MAMMALIAN BIOSTRATIGRAPHY OF THE LATER MIDDLE PLEISTOCENE IN BRITAIN

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ABSTRACT

This study explores and develops the potential of fossil mammals to differentiate between the various climatic episodes of the post-Anglian Middle Pleistocene in Britain. Mammalian fossils are particularly valuable as biostratigraphic indicators on account of their morphological evolution and rapid turnover, through origination and extinction of species. Furthermore, the large-scale climatic fluctuations that affected north-west Europe during the Quaternary produced major shifts in the geographical distributions of many species, resulting in discernible patterns of presence and absence in the fossil record of a particular region.

The development of a globally-applicable climatostratigraphic framework, based on the oxygen isotope record from deep-ocean sediments, has provided a new and challenging scheme for the interpretation of the British Quaternary record. Long fluvial sequences in Britain have been related to this record with considerable success, thereby providing a detailed archive of climatic change through the Pleistocene. The Thames valley was selected as a framework for the relative dating of the various climatic fluctuations, since it has been claimed to have the most reliably-dated long terrestrial sequence in the later Middle Pleistocene. The Thames model was therefore adopted as a testable hypothesis against which the mammalian evidence could be compared.

The findings of this study confirm the presence of four complete climatic cycles between the Anglian and the Holocene, each with its own distinctive mammalian suite. In addition, it has been possible to identify subdivisions within these temperate stages, probably representing smaller-scale climatic fluctuations within an interglacial, and perhaps corresponding to isotopic substages. It has been possible to resolve a long-standing controversy concerning the age of the British type Hoxnian Interglacial. Amino acid geochronology had suggested that sediments at Hoxne belonged to a later interglacial than deposits from the first post-Anglian temperate episode in the Thames valley, such as Swanscombe. The results of the present study reveal close similarity between the mammalian fauna from Hoxne and that from Swanscombe, suggesting that there was indeed a single Hoxnian Interglacial, and that it directly post-dated the Anglian (*i.e.* Stage 11). Sediments of this age can be distinguished from those attributable to two other late Middle Pleistocene interglacials, all of them distinct from and older than, the Ipswichian. It has been suggested that distinctive mammalian assemblages can be identified from interglacials equivalent to oxygen isotope stages 9 and 7; moreover, it is apparent that the assemblages from warm Substages 7c and 7a differed from one another in species composition. Certain useful characters have also been determined, which can permit useful separation of some of the late Middle Pleistocene cold episodes, although in comparison with the interglacials, the evidence from these is scanty.

The present study has provided a new biostratigraphic framework that may be both tested and refined as new sites become available in Britain, and also compared with the evidence from continental north-west Europe.

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CHAPTER 1. INTRODUCTION

This study explores not only the potential of fossil mammals to differentiate between the various climatic stages of the post-Anglian Middle Pleistocene in Britain, but also develops our knowledge of the changing mammalian fauna of this period. The recognition of fossil mammals as valuable biostratigraphic indicators in terrestrial Quaternary sequences stems from their rapid turnover, by origination and extinction of species, and also from the significant morphological evolution, often quantifiable, displayed by many mammalian lineages (Lister 1992).

The large-scale environmental fluctuations that affected this region throughout the Quaternary provide the background to major shifts in the distribution of terrestrial mammals in north-west Europe.

The recent development of a global climatostratigraphic framework, based on the detailed record of climatic fluctuations preserved in deep-sea sediments, has provided a new and challenging scheme for the interpretation of the British Quaternary record. Of particular significance is the implication of four major post-Anglian, pre-Devensian temperate stages in the oxygen isotope record, Stages 11, 9, 7 and Substage 5e. Previous biostratigraphic models based on mammals (Sutcliffe 1976; Currant 1986) and molluscs (Allen 1977) acknowledged a greater degree of climatic complexity than had been allowed for in the stratigraphic scheme of Mitchell *et al.* (1973) or the pollen-based mammalian biostratigraphic scheme of Stuart (1976, 1982), but still recognised only three post-Anglian interglacials. In this account, each successive major temperate stage will be shown to have given rise to a distinctive and unique faunal grouping, whereas cold-climate faunas can be demonstrated to have remained relatively stable, with only minor differences noted between certain stages.

The present investigation therefore proposes and tests a new mammalian biostratigraphy, applicable to the late Middle Pleistocene (*circa* 478 000 - 128 000 years B.P.), in which the Thames terrace system is used as a model for correlation. Long fluvial sequences in Britain have been related to the oxygen isotope record with considerable success, thereby providing a detailed archive of climatic change through the Pleistocene. The Thames valley was therefore selected as a framework for the relative dating of the various climatic fluctuations of the late Middle Pleistocene, since it is claimed to have the most reliably-dated long terrestrial sequence in Britain (Bridgland 1994). It must be stated however, that the Bridgland model, in which four post-Anglian interglacials are envisaged, is controversial and is challenged by Gibbard (1994, 1995b). It was therefore decided to adopt the Bridgland model as a testable hypothesis, against which the mammalian evidence could be compared.

In order that the present study be as comprehensive as possible, forty-nine sites were studied, covering a wide range of depositional environments, including river terraces, caves, raised beach deposits and open sites. For each locality, the mammalian assemblage (both mega- and microfauna) was critically re-examined in its entirety to review specimen provenance and specific identifications in museum collections, so that accurate species lists could be compiled. A detailed review of the stratigraphic sequence at each site was also undertaken and material of uncertain provenance disregarded. Only in this way was it possible to produce comprehensive lists of species from known stratigraphic horizons, thereby establishing a sound basis for a biostratigraphic study of this kind.

New fieldwork was also carried out at Swanscombe, Kent and important new interglacial assemblages excavated at Purfleet and Aveley in Essex.

For each temperate episode represented in the Thames sequence, a 'type assemblage' was identified from a sound stratigraphic context at a given locality. Each 'type assemblage' was defined upon the presence or absence of particular taxa of biostratigraphic significance and the general composition of the assemblage, including observations on size changes, particular morphologies or evolutionary stage in certain species. In contrast, the mammalian faunas from cold-climate episodes are relatively patchy and consequently much less well-known than those from temperate stages. Information on these faunas was therefore assembled from cold-climate deposits either pre- or post-dating interglacial deposits of established age, either in the Thames valley or elsewhere. Once the 'type assemblages' had been established, it was then possible to use this information to deduce the age of other isolated assemblages and to link the scheme with other long fluvial sequences, such as the Avon.

In addition, the present scheme incorporates palaeoenvironmental and palaeoclimatic evidence, taking into account not only information from mammalian remains, but also from a wide range of other biota (pollen, plant macrofossils, molluscs, ostracods and beetles) and from other sources such as sea levels. In this way, it was possible to assess and interpret mammalian succession in terms of climate, vegetation, land bridges and barriers to migration.

The biostratigraphic model has then been tested not only against the various models proposed by the lithostratigraphy, the oxygen isotope record and aminostratigraphy, but also against other biostratigraphic schemes based on floral and other faunal groups. It is envisaged that the scheme established in the present study will, in its own right, provide a testable model for the future.

CHAPTER 2. THE STRATIGRAPHIC FRAMEWORK OF THE LATER MIDDLE PLEISTOCENE

2.1. Introduction

The establishment of a stratigraphic framework for Quaternary terrestrial sequences is of critical importance in any biostratigraphic study. The wealth of information gathered over the last twenty years has progressively led a majority of British workers to acknowledge the shortcomings of the 1973 scheme of the Geological Society (Mitchell *et al.* 1973) and to recognise that much greater complexity is contained within the terrestrial stratigraphic record than previously imagined. Nevertheless, although our knowledge of the Pleistocene period continues to improve, there is still a frustrating lack of consensus about many of the fundamental issues in the later Middle Pleistocene, even down to the number of interglacials. One of the latest developments has been the application, to oceanic sediments, of oxygen isotope stratigraphy to determine the number and frequency of climatic fluctuations during the Pleistocene, thereby providing a new and challenging scheme for the understanding and interpretation of many sequences. In the light of this and promising recent results from studies of river terrace sequences (for example Bridgland 1994), there is at last real potential for progress to be made in the construction of a new stratigraphic framework.

2.2. The development of a British lithostratigraphic scheme

Post-war ideas on the nature of the Quaternary succession in Britain culminated in 1973 in a chronostratigraphic scheme proposed by the Geological Society (Mitchell *et al.* 1973). The scheme, which is still employed today by certain workers, highlighted the contemporary need for a standardisation of glacial and interglacial stages and was to shape the development of Pleistocene studies in Britain for the next decade. Using inferred climatic fluctuation as the basis for the division of Pleistocene time, the following chronostratigraphic stages were recognised in the sequence post-dating the early Pleistocene marine crags of East Anglia (in stratigraphical order, after Mitchell *et al.* 1973):

Flandrian/Holocene (warm)
Devensian (cold)
Ipswichian (warm)
Wolstonian (cold)
Hoxnian (warm)
Anglian (cold)
Cromerian (warm)
Beestonian (cold)
Pastonian (warm)

A means of relative dating and correlation between temperate stage deposits had previously been proposed by West (1963, 1968), which employed palynological biostratigraphy based upon observed and assumed distinctive monocyclic floral successions within depositional sequences to distinguish between different interglacial episodes. The 1973 scheme applied the palaeobotanical interpretations of the temperate deposits, together with geological evidence for the deposition of other sediments under extremely cold or even glacial conditions to provide a 'climato-stratigraphical' subdivision of the Pleistocene (Bridgland 1994).

Mitchell *et al.* (1973) recognised two interglacial episodes between the Anglian and the Holocene, the Hoxnian (based upon evidence from the type locality at Hoxne, Suffolk) and the Ipswichian (stratotype at Bobbitshole, Belstead, Suffolk). The Holocene was separated from the Ipswichian by the intervening Devensian cold stage, whilst the period of time between the Hoxnian and Ipswichian stages was ascribed to the Wolstonian, based upon a sequence of cold stage gravels, sands, clay and till occurring at Wolston in Warwickshire (Shotton 1973a, b).

However, the 1973 scheme was never intended to be immutable and flaws rapidly began to appear. The fragmentary nature of the terrestrial stratigraphic evidence, the lack of adequate boundary stratotypes and the legacy of past depositional and erosional processes resulted in considerable problems when comparing and correlating widely separated deposits that usually contained only partial pollen sequences (or in some cases, none at all). These deficiencies typified the British Pleistocene stratigraphic framework and led to a serious lack of precision within the formal chronostratigraphic scheme. Moreover, discrepancies between the palynological record and other lines of evidence, in particular from fossil mammals, revealed the possibility that more than one climatic cycle separated the Hoxnian and Ipswichian interglacials (Sutcliffe 1975, 1976; Sutcliffe and Kowalski 1976). A major issue in the revision of the 1973 scheme was the critical reappraisal of the Wolstonian type site.

2.3. Later Middle Pleistocene glaciations: evidence for the Anglian

Recent evidence suggests that in Britain, the only glaciation of Middle Pleistocene age that can be recognised with any certainty is the Anglian (Elsterian). The Anglian ice advance was the most southerly-reaching glaciation of the Pleistocene in Britain and was responsible for the major remodelling of the drainage systems of Eastern England (Rose *et al.* 1985). Understanding the position of the Anglian within the British stratigraphic sequence is crucial to the present study because Anglian till forms an important marker horizon in many Middle Pleistocene sites, and indeed, in whole regions.

On the coast of northern East Anglia, the onset of the Anglian cold stage is recorded in fluviatile and pond sediments containing late-Cromerian/early Anglian herb-based pollen assemblages with clear cold climate affinities, which record a progressive and severe deterioration in climate upwards through the profile (West 1980a). These sediments lie on top of Cromerian deposits and are associated with unequivocal periglacial phenomena indicative of the incidence of permafrost. Similar periglacial features illustrating the onset of cold climate conditions are found in the Barham Soil of south-east Suffolk, a well-developed palaeosol believed to have formed at the close of the Cromerian (Rose and Allen 1977; Rose *et al.* 1985) and capped by loess and coversand deposits of glacigenic origin.

Two distinctive till lithologies are visible within Anglian deposits: a chalky, very extensive upper Lowestoft Till Formation and a lower, more spatially-restricted Cromer Till Formation ('Norwich brick-earth') (West and Donner 1956; West 1977b; Shotton 1986). The deposits of the Cromer Till Formation are found only in north-east Norfolk and constitute a complex suite of three laterally uniform, well-sorted sandy tills, interbedded with meltwater sediments, probably laid down in a shallow-water lacustrine environment at the margin of an ice sheet, prior to its retreat (Zalasiewicz and Gibbard 1988). The progression southwards of the Anglian ice sheets from Scandinavia and the British Isles appears to have enclosed the North Sea basin and contained the waters of a number of northward-draining rivers, including the Thames, Rhine, Maas and Scheldt, thereby obstructing the free drainage of these rivers into the Atlantic Ocean and leading to the creation of a large ice-dammed lake in which the glacigenic sediments were laid down (Gibbard 1988a) (Figure 2.1). Subsequent catastrophic overspill from this lake during the Anglian is believed to have breached a chalk ridge in the area of the English Channel, thereby cutting a channel that would subsequently form the Straits of Dover (Gibbard 1988a, 1995a). This event was of particular importance, since it ultimately led to island status for Britain during subsequent periods of high sea level (interglacials), which in turn had a profound effect on mammalian dispersal in the region.

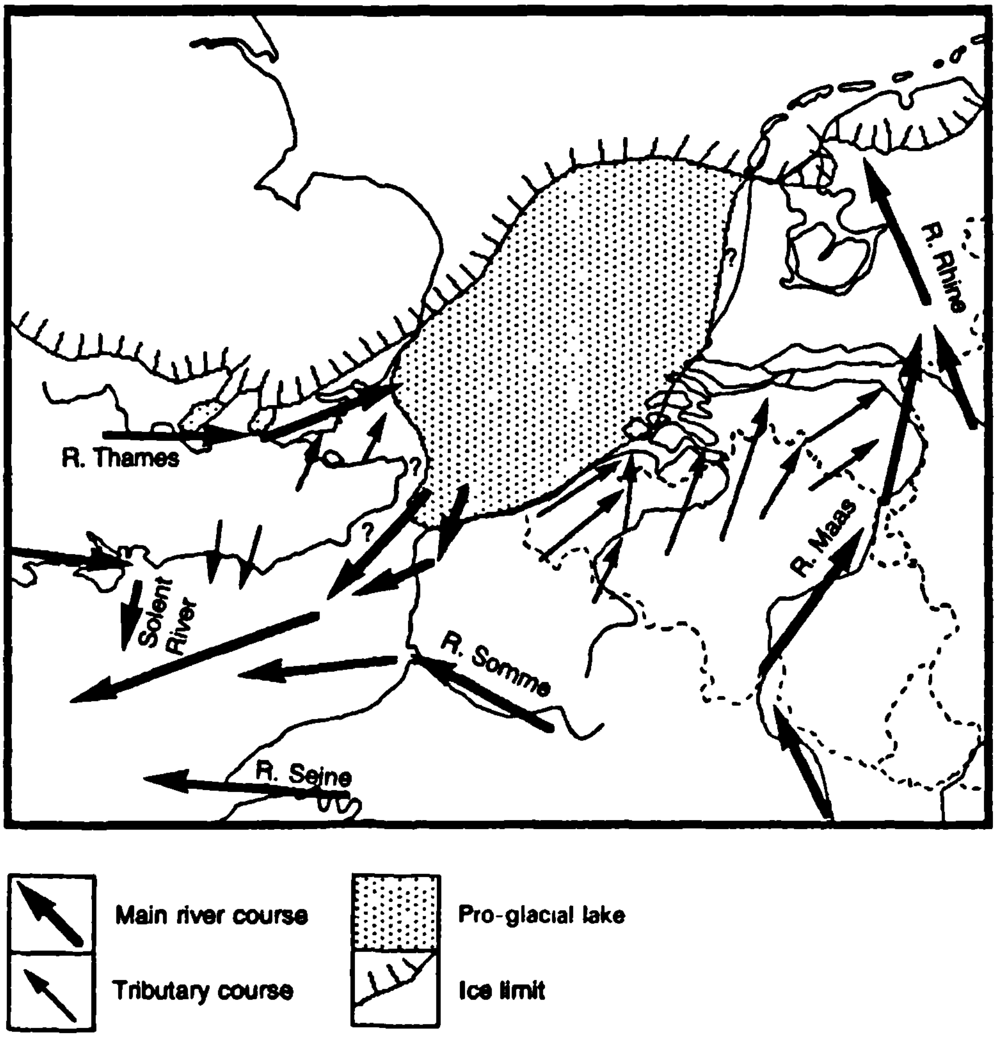


Figure 2.1 Palaeogeography of the North Sea area during the Anglian glacial maximum (Gibbard 1995a).

At the Anglian type site of Corton, Suffolk, (West 1961; Banham 1971; Mitchell *et al.* 1973; Shotton *et al.* 1977; Rose 1989a) the Cromer Till Formation is overlain by a lag gravel and outwash sands, which are succeeded in turn by the sandy Corton Beds (Bridge 1988). Overlying the Corton Beds is the chalky Lowestoft Till, deposited by an ice-sheet from the north-west (Bowen *et al.* 1986) and above it, localised lake clays (the Oulton Beds) and a flow till (the Pleasure Gardens Till) (Bridge 1988). The Lowestoft Till is absent in north-east Norfolk but demonstration that the Cromer Formation and the Lowestoft Formation interdigitate in the vicinity of Norwich (Cox and Nickless 1972) would suggest that the two formations are indeed contiguous and were deposited at approximately the same time during the late Anglian (Hart and Boulton 1991). Traditionally, parts of the Lowestoft Till were believed to be of younger, Wolstonian ('Gippingian') age (Baden-Powell 1948; West and Donner 1956; Clayton 1957a; Clayton 1960; Straw 1965) but more recent studies have confirmed that any visible differences may be attributable to facies variation within the same ice sheet (Allen 1982, 1988) or weathering of the upper part of the till (Bristow and Cox 1973; Perrin *et al.* 1979).

2.4. Post-Anglian glaciations and the Wolstonian debate

2.4.i. The observations and interpretations of F W. Shotton

The classic work of F.W. Shotton in the Coventry area included the mapping of a stratified sequence of glacial, fluvioglacial and glaciolacustrine sediments preserved on the interfluves between the valleys of the river Avon and its tributaries (Shotton 1953, 1968, 1977). These deposits were thought to represent a glacial advance in the Midlands, between the Anglian and Devensian ice advances, which was designated the 'Wolstonian' glaciation. The stratigraphic sequence observed in the vicinity of the type-site at Wolston, Warwickshire is shown in Table 2.1:

Dunsmore gravel
Wolston Series:
- Upper Wolston clay
- Wolston sand
- Lower Wolston clay

Baginton sand
Baginton-Lillington gravel
..................................hiatus
Bubbenhall clay

Table 2.1 The stratigraphic sequence at Wolston (from Shotton 1953).

The lowest member of the Wolstonian sequence, the Baginton-Lillington Gravel was deposited under cold conditions in the valley of the 'Proto-Soar', a river flowing north or north-eastward from the neighbourhood of Bredon Hill towards Leicester and beyond (Shotton 1988). Shotton reported that the gravel occurs to a maximum thickness of 14 ft (4.2m) and is almost exclusively composed of rounded, well-bedded quartzite pebbles, the majority of which have been reworked from the Bunter Beds (Shotton 1953). Beneath the Baginton-Lillington Gravel, Shotton detected isolated patches of Bubbenhall Clay, a red sandy clay with scattered small Bunter pebbles, resting on Keuper marl (Shotton 1929). In his earliest paper on the deposits, Shotton (1929) interpreted the Bubbenhall Clay as 'Older Boulder Clay', although by 1953 he was no longer certain that the sediments were true till. The Baginton-Lillington Gravel is in turn overlain by the Baginton Sand. The sand exhibits cross-bedding throughout most of its depth, becoming more horizontally-bedded towards the top. It was thought by Shotton to be the result of sedimentation in a lacustrine environment as an approaching glacier caused water to be ponded.

The initial arrival of ice into the 'Proto-Soar' from the north or north-west penetrated as far as Leamington Spa and led to the deposition of the Trias-rich Lower Wolston Clay. The basal member of this clay was later recognised as lodgement till and renamed the Thrussington Till (Rice 1968a; Shotton 1976). During the ensuing glacial retreat, a considerable depth (18m +) of laminated, horizontally bedded Bosworth Clays and Silts was deposited over a large area as still-water lacustrine sediments (Shotton 1953). A second, stronger glacial advance fed by two ice streams from the north-west and the north or north-east subsequently led to the emplacement of outwash sands and gravels (later named the Wigston Gravel and Sand by Rice, 1968a), before depositing the chalky till that forms the Upper Wolston Clay. The Dunsmore Gravel capping the sequence was formed by outwash as this ice retreated. Following the glacial phase, erosion of the Wolstonian deposits occurred and the Avon drainage basin was established, reversing the drainage previously existing in the 'Proto-Soar' and initiating the Avon system.

The sequence summarised above was regarded by Shotton as representing a post-Anglian, pre-Devensian glaciation for the following reasons:

1. A complete skull of *Hippopotamus* was obtained from the Avon third terrace deposits (Shotton 1929). The river Avon terrace gravels are incised into the Wolston Series, thereby confirming that the glacial deposits are pre-Last Interglacial (Ipswichian *sensu* Mitchell *et al.* 1973).

2. The Bubbenhall Clay recorded by Shotton (1953) from beneath the Baginton Sand and Gravel was attributed to the Anglian glaciation by Mitchell *et al.* (1973). The overlying deposits were therefore interpreted as post-Anglian.

3. The mammal fauna recovered from the Baginton Sand and Gravel was believed to confirm a post-Anglian age.

4. The nearby sites of Nechells (Kelly 1964; Shotton and Osborne 1965) and Quinton (Horton 1974) in the Birmingham area were assigned to the Hoxnian interglacial on the basis of palynology. Both sites are underlain and overlain by glacigenic deposits. Since both sites also lie to the south of the limit of the Devensian ice advance, the underlying till is *a priori* of Anglian age. The upper till was therefore interpreted as 'Wolstonian' (Shotton 1986).

2.4.ii. Revision of the Wolston sequence

There is little doubt that at least one post-Anglian, pre-Last Interglacial cold stage occured in Britain but the evidence presented below argues against it being the one that is represented at Wolston. The revised nomenclature for the Wolston deposits is shown in Table 2.2 below and will be adopted in the subsequent discussion:

Shotton 1953	Rice 1968	Shotton 1976 Rice 1981	Proposed nomenclature	
Dunsmore Gravel	(Not represented)	Dunsmore Gravel	Dunsmore Gravel	
Upper Wolston Clay	Upper Oadby Till Lower Oadby Till	Upper Oadby Till Lower Oadby Till	Upper Wolston Clay	Oadby Till
Wolston Sand	Wigston Sand and Gravel	Wolston Sand and Gravel	Wolston Sand and Gravel	
	Glen Parva Clay Rotherby Clay	Bosworth Clays and Silts	Lower Wolston Clay	
Lower Wolston Clay	Thrussington Till	Thrussington Till	Thrussington Till	?
Baginton Sand and Baginton-Lillington Gravel	Thurmaston Sand and Gravel	Baginton Sand and Baginton-Lillington Gravel	Baginton Sand and Gravel	

Table 2.2 Nomenclature of the Wolston glacial deposits (from Shotton 1953, 1976; Rice 1981 and Sumbler 1983a).

Recent remapping of the Midlands deposits has led to the conclusion that the glacial sequence at Wolston is in fact the westward continuation of Anglian deposits in East Anglia (Perrin *et al.* 1979; Sumbler 1983a, b; Rose 1987, 1988, 1989b, 1991). Reasons for regarding the Wolston deposits as Anglian in age are summarised below:

1. Lack of evidence for Shotton's supposedly Anglian 'Bubbenhall Clay' beneath the Wolston glacial sequence (Sumbler 1983a). This calls into question the basis for regarding the Wolstonian sequence as post-Hoxnian in age.

2. Doubt over the age and provenance of the mammalian remains reported by Shotton (Sumbler 1983a). It should be noted that the specimens were also reviewed by Lister

(1989) who eliminated much of the poorly-provenanced material but did not regard the remainder as particularly supporting an Anglian age (see Chapter 8).

3. Criticism of the palynostratigraphic control at Nechells and Quinton (Rose 1987). The precise stratigraphic relationship between the Oadby Till of the Wolston sequence and these two sites has never been established.

4. Lithological continuity of the chalky tills. Extensive deposits of Anglian chalky till have been documented as a single sediment body across much of eastern England (Bristow and Cox 1973; Perrin *et al.* 1973, 1979). In Leicestershire, this eastern till body, known locally as the Oadby Till (Rice 1981), contains a high Triassic clastic component. The Oadby Till interdigitates with, and is identical in mechanical and mineralogical composition to, the Trias-rich Thrussington Till of the type Wolstonian sequence (Perrin *et al.* 1979; Sumbler 1983a). Sumbler (1983a, b) therefore proposes that the Thrussington and Oadby Tills represent separate tongues of the same ice sheet, which were erroneously sub-divided without observational basis. It is consequently suggested that the chalky boulder clays of East Anglia and of the type 'Wolstonian' are equivalent in age, *i.e.* Anglian.

5. Reappraisal of the Baginton-Lillington Sands and Gravels. A distinctive major lithological unit composed of fluvial sands and gravels overlain by fluvial sands has been traced from the West Midlands to eastern East Anglia (Rose 1987, 1989b). This unit has been widely recognised across England and forms the Baginton Sands and Gravels in Warwickshire (Shotton 1953), the Thurmaston Sands and Gravels in Leicestershire (Rice 1981), the Bytham Sands and Gravels in south Lincolnshire (Rose 1989c), the Shouldham Sands and Gravels near Kings Lynn (Lewis 1989, 1991) and the Ingham Sand and Gravel in Suffolk (Clarke and Auton 1982). The deposits occupy a buried valley and have the sedimentological characteristics indicative of river transport and channel and overbank sedimentation. They are interpreted as having been deposited by a major tributary of the ancestral Thames that flowed across midland and eastern England from west to east prior to the Anglian (Figure 2.2). This former river has been referred to as the 'Bytham River' (Whiteman and Rose 1992).

The following observations are critical to the understanding of the age of the 'Bytham River' fluvial deposits:

1. At Snitterfield near Stratford upon Avon, the top of the Baginton Sands interdigitates with the base of the Wolston Clay (laid down in a pro-glacial lake), thereby confirming continuity of sedimentation and demonstrating that deposition of the upper part of the Baginton Sands immediately preceded the succeeding glaciation (Rose 1987).

2. Near Bury St Edmunds, the Ingham Sand and Gravel deposits have been found to interdigitate with the pre-Anglian and early Anglian Kesgrave Sands and Gravels, where they form a series of terraces (Rose 1987; Lewis, cited in Rose 1989b).

3. In East Anglia, the deposits are overlain by chalky till attributed to the Anglian, on top of which lie the interglacial deposits of the Hoxnian temperate stage (Rose 1987).

4. The deposits contain faunal material with pre-Anglian affinities at sites in Suffolk such as Warren Hill (Wymer *et al.* 1991). At Warren Hill and Rampart Field, Icklingham (Bridgland *et al.* 1995a), archaeological material has also been recovered from deposits attributed to the Ingham Sand and Gravel. Corroborative evidence for pre-Anglian/Elsterian human occupation in Europe has come from localities such as Boxgrove, West Sussex (Roberts 1986), Miesenheim I and Mauer, Germany (Roebroeks and van Kolfschoten 1994).

5. *Rhaxella* chert is absent from Ingham Sand and Gravel deposits in East Anglia. This precludes a post-Anglian age for their deposition as *Rhaxella* is consistently reworked into post-Anglian river gravels (Bridgland 1986).

6. The valley containing the 'Bytham River' sediments cuts across the Jurassic and Cretaceous escarpments, implying that the river system was initiated before the intervening lowlands came into existence (Rose 1987). The Wash and Fen basin was not eroded until the Anglian glaciation (Perrin *et al.* 1979), subsequent to the deposition of the Baginton-Lillington Gravels.

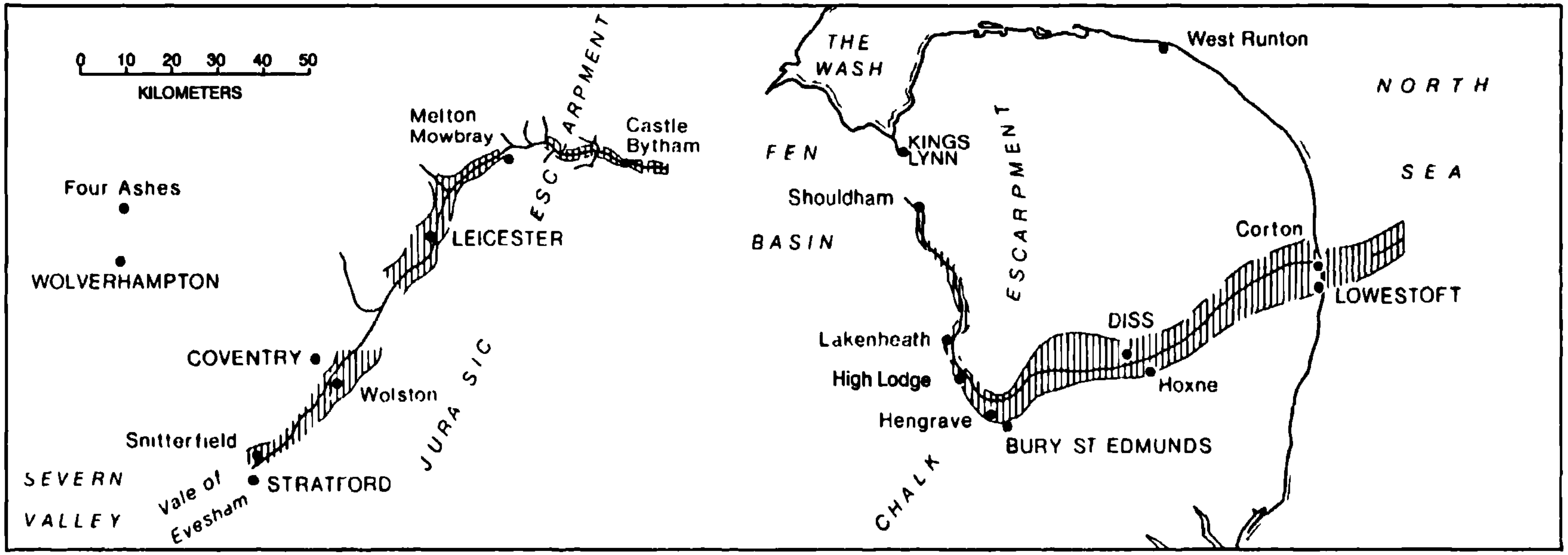


Figure 2.2 Diagram of the route of the 'Bytham River' (from Ashton *et al.* 1992).

Since the Baginton-Lillington Sands and Gravels, which were considered as type sediment for the basal part of the Wolstonian Stage, can be correlated with the Ingham River deposits, they must therefore also be pre-Anglian. Given the above lines of evidence, there is no longer any concrete basis for regarding the sequence at Wolston as being of any age other than Anglian. A revised correlation of the Wolston deposits is shown below (Figure 2.3).

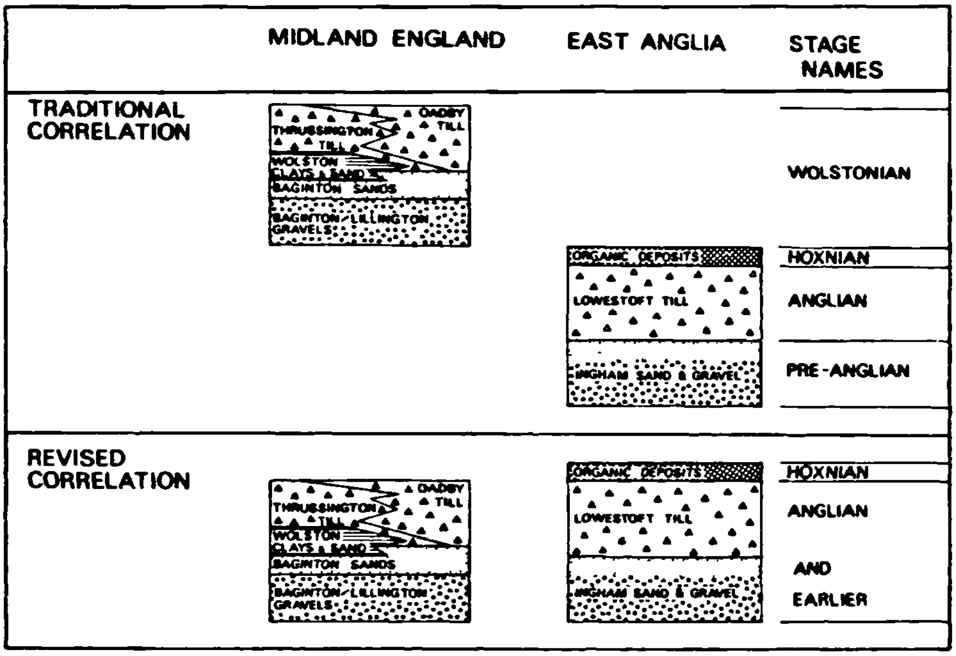


Figure 2.3 Traditional and revised correlation of 'Wolstonian' sediments in the Midlands and Eastern England (from Rose 1989b).

Abandonment of the Wolstonian as a stage name has been advocated (Rose 1987, 1988), leaving the composite cold period between the Hoxnian and Last Interglacial temperate stages without a stratotype. Whilst this has not met with satisfaction from all Quaternary workers (for example Gibbard and Turner 1988), no appropriate alternative type locality has yet emerged. As a temporary measure, Rose (1988) recommends the interval of time in question be known as the 'interval between the Hoxnian (*sensu stricto*) and the Ipswichian (*sensu stricto*)'. Other workers continue to employ the term 'Wolstonian' (in quotes) to denote the cold stage(s) in question without implying age equivalence with the deposits of its stratotype. Still others favour use of the continental term 'Saalian' (for example Bridgland 1994). Discussion of new evidence for post-Anglian- pre-Devensian cold stages is undertaken later in this chapter.

2.5. New interglacials in the later Middle Pleistocene

The idea that there was more than one post Hoxnian interglacial is not a new one (Zeuner 1945; Evans 1971) but it was not until the development of oxygen isotope stratigraphy (Emiliani 1955; Shackleton and Oppdyke 1973; Shackleton 1977) that it began to be more widely accepted.

Today, the stratigraphic evidence obtained from deep sea cores is widely used as a yardstick to define the Pleistocene succession. Pioneered in 1955 by Emiliani, the method derives from the fact that changes in the temperature of the ocean, caused by glacial-interglacial cycles, results in changes in the stable isotopic composition of ocean water. These are directly reflected in the isotopic composition of calcium carbonate foraminiferal tests from deep-sea cores. Studies of the foraminifera in deep-sea cores from the Pacific and Atlantic oceans has confirmed fluctuations through time in the ratios of two isotopes of oxygen contained in sea water, ^{16}O and ^{18}O (Emiliani *ibid*). As the numbers indicate, ^{16}O and ^{18}O differ in isotopic weight. During a glacial period, moisture which is drawn off *via* the hydrological cycle to build ice sheets, preferentially takes up the lighter ^{16}O isotope, leaving the oceans isotopically 'heavier' with a higher proportion of ^{18}O. As the ice caps melt during an interglacial stage, the returning water makes the ocean isotopically 'lighter'.

Emiliani subdivided the isotopic curves from the Atlantic and Pacific into sixteen stages. Warm stages (indicated by lower ^{18}O ratios) were given odd numbers and cold stages (higher ^{18}O ratios) were assigned even numbers. Stage 1 designated the present Holocene period and higher numbers indicated successively older warm and cold stages. The method was further developed by Shackleton (1967), who demonstrated that the variations in isotopic composition of the oceans were in fact due to fluctuations in global ice volume. The stratigraphic subdivision of the oxygen isotope record was subsequently extended, following analysis of the Pacific core V28-238, and no less than 23 isotopic stages younger than the Jaramillo geomagnetic event were recorded (Shackleton and Oppdyke 1973). This was replicated in the upper 9m of a nearby longer core V28-239 (Shackleton and Oppdyke 1976). The ages of the isotopic boundaries are based on interpolations from the known age of the geomagnetic events, based upon a continuous rate of sedimentation.

A major step forward came when a direct link was made between the oxygen isotope record and the orbital cycles central to the Milankovitch theory (Hays *et al.* 1976). Variations in the eccentricity of the Earth's orbital path around the Sun, the obliquity of the ecliptic and the precession of the equinoxes vary with known periodicity. The main periodicities are 400 000 and 100 000 years for eccentricity, 41 000 years for obliquity and 23 000 and 19 000 years for periodicity. The combined effect of these cyclic variables on total solar radiation reaching the earth was calculated by Milankovitch in the 1920s, who produced a complex curve showing the values for this figure through time. It has subsequently been observed that his results bear a remarkably close resemblance to those calculated for global ice volume, based on the oxygen isotope record. If it is accepted that the oxygen isotope sequence records what is fundamentally an orbitally-driven system, then the isotopic cycles as recorded in the ocean sediments are self-dating. This potentially provides us with a very detailed framework for looking at Quaternary sediments, biotas and events.

The advantages of this record are numerous. First, the deep-sea data does not reflect local or even regional conditions, but global events. Second, in comparison to the continental terrestrial evidence, the record is both continuous and relatively undisturbed. Third, it enables different cores from all over the globe to be compared with and cross-checked against similar readings from the accumulation of ice in the Greenland and polar ice-caps. Fourth, the isotopic stage boundaries and terminations (rapid changes from inferred glacial to interglacial conditions) can be interpreted as time-parallel horizons. Fifth, the sedimentary records can be dated and correlated independently by palaeomagnetism (Lowe and Walker 1984). However, interpretation of the isotopic evidence is not always straightforward, particularly since continuity of sedimentation cannot be proved and gaps in the record might thus go undetected. Moreover, since correlation between individual isotopic profiles is based largely on 'counting from the top', the possibility of homotaxial error is always present (*i.e.* different stages producing similar curves). Nevertheless, although there still remain some difficulties with the method and with correlation between the marine and terrestrial records, there is no doubt that the isotopic record contains a unique and complete record of Quaternary climatic change.

The recognition that there have been considerably more climatic fluctuations during the Middle Pleistocene than previously realised has provided much greater flexibility in interpreting the British stratigraphic record. The Anglian cold stage and the Last Interglacial mark the boundaries of the later Middle Pleistocene. The establishment of these two 'fixed points' within the oxygen isotope sequence is therefore of great importance. The *Hippopotamus* fauna of the Last Interglacial climatic optimum has been correlated with oxygen isotope Substage 5e on the basis of consistent radiometric dating of deposits clearly associated with this fauna to around 120 000 BP. Uranium-series (U-series) dating of speleothem sealing deposits containing a *Hippopotamus* assemblage at Victoria Cave, North Yorkshire has produced age-estimates of 120 000 ± 6 000 BP (Gascoyne *et al.* 1981) and these have since been corroborated at other Last Interglacial sites by further U-series age-estimates of 129 000 -116 000 BP obtained from stalagmite fragments from Bacon Hole, Gower (Schwarcz 1984b; Stringer *et al.* 1986; Sutcliffe *et al.* 1987), approximately 121 000 BP on travertine from the raised beach at Belle Hougue Cave, Jersey (Keen *et al.* 1981; Lister 1995) and 127 000 - 107 000 BP on flowstone from Minchin Hole, Gower (Schwarcz 1984a).

Of critical importance is the position, in relation to the oxygen isotope record, of the Anglian Stage. The Anglian has generally been correlated with oxygen isotope Stage 12, since it appears to represent one of the most severe cold episodes within the Middle Pleistocene deep-sea records (Shackleton and Oppdyke 1973; Shackleton 1987; Bowen *et al.* 1986). Whilst this correlation is technically conjectural, since it relies upon 'counting backwards' through the isotope curve from the present day (Isotope Stage 1), it has nevertheless received extremely strong support from recent work on the terraces of the Thames (Bridgland 1994 - see below), Severn and Avon rivers (Maddy *et al.* 1991, 1995) and from some of the more complete Pleistocene sequences on the continent. Consequently, if the Anglian is represented by Stage 12, three post-Anglian, pre-Last Interglacial temperate stages are implied in the oxygen isotope record (Stages 11, 9 and 7). The Hoxnian interglacial should logically be equated with Stage 11, since it immediately postdates the Anglian. However, whilst amino acid ratios from traditional 'Hoxnian' sites such as Swanscombe, Ingress Vale and Clacton support a

Stage 11 correlation, surprisingly lower ratios from the stratotype at Hoxne suggest a much younger age, equivalent to Stage 9 of the oxygen isotope record (Bowen *et al.* 1989).

2.5.i. The "Stage 9 interglacial"

The effective division of 'Hoxnian' localities into two separate stages has created particular problems with regards to nomenclature, for if the true Hoxnian (as defined at the type site) is not immediately post-Anglian, the deposits at Swanscombe and Clacton must therefore represent an unnamed interglacial. Accordingly, Bowen *et al.* (*ibid*) suggest that Swanscombe should now be regarded as the 'stratotype' for a formerly undefined post-Cromerian, pre-Hoxnian interglacial. This has led to considerable confusion, with many authors now referring to the 'Hoxnian *sensu* Swanscombe' or '*sensu lato*' and the 'Hoxnian *sensu* Hoxne' or '*sensu stricto*'. Of greater concern however, is a recent tendency amongst Quaternary workers to allot sites of 'Hoxnian' age to either Stage 11 or 9 according to preference, using amino acid ratios. Many sites placed in the wider 'Hoxnian group' on faunal and floral biostratigraphic grounds, including Hoxne itself (Singer *et al.* 1993), Marks Tey (Turner 1970), Barnham (Ashton *et al.* 1994a, b), Beeches Pit (Preece *et al.* 1991), Hitchin (Boreham and Gibbard 1995) and Hatfield (Sparks *et al.* 1969) are developed in shallow channels or depressions such as kettle holes, directly overlying Anglian Lowestoft Till and in a very restricted geographical area. Of this group, Hoxne and Hatfield have been placed in Stage 9 on the basis of their amino acid ratios (Bowen *et al.* 1989) (Figure 2.5). The situation is further complicated by the fact that other infilled hollows of Last Interglacial and Holocene age have also been discovered, for example at Wing, Leicestershire (Hall 1980) and Hockham Mere, Norfolk (Bennett 1983). This has reinforced the view that the use of sediment in closed depressions on the surface of glacial deposits is not a reliable means for demonstrating continuous sedimentation, nor their precise relative age (Bowen 1992).

The resultant implication that the Hoxnian sequences may in fact represent multiple interglacial events suggests that either there was a depositional break of some 90 000 years at some sites (including Hoxne itself) after the end of the Anglian, or that the underlying till is not all of the same age. The latter possibility has been recently has been supported by Sumbler (1995), who advocates the existence of a 'two-phase Anglian glaciation'. Thus, with the earliest Anglian deposits in the region of the Vale of St. Albans correlated with OIS 12, other tills (including, at Hoxne, the Lowestoft Till of the type Anglian succession) would be placed within the younger Stage 10. The Stage 9 attribution for the Hoxnian Interglacial would therefore no longer be regarded as anomalous and the 'Swanscombian' interglacial remains within Stage 11. However, this explanation cannot be entirely satisfactory on geological grounds, since there is ample justification for accepting that there is only one till body in the area under consideration (Perrin *et al.* 1979). The possibility of a depositional break at Hoxne following the end of the Anglian also seems unlikely since no visible break in sedimentation has been observed at the type-site following deposition of the Lowestoft Till (West 1956). Furthermore, the transition from the end of the Anglian into the Hoxnian has been traced in the palynological record in these 'dead ice' environments with a very high degree of resolution and that information, in turn, correlated very convincingly with the continental equivalent, the Holsteinian (Turner 1968, 1970). Contrary to the amino acid ratios, these other lines of evidence would therefore place Hoxne in an immediately post-Anglian/Stage 11 context. The extent to which fossil mammals support the separation of the Hoxnian sites and the place in the British Quaternary succession of Hoxne and other sites attributed to Stage 9 on the basis of their amino acid ratios will be discussed in later chapters.

2.5.ii. The "Stage 7 interglacial"

Since the mid 1970s, it had been apparent to some Quaternary workers that many interglacial sites did not fit comfortably into the Geological Society scheme that envisaged only two post-Anglian interglacials. The Ipswichian interglacial had become overburdened with deposits of various ages and there was a growing acceptance that at least *two* distinct warm episodes should be recognised between the Hoxnian and Devensian (Sutcliffe 1975). Evidence from fossil mammals in particular argued for a more complex chronology and the fundamental assumption that the main interglacial periods could be distinguished on palaeobotanical grounds was called into question, particularly given the fragmentary pollen records at all Ipswichian sites except Wing. Sutcliffe (1975) drew attention to the problem that where two similar warm phases occurred in close succession, it was possible that either:

i) they could not be readily distinguished on the basis of pollen, or

ii) that a false succession might be constructed at sites where only parts of the pollen sequence were present. This latter scenario is summarised in Figure 2.4 below. The Roman numerals refer to pollen biozones after Turner and West (1968) (I = Pre-Temperate, II = Early-Temperate, III Late-Temperate, IV Post-Temperate).

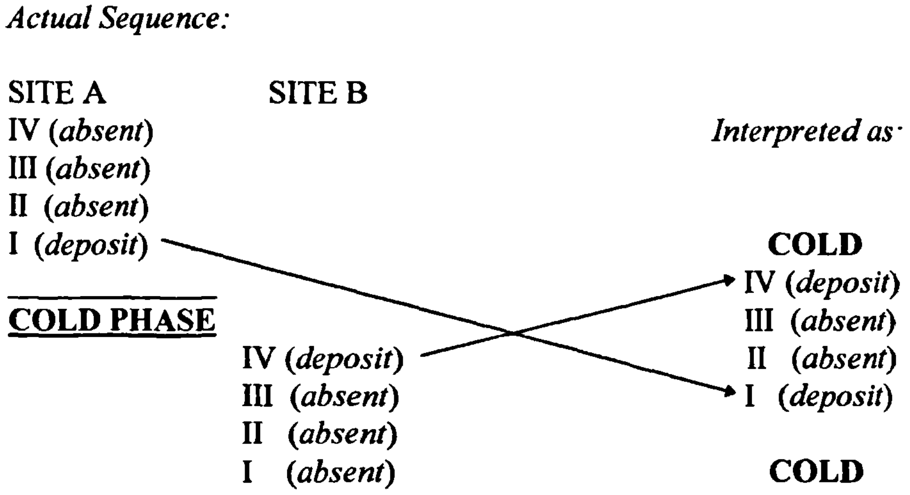


Figure 2.4 A potential sources of confusion in pollen-based correlation of stratigraphic sequences (after Sutcliffe 1975)

According to this model, it was possible that parts of more than one warm period had been credited to a single interglacial and called 'Ipswichian'. A key area in the discussion was the lower Thames valley. At Ilford, organic deposits spanning lateglacial pollen zones of the preceding glaciation and Ip I - Ip IIb were discovered. Mammalian remains recovered from the overlying 'brickearth' were accordingly believed to date from zones Ip III and Ip IV (West *et al.* 1964). Deposits at Aveley encompassed zones Ip IIb and Ip III (West 1969), while the deposits within the 'Upper Floodplain Terrace' at Trafalgar Square covered zone Ip IIb (Franks 1960). Correlation between the sites at Ilford and Aveley was widely accepted on the basis of mammalian biostratigraphy (Sutcliffe and Bowen 1973; Stuart 1976; Sutcliffe 1976). However, Sutcliffe (1960, 1964) considered the Ilford deposits to belong to a separate 'Ilford terrace', intermediate in age between the Boyn Hill and 'Upper Floodplain' terraces. This view was based upon differences between the mammal assemblages from the interglacial deposits of the Boyn Hill/Orsett Heath Formation at Swanscombe, from the 'Ilford terrace' and from the 'Upper Floodplain Terrace' at Trafalgar Square, and was supported by the separate recognition of the terraces themselves. At that time, no distinction was made between the deposits in the northern and southern pits at Ilford, which were later assigned to separate formations (the Lynch Hill/Corbets Tey Formation and the Taplow/Mucking Formation respectively) (Bridgland 1994, 6.2).

Not only are the Ilford and Aveley deposits situated at a higher level than Trafalgar Square, they also contain different mammalian assemblages that, according to Sutcliffe (1975), were impossible to square with the view that all three sites should be placed within the Ipswichian. Whereas the mammalian assemblage from Trafalgar Square is characterised by an assemblage including *Hippopotamus amphibius, Palaeoloxodon antiquus, Dama dama* and *Stephanorhinus hemitoechus*, the Ilford and Aveley assemblages are dominated by a primitive form of *Mammuthus primigenius* and *Equus ferus*. *Stephanorhinus kirchbergensis* (found in the preceding Hoxnian interglacial) is also present at Ilford, whereas *Hippopotamus* is apparently absent.

