Swanscombe (Barnfield Pit Skull Site NNR and Alkerden Lane Allotments SSSI)

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Highlights

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

Introduction

Barnfield Pit, now the 'Swanscombe skull site' NNR, is probably the most famous Pleistocene locality in Britain and is certainly the best known in the Thames valley. The site became the first geological NNR (National Nature Reserve) when it was donated to the nation by the former owners, the Associated Portland Cement Company Ltd, in 1954. In fact two old pits, the original Barnfield Pit and Colyer's Pit, were amalgamated during the early decades of this century to form the site later known as Barnfield Pit or, sometimes, as Milton Street Pit (Wymer, 1968). The Swanscombe site is of international renown as a result of the disCovery there, *in situ in* an old Thames gravel, of the fragmentary skull of an early human. Remarkably, three pieces of the same skull were found on separate occasions, in 1935, 1936 and 1955, from the same sedimentary unit (Marston, 1937; Wymer, 1955, 1964b). Together they form the back half of the skull of a young adult, possibly a woman (Stringer, 1985).

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

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

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

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

Description

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

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

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

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

Phase I: Basal Gravel (Ia)

An interpretation of the basal part of the Lower Gravel as a solifluction deposit was first suggested by Marston (1937, p. 31) on the grounds of its 'rough and tumble appearance … and the presence of scratched flakes …'. This view was reiterated by Paterson (1940) and Conway (1969, 1970a), the latter citing poor sorting and

the occurrence of 'nests' of thermally fract■ ured pebbles …' (Conway, 1970a, p. 90) in the basal part of the unit as evidence of a periglacial origin. The idea was, however, refuted by Kerney (1971), who recorded mollusc remains from near the base of the Lower Gravel that indicated a climate no less temperate than those from the remainder of the deposit or those from the Lower Loam. In contrast to both Conway's and Kerney's observations, Bridgland *et al.* (1985) considered that the basal part of the Lower Gravel, as exposed in the 1982 GCR section, differed from the bulk of the unit in that it was clast-supported and lacked shells, but was clearly fluvially deposited. They concluded that this basal layer might date from the final part of the cold-climatic interval that preceded the interglacial represented by the overlying deposits. The principal evidence in support of this claim is the absence of fossil material in this basal layer; this may, however, be a result of lithological differences, such as the paucity of matrix in this clast-supported gravel.

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

Lower Gravel (Ib)

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

'Midden' complex (Ic)

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

Lower Loam (Id)

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

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

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

Phase II: Lower Middle Gravel (IIa)

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

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

Upper Middle Gravel (IIb)

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

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

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

Phase Soliflucted clay (IIIa)

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

Channel deposits (IIIb)

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

Upper Loam (IIIc)

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

A further possible indication of a hiatus between the Upper Middle Gravel and the Upper Loam is the occurrence of patinated artefacts from the extreme base of the latter (Dewey, 1919, 1930; Burchell, 1931), comprising an assemblage quite distinct from that in the Middle Gravels (Wymer, 1968; Conway and Waechter, 1977). A further industry has been recovered from the upper part of the Upper Loam, made up of unabraded flint-knapping debris and white patinated hand-axes of twisted ovate type (Conway and Waechter, 1977). Ovates are unknown from Barnfield Pit below the level of the Upper Loam, although they make up a significant part of the assemblage from the gravels of the Craylands Lane Pit ([TQ 604 746]; Dewey and Smith, 1914; Smith and Dewey, 1914; Dewey, 1932; Wymer, 1968). Wymer (1968) considered the implements from that site to be derived from the same stratigraphical horizon as the base of the Upper Loam in Barnfield Pit.

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

Upper Gravel (IIId)

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

Higher Mains (IIIe)

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

Interpretation

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

The Swanscombe skull

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

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

The Palaeolithic record at Swanscombe

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

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

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

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

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

Palaeontological evidence from Swanscombe

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

1. The rhinoceroses *Dicerorhinus kirchbergensis* (Jager) and *D. hemitoechus* are both present (the former in units Ib–d and IIa and IIb, the latter in Ib).
2. The fallow deer is of a large race, *Dama dama clactoniana* (Falconer) (units Ib–Id, IIa and IIb).

3. Horse is present (units Ib–Id, IIa and IIb — becoming increasingly abundant in higher units).
4. Hippopotamus is absent.
5. Hyaena is absent.

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

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

The molluscan fauna from Swanscombe has provided the strongest evidence for correlating the sequence with the established Pleistocene chronostratigraphy (Castell, 1964; Kerney, 1971). The malacological collections from the various pits are amongst the richest from the British Middle Pleistocene, with several species unique to Swanscombe. Of particular importance is the so-called 'Rhenish suite', recognized by Kennard (1938), which first appears in the Phase II deposits. This comprises an assemblage of predominantly southern species, including *Corbicula fiuminalis, Viviparus diluvianus* (Kunth) and *Theodoxus serratiliniformis* (Geyer), several of which have been claimed to be characteristic of Rhine deposits. According to Caste11 (1964), *T. serratiliniformis* is characteristic of the 'Great Interglacial' (Hoxnian Stage), when it was restricted to the Rhine–Thames basin. The record of this species from Swanscombe (Figure 4.16) is the only one from Britain. The only other British occurrence of *Viviparus diluvianus* (Figure 4.16) is in the Clacton Estuarine Beds. Kennard (1938) interpreted the appearance of these 'Rhenish' Mollusca as evidence that the Thames and Rhine systems became linked after deposition of the Lower Loam (Id).

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

Thus the sediments at Swanscombe were correlated with the Hoxnian Stage interglacial, which was originally defined palynologically, despite the absence of a pollen sequence from this site. Pollen assemblages have since been obtained from much of the Swanscombe sequence (Mullenders in Wymer, 1974; Hubbard, 1982; see above, Description). Interpretation of these assemblages has led to suggestions of considerable stratigraphical complexity, with two or even three climatic cycles being recognized (Hubbard, 1982). However, this interpretation has failed to gain wide acceptance;

the validity of palynological studies of deposits with such low pollen concentrations has been questioned (Bridgland *et al.,* 1985; Turner, 1985). Turner considered it likely that various types of contamination have an important influence on palynological assemblages from sediments with a pollen-yield as poor as those at Swanscombe. Contamination could occur by the reworking of older pollen, by later pollen being introduced from percolating groundwater or by airborne modern grains being introduced during sampling and laboratory preparation. Turner also pointed out that sediments in which pollen preservation has been poor frequently contain only the more robust grains, leading to concentrations of certain taxa that result from diagenetic rather than vegetational factors; assemblages from such deposits need very careful interpretation, therefore. These points appear to seriously undermine the palaeoenvironmental and stratigraphical determinations based on pollen from this site, where none of the sediments yield abundant well-preserved pollen. Thus the pollen assemblages from Swanscombe should be interpreted with caution; where the palynological interpretation of the sediments contradicts evidence from other sources, the former should probably be disregarded.

Palaeoenvironmental and palaeogeographical significance of the Swanscombe sequence

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

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

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

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

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

Survey (see above, Wansunt Pit).

