglacial deposits		Moreton Gravel* Stebbing 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.