The differences in the mammalian assemblages made it unlikely that these two terraces could be contemporaneous and it was therefore suggested that they must either represent different parts of the same interglacial, or two different interglacials (Sutcliffe 1964, 1976; Sutcliffe and Kowalski 1976). The palynological succession obliges the mammoth-horse fauna of zones Ip III - Ip IV to be later in time than the hippopotamus fauna of zone IIb - beginning of zone III, but, in reality, a mammalian assemblage of Ilford type has never been found to overlie a hippopotamus assemblage in any Pleistocene deposit (Stringer *et al.* 1986). Indeed, the full Ipswichian pollen sequence from zone I to zone IV has only recently been discovered at Wing in Leicestershire (Hall 1980). However, as the site lacked mammalian remains, it could not clarify the situation any further.

The combined evidence from mammalian biostratigraphy and differences in the heights of the interglacial deposits led Sutcliffe (1976) to conclude that the Trafalgar Square deposits were laid down during the Ipswichian Interglacial, but that the Aveley and Ilford deposits accumulated during an earlier, post-Hoxnian, pre-Ipswichian temperate interval. The name 'Ilfordian' has been applied to this undefined stage by Bowen (1978) and Wymer (1985), which is thought to correlate with Oxygen Isotope Stage 7 (Shotton 1983c; Bowen *et al.* 1989; Bridgland 1994).

However, a considerable stratigraphic problem was posed by the recognition of zone Ip IIb pollen spectra in both the 'Ilford Terrace' deposits at Ilford and Aveley (West *et al.* 1964; West 1969) and in the 'Upper Floodplain Terrace' at Trafalgar Square (Franks 1960). In order to explain the difference in heights between the two sets of interglacial deposits, West (1972) suggested that the entire Ilford-Aveley area had been subjected to tectonic uplift (contrary to his views in earlier papers, where he concurred with the Geological Survey's mapping of the 'Ilford Terrace' as 'Taplow Gravel' (West *et al.* 1964; West 1969)). This interpretation was influenced by his conclusions that they could be correlated with the deposits at Trafalgar Square on palynological grounds.

Sutcliffe's differentiation of the Ilford and Aveley and Trafalgar Square mammalian assemblages into two separate interglacials was also contested by Stuart (1976, 1982), who considered that the characteristics differentiating these assemblages could be related to pollen biozones within the Ipswichian. Stuart (1976) noted that mammoth and horse were always absent from pollen biozone II, whereas hippopotamus was recorded only from pollen biozone II and the beginning of biozone III. He therefore suggested that the Ilford and Aveley faunas were in fact younger (rather than older) than the Trafalgar Square fauna and proposed that the greater elevation of the former deposits was the result of their deposition in tributary valleys, as opposed to in the main Thames valley, a line of argument subsequently upheld by Gibbard (1994, 1995b).

Stuart (1976) explained the failure to recognise a faunal assemblage of Ilford type either above or below a fauna of Trafalgar Square type by the lack of well-excavated cave sites of appropriate age. The absence of hippopotamus in Ip II deposits at Ilford was similarly explained by the limited occurrence of zone II deposits there and by the fact that mammalian remains were only recovered from the younger (zone III-IV) brickearths. The absence of hippopotamus at Aveley in zone IIb deposits was accounted for by the apparent paucity of the faunal assemblage. Furthermore, the presence at Ilford of *S. kirchbergensis* and a more primitive form of *Mammuthus primigenius*, both species that Sutcliffe (1976) had cited in order to demonstrate the greater antiquity of the 'Ilford Terrace', was refuted (Stuart 1976). The recognition of a separate Stage 7 interglacial on mammalian biostratigraphic grounds was also dismissed by Mayhew (1976) and Turner (1981b).

However, evidence from the heights of pollen-dated freshwater/marine sediment contacts and raised beach deposits at a variety of sites suggests that relative sea level rose well above the present level in zone Ip IIb, not falling ~~until~~ below present level until at least the end of zone Ip III (West 1972). It is consequently difficult to see when the lowering of sea-level occurred, that would have permitted the immigration into Britain of *M. primigenius*, *E. ferus* and humans by zone III. The suggestion that *M. primigenius* and *E. ferus* 'survived' the early part of the Ipswichian Interglacial in Scotland before moving south in zone Ip III (Stuart 1976) is unconvincing, particularly when one takes into account the fact that these species are present in southern Britain in fully interglacial conditions with no hint of the climatic deterioration that would have forced a move south. Furthermore, if the pollen biostratigraphy is to be believed, both species were already present in southern Britain, at Selsey in West Sussex, by zone II, whereas horse was present at Aveley in zone Ip IIb deposits, clearly contradictory to Stuart's (1976, 1982) position.

At this point in the debate, a stalemate had been reached. However, over the past two decades, new information has come to light in favour of a post-Hoxnian, pre-Ipswichian interglacial, equated with oxygen isotope Stage 7 (*circa* 200 ka BP) and which was preceded and followed by cold conditions. Re-evaluation of a number of sites previously placed in the 'Ipswichian' has shown them to fit more comfortably within this earlier stage. As a result, sites such as Ilford and Aveley , Northfleet (Kent), Stutton, Harkstead, Stoke Tunnel and Brundon (Suffolk) are now widely accepted as pertaining to Stage 7 (Shotton 1983c; Wymer 1985, 1988). This view is strongly supported not only by terrace stratigraphy (see later) but also by a variety of biological, archaeological, sea level and dating evidence:

1. Mammalian evidence: a distinctive mammalian assemblage including *Mammuthus* and *Equus* is present at all the above sites (see Chapter 6). Although both mammoth and horse are also found in many cold stage episodes and interstadials, it is important to emphasise that in this case, these species are found together in a fully interglacial context.

2. Molluscan evidence: the freshwater bivalve *Corbicula fluminalis* is an invasive coloniser that can occur in enormous numbers under suitable conditions (Preece 1995)

but has never been found in direct, un-reworked association with the Last Interglacial *Hippopotamus* fauna at any site in Britain, although it is a regular component of the malacological fauna in previous interglacials (Keen 1990; Meijer and Preece 1995). Consequently, its presence at (for example) Aveley and absence further upstream at Trafalgar Square would strongly suggest that these sites are not of the same age. It is noteworthy that the absence of *Corbicula* from Britain during the Last Interglacial suggests isolation of the island from the continent. *Corbicula* is found in many Dutch Eemian sites and would have readily colonised Britain had any fluvial link existed (Meijer and Preece *ibid*).

3. Coleopteran evidence: identification of British pre-Last Interglacial sites has also been proposed on the basis of the presence of the staphilinid beetle, *Oxytelus* (=*Anotylus*) *gibbulus* (Coope in Shotton 1983c; de Rouffignac *et al.* 1995). Although this species is present in some numbers at accepted 'Stage 7' sites, it is apparently absent from Last Interglacial deposits and may therefore serve as a useful biostratigraphic marker.

4. Archaeological evidence: the faunal assemblages described above are frequently found in association with flint artefacts showing use of the Levallois technique, a procedure which involves the preparation of the core in order to remove a flake of predetermined shape. Since evidence of human presence in the British Isles has yet to be established at any true Last Interglacial site, it is therefore reasonable to infer that the presence of archaeology denotes a pre-Last Interglacial site. Furthermore, whilst flint tool typology is no longer regarded as an acceptable means of correlating sites, the Levallois technique is a potentially useful marker. This technique first appears in the Thames valley sequence in the upper deposits of the Lynch Hill/Corbets Tey Formation, implying that it was first used during the mid-Saalian (Stage 8) (Bridgland 1994, 1996).

5. Sea-level evidence: radiometric and amino acid estimates for raised beaches at Minchin Hole (Sutcliffe and Currant 1984; Sutcliffe *et al.* 1987), Portland, Dorset (Davies and Keen 1985), Hopes' Nose, Torbay, Devon (Mottershead *et al.* 1987), Brighton, East Sussex (Keen 1995), and Jersey (Keen 1986) have produced results consistent with different eustatic sea levels between supposed Stage 7 and Substage 5e episodes.

6. Dating evidence: the re-evaluation of sites in the *Mammuthus-Equus-Corbicula* group has been upheld in some instances by both relative and radiometric dating. Amino acid ratios from these sites have consistently been higher (mean D/L value 0.16) than ratios from Last Interglacial sites (mean D/L value 0.09) (Bowen *et al.* 1989).

Amino acid epimerisation operates according to the following principles:

Following the death of an organism, chemical alteration occurs within the protein residues to produce compounds of a more simple chemical structure. The degree of alteration brought about by the chemical reactions is progressive (up to a point of equilibrium) and is therefore suitable as a basis for relative dating. The process of amino-acid diagenesis first involves the breaking of peptide bonds by hydrolysis to release amino-acids. This in itself is time- dependent, since the ratio of free amino-acids to peptide-bound acids will increase through time. Upon death of the organism, racemization and epimerisation of the amino-acids occurs, whereby the L-form (L-isomers) of individual amino-acids, which are present in the living animal, changes to the D-form (D-alloisomers) (Sykes 1991). This process is also time-dependent and the reaction will continue until there are equal amounts of both L- and D-forms. The D/L ratios can be measured using a number of chemical processes and the relative amount of diagenesis calculated. This is then used to impart relative ages to biostratigraphic and lithostratigraphic units (aminostratigraphy) and to establish a relative chronology.

Although any protein-bearing material can be used for amino-acid dating, in practice, the method has been used mainly on materials with 'tight' skeletal carbonate matrices, such as foraminiferal tests and the valves of some Mollusca (Miller and Hare 1980; Bowen *et al.* 1985, 1989). The problems with the method stem from the fact that several factors, other than time, can affect the D/L ratio (Sykes 1991). For example, the method is extremely sensitive to temperature and the warmer the climate, the faster the diagenesis. The method is also species-dependent, since different taxa have been shown to epimerise at different rates. Other factors which may potentially be sources of errors include pH, environmental contamination, intra-shell variation and different sample preparation methods (Sykes 1991). The consequence of this is that the method can only be applied to shells with analogous rates of diagenesis, over small areas where temperature regimes can be assumed to have been similar since the death of the analysed specimens.

In the Pleistocene of the British Isles, aminostratigraphy has been used to place raised beaches in chronological order (Andrews *et al* 1979; Davies and Keen 1984; Bowen *et al.* 1985; Bowen and Sykes 1988) and to determine the relative ages of estuarine, freshwater and terrestrial deposits (Miller *et al.* 1979, Bowen *et al.* 1989). The following model for land-sea correlations, based upon aminostratigraphy of non-marine Mollusca from British Pleistocene sites, has been produced (Figure 2.5):

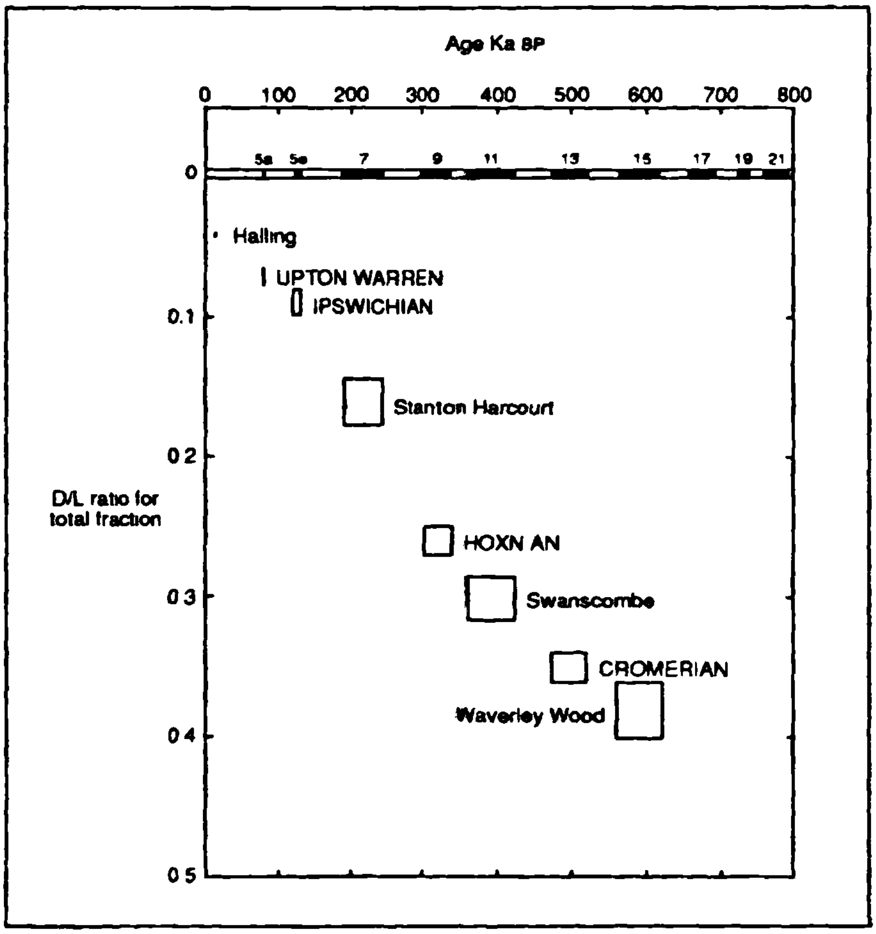


Figure 2.5 Correlation of D-alloisoleucine/L-isoleucine non-marine events in the British Isles, with odd-numbered oxygen isotope stages as tuned to orbital timescales (from Bowen *et al.* (1989)

However, whilst aminostratigraphy has been consistently successful in its separation of deposits of Last Interglacial age from those attributed to Stage 7, and separating Stage 7 from older deposits, the results from many older sites show marked discrepancies with other lines of evidence. The contentious attribution of Hoxne to OIS 9 has already been noted above and will be discussed at greater length in 4.1.

In certain cases, radiometric dating methods have also been applied with results that are also apparently consistent with a 'Stage 7' age, although such consistency is by no means common, due to the various limitations inherent in most methods. Uranium-series dating of bones from Brundon have produced ages of 230 000 ± 30 000 and 174 000 ± 30 000 years B.P. (Szabo and Collins 1975), whilst at Pontnewydd Cave (Clwyd), samples from a stalagmitic floor which overlie Middle Pleistocene hominid remains, have produced average ages of 224 000 +41 000 / -31 000 years B.P. (Ivanovich *et al.* 1984). Thermoluminescence dating of burnt flint from Pontnewydd has also yielded dates of 200 000 ± 25 000 years B.P. (Huxtable 1984). However, Szabo and Collins (1975) also tested bone, using Uranium-series dating from two sites commonly correlated with OIS 7 (Sutcliffe 1995a), namely Brundon (6.6) and Stutton (6.8). This yielded age-estimates of 230 000 ± 30 000 and 174 000 ± 30 000 years B.P. for Brundon, equivalent to Stage 7, and 125 000 ± 20 000 years B.P. for Stutton, equivalent to Substage 5e. Until such time as the effects of post-depositional modification can be fully adjusted for, it would seem prudent to treat Uranium-series age estimates on molluscs and mammalian bone with caution, since these materials are known to be open systems, allowing for the post-depositional migration of uranium.

In addition to the re-evaluation of old sites, recent investigations at new sites have also confirmed the validity of recognising a post-Hoxnian pre-Ipswichian interglacial at *circa* 200 000 years B.P. Two sites in particular have provided clear evidence of interglacial conditions that cannot be incorporated into the traditional stratigraphic framework: Marsworth (Buckinghamshire) and Stanton Harcourt (Oxfordshire). These sites are discussed in greater detail in 6.10 and 6.11 respectively but a brief summary is warranted here, beginning with Stanton Harcourt. In the vicinity of Oxford, the Summertown-Radley terrace of the Upper Thames valley is divisible into three superimposed lithological units (Briggs 1976, 1988; Briggs and Gilbertson 1980; Briggs *et al.* 1985) (although the possibility of a five-part sequence has recently been proposed by Bridgland 1994, see 6.11). At Dix's Pit, Stanton Harcourt, basal temperate deposits lie within a channel cut into the Oxford Clay (the Stanton Harcourt Channel). These deposits contain a typical *Mammuthus-Equus* assemblage (Currant 1985a), together with an extensive molluscan fauna, including *C. fluminalis*, a rich beetle fauna dominated by *O. gibbulus*, and pollen and plant macrofossils indicative of temperate conditions. Mean amino acid D/L values of 0.16 ± 0.016 from the channel (Bowen *et al.* 1989) correspond with a Stage 7 attribution. The overlying Stanton Harcourt Gravel contains a vertebrate assemblage (Sandford 1924; Currant 1985b) and a molluscan fauna of clear cold-climate affinities, together with intraformational ice-wedge casts and cryoturbation layers that confirm the development of periglacial conditions in the succeeding cold stage (Seddon and Holyoak 1985). The uppermost unit of the tripartite sequence, the Eynsham Gravel, contains abundant remains of *Hippopotamus* (Sandford 1924) of presumed Last Interglacial age. The Eynsham Gravel was once visible at its type locality, the nearby Eynsham Station Pit, but is unfortunately not present 4 km downstream at Stanton Harcourt itself. Nevertheless, although the full tripartite stratigraphy of the Summertown-Radley aggradation has never been recorded in direct superposition, the combination of supporting information points clearly to a warm-cold-warm succession, encompassing two separate interglacials: a pre-Last Interglacial temperate stage and the true Ipswichian. This view has however been challenged by Gibbard (1985) (see 6.11).

A more fortuitous situation is present at Marsworth (Buckinghamshire). Green *et al.* (1984) report a Lower Channel cut into the chalk, containing a *Mammuthus-Equus* mammalian assemblage and the beetle *O. gibbulus*. Pollen, coleopteran and molluscan remains indicate locally marshy conditions and dry grassland with restricted adjacent temperate woodland, whilst travertine blocks bearing the impressions of leaves of thermophilous trees and containing temperate Mollusca have been discovered at the base of the Lower Channel and dated by Uranium-series to 170 000-140 000 years B.P. Although these dates appear to be slightly too young for a complete match with Stage 7 (probably due to minor contamination of the travertine - A.P. Currant pers. comm.), they nevertheless provide corroboration of the other lines of evidence that Marsworth represents a pre-Last Interglacial temperate episode. Overlying the Lower Channel are thick colluvial deposits of involuted 'Coombe Rock', indicative of severe periglacial conditions. Incised into the surface of the 'Coombe Rock' is the Upper Channel which contains a typical Ipswichian mammalian assemblage, including *Hippopotamus*. Two temperate episodes are therefore recorded in stratigraphic superposition and separated by intensely cold (but apparently not glacial) conditions. The earlier Lower Channel is therefore interpreted as a post-Hoxnian, pre-Ipswichian interglacial (Green *et al.* 1984).

2.6. Evidence for new intervening cold stages

Although it now seems probable that the glacial deposits present at Wolston are Anglian in age, this does not preclude the existence of other as yet unnamed cold stages during the later Middle Pleistocene. Indeed, as many as three post-Anglian, pre-Last Interglacial cold stages are suggested in the oxygen isotope record: Stages 10, 8 and 6. Unfortunately, the precise nature of these intervening cold stages is far from clear since glaciation in Britain during these periods was apparently less extensive than in the Late Devensian (in dramatic contrast to evidence from the continent which suggests that in the Netherlands and Germany, the Stage 6 glaciation (as opposed to the Stage 12 Elsterian) was the most extensive). Much of the information has therefore been either obliterated or obscured. However, the Ridgeacre Till of the Midlands, the Basement Till of East Yorkshire (Catt and Penny 1966), the Welton Till in east Lincolnshire (Alabaster and Straw 1976) and the Warren House Till of coastal Durham (Francis 1970) have all been thought to fall within the post-Anglian, pre-Last Interglacial period (Bowen *et al.* 1986).

The Basement, Welton and Warren House Tills have been correlated on the basis of their stratigraphic position below Devensian till and their similar mineralogy, including the presence of Scandinavian erratics in the Basement and Warren House Tills (Madgett and Catt 1978). Their pre-Last Interglacial age is established by the presence of the Basement Till below the Last Interglacial raised beach at Sewerby, East Yorkshire (Catt and Penny 1966) and above the Speeton Shell Bed at Filey, East Yorkshire, assigned to Stage 7 by amino-acid ratios (Wilson 1991). The Ridgeacre Till, on the other hand, is stratified above 'Hoxnian' deposits at Quinton to the south of the Devensian ice limit. Furthermore, at Welton-le-Wold, Lincolnshire, Alabaster and Straw (1976) and Wymer and Straw (1977) record a 'Hoxnian' mammalian assemblage containing *P. antiquus* and *Equus* associated with handaxes from a sub-valley gravel sandwiched between bedrock and till. The overlying Welton Till is therefore interpreted as post-Anglian and pre-Devensian in age. However, the possibility that the Welton gravel is pre-Anglian should not be discounted since both *P. antiquus* and *Equus* are found in the late

Cromerian (Lister 1989) and large numbers of handaxes have since been documented in primary context at pre-Anglian sites such as Boxgrove, West Sussex (Roberts 1986; Wymer 1988; Roberts *et al.* 1994).

The age of these tills is hence still a matter of dispute, since they are not recognised over wide areas nor can an Anglian age be completely discounted. Although there are relatively few instances where interglacial deposits are found sandwiched between unambiguous cold stage deposits, more reliable evidence of the penultimate cold stage is perhaps obtainable at some of the recently evaluated Stage 7 sites, where signs of climatic deterioration are present towards the top of the sequence. Similarly, information may be gleaned from the basal horizons of Last Interglacial deposits. Listed below are some of the recently published localities that have been put forward as providing direct evidence for post-Anglian, pre-Last Interglacial cold episodes. All of these are discussed further in Chapter 7, with the exception of Tornewton Cave, which is considered in 6.21:

- Balderton, Lincolnshire. Brandon and Sumbler (1991) report a cold stage aggradation of sands and gravels containing abundant mammalian remains (Lister and Brandon 1991), which they relate to Stage 6 of the isotope record.
- Warwickshire Avon Terrace No.4. Gravels containing a 'cold stage' mammalian fauna together with *C. fluminalis* are recorded from No.4 Terrace deposits at Twyning, Gloucestershire (Whitehead 1989a, b).
- Stanton Harcourt, Oxfordshire. Cold stage gravels, containing *Mammuthus primigenius* and *Coelodonta antiquitatis* (Currant 1985b), overlie the temperate-climate deposits of the Stanton Harcourt Channel and underlie Last Interglacial deposits in the Eynsham Gravel. The cold stage represented by the Stanton Harcourt Gravel is therefore equated with Stage 6.
- Marsworth, Buckinghamshire. Deposits of 'Coombe Rock' from between the Upper and Lower Channels are referred to a pre-Last Interglacial cold stage.
- Bacon Hole, Mid Glamorgan. The lowest deposits in the cave, the Coarse Sands, underlie Last Interglacial deposits and contain evidence of a cold, dry climate with little local vegetation (Stringer *et al.* 1986). The Coarse Sands and their fauna are consequently placed in Stage 6.

- Tornewton Cave, Devon. Sutcliffe and Kowalski (1976) report a 'penultimate glaciation' mammalian assemblage from the 'Glutton Stratum', containing the steppe lemming *Lagurus lagurus*, common hamster *Cricetus cricetus* and extinct hamster *Allocricetus bursae*.

2.7. Towards a revised stratigraphic succession

No single stratigraphic scheme has currently been proposed that encompasses all the developments of the last twenty years. The oxygen isotope record has become widely used as a stratigraphic standard with which terrestrial sequences may be correlated, but apart from a general consensus that the Last Interglacial represents Substage 5e of the marine record, there has been little agreement regarding correlation of earlier stages of the Middle Pleistocene in Britain. If the correlation of the Anglian with Stage 12 is accepted, three temperate stages (11, 9 and 7) and three cold stages (10, 8 and 6) are indicated by the oxygen isotope record prior to the Last Interglacial. The determination of amino acid D/L ratios from a number of important sites within this time range has provided a reasonably consistent means of identifying sediments of Substage 5e and of Stage 7 age, but results from older deposits are less internally consistent and are often in direct conflict with other lines of evidence, especially mammalian biostratigraphy.

Many of the radiometric age-estimates have shown similar marked inconsistencies. The diverse nature of Pleistocene deposits in Britain has encouraged the development of a wide array of relative and absolute dating techniques, which have been implemented with varying degrees of success. In recent years, an increasingly heavy emphasis has been placed upon the importance of absolute dates or 'age estimates', thereby leading to the occasionally indiscriminate application of certain techniques, despite the fact that the methods are often at the developmental stage and relative dating methods are often the only ones appropriate at individual sites. Many absolute dates from Pleistocene sites have thus been at odds with other lines of evidence due to shortcomings concerning either suitability of materials for dating, or a limited time range for the dating technique in operation.

In addition to Uranium-series dating, Thermoluminescence (TL) and Optically-stimulated luminescence (OSL) dating have been used in an attempt to date sediments at various British Pleistocene sites, although so far no demonstrably reliable dates over about 125 000 B.P. have been obtained. A summary of the problems of dating pre-Devensian sediments using TL is provided by Parks and Rendell (1988). Noticeably, all published TL dates on Middle Pleistocene sediments in this country seem to consistently underestimate the age of the deposits. For example, TL dates from the Lower and Upper Loams at Swanscombe, Kent, suggested ages of 228 800 ± 23 300 and 202 000 ± 15 200 years B.P. respectively (Bridgland *et al* 1985). These dates would place the full Swanscombe sequence within OIS 7, a position clearly at odds with the vast body of lithostratigraphical and biostratigraphical evidence from the site, which suggest correlation with an earlier temperate episode, probably OIS 11 (see Swanscombe, 4.2). TL dates on deposits from Northfleet, attributed to OIS 7 (Bridgland 1994, Northfleet, 6.5), ranged from 149 200 to 115 600 years B.P., results that would also seem to point to a younger age (Parks and Rendell 1988). Similarly, TL dates on silts within the Stanton Harcourt Gravel of 91 000 ± 8 000 and 93 000 ± 9 000 years B.P. by Seddon and Holyoak (1985) place the site within the early Devensian, again far younger than the proposed correlation of this period of gravel deposition with OIS 6 (Bridgland 1994; see 7.5). TL dating on burnt flint from archaeological sites has occasionally been more consistent with other lines of evidence, although the older the site, the more likely the discrepancy. Dates on a burnt flint core from the Buff Intermediate Layer at Pontnewydd Cave, Clwyd (Huxtable 1984) and on burnt flints from Layers C and D at La Cotte de St. Brelade, Jersey (Huxtable 1986) have both fallen within the 200-250 000 years B.P. range, which is in keeping with the contexts of the sites (see Pontnewydd, 6.25).

2.8. The history of the Thames during the Middle Pleistocene

One of the most significant developments of this century has been the modelling of the evolution of the river Thames and of its terrace sequence (Hinton and Kennard 1905; Dewey *et al.* 1924; King and Oakley 1936; Evans 1971; Gibbard 1985, 1994; Bridgland 1988, 1994; Bridgland *et al.* 1995b, c). Major downcutting events (rejuvenation) in response to climatic change, coupled with progressive uplift of the continental crust areas have resulted in the familiar ‘flight of stairs’ terrace sequence visible in the Thames valley (Bridgland and Allen 1996) (Figure 2.6).

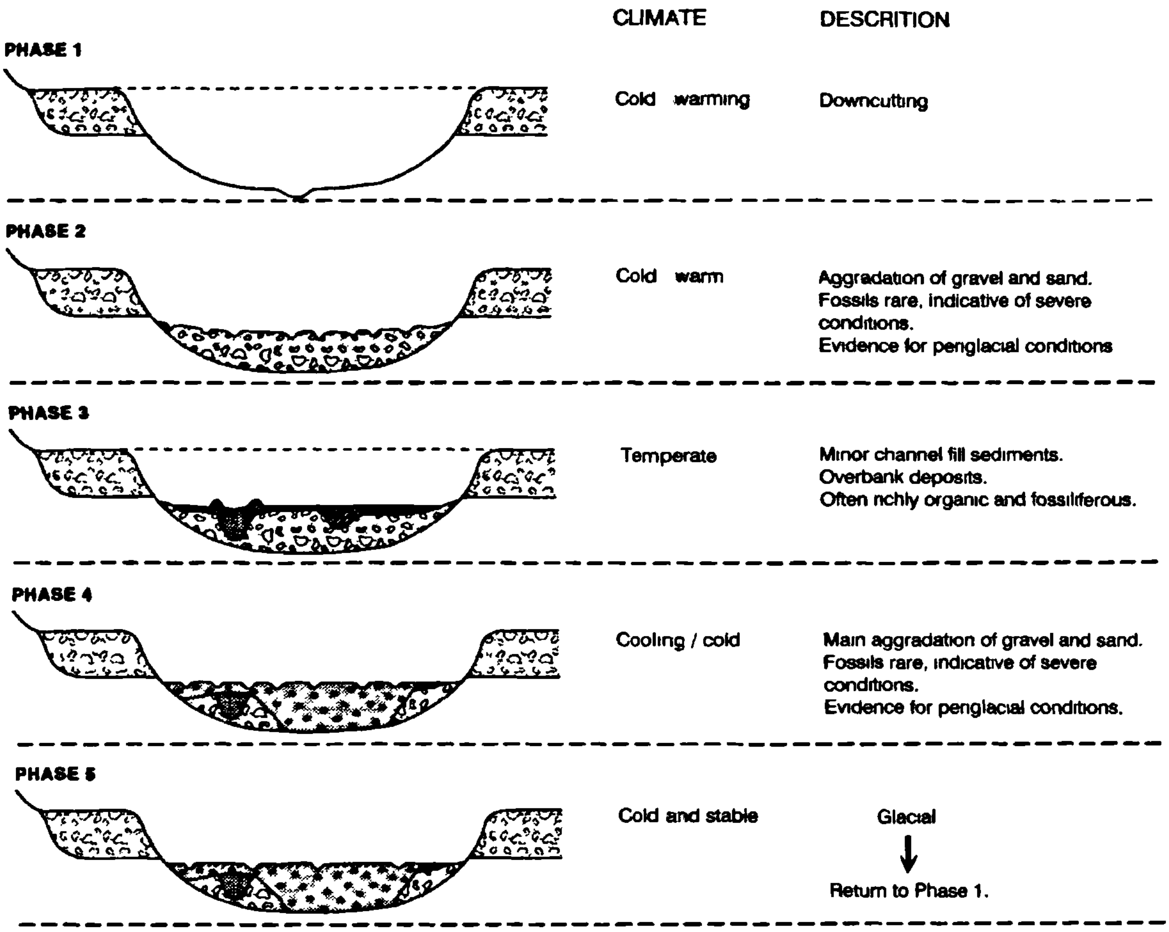


Figure 2.6 Model for explaining the formation of aggradational terraces in synchrony with climatic fluctuation during the Quaternary (modified from Bridgland 1995 and Bridgland and Allen 1996).

Tracing terraces between the Upper and Middle Thames has long been problematic due to poor terrace preservation in the intervening Goring Gap, but composite long-profile diagrams have proved particularly successful in establishing the heights of the various gravel formations over long distances (Bridgland 1994).

During the Early Pleistocene, a much-enlarged proto-Thames drained a large part of southern Britain including the West Midlands and parts of Wales (Bridgland *ibid*). Extensive high-level gravel deposits were laid down before the river reduced in size through the loss of its headwaters beyond the Cotswolds. Prior to the Anglian glaciation, the Thames occupied a more northerly route than at the present day, flowing through south Hertfordshire, central and northern Essex and East Anglia. At this time, the Medway drained the eastern part of Essex, probably receiving the Darent as a left bank tributary (Bridgland 1995). The Middle Thames Westmill Lower Gravel/Winter

Hill Gravel marks the last aggradational phase of the Thames before advancement of the early Anglian Ware Till ice in the Vale of St. Albans brought about ponding of the river and the formation of substantial ice-dammed lakes in the Hertford and Watford areas (Cheshire 1981) (Figure 2.7A). Overspill from the Vale of St. Albans into the Mole-Wey valley and from there into the Wandle caused the development of a spillway system (Gibbard 1995b) until finally, the incision of a spillway from the Wandle into the Darent-Cray valley caused the Thames to adopt the Darent-Medway system (Bridgland 1995; Gibbard 1995b). The diverted Thames thus took up its modern course through central London towards Southend-on-Sea, from where it flowed north to rejoin its original course near Clacton (Bridgland 1988, 1994) (Figure 2.7B). Although the northward part of this post-diversion route is no longer present in the course of the modern Thames between London and its estuary, it has been traced offshore in a drowned extension of the valley (Bridgland and D'Olier 1995).

The decay of the Ware Till ice (the first of the four ice advances during the Anglian in southern Britain) led to the initiation of independent drainage in the Lea and Colne valleys, whilst the second ice advance, the Stortford Till ice, extended further south reaching Finchley and Hornchurch (Bridgland 1994). The maximum extent of Anglian ice may be seen at Hornchurch Railway Cutting, where a remnant of Anglian till is overlain by a post-diversion Thames gravel. This locality is of unique importance since it firmly establishes the Anglian till as a stratigraphic marker in the Thames sequence.

The earliest post-diversion formation in the Middle Thames, the Black Park Gravel, is regarded as coeval (at least in part) with glaciation in the Vale of St. Albans and has been correlated by Gibbard (1979) with the Dartford Heath Gravel, part of the highest level terrace of the Lower Thames. The age of the Dartford Heath Gravel continues to be the subject of long-standing controversy (Hinton and Kennard 1905; Chandler and Leach 1911, 1912a; Smith and Dewey 1914; Dewey *et al.* 1924; Zeuner 1945; White *et al.* 1995) since it has implications for the dating of the rest of the terrace sequence in the Lower Thames.

The correlation of Gibbard is notably in conflict with the views of Bridgland (1994, 1995), who believes that the Dartford Heath Gravel is part of the Boyn Hill Orsett Heath Gravel formation. In support of his claim, Bridgland cites the steep downstream profile of the Black Park Gravel (probably the result of rapid downcutting by the newly diverted

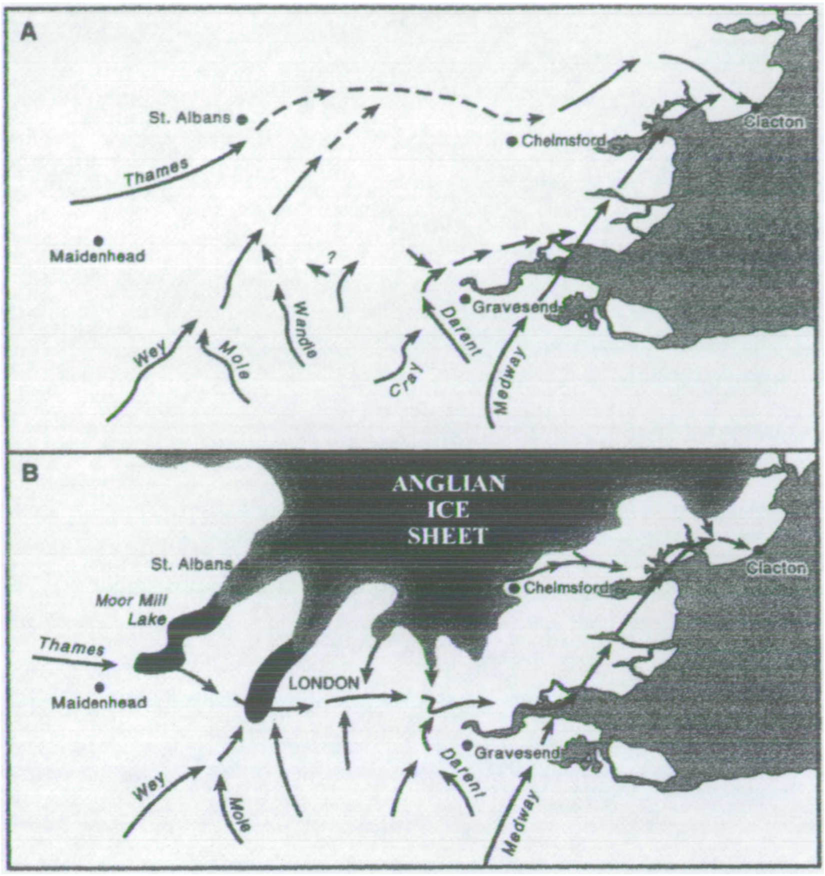


Figure 2.7 Diagram of the courses of the Thames and its tributaries immediately prior to (A) and immediately after (B) the glacial diversion of the river during the Anglian (from Bridgland 1995, after Bridgland and D'Olier 1995).

Thames), which appears to fall below the level of the Boyn Hill Gravel before reaching Dartford (Evans 1971; Bridgland 1994). The Black Park Terrace continuation is therefore not visible in the Lower Thames although it may well be represented within channel deposits that underlie the Boyn Hill aggradation. Additionally, the low altitude of the Hornchurch Till, which overlies London Clay at 25m O.D., also places the Black Park - Dartford Heath correlation in doubt, since it suggests that the valley system there had already been excavated to over 12m below the supposed Black Park base level at Dartford by late Anglian times (Bridgland *ibid*; Whiteman and Bridgland 1995), whilst the recorded thickness of the Dartford Heath Gravel itself implies a single aggradation up to 20m thick (Bridgland 1994). Although the upper surface height of the Dartford Heath Gravel, at 42m O.D., is approximately 8m higher than Swanscombe, it is possible that the Dartford Heath spread has preserved its original upper surface by way of its protected position in the apex of a former bend in the river's course (Bridgland 1995). Furthermore, the reports by Dewey *et al.* (1924) and Dewey (1959) of buried channels beneath Dartford Heath Gravel, cut to the base level of the Swanscombe Lower Gravel, would also suggest that that the Dartford Heath Gravel is part of the same aggradation as the upper part of the sequence at Swanscombe.

The most recent comprehensive schemes covering the Lower Thames area were presented by Bridgland (1994) and Gibbard (1994), but differ considerably in their interpretation of many of the key sites under consideration here. The Bridgland terrace model is preferred here to that of Gibbard (1985, 1994) since it is based primarily on terrace stratigraphy and the long-profiling of gravel formations. The model for terrace succession as proposed by Bridgland (1988, 1994) expands the original tripartite sequence (Boyn Hill, Taplow and Floodplain terraces) established by the Geological Society (Dewey *et al.* 1924) and recognises four major post-Anglian gravel formations in the Lower Thames: the Orsett Heath (Boyn Hill) Gravel, the Corbets Tey Gravel, the Mucking Gravel and beneath the alluvium of the modern floodplain, the East Tilbury Marshes Gravel.

Preserved within these cold-climate gravel aggradations are interglacial sediments indicative of four separate temperate episodes between the Anglian and the Devensian and correlated with Stages 11, 9, 7 and 5e of the oxygen isotope record. Two additional full interglacials are therefore recognised between the conventional Hoxnian (represented at Swanscombe) and Ipswichian (represented at Trafalgar Square) Stages. This corresponds well with the four post-Anglian interglacial groupings defined by Bowen *et al.* (1989) on the basis of amino acid ratios and confirms the likely position of the Anglian in isotope Stage 12. An idealised transverse section through the Lower Thames terraces as defined in the Bridgland model is shown below in Figure 2.8.

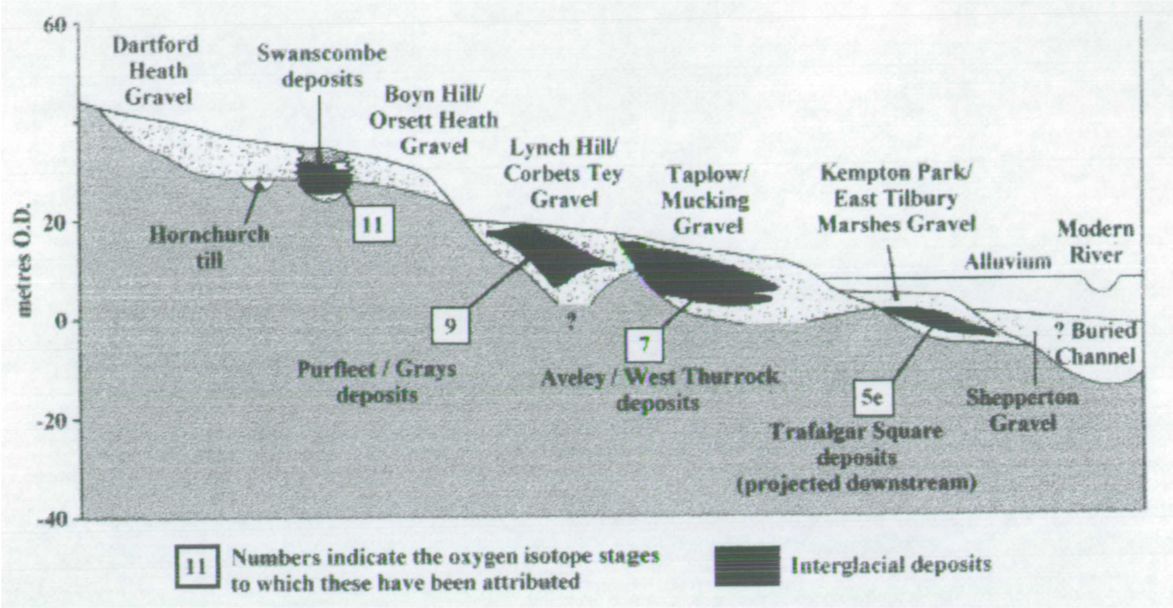


Figure 2.8 Transverse section through the terraces of the Lower Thames (modified from Bridgland 1994).

Further support for the Bridgland model has also come from recent studies of the terraces in the Avon (Bridgland *et al.* 1989; Whitehead 1989a, b; Maddy *et al.* 1991; de Rouffignac *et al.* 1995) and Severn valleys (Bridgland *et al.* 1986; Maddy *et al.* 1995), which have provided similar corroborative evidence for four post-Anglian interglacials (Figure 2.9).

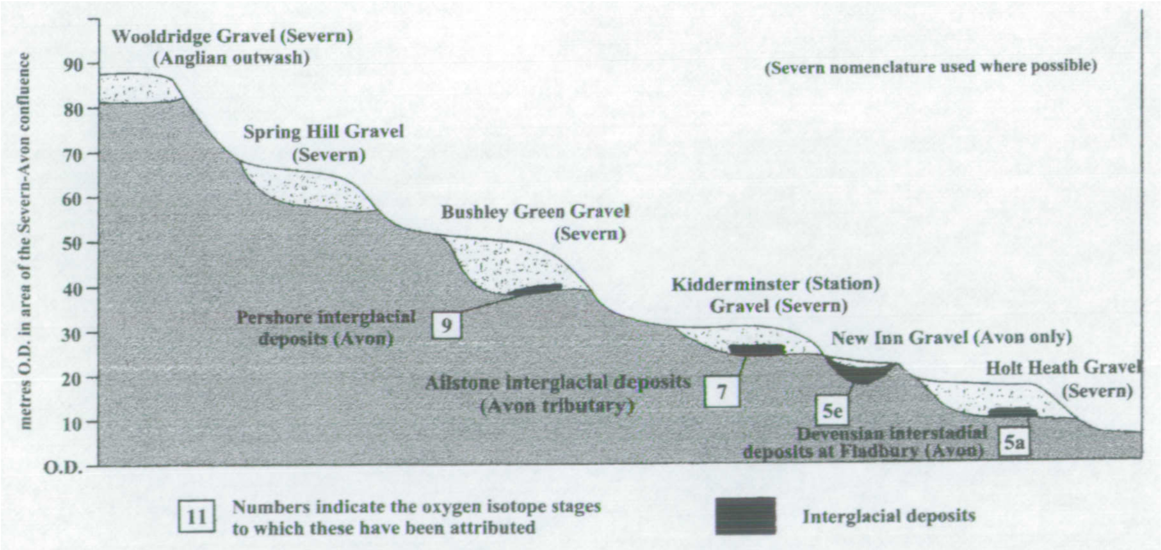
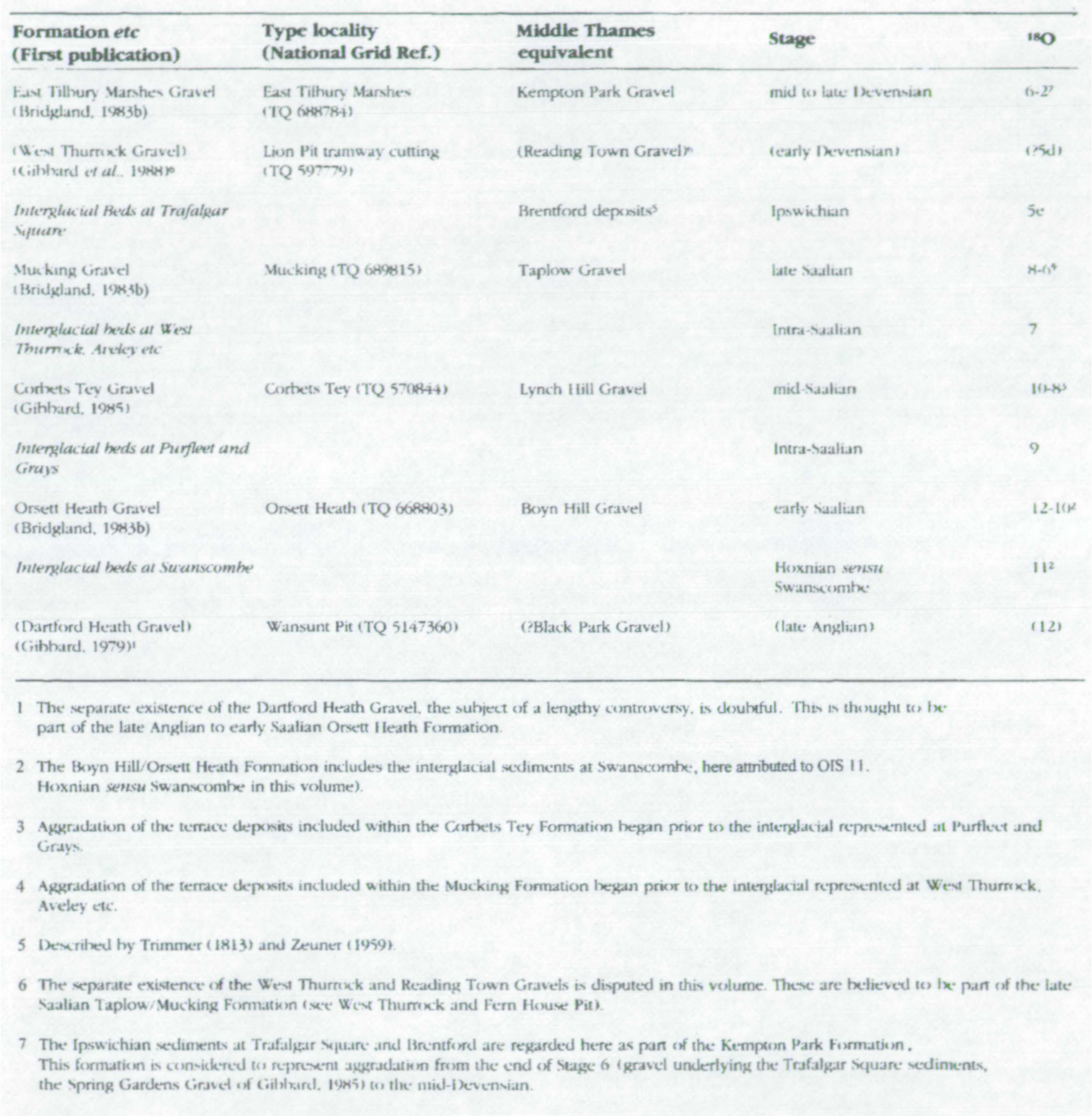


Figure 2.9 Transverse section through the terraces of the Warwickshire/Worcestershire Avon (courtesy of D. Maddy/D.R. Bridgland).

Table 2.3 outlines the lithostratigraphic formations used by Bridgland in the Lower Thames with proposed correlations with the Middle Thames sequence, Pleistocene stages and oxygen isotope stages.



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

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

2 The Boyn Hill/Orsett Heath Formation includes the interglacial sediments at Swanscombe, here attributed to OIS 11. Hoxnian *sensu* Swanscombe in this volume).

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

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

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

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

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

Table 2.3 The Pleistocene fluvial sequence in the Lower Thames, with proposed correlation with the Middle Thames sequence, Pleistocene stages and oxygen isotope stages (modified from Bridgland 1994).

Gibbard's scheme, on the other hand, favours biostratigraphical correlations based upon palynological evidence and continues to adhere closely to the stratigraphic template of Mitchell *et al.* (1973). Gibbard (1994) recognises fourteen distinct post-Anglian lithostratigraphic divisions in the Lower Thames (summarised below in Table 1.4), including two further gravel spreads: the Black Park Gravel and the West Thurrock Gravel (interpreted as part of the Orsett Heath Gravel and the Mucking Gravel respectively by Bridgland 1994).