The most important of the other Swanscombe localities is probably the Ingress Vale site, or Dierden's Pit ([TQ 595 748]; (Figure 4.17)), separated from Barnfield Pit by a dry valley (the Ingress Vale). The former pit (now defunct) produced a wealth of faunal material and a confusing archaeological assemblage, but lacked the stratigraphical complexity of the skull site. It was so rich in molluscan remains that it was frequently referred to as the 'shell pit'. These came from a sandy 'shell bed' that also yielded a large collection of mammalian remains (Sutcliffe, 1964, Appendix; Wymer, 1968). There has, unfortunately, been considerable uncertainty about the correlation of these deposits with the sequence at Barnfield Pit. The earliest discoveries of palaeoliths in Dierden's Pit were well-made, sharp, patinated hand-axes found around the turn of the century, apparently in the shell bed (Stopes, 1900, 1903; Newton, 1901; Kerney, 1959b; Wymer, 1968). These discoveries led to detailed investigations, which produced collections of faunal remains and artefacts from the shell bed that were considered comparable with material from the Lower Gravel at Barnfield Pit (Dewey and Smith, 1914; Smith and Dewey, 1914), pointing to a correlation that is also supported by the altitudinal relations of the two sites (Wymer, 1968). In particular, large collections of Clactonian flakes and several chopper-cores were obtained from the deposit by Dewey and Smith and, more recently, by P.J. Tester and J.N. Carreck (Wymer, 1968). Wymer (1968) suggested that the earlier finds of Acheulian implements may have been from loamy deposits overlying the shell bed and was inclined to support the correlation of the latter with the Lower Gravel. However, Kennard (1916) was adamant that Acheulian material occurred in the Ingress Vale shell bed and that the fauna was contemporary with this industry. This controversy appears to have been resolved by Kerney (1959b, 1971, in Sutcliffe, 1964), who recorded the discovery of an Acheulian industry in the shelly deposits at Dierden's Pit, from what was apparently the reopening of the sections studied by Dewey and Smith. Kerney's material was entirely made up of flakes, including many of Clactonian type. Some, however, were distinctive hand-axe finishing flakes (Kerney, 1959b). The assemblage was studied by Marston (in Kerney, 1959b), in whose opinion the objects were unequivocally Acheulian and closely comparable to a series in his possession from the Upper Middle Gravel (IIb) of Barnfield Pit.

Kerney also reassessed the molluscan and vertebrate faunas from Dierden's Pit. He noted the presence of the characteristic 'Rhenish' molluscan suite and concluded that the Ingress Vale deposits belonged to the 'late temperate substage' of the interglacial, placing them above the Lower Loam of Barnfield Pit but earlier than the bulk of the Middle Gravel. The faunal assemblage from Dierden's Pit is indicative of temperate woodland, thus contrasting with the open-habitat fauna from the Upper Middle Gravel (Sutcliffe, 1964; Kerney, 1971). Kerney considered the latter assemblage to post-date that from Dierden's Pit and to imply climatic deterioration later in the interglacial. However, the presence of ovate hand-axes in the collections from the Dierden's Pit shell bed (Stopes, 1903) may indicate an age slightly younger than the Upper Middle Gravel, comparable perhaps with the higher deposits at Rickson's Pit (Kerney, 1959b; below). A unique find from Dierden's Pit is a vertebra of bottle-nosed dolphin (*Tursiops truncatus* (Montague)) in the Hinton collection (Sutcliffe, 1964), the presence of which has sometimes been claimed as evidence of proximity to the contemporary coast (Kerney, 1971). However, Stuart's (1982a) suggestion, that this represents an individual that swam up the river and became stranded, seems more plausible, considering the paucity of other indications of a marine influence at Swanscombe.

Another important site at Swanscombe was Rickson's Pit [TQ 608 743]; (Figure 4.17), now entirely quarried away (Tester, 1955), which shared with Barnfield Pit the important stratigraphical superposition of Acheulian above Clactonian industries. The succession at Rickson's Pit was less complex than that at Barnfield Pit, however, comprising a sequence of gravels and sands, and generally lacking the well-defined barns of the latter site (Dewey, 1932, 1934; Wymer, 1968; Waechter, 1973; Roe, 1981). The lowest gravel, 1 m thick and conspicuously coarser than any above, contained an uncontaminated Clactonian industry, indicating broad correlation with the Phase I deposits at Barnfield Pit. Above this was *c.* 3 m of sandy gravel rich in shells, likened to the Ingress Vale shell bed by Kerney (1971). This was in turn overlain by a further 2–3 m of even- and current-bedded sand and gravel. The upper part of the sequence contained hand-axes, confirming correlation with post-Phase I deposits at Barnfield Pit. However, the uppermost layers have yielded finely made ovate hand-axes of a type unknown at Barnfield Pit before the Upper Loam (IIIc), as well as at least one Levallois tortoise core (Burchell, 1931; Wymer, 1968). Burchell (1933) classified the industry from the Swanscombe Upper Loam as 'Levalloisian A'. He also noted remnants of a much denuded loam capping the sequence at Rickson's Pit, beneath which patinated artefacts occurred in identical fashion to those beneath the Upper Loam at Barnfield Pit (Burchell, 1931, 1934b). These observations suggest that the sequence at Rickson's Pit once represented a condensed version of the full Swanscombe succession. Levallois material from the upper levels of this and other sites at Swanscombe has probably been incorporated from above, perhaps by cryoturbation.

A further important site formerly existed at Swanscombe, the Craylands Lane Pit [TQ 604 746], which lay to the east of the GCR site (Figure 4.17). It exposed gravels and sands overlying Chalk at a level comparable to the base of the Lower Middle Gravel at Barnfield Pit. Correlation with post-Phase I deposits is confirmed by the occurrence of hand-axes in the gravels at Craylands Lane. As with Rickson's Pit, ovate hand-axes and Levalloisian material were recovered (Dewey and Smith, 1914; Smith and Dewey, 1914), indicating that sediments equivalent to the Phase III deposits of Barnfield Pit were present (Wymer, 1968; Waechter, 1973). Other nearby sites, of less significance, were documented by Wymer (1968).

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

Correlation of the Swanscombe sequence with the Lower Thames terrace deposits on the Essex side of the river is not entirely straightforward. The only sites north of the Thames for which a Hoxnian age has been suggested are at Grays and Little Thurrock, which are at a lower altitude than the Swanscombe sequence and are regarded here as part of a separate, later formation (Figure 4.3). This difference in elevation led to the suggestion that the Grays deposits represent the time interval between the deposition of the Phase I and II sequences at Swanscombe (King and Oakley, 1936; below). The deposits on the Essex side of the Lower Thames valley mapped as Boyn Hill Gravel, reclassified recently as Orsett Heath Gravel (Bridgland, 1988a; Gibbard *et al.,* 1988), comprise unfossiliferous sands and gravels suggestive of a cold climate. The identification of these sediments as a downstream continuation of the Boyn Hill Gravel of the Middle Thames has recently been upheld (Bridgland, 1988a; Gibbard *et al.,* 1988). The Boyn Hill/Orsett Heath Gravel is interpreted as a periglacial braided-river deposit and has been attributed by Gibbard (1985) to the early Saalian Stage (Wolstonian). This dating is, in fact, largely based on the interpretation of the stratigraphical relations between the Boyn Hill/Orsett Heath Gravel and the Swanscombe sequence (Gibbard, 1985, pp. 136–137). Gibbard considered the palaeontological evidence for climatic cooling in the higher levels of the Swanscombe sequence (above the Lower Middle Gravel — IIa) to reflect a transition from the Hoxnian Stage interglacial to the glacial conditions of the early Saalian (Wolstonian) Stage. He pointed to the similarity in elevation between the top of the sequence at Swanscombe and the local Orsett Heath Gravel (both may be considered to underlie the Boyn Hill Terrace surface) as evidence supporting their proximity in age. However, no record exists of cold-climate sediments of Orsett Heath Gravel type overlying any part of the Swanscombe sequence. According to the climatic model for terrace generation presented in Chapter 1 of this volume, interglacial sediments represent the middle of three phases of aggradation that can typically be recognized within individual terrace formations. The accumulation of such temperate-climate deposits is both preceded and followed by aggradation in a cold climate. The Basal Gravel at Swanscombe (Ia) has sometimes been attributed to a cold climate and so may represent the pre-interglacial aggradational phase of the Boyn Hill/Orsett Heath Formation. The subsequent post-interglacial aggradational phase, which is usually the best-represented in surviving terrace deposits (Chapter 1), appears not to have contributed to the sequence at Swanscombe; the river may have migrated to another part of the floodplain during this phase, thus fortuitously allowing the survival of the Swanscombe interglacial sediments.