Event	Dating evidence	Climate	Stage
Aggradation of Tilbury Deposits	C14	t	Flandrian
Deposition of Shepperton Gravel and tributary valley floodplain gravel (c. 15 000-10 000 BP)	C14	c	Late
Downcutting (c. 30 000 15 000 BP)			
Deposition of main mass of Langley Silts			
Deposition of East Tilbury Marshes Gravel and tributary equivalents (?c. 45 000-30 000 BP)	C14	c-t-c	Middle Devensian
Downcutting			
Deposition of West Thurrock Gravel		c	?early
Downcutting			
Deposition of Aveley Silts and Sands and equivalents	p, v	t	Ipswichian
Deposition of Spring Gardens Gravel		?c in part	
Downcutting			
Deposition of Mucking Gravel		c	
Downcutting			
Deposition of Corbets Tey Gravel		c	Wolstonian
Downcutting			
Deposition of Orsett Heath Gravel		c	
Downcutting			
Deposition of Swanscombe Middle Gravel	m,v	t-c	
Deposition of Swanscombe Lower Loam	m,v	t	Hoxnian
Deposition of Swanscombe Lower Gravel	m,v	t-c	
Downcutting			
Deposition of Dartford Heath Gravel		gl,c	late
Initiation of Lower Thames Valley and Glaciation		gl,c	Anglian
Deposition of Woodford Green Gravel and equivalents		c	?early
Downcutting			
Deposition of Buckhurst Hill Gravel and equivalents		c	
Downcutting			
Deposition of Debden Green Gravel and equivalents			pre-Anglian
Downcutting			
Deposition of High Beach Gravel and Equivalents			

C14, radiocarbon dating; v, vertebrate remains, p, pollen; m, Mollusca; t, temperate; c,cold; a, aeolian activity; gl, glacial. The stage subdivisions follow Mitchell *et al* (1973) and Gibbard & Turner (1990).

Table 2.4 Sequence of events in the Lower Thames, with evidence of dating methods and inferred climate (modified from Gibbard 1995b).

The dangers of over-reliance on correlations based upon limited and frequently poorly-preserved palynological evidence are particularly well illustrated in Gibbard's 'Aveley Silts and Sands Member', a unit which not only occurs at a variety of altitudes but also incorporates interglacial deposits that Bridgland (1994) recognises as belonging to three separate terraces. Gibbard is therefore forced to invoke the action of tributaries such as the Mar Dyke in order explain repetition of the same climatic sequence in different terraces, since the Thames cannot have flowed at different floodplain levels at the same time. As will be demonstrated in later chapters, Gibbard (1994) attributes a range of sites in the 'Aveley Silts and Sands Member' to the Ipswichian, contrary to a wealth of other evidence from fossil mammals, molluscs, archaeology and amino acid geochronology, all of which suggest older ages.

2.9. Conclusions

The scene has now been set for the development of a new British chronological scheme. Biostratigraphic information from fossil mammals will therefore be tested not only against the various models proposed by lithostratigraphy, the oxygen isotope record and amino acid geochronology but also against other biostratigraphic schemes relating to both floral and other faunal groups.

CHAPTER 3. TAXONOMY AND IDENTIFICATION

3.1. Introduction

This chapter outlines some of the principal taxonomic and identification criteria for each of the mammalian species encountered in this study. Information concerning the stratigraphic range and the environmental or climatic preferences of each species is also provided. In the case of extinct species, deductions as to their approximate preferred habitat have been made only where the anatomy of the species concerned permits sensible conclusions to be reached. With regard to extant species, details of preferred habitat(s) at the present day are given, although the relatively broad environmental tolerances of many modern mammals dictate that only some of the more commonly-inhabited environments are listed.

N.B. Where comments on dental morphology are made, lower case letters have been used to denote lower teeth, whilst upper case letters indicate upper teeth.

3.2. Insectivora

INSECTIVORA Bowdich, 1821

Erinaceidae Bonaparte, 1838
Erinaceus europaeus L., 1758, hedgehog

Records of hedgehog are extremely rare in British Pleistocene deposits and are restricted to interglacial occurrences. In deposits of early Middle Pleistocene age, *Erinaceus* cf. *europaeus* and *Erinaceus* sp. have been recorded from West Runton, Norfolk and Westbury-sub-Mendip, Somerset respectively (Stuart 1996; Bishop 1982) but the fragmentary nature of remains usually renders identification to species level difficult. The only British late Middle Pleistocene record *E. europaeus* is from the Otter Stratum in Tornewton Cave, Devon (6.21). The teeth of the living *E. europaeus* are heavy and blunt in aspect, reflecting an omnivorous rather than strictly insectivorous diet. The P4 is particularly large with a well-developed protocone, hypocone and metacone. The substantial p4 has a high anterior three-cusped part, similar to the first triangle of the lower molars (Miller 1912). The postcranial skeleton is much larger and more robust than that of other insectivores known from the British Pleistocene but is less specialised. Characters for the identification of the long bones are given by Chaline (1966). In particular, the curved diaphysis of the femur and the fusion of the fibula to the midpoint of the tibial diaphysis are distinctive. *E. europaeus* is distributed throughout the deciduous and Mediterranean zones of western Europe and northern Russia at the present day. It is most abundant in areas of lowland grassland with adjacent deciduous woodland, hedgerows or scrub (Corbet and Harris 1991).

Soricidae Gray, 1821
Sorex araneus L., 1758, common shrew

The presence or absence of pigmentation in the teeth of the Soricidae is an important diagnostic character, although this may not always be visible in fossil material. The teeth of the genus *Sorex* are red-tipped due to the deposition of iron in the outer layer of enamel. This is thought to increase resistance to abrasion or to maintain sharp cutting edges on the teeth, through differential rates of wear between the harder red enamel and the softer white enamel (Vogel 1984). In *S. araneus*, the upper incisor is hook-shaped and five upper unicuspid teeth are present, which decrease evenly in size from front to back. The lower incisor is tricuspulate. In the mandible, the mental foramen is situated below the trigonid of the m1. The morphology of the mandibular condyle and height of the ramus are also significant diagnostic features (Figure 3.1). Further characters for the identification of the dentition, skull and postcranial skeleton are given in Chaline (1974). The earliest occurrence of this species in Britain is hard to ascertain, since specific determination is often difficult but probable records extend back to at least the late Cromerian at Waverley Wood, Warwickshire (Shotton *et al.* 1993). The common shrew is today found in a wide range of habitats, wherever low vegetation cover is afforded. It is most abundant in thick grass, bushy scrub and deciduous woodland (Corbet and Harris 1991) and is distributed throughout the whole of Europe (except for the Mediterranean region), although it is replaced in Jersey, most of France and Switzerland by the closely-related and almost identical French shrew, *S. coronatus* (Millet) (Churchfield 1988).

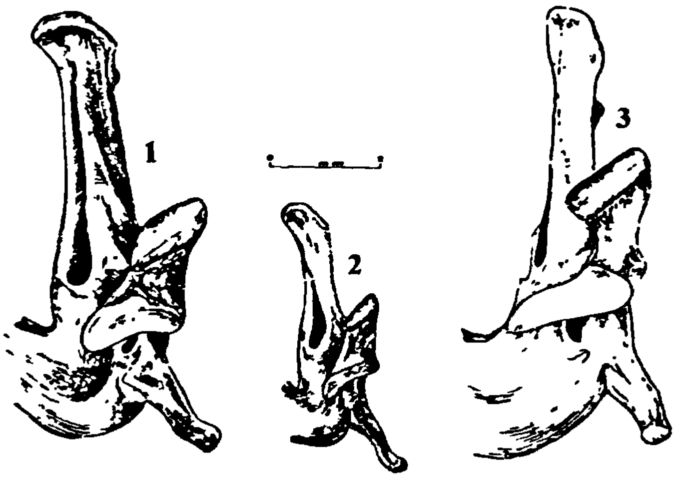


Figure 3.1 Comparison of mandibular condyles of (1) *Sorex araneus*, (2) *Sorex minutus* and (3) *Neomys fodiens* (modified from Chaline 1966).

Sorex minutus L., 1766, pygmy shrew

The pygmy shrew is the smallest native British shrew and can be easily distinguished on the basis of size alone. It possesses the red-stained teeth seen in *S. araneus* and also has the same arrangement of five upper unicuspid teeth, although in contrast to *S. araneus*, the third unicuspid is larger than or as large as the second. The morphology of the mandible is also a diagnostic character (Figure 3.1). *S. minutus* has a relatively long fossil history, appearing sporadically since the Early Pleistocene onwards, apparently remaining very conservative in size and morphology (Bishop 1982). In the British early Middle Pleistocene, it has been recorded from the Freshwater Bed at West Runton (Stuart 1996) and from Westbury-sub-Mendip (Bishop 1982) and is a regular component of interglacial assemblages in most late Middle Pleistocene sites. At the present day, *S. minutus* is widespread throughout Europe and is the only soricid to have successfully reached Ireland (Matthews 1960). The preferred habitat is grassland, although woodland and other habitats where there is good ground cover are also readily occupied (Corbet and Harris 1991).

Neomys fodiens (Pennant), 1771, water shrew

The water shrew is larger than the common shrew but possesses the same red-tipped teeth. *Neomys* has only four upper unicuspid teeth (as opposed to five in *Sorex*) and the lower incisor has a smooth upper surface, retaining a single, poorly-defined denticle. The first upper incisors are large with very long, curved anterior cusps, whilst the posterior cusps are shorter than in other species (Corbet and Harris 1991). The ascending mandibular ramus is characteristically sturdy and the articulation slender (Stuart 1982) (Figure 3.1). *N. fodiens* represents the largest of the British Pleistocene water shrews (Hinton 1911). Hinton (*ibid.*) does not consider this species to be present until the Late Pleistocene, referring earlier occurrences to either *N. newtoni* Hinton in the early Middle Pleistocene or to *N. browni* Hinton in the late Middle Pleistocene. *N. fodiens* is present throughout mainland Britain at the present day, preferring clear, fast-flowing rivers and streams although they may also be found in ponds. Sporadic occurrences up to three kilometres from water have been reported in deciduous woodland, hedgerows and grassland (Corbet and Harris 1991).

Neomys browni Hinton, 1911, extinct water shrew

Hinton (1911) first described *N. browni* from Grays, Essex (5.2), which is the only published locality to have yielded this species. The mandible is slightly smaller than that of *N. fodiens* and the coronoid process is low and broad. The condyle is small but the superior facet is very broad. The teeth (which are red-tipped) are slightly larger than in *N. fodiens*, with a strongly developed cingulum (Hinton *ibid*). *N. browni* probably represents a transitional form between the small early Middle Pleistocene water shrew, *N. newtoni* and the larger, modern species *N. fodiens* and may therefore be a useful biostratigraphic marker (Figure 3.2, Tables 3.1 and 3.2). Whether it indeed represents a legitimate, distinct species is open to question, since its identification is based principally on size.

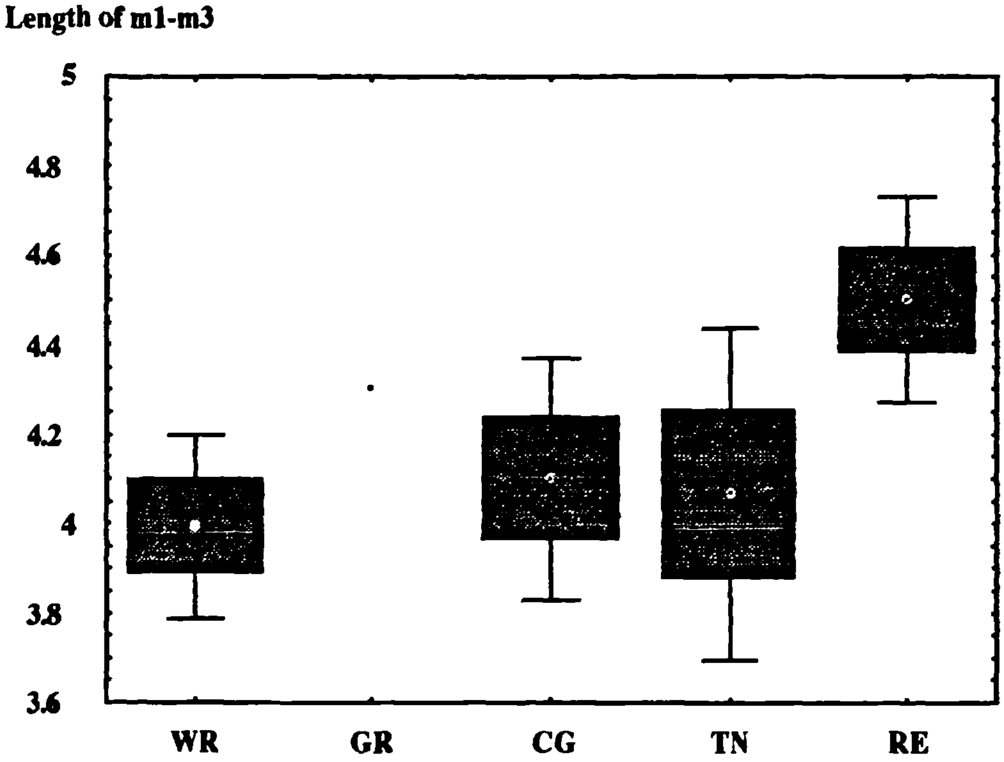


Figure 3.2 Plot of lower m1-m3 lengths of *Neomys* from selected localities. For each sample, the plot shows mean ± 2 standard deviations. Key: WR = West Runton (Cromerian), GR = Grays (OIS 9), CG = Cudmore Grove (OIS 9), TN = Tornewton Cave Otter Stratum (OIS 7), RE = Recent. See Table 3.1 for data.

SITE	N	MIN (mm)	MAX (mm)	MEAN (mm)	SE	SD
WR	8	3.8	4.1	3.99	0.037	0.105
GR	1	4.3	4.3	4.3	-	-
CG	9	3.9	4.3	4.1	0.046	0.137
TN	3	3.85	4.2	4.07	0.109	0.189
RE	5	4.35	4.6	4.5	0.052	0.117

Table 3.1 Measurements of m1-m3 length in *Neomys* from selected localities (see Figure 3.2 for key).

	WR	GR	CG	TN	RE
WR	-	-	-	-	-
GR	-	-	-	-	-
CG	t - 0.178 df - 15 p = 0.1	-	-	-	-
TN	-	-	t 0.336 df = 10 p = 0.74	-	-
RE	t = 8.1 df = 11 p = ***	-	t = 5.49 df - 12 p = ***	t = 4.08 df 6 p = **	-

Table 3.2 t-test on *Neomys* data from selected localities. See Figure 3.2 for key.

no statistical significance = $p > 0.05$
* = $p < 0.05$
** = $p < 0.01$
*** = $p < 0.001$

Figure 3.2 above shows the increase in size from the Cromerian *Neomys newtoni* to Recent *Neomys fodiens*. Water shrews from the late Middle Pleistocene localities of Grays (5.2), Cudmore Grove (5.3), Essex and Tornewton Cave (Otter Stratum) (6.21) occupy an intermediate position, differing most significantly from Recent populations. No significant difference is apparent between *Neomys* from deposits attributed to Stage 9 (Grays and Cudmore Grove) and deposits attributed to Stage 7 (Tornewton Cave Otter Stratum).

Crocidura leucodon, Hermann, 1780, bicoloured white-toothed shrew

The crocidurine shrews are a rare element of the British late Middle Pleistocene fauna and their appearance in the fossil record is of great biostratigraphic significance. Their taxonomy is extremely complex and the modern species may sometimes only be separable on the basis of pelage colour (Jenkins 1976). They are distinguished from the other Pleistocene soricids by the absence of red-brown pigmentation in the enamel of the crowns of the teeth and by the possession of only three upper unicuspid teeth and an acuspulate lower incisor. The posterior lobe of the upper incisor is noticeably less than half the height of the main cusp (Miller 1912) and in the m3, the talonid is greatly reduced and the hypoconid and entoconid have coalesced, so that the crown is 4-cusped, instead of 5-cusped as in *Sorex* and *Neomys*. In comparison to other soricids, the teeth of *Crocidura* are relatively large in proportion to the jaw (Stuart 1982). The morphology of the P4 and of the mandibular condyle are also important characters in the separation of the various crocidurine species (Figure 3.3). In the three species referred to here, the mental foramen is situated below the area between the paraconid and the protoconid of the m1. White-toothed shrews are absent from the British mainland at the present day, although *C. russula* Hermann and *C. suaveolens* (Pallas) occur in the Channel Islands and the Scilly Isles. While the European mainland populations are relatively homogenous, considerable variation is shown in the island populations (Jenkins 1976), making identification difficult. The predominantly southern distribution of *Crocidura* at the present day suggests that its presence in Britain during the later Middle Pleistocene might be indicative of warmer conditions than at the present day. *Crocidura* was apparently absent from both the Hoxnian and Ipswichian Interglacials (Currant 1989b) but is present in deposits now thought to represent additional interglacials in the British sequence (Bridgland 1994), such as the Essex localities of Purfleet (5.1), Grays (5.2), Cudmore Grove (5.3) and Aveley (6.1). It also occurs at Itteringham, Norfolk (Currant *ibid*) (6.3) and in the Otter Stratum in Tornewton Cave (Rzebik 1968) (6.21, Figure 6.48)

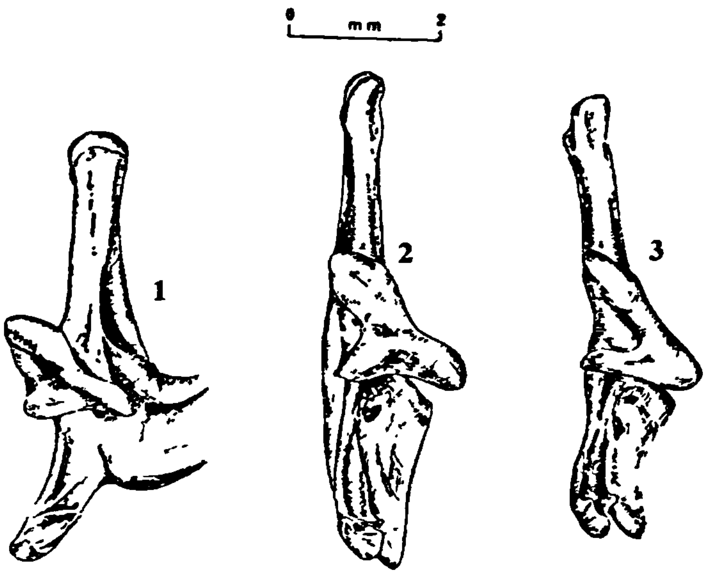


Figure 3.3 Comparison of mandibular condyles of (1) *Crocidura leucodon*, (2) *Crocidura russula* and (3) *Crocidura suaveolens* (modified from Chaline 1966).

Crocidura leucodon is today distributed throughout much of western and central Europe, although it is absent from the British Isles and Scandinavia (Brown *et al.* 1992). It is thought to have invaded Europe from the Near East for the first time after the Weichselian (Catzeflis 1984). *C. leucodon* may be separated from *C. russula* (the only species with which it is likely to be confused) by the morphology of the P4. In *C. leucodon*, the P4 has a higher cutting edge, a more prominent cingulum and a better-developed paracone, which is larger than the preceding third unicuspid (Miller 1912). Where the height of the paracone relative to the preceding third unicuspid cannot be measured (for example through wear), the height of the paracone in relation to maximum tooth length still permits separation of *C. leucodon* from *C. russula*. The preferred habitat of this species is dry ground, hedgerows and woodland margins (Chaline 1966).

Crocidura russula Hermann, 1780, greater white-toothed shrew

Crocidura russula is the largest of the three white-toothed shrews described here. Three unpigmented upper unicuspids are present, the second of which is only slightly smaller than the third (Corbet and Harris 1991). The morphology of the P4 is of particular specific importance. The antero-external cusp of the paracone of the P4 in *C. russula* is clearly separated from the metacone and it is smaller in size than the preceding third unicuspid. Fossil remains attributed to this species have been found in Tornewton Cave (Catzeflis *et al.* 1985) (6.21). In the British Isles at the present day, it is found only on the Channel Islands of Guernsey, Alderney and Herm (where it is probably a human introduction), although it is widespread in south-west Europe (Corbet and Harris 1991). *C. russula* is fairly common in woodland, hedgerow and grassland habitats at the present day.

Crocidura suavolens (Pallas, 1811), lesser white-toothed shrew. Synonym: *Crocidura cassiteridum* Hinton 1924

Crocidura suaveolens is the smallest of the three white-toothed shrews mentioned here. It possesses three upper unicuspid teeth, the second of which is markedly smaller than the third. As with the other European species of *Crocidura*, the morphology of the P4 is an important identification character. Today, this species is present across much of southern and central Europe, although it is confined to the western coasts of France, Spain and Portugal. In Britain, it is found only on Jersey and Sark in the Channel Islands and on all but the smallest of the Scilly Isles. Although it has been suggested that this shrew may be a glacial relict on these islands, they are more likely to have been introduced (probably accidentally) by traders from France or northern Spain during the Iron Age or possibly earlier (Churchfield 1988). *C. suaveolens* is found in most habitats that afford adequate cover, particularly in bracken stands, woodlands and hedgerows. On the Scilly Isles, this species is found amongst boulders and coastal vegetation, whilst on Jersey, it frequently occurs in sand dune, scrub or heathland zones (Corbet and Harris 1991).

Talpidae Gray, 1821

Desmana moschata L., 1758, Russian desman

The dentition of the talpids approaches the basic mammalian pattern more closely than that of the other insectivores, with three small incisors, a canine, four premolars and three molars in each side of the upper and lower jaw. In the upper jaw, the canine is very large and of the four unicuspid premolars, the fourth is much the largest. In the lower jaw, the canine is very small and it is the caniniform anterior premolar which is the most enlarged. The dentition of *Desmana* follows this general pattern, although it is larger than in *Talpa* and shows a particular degree of modification in the incisors, those on the premaxillae being reduced to one caniniform tooth on either side (Stuart 1982). In the upper molars, the mesostyle is divided into two separate cusps, producing two 'V'-shaped figures in occlusal view (Schreuder 1940) in contrast to the 'W' shape in other talpids (Miller 1912). A strong cingulum runs along the anterior and posterior side of the M1 and M2, distinguishing them from the upper dentition of the Pyrenean desman, *Galemys pyrenaicus* (Geoffroy) (Schreuder 1940). The lower molars are distinct in that the cristid obliqua of the hypoconid almost meets the (unworn) metaconid, whereas in other Talpidae, it ends low against the protocristid (Schreuder *ibid*). The mandible is also distinct from *Talpa* in its relatively flat undersurface (Figure 3.4).

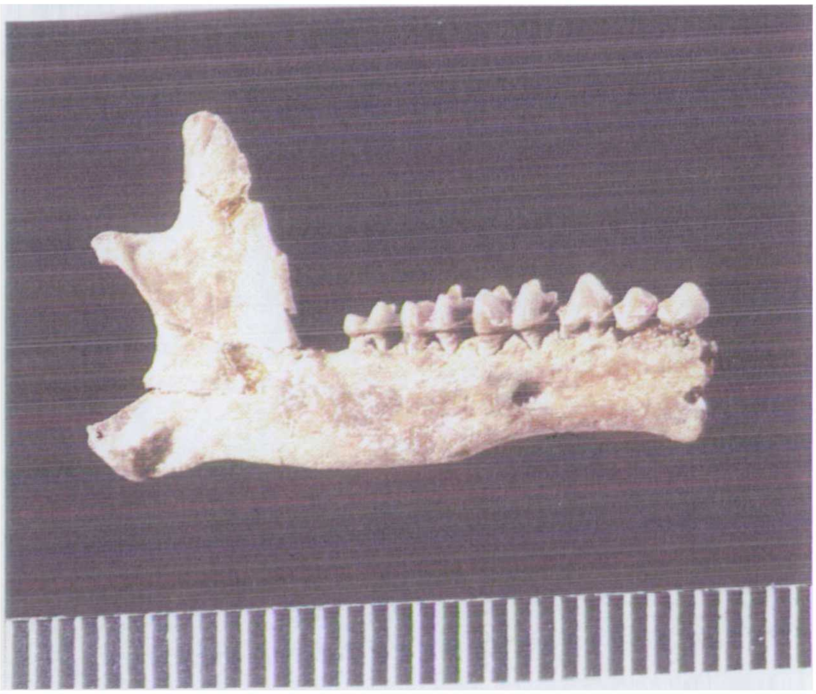


Figure 3.4 Right dentary with p2-m3 *in situ* of *Desmana moschata* (M6147, N.H.M.L.), West Runton (buccal view, scale in mm).

The postcranial skeleton is generally mole-like but shows modifications for an aquatic lifestyle, such as elongated hind feet and laterally flattened vertebrae. The caudal vertebrae are hexagonal in cross-section and are flanked by H-shaped chevron bones (Stuart 1982). The humerus and clavicle are noticeably robust to assist burrowing and nest-building in the banks of rivers and ponds (Schreuder 1940). The earliest record of desman in Britain is from the Pastonian Crag at West Runton, Norfolk, which has been referred to as a yet unnamed species, also found in the Tiglian Tc5 of Tegelen in the Netherlands (Freudenthal *et al.* 1976). Cromerian material from the Forest Bed has been assigned by Schreuder (1940) to *D. moschata magna*, a slightly smaller subspecies than either the recent *D. moschata* or the Mosbach form *D. moschata mosbachensis*. Bishop (1982) attributes the desman from Westbury-sub-Mendip to *D. moschata*, describing it as intermediate in size and morphology between the recent species and that from West Runton. Desman is an extremely rare component of British later Middle Pleistocene mammalian assemblages and is recorded only from Hoxne (Singer *et al.* 1993) (4.1) and from Barnham (P. Schreve pers. comm.) (4.5), both in Suffolk. Examination of the material from Hoxne reveals that it is comparable in both size and morphology to the living *D. moschata*, being considerably larger than the subspecies from West Runton (Stuart 1975, 1981; Stuart, in Singer *et al.* 1993,). Today, *D. moschata* inhabits the rivers of south-eastern Russia, such as the Ural, the Volga and the Don, never venturing far from water. The major cause of mortality is catastrophic high flooding at the end of winter, when its nest becomes inundated (Schreuder 1940).

Talpa europaea L., 1758, common mole

The postcranial skeleton (and in particular, the forelimb) of the mole is specialised for a fossorial way of life. The much-enlarged 'figure-of-eight' shape humerus is highly characteristic and easily recognised. The sternum is also enlarged into a keel, which provides extended attachment for the muscles used in burrowing. Although *T. europaea* is clearly larger than the extinct small mole *T. minor* (Freudenberg, 1914) (Figure 3.5), it has apparently experienced a progressive increase in size throughout the Early and Middle Pleistocene, irrespective of the marked sexual dimorphism shown by both species. Early Pleistocene mole material has frequently been attributed to *T. fossilis* Petenyi, a form morphologically similar to *T. europaea* but intermediate between it and *T. minor* in size (Bishop 1982). *T. europaea* material described from West Runton by Stuart (1975) is particularly small and has consequently been referred to *T. fossilis*, while the *T. europaea* from the later Cromerian Complex site of Westbury-sub-Mendip is much larger and approaches the modern species in size (Bishop 1982). *T. europaea* is today distributed throughout mainland Britain and most of continental Europe, mostly favouring deciduous woodland but generally present wherever the soil is deep enough to permit tunnel construction and the ground is not subject to permanent or seasonal freezing (Corbet and Harris 1991; Stuart 1982). It is notably absent from the modern Irish mammal fauna, presumably because it failed to colonise prior to the Holocene rise in sea-level.

Talpa minor (Freudenberg, 1914), extinct small mole

Talpa minor has been recognised in several British early Middle Pleistocene assemblages, including Sugworth, Oxfordshire (Stuart 1980), Westbury-sub-Mendip (Bishop 1982) and Boxgrove, West Sussex (personal observation). The latest known occurrence of this species is in sites of Hoxnian age, such as Swanscombe, Kent (Schreve 1996) (4.2) and Barnham (Ashton *et al.* 1994b) (4.5) *T minor* is presumed to have shared a similar ecology and co-existed with the larger species, *T. europaea* throughout the earlier part of the Middle Pleistocene. The dentition and skeleton are constructed on the same plan as *Talpa* but are very much smaller in size (Figure 3.5).

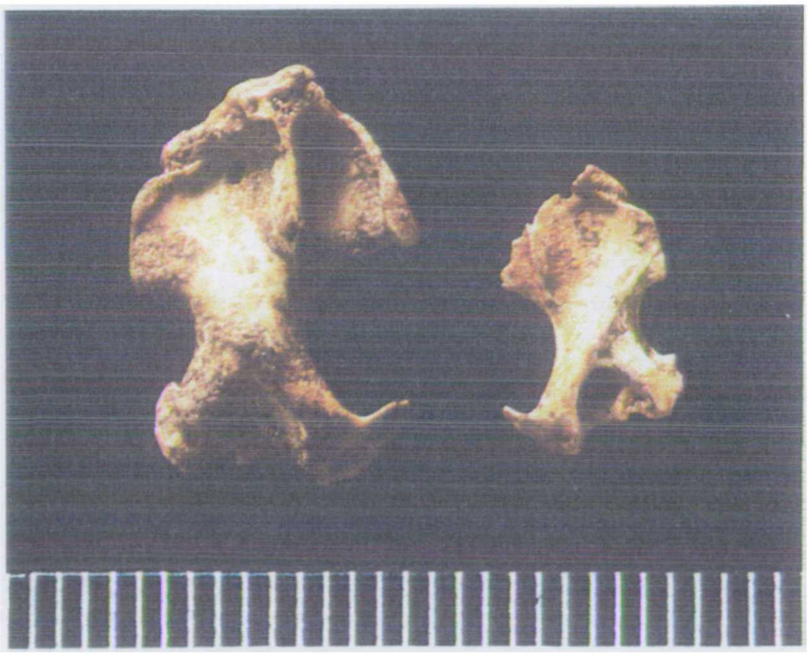


Figure 3.5 Comparison of humeri of *Talpa europaea* (left) and *Talpa minor* (right) (N.H.M.L), Westbury-sub-Mendip (posterior view, scale in mm).

3.3. Chiroptera

CHIROPTERA Blumenbach, 1779

Vespertilionidae Gray, 1821

Eptesicus serotinus (Schreber, 1774), serotine bat

Fossil bats are rather rare in the British Pleistocene record. As one would expect, cave sites are more likely to contain bat remains and an assemblage from the early Middle Pleistocene cave site of Westbury-sub-Mendip has yielded six species (Currant 1989a). However, bats are also occasionally known from open sites. An upper second molar of *E. serotinus* has been recovered from the later Middle Pleistocene site of Cudmore Grove (Currant *ibid*) (5.3) and bat remains are also known from Purfleet (Bridgland *et al.* 1995) (5.1). The postcranial skeleton displays the characteristic modifications associated with flight, namely a strong clavicle, a well-developed sternal keel for attaching the enlarged pectoral muscles, an elongated radius, fused wrist bones and greatly elongated fingers (excepting the first finger which possesses a strong claw for gripping and therefore has no part in supporting the wing membrane). The hindlimbs are greatly reduced, whilst the head of the femur has become modified to allow the knee to bend in the opposite direction to most mammals (Matthews 1960). The serotine is a relatively large, robust bat. It possesses only two upper incisors and relatively large canines. The anterior premolar is absent from the upper jaw and greatly reduced in the lower, while the molar teeth are very similar to those of the soricids, as a function of their common insectivorous diet. The M3 is much reduced. The serotine today occurs mainly in lowland open flat country and woodland edge or hedgerow across most of the Palaearctic (Corbet and Harris 1991). Although roosts are now frequently found in older buildings, caves and tree hollows are also occupied.

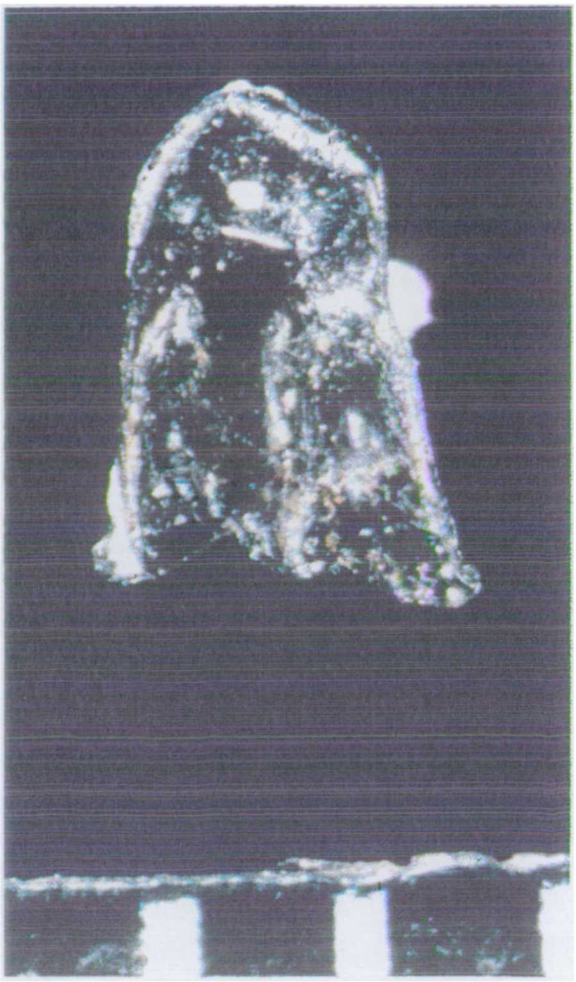


Figure 3.6 Left M2 of *Eptesicus serotinus* (N.H M L.), Cudmore Grove (occlusal view, scale in mm).

Barbastella barbastellus (Schreber, 1774), barbastelle bat

The barbastelle bat is today distributed across most of central and southern Europe, extending as far west as northern England (Corbet and Harris 1991). A single record from the later Middle Pleistocene in Britain has come from interglacial deposits at Aveley (Bridgland *et al.* 1995c; Bridgland and Foreman 1996) (6 1) (Figure 3.7). The description is as for the serotine bat (above), although the teeth are relatively smaller and more slender and an anterior upper premolar is present, although extremely small (Miller 1912). At the present day, the barbastelle prefers wooded river valley habitats and roosts in hollow trees or caves during very cold weather (Corbet and Harris 1991)

Figure 3.7 Upper molar of *Barbastella barbastellus* (N.H.M.L.), Aveley (occlusal view, scale in mm).

3.4. Primates

PRIMATES L., 1758

Cercopithecidae Gray, 1821
Macaca sylvanus (L., 1758), Barbary macaque

The teeth are rooted and unspecialised in aspect, reflecting a generalised diet. The crowns of the cheek teeth show a fairly simple pattern of low, blunt cusps and cement is absent from the crowns but is present on the roots (Figure 3.8). The incisors are small and spatulate but the canines are relatively large (particularly in the male), high-pointed teeth with subconical crowns and a deep longitudinal groove. The three molars are squarish in shape and have 4-5 cusps. Both the m3 and M3 are smaller than the anterior molars. The postcranial skeleton is very similar to humans but much smaller. The first phalanges are distinctive, in that they bear a small ridge on the posterior surface which holds the tendons in place during climbing. A unique characteristic in the modern species is the absence of a tail, as in the true apes, although the fossils give no information on this trait in the Pleistocene form (Kurtén 1968). The earliest British record of *Macaca* is from the 'Monkey gravel' of West Runton, a thin gravel which overlies the West Runton (Hinton 1908). Further remains have been recorded from the West Runton Freshwater Bed itself (Stuart 1996), Hoxne (Singer *et al.* 1993) (4.1), Swanscombe (Schreve 1996) (4.2), Purfleet (5.1) (Figure 5.8), Grays (Hinton 1910b) (5.2) (Figure 3.8) and Cudmore Grove (Bridgland *et al.* 1988) (5.3). *M. sylvanus* does not however appear to have survived in Britain later than OIS 9. Today, *M. sylvanus* is found in the Atlas mountains of North Africa, although an introduced population thrives on Gibraltar. The preferred diet of the Barbary macaque is plant food, including berries, fruits, leaves and grains (Nowak 1991).

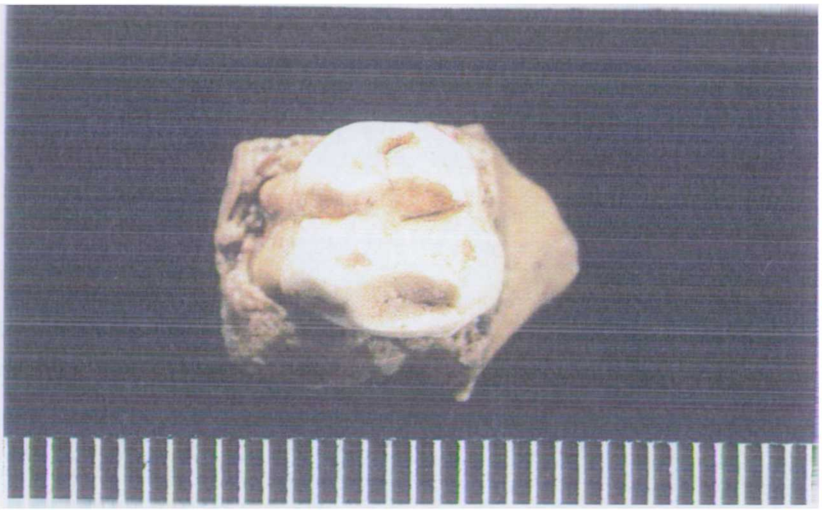


Figure 3.8 Molar of *Macaca sylvanus* (M1892, N.H.M.L.), Grays (occlusal view, scale in mm).

Hominidae Gray, 1825
Homo sp., hominid

Although artefacts and other evidence of human occupation are frequently encountered in Middle Pleistocene sites, the actual physical remains of the hominids themselves are extremely rare. British finds from the early Middle Pleistocene comprise a midshaft of a tibia and two teeth from Boxgrove, regarded as a more advanced form than *Homo erectus* and assigned to *Homo heidelbergensis* (Roberts *et al.* 1994; C.B. Stringer pers.

comm.). From the later Middle Pleistocene of Britain, hominid remains include a partial cranium from Swanscombe (Marston 1937; B.O. Wymer 1955) (4.2). The Swanscombe skull shows the development of early Neanderthal features and is classed as 'archaic' *Homo sapiens*. This may or may not be the ancestor of *H. sapiens sapiens* (cf. Stringer 1990 and Wolpoff 1989 for contrasting views). Numerous remains of fully fledged Neanderthals have been recovered from the cave site of Pontnewydd, Clwyd (Stringer 1984) (6.26). The human skull is specifically diagnostic. The incisors and canines are spatulate in form, while the premolars and molars are low-crowned, bunodont and relatively square in shape. The postcranial skeleton has become modified for upright posture: the femur is particularly straight, the tibia and fibula are unfused and the feet are adapted for plantigrade locomotion. Further characters for the identification of the postcranial skeleton are given in Genet-Varcin (1966) and Hillson (1992). Human colonisation of Europe can be reliably demonstrated only after *c.* 500 000 years b.p. (Roebroeks and van Kolfschoten 1994) at sites such as Mauer, Miesenheim I (both in Germany) and Boxgrove. Considerable debate has taken place over the preferred environment of the early hominids, in particular whether densely-forested habitats were occupied (Gamble 1986; Roebroeks *et al.* 1992).

3.5. Lagomorpha

LAGOMORPHA Brandt, 1855

The lagomorphs possess two pairs of upper incisors which distinguishes them from the rodents. The second pair are much smaller than the first and set behind, as opposed to alongside them. The cheek teeth are short and fairly broad with a characteristic pattern of transverse ridges, adapted for lateral and longitudinal grinding movements. Six rootless cheek teeth are present in the upper jaw and five in the lower jaw.

Ochotonidae Gray, 1821

Ochotona pusilla (Pallas, 1778), steppe pika

The steppe pika is smaller than both hares and rabbits, with much shorter hind legs and a typical lagomoph dentition. *O. pusilla* is a relatively rare element in the British

Middle Pleistocene fauna. It is recorded in the Cromerian Complex at Westbury-sub-Mendip (Stringer *et al.* 1996) but is present at only one late Middle Pleistocene locality, Pontnewydd Cave (6.25). It is more commonly encountered in the Late Devensian and a single record is also known from the early Flandrian (Stuart 1982). At the present day, the steppe pika is restricted to the central part of the Palaearctic steppe, where it lives in large colonies in extensive burrows. Its presence in Britain during the Pleistocene is therefore thought to reflect a continental, steppic component.

Leporidae Gray, 1821

Lepus europaeus Pallas, 1778, brown hare

The brown hare is the largest of the British lagomorphs and is distinguished from the mountain hare *Lepus timidus* (L., 1758) and the rabbit *Oryctolagus cuniculus* (L., 1758) by its large size and relatively long limbs. The skulls of both British hares can be separated from rabbit by the wider posterior nasal opening and the fusion of the interparietal and superoccipital (Corbet and Harris 1991). Koby (in Chaline 1966) cites minor differences in the anterior upper premolar and in the cross section of the incisors as diagnostic characters for the separation of *L. europaeus* from *L. timidus*. The postcranial skeleton is described and figured by Chaline (*ibid*). The Pleistocene history of *L. europaeus* is poorly known and the species may have been introduced to the British Isles by man during Holocene. Today, the brown hare is most abundant on arable land and in grass fields, where grazing is plentiful. Woodlands and hedgerows are used as resting areas during the day, particularly in winter (Corbet and Harris 1991).

Lepus timidus L., 1758, mountain hare

In *L. timidus*, the root of the upper incisor extends behind the suture of the premaxilla and maxilla, whereas in *L. europaeus*, it does not reach the suture (Corbet and Harris 1991). The postcranial skeleton is described and figured by Chaline (1966). The mountain hare is today distributed throughout the Palaearctic in tundra and boreal forest zones and in the British Isles, two indigenous subspecies are recognised which are subspecifically distinct from the Northern Eurasian *L. t. timidus*: *L. t. scoticus* in the Scottish Highlands and *L. t. hibernicus* in Ireland. In Scotland, the mountain hare feeds predominantly on heather (*Calluna vulgaris*) and grassland, always occupying higher ground than the brown hare (Corbet and Harris 1991).

Oryctolagus cuniculus (L., 1758), rabbit

Later Middle Pleistocene occurrences of *O. cuniculus* have so far been limited to the Hoxnian Interglacial, at Swanscombe (Stuart 1974; Schreve 1996) (4.2) and Barnham (Ashton *et al.* 1994b) (4.5). More recent finds, such as the specimen from the Mesolithic site at Thatcham in Berkshire (King 1962), have proved to be recent intrusions. Rabbit is apparently absent throughout the British later prehistoric and early historic periods, until its reintroduction by the Normans (Corbet and Harris 1991). The rabbit may be differentiated from the various species of hare on the basis of dental characters, such as differences in the lower anterior premolar (Chaline 1966) although postcranial elements are best distinguished by biometrical techniques (Stuart 1982). The skull of the rabbit has narrower nasal passages and a longer bony palate than in the hare and also shows a suture delimiting the interparietal bone, which is absent in hares (Corbet and Harris 1991). The rabbit's most common habitat is short grassland, with appropriate woodland, hedgerow or scrub cover in close proximity to feeding areas (Corbet and Harris *ibid*).

3.6. Rodentia

RODENTIA Bowdich, 1821

Sciuridae Gray, 1821
Sciurus vulgaris L., 1758, red squirrel

Remains of the red squirrel are frequently confused with those of the ground squirrels, since they are of similar size and morphology. Characters for the separation of *Sciurus* from *Citellus* are given by Chaline (1966). Of note is the reduction in size of the upper anterior premolars and the lower cusps of the cheek teeth in *Sciurus*, compared to *Citellus*. The dentition of the red squirrel is adapted for gnawing, with a single pair of continuously-growing, sharp incisor teeth in both the upper and lower jaws. The cheek teeth are rooted and low-crowned with low, rounded cusps on the margins, connected to each other by weak transverse ridges (Matthews 1960) (Figure 3.9).

Figure 3.9 Molar of *Sciurus vulgaris* (cast, M36625, N.H.M.L.), Belhus Park (occlusal view, scale in mm).

The posterior part of the skull is considerably more rounded than in *Citel us* but it is the postcranial skeleton which is most distinctive, since that of the red squirrel shows modifications for climbing. The hindlimbs are disproportionately long and heavy, with plantigrade feet, long toes and a well-developed tail for balance, thermoregulation and use as a signalling device (Corbet and Harris 1991). The earliest occurrence of squirrel in Britain is of *S. whitei* Hinton from the marine 'Monkey Gravel', a unit attributed to Cr III (Stuart 1982) which overlies the Freshwater Bed at West Runton (Hinton 1914). Janossy (in Sutcliffe and Kowalski 1976) regards *S. whitei* as the probable ancestor of *S. vulgaris*. A *Sciurus* humerus has also been recorded from Ostend, Norfolk (Newton 1882a) in deposits of probable Cromerian Interglacial IV age. Pleistocene occurrences of red squirrel are rare but have been recorded in interglacial assemblages, such as Cudmore Grove (5.3), Belhus Park, Essex (5.4) and Itteringham (6.3). *S. vulgaris* was at one time widespread throughout British woodlands although populations have since dramatically declined. It is found in both boreal coniferous forests and broad-leaved woods (Corbet and Harris 1991).

Citellus citellus (L., 1766) (– *Spermophilus (Urocitellus) primigenius* Kormos, 1934), ground squirrel or suslik

This large form of ground squirrel is distinct from the smaller *S. superciliosus* (Kaup) which is found in Last Glaciation deposits throughout Europe and is probably conspecific with the living *C. major* Pallas. The earliest records of *C. citellus* are from the Arctic Freshwater Beds, deposits which pre-date Anglian till at Mundesley, Norfolk (Newton 1882b; West and Wilson 1966) but the greatest abundance of this species has been noted in the deposits of the lower Middle Terrace of the Thames (Cheadle 1876a; Lydekker 1885; Whitaker 1889; Kennard 1944) (6.18) (Figure 6.43). The teeth are similar in plan to those of *S. vulgaris* but differ in numerous small details, principally the result of a tendency towards greater height of tubercles and main ridges (Miller 1912). The crowns of the upper molars are a conspicuous 'U' shape in occlusal view when moderately worn (Figure 3.10). The lower molariform teeth are similar to *Sciurus*, although the crowns are higher and more compressed, the cusps much more prominent and the central depression deeper and narrower. The skull is considered more massive than in *Sciurus* and the postcranial skeleton is slightly modified to cope with a strictly terrestrial existence. The limbs are generally more robust than *Sciurus*, with less elongated feet and short, flattened dorsal vertebrae (Miller *ibid*). This species is probably conspecific with the living Siberian species, *Spermophilus undulatus* Pallas, which today inhabits the tundra steppes in central and eastern Asia (Mayhew in Stuart 1982; Sutcliffe and Kowalski 1976).

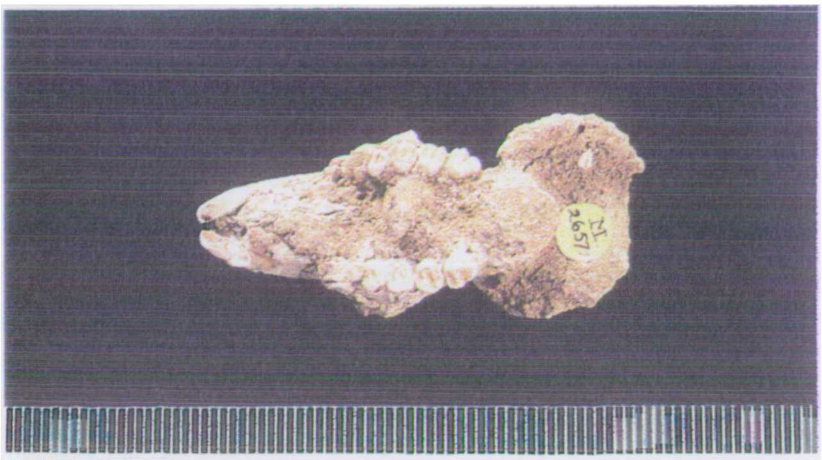


Figure 3.10 Cranium and palate of *Citellus citellus* (M26572, N.H.M.L.), Erith (occlusal view, scale in mm).

Castoridae Gray, 1821

Castor fiber L., 1758, European beaver

C. fiber is known in Britain from the Red Crag until the Holocene (Sutcliffe and Kowalski 1976). Although now absent from the modern native British fauna, the European beaver was formerly widespread throughout the Palaearctic, preferring a habitat of aspen or birch woods around the shores of lakes and rivers. The dentition of *C. fiber* is highly diagnostic, particularly the long, curving incisors. The upper cheek teeth display a distinctive pattern of enamel foldings: three narrow re-entrant folds on the external side and a single wider fold on the internal (Miller 1912). In the lower cheek teeth, the pattern is reversed (Figure 3.11). Dental cement is present. The skull is low, robust and heavily-built and the long bones stocky and perfectly adapted for swimming. The femur is particularly distinctive, since the *trochanter majus* projects well beyond the articulation (Schmid 1972).

Figure 3.11 Left dentary of *Castor fiber* (23767, N.H.M.L.), Ilford (occlusal view).