Biostratigraphical correlation and geochronometric dating

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

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

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

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

1971). The revised chronostratigraphical scheme of Bowen *et al.* (1989) upholds this correlation, since shells from the Clacton deposits also yield amino acid ratios suggestive of Stage 11 (Chapter 5), implying that they too may be pre-Hoxnian (*sensu* Hoxne). Because of the problems that exist in reconciling biostrat-igraphy with geochronology in this part of the British Pleistocene, the term Hoxnian Stage *sensu* Swanscombe is used to refer to the Stage 11 interglacial episode in this volume (Chapter 1).

The significance of the Swanscombe deposits within the Thames terrace sequence

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

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

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

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

Evans (1971) presented another complex interpretation of the Swanscombe sequence in his pioneering attempt to relate the Thames terraces to the global marine (oxygen isotope) record. He correlated the Lower Gravel and Lower Loam at

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

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

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

The rejuvenation that separated the Boyn Hill floodplain from that on which the Black Park Gravel was deposited cannot, therefore, be recognized downstream from London. This event, which presumably occurred before the end of the Anglian Stage, may have had little effect in this area, where sediments equivalent to the Black Park Formation of the Middle Thames are thought to be directly overlain by gravels of the Boyn Hill Formation. It is difficult to determine whether any significant down-cutting occurred in the valley downstream from London at this time, as any evidence would have been buried by the subsequent aggradation of the Boyn Hill Gravel to over 40 m O.D. Further upstream this rejuvenation is of considerable importance; for example, it coincided with the abandonment of the 'Ancient Channel' between Caversham and Henley (Chapter 3, Highlands Farm Pit). It has already been noted (Chapters 1 and 3) that the initiation of Black Park Gravel deposition was intimately related to the glaciation of the London Basin and the resultant diversion of the Thames; special circumstances therefore controlled the formation of this terrace, which was not generated by climatic fluctuation in the way that most other Thames terraces have been (see Chapter 1 — climatic model for terrace generation). It may be that the diversion of the Thames pre-empted the climatically induced rejuvenation event that was due to occur towards the end of the Anglian cold episode, causing the incision from the Winter Hill to the Black Park level. The time interval represented by the Black Park Gravel was evidently short; it was insufficient for a separate terrace feature to become established throughout the catchment, since the Black Park Formation can be shown to converge upstream with the earlier Winter Hill Formation (see Chapter 1 and (Figure 1.3)). The subsequent incision to the Boyn Hill level may have occurred in response to isostatic uplift following the disappearance of the Anglian ice sheets from Hertfordshire. Certainly the evolution of the terrace system at this time reflects the disruption and instability brought about by the Anglian glaciation and cannot be explained solely by the climatic model applied to other parts of the sequence.

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

Final commentary

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

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

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

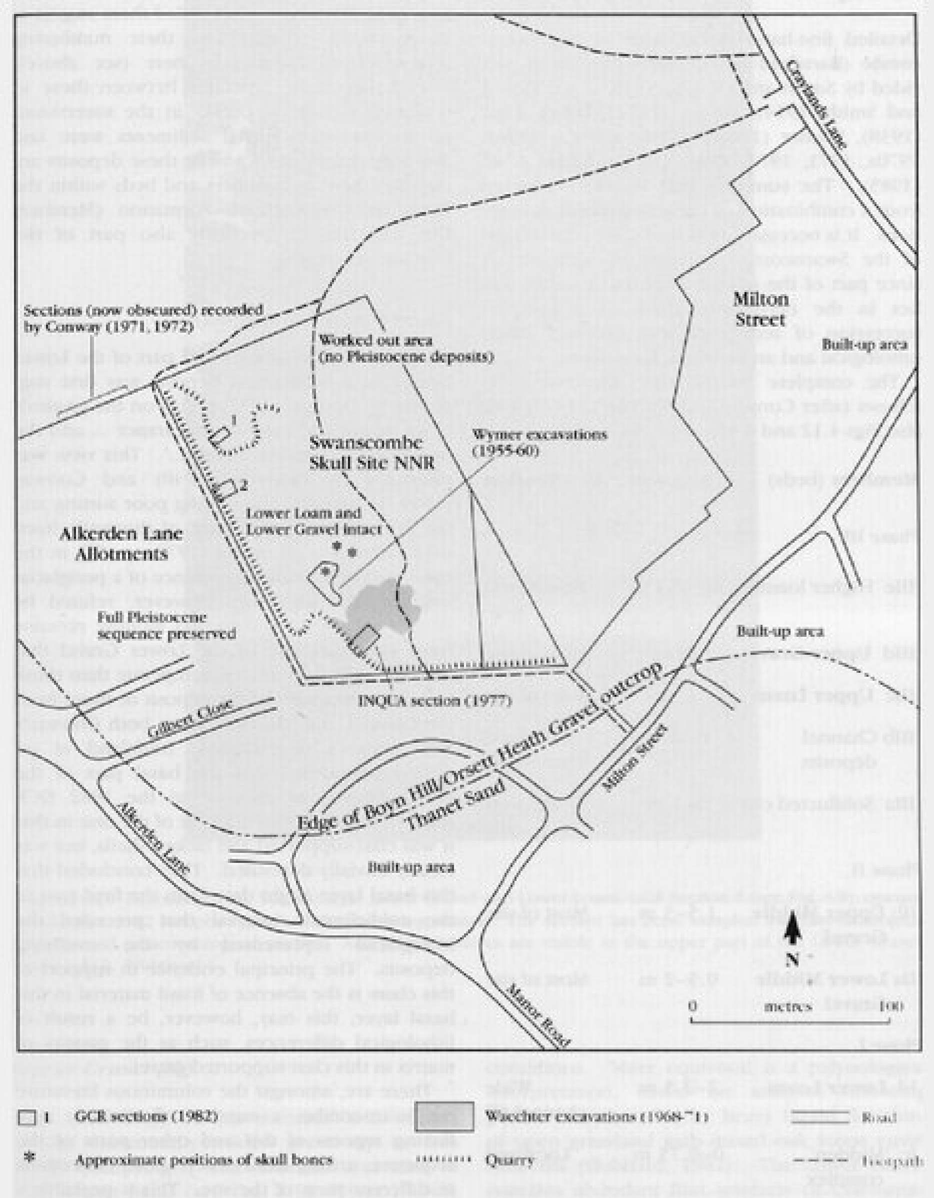
SSSI, where the full Swanscombe sequence is preserved. In this area the survival of the higher layers, particularly the clayey slope and overbank deposits that cap the sequence, will hopefully have protected the faunal content of the lower material from weathering.

Conclusions

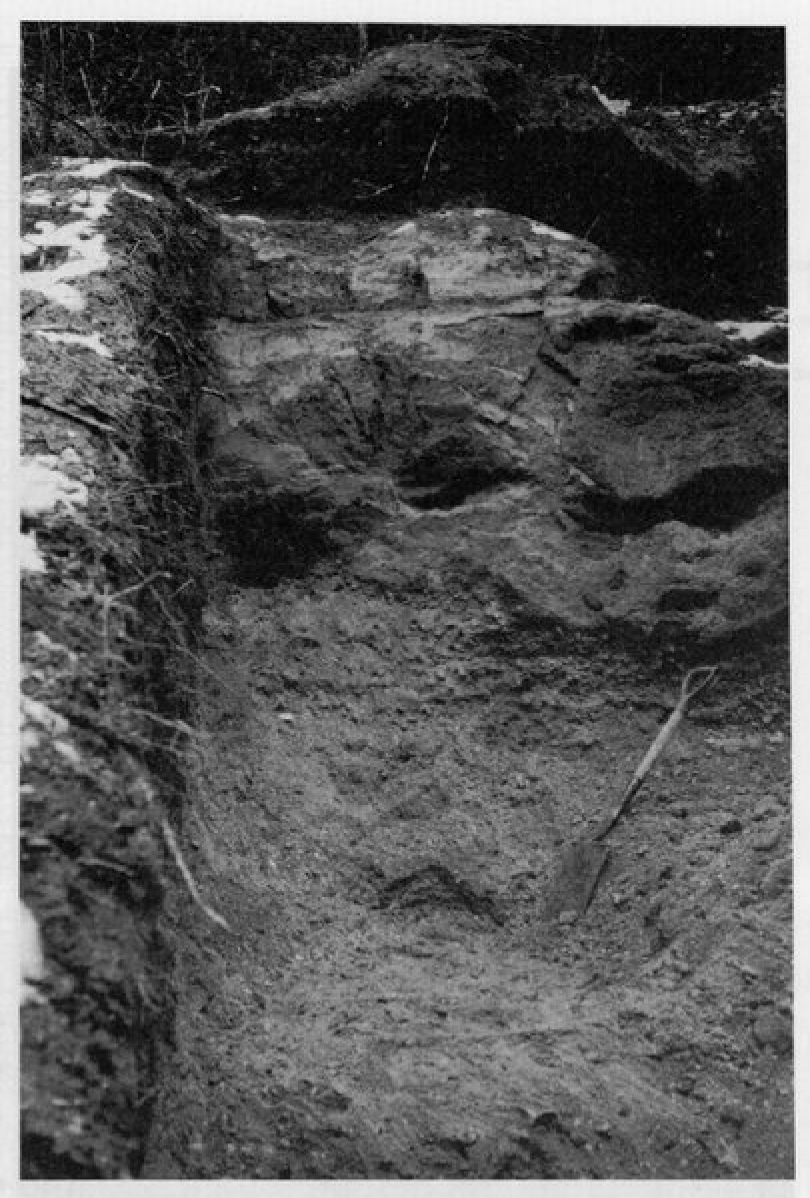
Swanscombe is probably the most famous British Pleistocene site; it is of international renown because of the discovery there of the fragmentary skull of an early Stone Age woman. Even without this find, the site would be of enormous importance. It combines a complex record of deposition by the Thames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