Trogontherium cuvieri Fischer, 1819, extinct giant beaver

The lower incisor of *Trogontherium* differs from *Castor* not only in size (being appreciably larger) but also in shape. In *Trogontherium*, the anterior enamel surface is well-rounded and covered with longitudinal striations, while the inner (mesial) surface of the tooth is convex (Owen 1846; Chaline 1966). In *Castor*, both the anterior and posterior faces are flatter and the enamel smoother. The occlusal pattern on the cheek teeth of *Trogontherium* is also much simpler and the teeth have no cement (Figure 3.12). A small, primitive species, *T. minus* Newton, is recorded from the Red Crag Nodule Bed at Felixstowe, Suffolk (Newton 1890b). The earliest record of *T. cuvieri* is from deposits related to the Norwich Crag (Stuart 1974). Remains of an extinct giant beaver from the Early Pleistocene of Britain and north-west Europe were assigned by Schreuder (1951) to *T. boisvilletti* (Laugel), with the slightly more advanced species, *T. cuvieri*, replacing *boisvilletti* towards the east. *Trogontherium* has been recognised as a common element of both Cromerian and Hoxnian mammalian assemblages and it seems likely that the Hoxnian specimens in particular represent the more advanced *T. cuvieri* (Sutcliffe and Kowalski 1976). Mayhew (1978) identified two distinct trends in the evolution of *Trogontherium* during the Early and Middle Pleistocene. The first trend documents a significant diminution (irrespective of size of the individual) in the length to width ratio of the incisor dimensions through time. The second trend relates to the anterior extension of the p4 through the development of an accessory antero-internal fold, and the posterior extension of the M3. Both these changes are considered to be of biostratigraphic significance.

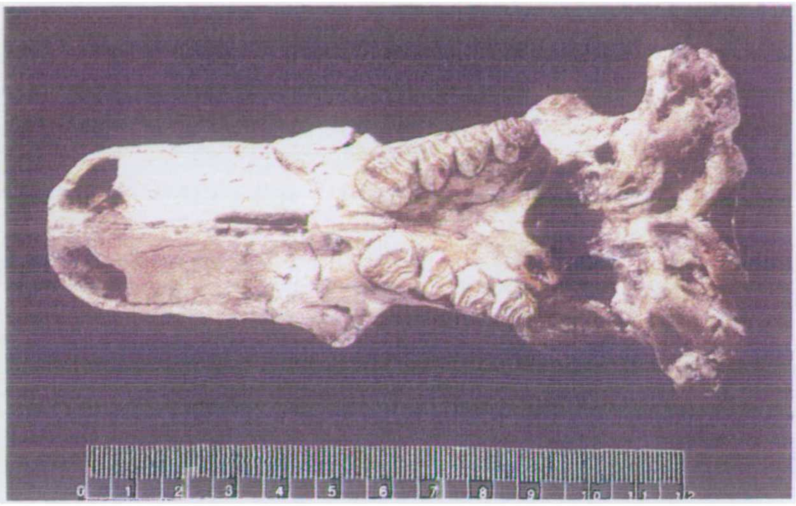


Figure 3.12 Cranium and palate of *Trogontherium cuvieri* (M6127, N.H.M.L.), East Runton (occlusal view)

Trogontherium coexisted with *Castor* until the end of the Hoxnian Interglacial but probably exploited a different ecological niche, similar to that of the living South American coypu, *Myocastor coypus* (Molina). The abundance of remains of *T. cuvieri* in fluviatile and lacustrine deposits indicates that the species was closely associated with water. In sites with fine-grained deposits, remains of *T. cuvieri* tend to outnumber those of *C. fiber*, thereby suggesting that the former favoured slower-flowing or standing water when both species co-occur (Stuart 1982). The areas for muscle attachment on the skull in *Trogontherium* show that the jaw muscles functioned differently to *Castor* and whilst the incisors are clearly not adapted for felling trees as in *Castor*, they may have served to prise off bark (Mayhew 1978). Similarly, the caudal vertebrae of *Trogontherium* show no signs of the strong lateral processes which characterise the laterally flattened tail of *Castor* (Mayhew *ibid*) and the species may thus have been considerably less aquatic. All stratified records of *Trogontherium* in Britain are restricted to temperate deposits (Stuart 1982).

Cricetidae Rochebrune, 1883

The hypsodont cheek teeth of microtine rodents are highly diagnostic. The cusps are elongated and prismatic in form, comprising a hard enamel rim surrounding a dentine core. The ends of the prisms wear to form a characteristic occlusal pattern of alternating triangles and transverse loops and give rise to a number of salient angles and re-entrant folds along the inner and outer borders of the tooth (Hinton 1926a). The anterior end of each upper molar and the posterior end of each lower molar is formed by a crescentic or pyriform transverse loop, the inner and outer extremities of which form the first inner and outer salient angles. The triangles behind or in front of the transverse loops are arranged in two series, an inner and an outer, the members of which alternate with one another. The apex of each triangle forms a salient angle, separated from its neighbour by a re-entrant fold, which in many genera is partly filled with cement. At the anterior end of the m1 and the posterior end of the M3, the triangles are succeeded by a complex structure, the anterior or posterior loop, the morphology of which is often of great systematic importance.

By delaying the timing of root formation until progressively later in the lifetime of the individual, many species have now evolved non-rooted molars with permanently growing crowns. The continuously growing teeth in many vole species and the increased chewing surface created by the enamel plications in the molars are efficient means of dealing with a comparatively less omnivorous diet of tough grasses and stems. A progressive increase in hypsodonty has occurred independently in many microtine lineages.

Cricetus cricetus (L., 1758), hamster

The enamel pattern is characterised by the presence of noticeable supplemental median loops or islands in the maxillary teeth. The M1 in particular is characterised by three pairs of tubercles, separated by a deep pit in the median line between the tubercles. At a certain stage of wear, these pits assume the form of enamel islands or of re-entrant loops, resulting in an occlusal pattern of six triangles arranged in opposite pairs (Miller 1912). The cusps are arranged alternately, instead of in pairs as in mice (Stuart 1982) (Figure 3.13). A large form of *C. cricetus* is known from the Cromerian Freshwater Bed of Norfolk (Newton 1909) and further remains have also been recorded from Tornewton Cave (Kowalski 1967) (6.21). *C. cricetus* ranges at the present day across much of central Europe from northern France into Russia and the Near East, favouring steppes, parkland and meadows, although in Europe it now occurs in association with arable fields (Sutcliffe and Kowalski 1976).

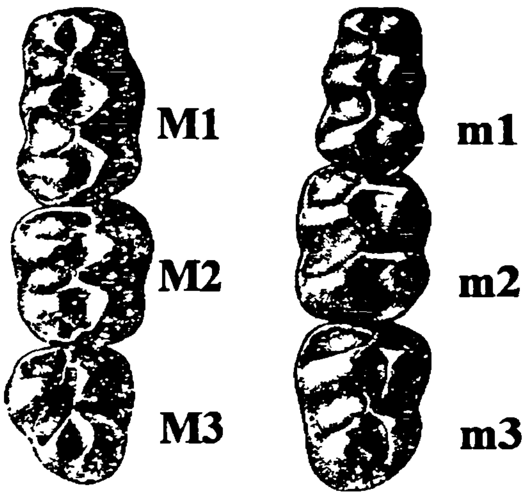


Figure 3.13 Right upper dentition (left) and left lower dentition (right) of *Cricetus cricetus* (modified from Miller 1912, not to scale).

Allocricetus (Cricetulus) bursae Schaub 1930, dwarf hamster

Although a relatively common fossil on the continent, *A. bursae* has been recorded from only three sites in Britain: Westbury-sub-Mendip (Stringer *et al.* 1996), Tornewton Cave (Kowalski 1967) (6.21) and Hutton Cave, Somerset (Sanford 1870) (6.23). Earliest records of this species come from the late Villafranchian and early Middle Pleistocene in Europe (Hír 1996) and the species persists into the Holsteinian and Eemian (Kurtén 1968). Considerable disagreement remains over the identity of this small hamster, since it is possible that it may be conspecific with one of the many living hamsters of the Palaearctic steppe, most probably *Cricetulus migratorius* (Pallas).

Dicrostonyx torquatus (Pallas, 1779), collared lemming

The cheek teeth of *D. torquatus* are highly distinctive, with multiple enamel foldings. The internal and external folds are approximately the same size and there is no cement in the re-entrant folds. The m1 consists of 5 external salient angles and 6 internal (including the anterior and posterior loops), making up 7 complete triangles before the posterior loop (Chaline 1966) (Figure 3.14).

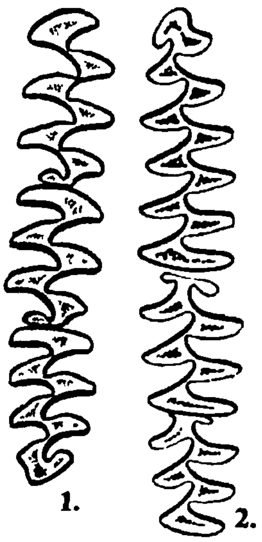


Figure 3.14 Right upper (1) and left lower (2) dentition of *Dicrostonyx. torquatus* (modified from Hinton 1926b, not to scale).

The earliest record of *Dicrostonyx* in Britain is probably from the early Middle Pleistocene deposits at Westbury-sub-Mendip (Bishop 1974), although the species is recorded as far back as the late Early Pleistocene in Europe (van der Meulen and Zagwijn 1974). Hinton (1910a) distinguished two species of fossil *Dicrostonyx*, in addition to the modern *D. torquatus*. *D. gulielmi* Sanford was believed to occur at sites such as Erith, Kent (Newton 1890a) (6.19) and Hutton Cave (Sanford 1870) (6.24), of later Middle Pleistocene age. Hinton (1926b) describes *D. gulielmi* as being of *D. torquatus* type but bigger and with broader teeth. Further slight differences were also thought by Hinton to be present in the dentition, in that the postero-internal vestigial angles of the M1 and M2 in *D. gulielmi* are larger in the M2, whereas in *D. torquatus*, they are equal or larger in the M1. A second fossil species, *D. henseli* Hinton was believed to have occurred in the Late Pleistocene at Ightham Fissures, Kent and in the

Lea Valley. However, it is now generally accepted that all living forms (with the exception of the Canadian *D. hudsonianus* Pallas) belong to one species, *D. torquatus*. At most, the European fossil forms may be subspecifically different from Recent ones but this seems unlikely. Janossy (1954, in Sutcliffe and Kowalski 1976) found in Hungarian caves not only all possible intermediate forms between *D. gulielmi* and *D. henseli* but also specimens with the left tooth-row of one type and the right one of the other. It therefore seems probable that there was only one species of collared lemming during the Pleistocene and that it was conspecific with the living *D. torquatus*. Like *Lemmus*, *Dicrostonyx* appears in association with temperate faunas during the Middle Pleistocene, although it is characteristic of cold stages in the Late Pleistocene. It does however, appear to have had a less broad climatic tolerance than *Lemmus* and can be usually associated with a steppe element or with ensuing cold conditions at many sites (Bishop 1982). Today, the collared lemming inhabits the Arctic regions of northern Canada, Greenland and Russia, preferring well-drained ground where it feeds chiefly on cotton sedge.

Myopus schisticolor (Lilljeborg, 1844), wood lemming

Kowalski (1977) suggests that *Myopus* did not reach Europe until the Holocene. However, this apparent absence in the fossil record may be explainable by the fact that the species is very difficult to recognise. An early record of *M. schisticolor* in Britain has recently been established at Boxgrove (Pitts and Roberts 1996) and future revision of material attributed to *Lemmus* may yet increase numbers of this species in the fossil record. *Myopus* is characterised by a combination of the skull and teeth of *Lemmus* with the general body form of the voles. The teeth are virtually indistinguishable from *L. lemmus*, although in a few specimens, the outer re-entrant angle of the m3 is occasionally so poorly-developed that it fails to cut off a distinct triangle from the outer extremity of the second transverse loop, a condition rarely (if ever) found in *L. lemmus* (Miller 1912). The vole-like body is slightly more robust than *Microtus agrestis*, the legs are not shortened nor the feet enlarged as in *L. lemmus*. In Europe at the present day, the wood lemming is distributed in the boreal forests of southern Norway and central Sweden, extending eastward into Finland (Miller *ibid*), where it feeds predominantly on mosses.

Lemmus lemmus (L., 1758), Norway lemming

The rootless teeth of *Lemmus* present fewer enamel loops than *Dicrostonyx* and the re-entrant folds contain cement. The m1 has a narrow, pointed anterior loop and at least 4 internal and 3 external salient angles, making up 3 closed triangles anterior to the posterior loop (Chaline 1966) (Figure 3.15). Enamel is present in equal thickness on both the concave and the convex sides of the salient angles. The lingual infolds are generally much deeper than the labial infolds in the lower molars and *vice versa* in the upper molars. The upper incisors are distinguished from those of other European rodents by the slight groove that is present on the anterior face (Stuart, in Singer *et al.* 1993), whilst the skull shows modifications for a fossorial way of life (Hinton 1926b). The anterior loop is formed by a pair of broadly confluent triangles and by a small anterior loop proper.

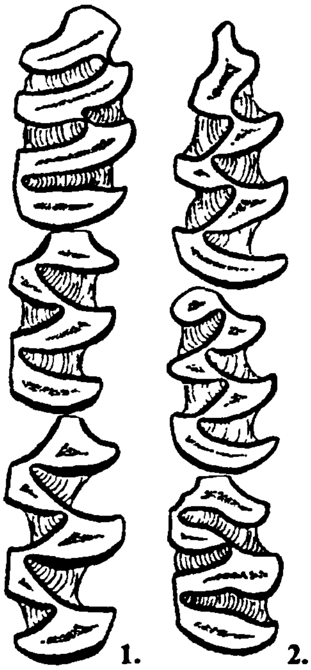


Figure 3.15 Right upper (1) and left lower (2) dentition of *Lemmus lemmus* (modified from Hinton 1926b, not to scale).

Remains of *Lemmus* are first recorded from the middle Villafranchian in eastern Europe (Sutcliffe and Kowalski 1976), although *L. lemmus* does not apparently appear in Britain until the end of the Cromerian complex at sites such as Westbury-sub-Mendip

(Bishop 1974). The species has also been recorded at Hoxne (Stuart, in Singer *et al.* 1993) (4.1) Swanscombe (Sutcliffe 1964) (4.2), Crayford, Kent (Kennard 1944) (6.18) and Pontnewydd, Clwyd (6.25). In the Middle Pleistocene, *L. lemmus* appears to be present during cooler phases, within or at the close of interglacial periods, whereas in the Late Pleistocene, it is a typical cold stage element. Today, *L. lemmus* has a boreal distribution in arctic region of Europe, extending no further south than southern Norway (Miller 1912). It lives chiefly on marshland, especially where grass and sedge are the main vegetation.

Clethrionomys glareolus (Schreber, 1780), bank vole

The cheek teeth are small and flat-crowned with cement in the re-entrant folds. Of particular note is the retention of closed roots by this species (a comparatively primitive microtine feature). Unlike the molars of other microtine rodents, growth stops in adult life and the teeth become worn down. The enamel of the cheek teeth is relatively thick and the salient angles are rounded at the tips. The m1 has five internal and four external salient angles (including the anterior and posterior loops) (Figure 3.16).

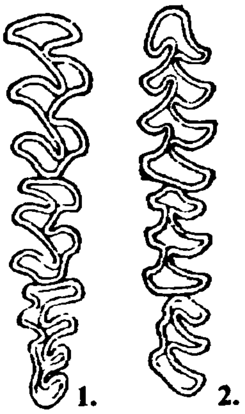


Figure 3.16 Right upper (1) and left lower (2) dentition of *Clethrionomys glareolus* (modified from Miller 1912, not to scale).

The triangles are often not completely closed in mid-wear. *Clethrionomys* has been recorded from all interglacials since the Cromerian (Stuart 1974, 1982) and is still extant at the present day. Today, the bank vole is widely distributed throughout western and central Europe, ranging as far north as the edge of the tundra zone but preferring a habitat of mature, mixed deciduous woodland (Corbet and Harris 1991). The coabundance of *C. glareolus* with the wood mouse *Apodemus sylvaticus* (L.) in Pleistocene assemblages has been cited as indicative of interglacial conditions (Chaline 1966; Currant 1986).

Arvicola terrestris cantiana (Hinton, 1910), water vole (primitive morphotype)

The earlier Pleistocene vole, *Mimomys savini* Hinton, is widely supposed to be the direct ancestor of the earliest representatives of the genus *Arvicola*. The dentition of the latter differs from that of the former only in the absence of roots, as seen in the holotype of *A. cantiana* (Hinton) from Ingress Vale, Kent. The first occurrence of *Arvicola* and the boundary between *Mimomys* and *Arvicola* faunas, together with the various evolutionary stages of *Arvicola*, have been widely used as biostratigraphic markers or to characterise mammalian biozones (cf. von Koenigswald and van Kolfschoten 1996). In the past, it was thought that *Arvicola* first appeared during the Elsterian (Koenigswald 1973) or even later, during the Holsteinian (Heinrich 1987) but it is now recognised that the transition from *Mimomys* to *Arvicola* took place much earlier, during the early Middle Pleistocene (von Koenigswald and van Kolfschoten 1996).

Much of the early dispute as to the timing of the transition stems from the different methods of subdividing deposits of 'Cromerian' age. The sequence exposed at the type site of West Runton was regarded by West (1980a) as representing a single interglacial stage, the Cromerian *sensu stricto*, subdivided into four pollen zones (Cr I-Cr IV). On the other hand, in the Dutch classification of the 'Cromerian Complex', four distinct interglacials (Interglacials I-IV), separated by periods of cold climate, have been recognised (Zagwijn 1985). The view that *Arvicola* appeared during the Elsterian or even later was based on the presence of the ancestral *M. savini* at West Runton, then correlated with the Dutch late Cromerian interglacial (Interglacial IV) on the basis of palynological evidence by West (1980a). However, at Ostend, also assigned to Cromerian pollen zone IV, *A. t. cantiana* was recovered from deposits clearly pre-dating the Anglian till (Stuart and West 1976).

This implied that both *M. savini* and *A. t. cantiana* were present during the same interglacial and although this would demand that the transition occurred within a relatively short period, there is no *a priori* reason why it should not have happened

(Stuart and Lister, in Gibbard *et al.* 1991). Stuart (1988) has also emphasised the possibility that the transition did not occur simultaneously over the entire range and that *Arvicola* might have replaced *Mimomys* over only part of the range, leading to their co-existence for some time until their distributions were disrupted by climatic fluctuations. However, as a solution to the problem of their co-existence, it was suggested that *M. savini* was present only in the lower part of the Cromerian *sensu stricto* (pollen subzones Cr Ib-Cr IIb), as represented in the West Runton Freshwater Bed, and that *Arvicola* appeared during a later zone of the same interglacial, pollen zone Cr IV, as seen at Ostend (Stuart and West 1976; Stuart and Lister, in Gibbard *et al.* 1991).

Further localities, which are regarded as Cromerian zone IV in age, have also yielded remains of *A. t. cantiana*, including Westbury-sub-Mendip (Bishop 1982) and Boxgrove (Roberts 1986). These findings are paralleled on the continent in a number of localities in the Netherlands, including Noordbergum, the typesite of the Dutch Cromerian Interglacial IV (van Kolfschoten 1990). The principal difficulty with the scenario described above is that the differences between the mammalian faunas from West Runton and the Ostend/Westbury/Boxgrove group are apparently too great to correlate both faunas with the same same interglacial (albeit different parts). For example, considerable biometrical differences between the West Runton and Westbury assemblages have been noted in a number of groups, including insectivores, rodents and carnivores (Bishop 1982; van Kolfschoten 1990). Similar differences have also been noted in the molluscan assemblages (Meijer and Preece 1996). Consequently, if all British Cromerian sites are indeed referrable to a single interglacial, it would imply a quite improbable degree of faunal heterogeneity. Therefore, although the co-existence of *Mimomys* and *Arvicola* at the same place and time in their evolutionary history is a real possibility, examination of complete mammalian assemblages from these north-west European sites from a biostratigraphic point of view, reveals that the differences are simply too great to be incorporated within one interglacial. It has therefore been proposed that the mammalian fauna from West Runton should be correlated with an earlier interglacial of the Dutch Cromerian Complex, possibly Interglacial II (van Kolfschoten 1990; van Kolfschoten in Gibbard *et al.* 1991; Stuart 1996; von Koenigswald and van Kolfschoten 1996) and that the Boxgrove-Westbury-Ostend group should be correlated with Cromerian Interglacial IV (Roberts 1990; van Kolfschoten 1990; von Koenigswald and van Kolfschoten 1996; Stringer *et al.* 1996). Further support for this has come from palynological data, again correlating West Runton with Interglacial II (Zagwijn 1996). However, although the majority of workers now accept that the Cromerian *sensu lato* encompasses more than one interglacial, many of the mammalian assemblages can still be related to zones in the vegetational succession within their respective interglacials.

As already outlined, until recently, the first appearance of *Arvicola* was thought to have occurred during Interglacial IV of the Cromerian Complex at sites such as Ostend. Recent studies from Westbury-sub-Mendip have, however, revealed the presence of a second interglacial optimum (Units 15 2+4), separated from the underlying interglacial of Unit 11 by cold conditions. This logically casts considerable doubt over the correlation of the site with only Cromerian Interglacial IV, or indeed pollen subzone Cr IV of the palynological model (Stringer *et al.* 1996). Both of the Westbury interglacials contain *Arvicola* and neither mammalian assemblage is a good match with West Runton. If the lower interglacial represents Cromerian Interglacial IV, the upper interglacial might therefore be correlated with the Hoxnian, since it is the next named stage. This is clearly impossible, since the upper Westbury interglacial contains well-established pre-Anglian species such as *Sorex savini* Hinton and *Sorex runtonensis* Hinton. Moreover, the upper Westbury interglacial unit (15/2+4) is succeeded by sediments laid down under apparent periglacial conditions (units 15/8, 18 and 19) and containing a mammalian assemblage with boreal-cold affinities, including *Microtus oeconomus* (Pallas), *Ochotona* cf. *pusilla* (Pallas), *Cricetulus migratorius* (Pallas) and *Rangifer tarandus* L., (Stringer *et al. ibid*). These cold climate deposits at Westbury may well equate with the Anglian cold stage. They also strongly parallel the stratigraphic succession at Boxgrove, where climatic deterioration into a full cold stage can be identified above the temperate Unit 4c (Roberts 1986). It therefore seems feasible that the upper Westbury interglacial should be correlated with Interglacial IV and the lower with a preceding interglacial (Interglacial III ?). A similar sequence of events has been observed at Kärlich in Germany, where an assemblage containing *A. t. cantiana* has been collected from the hornblende-dominated deposits of unit Gb. This unit lies below the hornblende-augite boundary which marks the transition to Interglacial IV of the Cromerian Complex, thereby implying that unit Gb might be correlated with Interglacial III (van Kolfschoten and Turner 1996). A second interglacial containing *A. t. cantiana*, correlated with Interglacial IV is present at the nearby site of Miesenheim I, this time in younger augite-rich deposits, above the hornblende-augite boundary. The stratigraphic position of Miesenheim I above unit Gb at Kärlich can be demonstrated through correlation of tephra deposits, present in both sites (see Figure 3.17).

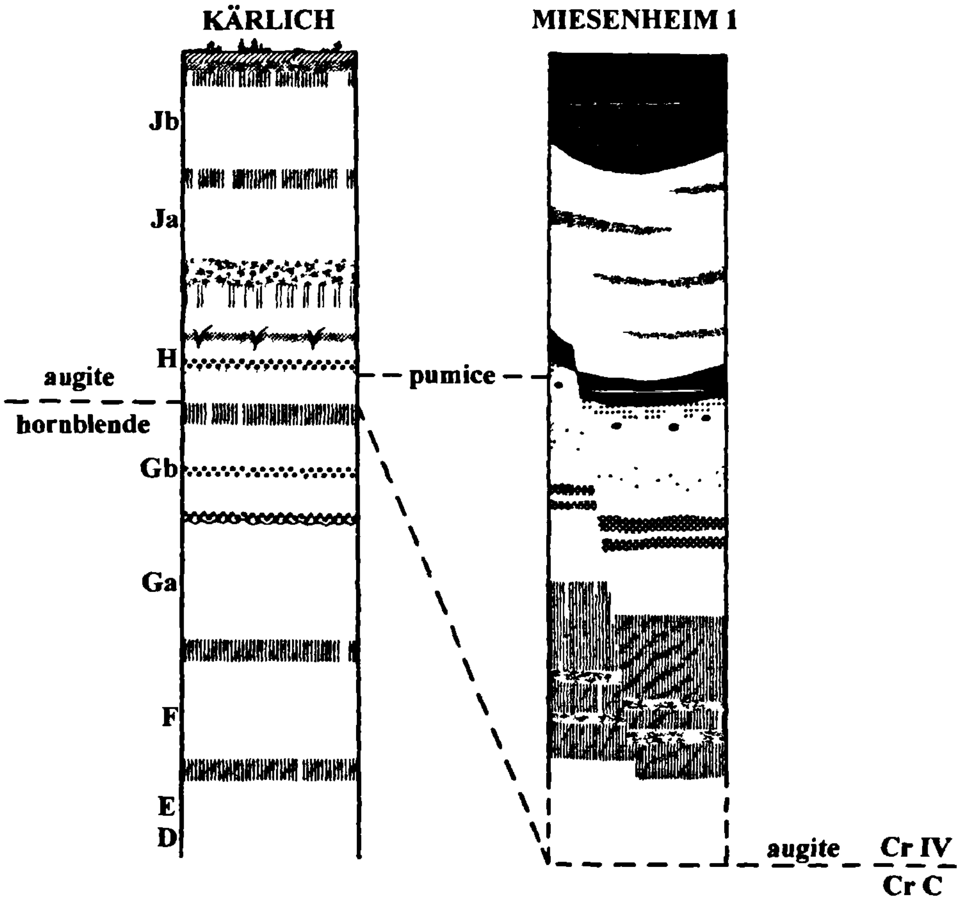


Figure 3.17 Correlation of the Kärlich and Miesenheim I sections based on the dominance of augite and hornblende and the occurrence of identical tephra (pumice) deposits (modified from van Kolfschoten and Turner 1996).

To sum up, there is now good evidence that *Arvicola* was present during the interglacial immediately preceding what is currently recognised as Interglacial IV of the Cromerian Complex, thereby placing the boundary between *Mimomys* and *Arvicola* faunas in an even earlier stage. It is anticipated that transitional populations, such as that from Prezletice (Czech Republic) will eventually be related to an interglacial stage between West Runton and Kärlich/Westbury (von Koenigswald and van Kolfschoten 1996). One further point of interest relates to the recently-proposed possibility of five interglacials in the Cromerian Complex. Support for this has come from malacological data, which suggests the positioning of West Runton between Interglacials I and II of the Dutch Cromerian Complex (Meijer and Preece 1996), thereby creating a fifth potential interglacial within the Complex.

Differences in the occlusal patterns of the m1 of the oldest representatives of *Arvicola* led Hinton (1926b) to distinguish a number of morphotypes upon which he based distinct species. However, more recent studies have shown that the different morphotypes co-occur in certain assemblages, for example from Petersbuch (von Koenigswald 1970) and Miesenheim 1 (van Kolfschoten 1990). Subsequently, all primitive representatives of *Arvicola*, such as *A. bactonensis*, *A. greenii*, *A. praeceptor* and *A. mosbachensis* have been regarded as synonyms of *A. cantiana* (Hinton), since this name had priority (Sutcliffe and Kowalski 1976). More recently however, the large variation in modern *Arvicola terrestris* populations (Röttger 1987) has led to the conclusion that all the fossil north-west and central European assemblages of the genus *Arvicola* should be regarded as subspecies of *A. terrestris* (van Kolfschoten 1990). Fossil *Arvicola* which used to be referred to the distinct species *A. cantiana* are now, therefore, assigned to *A. terrestris cantiana.*

Dental characteristics, such as the thickness of the enamel on one or more molars, the morphology of the m1 and M3 and the size of the molars (in particular the m1) have been used to make taxonomic and biostratigraphic deductions. The enamel pattern of the m1 in *Arvicola* is relatively simple, with three outer and five inner salient angles present, forming three closed triangles (Figure 3.18).

Figure 3.18 Right lower dentition of *Arviola terrestris cantiana*, showing *Mimomys* fold on m1, Barnham (from Schreve 1993).

All parts in front of the third triangle are merged into the anterior loop. The M3 is also characteristic, with 3 salient angles on each side. *Arvicola terrestris cantiana* is characterised by relatively small and permanently growing rootless molars which display '*Mimomys*' enamel differentiation (*i.e.* the enamel of the trailing (convex) edges is markedly thicker than that of the leading (concave) edges). The living NW European *Arvicola terrestris terrestris* (L.), on the other hand, has relatively larger molars which display a '*Microtus*' enamel differentiation, with thicker enamel on the leading (concave) edges of the salient angles (Figure 3.19). Throughout the Middle and Late Pleistocene, an evolutionary trend is apparent in the water vole lineage as the molars increase in size and the thickened enamel on the convex sides of the molars reduces. A further trend is also visible, namely the progressive loss of the primitive '*Mimomys* fold' in the m1. The stratigraphically earliest forms of *Arvicola* from the end of the Cromerian Complex still retain the *Mimomys* fold and this trait is still present in a relatively high percentage of individuals from Hoxnian deposits. In later interglacials, that number has dwindled or even disappeared.

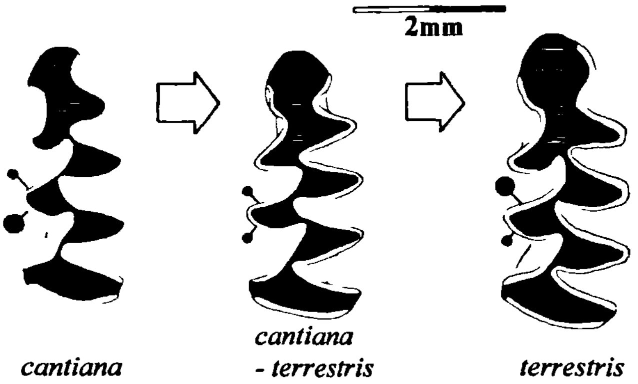


Figure 3.19 Development of the enamel layer in *Arvicola* (modified from Sutcliffe and Kowalski 1976).

To quantify the differences in the thickness of the enamel of the molars, Heinrich (1978, 1982) devised a process which measured the thickness of each side of the salient angle of the m1, divided the value of the trailing edge by that of the leading edge, and averaged the values between the different salient angles. This figure was then multiplied by 100 to give the so-called 'SDQ' (Schmelz-Dicken-Quotient) value. Broadly speaking, the older populations of *Arvicola* are characterised by high SDQ values in the order of 120-95, whereas the younger populations have lower values of less than 95 (van Kolfschoten 1990). The terminology used to describe each of the forms, according to their SDQ and stage of morphology, varies considerably according to author. Heinrich (1982) proposed the name *A. cantiana* for molars with a *Mimomys* enamel differentiation and an SDQ greater than 100 and *A. terrestris* for molars with a *Microtus* differentiation and an SDQ of less than 100. Using the SDQ method, Carls (1986) defined a new species, *Arvicola hunasensis*, from late Middle Pleistocene deposits at Hunas in southern Germany. The molars of this species are characterised by equally thick enamel on both sides of the dentine fields, a morphology intermediate between the fossil *A. t. cantiana* and the living NW European *A. terrestris*. Molars which do not show a clear enamel differentiation have previously been assigned to '*A. cantiana/terrestris*' (Sutcliffe and Kowalski 1976). In a recent study of NW European fossil *Arvicola*, van Kolfschoten defined the following three subspecies: *A. t. cantiana* (SDQ >120), *A. terrestris* ssp. A (SDQ 120-95) and *A. terrestris* ssp. B (SDQ <95). According to this method, intermediate forms are assigned to separate subspecies for biostratigraphic convenience (van Kolfschoten 1990).

However, Röttger's (1987) studies of variability in extant *Arvicola* populations from Europe, Turkey and Iran discovered extremely high intraspecific variation in the enamel thickness of the molars. The western European populations of *A. t. sherman* show the so-called *Microtus* enamel differentiation (mean SDQ values of the m1 ranges between 65.7 and 78.1), whereas the populations from Iran of *A. t. persicus* show the *Mimomys* enamel differentiation (mean SDQ of the m1: 134.4). The values for the Hungarian and Italian populations are intermediate. It has since become equally apparent that the trend in enamel differentiation in fossil *Arvicola* is not a simple progressive one of decreasing SDQ values but is subject to important fluctuation, both temporally and geographically (van Kolfschoten 1990). Whilst this is very interesting from an evolutionary standpoint, it was felt that SDQ is not an appropriate biostratigraphic tool for the purpose of the present work. Measurements of the length of the m1 have therefore been used to demonstrate the evolution of *Arvicola* in the British fossil record, since these are not subject to such fluctuations (Figure 3.20, Tables 3.3 and 3.4).

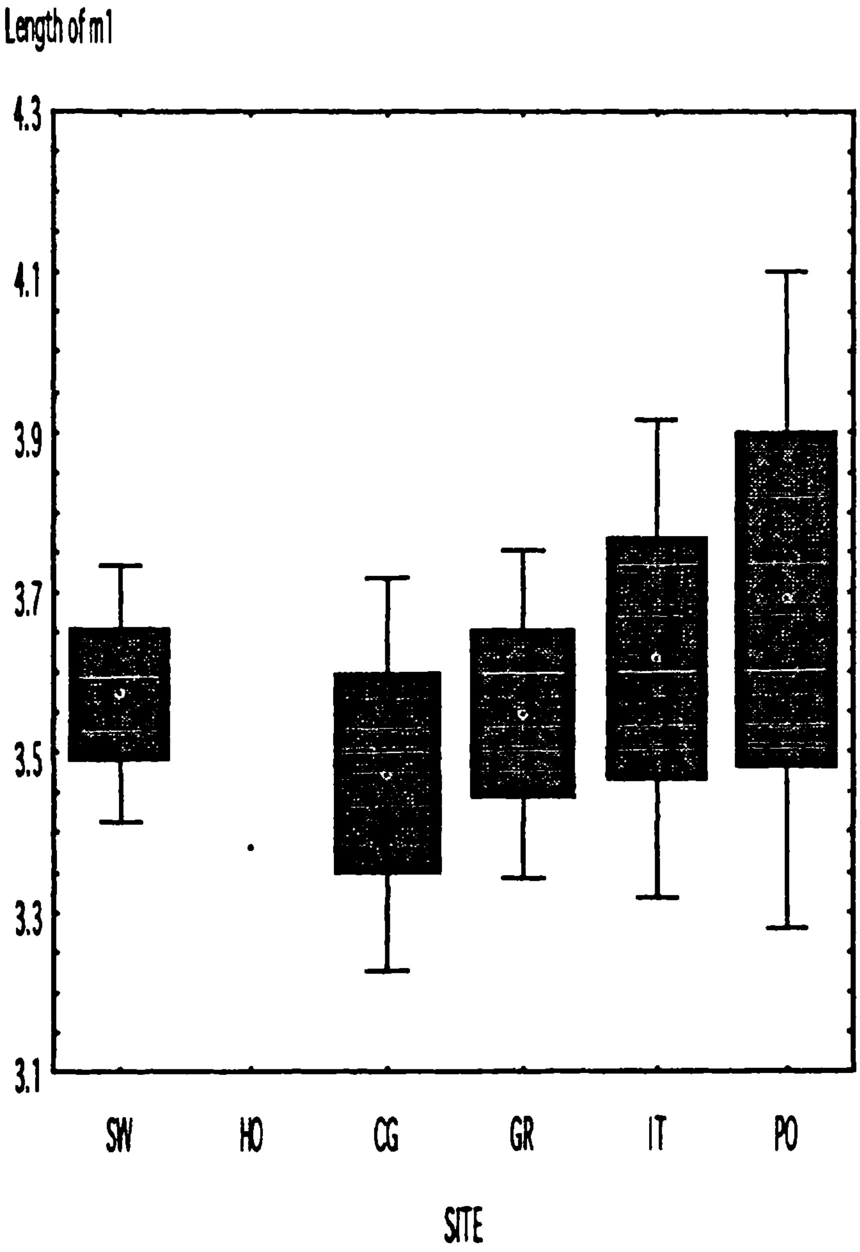


Figure 3.20 Lower m1 lengths of *Arvicola* from selected localities. For each sample, the plot shows mean ± 2 standard deviations. Key: SW = Swanscombe (Hoxnian, OIS 11), HO = Hoxne (Hoxnian, OIS 11), GR = Grays (OIS 9), CG = Cudmore Grove (OIS 9), IT = Itteringham (OIS 7), PO = Pontnewydd (OIS 7). See Table 3.3 for data.

SITE	N	MIN (mm)	MAX (mm)	MEAN (mm)	SE	SD
SW	4	3.48	3.66	3.57	0.041	0.082
HO	1	3.38	3.38	3.38	-	-
GR	7	3.39	3.68	3.54	0.039	0.104
CG	67	3.19	3.82	3.47	0.015	0.125
IT	19	3.30	3.94	3.62	0.035	0.152
PO	3	3.45	3.84	3.69	0.121	0.210

Table 3.3 Lower m1 lengths of *Arvicola* from selected localities (see Figure 3.20 for key).

	SW	HO	CG	GR	IT	PO
SW	-	-	-	-	-	-
HO	-	-	-	-	-	-
CG	t = 1.57 df = 69 p = 0.121	-	-	-	-	-
GR	-	-	t = 1.52 df = 72 p = 0.133	-	-	-
IT	-	-	-	t = 4.21 df = 84 p = ***	-	-
PO		-	-	-	t = 0.75 df = 20 p = 0.464	-

Table 3.4 t-test on *Arvicola* data from selected localities. See Figure 3.20 for key.

no statistical significance – $p > 0.05$

* = $p < 0.05$

** = $p < 0.01$

*** = $p < 0.001$

Figure 3.20 shows a progressive increase through time in the length of the first lower molar in *Arvicola.* A single specimen from Hoxne is smallest (3.38mm), although there is no significant difference between the Hoxnian sample (Hoxne and Swanscombe) and those from the Stage 9 localities of Cudmore Grove and Grays. The Grays and Cudmore Grove samples are internally consistent but are significantly smaller than samples from the Stage 7 localities of Itteringham and Pontnewydd.

At the present day, *A. terrestris* has an extremely wide Palaearctic distribution, extending throughout most of Europe to Siberia and the Pacific Ocean in the east and as far as Iran in the south (Corbet 1978). The species shows large internal variability which has led to its subdivision into a large number of subspecies. A closely-related species, *A. sapidus* has a much more restricted distribution at the present day, ranging from Portugal through Spain and southern France and eastwards to the Italian border. Modern *A. terrestris* is most commonly found along the densely-vegetated banks of streams and rivers, generally where the current is slow and water is present throughout the year (Corbet and Harris 1991). However, water voles may also be found at considerable distance from water at the present day and their presence in a fossil assemblage is consequently not neccessarily an indication of the proximity of water.

Microtus agrestis (L., 1761), field vole

As with all species of *Microtus*, the molars are rootless and the upper incisors have no longitudinal grooves. Only the additional postero-lingual loop on the M2 distinguishes the field vole from the common vole. Other isolated teeth cannot be used for separating *M. agrestis* from *M. arvalis*. The m1 of *M. agrestis* is generally less symmetrical and has a more complex anterior loop than the m1 of *M. arvalis* but there is considerable overlap in the range of morphological variation (van Kolfschoten 1991). Five closed triangles are present in front of the posterior loop of the m1. The anterior loop is relatively symmetrical, compared to other species of *Microtus* and the dental enamel is thickest on the convex sides of the angles (Figure 3.21). The first occurrence of true *M. agrestis* is recorded as being in the Hoxnian, at sites such as Hoxne (Singer *et al.* 1993) (4.1), Swanscombe (Schreuder 1950) (4.2) and Clacton-on-Sea, Essex (Singer *et al.* 1973) (4.4). Today, the field vole is the only species of *Microtus* on the British mainland, where it is ubiquitous and inhabits mainly rough, often damp grassland (Corbet and Harris 1991).

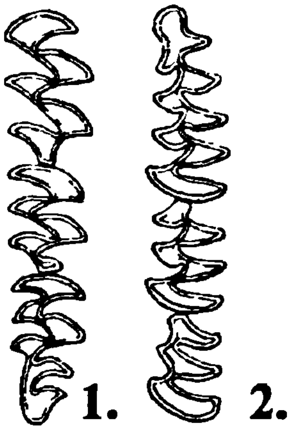


Figure 3.21 Right upper (1) and left lower (2) dentition of *Microtus agrestis* (from Miller 1912, not to scale).

Microtus arvalis (Pallas, 1779), common vole

The dentition is the same as that described for *M. agrestis*, with the absence of the postero-lingual loop on the M2 being the only distinguishing character (Figure 3.22). It is precisely this lack of distinctive characters that has resulted in the Pleistocene history of this species being so poorly known (cf. Sutcliffe and Kowalski 1976). It is possible that specimens referred to '*M. agrestis* or *M. arvalis*' or to *Microtus* sp. from Hoxne (4.1), Swanscombe (4.2), Clacton-on-Sea (4.4) and Barnham (4.5) may indeed belong to *M. arvalis* but further determination is unfortunately impossible. The first indisputable record of this species in Britain is from Late Devensian-early Holocene sites, such as Ightham Fissures (Barrett-Hamilton and Hinton 1910-21). *M. arvalis* has been recorded by many authors in the Devensian (*e.g.* Corbett in Sutcliffe and Kowalski 1976), although its presence during this cold stage seems unlikely from an ecological point of view. Most of the morphotypes attributed to *M. arvalis* in museum collections are actually attributable to the narrow-skulled vole, *Microtus gregalis* (Pallas) (A.P. Currant pers. comm.), a species present in Britain during the Devensian but absent in all earlier sediments (Sutcliffe and Kowalski 1976). However, a possible early record of *M. arvalis* has come from late Middle Pleistocene site of Cudmore Grove (5.3). Measurements of m1 lengths in *M. agrestis/M. arvalis* specimens from this locality reveal the presence of two distinct size categories (A.P. Currant pers. comm.). It seems unlikely that the dentition reflects sexual dimorphism in *M. agrestis* (which has definitely been recorded at the site) and it is therefore tentatively suggested that the size differentiation reflects the presence of both *M. agrestis* and *M. arvalis*. This would represent the earliest known occurrence of *M. arvalis* in Britain.

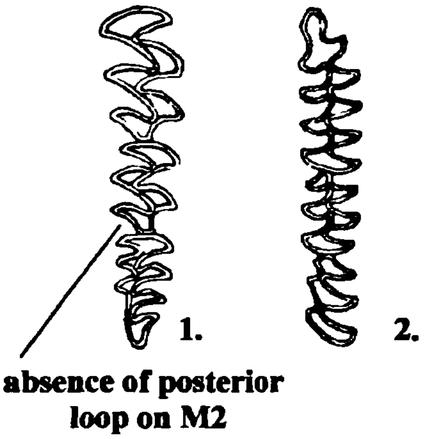


Figure 3.22 Right upper (1) and left lower (2) dentition of *Microtus arvalis*, showing absence of posterior loop on M2 (modified from Miller 1912, not to scale).

In the British Isles at the present day, *M. arvalis* is restricted to Guernsey and six of the Orkney Islands, where it was probably introduced by man (Corbet and Harris 1991). It inhabits a wide range of environments, from coniferous woodlands to marshes and meadowland (Corbet and Harris *ibid*).

Microtus gregalis (Pallas, 1779), narrow-skulled vole

The first lower molar in *M. gregalis* is readily identifiable. Three inner and two outer closed triangles are present and the anterior loop has a distinctive 'mitten-shape' (Figure 3.23). An ancestral morphotype of this species is known from early Middle Pleistocene temperate episodes at West Runton (Stuart 1996) and Westbury-sub-Mendip (Stringer *et al.* 1996) as *Pitymys gregaloides* (A.P. Currant pers. comm.). A single occurrence in the late Middle Pleistocene is recorded at Pontnewydd Cave (6.25) but the majority of finds are known from the Devensian (Sutcliffe and Kowalsi 1976). Devensian remains of *M. gregalis* display a far greater degree of intra-specific morphological variation than earlier populations and ~~are~~, as a result, have frequently been erroneously attributed to *M. agrestis* or *M. arvalis* (A.P. Currant pers. comm.). Today, *M. gregalis* occurs throughout much of the northern tundra zone but is also present in the wooded steppes of central Asia (Stuart 1982).

Microtus oeconomus (Pallas, 1776), northern vole

The first lower molar of *M. oeconomus* is highly characteristic and readily distinguishable from all other species of *Microtus*. Three inner and two outer closed triangles are present. The anterior loop is very short, so much so that there is no re-entrant angle on the outer side, whereas the inner re-entrant angle is reduced to a shallow concavity. The antero-internal triangle is broadly confluent with the anterior loop.

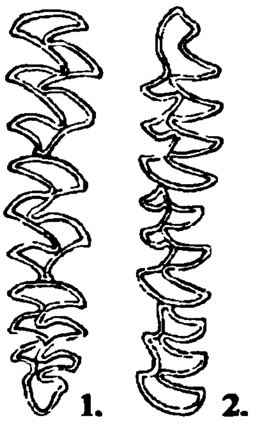


Figure 3.23 Right upper (1) and left lower (2) dentition of *Microtus oeconomus* (from Miller 1912, not to scale).

At the sites of Crayford and Erith (6.18) and Clevedon Cave, Somerset (7.3), two species of *Microtus* were recorded by Hinton, the northern vole, *M. ratticeps* (= *oeconomus*) and the snow vole, *M. nivalis* (Hinton) (Hinton 1907a). At Clevedon Cave, Hinton also described a further, new species, *Microtus malei*, which he defined as a member of the *M. nivalis* group (Hinton 1907b). However, the variability of the occlusal patterns in these vole species is so great that Hinton later acknowledged that he had selectively figured teeth only with the nivaloid form. He subsequently refuted the existence of *M. malei* as a distinct species, dismissing any affinity with *M. nivalis* and preferring to regard the specimens in question as having a generalised dental pattern which was probably characteristic of the ancestor of both the northern and snow voles (Hinton 1910b). *M. malei* was resurrected as a valid species by Chaline (1972), who designated the specimen M26481 (N.H.M.L.) from Clevedon Cave as the lectotype. In his opinion, all the specimens from Clevedon Cave, determined by Hinton as belonging to *M. malei, M. oeconomus* and *M. nivalis*, represent only one (highly variable) species, *M. malei*, which does not resemble the living European *M. nivalis.* According to Chaline, *M. nivalis* developed from *M. malei* during the Late Pleistocene and was not present in Britain.

Sutcliffe and Kowalski (1976) opposed the views of Chaline, as outlined above. They (like Hinton) dismissed the existence of *M. malei* but favoured *M. nivalis* as the form represented at Crayford, Clevedon Cave and in the Glutton Stratum at Tornewton Cave. However, recent re-examination of the material in question reveals that the remains variously attributed to *M. malei* or *M. nivalis* are in fact all variants of *M. oeconomus* (Stuart 1982). When *M. oeconomus* is the dominant species (as is the case at these sites), intraspecific morphological variability is amplified (A. Currant pers. comm.). It is therefore proposed that the variations exhibited by the m1s are simply individual expressions along the range of *M. oeconomus* variability. *M. malei* and the other British 'nivaloid' forms should therefore be regarded as 'morphotypes', arbitrarily established by the dissection of the *M. oeconomus* lineage. *M. nivalis* has therefore never been a part of the British Pleistocene fauna and indeed, not a single example of the highly diagnostic simple M3 of this species has ever been recovered from any site (Stuart 1982). In addition to the patterns of variability, the molars of *M. oeconomus* also show a progressive increase in size throughout the later Middle Pleistocene, reaching their maximum in deposits attributed to OIS 6, for example at Clevedon Cave and Bacon Hole (West Glamorgan), where sediments containing large *M. oeconomus* can be shown to directly underlie deposits of Last Interglacial age (Figure 3.24, Tables 3.5 and 3.6).

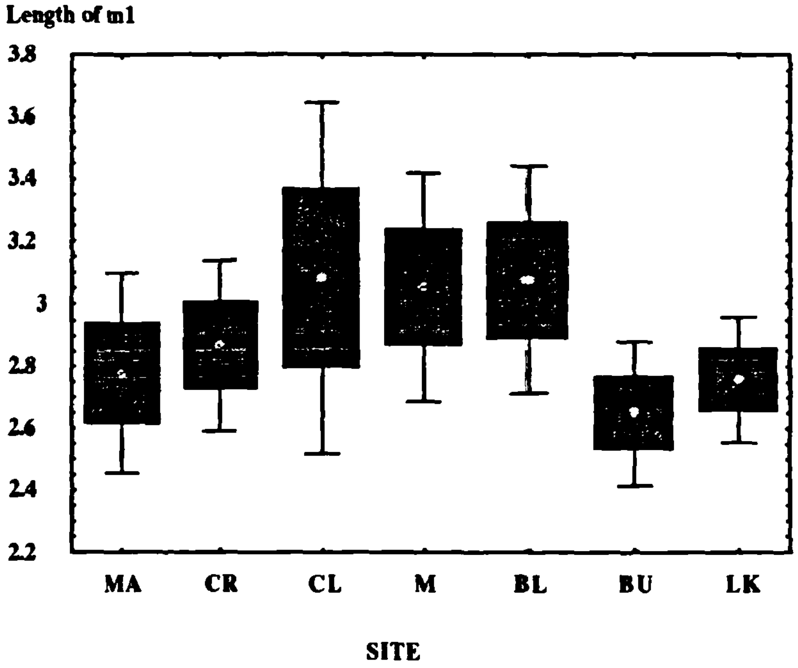


Figure 3.24 Lower m1 lengths of *Microtus oeconomus* from selected localities. For each sample, the plot shows mean ± 2 standard deviations. Key: LK = Lime Kiln Hill Quarry (Devensian), BU = Bacon Hole (Last Interglacial), BL = Bacon Hole basal pebble deposits and coarse sands (OIS 6), M = Minchin Hole Lower Red Cave Earth (OIS 6), CL = Clevedon Cave (OIS 6), CR = Crayford (late OIS 7), MA = Marsworth (OIS 7) (See Table 3.5 for data).