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

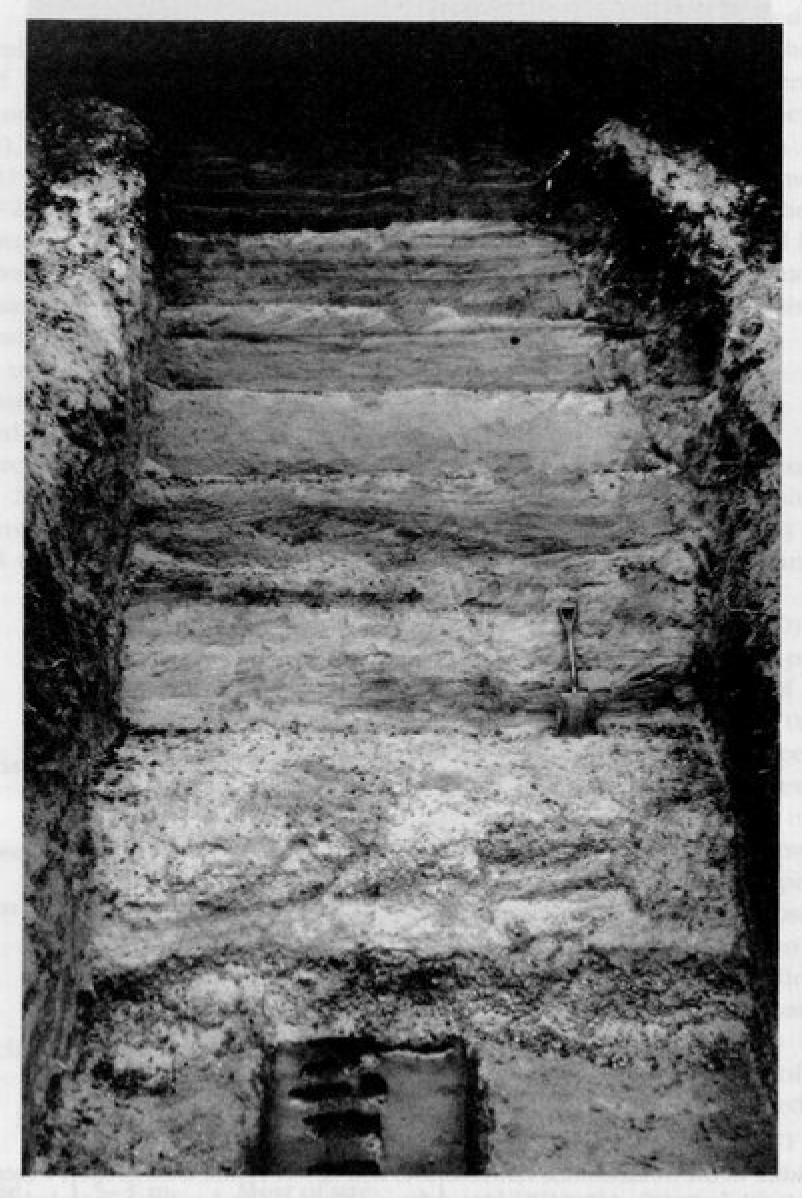
References



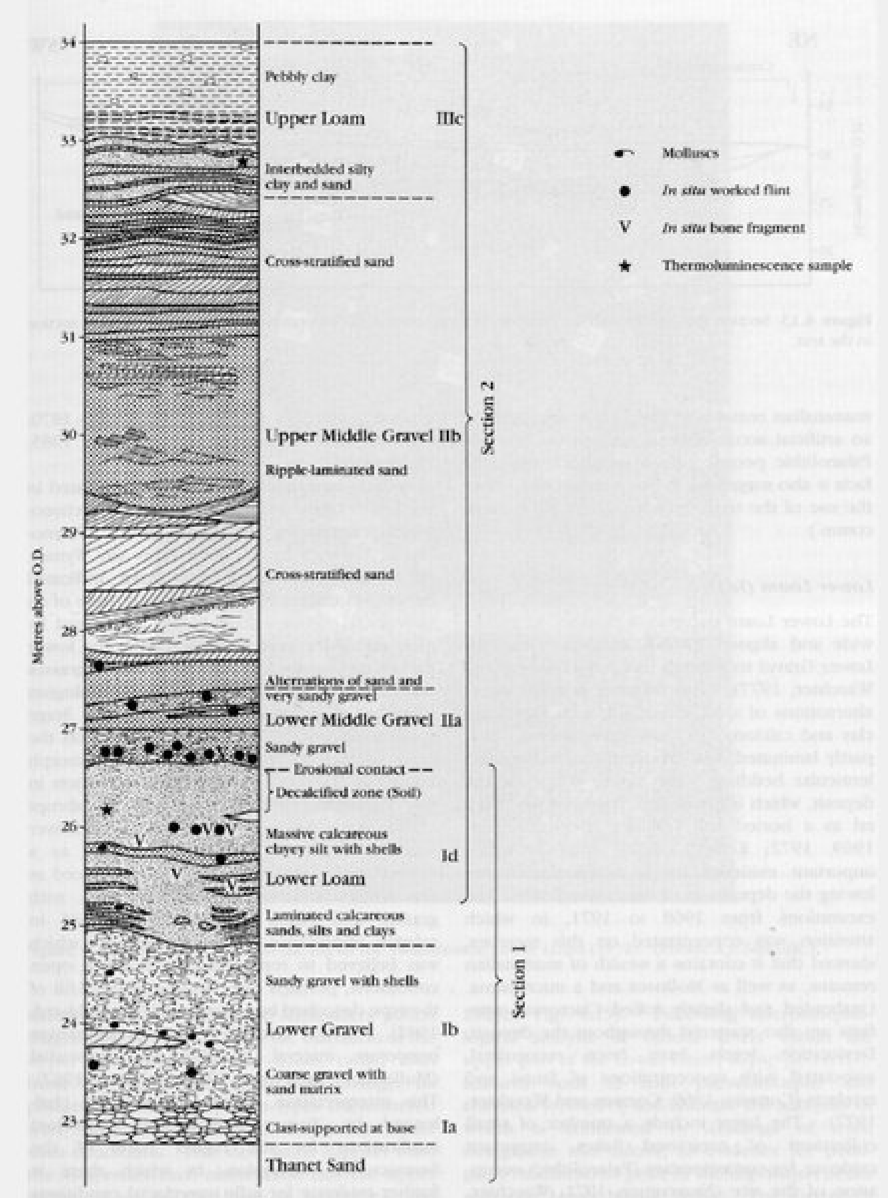
(Figure 4.9) Map of the Swanscomhe skull site and adjacent areas.



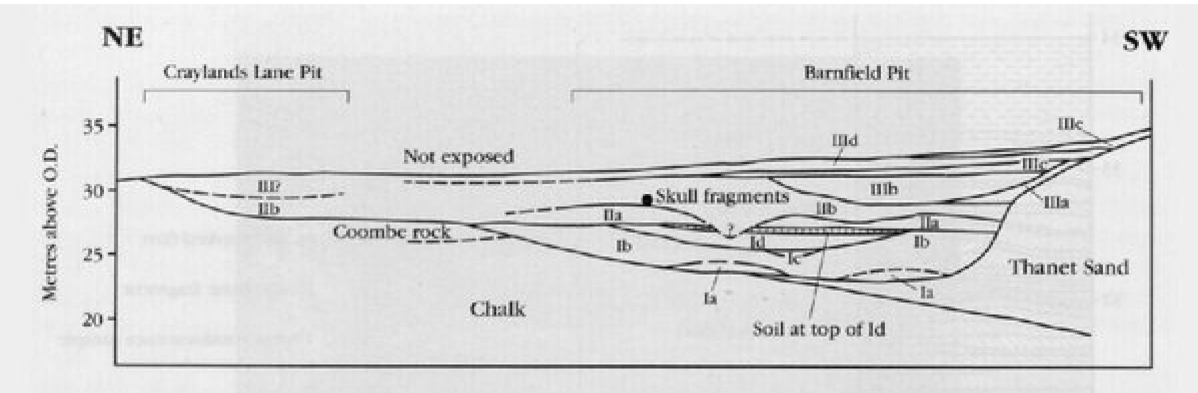
(Figure 4.10) Exposure in the Swanscombe Lower Gravel and Lower Loam, GCR Section 1 (see Fig. 4.9), opened in October 1982 but photographed the following winter. The section has been sampled for clast-lithological analysis and palaeontological studies. Articulated bivalves are visible in the upper part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



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

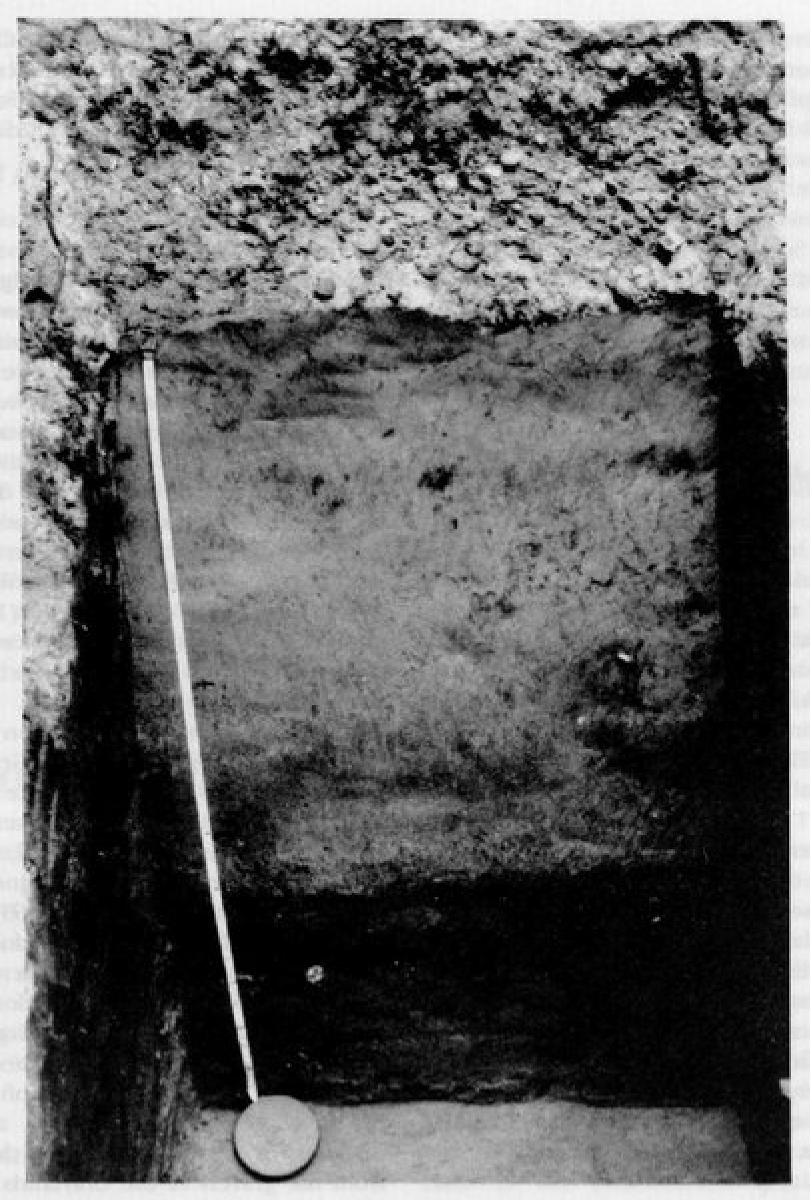


(Figure 4.12) The sequence at Swanscombe. based on the exposures excavated by the GCR Unit in 1982 (after Bridgland et al., 1985).

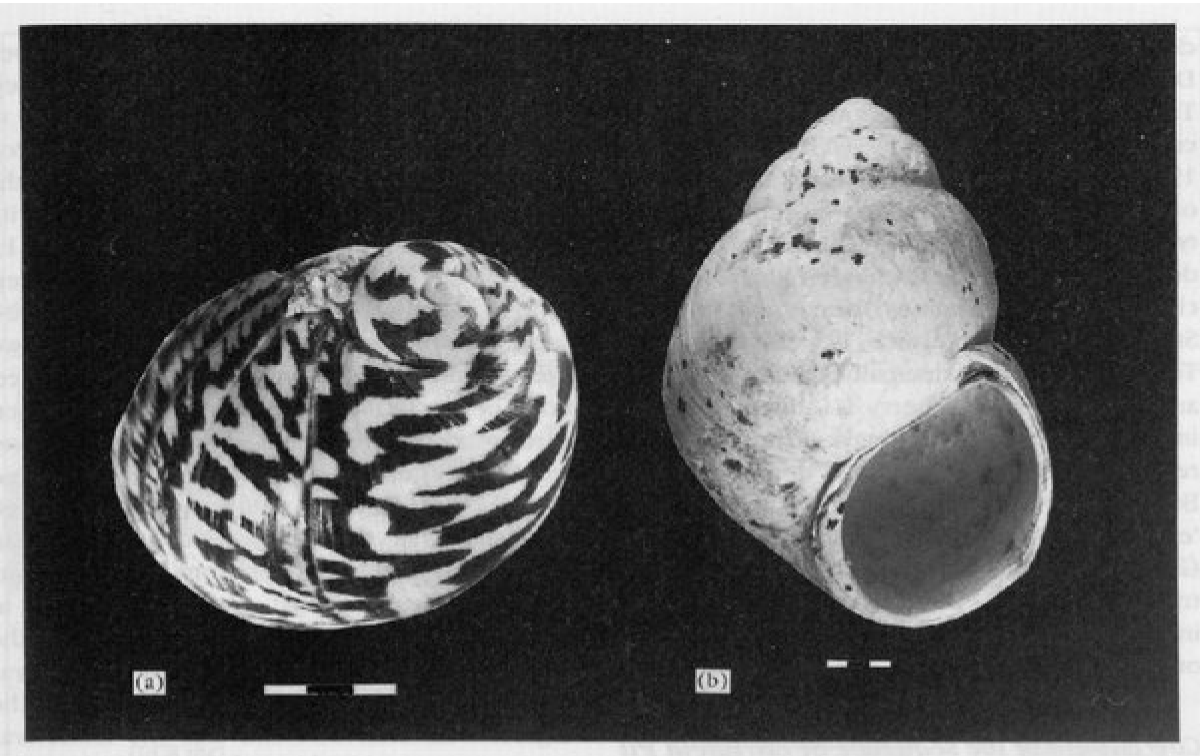


(Figure 4.13) Section through the terrace deposits at Swanscombe. The notation follows the description section in the text.

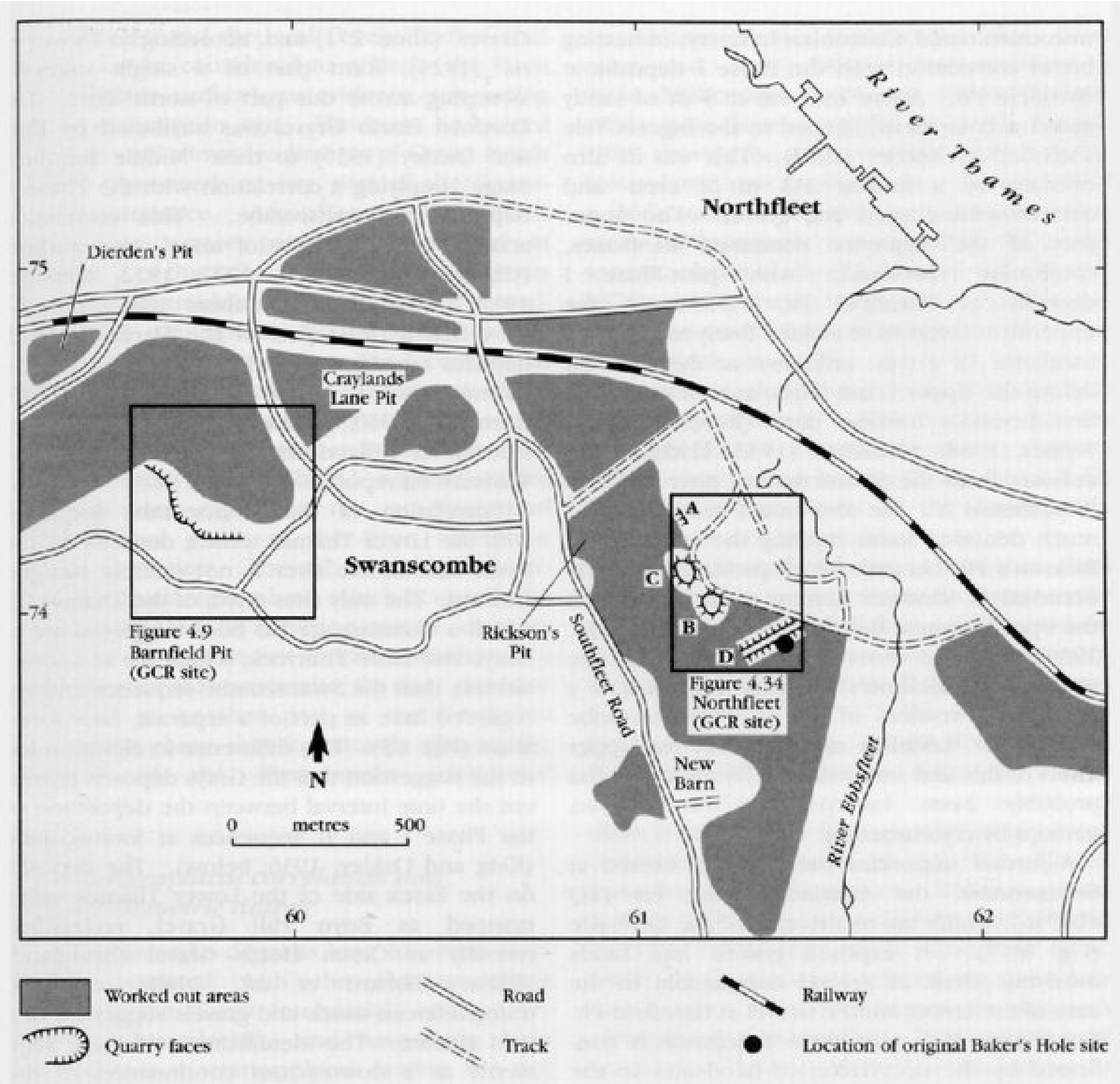
(Figure 4.14) Animal footprints in the top of the Swanscombe Lower Loam (1972). (Photo: A.J. Sutcliffe.)



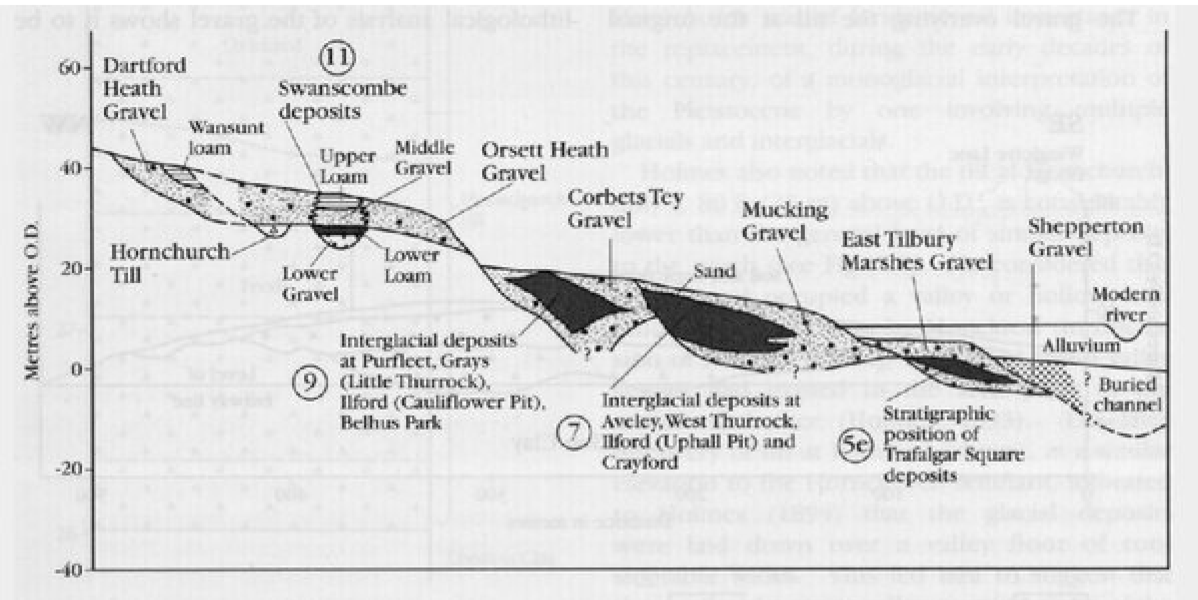
(Figure 4.15) Photograph of buried soil in the upper part of the Swanscombe Lower Loam. (Photo: D.R. Bridgland.)