SITE	N	MIN (mm)	MAX (mm)	MEAN (mm)	SE	SD
LK	21	2.54	2.95	2.75	0.022	0.012
BU	93	2.32	2.92	2.65	0.012	0.119
BL	3	2.88	3.25	3.08	0.107	0.186
M	5	2.9	3.26	3.05	0.083	0.186
CL	13	2.87	3.96	3.08	0.080	0.288
CR	12	2.57	3.14	2.87	0.041	0.141
MA	6	2.57	2.95	2.78	0.067	0.165

Table 3.5 Lower m1 lengths in *Microtus oeconomus* from selected localities (see Figure 3.23 for key).

	LK	BU	BL	M	CL	CR	MA
LK	-	-	-	-	-	-	-
BU	t = 3.88 df = 12 p = ***	-	-	-	-	-	-
BL	-	-	-	-	-	-	-
M	-	-	t = 0.181 df = 6 p = 0.86	-	-	-	-
CL	-	t = 9.87 df = 104 p = ***	t - 0.028 df = 14 p = 0.97	t = 0.211 df = 16 p = 0.84	-	-	-
CR	-	-	-	-	t = 2.357 df = 23 p = *	-	-
MA	-	-	-	-	-	t = 1.21 df = 16 p = 0.24	-

Table 3.6 t-test on *Microtus oeconomus* data from selected localities. See Figure 3.23 for key.

no statistical significance = $p > 0.05$

* = $p < 0.05$

** = $p < 0.01$

*** = $p < 0.001$

M. oeconomus is a relatively common fossil species of the Middle and Late Pleistocene in Britain. It is first recorded in the Freshwater Bed at West Runton (Stuart 1996) and is still extant at the present day, although it is absent from Britain, occurring no further west than the Netherlands and Germany (Sutcliffe and Kowalski 1976). *M. oeconomus* is today most widely distributed throughout the northern tundra and taiga zones of continental Europe, especially in wet, grassy habitats, and in the more wooded steppe habitats to the south, from Scandinavia across to Siberia (Miller 1912; Stuart 1982).

Microtus (Terricola) subterraneus (de Selys Longchamps) (¯ *Pitymys arvaloides* Hinton, 1923), pine vole

This species was first recognised in the British Middle Pleistocene under the genus *Pitymys*. Two different species, *P. gregaloides* and *P. arvaloides* were described by Hinton (1923a) from the Freshwater Bed at West Runton. The two are separated by differences in the morphology of the anterior loop and co-occur in many deposits of early Middle Pleistocene age. However, whereas the *gregaloides* morph does not apparently continue after the Anglian cold stage, the *arvaloides* morph persists into (but not beyond) the Hoxnian (Sutcliffe and Kowalski 1976). There is considerable discussion as to whether *Pitymys* should be regarded as merely a subgenus of *Microtus* or whether it has genuine generic status (Sutcliffe and Kowalski *ibid*). The cheek teeth are virtually indistinguishable from those of other closely-related *Microtus*, except that in *M. subterraneus*, the two angles immediately behind the anterior loop of the m1 are broadly confluent. The cheek teeth have well-differentiated enamel and are visually quite complex. The m1 has at least five outer and six inner salient angles and at least seven closed triangles in front of the posterior loop. The inner and outer salient angles and the re-entrant folds are approximately equal in size and depth (Figure 3.25). No dental cement is present (Hinton 1926a). *P. arvaloides* is now widely regarded as being conspecific with the living European pine vole, *Microtus (Terricola) subterraneus*. *M. subterraneus* is important as a post-Anglian biostratigraphic marker, since it is present in Hoxnian sites such as Hoxne (Singer *et al.* 1993) (4.1), Swanscombe (Schreve 1996) (4.2) and Barnham (Ashton *et al.* 1994) (4.3), but is not known from any later interglacial deposit in Britain. As the name indicates, *M. subterraneus* has a largely fossorial existence, due to severe above-ground competition from other species of *Microtus*. The skull and postcranial skeleton therefore show certain modifications for this lifestyle. Only in the south-eastern central Asian highlands, where other species of *Microtus* are absent, does the *subterraneus* form exist above ground. These representatives consequently show cranial modifications which parallel those seen in other *Microtus* in other parts of the world (Hinton 1926a). The living *M subterraneus* is absent from Britain at the present day but occurs throughout much of western and central Europe in the southern half of the temperate forest zone (Stuart 1982).

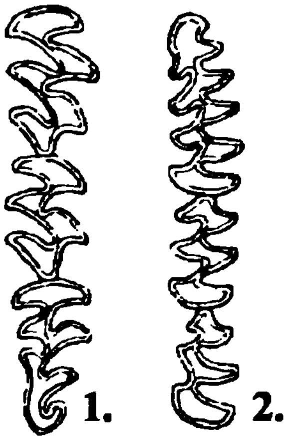


Figure 3.25 Right upper (1) and left lower (2) dentition of *Microtus* (*Terricola*) *subterraneus* (from Miller 1912, not to scale).

Lagurus lagurus (Pallas, 1773), steppe lemming

The molars are rootless, there is no dental cement and the thickness of the enamel is not uniform on both sides of the teeth. In addition to the posterior loop, the m1 has five triangles. The anterior two are generally separated from each other but may occasionally be confluent (although never to the degree seen in *M.* (*T.*) *subterraneus*. The M3 is very distinctive, comprising three closed enamel triangles behind the anterior loop and a strongly lengthened posterior loop with well-defined lateral salient angles (Kowalski 1967). *L. lagurus* is thought to have developed during the Middle Pleistocene from more primitive forms of the genus (Sutcliffe and Kowalski 1976). The fossil remains of this species are relatively common in Late Pleistocene localities in central and eastern Europe, although they are much less common in the west (Sutcliffe and Kowalski *ibid*). In Britain, *L. lagurus* has been found only in Tornewton Cave (Kowalski 1967). The steppe lemming is today distributed throughout the steppe zone of Eurasia from the River Dniepr to Mongolia, also inhabiting desert and mountainous areas below 2200 metres above sea level.

Muridae Gray, 1821

Apodemus sylvaticus (L., 1758), wood mouse

On the basis of size and morphology, British Middle Pleistocene mice may be divided into two separate groups, both belonging to the genus *Apodemus*. Specimens may be assigned to *Apodemus sylvaticus* as opposed to the small extinct *A. maastrichtiensis* van Kolfschoten largely on the basis of size, although morphologically, remains of wood mouse are extremely difficult to separate from those of the yellow-necked mouse, *A. flavicollis* (Melchior). However, since the latter species has so far been irrefutably demonstrated only in terminal Late Pleistocene and Holocene deposits in Britain (Sutcliffe and Kowalski 1976), it has always been assumed (perhaps incorrectly) that earlier occurrences are referable to *A. sylvaticus*. The incisors of *A. sylvaticus* are distinct from those of the voles and lemmings in that they are laterally flattened and have a sharper, slightly concave biting surface. The upper incisor is strongly curved, forming a neat semi-circle. The cheek teeth are low-crowned, with a highly-distinctive pattern of low tubercles, reflecting a mixed vegetarian diet. The M1 of the wood mouse has four roots and the tubercles are arranged in three longitudinal rows, which become crescentic with wear. The lower molars consist of a series of equal, paired tubercles, with each tooth terminating in a single, small median tubercle (Miller 1912). Two or three accessory tubercles are present on the outer border of the m1. At the present day, *A. sylvaticus* is widely distributed throughout the woodland and steppe zones of the Palaearctic, although it does not extend far into the coniferous zone. In Britain, the species is ubiquitous and occupies most habitats, including woodland, grassland, heather, blanket bog and sand dunes (Corbet and Harris 1991).

Apodemus maastrichtiensis van Kolfschoten, 1985, extinct small mouse

As previously stated, small size is a significant character in the identification of *Apodemus maastrichtiensis* but several morphological characters are also important. Murid dentition is described according to Miller (1912), who numbered the tubercles from 1 to 9 (Figure 3.26).

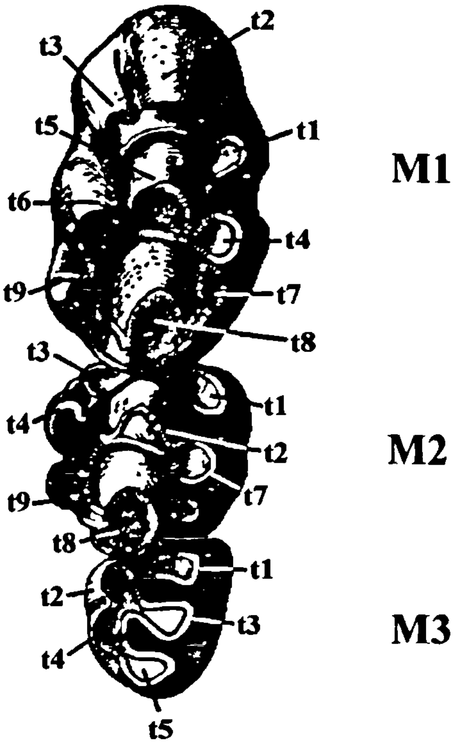


Figure 3.26 Numbering of tubercles on the upper cheek teeth in *Apodemus* (after Miller 1912, not to scale).

In *A. maastrichtiensis*, the tubercles t7 and especially t9 of the M1 and M2 and t3 of the M3 are small. The cusps of the m1 and m2 are particularly steep and the angle formed by the posterior parts of the chevrons is large. The anterior cusps of the m1 have only a low connection with the posterior cusp and the m2 has a small antero-labial cusp and a small terminal heel (van Kolfschoten 1991). *A. maastrichtiensis* appears to be related to "*Parapodemus*" *coronensis* Schaub from the early Biharian of Brassó in Romania (van Kolfschoten *ibid*). The species is present in British late Cromerian localities, such as Boxgrove (Pitts and Roberts 1996) and at the Hoxnian site of Barnham (Ashton *et al.* 1994b) (4.5). The latest known occurrence is from Saalian levels at the sites of Maastricht-Belvedere and Wageningen-Fransche-Kamp in the Netherlands (van Kolfschoten 1990, 1991) (Table 3.7). A new record of this species (and apparently the latest British occurrence) is from Stutton, Suffolk, attributed to Stage 7 (6.8).

SITE	N	MIN (mm)	MAX (mm)	MEAN (mm)	SE	SD
Wageningen						
m1 length	1	1.42	1.42	1.42	-	-
m1 width	1	0.85	0.85	0.85	-	-
Stutton						
m1 length	1	1.5	1.5	1.5	-	-
m1 width	1	0.9	0.9	0.9	-	-

Table 3.7 Comparison of measurements of m1 in *Apodemus maastrichtiensis* from Wageningen-Fransche-Kamp, Netherlands (from Kolfschoten 1990, 1991) with *A. maastrichtiensis* from Stutton, Suffolk.

3.7. Cetacea

CETACEA Brisson, 1762

Delphinidae Gray, 1821
Tursiops truncatus (Montagu, 1821), bottle-nosed dolphin

Dolphins are an extremely rare element of later Middle Pleistocene assemblages in the Thames valley, present only at Ingress Vale (Sutcliffe 1964) (4.3) and Grays (5.2) (Figure 3.27). They are easily recognised on the basis of the postcranial skeleton, which is evidently adapted for an aquatic existence, and from their distinctive peg-like teeth (10-13 mm in diameter in *T. truncatus*) (Corbet and Harris 1991). Small populations of the bottle-nosed dolphin exist in scattered localities in bays and estuaries around the coast of the British Isles at the present day (Corbet and Harris *ibid*). This species is more frequently found in inshore localities and the two later Middle Pleistocene specimens probably became beached upstream of the Thames estuary.

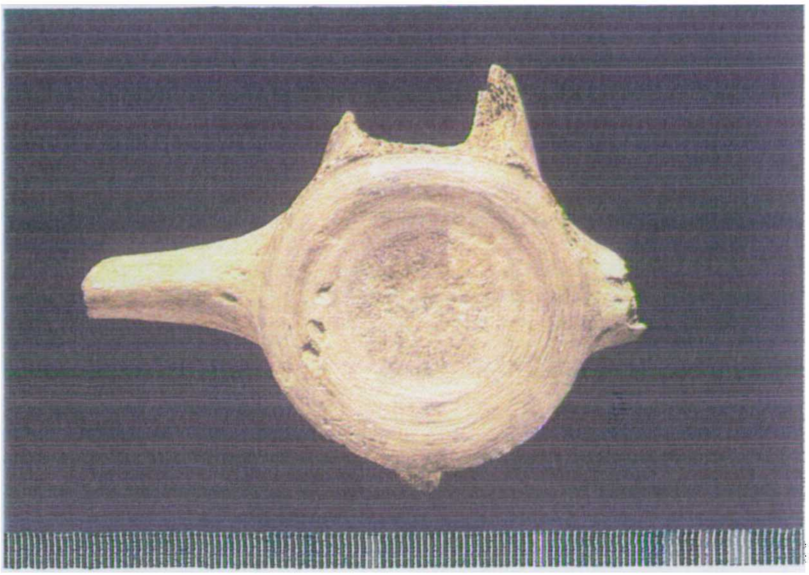


Figure 3.27 Vertebra of *Tursiops truncatus* (20274, N.H.M.L.), showing gnawmarks, Grays (posterior view, scale in mm).

3.8. Carnivora

CARNIVORA Bowdich, 1821

Canidae Gray, 1821
Canis lupus L., 1758, wolf

The dentition of all canids is characterised by the development of the P4 and m1 into secodont carnassial teeth. In the lower carnassial, the protoconid and paraconid ridges form the main cutting edge, whilst the metaconid is generally reduced. The posterior part of the m1, the talonid, forms a low 'basin' for grinding and crushing (Hillson 1986). The m1 of *C. lupus* increases in length in British specimens through the Middle and Late Pleistocene until it reaches a maximum length of about 32 mm in the Devensian (Figure 3.28). These results are paralleled by findings on the continent by Bonifay (1966, 1971). With regards to the postcranial skeleton, the form of the humerus is distinctive, with spreading distal condyles and the presence of a *foramen supratrochleare* (Schmid 1972). According to Bonifay (1971), the first known occurrence of the true wolf is in the Holsteinian and the species is still in existence at the present day. In the Holocene, the wolf was formerly widespread in many environments in the Palaearctic, although its distribution today has been greatly affected by human interference. It is a common fossil in both warm and cold stage Pleistocene deposits.

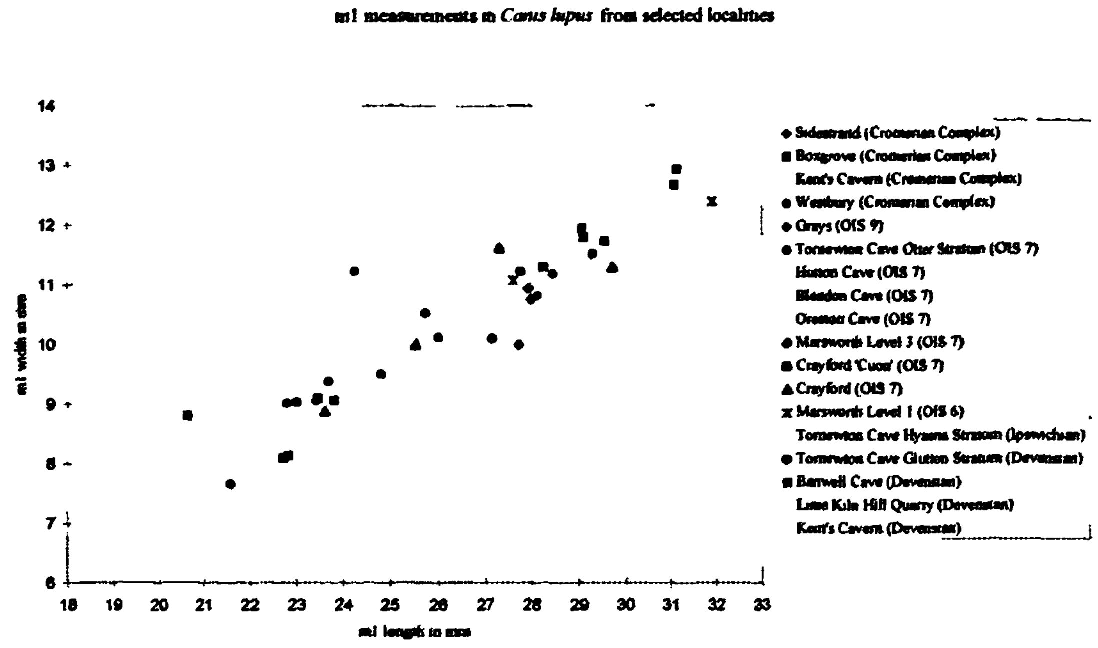


Figure 3.28 Length of m1 in *Canis lupus* from selected Pleistocene localities.

Canis lupus mosbachensis Soergel, 1925, extinct small wolf

C. l. mosbachensis may be distinguished from *C. lupus* on the basis of its smaller size, although it is much larger than the fox, *V. vulpes* or arctic fox, *A. lagopus*. This subspecies is present at many British and continental early Middle Pleistocene sites, including West Runton (personal observation), Westbury (Bishop 1982) and Boxgrove (personal observation). Bonifay (1971) considers *C. l. mosbachensis* to be synonymous with the Early Pleistocene *Canis etruscus* Major and has proposed a continuous evolution from *C. etruscus* to the large *C. lupus*, whilst Torre (1974) regards *C. l. mosbachensis* as a subspecies, intermediate between *C. etruscus* and *C. lupus lupus*. Bonifay (1971) identifies an intermediate form, *C. l. lunellensis* from Lunel-Viel in France, dated to the Holsteinian, which she suggests is the first true representative of the true wolves in Europe. However, there are no apparent morphological differences between *C. l. mosbachensis* and *C. l. lunellensis* (with the possible exception of a slightly more pronounced metaconid in the latter) and the only means of discrimination is apparently the marginally larger size of *C. l. lunellensis* (Bonifay *ibid*).

Vulpes vulpes L., 1758, fox

Remains of *V. vulpes* may be distinguished from those of the larger canids by their small size and slender form (Figure 3.29). The fox is further differentiated from the Arctic fox (*Alopex lagopus* (L.)) on the basis of its larger size and greater robusticity. In *V. vulpes*, the mandibles are more elongated in relation to the size of the skull than in *A. lagopus* and the premolars are subsequently more widely spaced. Further characters pertaining to the dentition and postcranial elements are listed in Reynolds (1909) and Koby (1959). *V. vulpes* probably evolved from the ancestral *V alopecoides* during the Middle Villafranchian (Kurtén 1968). The earliest remains of *V. vulpes* in Britain are known from Westbury (personal observation) and the species is still present in most of the western hemisphere today. The fox is a regular component of both cold and warm stage Pleistocene assemblages, frequently co-occurring with *C. lupus*. The fox is a highly adaptable, unspecialised, versatile species, which at the present day inhabits a wide variety of environments, particularly fragmentary habitats where there is the greatest diversity of food and cover (Corbet and Harris 1991).

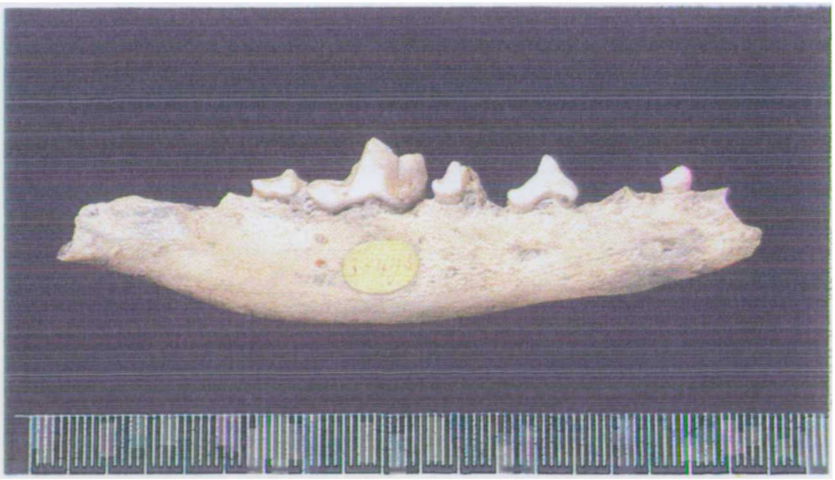


Figure 3.29 Right dentary of *Vulpes vulpes* (38495, N.H.M.L.), Grays (scale in mm).

Cuon alpinus Pallas, 1811, alpine dhole

The genus *Cuon* is first recognised in Europe in the Early Pleistocene Upper Val d'Arno of Italy as *C. majori* Del Campana (= *C. dubius* Teilhard) (Maglio 1975). The dentition of this primitive dhole resembles that of *Canis* so closely *"that it would be referred to that genus had not its descendants evolved into fully fledged dholes"* (Kurtén 1968, 111). The trend toward increasing reduction of the tubercular teeth and development of sharply trenchant blades in their cusps, as seen in the modern *C. alpinus* Pallas, is visible in its first stages in *C. majori*. The molar dentition is still complete, although it is somewhat reduced in size and the cusps are rather more pointed than in *Canis* (Kurten *ibid*).

It is not until the early Middle Pleistocene that the m3 is lost within the dhole clade, as shown in late Cromerian Complex examples of *Xenocyon lycaonoides* Kretzoi (= *C. majori stehlini* (Thenius)) from Rosières, France (Kurten *ibid*) and Westbury-sub-Mendip (Bishop 1982). These dholes are very large and their postcranial remains are easily distinguishable from those of the contemporary small wolf *C. l. mosbachensis* Soergel. The modern *C. alpinus* is first recorded in the early Middle Pleistocene at Hundsheim and Mosbach, Germany. Early variants still display three cusps in the m1 but these are very much reduced (Kurtén 1968). The transformation of the lower tubercular molar into a single-cusped sharply-trenchant tooth continues through the later Middle Pleistocene until its completion in the Late Pleistocene of Europe in the form of *C. alpinus europaeus* Bourguignat. The Middle Pleistocene occurrence of the dhole is recorded at Crayford by Stuart (1982) and Sutcliffe (1985). However, it can now be demonstrated that neither the dental formula nor the morphology of the teeth of the specimen in question agrees with *Cuon* (see Crayford 6.18, Figures 6.44a and b). The postcranial skeleton is difficult to separate from that of *Canis*, although the proportions of the limbs of the dhole are relatively shorter (Bonifay 1966). Today, dholes are found from Russia in the west to Malaysia and southern China in the east. They inhabit open woodlands and forests and hunt in packs of up to thirty individuals, preying mostly on deer.

A 'hyaenoid wolf' or hunting dog, *Lycaon anglicus*, was described and figured by Falconer from Spritsail Tor Cave, Gower (Murchison 1868). A subsequent full description by Lydekker (1884) explained the attribution of the specimen to *Lycaon* on the basis of a distinct anterior talon on the p4. However, Reynolds (1909) in a full review of the Pleistocene canids, estimated that the specimen has in fact more characters in common with *C. lupus* and should therefore be regarded as an 'abnormal wolf', in view of the known variability in canid teeth.

Ursidae Gray, 1825

Ursus arctos L., brown bear

Brown bears are common Pleistocene fossils and occur in both temperate and cold stages. The cheek teeth of the brown bear are bunodont and adapted for crushing (Figure 3.30). The M2 has two main buccal cusps (paracone and metacone). In contrast to the cave bear *U. spelaeus*, *U. arctos* nearly always retains two small anterior premolars in the upper jaw and at least one in the lower jaw (Reynolds 1906). The teeth of the brown bear are also generally higher-crowned than those of the cave bear. Remains of *U. arctos* from the later Middle Pleistocene site of Pontnewydd Cave, Clwyd, reveal the presence of 'spelaeoid' characters in the dentition (Currant 1984). This may be a reflection of a greater dietary dependence on vegetation or of a genetically-isolated brown bear group. The postcranial remains are generally more robust than in large felids of equivalent size but are smaller than those of the cave bear. The brown bears have their origins in China, where they have a continuous record from the early Middle Pleistocene until the present day (Kurtén 1968). According to Kurtén (1959), they share a common ancestor with *U. spelaeus* in the small Early Pleistocene bear, *U. etruscus* Cuvier. The brown bear appears in Europe for the first time during the Holsteinian interglacial at sites such as Lunel-Viel, France, where it co-existed with the cave bear (Kurtén 1968). It did not enter Britain until OIS 9. The species is still in existence at the present day, although its modern distribution has been much constricted by human activity. The range today occupies much of Europe and into Asia, where sufficient tracts of forest remain (Corbet and Harris 1991).

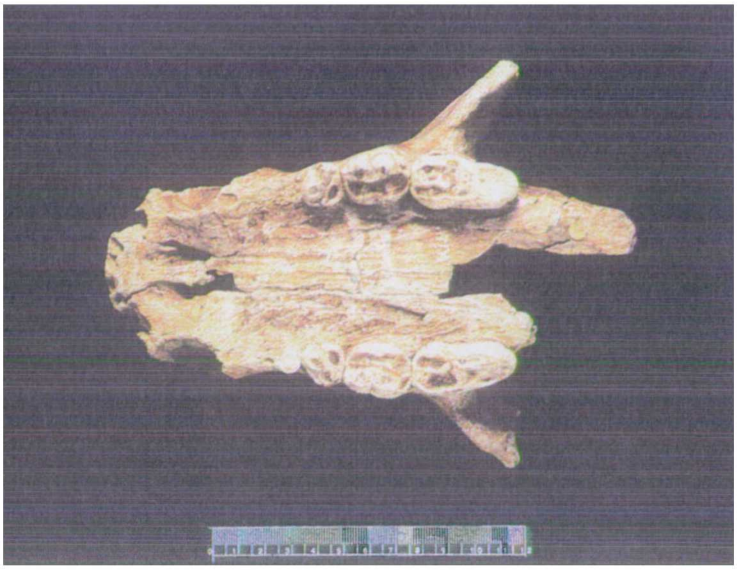


Figure 3.30 Palate and dentition of *Ursus arctos* (M5041, N.H.M.L.), Ilford (occlusal view).

Ursus spelaeus (Rosenmüller and Heinroth, 1794), cave bear

U. spelaeus evolved from the early Middle Pleistocene *U. deningeri* and appears as a distinct species for the first time in faunas dating to the Hoxnian interglacial. In continental Europe, this species is present in Saalian assemblages but becomes most common during the Weichselian, at the end of which it became extinct (Kurtén 1968). Although extremely similar to *U. arctos*, overall body size is larger, although the limbs (in particular the tibia) are relatively short (Reynolds 1906). Several features are nevertheless present in the cranium and dentition of *U. spelaeus* which permit its distinction on morphological grounds (Rosenmüller 1804). The skull of the cave bear presents a well-defined sagittal crest, while the frontal region is markedly domed in aspect (Figure 3.31). Furthermore, the three anterior premolars are generally absent in *U. spelaeus* and whilst this character is by no means universal, it remains one of the best means of separating cave bear from brown bear. The teeth of *U. spelaeus* are also lower-crowned and with a greater development of accessory tubercles than in *U. arctos*. This is probably a diet-related character, since cave bears are thought to have been considerably less carnivorous than the brown bear (Bishop 1982; Bocherens *et al.* 1990). *U. spelaeus* is known to have occurred in both temperate and cold stage deposits across Europe, although it appears to have favoured a temperate, more oceanic climate (Kurtén 1968).

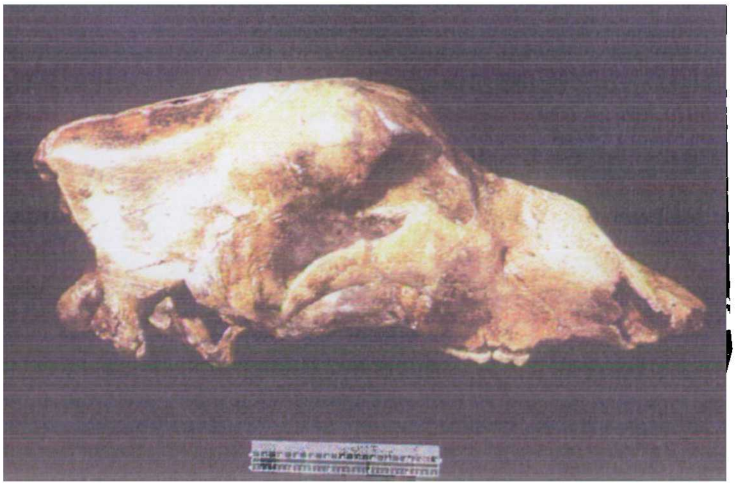


Figure 3.31 Cranium of *Ursus spelaeus* (M18966, N.H.M.L.), Basal Gravel, Swanscombe (right lateral view).

Mustelidae Swainson, 1835

Mustela erminea L., 1758, stoat

The stoat is slightly larger than the weasel but smaller than the polecat, although there can be some overlap between the bottom and top ranges of each species. The skull is flattened with a narrow brain-case. Five lower cheek teeth are present, all of which are highly specialised for a carnivorous diet. Unlike the polecat, the enamel of the lower incisor in the stoat is not rugose (Miller 1912). Little is known of the history of *M. erminea*, although the immediate ancestor is thought to be *M. palerminea* Kormos which was common in Europe until the end of the Cromerian. Stoats are today distributed throughout Britain and are present any habitat, at any altitude, where there is sufficient cover and prey. Woodland, moorland, mountainous areas and marshes are all occupied but open spaces are avoided (Corbet and Harris 1991).

Mustela nivalis L., 1766, weasel

As with the stoat, marten and otter, the weasel possesses a rather reduced dentition, adapted for slicing flesh. The weasel is the smallest British carnivore and can usually be distinguished on the basis of size, However, care is needed since all species of *Mustela* show marked sexual dimorphism (Stuart 1982). Furthermore, in both present-day stoats and weasels, there is a tendency for the average body size to decrease northwards, contrary to Bergmann's Rule (Kurtén 1968). Each species may therefore shift up or down a size category depending on climatic influence, and at the present day a southern European weasel may attain the size of a Scandinavian stoat. In addition, a closely-related and even smaller living counterpart, the least weasel *M. rixosa* Bangs, frequently replaces but also co-occurs with *M. nivalis* in northern Europe. The combination of sexual dimorphism and the effects of climate therefore render identification of fossil weasels extremely difficult, particularly with fragmentary material. Early Middle Pleistocene weasel remains from the West Runton Freshwater Bed, Norfolk, have been attributed to *M. praenivalis* Kormos (Kurtén *ibid.*), although most recent accounts list *M. nivalis* (Stuart 1996). The gradual transition from the ancestral species is thought to have been completed by the end of the Anglian/Elsterian (Kurtén 1968). A single record is known from the British late Middle Pleistocene, at Itteringham, Norfolk (6.3). *M. nivalis* is distributed throughout Britain at the present day, occupying a very wide range of habitats. In severe climates, woodland cover is preferred to open ground in winter, although weasels are capable of spending an entire season under the snow. In temperate, open country, the weasel is restricted to hedgerows and other cover (Corbet and Harris 1991).

Mustela putorius L., 1758, polecat

The polecat is intermediate in size between the stoat and the pine marten. The skull of *M. putorius* is robust and rather flat, with a short rostrum, a short, broad, braincase and long, nearly parallel-sided postorbital constriction (Figure 3.32). The upper canines are long, narrow and almost straight (Corbet and Harris 1991). The earliest record of polecat of modern type is from the Cromer Forest Bed (Kurtén 1968). Two records from the British late Middle Pleistocene are known, from Cudmore Grove (5.3) and Bleadon Cave (6.22). In the British Isles, the formerly widespread range of the polecat is today restricted to Wales and the border counties. A variety of habitats is occupied, including woodland, marsh, riparian and coastal environments (Corbet and Harris 1991).

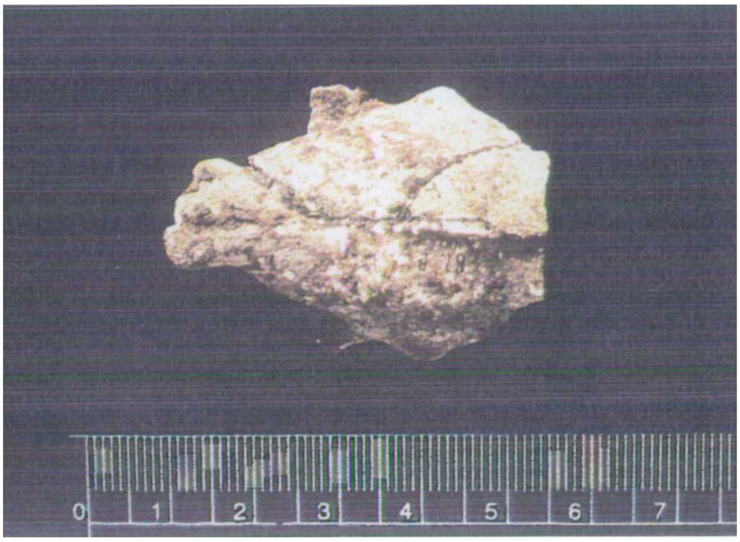


Figure 3.32 Partial cranium of *Mustela putorius* (TTNCM:41/1995/(~~G1007~~) Somerset County Museum), Bleadon Cave (dorsal view)

Martes martes (L., 1758), pine marten

The dentition demonstrates the typically sharp canines and cutting carnassials of the Mustelidae The upper incisors are small and four pairs of premolars are present in the upper and lower jaws, increasing in size from front to back. One upper and two lower molars are present. The first record of *Martes* in Britain is from the early Middle Pleistocene Forest Bed of Norfolk, which Kurtén (1968) attributes to the primitive *M. vetus* Kretzoi, the probable ancestor of *M. martes*. Kurtén further proposes that *M. martes* does not appear until the Late Pleistocene and refers all Middle Pleistocene martens to the ancestral species. A single record, from Swanscombe (4.2), is known from the British later Middle Pleistocene. The pine marten is today distributed throughout the forested areas of Europe, except in Spain, Greece and parts of the former Soviet Union (Corbet and Harris 1991). It is found in a wide range of habitats, including coniferous and deciduous woodland, scrub, moorland and coastal areas (Corbet and Harris *ibid*).

Meles meles (L., 1758), badger

The dentition of the badger is adapted for a~~n~~ more omnivorous diet than other British mustelids, with small chisel-like incisors and prominent canines. Specialised secodont teeth are absent and the molars are blunted and flattened to assist grinding, a trend which has developed since the Tertiary as an adaptation to a less carnivorous diet (Kurtén 1968). The P4 is triangular in form with a short, robust main blade (paracone) and a subsidiary blade in the form of a cusp (Hillson 1986). The M1 is very characteristic and comprises a broad rhomboidal crown with three cusps on the buccal edge and a rounded lingual edge. The mandible is straight and the basal edge rises sharply up to meet the ascending ramus (Turner 1990), whilst the cranium is relatively small with a prominent interparietal ridge. The postcranial skeleton is stocky but powerfully built, with comparatively short limbs, strong feet and claws. Remains of badger are uncommon in the British Middle Pleistocene record and seems to have been restricted to interglacial episodes, for example at Cudmore Grove (5.3), Itteringham (6.3) and the Otter Stratum at Tornewton Cave (6.21). The stratigraphic ranges of the fossil forms are poorly understood. The Middle Villafranchian badger from St. Vallier, France has been attributed to *M. thorali* Viret, a form thought to be ancestral to *M. meles*, whilst badgers very similar to the modern species are held to have inhabited Europe from the early Middle Pleistocene onwards (Kurtén 1968). *M. meles* is today very widespread throughout Britain, being absent only from areas of high altitude and lowland regions prone to flooding (Corbet and Harris 1991). A preference is shown for deciduous and mixed woodland habitats, although setts are also dug in hedgerows and scrub, coniferous woodland and open areas (Corbet and Harris *ibid*).

Lutra lutra (L., 1758), otter

Lutrine fossils are rare in the fossil record and remains of *L.* cf. *lutra* are known only from two British late Middle Pleistocene sites, Hoxne (4.1; Figure 3.33) and Grays (5.2). In comparison to other mustelids, the skull of *Lutra* is broad and low, with a narrow post-orbital constriction. The teeth have sharp cutting edges and the small premolars are opposed for greater trenchant action. The lower carnassial possesses three well-developed anterior cusps and a posterior heel (Miller 1912). The P4 has a sharp cutting blade on the buccal side, formed by the paracone and metacone (Willemsen 1990). The postcranial skeleton is adapted for an aquatic lifestyle, with short legs and a long, laterally flattened tail. An early Middle Pleistocene otter from the West Runton Freshwater Bed, Norfolk, has been attributed to an extinct species, *L. simplicidens* Thenius (Willemsen *ibid*) on the basis of both dental and postcranial differences from *L.*

lutra. Kurtén (1968) remarks that while the dentition of *L. simplicidens* may be more primitive than that of *L. lutra*, the limbs are more specialised. The two species are nevertheless closely related, although *L. simplicidens* is not considered to be the direct ancestor of the modern species (Kurtén *ibid*). Both Kurtén (*ibid*) and Willemsen (1990) consider that *L. lutra* does not appear in Europe until the Late Pleistocene. *L. lutra* is still found throughout much of Ireland and Scotland but is absent from central England. Population numbers have been in severe decline since the 1950s in other areas of England due to indiscriminate use of pesticides, water pollution, river management and human recreational activities (Corbet and Harris 1991). Otters inhabit lakes, rivers and streams and are capable of overland journeys between watersheds. In coastal areas, they may alternate between marine and freshwater habitats or live entirely on the coast (Corbet and Harris *ibid*).

Figure 3.33 Comparison of a left calcaneum (4682, N.H.M.L.) of *Lutra lutra* from Hoxne (AL3 West) (left) against a Recent specimen (right) (anterior view, scale in mm).

Cyrnaonyx antiqua (Blainville, 1841), extinct clawless otter

The dentition of the clawless otter differs from that of *Lutra* in possessing broader, blunt-cusped teeth which are adapted for crushing crustaceans and molluscs (Kurtén 1968).

The P4 is particularly broad, with a large talonid almost covering the lingual side of the trigonid. The lower premolars are very robust, as is the m1, which has a broad talonid that is lingually more expanded than in *Lutra* (Willemsen 1990). Two mental foramina are present in the mandible, one under the p2/p3 and one below the p4. *C. antiqua* has previously been included in the modern genus *Aonyx*, with which it has many features in common. The major differences justifying generic separation are, however, outlined by Willemsen in a revision of the Quaternary Lutrinae (Willemsen *ibid*). The postcranial skeleton also shows considerable differences from *Lutra* (Willemsen *ibid;* Singer *et al.* 1993). An otter previously included in the genus *Aonyx*, from Early Pleistocene deposits at Bramerton, Norfolk has been reassigned to *Enhydra reevei* (Newton) (Willemsen 1990). *C. antiqua* is considered by Kurtén (1968) to be the most advanced of the fossil species and was apparently distributed throughout Europe during the Holsteinian and Saalian (Willemsen 1990). This species has only been recovered from one later Middle Pleistocene site in Britain, from the Otter Stratum in Tornewton Cave (Sutcliffe and Zeuner 1962) (Figure 3.34).

Figure 3.34 Left dentary of *Cyrnaonyx antiqua* (N.H.M.L.), Otter Stratum, Tornewton Cave (left lateral view, scale in mm).

Hyaenidae Gray, 1869

Crocuta crocuta Erxleben, 1777, spotted hyaena

The spotted hyaena is one of the best-represented fossil carnivores. The dentition of *C. crocuta* is highly specialised. The post-carnassial molars are either vestigial or have been lost completely and the m1 is bi-cusped, as in felids. The canines are rather small, whereas the premolars have been modified into massive conical structures, adapted for crushing bones (Stuart 1982). Turner (1981a) has demonstrated that from the Ipswichian to the Devensian, there was a decrease in the tooth size of p1-3 and an increase in the size of p4-m1 in *C. crocuta*. This indicates an overall shift in power and chewing efficiency towards the more posterior cheek teeth during the Devensian. The ancestor of *C. crocuta* is thought to be the Villafranchian *C. sivalensis* (Falconer and Cautley), which radiated from India in the early Middle Pleistocene (Kurtén 1968). *C. crocuta* first appeared in Britain in the early Cromerian Complex at West Runton, Norfolk (Stuart 1974, 1996) and went on to be the only species of hyaena present in Britain during the later Middle Pleistocene. Later Cromerian Complex finds of *C. crocuta* include remains from Westbury-sub-Mendip (Bishop 1982). The species is apparently absent from Hoxnian deposits, such as Swanscombe (Sutcliffe 1964) (4.2), although it is present at Purfleet (5.1; Figure 5.10) and Grays (5.2; Figure 3.35). The European fossil form was considerably larger than the living African spotted hyaena, reaching a particularly robust maximum in the Late Pleistocene (Kurtén 1968). In addition to the fossilised bones and teeth of *C. crocuta*, the presence of this species in the past may be deduced from coprolites and from gnawed or digested bone fragments. Today, *C. crocuta* is restricted to sub-Saharan Africa, inhabiting savannah and semi-desert regions, where it both hunts and scavenges a wide range of prey.

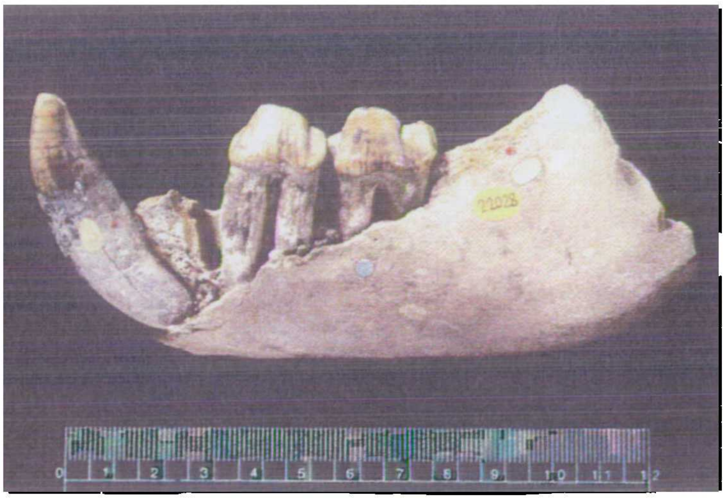


Figure 3.35 Left dentary of *Crocuta crocuta* (22028, N.H.M.L.), Grays (left lateral view).

Felidae Gray, 1821

Felis (*Lynx*) *lynx* (L., 1758), Northern lynx

Three species of lynx occurred during the Middle and Late Pleistocene, the extinct *Felis* (*Lynx*) *spelaea* and two extant forms, the Northern lynx *Felis* (*Lynx*) *lynx* and the Pardel lynx *Felis* (*Lynx*) *pardina* (Temminck) (Kurtén 1968). The Northern lynx is the largest of the three species and has a less secodont dentition than the other two (Bonifay 1971). The P4 is typical of the species and has a single large cusp (paracone), with an elongated parastyle on the buccal side, a low protocone on the lingual side and a flat, elongated metacone to the posterior (Turner 1990). The third cusp of the lower carnassial is particularly well-developed and around 10% of individuals possess a small second lower molar (Kurtén 1968). The most likely ancestral species is the Villafranchian Issoire lynx, *F. issiodorensis* Croizet and Jobert (Kurtén *ibid*). A single specimen attributed to *Felis* (*Lynx*) sp. has been recorded from early Middle Pleistocene deposits at Westbury-sub-Mendip (Bishop 1982). The earliest recognised finds of *F. lynx* are thought to be from the Weimar travertines, Germany (Kurtén 1968), traditionally attributed to the Eemian but quite possibly of Stage 7 age (Bridgland *et al.* 1997). However, a new record from Hoxne (4.1; Figure 3.36), tentatively attributed to *F. lynx*, would suggest that the history of the species perhaps extends back to the Hoxnian Interglacial. The lynx was relatively abundant during the Late Glacial in Britain but apparently disappeared from this country during the early Flandrian. The latest occurrences are in Mesolithic sites, such as Steetley Cave, Yorkshire (Jenkinson 1983). At the present day, the range of the Northern lynx has been restricted by human interference to the forested zones of Scandinavia and north-eastern Europe. Its dependence on mature woodland and dense undergrowth for a habitat would restrict its occurrence in the fossil record to boreal phases. The Pardel lynx is today confined to the Iberian peninsula, although during the Middle and Late Pleistocene, a large form of this species was also present in central Europe, where its range overlapped with *F. lynx* (Kurtén 1968).

Figure 3.36 Left astragalus fragment of cf. *Felis lynx* (right), Hoxne Lower Industry (4832, N.H.M.L.), compared with a modern Northern lynx from Labrador (left) (Newton Coll., N.H.M.L.) (anterior view, scale in mm).

Felis (*Felis*) *silvestris* Schreber, 1777, wild cat

Remains of small cats are relatively rare in the Middle Pleistocene fossil record. They are clearly separable from other felids on the basis of their small size, which is slightly larger than that of a domestic cat, whilst their dental and skeletal morphology is very similar to that of the lion in miniature. The ancestral species appears to be *F. lunensis* Martelli, which has been identified in the Forest Bed of West Runton (Kurten 1965). *F. lunensis* is characterised by the particularly short diastema between the canine and the first premolar, the absence of an accessory posterior cusp on the p3 and by the relatively high, short antero-posterior diameter of the main cusp on the p4 (Kurten *ibid*). *F. silvestris* itself does not appear until the Holsteinian and is first recorded from sites such as Heppenloch in Germany, Lunel-Viel in France (Kurtén *ibid*) and Swanscombe (Schreve 1996) (4.2; Figure 3.37). It is distinguished from the ancestral *F. lunensis* by a longer diastema, by the presence of a small accessory posterior cusp on the p3 and by its greater overall size. Kurtén (1965) suggests that the Heppenloch individual may be an intermediate form between *F. lunensis* and *F. silvestris*, implying that the transition occurred some time during the Anglian/Elsterian. Today, the wild cat is distributed in woodland, savanna and steppe zones from Europe to western China and India. In Britain, the range is restricted by the presence of the central Scottish industrial belt and the species is confined to upland forests, moorland and hills in central and northern Scotland (Corbet and Harris 1991).

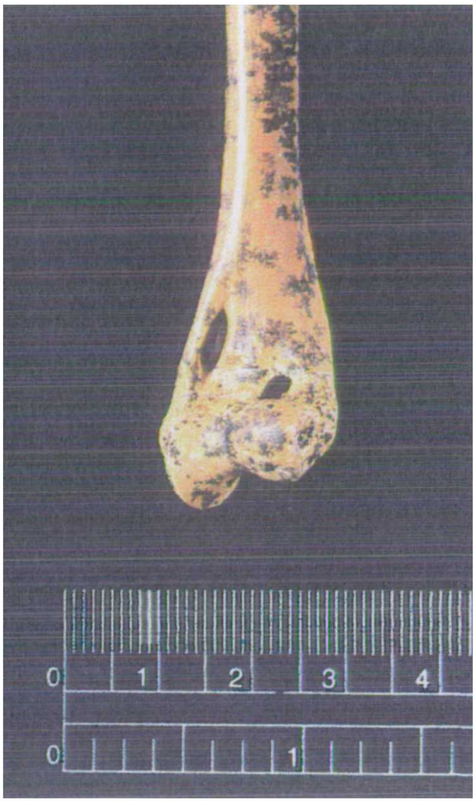


Figure 3.37 Left humerus of *Felis silvestris* (M43921, N.H.M.L.), Lower Gravel 'midden', Swanscombe (anterior view).

Felis chaus Güldenstaedt 1776, jungle cat

The jungle cat is skeletally similar to *F. silvestris* described above but the limb bones are relatively longer. A single record, discovered by the author at Aveley (6.1) during this study, is known from Britain. The finds consist of an articulating right humerus, radius and ulna, a proximal right scapula, two metacarpals and a first phalanx. The present-day distribution of *F. chaus* extends from Egypt across central Asia to southern China. The preferred habitat is marshland and open grassland.

Panthera leo (L., 1758), lion

The taxonomy of the Pleistocene lion is unclear, since the validity of the genus *Panthera* has been questioned (Anderson and Jones 1984). Previous workers, such as Bonifay

(1971) have referred this species to the genus *Felis*, calling it *F. spelaea* but the name *Panthera* is retained here. Much of the confusion stems from the pronounced sexual dimorphism shown in the fossil lions, which has caused their erroneous separation into various species and subspecies. The lion is the largest of the later Middle Pleistocene fossil felids found in Britain and was present in both warm and cold stages. The mandibles are large with a straight horizontal ramus (Figure 3.38). In the upper dentition, the cheek teeth are reduced to P3, P4 and M1.

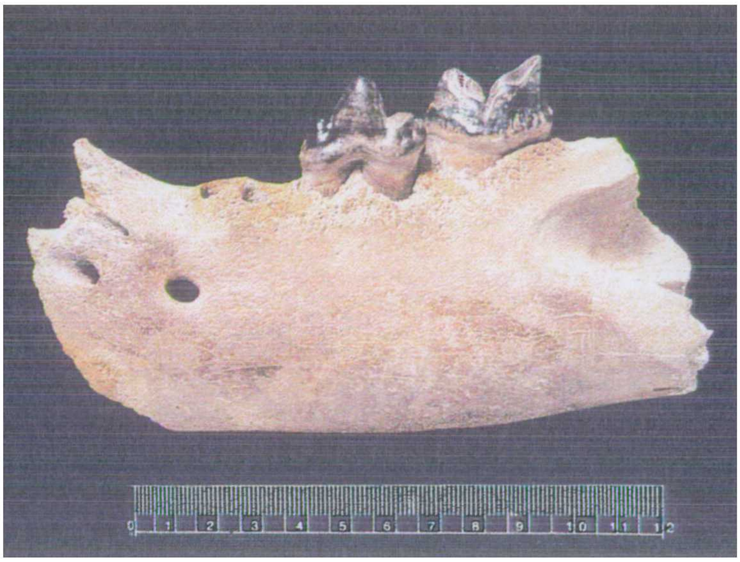
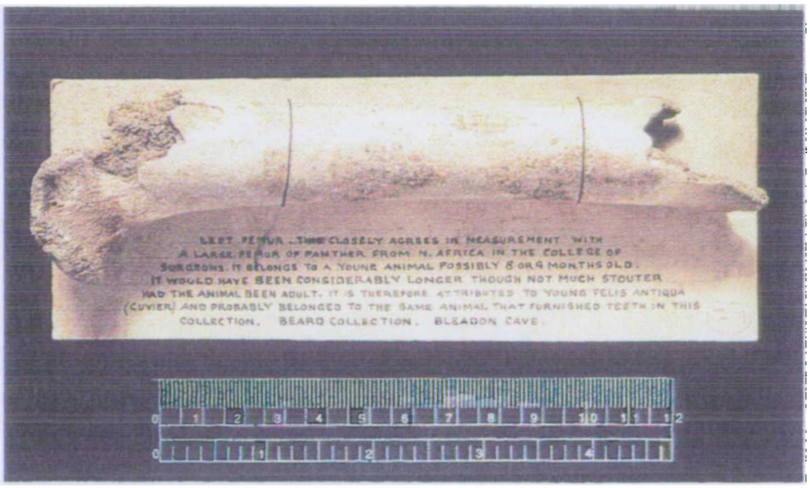


Figure 3.38 Left dentary of *Panthera leo* (M48385), Lower Channel, Marsworth (left lateral view).

The deposits at Westbury-sub-Mendip may record the earliest occurrence of *P. leo* in Britain (Turner 1995), although Stuart (1982) lists its presence at Pakefield, Suffolk, in deposits of earlier Cromerian Complex age. With regard to the later Middle Pleistocene, the lion was apparently the most abundant predator during every interglacial, with the exception of Stage 9 (see Chapters 5 and 8). The lion probably survived in the Balkans and Asia Minor in historic times but these groups have since been eradicated by human hunting, as have other populations in the Arabian peninsula, North Africa and the South African Cape. Only two groups of lion exist at the present day, a small group in the Gir Forest of India and a much larger population in East Africa.

Panthera pardus L., leopard

Remains of leopard are extremely rare in the British Pleistocene record. A small leopard-like cat *P. pardoides* (Owen) recorded from the Antian-early Baventian cliff deposits at Easton Bavents, Suffolk (Spencer 1959) was long thought to be the probable ancestor of later leopards (Kurtén 1968). However, the specimen in question has since been re-identified as belonging to a large cheetah, *Acinonyx pardinensis* Croizet and Jobert (Turner 1995). A large leopard, *P. gombaszoegensis* (Kretzoi) (similar in size to the jaguar *P. onca* (L.), intermediate between the modern leopard and lion), has been recorded from the early Middle Pleistocene site of Westbury-sub-Mendip (Bishop 1982) and is probably present as the smaller of the two large felids in the type Cromerian deposits at West Runton, Norfolk. *P. gombaszoegensis* has not been certainly recorded in Britain later than the Anglian, although a latest possible occurrence at Swanscombe been suggested by Turner (1995), although it is not clear what this identification is based upon. Remains of *P. pardus* are considerably smaller than *P. gombaszoegensis*. Like the lion, *P. pardus* entered Europe at the beginning of the Cromerian complex and is first recorded at Le Vallonnet, France (Turner *ibid*) and later at Mauer, Germany (Kurtén 1968). Later Middle Pleistocene records of this species in Britain are apparently restricted to two cave deposits of Stage 7 age, such as Bleadon Cave (6.22; Figure 3.39) and Pontnewydd Cave (6.25). At the present day, the leopard is distributed throughout the Old and New World in a wide variety of environments, from tropical rainforest and savanna to steppe and montane regions above the snow-line (Kurtén 1968).



LEFT FEMUR. THIS CLOSELY AGREES IN MEASUREMENT WITH
A LARGE FEMUR OF PANTHER FROM N. AFRICA IN THE COLLEGE OF
SURGEONS. IT BELONGS TO A YOUNG ANIMAL POSSIBLY 8 OR 9 MONTHS OLD.
IT WOULD HAVE BEEN CONSIDERABLY LONGER THOUGH NOT MUCH STOUTER
HAD THE ANIMAL BEEN ADULT. IT IS THEREFORE ATTRIBUTED TO YOUNG FELIS ANTIQUA
(CUVIER) AND PROBABLY BELONGED TO THE SAME ANIMAL THAT FURNISHED TEETH IN THIS
COLLECTION. BEARD COLLECTION. BLEADON CAVE.

Figure 3.39 Femoral shaft of juvenile *Panthera pardus* (TTNCM:41/1995/<G870>, Somerset County Museum), Bleadon Cave (right lateral view).

3.9. Proboscidea

PROBOSCIDEA Illiger, 1811

Elephantidae Gray, 1821

Palaeoloxodon antiquus (Falconer and Cautley, 1845), straight-tusked elephant

This species is frequently referred to as *Elephas antiquus*, following Maglio (1973) who considers diagnosis of the genus *Palaeoloxodon* to be inadequate. However, the name *Palaeoloxodon* will be retained here, since it is the name most commonly employed in British Quaternary literature (for example Stuart 1982; Sutcliffe 1985; Lister *et al.* 1990). The molar teeth of *P. antiquus* are extremely distinctive and are normally easy to separate from those of *Mammuthus*. In *P. antiquus*, the teeth are relatively longer and thinner with a narrow crown, the plates more widely spaced and the enamel thicker and more coarsely wrinkled than in *M. primigenius* (Blumenbach, 1803). Further differences between the two species are also discernible in the early stages of tooth wear. In *P. antiquus*, the early stages of wear in the lamellae usually show a pattern of one elongated oval ring (annulus) flanked by two small, circular annuli on the occlusal surface (Figure 3.40). In contrast, the lamellae of all mammoth molars are subdivided into finger-like projections towards their apex, so in the early stages of wear, these form a line of small rings on the occlusal surface. A prominent median expansion often occurs during wear in the molar plates of *P. antiquus*, resulting in the highly characteristic rhomboid ('loxodont') lamellar form, which recalls in some respects that observed in the modern African elephant (*Loxodonta africana*), although slightly less exaggerated. As the common English name suggests, the tusks of *P. antiquus* are straight or only slightly curved. The postcranial skeleton is described in Adams (1877-1881), Andrews and Cooper (1928), Trevisan (1942, 1947), Melentis (1963), Beden and Guérin (1975) and Kroll (1991). Current evidence indicates the clear presence of *P. antiquus* in Britain by the late Cromerian Complex (for example at Ostend, Norfolk) and possibly even earlier, in association with the latest known *Mimomys* faunas at Kessingland/Pakefield, Norfolk. However, straight-tusked elephant is as yet unknown from the type Cromerian deposits at West Runton, Norfolk and from correlated continental sites, such as Voigtstedt, Germany (A. Lister pers. comm.). Straight-tusked elephant is a consistent faunal element of all post-Anglian interglacials, where it is usually found in association with temperate forest (Stuart 1982). It apparently became extinct in Britain at the end of the Last Interglacial, although it survived well into the Devensian in southern Europe (Stuart 1991).

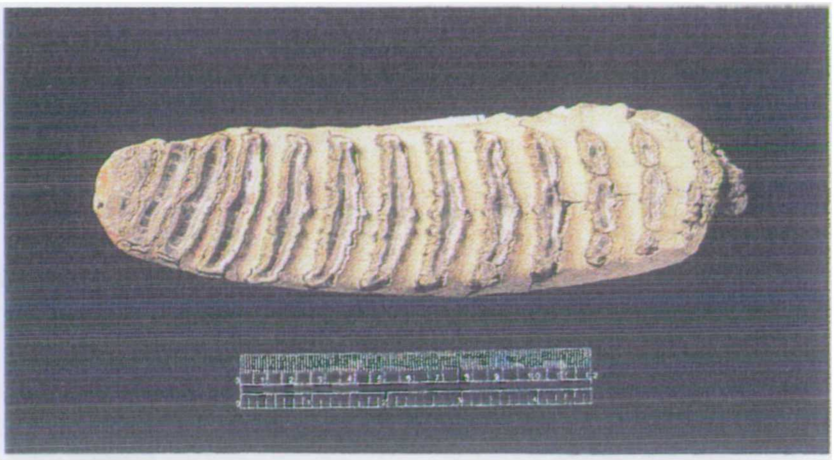


Figure 3.40 Right lower m1 of *Palaeoloxodon antiquus*, (22017b), Grays (occlusal view).

Mammuthus primigenius (Blumenbach, 1803), woolly mammoth

The mammoth lineage shows significant morphological change from the Late Pliocene through to the Late Pleistocene. Although important changes in the cranium and postcranial skeleton occur during this time period, the most commonly available and diagnostic elements are the molar teeth (Lister 1996). Three main trends are discernible in the molar teeth over time, which are particularly well-expressed in the M3. The crowns double in height, the number of enamel plates (lamellae) in the teeth doubles and the thickness of the enamel becomes reduced by about two-thirds (Lister 1993a). The increased 'tooth-life' resulting from these changes is thought to reflect an adaptation to the coarse vegetation of the 'steppe-tundra' biome, corresponding with a shift in the distribution of *Mammuthus* from warmer, forested habitats to cold, open regions during the Pleistocene (Lister *ibid*). On the basis of these trends, three chronospecies have been defined: the broadly Early Pleistocene *M. meridionalis*, the broadly Middle Pleistocene *M. trogontherii* and the broadly Late Pleistocene *M. primigenius*. Their chronological replacement and the lack of alternative ancestors imply that they represent an approximate evolutionary line of descent (Lister *ibid*).

However, caution should be employed when identifying specimens as overlap between the morphological ranges can be seen at successive stages in the sequence.

The steppe mammoth *M. trogontherii* in the type Cromerian at West Runton is of typically very large size, with high crowned molars and a relatively low plate count of 19-22 plates in the M3, compared to the standard Devensian *M. primigenius*, which counts an average of about 24 plates in the M3 (Falconer, in Murchison 1868). In the intervening period of time, it has been demonstrated that during successively later Middle Pleistocene interglacials, whilst plate number and hypsodonty index in the molars remain similar to *M. trogontherii*, there is a broad trend towards reduced size (Lister 1996). In the later Middle Pleistocene site of Uphall pit, Ilford, attributed to Stage 7 (6.2), the same plate count is retained, although size reduction in the tooth continues still further (Figure 3.41). The combination of small size and relatively low plate count has been noted as a consistent feature in the Ilford population by a variety of early authors, including Davies (1874), Adams (1877-81), Sandford (1924) and Moir and Hopwood (1939) and a similar combination of features has also been noted in certain teeth from other Stage 7 interglacial sites, including Northfleet (6.5), Brundon (6.6), the Lower Channel at Marsworth (6.10), Stanton Harcourt (6.11) and the Crayford brickearths (6.18). This has led to the conclusion that the presence of the 'Ilford type' mammoth may be of biostratigraphic importance. However, it must be emphasised that it is the combination of small size and low plate number which is significant in identifying the 'Ilford type' mammoth, since neither one of these characters is sufficient alone (Lister 1996 submitted). A further feature, which may be of biostratigraphic importance, concerns the degree of annulation in the molars. As wear progresses, the annuli rapidly fuse into a single, elongate lamellar structure but since mammoth teeth wear from front to back, a degree of annulation is normally present in the posteriormost lamellae in specimens of all stratigraphic ages (Lister 1996 submitted). In the Ilford sample and at a handful of other sites of probable Stage 7 age, the degree of annulation is particularly pronounced because the finger-like subdivisions are unusually deep. The annulated form of the lamellae therefore persists into the anterior part of the chewing surface. However, this feature evidently shows great individual and spatial variability, since it is absent from the Stanton Harcourt and Marsworth populations and from most of the Brundon specimens although it is present in some (but not all) specimens from

Crayford, Northfleet, Hutton Cave (Somerset) Stoke Tunnel (Suffolk) and Lexden (Essex) (Lister 1996 submitted).

Figure 3.41 Left first upper molar of *Mammuthus primigenius* (44934, N.H.M.L.), Ilford (occlusal view).

Molar evolution in the mammoth lineage has long been cited as an example of gradualistic change (see Lister 1993a, b, 1996 in press), although this apparently only holds true for the first *c* 2 million years of Eurasian mammoth evolution. Traditionally, it was thought that intermediate forms between *M. trogontherii* and *M. primigenius* began to occur as early as the Elsterian, that forms closer to *M. primigenius* than *M. trogontherii* appeared during the Saalian and that the fully-evolved *M. primigenius* was restricted to the Late Pleistocene, particularly in Devensian/Weichselian assemblages (Adam 1961; Kurtén 1968). However, it now seems that between *c.* 400 000 and 200 000 years B.P., more 'primitive' samples (such as the Ilford 'type' mammoths), which tend to be associated with wooded interglacial episodes, alternate with more 'advanced' samples, which are associated with colder, more open habitats and which predominate after 200 000 years B.P. Samples from apparently pre-Ipswichian, cold stage deposits, such as Homersfield, Norfolk, La Cotte de St. Brelade, Jersey, and Balderton, Lincolnshire appear as advanced as those from Devensian localities. Fully-evolved *M. primigenius* is therefore present in Britain well before the Devensian, and possibly as early as the Anglian (OIS 12?), if the stratigraphic position of sites such as Homersfield, Norfolk is correct (cf. Coxon 1979) and the provenance of their *M. primigenius* remains can be assured (see Chapter 8). Furthermore, at some of the Stage 7 sites, including

Marsworth and Brundon, molars of 'advanced' condition have been found in association with those of 'Ilford type' (Lister 1996 submitted). There is thus no clear morphological trend linking 'Ilford type' molars to typical Devensian ones and it may subsequently be reasoned that the 'Ilfordian' and Devensian types represent biological populations of subspecific or even specific status, which probably co-existed at certain points during the later Middle Pleistocene (Lister 1993a, 1996 submitted).

The tusks of *M. primigenius* are distinctly curved, in contrast to those of *P. antiquus*. The molars are also very diagnostic. As illustrated above, the crowns are broad and the plates are thin and closely spaced, with very thin, finely-wrinkled enamel. A thick layer of cement is often present, particularly around the edges of the occlusal surface. The plates in wear lack the median expansion seen in *P. antiquus* and instead form thin bands on the occlusal surface. Criteria for the identification of the postcranial skeleton are given in Adams (1877-1881), Osborn (1942), Garrutt (1964) and Olsen (1972). As already stated, during Stage 7, *M. primigenius* is found in association with temperate mixed-oak woodland and other interglacial elements. More usually however, the woolly mammoth is known from cold stage or interstadial deposits, in predominantly open grassland, steppe or steppe-tundra environments. It was previously thought that the mammoth had become extinct in Britain by the end of the last glacial maximum (*c.* 18 000 years B.P.). However, recent finds of mammoth from Condover, Shropshire, reveal that the mammoth was still present in this country during the late glacial, *c.* 12 800 years B.P. (Coope and Lister 1987).

3.10. Perissodactyla

PERISSODACTYLA Owen, 1848

Equidae Gray, 1821

Equus ferus Boddaert, 1785, horse

The taxonomy of the Pleistocene equids is extremely complicated and the number of different names assigned to the various forms is particularly confusing. '*Equus caballus*' has been used by certain authors to describe Pleistocene caballine horses (Prat 1966), although this term is only really appropriate for domesticated animals (Gentry *et al.* 1996). Consequently, the name *Equus ferus* has been applied throughout this work to all British later Middle Pleistocene caballine equids.

The cheek teeth of the Equidae are hypsodont with a complex pattern of enamel folds (Figure 3.42).

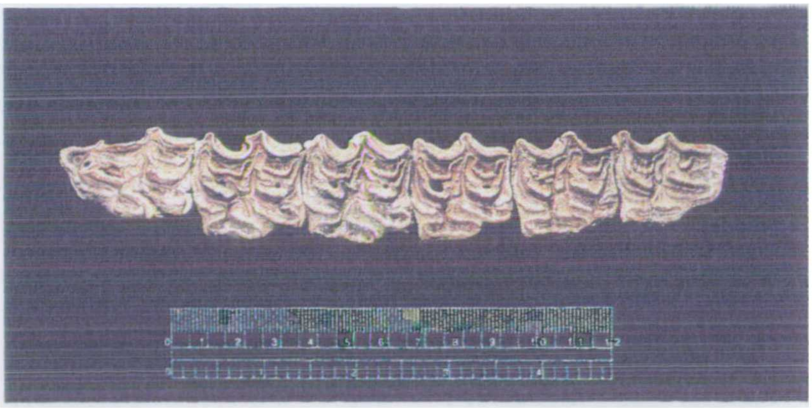
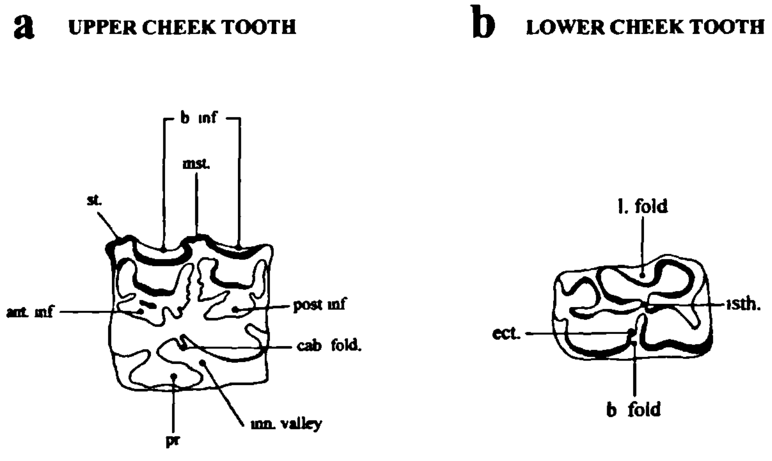


Figure 3.42 Associated L P2-M3 of *Equus ferus* (M25864a-f, N.H.M.L.), Aveley (occlusal view).

Two species with relatively primitive dental morphology, a medium-sized horse *E. stenonis* Cocchi and a larger animal *E. süssenbornensis* Wüst occur in deposits of early Pleistocene age, although only *E. süssenbornensis* persisted into the early Middle Pleistocene. The upper cheek teeth of these two species are characterised by a relatively short 'zebrine' protocone, whilst the inner valley often ends in a series of enamel folds or extends across the occlusal surface until it approaches the anterior infundibulum. The caballine fold is absent, the buccal infoldings are flat or only slightly concave and the vertical buccal grooves on the para- and mesostyle are usually missing (Turner 1990). The lower cheek teeth have a diagnostic 'V' shaped lingual fold and the buccal fold extends to the isthmus and occasionally beyond (Turner *ibid*). The first caballine horses also appeared during the early Middle Pleistocene and have most frequently been assigned to *E. mosbachensis* Reichenau (Prat 1966). The early caballines were of large size and possessed relatively advanced dentitions, compared to the stenonid forms. The upper cheek teeth (Figure 3.43a) are characterised by elongated 'caballine' protocones and the inner valley usually terminates in a simple caballine fold. The buccal infoldings are concave and both the para- and mesostyle have outer vertical grooves, although these may not be present in the upper dentition. The lower cheek teeth (Figure 3.43b) have a 'U' shaped lingual fold and the buccal fold does not extend beyond the isthmus (Turner 1990). However, 'primitive' characters can occasionally occur in the teeth of later Middle and Late Pleistocene caballine horses, so any attempt to date an assemblage on 'primitive' or 'progressive' morphology alone is generally not advisable (Turner *ibid*).



a UPPER CHEEK TOOTH

b LOWER CHEEK TOOTH

a: pr.: protocone; inn. valley: inner valley; cab. fold: caballine fold ant. inf.: anterior infundibulum; post. inf.: posterior infundibulum b.inf.: buccal infolding; pst.: parastyle; mst.: mesostyle
b: l. fold: lingual fold; b. fold: buccal fold; isth.: isthmus; ect.: ectostylid

Figure 3.43 Terminology used in the text to described the morphology of *Equus* upper cheek teeth (a) and lower cheek teeth (b) (modified from Turner 1990).

From the later Middle Pleistocene onwards, a general reduction in size can be seen in both the dentition and the overall body size of the caballine horses, although the variation is unfortunately not so great that specimens can always be referred with any certainty to one of the many named species. Furthermore, in the past, the age resolution of many of the sites was too poor to establish any meaningful succession (Forstén 1991). With an improved stratigraphic framework, some broad size changes have nevertheless been noted in British fossil horses throughout the late Middle Pleistocene. The most noticeable reduction in size occurs at the very end of this period when a substantially smaller species of caballine horse was present in Britain, in deposits attributed by the author to OIS 6, including the basal sands in Bacon Hole (7.1; Figure 7.3), Clevedon Cave (7.3) and Coombe rock deposits at Marsworth (7.4) and Black Rock, Brighton (7.7). A dental peculiarity, in the form of hypoconal constrictions, is also present in the upper molars of these small caballines. Although size decrease is usually believed to occur in response to climatic warming in accordance with Bergmann's Rule, during the Middle Pleistocene, Eurasian horses tended to have been particularly large during the temperate periods. If glaciations became increasingly rigorous through time, body size decrease in the later Middle Pleistocene horses may have been an adaptation to more rigorous climatic or vegetational conditions (Forstén 1996). Corroborative evidence for climatic severity during the cold stage immediately preceding the Last Interglacial is provided by mollusca at Bacon Hole (Stringer *et al.* 1986) and by periglacial deposits at Marsworth and Brighton.

The postcranial bones of the horse are relatively slender for such a large animal, whilst the third metapodials ('cannon bones'), with their single distal articulation, are particularly diagnostic (Schmid 1972). The second and fourth metapodials are reduced to small 'splint bones'. The *fossa plantaris* in the femur is particularly deep and a third trochanter is present. *E. ferus* was apparently ubiquitous in Britain during both warm and cold periods in the Pleistocene, although it is conspicuously absent from deposits of Last Interglacial age (Sutcliffe 1995a). The preferred habitat of the horse is grassland, although this may have taken the form of open steppe, woodland clearings or river floodplains during the different climatic stages of the Pleistocene.

Equus hydruntinus Regalia, 1904, extinct stenonid horse ('wild ass')

Remains of *E. hydruntinus* are generally scarce in Britain, possibly because of a lack of recognition. Eisenmann (1992) records that no good fossils of this species are known prior to those from Lunel-Viel in France (thought to be *ca.* 300 000 years old), although the presence of three specimens from Swanscombe (4.2) would substantially pre-date this record, if the attribution of Swanscombe to OIS 11 (Bridgland 1994) is correct. *E. hydruntinus* has also been recorded from the upper cave at Oreston, Devon, attributed to OIS 7 (6.24), whilst a potential third record from Marsworth, Buckinghamshire (Green *et al.* 1984) has proved to be a small form of *E. ferus* (see above). The shape of the skull in the *E. hydruntinus* from Lunel-Viel is closer to hemiones than to any other equid species (Eisenmann 1992). The microdont cheek teeth are primitive in aspect and can be differentiated on morphological grounds from those of recent asses (*E. asinus* L.) and onagers (*E. hemionus* Pallas). The protocone in the upper cheek teeth of *E. hydruntinus* is generally short, whereas in *E. asinus* and *E. hemionus* it is oval. The caballine fold is often weakly-present or absent and the end of the inner valley often extends across the occlusal surface until it is nearly touching the anterior infundibulum. The buccal infoldings between the parastyle and mesostyle are only slightly concave and are often flat, whereas the vertical groove on their buccal faces is normally absent (Turner 1990) (Figure 3.44). In the lower cheek teeth, the buccal fold is very deep and often touches the lingual fold. The ectostylid is often absent or only weakly-developed and the lingual fold is straight and sharply-pointed (Turner *ibid*). The postcranial bones are easily distinguished from *E. ferus* on the basis of their small size and noticeably slender form (particularly the third metapodials), although they are not sufficiently distinct in size from *E. asinus* and *E. hemionus* as to permit separation on fragmentary material alone. *E. hydruntinus* probably evolved from a horse similar to the early Middle Pleistocene *E. altidens* through a decrease in size but with little change in proportions (Forstén 1986). The species is recorded from both warm and cold stages in the European Pleistocene (Prat 1966) and apparently survived into the Neolithic (Bökönyi 1954). Its much greater predominance in southern Europe presumably reflects a liking for warmer climes and although little is known of its palaeoecology, the species probably favoured open herbaceous vegetation (Turner 1990).

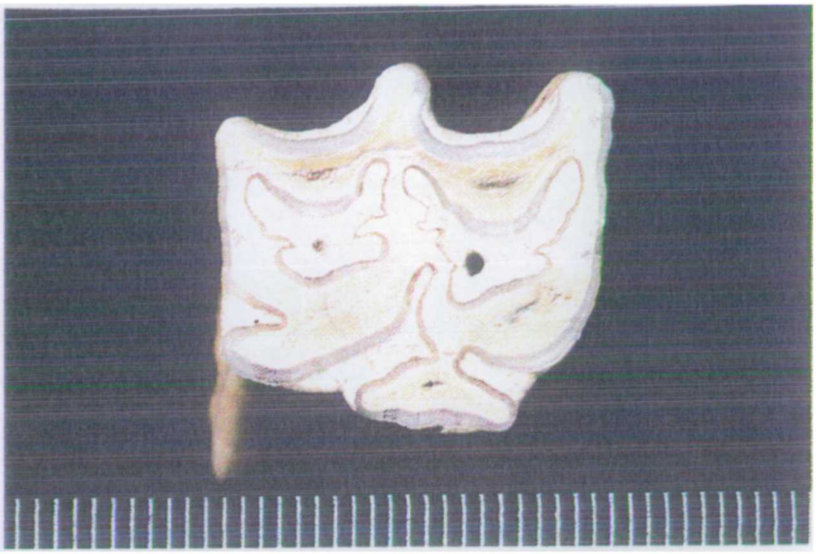


Figure 3.44 Sectioned right M2 of *Equus hydruntinus* (36920, N.H.M.L.), Oreston (occlusal view, scale in mm)

Rhinocerotidae Owen, 1845

The relationships of the European Plio-Pleistocene rhinoceroses are somewhat controversial (see Fortelius *et al.* 1993). Traditionally, all species of Middle Pleistocene fossil rhinoceros (excluding *Coelodonta*) have been assigned to the genus *Dicerorhinus* Gloger, although they have little in common with the living Sumatran rhinoceros (*D. sumatrensis* (Fischer) and may in fact be more closely related to the genus *Rhinoceros* Linnaeus (Groves 1983). Recent revision of Pleistocene rhinocerotid taxonomy has now placed the 'non-woolly' Pleistocene taxa in the genus *Stephanorhinus* Kretzoi (Groves *ibid*, Fortelius *et al.*1993), thereby establishing the distinction between the fossil forms and the living member of the genus *Dicerorhinus*.

Stephanorhinus hemitoechus (Falconer, 1868), extinct narrow-nosed rhinoceros

The skull of *S. hemitoechus* is very different in shape and proportions to *S. kirchbergensis* (Jäger) in that it is low and dolichocephalic, broad across the zygoma and orbits and the occipital plane is inclined backwards (Fortelius *et al.* 1993). The shape of the occiput is rounded. The maxillae and zygomatic arches are relatively slender, the nasals are low and the horn bases only weakly-developed. The mandible is lighter than that of *S. kirchbergensis*, with a comparatively slender and narrow symphysis. The angle between the ascending and horizontal rami exceeds 90°, since the ascending ramus is angled backwards (Fortelius *et al.* 1993). The dentition is relatively shifted forward, so that the anterior rim of the orbit lies above the contact between the M2 and M3. The cheek teeth themselves are high-crowned with finely rugose enamel and thick, locally-present cement. The profiles of the ectolophs show relatively strong undulations in the upper cheek teeth, a feature typical of *S. hemitoechus* (Guérin 1980) (Figure 3.45) and the ectoloph of the M3 is relatively long, compared to other species (Fortelius 1982). The anterior teeth are reduced and the posterior teeth enlarged, whilst the upper premolars frequently support a metacone style. The lower cheek teeth have pronounced vertical folds on the buccal sides between the meta- and hypolophids (Fortelius *et al.* 1993). Characters for the separation of the postcranial elements of *S. hemitoechus* are given by Fortelius *et al.* (*ibid*).

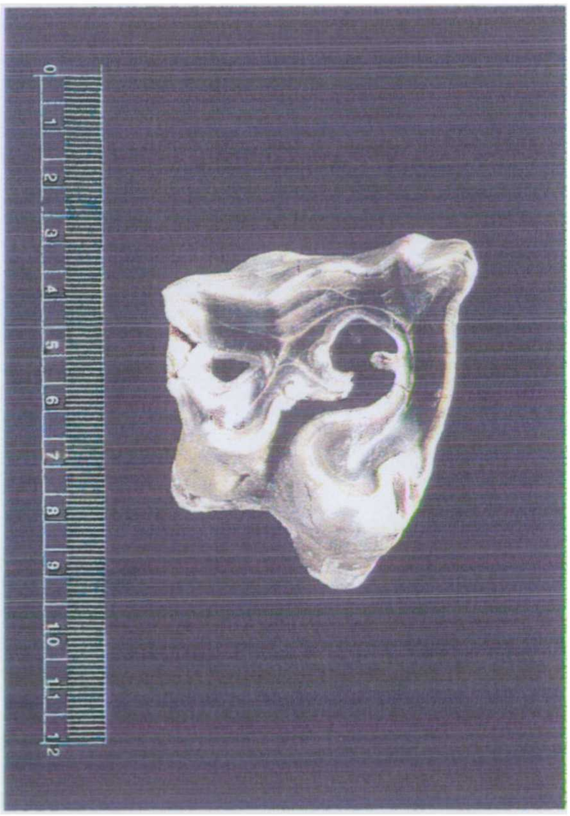


Figure 3.45 Right M2 of *Stephanorhinus hemitoechus* (M18793, N.H.M.L.), Grays (occlusal view).

S. hemitoechus is restricted to interglacial occurrences in Britain, although unlike *S. kirchbergensis*, its presence is thought to be indicative of the proximity of more open vegetational conditions. The short limbs of this species, combined with a low-slung cranium and hypsodont, ectolophodont molars suggest that *S. hemitoechus* was an intermediate feeder on low-growing vegetation (Fortelius 1982). The limb joints are relatively shallow and the proportions fairly cursorial, thereby indicating locomotion in a more open landscape (Fortelius *et al.* 1993). The first occurrence of this species in Britain is in later Middle Pleistocene deposits at Swanscombe, Kent, although it has been recorded on the continent at the early Middle Pleistocene site of Mosbach in Germany (Fortelius *et al. ibid*). *S. hemitoechus* was the only species of rhinoceros present in Britain during the Last Interglacial and finally became extinct during the Devensian.

Stephanorhinus kirchbergensis (Jäger, 1839), extinct Merck's rhinoceros

The skull of *S. kirchbergensis* is highly characteristic and is usually larger and deeper than that of other stephanorhines. Diagnostic characters are given by Zeuner (1934), Azzaroli (1962) and Loose (1975). The occiput is anteriorly-inclined and trapezoidal in shape, being larger at the base and lacking a pronounced occipital crest. The nasals, maxillaries and zygomatic arches are particularly massive. The anterior rim of the orbit lies above the M1, rather than further back as in *S. hemitoechus*, whilst the posterior edge of the nasal notch reaches only to the P3 (Fortelius *et al.* 1993). The mandible is massive and deep, with a strong, broad symphysis and an approximate angle of 90° between the horizontal and ascending rami. The dentition of *S. kirchbergensis* is also extremely diagnostic, since the teeth are relatively large with characteristically bulbous, inflated lingual lophs and very smooth enamel (Figures 3.46a and b).

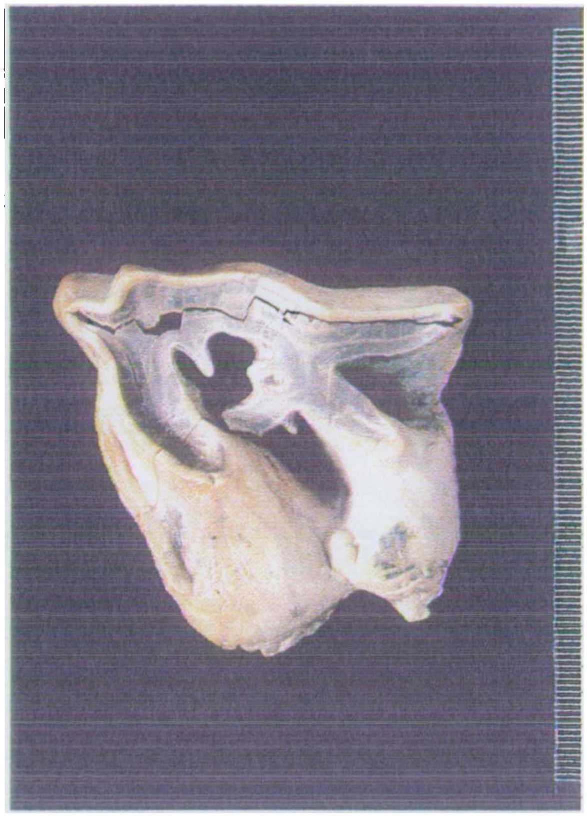


Figure 3.46a Left M2 of *Stephanorhinus kirchbergensis* (20249, N.H.M.L.), Grays (occlusal view, scale in mm).

Figure 3.46b Left M2 of *Stephanorhinus kirchbergensis* (20249, N.H.M.L.), Grays (left lateral view, scale in mm), showing inflated lingual lophs.

Coronal cement is usually absent. The premolars are quite hypsodont, while the molars are less so and the upper premolars are lingually short and mesially broad, a typical feature of the species (Fortelius *et al. ibid*). The profiles of the ectolophs in the upper cheek teeth are much less undulated than in *S. hemitoechus* (Guérin 1980), although the teeth are extremely ectolophodont since the buccal sides are much higher than the lingual (Fortelius 1982). Characters for the separation of the postcranial elements of *S. kirchbergensis* are given by Fortelius *et al.* 1993). The metapodials (particularly the third metacarpal and metatarsal) of this species are particularly recognisable, since they are much longer than in other Pleistocene rhinoceroses.

S. kirchbergensis is a characteristic element of forested interglacial episodes and first appears in Britain during the Hoxnian, at sites such as Swanscombe (4.2) and Clacton (4.4), although it has been recorded in an earlier context at the early Middle Pleistocene locality of Mosbach in Germany (Fortelius *et al. ibid*). Despite some disagreement over the latest records of this species in Britain (cf. Stuart 1976; Sutcliffe 1995a), *S. kirchbergensis* is very much in evidence at sites such as Ilford (Uphall Pit) (6.2), Lion Pit tramway cutting (6.4) and Crayford (6.18), attributed to the Ipswichian (Stuart 1976) or more recently to OIS 7 (Wymer 1988; Bridgland 1994; Sutcliffe 1995a). *S. kirchbergensis* disappeared from Britain during the ensuing cold stage (OIS 6), although it apparently survived on the continent until the end of the Eemian (Kurtén 1968). The absence of *S. kirchbergensis* from the British Last Interglacial has been explained by its failure to recolonise (along with its forest habitat) before a rise in sea level during the early Ipswichian cut off access to the island (von Koenigswald 1992). However, it is equally plausible that some of the continental sites with *S. kirchbergensis* may have been misattributed to the Eemian and may really be of Stage 7 age, thereby raising the possibility of extinction of this species across Europe during OIS 6. The ectolophodont dentition with very high-crowned premolars but moderately hypsodont molars, combined with a high head posture and long legs suggest that this animal was predominantly a browser. The strongly-concave limb articulations suggest locomotion in a closed forest or woodland environment (Fortelius *et al.* 1993).

Coelodonta antiquitatis (Blumenbach, 1807), woolly rhinoceros

Basic characters for the identification of this species are given by Bouchud (1966a) and Guérin (1980). The massive skull is very diagnostic, since the nasal septum is completely ossified. The occiput is large and squarish, with a heavy occipital crest. The teeth are large and hypsodont with extremely rugose enamel and layers of cement layers between the enamel folds on the occlusal surface and on the external walls. The upper dentition is highly distinctive since the crista and crochet fuse to form an isolated enamel islet (medifossette) on the occlusal surface (Figure 3.47).

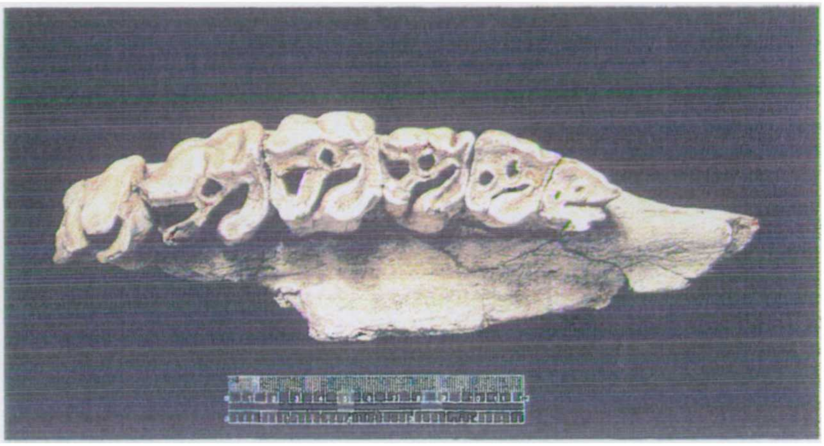


Figure 3.47 Right maxilla with P2-M3 *in situ* of *Coelodonta antiquitatis* (GSM 117013, British Geological Survey Museum), Northfleet (occlusal view)

The permanent lower cheek teeth are formed of two lobes which, when viewed from the lingual side, have 'V' shaped anterior valleys and 'U' shaped posterior valleys and pronounced external synclines (Turner 1990). With wear, the anterior lobe of the lower teeth assumes an angular form and the posterior a crescent form on the occlusal surface. The postcranial skeleton is relatively large and robust in comparison with the interglacial species of rhinoceros.

The earliest appearance of *C. antiquitatis* in Europe is a matter of contention, with both Anglian and Saalian occurrences cited. *C. antiquitatis* has been identified in Britain at three sites of reportedly Anglian age: Homersfield (Stuart 1982; Lister 1989), King's Newnham/Lawford Pit, Warwickshire and Lillington, Warwickshire (Shotton 1953; Lister 1989), and also at three Elsterian sites in Germany, namely Bad Frankhausen, Bornhausen and Neuekrug (Bouchud 1966a).

Guérin (1980), on the other hand, limits the first occurrence of the species to the Saalian, regarding the Saalian woolly rhinoceroses as a more primitive subspecies, *C. antiquitatis praecursor* and recognising a second subspecies, the more evolved and robustly-built *C. antiquitatis antiquitatis* as the Weichselian representative. According to Guérin, the M3s of the Saalian subspecies display a rectangular form, while those of the Weichselian animals possess a triangular form, although this biostratigraphical character has since been dismissed by van Kolfschoten (in van Kolfschoten and Roebroeks 1985). Guérin (1980) also considers the third metatarsal of *C. antiquitatis* to be shorter and stockier in the Weichselian than in the Saalian and the radius to be longer and stouter but again, little supporting evidence was found for this by Turner (1990) since fossils of *C. antiquitatis* tend to be extremely robust whatever the age of their deposit.

However, although there appears to be little basis for Guérin's proposed subspecific division of *C. antiquitatis*, recent investigation by van Kolfschoten (1990) and Turner (1990) into the later Middle Pleistocene mammalian biostratigraphy of the Netherlands and Germany respectively also places the first appearance of the species within the Saalian. Re-examination of the British evidence has drawn similar conclusions, since the provenance of the *C. antiquitatis* material at Lillington and the attribution of the remaining aforementioned British localities to the Anglian glaciation is debatable (see Chapter 8). The first appearance of *C. antiquitatis* in Britain is therefore considered to occur broadly within the Saalian and quite possibly in Stage 8, with sites such as Northfleet (6.5) and Stoke Newington, London (currently under reinvestigation, Schreve and White in prep.) being the most likely candidates to demonstrate this, although an Anglian age is also possible.

C. antiquitatis is usually associated with cold stage faunas and is a typical element of the open steppe. It is nevertheless recorded from interglacial deposits at Uphall Pit, Ilford (6.2), Northfleet (6.5), Crayford (6.18) and the upper cave at Oreston (6.24), attributed by the author to the later part of OIS 7, where its presence more probably confirms the opening-up of the environment and the development of steppic grassland as opposed to a cold climate. The low-slung head, compact build and hypsodont, plagiolophodont molars suggest that *C. antiquitatis* was a grazer (Zeuner 1934; Fortelius *et al.* 1993). The woolly rhinoceros is a common element of Devens an assemblages and continued to exist in north-west Europe until the end of the Late Pleistocene.

3.11. Artiodactyla

ARTIODACTYLA Owen, 1848

Suidae Gray, 1821
Sus scrofa L., 1758, wild boar

Sus is a surprisingly uncommon find in the fossil record and is restricted to interglacial faunas in north-west Europe. The tusks of the wild boar are easily recognisable, being triangular in cross-section and considerably smaller than those of the hippopotamus, with which they might possibly be confused (Stuart 1982). The molar teeth are well-adapted for an omnivorous diet, being low-crowned and bunodont with complex enamel wrinkles (Figure 3.48). The oldest record of the genus in Britain, from the Red Crag Nodule Bed, has been referred to *S. strozzi* Meneghini. Later remains, such as those from West Runton, Norfolk, are assigned to *S. scrofa* (Stuart 1996). The wild boar is a characteristic inhabitant of deciduous woodland and today enjoys a widespread distribution across Europe and Asia (Corbet and Harris 1991).

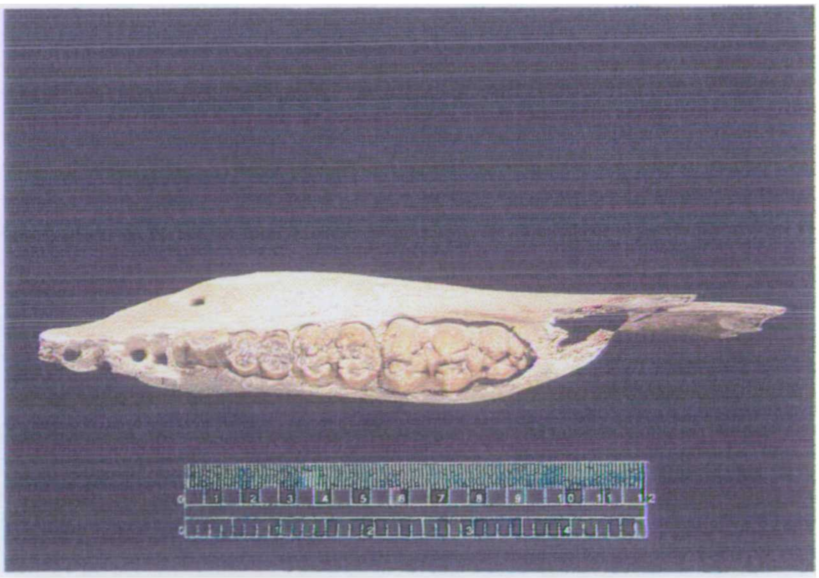


Figure 3.48 Left dentary with p4-m3 *in situ* of *Sus scrofa* (M21295, N.H.M.L.), Grays (occlusal view).

Cervidae Gray, 1821

Megaloceros giganteus (Blumenbach,1803), extinct giant deer

The earliest certain records of *M. giganteus* in Britain are from the Hoxnian interglacial, based on fossils from the Lower Gravel and Lower Loam at Swanscombe (Sutcliffe 1964) (4.2). Two possible earlier occurrences of this species are firstly, a skull from deposits attributed to the Anglian glaciation at Homersfield (Stuart 1982; Lister 1989) (although the exact provenance of this material is open to question (see Chapter 8) and secondly, an unstratified toe bone of a large cervid from Baginton-Lillington Gravels at Waverley Wood Quarry, Warwickshire (Shotton *et al.* 1993). The earliest entry of *M. giganteus* into this country may therefore have been during the Anglian. Megalocerine species pre-dating the appearance of *M. giganteus* in Europe include *M. savini* (early Middle Pleistocene) and *M. verticornis* (late Early to early Middle Pleistocene). The ancestor of *M. giganteus* may be one of these species, although a clear relationship has yet to be demonstrated (Lister 1994). The various species of *Megaloceros* may be identified by the form of their antlers, in particular the development of the basal tine. The antlers of *M. giganteus* are very diagnostic and commonly span 3.5 metres in large stags. However, antlers of *M. giganteus* from the Holsteinian '*antiquus* gravel' at Steinheim in Germany are remarkable for their narrow span (approximately 1.35 metres), due in part to their particularly upright orientation (Lister *ibid*). The Steinheim specimens also have peculiarly expanded, almost circular brow tines (Berckhemer 1941) which have not been observed in any of the numerous specimens of Late Glacial giant deer from Ireland. Although the three *M. giganteus* antler bases from Swanscombe are all incomplete, measurements of the width of the brow tine base where it inserts on the beam reveal the same broadness as seen in the Steinheim antlers (Lister *ibid*). It therefore seems possible that the Swanscombe giant deer also possessed these unusually broad brow tines, a feature of potential biostratigraphic significance. The outer surface of megalocerine antlers is smooth, while the horizontal curvature of the beam above the burr clearly differentiates antlers of *Megaloceros* from those of *Cervus* (Lister 1987) (Figure 3.49).

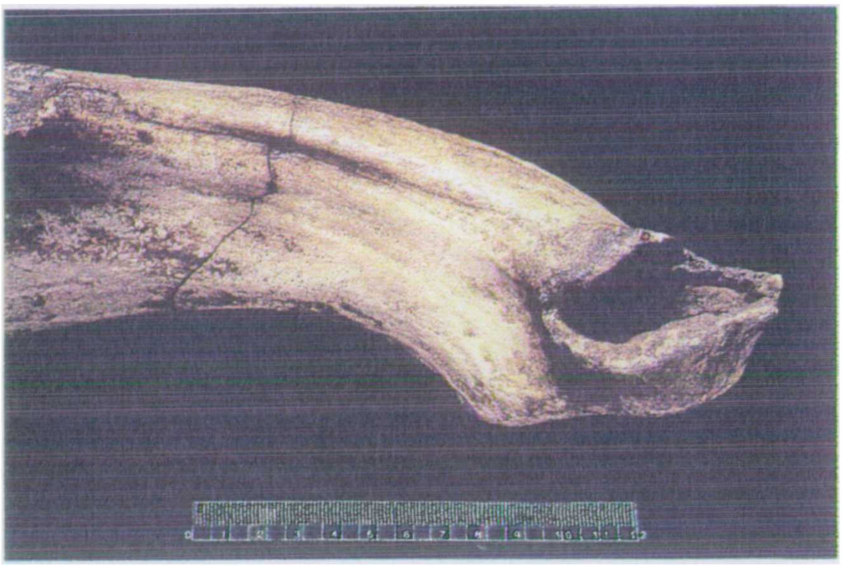


Figure 3.49 Shed right antler of *Megaloceros giganteus* (M20589, N.H.M.L.), Upper Middle Gravel, Swanscombe (anterior view)

In *M. giganteus*, a single basal tine is placed low down near the base of the beam. The mandible of *Megaloceros* is characterised by a thickening of the jaw below the m2-m3 (Turner 1990; Lister 1994). The teeth are similar to those of red deer in their morphology and rugose enamel but are substantially larger. Criteria for the identification of the postcranial elements are given in Lister (1981). *M giganteus* is known to have occurred in both warm and cold periods during the Middle and Late Pleistocene and probably inhabited more open areas, being restricted from dense forests by their enormous antlers (Stuart 1982). The giant deer is particularly common in Irish marl deposits pertaining to the Allerød interstadial (*ca.* 11 000 B.P.) before its subsequent extinction at the end of the Devensian.

Dama dama (L., 1758), fallow deer

The earliest known occurrence of fallow deer is in the West Runton Freshwater Bed (Azzaroli 1953; Lister 1984b). The fallow deer is today characteristic of mature deciduous or mixed woodland and all known Pleistocene occurrences of this species have been restricted to interglacial episodes. The antlers are very diagnostic, since they possess two tines and terminate in a broad, 'fingered' palmation. The surface of the antler in *D. dama* is also very different to that of *C. elaphus* Linnaeus, being much smoother and lacking the pronounced pearling seen in the latter. Remains of *Dama* from the Clacton channel deposits were given the species name *D. clactoniana* by Falconer (1868) because they differed from the living European *D. dama* in having a larger body size and antlers with a narrower palmation and an extra (third) anterior tine above the second (Figure 3.50).