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



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

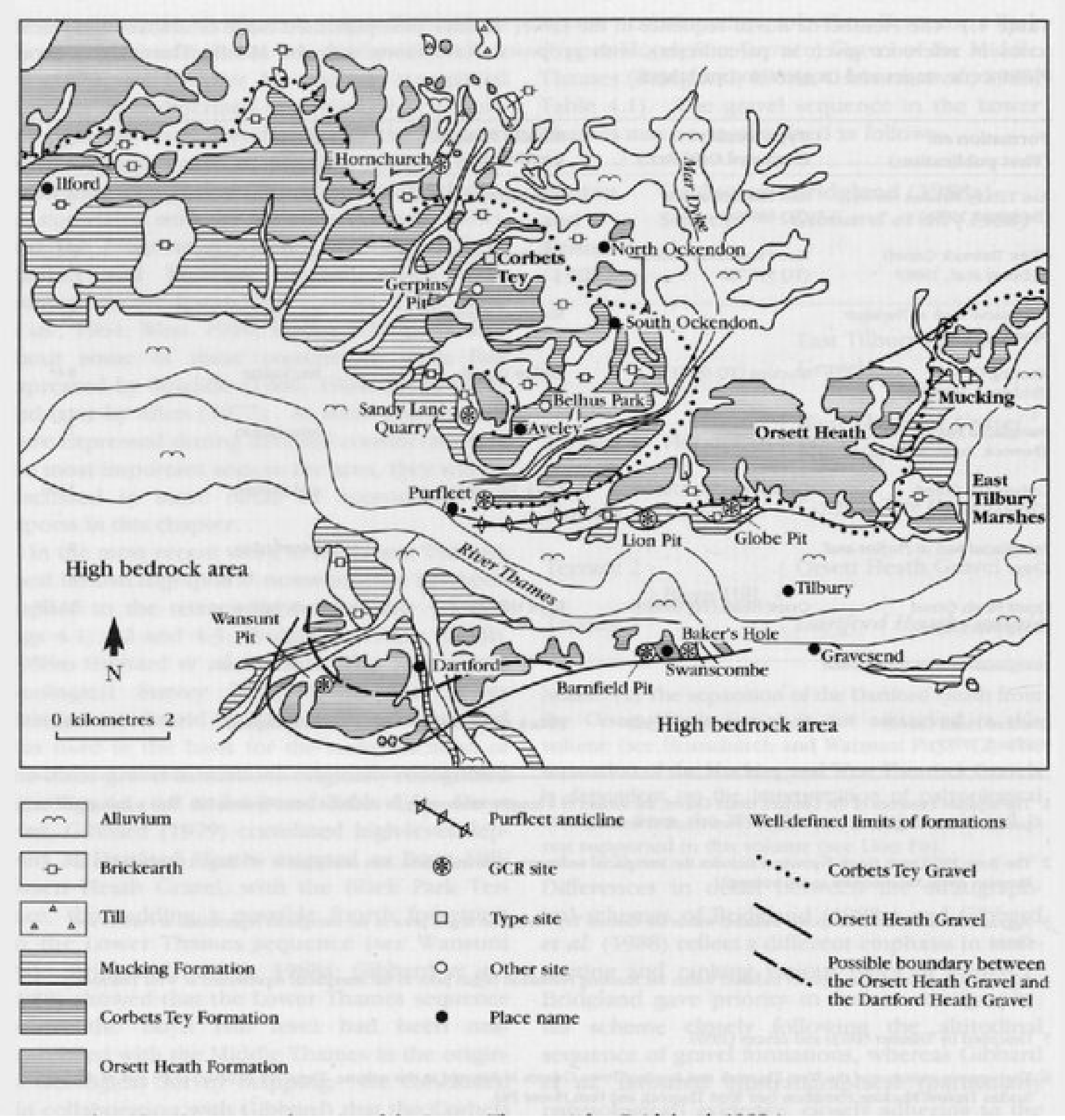


(Figure 4.3) Idealized transverse section through the terraces of the Lower Thames. The odd-numbered (warm) oxygen isotope stages to which the various interglacial deposits are attributed are indicated (numbers in circles). The stratigraphical position of the Trafalgar Square deposits is shown.

			Flint			Chalk	Southern		Exotics								
Gravel	Site	Sample	Tertiary	Nodular	Total	[1]Chalk	Gnsd chert	Total	Quartz	Quartzite	Carb chert	Rhax chert	Igneous	Total	Ratio (qtz:qtzt)	Total count	National Grid Reference
East Tilbury	E.Tilbury Mshs	1 *D*	58.9	9.9	96.2		0.9	1.1	0.9	0.7	0.5	0.3	0.3	2.7	1.40	745	TQ 6880 7843
Marshes Gr.	11.2-16	1 *D*	49.5	6.6	92.2		1.5	1.6	3.2	1.4	0.6	0.2	0.1	6.1	2.21	979	
Mucking	Lion Pit - lwr gravel	1 *D*	47.8	35.9	97.5	(1.1)	0.7	0.7	0.7	1.1				1.8	0.67	276	TQ 5978 7821
Gravel	('floor') *11.2-16*	*1 D*	*50.2*	*19.6*	*95.7*	*(0.3)*	*0.6*	*0.6*	*1.8*	*0.9*	*0.6*		*0.3*	*3.7*	*2.00*	*327*	
	upper gravel [2]	2 *D*	67.1	5.9	95.3		0.8	0.8		3.5				3.9		255	TQ 5978 7809
	11.2-16	*2 D*	*59.4*	*3.2*	*94.2*		*1.1*	*1.1*	*1.9*	*1.5*	*0.4*	*0.4*		*4.7*	*1.29*	*465*	
	Mucking	1A *D*	64.0	9.3	97.0		1.1	1.1	0.9	0.6		0.1		1.8	1.50	708	TQ 6892 8154
	11.2-16	*1A D*	*57.7*	*4.9*	*92.1*		*1.9*	*1.9*	*3.1*	*1.2*	*1.1*	*0.2*	*0.1*	*6.0*	*2.55*	*901*	
		1B *D*	57.4	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 7837
	11.2-16	*1A*	*36.3*	*7.6*	*86.6*		*1.0*	*1.1*	*3.9*	*3.7*	*3.1*	*0.5*	*0.2*	*11.7*	*1.04*	*618*	
		1B	47.7	18.1	95.0	(37.5)	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*	*(9.1)*	*2.5*	*2.7*	*4.0*	*2.9*	*0.5*	*0.1*	*0.1*	*8.3*	*1.40*	*1391*	
Gravel		4 *D*	30.5	11.8	94.1	(0.4)	2.7	2.8	1.1	0.8	0.4	0.1		2.7	1.29	857	TQ 5974 7430
	11.2-16	*4 D*	*28.1*	*8.8*	*90.6*	*(0.3)*	*3.5*	*3.8*	*2.7*	*1.5*	*0.9*	*0.2*		*5.6**	*1.74*	*1494*	

* Not separately recorded
D (after sample number) indicates that the sample concerned came from downstream of the contemporary Darent confluence.
[1] -Chalk, a non-durable, is only present locally and was therefore excluded from calculations, but shown instead as a % of the total durable material.
[2] Lion Pit tramway cutting sample 2 is from the upper gravel in section 2;
[3] The Belhus Park samples are from the organic sediments within the Corbets Tey Formation and from the gravel overlying the organic sediments;
[4] The Globe Pit North sample is from the Orsett Heath Gravel outcrop in the northern part of the old workings, outside the GCR site.