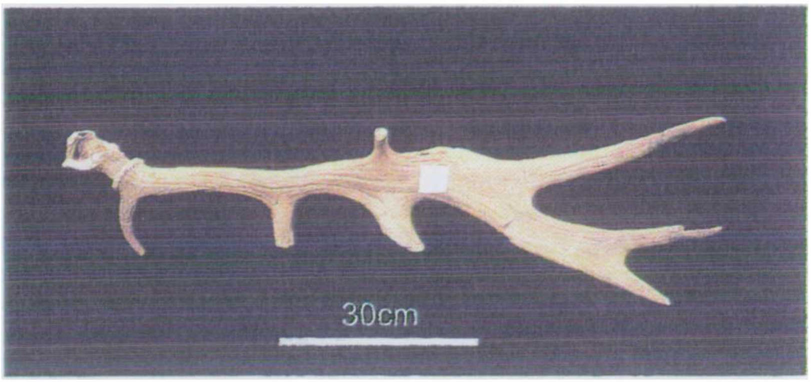


Figure 3.50 Unshed left antler and frontlet (A2 '0', N.H.M.L.) of *Dama dama clactoniana,* Lower Gravel 'midden', Swanscombe.

Following doubts about the validity of such a taxonomic distinction by Reynolds (1929), Bate (1937) and Sutcliffe (1964), the *clactoniana* form was later relegated to subspecific status (Leonardi and Petronio 1976). *D. d. clactoniana* Falconer is of particular biostratigraphic significance, since it is apparently only present in Britain during the Hoxnian interglacial. By the time of the Ipswichian interglacial, the fallow deer in Britain was of a size intermediate between Hoxnian and Recent British animals and probably possessed antlers very similar to the modern *D. d. dama* (Sutcliffe 1964; Lister 1986). The timing of the transition (if such occurred) from *D d. clactoniana* to *D d dama* therefore took place between the Hoxnian and Ipswichian interglacials, although the paucity of appropriate intermediate material has, to date, rendered greater precision impossible. Lister (1981) has identified various dental characters of biostratigraphic significance, particularly relating to the occlusal pattern, which may be used to differentiate Hoxnian *Dama* from Cromerian and Ipswichian samples. Criteria for the identification of the postcranial elements are also given in Lister (*ibid*). The fallow deer had become extinct in Britain by the Devensian but was reintroduced (almost certainly by the Normans) in the eleventh century, when it was released in forests as hunting quarry (Corbet and Harris 1991).

Cervus elaphus L., 1758, red deer

The earliest representatives of the red deer from continental 'Cromerian' sites such as Mosbach (Beninde 1937; Kahlke 1960), Voigstedt (Kahlke 1956b) and Süssenborn (Kahlke 1956a, 1969) have been assigned to the subspecies *C. e. acoronatus* Beninde due to the form of the antler, which consistently ends in a simple two-point fork instead of a many-pointed 'crown'. From the Hoxnian until the present day, red deer have possessed the genetic potential to develop a crown and are therefore assigned to the subspecies *C. e. elaphus* (Lister 1986). Today, the 'classic' formation in a modern mature male consists of brow, bez and trez tines and a fork or cup of points at the top of the beam (Figure 3.51), although this character is not expressed in all individuals in all populations. The timing of the transition from acoronate to coronate red deer is not precisely known, although it is presumed to have occurred at some point during the Anglian/Elsterian (Lister 1986). Di Stefano and Petronio have however identified a new subspecies *C. e. eostephanoceros,* which they believe to be an intermediate form, present in Europe during the late Galerian (Di Stefano and Petronio 1993). A further form "*Cervus*" *elaphoides,* founded by Kahlke (1960) on the basis of specimens from the Mosbach sands and thought to be a stratigraphic marker for the early Middle Pleistocene, has since been reidentified as juvenile *C. e. acoronatus* (Lister 1990).

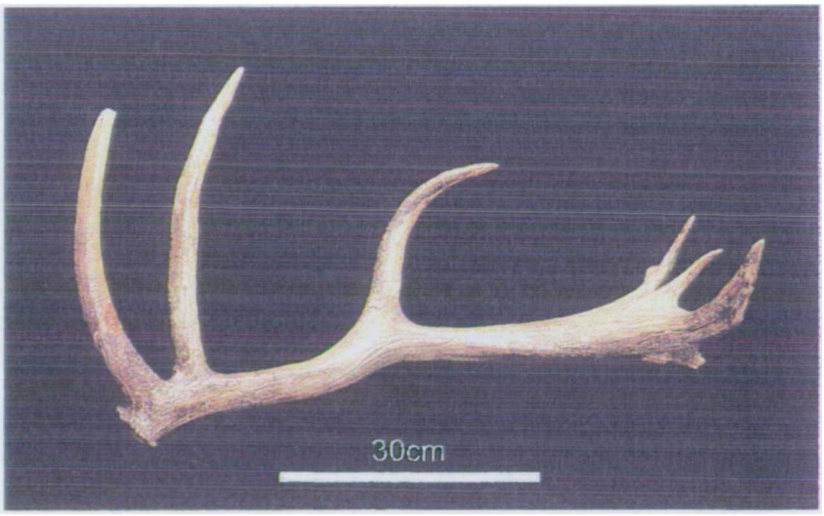


Figure 3.51 Shed right antler of *Cervus elaphus* (45335, N.H.M.L.), Ilford.

The antler beam in *C. elaphus* displays prominent 'pearling' and 'guttering', giving the surface of the antlers a characteristic 'knobbly' appearance. The dentition is of typical cervid form, with rugose enamel (Figure 3.52). Criteria for the identification of the postcranial elements are given in Lister (1981). Enormous size variation is visible in red deer between different Pleistocene episodes. Although generally more abundant during temperate stages, the red deer was present in both warm and cold episodes during the Middle and Late Pleistocene and is therefore not indicative of any one environment (Lister 1984b, 1986). Today, *C. elaphus* is widely distributed in many habitats throughout western Europe, Asia and North America, even ranging as far south as North Africa (Corbet and Harris 1991). In Britain, the red deer is now most commonly found on the open moorlands of the Scottish Highlands, although it was formerly widespread throughout woodland areas.

Figure 3.52 Right dentary with complete dentition of *Cervus elaphus* (19843, N.H.M.L.), Grays (occlusal view).

Alces alces L., 1758, elk

The precursors of this species, *A. gallicus* and *A. latifrons* occur in deposits of Late Pliocene to late Early Pleistocene, and early Middle Pleistocene age respectively in Eurasia (Lister 1984a, 1993a, b), with the latest known remains of *A. latifrons* in Britain from the type Cromerian West Runton Freshwater Bed. Claims for an intermediate form between *A. latifrons* and *A. alces* have been put forward at sites attributed to the Eemian (Kahlke 1975, 1976; Lister 1993a). A single upper molar from Grays (5.2) (Figure 3.53) has been identified as *Alces* sp. (Lister 1984a). Although the specimen is of the same size as *A. alces* (*i.e.* smaller than *A. latifrons*), there is not enough evidence to identify it to species level (A. Lister pers. comm.). The elk is an extremely rare component of Middle Pleistocene fossil assemblages in Britain, although its remains are slightly more common during the Devensian, Late Glacial and Mesolithic (Lister 1984a), probably in response to the development of boreal forest during these periods. Criteria for the identification of the postcranial elements are given in Lister (1981). The enamel of the teeth is smoother than in *Cervus* and *Megaloceros*. The premolars are more molarised than in other deer (with the exception of *Rangifer*) and the cusp pattern is highly distinctive (Stuart 1982) and the antlers are also readily diagnostic. The beam of *A. alces* is very reduced, horizontal, unbranched and devoid of tines, terminating in a broad, digitated palmation. A progressive and dramatic reduction in beam size is discernible over time, from *A. gallicus* - *A. latifrons* - *A. alces* (Lister 1993a, b). Today, the elk is restricted to zones of coniferous woodland in northern Europe, Asia and North America.

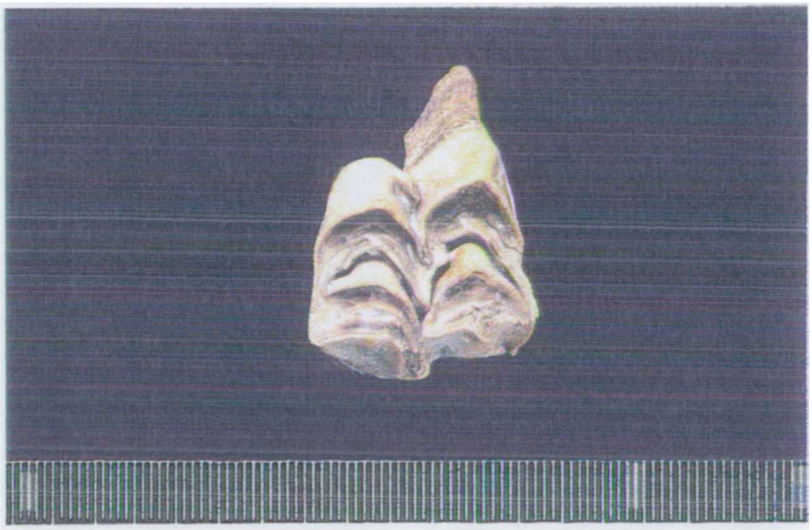


Figure 3.53 Left M1 or M2 of *Alces alces* (28079, N.H.M.L.), Grays (occlusal view, scale in mm).

Rangifer tarandus, L., 1758, reindeer

Although reindeer remains are apparently common throughout Europe in deposits relating to each of the major cold stages (Lister 1986), they are surprisingly uncommon in the British Middle Pleistocene. Following an early appearance in probable Anglian levels at Westbury-sub-Mendip (Stringer *et al.* 1996), no further unequivocal records of

R. tarandus are known from Britain until the Devensian, with the sole exception of Balderton, Lincolnshire, attributed to OIS 6 (Lister and Brandon 1991). Reindeer antlers are especially diagnostic and are carried by both sexes. The beam is long and slender, either sharply angulated halfway along or sweeping upwards in a pronounced forward-directed curve. Two basal tines are present, placed low down and usually with palmated ends. The beam and tines are relatively thick-walled and have a smooth outer surface with broad, shallow gutters. The teeth are smaller than in *C. elaphus*, rounded and very low-crowned, with smooth enamel and more pronounced folding of the enamel on the buccal and lingual faces (Turner 1990). Molarisation of the p3 and p4 is typical for this species. Criteria for the identification of the postcranial elements are given in Bouchud (1966b) and Lister (1981). The metapodials of *R. tarandus* differ from those of other cervids in possessing an extremely pronounced posterior groove with splayed distal epiphyses. Reindeer forms large herds and is still present in the tundra and taiga of most of northern Europe at the present day.

Capreolus capreolus (L., 1758), roe deer

The roe deer is the smallest of the British Pleistocene deer and fossil remains are thus easily recognisable on size alone. The antlers are short (less than 30 cm), very upright and heavily pearled, with a prominent coronet at the base (Figure 3.54). Three tines are usual in most mature male individuals. Roe deer is first recorded in Britain in the West Runton Freshwater Bed (Stuart 1975, 1996) and then appears in every succeeding temperate stage. Kahlke (1956b) has referred early Middle Pleistocene roe deer to *C. süssenbornensis* on the basis of their somewhat larger body size and more elliptical antler section than in living animals, although these characters have since been deemed insufficient for taxonomic distinction (Lister 1986). *C. capreolus* is generally associated with areas of suitable woodland cover (open mixed, coniferous or purely deciduous woodland) and is restricted to interglacial occurrences in Britain during the Pleistocene (Lister 1986; Corbet and Harris 1991). Roe deer (*Capreolus capreolus*) is however an uncommon element of the fossil record, being generally poorly-represented at those British Pleistocene fossil localities where it occurs. It is uncertain whether the lack of specimens reflects a genuine rarity of this species during the various interglacials or a general taphonomic bias against this species (Lister 1986).

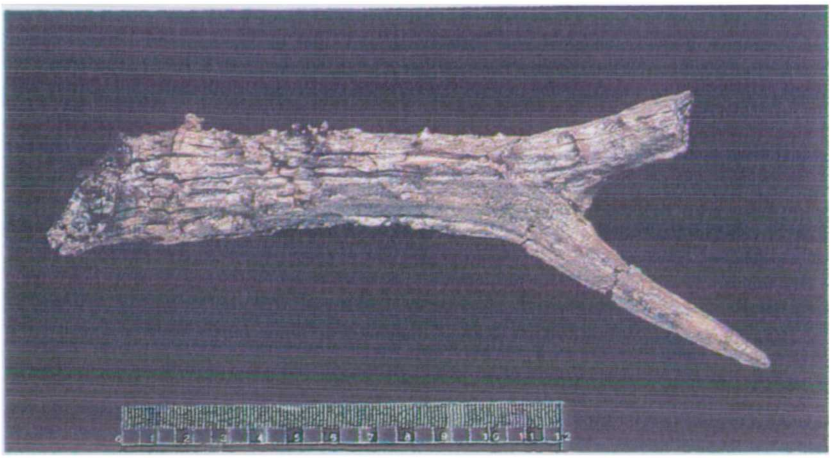


Figure 3.54 Unshed antler of *Capreolus capreolus* (13.16706, Harrison Zoological Museum), Cudmore Grove (posterior view).

Bovidae Gray, 1821

Bos primigenius Bojanus, 1827, aurochs and *Bison priscus* Bojanus, 1827, bison

Remains of large bovids (*Bos primigenius* or *Bison priscus*) are notoriously difficult to identify to species level and various attempts to define diagnostic characters based on postcranial bones or teeth have been made by a number of authors (Schertz (1936), Reynolds (1939), Olsen (1960), Browne (1983) and Gee (1993)). Further difficulties are presented by the pronounced sexual dimorphism in both *Bos* and *Bison* (the males being larger) and by the wide range of morphological variability in both species. The skulls and horn cores of the two species are however, easily separable. In *B. primigenius*, the horns are twisted in two planes, both forwards and upwards (Figure 3.55), whereas in *B. priscus*, the horns are angled upwards only (Figure 3.56).

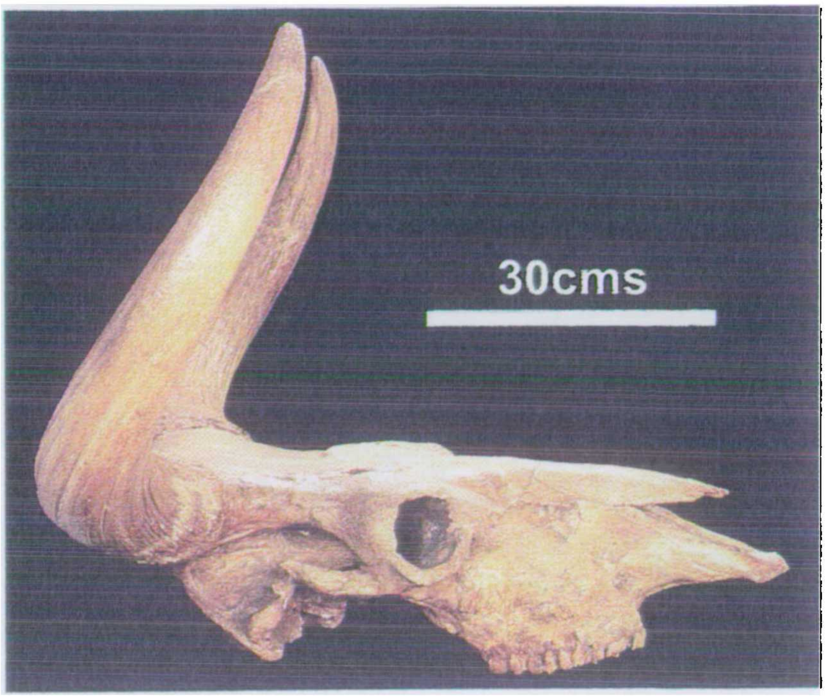


Figure 3.55 Complete cranium and horns of *Bos primigenius* (N.H.M.L.), Ilford (right lateral view).

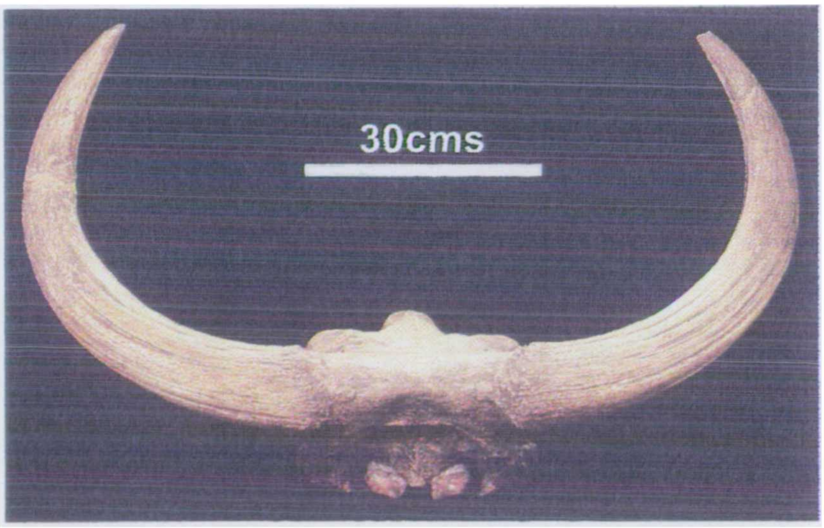


Figure 3.56 Incomplete cranium and horns of *Bison priscus* (45392, N.H.M.L.), Ilford (posterior view).

The metapodials (particularly the metacarpals) are also widely cited as displaying useful diagnostic features (Schertz 1936; Olsen 1960; Browne 1983; Gee 1993). Those of *B. primigenius* taper gently outwards from diaphysis to distal epiphysis (Figure 6.4), while those of *B. priscus* diverge outwards above the distal epiphysis, resulting in a 'shouldered' appearance. The applicability of other discriminant characters in the postcranial elements is discussed by Gee (1993). Attempts have also been made to identify *Bos* or *Bison* on the morphology of the upper and lower cheek teeth (Delpech 1983). The problem of separating the fossil remains of *Bos* and *Bison* has been compounded by questions as to the taxonomic validity of the two genera, since captive populations have been shown to be capable of interbreeding (Krasinska 1971). The two living species, the Eurasian wisent *Bison bonasus* L. and the North American *Bison bison* L. differ from each other in general body form and colour but the Pleistocene steppe bison, as portrayed in Upper Palaeolithic cave paintings, was apparently unlike either extant species. Reconstruction of a mummified *B. priscus* carcass from Alaska has revealed that in addition to differences in pelage colour and length, the dorsal hump in the Pleistocene bison was higher, more convex and placed more posteriorly along the spine than in any living bison (Guthrie 1990).

Bos primigenius first appeared in Britain during the Hoxnian interglacial at sites such as Swanscombe (4.2) and was present during each successive interglacial. Although *Bison priscus* is known from early Middle Pleistocene sites in Germany, such as Mauer and Mosbach (Turner 1990), the steppe bison does not seem to have entered Britain until after the Anglian, apparently replacing the small, gracile *Bison schoetensacki* Freudenberg, which was present in Europe during the Cromerian and has been tentatively identified at Waverley Wood (Shotton *et al.* 1993). *Bison priscus* is found in most interglacial and cold stage assemblages. The European bison today survives only as protected herds in Poland and the Caucasus, where it lives in mixed woodlands with some open areas (van der Brink 1967). The American bison prefers open grassland but also ranges into forested areas (Stuart 1982). Remains of the late Middle Pleistocene *B. primigenius* are found in association with mixed temperate woodland with some open grassland. The aurochs was finally hunted to extinction in the seventeenth century in Poland (Stuart 1982).

Ovibos moschatus Zimmerman, musk ox

Remains of musk ox are extremely rare in British late Middle Pleistocene sites and are known from Crayford (Dawkins 1872; Kennard 1940) (6.18; Figure 3.57) and Balderton (Lister and Brandon 1991) (7.6). Dawkins (1872) referred to the Crayford musk ox as the modern *Ovibos moschatus*, although Kennard assigned it to a new species, *Ovibos spurrelli*. An extinct species of larger, more lightly-built musk ox, *Praeovibos priscus* Staudinger, is recorded by an unstratified find from the Cromer Forest Bed Formation (Stuart 1982). Although the musk ox is restricted at the present day to the arctic tundra of northern Canada, Greenland and Alaska, the fossil distribution of this species indicates that its past range encompassed parts of Siberia, France, Germany and southern Britain at the height of the Last Glaciation (Dawkins 1863). The osteology of the musk ox is in many ways intermediate between *Bos* and *Ovis*. Dawkins (*ibid*) lists the tapering of the anterior part of the skull, the prominence of the orbit and the absence of an accessory column in the upper teeth as sheep-like characters. The limb bones are also relatively small in comparison with *Bos* and *Bison*. The skull of the musk ox is however highly characteristic, with massive thick-based horn cores covering most of the top of the cranium and almost meeting in the mid-line (Stuart 1982).

Figure 3.57 Associated right p4-m3 of *Ovibos moschatus* (50099, N.H.M.L.), Crayford (buccal view).

CHAPTER 4. THE HOXNIAN INTERGLACIAL

4.0. Introduction

This chapter will examine the mammals of the Hoxnian Interglacial. Nine sites are reviewed in this section, including the type-site of Hoxne (Suffolk), Swanscombe (Kent), Ingress Vale (Kent), Clacton-on-Sea (Essex), Barnham (Suffolk), Beeches Pit at West Stow (Suffolk), Copford (Essex), Hitchin (Hertfordshire) and Woodston (Cambridgeshire). The location of these sites is shown in Figure 4.1.

Recent debate over the age of the Hoxnian Interglacial has stemmed largely from the results of aminostratigraphy, which has split sites previously all considered to be of Hoxnian age into two groups, the older correlated with Stage 11 of the oxygen isotope record and the younger with Stage 9. Sites assigned to Stage 9 include Hoxne itself (Bowen *et al.* 1989) and Woodston Horton *et al.* 1992), while sites assigned to Stage 11 include Swanscombe, Ingress Vale, Clacton (Bowen *et al.* 1989) and Barnham (Ashton *et al.* 1994b). One would consequently expect there to be some faunal differences between the two groups since they potentially belong to quite separate interglacials. However, since all the aforementioned localities have been correlated at some point with the Hoxnian Interglacial on the basis of biostratigraphy, the possibility that two interglacials are producing the same signals in the fossil record must also be taken into account.

The following section will first analyse the evidence from Hoxne in order to establish the nature of the mammal fauna of the Hoxnian Interglacial and to identify species of biostratigraphic significance. This information will then be compared with mammalian evidence from the above-named localities and any similarities or differences noted. In this way, it is hoped to that the following questions may be addressed:

1. What are the species of biostratigraphic significance in the Hoxnian Interglacial ?
2. What are the differences (if any) between the mammal fauna from Hoxne and that from sites attributed to Stage 11 ?
3. Does the mammalian evidence support the differentiations based upon aminostratigraphy?

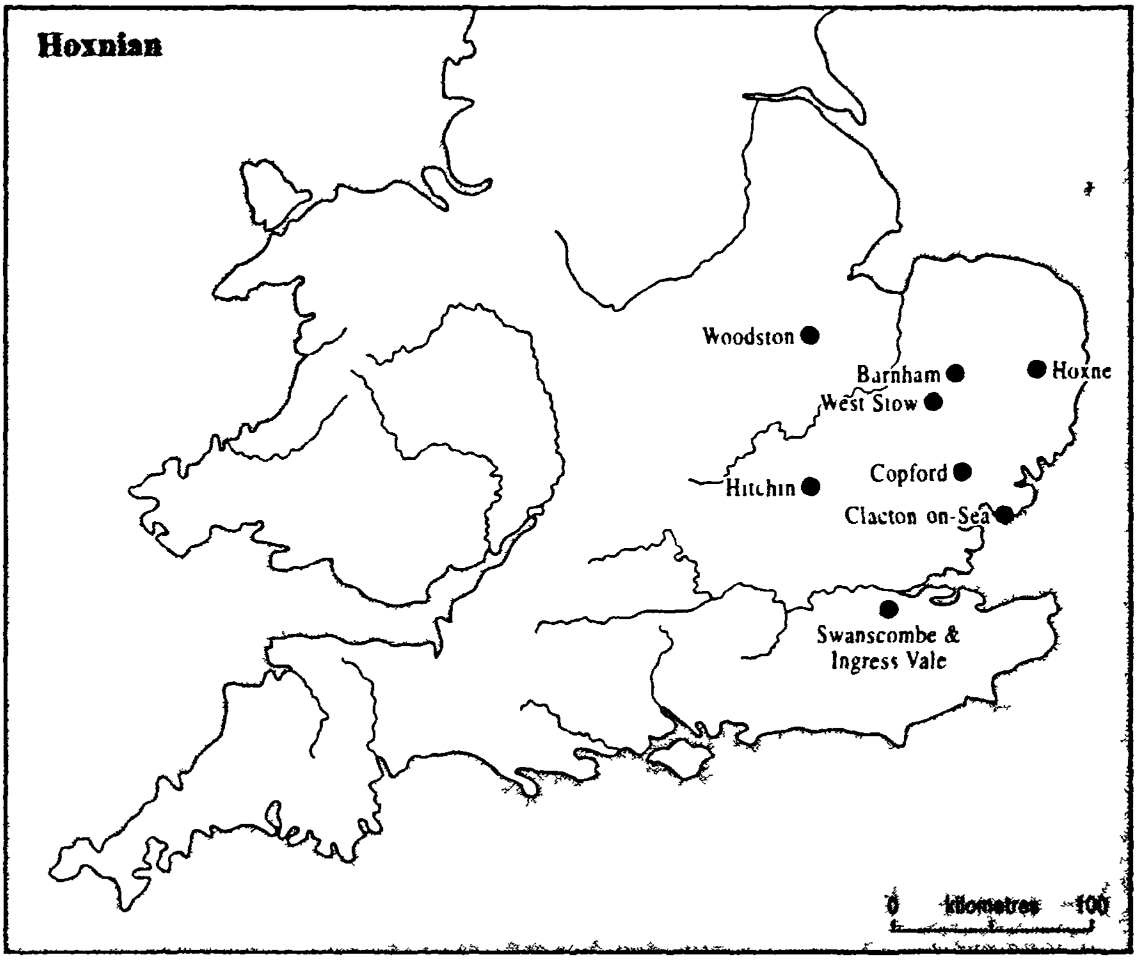


Figure 4.1 Location of Hoxnian sites.

4.1. HOXNE, SUFFOLK (TM 176769)

4.1.1. Location of the site

The village of Hoxne is located at 36m O.D. on the interfluve the River Dove and Goldbrook stream, near to their point of intersection with the River Waveney which divides the counties of Norfolk and Suffolk (Figure 4.2). The Palaeolithic site is situated in former brickworks, a short distance to the south of the village, on the Hoxne to Eye road. It comprises the Old Brick Pit on the east side of the road (the site of the very first investigations) and the Oakley Park Pit on the west side, which was opened around the latter part of the nineteenth century.

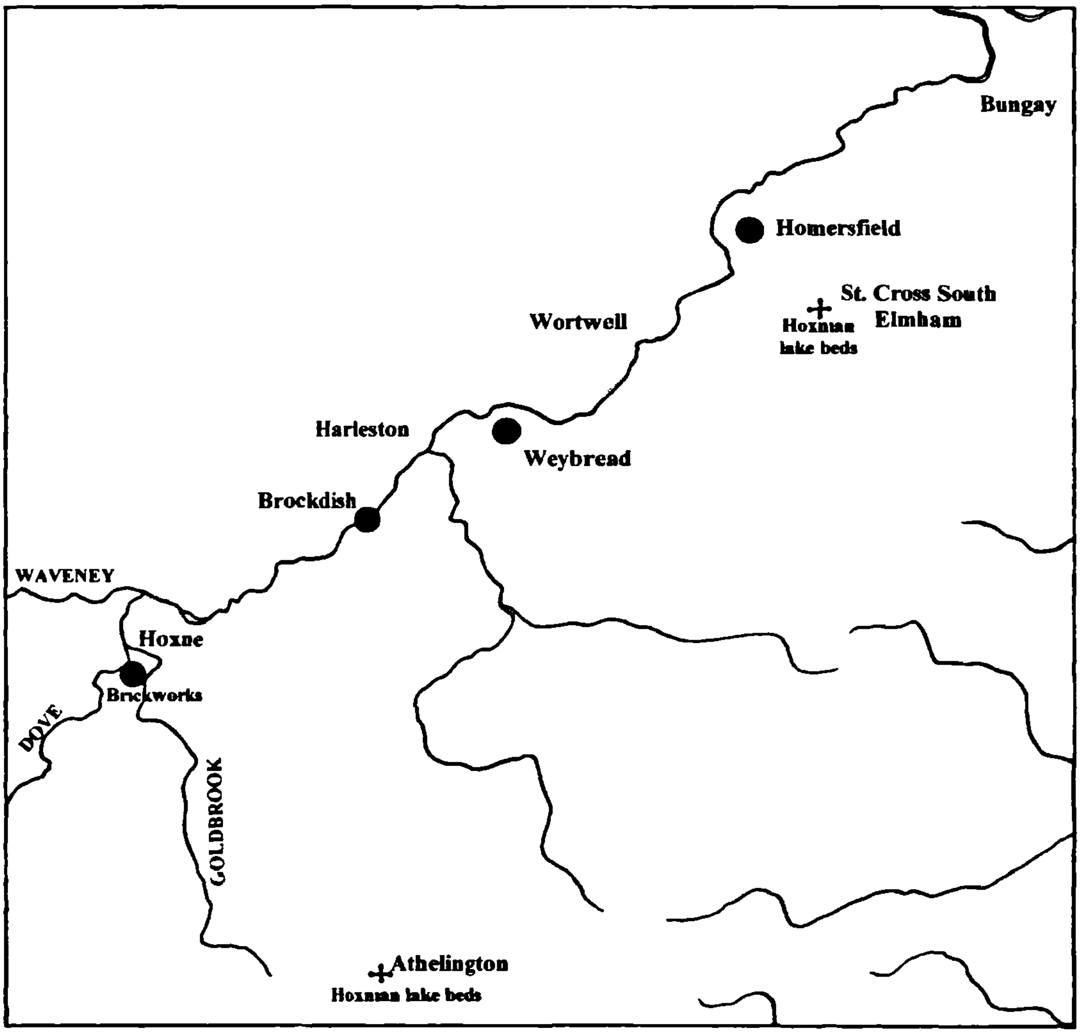


Figure 4.2 Location of the Hoxne brickworks (modified from Singer *et al.* 1993).

4.1.2. History of research

Hoxne is renowned as one of the most celebrated sites for archaeology and Quaternary science, since it was there in 1797, that John Frere first established the great antiquity of the human species. In his famous account to the Society of Antiquaries in London, Frere reported how he had witnessed the discovery of 'weapons of war, fabricated and used by a people who had not the use of metals' (Frere 1800). The flint tools (handaxes) that Frere observed, were associated with fragments of wood and with 'some extraordinary bones, particularly a jaw-bone of enormous size, of some unknown animal, with the teeth remaining in it' (Frere *ibid*). The significance of Frere's report lies in his perception of the stratigraphical relationship of the deposits overlying the handaxes to the present topography of the Waveney valley, with the inevitable conclusion that their deposition must relate to '.... a very remote period indeed; even beyond that of the present world' (Frere *ibid*). His inspired observations were unfortunately ignored until the 1850s, when the debate over the alleged association of flint implements with extinct animals and the question of Man's antiquity was reopened.

In 1859, Joseph Prestwich and John Evans returned from Abbeville, convinced by Boucher de Perthes that flint tools were indeed contemporary with an extinct fauna. They revisited Hoxne to confirm Frere's findings (Evans 1860), whereupon Prestwich carried out some excavations and opened several boreholes. He was able to demonstrate that all the deposits there lay in a hollow in glacial till and that they mainly comprised the infillings of a freshwater lake (Prestwich 1860). Around that time, various people appear to have been active in the collection of flint implements from the pit but no more serious investigations were carried out until those undertaken by Belt (1876). Other early references to the site appear in Whitaker and Dalton (1887) and in Reid and Ridley (1888). Reid and Ridley (*ibid*) demonstrated that the clay was lacustrine and contained deposits with arctic and temperate plant remains. These small-scale explorations culminated in the commissioning of much more detailed systematic excavations, which were undertaken in 1895 by Clement Reid on behalf of the British Association (Evans *et al.* 1896). These excavations attempted to ascertain the relationship of the Palaeolithic deposits to the underlying glacial deposits and to the lacustrine beds. Evans *et al.* (*ibid*, 411) concluded that "the Palaeolithic deposits at Hoxne are therefore not only later than the latest Boulder Clay of East Anglia, but are separated from it by two climatic waves with corresponding changes in the flora". Reid thus interpreted the succession correctly, noting that the Arctic conditions succeeded the temperate lake beds.

A hiatus in scientific investigation at the site then occurred until after the end of World War I, but the commercial extraction of the brickearth continued, and following the exposure of new deposits in the 1920s, further excavations were undertaken by J. Reid Moir between 1924 and 1926 on behalf of the British Association and then again in 1934 on behalf of the American School of Prehistoric Research. Moir established the presence of at least two separate Palaeolithic industries but his interpretation of the stratigraphy was confused by his preconceived ideas of artefact typology (Moir 1926, 1934, 1935). Between 1951 and 1954, extensive stratigraphical and palaeobotanical studies were carried out by R.G. West, allowing a detailed interpretation of the sequence to be established for the first time (West 1956). Most significantly, the pollen analyses established the fully interglacial nature of the lower series of deposits and established Hoxne as the type site for the Hoxnian Interglacial in Britain. These studies were carried out in conjunction with new investigations into the archaeological industries at the site by McBurney (West and McBurney 1954). The final series of multidisciplinary excavations was undertaken by R. Singer and J.J. Wymer of the University of Chicago (Wymer 1983, 1985; Gladfelter 1973, 1975a, b, c; Singer and Wymer 1976; Singer *et al.* 1993). These excavations exposed nearly all the previously recorded strata and important collections of faunal and archaeological material were made. Brickmaking at the pit had ceased by that time, although clay was still being dug for the manufacture of pipes until 1955 (Singer *et al.* 1993). The Old Brick Pit is now partly overgrown and partly used as a contractor's yard and the Oakley Park Pit is now levelled and landscaped and contains a private residence.

4.1.3. Geological background and provenance of mammalian remains

The stratigraphic sequence at Hoxne will be reviewed in some detail below, since this site is the type locality for the Hoxnian Interglacial.

The Hoxne interglacial deposits fill a depression in the Lowestoft Till. It has been suggested that the depression in question is a kettle hole (West 1956), but since no corroborative evidence of such as slumping or faulting of the surrounding till has been observed, it is more likely that deposition occurred in a poorly-drained ground moraine swale, immediately following retreat of the Anglian ice (Gladfelter, in Singer *et al.* 1993). The elevation of the lake clay margin varies from about 32m O.D. on the west shore to about 23m O.D. on the south-east shore (West 1956). The basin is estimated to have been 550-600m in diameter with a depth of up to 14m of water (Gladfelter, in Singer *et al.* 1993). The deposits may be divided into a lower and an upper sequence, separated by an unconformity. A schematic cross-section of the deposits is shown in Figure 4.3.

The observed stratigraphic succession is as follows:

Lower Sequence:

Stratum G: 'Chalky Boulder Clay', 4-20m thick. This is a glacial till attributed to the Anglian Lowestoft Till and deposited by ice moving in a general west-east direction (West 1956; West and Donner 1956). The till lies immediately beneath the interglacial deposits and is exposed in several places in the brickworks. No erosional unconformity is apparent at the junction between the till and the overlying interglacial deposits, thereby indicating that the basin was not eroded in the till before the deposition of the interglacial sediments and that sedimentation began soon after the disappearance of the ice (West *ibid*). The till consists of a stiff blue-grey sandy clay with abundant striated chalk pebbles, flints and other rocks including many of Jurassic origin, passing upwards into a grey sandy clay with small chalk pebbles (West *ibid*). No artefacts or faunal remains have been recovered from this unit, although a pollen spectrum is reported (West 1956; Mullenders, in Singer *et al.* 1993).

Stratum F: Lacustrine clay-mud, up to 45cm thick. This represents the earliest depositional unit within the basin that was formed in the till surface on retreat of the glacial ice. This unit consists of hard grey, slightly sandy, very calcareous clay-mud, but towards the base there is considerable lithological variation, with bands of chalky pebbles, coarse sandy detritus mud with compressed twigs and seeds, shelly marl with abundant seeds and shelly clay-mud variously present.

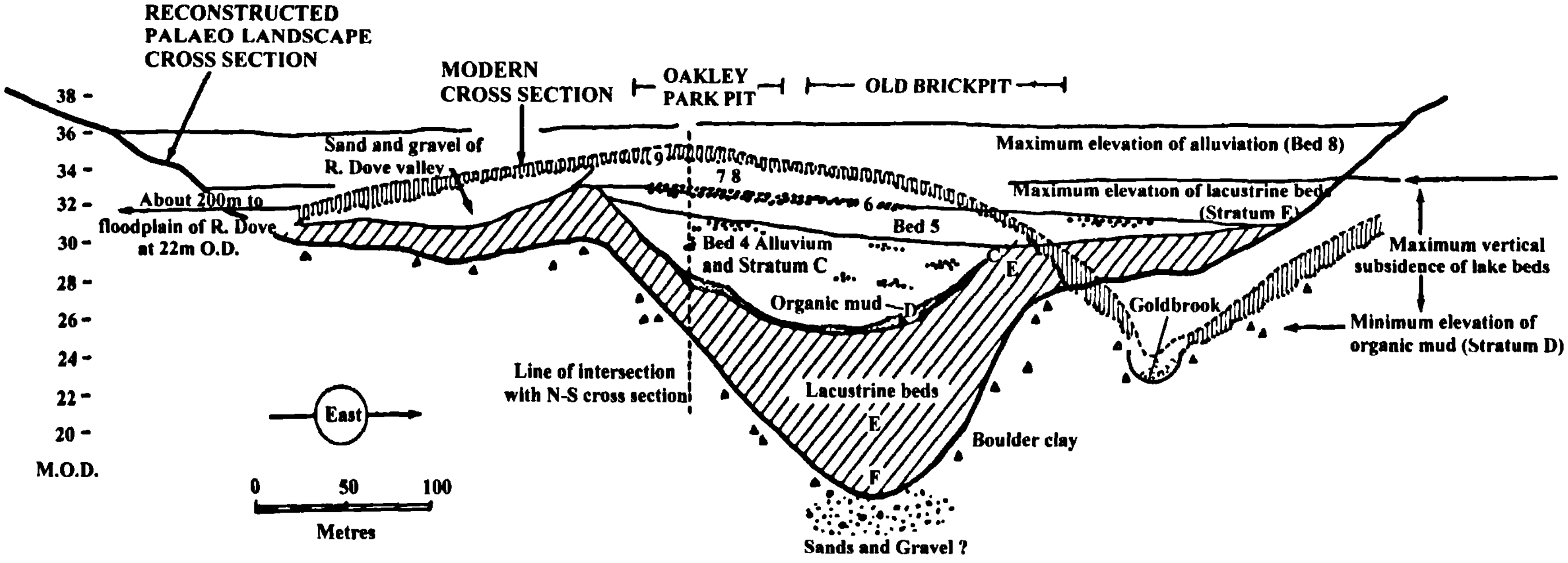


Figure 4.3 East-west schematic reconstruction of the stratigraphic sequence at Hoxne (modified from Singer *et al.* 1993)

These differences have been interpreted as the result of factors related to the depth of the water (West 1956). No artefacts are known from this level. The pollen profile is indicative of cold climatic conditions (Gladfelter, in Singer *et al.* 1993). A radius and metacarpal of red deer (*C. elaphus*) are recorded from this unit, lying on top of Lowestoft Till (Spencer, in West 1956).

Stratum E: Lacustrine clay-mud, up to 6.5m thick at the centre of the basin. This unit encompasses the main body of the interglacial deposits and lies conformably on top of Stratum F. It consists of a compact, unstratified brown-green calcareous clay-mud (West 1956) and is interpreted as the product of slow accumulation in slack, but not stagnant, water. This unit is considered to mark the onset of the Hoxnian Interglacial in the pollen record and covers zones Ho I and II. No archaeology is known from deposits assigned to the first two subzones of Ho II (Ho IIa and Ho IIb), although immediately preceding the end of subzone Ho IIc, a deforestation phase with the first signs of human activity (artefacts, broken mammalian bones and charcoal), has been noted (Gladfelter, in Singer *et al.* 1993).

Stratum D: Peaty detrital mud, up to 40cm thick at the centre of the basin. This unit lies conformably on top of the lacustrine clay-mud and is thought to have been deposited during a fall in the water level of the lake, at a time of development of alder carr around the lake margins. It consists of a non-calcareous, laminated brown detrital mud, becoming coarser towards the top (West 1956). Faunal remains and numerous artefacts referable to the 'Lower Industry' are found on and sometimes in this mud but are not considered as contemporary with its formation. It is suggested that they were deposited on the surface of the mud at some subsequent time by natural agencies, while those in the mud are thought to have sunk into it.

The sequence is then broken by an unconformity, followed by deposition of the Upper Sequence.

Upper Sequence:

Bed 4 (Stratum C): Lacustrine and fluviatile deposits, up to 3.5m thick. These variable deposits lie unconformably on the lower lake deposits. The unconformity is sharply marked by a period of erosion, leading to the partial destruction of Stratum D, at a time of lower water level before the deposition of Stratum C. The deposits consist of a grey-brown sandy silt, rich in organic matter, which passes upwards into yellow and grey laminated calcareous muddy silt, alternating with a compact brown-grey brecciated clay-mud (West 1956). They are interpreted as the effects of a slowly rising water level which drowned the alder carr, accompanied by an increased discharge as the site became part of a major river system (Gladfelter, in Singer *et al.* 1993). A cool climate is inferred from the presence of arctic voles and lemmings (Stuart, in Singer *et al.* 1993) (although see below). Much of the archaeological material from the site is found in the lower part of this stratum, most of it located on the former margins of the lake. This industry consists of mint-fresh ovate and cordate handaxes and is hereafter known as the Lower Industry. A coarser sandy gravel is interbedded with the top of Stratum C, the most likely source of Frere's handaxes (Singer *et al.* 1993). The industry from this upper part of Stratum C is referred to as the 'Middle Industry', in order to differentiate it from the Lower Industry below and from that found above it in Bed 5. Much of the faunal material collected prior to the University of Chicago excavations is thought to have come from this upper part of Stratum C (Gladfelter, in Singer *et al.* 1993).

Bed 5: Brown silt. This is interpreted as the deposit of a river with varying discharge levels. A more temperate climate is inferred from the finer and less variable sediments, an increase in tree pollen and the fauna. Fresh and rolled artefacts occur within this bed at various levels (the 'Upper Industry'). These are interpreted as pieces discarded on dry land surfaces and incorporated into the silt by flooding. Faunal remains are scarce due to leaching (Gladfelter *ibid*).

Bed 6: Coarse gravel. This unit overlies Bed 5 and interdigitates with it in the southern part of Oakley Park Pit. It consists of a coarse, sandy gravel, varying from 0.3 to 1m in thickness (Gladfelter *ibid*). The lower part is bedded and clearly of fluviatile origin; elsewhere its almost total decalcification has destroyed the bedding structure, leading to the mistaken interpretation of it as a glacial till (West 1956). The gravel contains more than 1200 rolled, abraded and broken palaeoliths, probably derived from the valley sides. No fauna was recovered from this horizon.

Beds 7 and 8: Laminated sands and silts (southern part of the Oakley Park Pit only). These units comprise almost 2m of well-bedded sands with layers of fine gravel and of clayey silt. The presence of ice-wedge casts within these beds demonstrates cold climatic conditions (Gladfelter, in Singer *et al.* 1993).

Bed 9: Gravelly sand. The sequence is capped by approximately 2m of unstratified grey or brown fine sand with occasional stones (West 1956; Gladfelter, in Singer *et al.* 1993). The elevation of the top of this unit varies between 36.7 and 31.5m O.D. (Gladfelter *ibid*). The lithology suggests that this deposit was formed during a periglacial climate (West 1956). No artefacts or faunal remains were recovered from within Bed 9.
The stratigraphical sequence is summarised in Table 4.1.

Archeological Layer			*Bed* *(Gladfelter 1975a, 1975b)*	*Stratum* *(West 1956)*
Cutting XXIX	*Main Cutting*	*West Cutting*		
1 2			9	A1
3 4 5		1 Contorted near-surface deposits comprising intermixed Beds of the Upper Sequence	8 7	A2
6 7			6 5	
8			4	B
		2 Major part of Stratum C (without artifacts)	No Bed designation, lateral equivalent of Bed 4, principally a fine clastic, clayey member	C
	1	3 20 cm above base of Stratum C 4 Base of Stratum C, above Stratum E	3 Exposed only in Cutting 2 XXIII; probably equivalent 1 to base of stratum C in Main and West Cuttings	
	2			D
	3			E
				F G

Table 4.1 Stratigraphical terminologies for the Hoxne sequence (from Singer *et al.* 1993).

4.1.4. Palaeontology

The mammalian remains from Hoxne are critical to the understanding of the age of the site, in that they form the 'type assemblage' for the Hoxnian Interglacial. The following list of mammalian species (see below) has been compiled from material in the Natural History Museum in London, the British Geological Survey Museum, Keyworth, Ipswich

Museum and Oxford University Museum, thereby drawing together, for the first time, material collected by all the various investigators. A total of 512 specimens was examined. The present study has demonstrated that 28 mammalian species may be reliably identified at Hoxne and to this may be added *Homo*, in the form of artefacts and cutmarked bones. A new species discovered during the present study is Northern lynx (*Felis* (*Lynx*) *lynx*). This has been identified on the basis of a fragment of a left astragalus (4832) from AL3 West (Lower Industry) (see Figure 3.36), which matches closely that of a modern Northern lynx from Labrador (Natural History Museum, London, Newton Collection, 1885). A small canid, tentatively assigned to *Canis lupus*, has also been identified on the basis of a right cuneiform (forelimb) (5048). Three additional specimens of *Stephanorhinus* sp. have been identified, together with one further specimen of *C. fiber* from the University of Chicago excavations.

Species List (Mammalia) from Hoxne, Suffolk

Insectivora

Sorex cf. *araneus* L., common shrew

Sorex cf. *minutus* L., pygmy shrew

Neomys sp., water shrew

Desmana moschata (Pallas), Russian desman

Talpa minor Freudenberg, extinct small mole

Primates

Macaca sylvanus (L.), Barbary macaque

Homo sp., hominid (artefacts, cutmarks on bones)

Rodentia

Castor fiber L., European beaver

Trogontherium cuvieri Fischer, extinct giant beaver

Lemmus lemmus (L.) or *Myopus schisticolor* (Lilljeborg), Norway or wood lemming

Clethrionomys glareolus (Schreber), bank vole

Arvicola terrestris cantiana (Hinton), water vole (primitive morphotype)

Microtus agrestis (L.), field vole

Microtus arvalis (Pallas), common vole

Microtus agrestis (L.) or *Microtus arvalis* (Pallas), field or common vole

Microtus (*Terricola*) *subterraneus* (de Selys Longchamps) (– *Pitymys arvaloides* Hinton), European pine vole

Microtus sp., indet. vole

Apodemus cf. *sylvaticus* (L.), wood mouse

Carnivora

cf. *Canis lupus* L., small wolf

Ursus sp., indet. bear

Lutra lutra (L.), otter

Felis (*Lynx*) cf. *lynx* (L.), Northern lynx

Panthera leo (Goldfuss), lion

Proboscidea

Palaeoloxodon antiquus Falconer and Cautley, straight-tusked elephant

Elephantidae sp., indet. elephant

Perissodactyla

Equus ferus Boddaert, horse

Stephanorhinus cf. *hemitoechus* (Falconer), narrow-nosed rhinoceros

Stephanorhinus sp. indet. rhinoceros

Artiodactyla

Megaloceros giganteus (Blumenbach), giant deer

Dama dama ssp. indet., fallow deer

Cervus elaphus L., red deer

Capreolus capreolus (L.), roe deer

Cervidae sp. indet. deer

Bos primigenius Bojanus, aurochs

Bovidae sp., indet large bovid (*Bos* or *Bison*)

Table 4.2 below provides a breakdown of the species list into numbers of specimens per species (including specimens that lack stratigraphic data), also expressed as a percentage of the total mammalian assemblage from the site. Minimum numbers of individuals have also been calculated (these figures do not include specimens that cannot be assigned to a stratigraphic horizon).