(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.

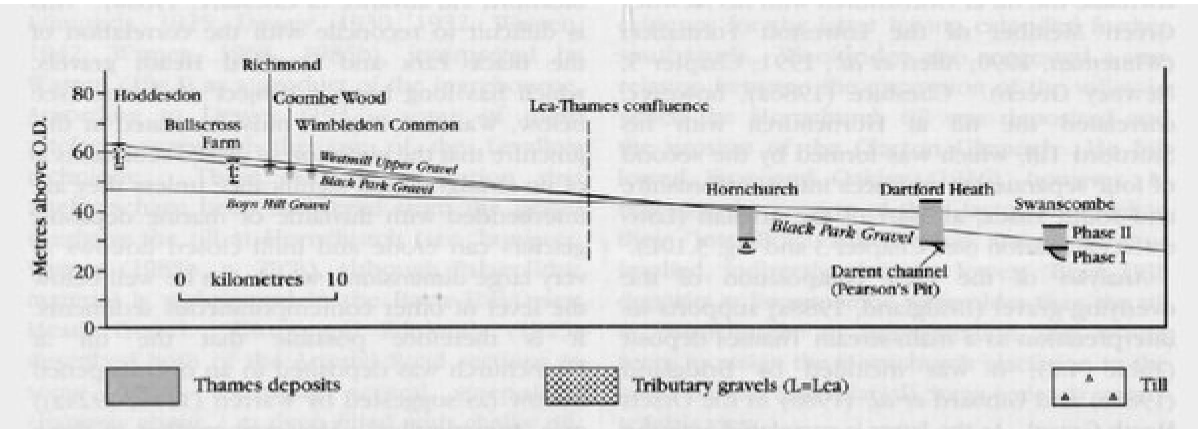


(Figure 4.1) The Pleistocene deposits of the Lower Thames (after Bridgland, 1988a).

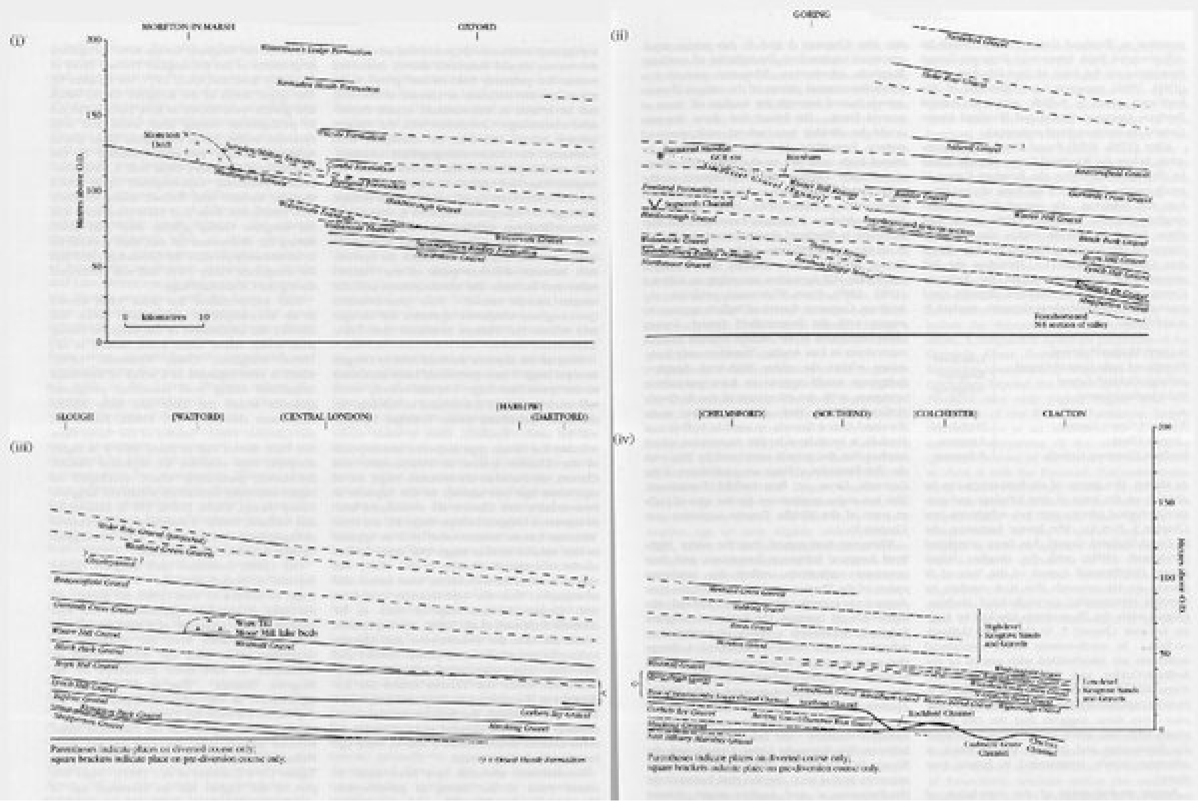
Age (in thousands of years)	Upper Thames	Middle Thames		Lower Thames	Essex	Stage	δ18O
	Recent floodplain and channel deposits. Holocene alluvium of floodplain and coast					Holocene	1
10							
	Northmoor Gravel	Shepperton Gravel		Submerged	Submerged	late Devensian	2-4
	Rejuvenation event						
71							
		Temperate climate deposits at South Kensington (Isleworth and Kempton Park		Submerged	Submerged	early/mid Devensian? interstadial(s)	5a &/or 5c?
?							
		Reading area	**Slough area**				
	Cold climate gravels above Eynsham Gravel	U. levels of Taplow Gravel	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?	Basal Boyn Hill Gravel?		Basal Orsett Heath Gravel (incl. Basal Gravel at Swanscombe)	Southend/Asheldham/Cudmore Grove/Clacton Channel - basal gravel		
	Rejuvenation event						
	Freeland Formation	Black Park gravel				Anglian	12
	Moreton Drift?	Anglian glacial deposits		Hornchurch Till	U. St Osyth/U. Holland Gravel		
	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 Fm 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.



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



(Figure 1.3) Longitudinal profiles of Thames terrace surfaces throughout the area covered by the present volume. The main sources of information used in the compilation of this diagram are as follows: Arkell (1947a, 1947b), Briggs and Gilbertson (1973), Briggs et al. (1985), Evans (1971) and Sandford (1924, 1926) for the Upper Thames; Gibbard (1985) and Sealy and Sealy (1956) for the Middle Thames; Bridgland (1983a, 1988a) and Bridgland et al. (1993) for the Lower Thames and eastern Essex; Whiteman (1990) for central Essex.