Species	Number of specimens	Percentage of total assemblage (%)	Minimum number of individuals (M.N.I.)
Insectivora			
S. cf. *araneus*	2	0.39	2
S. cf. *minutus*	2	0.39	2
Neomys sp.	3	0.58	1
D. moschata	67	13.08	2
T. minor	1	0.19	1
Primates			
M. sylvanus	3	0.58	2
Rodentia			
C. fiber	5	0.97	3
T. cuvieri	24	4.68	6
L. lemmus or *M. schisticolor*	25	4.88	3
C. glareolus	2	0.39	2
A. t. cantiana	36	7.03	6
M. agrestis	3	0.58	2
M. arvalis	2	0.39	2
M. agrestis or *M. arvalis*	6	1.17	4
M. (T.) subterraneus	6	1.17	5
Microtus sp.	153	29.88	8
A. cf. *sylvaticus*	2	0.39	1
Carnivora			
cf. *C. lupus*	1	0.19	1
Ursus sp.	2	0.39	1
L. cf. *lutra*	3	0.58	1
F cf. *lynx*	1	0.19	1
P. leo	1	0.19	1
Proboscidea			
P. antiquus	4	0.78	2
Elephantidae sp.	13	2.53	2
Perissodactyla			
E. ferus	178	34.76	7 (2 juv., 5 adults)
S. cf. *hemitoechus*	1	0.19	1
Stephanorhinus sp.	8	1.56	3
Artiodactyla			
M. giganteus	6	1.17	4
D. dama ssp. indet.	12	2.34	4 (1 juv., 3 adults)
C. elaphus	51	9.96	6
C. capreolus	11	2.14	3
Cervidae sp.	55	10.74	7 (1 juv., 6 adults)
B. primigenius	1	0.19	1
Bovidae sp.	9	1.75	3

Table 4.2 Breakdown of the mammalian species list from Hoxne, showing numbers of specimens per species, the percentage of the total assemblage per species and minimum numbers of individuals.

4.1.5. Palaeoenvironmental and palaeoclimatic interpretation

Table 4.3 below shows the number of specimens per species for each stratigraphic unit that has yielded fossil mammals at the site. Numbers in brackets reflect the percentage provided by each species of the total assemblage in each stratigraphic unit. The stratigraphic units are as follows: Stratum F, Stratum E, Stratum C, Bed 4 (Cutting XXIX) and Bed 5 (Cutting XXIX). A more detailed breakdown of the species present in all cuttings at the site is provided in the Appendix.

N.B. This table does not take into account material for which the stratigraphic horizon at the site is unknown. Hence, for example, the small canid and *Bos primigenius* are not shown since each is represented only by a single specimen which is unfortunately unprovenanced.

Pollen spectra from the Lowestoft Till (Stratum G) are typical of a coniferous forest of subarctic or subalpine type, with large groves of *Picea* (spruce) and to a lesser extent, *Pinus* (pine). Grasses and sea buckthorn (*Hippophaë*) colonised the open spaces (Mullenders, in Singer *et al.* 1993). Mammalian remains have not been recovered from this horizon. Reconstruction of the climate and environment at the time of deposition of Stratum F is complicated. West (1956) attributes this stratum to the 'Late Glacial' stage (Stage I), immediately preceding the interglacial deposits. Mullenders (in Singer *et al.* 1993) suggests that the climate appears to have been cool, rather than subarctic, although Turner (1968) compared the plant macrofossils from the base of this unit to full glacial floras (zone 1 Lo). Arboreal pollen (AP) values are high (54%) but consist predominantly of *Hippophaë* (38%). The remaining AP component is dominated by *Betula* (birch), possibly the dwarf birch (*B. nana*). Grasses, sedges and herbs are also present. The palaeobotanical remains are therefore considered to reflect a climate comparable to that found above the timberline in the shrub zone between grassland and subarctic forest (Mullenders, in Singer *et al.* 1993).

However, the climatic implications of the coleopteran remains from Stratum F are rather problematic, since the fauna consists of species with incompatible geographic ranges at the present day (Coope, in Singer *et al.* 1993). The assemblage contains not only a group of cold-indicating, boreal (or boreo-montane) inhabitants, including *Diacheila*

Species	F	E	C	Bed 4	Bed 5
S. cf. *araneus*	-	-	1 (0.3)	1 (0.39)	-
S. cf. *minutus*	-	-	1 (0.3)	1 (0.39)	-
Neomys sp.	-	-	-	3 (1.17)	-
D. moschata	-	-	63 (19.38)	4 (1.56)	-
T. minor	-	-	-	1 (0.39)	-
M. sylvanus	-	-	1 (0.3)	2 (0.78)	-
C. fiber	-	-	2 (0.61)	1 (0.39)	1 (4.54)
T. cuvieri	-	9 (90)	10 (3.07)	3 (1.17)	1 (4.54)
L. lemmus or *M. schisticolor*	-	-	1 (0.3)	23 (9.01)	-
C. glareolus	-	-	1 (0.3)	1 (0.39)	-
A. t. cantiana	-	-	5 (1.53)	30 (11.76)	-
M. agrestis	-	-	-	3 (1.17)	-
M. arvalis	-	-	-	2 (0.78)	-
M. agrestis or *M. arvalis*	-	-	1 (0.3)	5 (1.96)	-
M. (T.) subterraneus	-	-	-	6 (2.35)	-
Microtus sp.	-	-	2 (0.61)	151 (59.21)	-
A. cf. *sylvaticus*	-	-	-	2 (0.78)	-
Ursus sp.	-	-	1 (0.3)	1 (0.39)	-
L. cf. *lutra*	-	-	3 (0.92)	-	-
F cf. *lynx*	-	-	1 (0.3)	-	-
P. leo	-	-	1 (0.3)	-	-
P. antiquus	-	* see below	?1 (0.3)	-	-
Elephantidae sp.	-	-	-	7 (2.74)	5 (22.72)
E. ferus	-	-	125 (38.46)	2 (0.78)	6 (27.27)
S. cf. *hemitoechus*	-	-	1 (0.3)	-	-
Stephanorhinus sp.	-	-	2 (0.61)	1 (0.39)	1 (4.54)
M. giganteus	-	-	2 (0.61)	1 (0.39)	3 (13.63)
D. dama ssp. indet.	-	-	10 (3.07)	-	1 (4.54)
C. elaphus	1 (100)	-	41 (12.61)	1 (0.39)	1 (4.54)
C. capreolus	-	-	7 (2.15)	-	1 (4.54)
Cervidae sp.	-	-	39 (12)	3 (1.17)	2 (9.09)
Bovidae sp.	-	-	3 (0.92)	-	-

* *P. antiquus* recorded from Stratum E by Turner (1970).

Table 4.3 Number of specimens per stratigraphic unit at Hoxne.

polita (today living no nearer to the British Isles than the Kola peninsula of arctic Russia) and tundra species, such as *Boreaphilus nordenskioeldi* and *Bembidion hasti*, but also relatively southern species, such as the ground beetle *Carabus granulatus* and the water beetle *Colymbetus fuscus*. The most plausible explanation for this assemblage is that Stratum F accumulated during a period of rapid climatic change, with mean Julytemperatures estimated to be 10° C, rising rapidly to 15° C. Given the stratigraphical position of this unit, it seems likely that the small group of arctic species may indicate the terminal stages of the Anglian glaciation. The palaeoenvironment, as indicated by the coleopteran assemblage, consisted of stationary water with aquatic vegetation and plant detritus on the bottom and a lushly-vegetated, marshy habitat on the banks. The land further away from the lake was apparently open and bleak, with sparse vegetation, as suggested by the presence of species such as *Amara quenseli*, *Notiophilus aquaticus*, *N. aestuans* and *Chrysolina latecincta* (Coope, in Singer *et al.* 1993). Molluscan remains from Stratum F comprise the following freshwater species: *Valvata piscinalis*, *Lymnaea truncatula*, *L. peregra*, *Sphaerium corneum*, *Pisidium casertanum*, *P. obtusale*, *P. milium*, *P. subtruncatum*, *P. henslowanum* and *P. nitidum* (Kennard and Oldham, in Moir 1935). Mammalian remains from Stratum F consist only of red deer, *Cervus elaphus* (Spencer, in West 1956). This association with an apparently treeless landscape is not unparalleled in the British Pleistocene, since red deer remains are also known from the middle Devensian, in association with open herbaceous vegetation (Lister 1984b). Stratum F may therefore be considered to reflect the closing phases of the Anglian glaciation, at a time of rapid climatic amelioration.

The Hoxnian Interglacial proper begins with the onset of the Pre-temperate stage (Ho I of Turner, 1970, substage IIa of West, 1956) at the base of Stratum E. Mean AP levels rise sharply to 77%, comprising mostly *Betula* and *Pinus*. Towards the end of this substage, there is an expansion of temperate woodland, signalled by a rise in oak (*Quercus*) and other thermophilous trees, such as *Alnus* (alder), *Tilia* (lime), *Ulmus* (elm), *Fraxinus* (ash) and *Ilex* (holly) until mixed-oak forest is completely dominant in Zone Ho II (mean AP 93%). Three pollen subzones are defined for the upper sediments of Stratum E: subzones IIa, IIb and IIc (substages IIb, IIc and IId of West, 1956). The thermal optimum is estimated to have been reached at the end of subzone IIa, with more humid conditions developing, as evidenced by a rise in alder pollen. By subzone IIb, alder forest is dominant, followed by oak and hazel (*Corylus*). Type X pollen is also present and *Taxus* (yew) rises to a peak of 22.5% of AP values at the end of this period. The climate is interpreted as being less warm than at the end of subzone IIa, but wetter. In subzone IIc, alder is still the dominant tree but with hazel, oak and yew also important (Mullenders, in Singer *et al.* 1993). Type X pollen and the water fern *Azolla filiculoides* are also present (Mullenders *ibid*; West 1956). Towards the end of this subzone, a high non-arboreal pollen (NAP) phase has been noted (West 1956; Turner 1970; West 1980b). This has been observed in all Ho IIc pollen profiles from infilled lake basins but has not been found in the estuarine deposits of Woodston, Cambridgeshire (Horton *et al.* 1992; 4.9). The deforestation has variously been ascribed to regional forest fires (possibly initiated through human agency) (West 1956; Turner 1970) or to climatic factors (Mullenders, in Singer *et al.* 1993). At the end of this subzone, the first indications of climatic deterioration are observed in the pollen record (Mullenders *ibid*).

Only two species of freshwater mollusc have been recorded from Stratum E: *Bithynia tentaculata* and *Valvata piscinalis* (Sparks, in West 1956). Mammalian remains from Stratum E consist of extinct giant beaver *T. cuvieri* (Spencer, in West 1956) and straight-tusked elephant *P. antiquus* (Turner 1970). *T. cuvieri* is only known from interglacial deposits in Britain and is most abundant in association with fine-grained, water-lain sediments, thereby confirming the proximity of a water source (Stuart 1982). *P. antiquus* is also a characteristic component of temperate faunas, usually in association with deciduous or mixed woodland (Stuart *ibid*). Sediment adhering to a *P. antiquus* mandible from Stratum E yielded pollen characteristic of the high NAP phase of Ho IIc (Turner 1970).

The organic detrital mud of Stratum D contains pollen assigned to the Late-temperate stage (Ho III) by West (1956) (equated with Ho IIIa at Marks Tey by Turner, 1970). This period is characterised by an alder-hazel-elm association. Evidence of progressive climatic deterioration is apparent, with the oak forest being progressively replaced by conifers such as *Abies* (fir), and by *Carpinus* (hornbeam) (West 1956; Mullenders, in Singer *et al.* 1993). The apparent absence in parts of the site of deposits containing pollen of subzone Ho IIIa age suggests that localised sedimentation and erosion conditions varied considerably during deposition of Stratum D (Mullenders *ibid*). 106 coleopteran taxa have been recovered from this stratum (Coope, in Singer *et al.* 1993). These record the transition, during the final stages of silting-up of the lake, from a predominantly aquatic environment at the base of the deposits to more marshy habitats at the top. Various species of water beetles and an aquatic weevil from the lowest samples are indicative of shallow weedy ponds with still or standing water and overgrown vegetation. This suggests that the area was drying up rapidly and that expanses of open water were no longer available (Coope *ibid*).

The presence of tall, reedy vegetation and lush water meadows at the water's edge is indicated by species such as *Notaris bimaculatus* and *Donacia semicuprea*, although much of the grass and sedge appears to have been affected by smut fungus, as attested to by the presence of large numbers of *Phalacrus caricis*, the larvae of which feed on the spores. Coope (*ibid*) states that the incidence of this disease must have been of massive proportions, thereby rendering the grazing unpalatable or indeed poisonous. This is somewhat supported by the relatively low numbers of dung beetles in Stratum D, which suggest that large herbivorous mammals were rare in the vicinity at that time, and by the low incidence of carrion beetles, also indicating that few vertebrates were present. The progressive choking of the pond by accumulating vegetational detritus is indicated by *Cercyon* and *Cryptopleurum*, which inhabit heaps of decaying plant remains. The numbers of carabid ground beetles also begins to increase as the number of water beetles declines. Species associated with old, mature forests and dead wood are also present (Coope *ibid*). No mammalian remains are recorded from Stratum D.

Stratum C is assigned to the Early-Glacial stage (stage IV) by West (1956), although Mullenders (in Singer *et al.*, 1993) suggests that this stratum contains pollen from substages Ho IIIb, Ho IVa and Ho IVb. The landscape appears to have been locally open, as indicated by the large numbers of spores and the fern *Dryopteris* (Mullenders *ibid*). This is consistent with the open moorland inferred from the mosses (Evans *et al.* 1896) or the 'oceanic heath' vegetation of a park tundra (West 1956). A cool, humid climate is implied (Mullenders, in Singer *et al.* 1993). Stands of temperate woodland do however appear to have remained a significant element (Mullenders *ibid*), with AP values (predominantly alder and birch, with a rapid rise in fir and pine) remaining high throughout this stage. Six species of arctic plant have also been recovered from Stratum C, although the actual conditions are believed to be more truly reflected by the temperate flora (Mullenders *ibid*).

Mammalian remains from Stratum C were recovered from two areas during the University of Chicago excavations, AL3 West and AL1 Main, both associated with the Lower Industry (Singer *et al.* 1993). The assemblage from the former is considered to be *in situ*, while the latter has been disturbed, although the faunas are similar (Stuart *et al.*, in Singer *et al.* 1993). The presence of temperate, mainly deciduous woodland is indicated by remains of *D. dama*, *C. capreolus*, *M. sylvanus* and *C. fiber*. *F. lynx* is also dependent upon mature woodland, with plenty of ground cover, the latter also required by *S. araneus* and *C. glareolus*. However, open grassland appears to be the most dominant habitat type, as attested to by abundant remains of *E. ferus* (125 specimens out of 325 (38.46%) in Stratum C). *C. elaphus* is the second most common species in Stratum C (38 specimens, 11.69% of the assemblage from Stratum C), with small numbers of other large grazers requiring relatively open conditions also present, including rhinoceroses (3 specimens), large bovids (3 specimens) and *M. giganteus* (2 specimens). A significant component of the mammalian assemblage from Stratum C (25.53%) is composed of species directly associated with water: *D. moschata*, *C. fiber*, *T. cuvieri*, *A. t. cantiana* and *L. lutra* (Figure 3.33). These species indicate the proximity of relatively slow-flowing or still freshwater with well-vegetated banks. The fish assemblage from Stratum C is dominated by Cyprinids, including roach (*Rutilus rutilus*), tench (*Tinca tinca*) and rudd (*Scardinius erythropthalmus*), and their associated predator, the pike (*Esox lucius*) (Stuart *et al.*, in Singer *et al.* 1993). The Cyprinids reflect the presence of still or slow-flowing water and require summer water temperatures of at least 18° C for spawning (Wheeler 1969). The continuation of fully temperate climatic conditions, as suggested by the pollen evidence, is corroborated by the presence of *D. dama* and *T. cuvieri*, both of which are restricted to interglacial occurrences.

The mammalian assemblage from Bed 4 is considered to be reworked either from the base of Stratum C or from a deposit of similar age (Stuart *et al.*, in Singer *et al.* 1993). The palaeoenvironmental reconstruction from the mammalian remains is therefore similar, with deciduous woodland and grassland habitats both represented. The small vertebrate assemblage is much larger than that of Stratum C (233 specimens of Soricidae, Cricetidae and Muridae, 91.37% of the assemblage from Bed 4), possibly due to differential sorting by the current. Grassland voles (*M. agrestis*, *M. arvalis*, *M. subterraneus* and *Microtus* sp.) are by far the most numerous (71.67% of the small mammal assemblage), with lemming also well represented (9.87% of the small mammal assemblage). The environmental implications of lemming in Stratum C and in greater numbers in Bed 4 is discussed at length in Stuart *et al.* (in Singer *et al.* 1993). Today, the Norway lemming (*Lemmus lemmus* is mainly confined to the Palaearctic tundra and open montane areas, birch and willow scrub (Corbet 1966). Since no other 'cold' indicators, such as reindeer (*Rangifer tarandus*) have been recovered from either Bed 4 or Stratum C (from which Bed 4 was probably reworked), the presence of lemming appears somewhat 'disharmonious' in the context of the rest of the mammalian assemblage.

It is possible that the lemming remains at Hoxne may in fact represent a large form of wood lemming (*Myopus schisticolor*), a species which inhabits the boreal forest south of the arctic tundra zone at the present day. Dental remains of this species are indistinguishable from *L. lemmus* (see Chapter 3), although body size of the modern animal is considerably smaller than *Lemmus*. However, given the size changes experienced by many mammalian lineages during the Pleistocene, the appearance of a large form of *M. schisticolor* would not be abnormal. Even taking this into account, wood lemming would still be somewhat out of place in a fauna otherwise consistent with regional temperate forest (Stuart, in Singer *et al.* 1993). It is therefore concluded that the ecological tolerances of *L. lemmus* (? *M. schisticolor*) have possibly changed since the Middle Pleistocene and that past populations were able to occupy much wider environmental niches. However, it is equally possible that the environment during the Hoxnian Interglacial simply has no modern analogue. Other records of *L. lemmus* from pre-Anglian interglacial sites at Westbury-sub-Mendip, Somerset (Bishop 1982) and from Sugworth, Berkshire (Stuart 1980 and unpublished, in Singer *et al.* 1993) suggest that this species appeared in conjunction with the closing phases of interglacials and the development of more open vegetation. This corresponds well with the predominance of open grassland voles from Bed 4.

In addition to the presence of extensive areas of open grassland and herbaceous vegetation at the time of deposition of Bed 4, deciduous woodland is also suggested by A cf. *sylvaticus*, *M. sylvanus* and *C. fiber*. The proximity of a large body of slow-flowing or still freshwater with abundant vegetation is attested to by the relative abundance of *A. t. cantiana* (30 specimens out of 255), with smaller numbers of *D. moschata* (4 specimens), *Neomys* sp. (3 specimens), *T. cuvieri* (3 specimens) and *C. fiber* (1 specimens). The continuation of temperate conditions is indicated particularly by *A.* cf. *sylvaticus* and by the extinct small mole *Talpa minor*. Molluscan remains from Bed 4 include abundant *Valvata piscinalis* with smaller numbers of *Bithynia tentaculata*, *B. inflata* and *Pisidium clessini*. The dominance of *V. piscinalis* is considered suggestive of a lake or large water body (Kerney, in Singer *et al.* 1993).

A mixture of open and closed habitats still apparently prevailed in Bed 5. The presence of *E. ferus* (6 specimens out of 22) and *M. giganteus* (3 specimens) both indicate relatively open conditions, while *C. fiber*, *D. dama* and *C. capreolus* (1 specimen of each) indicate the presence of temperate woodland. *C. fiber* and *T. cuvieri* confirm the persistence of a large body of water in the vicinity. The mixed vegetational conditions are repeated in the pollen diagrams from Beds 5 to 8, which indicate frequent, rapid swings in the ratio of AP to NAP, probably reflecting truncation of or complete gaps in the pollen record (Mullenders, in Singer *et al.* 1993). Phases of low AP are characterised by the extension of grasses, *Artemisia* (mugwort), Urticaceae (nettle family), *Plantago* (plantain) and by the sporadic presence of *Hippophaë*. During these periods, *Pinus* dominates or co-dominates with *Alnus*. Phases of high AP retain or show increases in thermophilous trees and shrubs: *Quercus*, *Tilia*, *Ulmus*, *Hedera*, *Fraxinus* and *Corylus*. Beds 5 and 6 appear to be the more temperate of these alluvial beds. Two rises in NAP correspond with evidence of periods of ice-wedge development in Beds 7 and 8.

4.1.6. Biostratigraphy and correlation

Mammalian studies

The Hoxnian Interglacial has traditionally been regarded as the first post-Anglian temperate stage in Britain (Mitchell *et al.* 1973). However, recent attempts by Bowen *et al.* (1989) to relate elements of the British terrestrial sequence to the oxygen isotope record on the basis of amino acid analyses on molluscan remains, have assigned the Hoxne type site (and consequently the Hoxnian Interglacial *sensu stricto*) to OIS 9. The same study places other sites formerly also regarded as Hoxnian, such as Swanscombe and Clacton, in the immediately preceding interglacial, OIS 11, a correlation which is in agreement with the topographical position of these sites within the Lower Thames terrace sequence (Bridgland 1994). The consequent implication is that differences should be apparent between Hoxne and Swanscombe in terms of their mammalian assemblages, since they potentially belong to quite distinct interglacials. This section aims to establish the characteristics of the mammalian fauna during the Hoxnian Interglacial, before examining the evidence from Swanscombe to see how it compares.

The Hoxne mammal assemblage will be considered in detail below and its composition used to define the characteristic components of the Hoxnian Interglacial mammal fauna.

The mammalian assemblage from Hoxne differs from that of the immediately pre-Anglian early Middle Pleistocene in several important characters (Stuart 1982; Currant 1989b). There is a marked decrease in diversity in the small mammal fauna, with the disappearance of the shrews *Sorex runtonensis* and *Sorex* (*Drepanosorex*) *savini* and the vole *Pliomys episcopalis*, while the cave bear *Ursus deningeri* is replaced by the more advanced *Ursus spelaeus*. Other species present in the late Cromerian Complex, such as *Megaloceros verticornis*, are also absent. The Hoxnian Interglacial, as represented at the type site, also witnesses the first appearance in Britain of four species that are not found in the preceding Cromerian Complex: field vole (*Microtus agrestis*), narrow-nosed rhinoceros (*Stephanorhinus hemitoechus*), giant deer (*Megaloceros giganteus*) and aurochs (*Bos primigenius*). A further important characteristic of the Hoxnian Interglacial is that the spotted hyaena, *Crocuta crocuta*, which is present in the preceding interglacial at Boxgrove and Westbury-sub-Mendip, is apparently absent. To this may be added the hippopotamus (*Hippopotamus amphibius*), which is also absent from this interglacial.

Having reviewed the various presences and absences above, the remaining elements of the Hoxnian Interglacial mammalian fauna will now be considered in detail, with special emphasis on those species of biostratigraphic significance, beginning with the extinct giant beaver, *Trogontherium cuvieri* (Figure 4.4). This species is a notable component of the Hoxne assemblage, comprising 4.68% of the total number of specimens. Its major importance as a biostratigraphic indicator lies in the fact that it is unknown from deposits post-dating the Hoxnian Interglacial. A second feature of biostratigraphic significance in this species was identified by Mayhew (1978) and relates to a diminution through time of the length:width ratio in the lower incisors (see Chapter 3). The dimensions of the Hoxne specimens are smaller than those from the Cromerian of West Runton and are thus consistent with a younger age for the former (Stuart *et al.*, in Singer *et al.* 1993). During the Hoxnian Interglacial, *T. cuvieri* coexisted with the European beaver (*Castor fiber*) but probably exploited a different ecological niche (see Chapter 3).

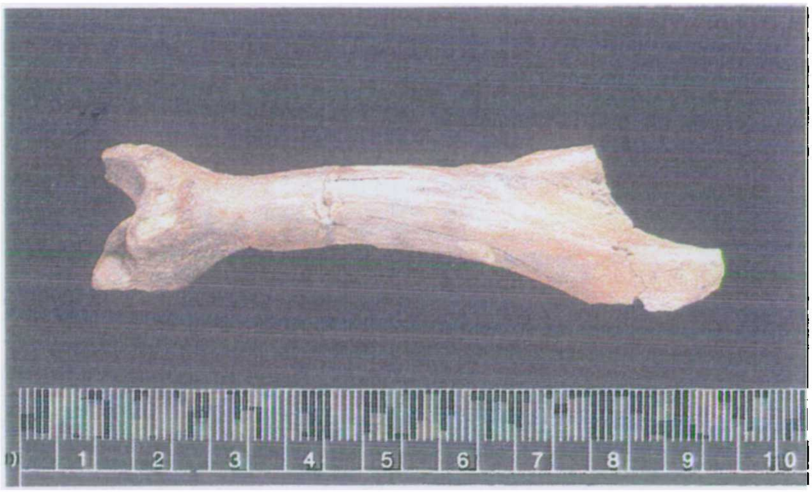


Figure 4.4 Distal left tibia, *Trogontherium cuvieri*, (5205, N.H.M.L.), AL3 West (Lower Industry), Hoxne.

With regard to the small mammal fauna, three species of biostratigraphic importance are present at Hoxne: the extinct small mole *Talpa minor* and the European pine vole *Microtus* (*Terricola*) *subterraneus*, neither of which are found in British deposits post-dating this interglacial, and the water vole, *Arvicola terrestris cantiana*. Although the Hoxne sample size of first lower molars of water vole is small (n=4), some general points may be made regarding the biostratigraphic significance of this species. All the remains are referable to the primitive morphotype, *A. t. cantiana* (= *A. cantiana* Hinton), with the enamel of the trailing (convex) edges being markedly thicker than that of the leading (concave) edges of the molars. The single measurable molar is also of small size (see 3.20; Tables 3.3 and 3.4). This is consistent with the relative antiquity of the Hoxne *Arvicola* remains, although again the small sample size prevents this from being a statistically significant figure. One lower first molar (3198) retains the ancestral *Mimomys* fold, a primitive feature which is present at low frequency in stratigraphically early populations of *Arvicola*.

The presence at Hoxne of *Desmana moschata* also differentiates the Hoxnian mammalian assemblage from that of the Last Interglacial (Stuart 1982). Comparison of the Hoxne *Desmana* with that from the type Cromerian at West Runton reveals that the Hoxne desman was larger (Stuart *et al.*, in Singer *et al.* 1993). This is consistent with an overall increase in size in the Russian desman from the early Middle Pleistocene to the present day (see Chapter 3). The record of Norway lemming (*Lemmus lemmus*) (or wood lemming, *Myopus schisticolor*) may also be of biostratigraphic significance in characterising the later part of the Hoxnian Interglacial. Its occurrence at Hoxne probably relates to decreasing forest cover and to the establishment of herbaceous vegetational communities (Stuart, in Singer *et al.* 1993).

The primate remains at Hoxne include the Barbary macaque *Macaca sylvanus* (Singer *et al.* 1982). This species is not known to occur in deposits of OIS 7 or later age, thereby confirming that the sequence at Hoxne pre-dates this cut-off point. Carnivore remains are rather poorly represented at the site (only 1.56% of the total number of specimens). These consist of a single specimen of a small canid, tentatively assigned to *C. lupus*. The specimen in question (Natural History Museum 5048) is intermediate in size between fox (*Vulpes vulpes*) and the modern wolf *C. lupus*. However, since local populations of wolves tend to adapt according to their prey size, this is probably not a character of biostratigraphic significance or worthy of subspecific status. It is more likely that the Hoxne canids were targeting small and medium-sized prey or possibly scavenging, thereby leaving the larger prey for the bigger predators at the site, lions and bears. The two specimens of *Ursus* are insufficient for specific determination, but given the post-Anglian context of the Hoxne deposits, they are unlikely to be from *U. deningeri*. A larger sample size, including cranial and dental material, would permit differentiation between the cave bear (*U. spelaeus*) and the brown bear (*U. arctos*). Two rare carnivores, *F. lynx* and *L. lutra*, are also recorded.

The equid material from Hoxne is all referable to the caballine horse, *Equus ferus*. No significant size difference has been noted between the Hoxne horses and those from Swanscombe (4.2), Clacton (4.4) and Steinheim in Germany (Egginton, in Singer *et al.* 1993). The protocones on the upper cheek teeth are also noticeably pointed and triangular in the Hoxne material, a feature in common with the Steinheim *E. ferus*, considered to be of Holsteinian age and broadly equivalent to the Hoxnian. The red deer remains from Stratum C at Hoxne compare closely with a sample of red deer from the Mesolithic site of Star Carr (North Yorkshire) in terms of mean skeletal size (Lister, in Singer *et al.* 1993). Interestingly, the mean body size of the Hoxne red deer is clearly larger than that of the deer from either Swanscombe or Clacton. This difference in body size would not be expected from sites of identical age in the same geographical area, but would be entirely consistent with even a small difference in age, such as between successive zones of an interglacial (Lister, in Singer *et al.* 1993). A radius and metacarpal in Ipswich Museum (1953-49), found on the surface of the late-Anglian Stratum F (West 1956), are of small size although there is not sufficient statistical justification to extend this observation to a whole population (Lister, in Singer *et al.* 1993). However, if their small size were corroborated by further finds from this horizon, this might prove a suitable comparison with the small Swanscombe and Clacton animals, to which Stratum F is potentially closer in age. Alternatively, the small size of these animals might be a direct result of the poor nutritional quality of the vegetation during the late Anglian (Lister *ibid*).

Fallow deer remains from Swanscombe (4.2) and Clacton (4.4) have been referred to *Dama dama clactoniana* on the basis of their large size and particular antler morphology (see Chapter 3) (Sutcliffe 1964; Leonardi and Petronio 1976; Lister 1986). Unfortunately, the subspecific identity of the Hoxne fallow deer cannot be established, since no antlers have been recovered. However, the Hoxne specimens group significantly closely, on the basis of body size, with those from Swanscombe and Clacton, thereby demonstrating that these animals were larger than Recent fallow deer (Lister, in Singer *et al.* 1993). The giant deer *Megaloceros giganteus* appears in Britain for the first time during the Hoxnian Interglacial and is represented by six specimens at Hoxne. Evidence from the Holsteinian site of Steinheim, considered to be broadly contemporary with the Hoxnian Interglacial, shows the *M. giganteus* antlers of this time to be of a different form to those of Irish Late-Glacial animals (see Chapter 3). Due to poor preservation in the Hoxne material, this feature cannot be detected, although there is limited evidence for its presence at Swanscombe. The body size of the Hoxne giant deer from Beds 4 and 5 is comparable with that of Late-Glacial specimens and implies a larger animal than that found at Swanscombe, despite the small sample size (Lister, in Singer *et al.* 1993). This conclusion would parallel the findings for red deer (see above) and would be quite plausible for a small difference in age between the two localities, within the span of an interglacial.

Having thus considered the Hoxne mammalian assemblage as a whole, it is now possible to pick out certain key indicator species which may be regarded as diagnostic of the Hoxnian Interglacial, where a post-Anglian context can be unequivocally demonstrated. These are:

- *Talpa minor*, extinct small mole
- *Trogontherium cuvieri*, giant beaver
- *Microtus* (*Terricola*) *subterraneus*, European pine vole

Clearly, none of the species listed should be taken in isolation as Hoxnian indicators, since all three are known to occur during the Cromerian Complex but in circumstances where a post-Anglian context can be ascertained, the presence of any one of the above-named species is sufficient to strongly suggest contemporaneity Hoxne and thus to imply correlation with the Hoxnian Interglacial.

Palynological studies

The interglacial deposits at Hoxne are considered to span the four stages of the Hoxnian Interglacial. West (1956) compared the pollen spectra from the upper part of the Hoxne sequence (stage III) to those from the interglacial deposits at Clacton (Pike and Godwin 1953) (4.4), noting the similarity in the decline of the mixed-oak forest and the rise of coniferous forest in which *Abies* was an important component. West (*ibid*, 340) states "It is therefore very probable that the interglacial deposits at Clacton and Hoxne belong to the same interglacial period". No similarity was found between the Hoxne pollen diagrams and diagrams from the Cromer Forest Bed and from Last Interglacial deposits at Histon Road, Cambridge (West *ibid*). Two species of potential biostratigraphic significance have been recorded at Hoxne, the unidentified plant 'Type X' and the water fern *Azolla filiculoides*. These species are unknown from deposits later than the Hoxnian *sensu lato*.

Malacological studies

The molluscan assemblage from Hoxne is described by Sparks (in West 1956). No extinct species have been recorded from the site, with the exception of *Pisidium clessini*, and the assemblage is not therefore age-diagnostic, being otherwise indistinguishable from a Holocene fauna.

4.1.7. Discussion and conclusions

The age of the interglacial deposits at Hoxne has been the subject of considerable discussion (see Chapter 2) and no firm conclusion has so far been reached, even in the most recent publication by Singer *et al.* (1993). Attempts to date the sequence by absolute methods have also met with mixed results (see below).

The interglacial deposits at the site directly overlie Anglian Lowestoft Till, an important stratigraphic marker which provides a *terminus ante quem* for the temperate stage deposits. If deposition in the Hoxne basin began immediately after the Anglian deglaciation, the Hoxnian Interglacial would logically represent the first post-Anglian interglacial and thus the first of the four post-Anglian interglacials that are indicated in the Thames valley (Bridgland 1994). This proposition has received support from the lithostratigraphic evidence at the site, which indicates a continuity of deposition from the end of the Anglian into the succeeding interglacial (West 1956). An unbroken transition from the end of the Anglian to the Hoxnian Interglacial has also been traced in the pollen record with a very high degree of resolution and that information in turn found to correspond closely with the continental Holsteinian (Turner 1970), considered to be of OIS 11 age (Sarnthein *et al.* 1986).

Similar lithostratigraphic sequences with highly similar patterns of vegetational development, also attributed to the Hoxnian, have been found in other lake basins and hollows on the Lowestoft Formation at Marks Tey, Suffolk (Turner 1970), Slade Oak Lane, Buckinghamshire (Gibbard *et al.* 1986) and at numerous sites in Hertfordshire, including Fisher's Green (Gibbard and Aalto 1977), Hatfield (Sparks *et al.* 1969), Hitchin (Boreham and Gibbard 1995) (4.8), Bell Lane (Gibbard 1974, 1977) and Stanborough (Sparks *et al.* 1969). Correlation of the Hoxne deposits with the Thames valley sites of Swanscombe (4.2) and Clacton (4.4) has also been proposed on the basis of their similar mammalian faunas (Stuart 1974, 1977, 1982; Currant 1989b). The combined litho- and biostratigraphic evidence therefore places Hoxne immediately after the Anglian and consequently implies correlation of the Hoxnian Interglacial with OIS 11, if the position of the Anglian in OIS 12 is accepted.

However, recent suggestions that interglacial sequences filling enclosed lake basins may represent multiple interglacial events (Bowen *et al.* 1989; Bowen 1992) have introduced the possibility that the interglacial represented at Hoxne is not immediately post-Anglian in age. These studies, based upon aminostratigraphy, propose correlation of the Hoxnian type site with OIS 9, a correlation that is supported by TL and ESR dates of *c.* 300 ka on burnt flint and tooth enamel respectively from the Lower Industry (Singer *et al.* 1993). If one gives credence to the amino acid ratios and the absolute dates from Hoxne, the implication that the Hoxnian Interglacial did not directly succeed the Anglian would apparently suggest the following:

i. either there was a considerable hiatus at some sites following the Anglian glaciation, before the deposition of temperate sediments, or

ii. the glacial till that underlies many Hoxnian sites is not all of the same age, or

iii. the Hoxnian sequences really do represent multiple interglacial events that because of homotaxis are indistinguishable in the floral and faunal record.

With regard to the first option, there is indeed no *a priori* reason to infer a directly post-Anglian age for any deposit simply because it rests on top of Anglian till. As Bowen (1992) has pointed out, the presence of infilled hollows in Anglian till of Last Interglacial and Holocene age, for example at Wing, Leicestershire (Hall 1980) and Hockham Mere, Norfolk (Bennett 1983) respectively, has reinforced the view that the use of sediment in depressions on the surface of glacial deposits is not a reliable means for demonstrating continuous sedimentation, nor their precise relative age. However, this does not appear to be the case at Hoxne, where the absence of an unconformity suggests that there was no break in sedimentation from the end of the Anglian into the interglacial (West 1956). This is strongly supported by the palynological record from the site which also indicates a continuity of deposition (West *ibid*, Mullenders, in Singer *et al.* 1993).

The possibility that the underlying tills are of different ages has been recently has been upheld by Sumbler (1995) (see Chapter 2), who advocates the existence of a 'two-phase Anglian glaciation'. Thus, with the earliest Anglian deposits in the region of the Vale of St. Albans correlated with OIS 12, other tills (including, at Hoxne, the Lowestoft Till of the type Anglian succession) are placed within the younger Stage 10. The Stage 9 attribution for the Hoxnian Interglacial would therefore no longer be regarded as anomalous. This position however contradicts that of other authors, who favour lithological continuity of the chalky tills and who have documented Anglian chalky till as a single sediment body across much of eastern England (Bristow and Cox 1973; Perrin *et al.* 1973, 1979).

The possibility that two interglacials (OIS 11 and 9) are indistinguishable in the floral and faunal record and have accordingly been amalgamated into one 'Hoxnian' group must also be considered. In terms of their palynology, Stages 9 and 11 appear to have similar characteristics, such as the presence of Type 'X' and *Azolla filiculoides* and the abundance of *Abies*. This situation is paralleled in mainland Europe, where much more complete records exist (Urban *et al.* 1991; de Jong 1991). Until the exact status of these interglacial events is defined, the biostratigraphic significance of such taxa must be treated with caution (Roe 1995). However, the present study will demonstrate that the mammalian record has the potential to distinguish unequivocally between the Stage 11 and 9 interglacials and to accordingly establish the true position of Hoxne within the British Quaternary. In order for this to be achieved, it is necessary to consider the mammalian evidence from long fluvial records such as the Thames, where a sequence of four terraces, each containing interglacial sediments, has already been established (Bridgland 1994). Having established the nature of the mammalian fauna of the Hoxnian Interglacial and identified three key species of biostratigraphic importance, the following section aims to compare the evidence from Hoxne with that from Swanscombe (4.2), a site whose topographical position places it securely in the first post-Anglian interglacial in the Thames valley and which has been correlated with Stage 11 on the basis of several lines of evidence (Bowen *et al.* 1989; Bridgland 1994). The question of the number of interglacial episodes present at Hoxne will also be addressed.

4.2. BARNFIELD PIT (SWANSCOMBE SKULL SITE N.N.R.), SWANSCOMBE, KENT (TQ 598743)

4.2.1. Location of the site

The former sand, gravel and chalk pit is located on the southern edge of the Lower Thames basin, 5 km to the east of Dartford (Figure 4.5). The site now known as Barnfield Pit (also seen referred to as the Milton Street Pit in older literature) comprises two old pits, the original Barnfield Pit and Colyer's Pit, which were amalgamated in the early decades of the twentieth century (Wymer 1968).

4.2.2. History of research

Since the late 1800s, Barnfield Pit been the focus of intensive archaeological, geological and palaeontological research. Even before the first published reference to the site as a source of Palaeolithic flint implements by Spurrell (1883a), the Swanscombe area had already become popular with the antiquarian collectors who regularly visited the pits along the high terrace of the Lower Thames in their search for artefacts. The first cement works had been established at Swanscombe as early as 1825, but after 1851 there was a dramatic intensification in the production of Portland cement and the quarrying of the deposits by hand well into the following century provided unrivalled opportunities for the collecting of archaeological and palaeontological material (Conway 1996).

However, it was not until 1912 that systematic excavations were undertaken by Smith and Dewey (1913, 1914) and the geological sequence was described in detail for the first time. Smith and Dewey documented Thanet Sand to the south and Chalk to the north, which formed the 'bench' of what was described as the 100 ft Terrace or Boyn Hill Terrace, upon which the classic sequence of Lower Gravel, Lower Loam, Lower Middle Gravel, Upper Middle Gravel, Upper Loam and Upper Gravel was recorded. The sequence was attributed to the Mindel/Riss interglacial on the basis of the height of the terrace (Breuil 1932). It was noted that flint artefacts from the Lower Gravel consisted only of flakes and cores, while the Middle Gravel and Upper Loam produced

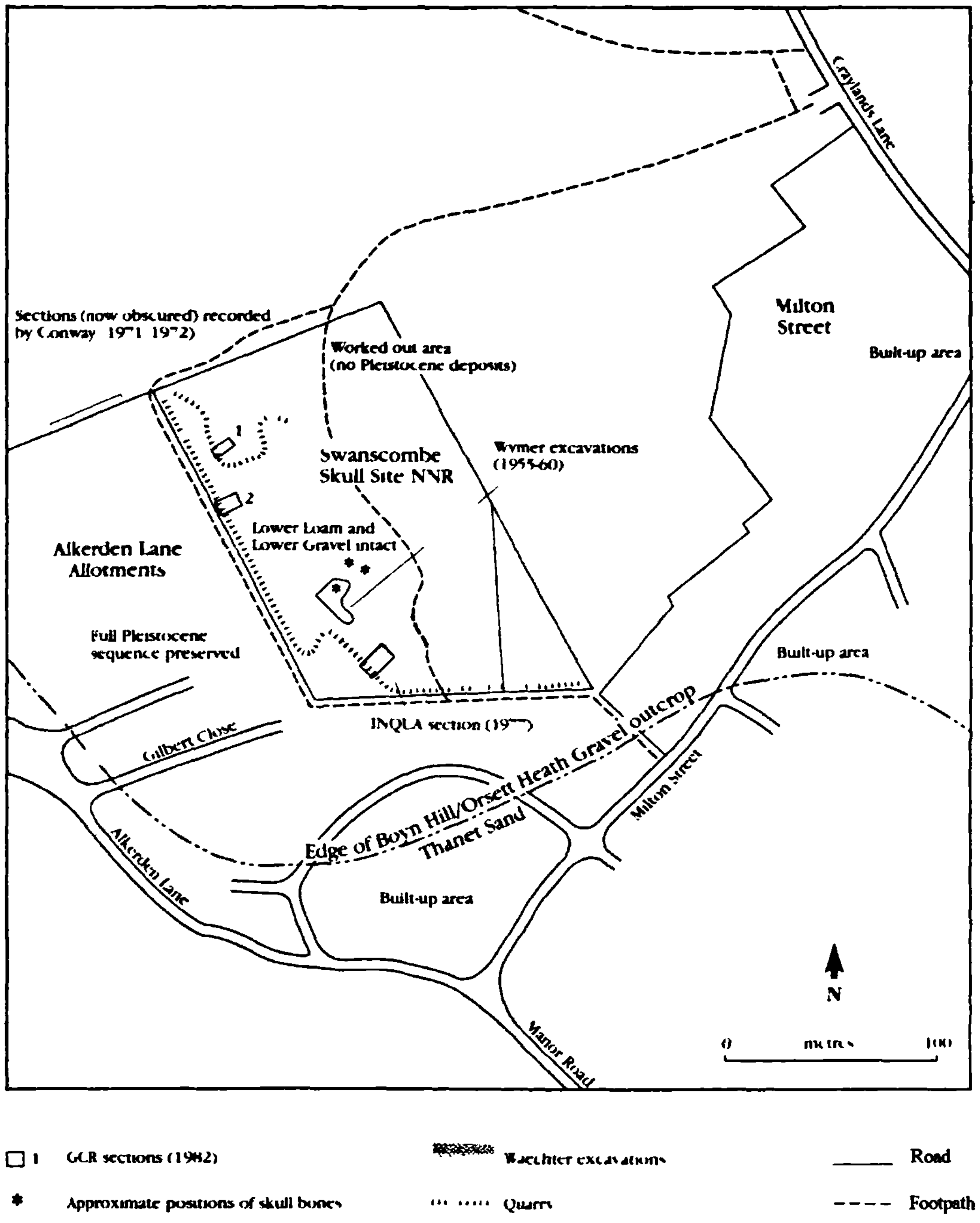


Figure 4.5 Location of Barnfield Pit (Swanscombe Skull Site N.N.R.) and adjacent areas (from Bridgland 1994).

abundant bifaces, those from the Upper Loam (twisted ovates) being perceived as the most advanced in form. The apparent progression in artefact typology, which resembled that seen by Commont in the terraces of the Somme in northern France, was reinforced by the work of Chandler (1928, 1932, 1935, 1942), who classified the archaeological assemblage from the Lower Gravel as Clactonian, thereby drawing parallels between the earliest deposits at Swanscombe and those at Clacton-on-Sea in Essex. It was thus claimed that the evolutionary progress of Palaeolithic industries in Britain could be demonstrated at a single site for the first time (Wymer 1964, 1968).

Barnfield Pit subsequently became a site of international renown in 1935 as a result of the finding, *in situ*, of a fragment of early human skull in the Upper Middle Gravel by a local dentist and amateur collector, A.T. Marston (Marston 1937). Marston recovered a second fragment of the same skull from the Upper Middle Gravel in 1936 and a third refitting piece was later found by J.J. Wymer in 1956 (Wymer 1964). The initial discovery led to a series of excavations in the Middle Gravels, originated by Cotton in 1938 (Swanscombe Committee 1938) and followed up by Ashley-Montagu in 1948 (Ashley-Montagu 1948, 1949). Major collections of mammalian material were made during those ten years by Marston himself and by A.S. Kennard. At that time, most of the sequence was attributed to the 'Great Interglacial' and the Upper Gravel to the Riss (Saalian) glaciation (King and Oakley 1936), although Paterson (1940) assigned the Upper Loam and Upper Gravel to the Last Interglacial and last glaciation respectively.

The site became the first geological National Nature Reserve, when it was donated to the nation by the Associated Portland Cement Company in 1954. Major multidisciplinary excavations were subsequently carried out by B. and J. Wymer in the Middle Gravels between 1955 and 1960 (Wymer 1964) and by J. Waechter in the Lower Gravel and Lower Loam between 1968 and 1972 (Waechter 1969, 1970, 1971, 1972; Conway *et al.* 1996). 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 the 50th anniversary celebration of the discovery of the hominid skull (Duff 1985). Further research excavations were undertaken under the auspices of the Geological Conservation Review (Bridgland *et al.* 1988; Bridgland 1994). In 1982, the full sequence was exposed in the north-west corner of the site, for geological appraisal and sampling, including the collection of material for thermoluminescence dating (Bridgland *et al.* 1985) and for detailed examination of the weathering horizon at the top of the Lower Loam (Kemp 1985). In 1986, the Lower Loam and Lower Gravel were re-exposed for sampling for microvertebrates and to collect calcite coatings from pebbles in the Lower Gravel in order to obtain uranium-series dates (Bridgland 1994). The most recent investigation of the sections at Swanscombe took place in 1995 prior to a field meeting of the Quaternary Research

Association (Ashton *et al.* 1995). Waechter's Section H on the edge of the 1968-72 main area (Figure 4.5) was reopened, as were the two sections originally cut for the Geological Conservation Review (GCR 1 and 2, Figure 4.5).

The rich palaeontological material at the site has been subject to numerous studies over time. Reviews of the mammalian evidence have been provided by Schreuder (1950), Sutcliffe (1964), Stuart (1982), Lister (1986), Currant (1996) and Schreve (1996). Avifaunal and ichthyofaunal remains have been reviewed by Parry (1996) and Irving (1996) respectively. Analysis of the molluscan fauna has been undertaken by Kennard (1938) and Kerney (1971) and of the ostracod fauna by Robinson (1996).

4.2.3. Geological background and provenance of mammalian remains

The deposits at Barnfield Pit have been mapped as Boyn Hill Gravel (= Orsett Heath of Bridgland 1983, 1994) by the Geological Survey. They consist of gravels, sands and loams, which rest on an eroded surface of Thanet Sand and Chalk at about 22.5m O.D. and reach a maximum height of 35.5m O.D. At Hornchurch, Essex (NGR TQ 547874), the Boyn Hill/Orsett Heath gravels overlie glacial till or 'Chalky Boulder Clay' (Holmes 1894; Dines and Edmunds 1925). Approximately 5m of gravel, with its surface at 32.5m O.D., rests on a till surface at 27.5m O.D., which in turn rests on an eroded surface of London Clay at about 24.5m O.D. (Bridgland 1994). The Chalky Boulder Clay of Essex is widely accepted as Anglian in age and the interglacial sediments within the Boyn Hill/Orsett Heath terrace must therefore be considered as representing the first immediately post-Anglian interglacial (Bridgland 1994) (Figure 2.8). This provides a *terminus ante quem* for the chronology of the ensuing terrace sequence in the Lower Thames valley. The stratigraphy at Swanscombe will be reviewed in some detail below, since this site will be used to establish the position of the Hoxnian Interglacial within the British Quaternary sequence, for the purposes of the present study.

The literature on the Swanscombe deposits is particularly extensive and descriptions are provided (amongst others) by Smith and Dewey (1913, 1914), Dewey and Smith (1914), Dewey (1932, 1959), Dines *et al.* (1938), Wymer (1964, 1968), Conway (1969, 1970, 1971, 1972, 1985), Bridgland *et al.* (1985), Bridgland (1994) and Conway *et al.* (1996). Although conflicting observations of the sequence occasionally arise, these are probably

the result of lateral variation within the sediments, stemming from observation of sections in different parts of the site (Bridgland 1994). The complete Swanscombe sequence is as follows (after Conway and Waechter (1977), Bridgland (1994) and Conway *et al.* (1996))
(see Figure 4.6):

Members (beds)	**Thickness**	**Distribution**
Phase III		
IIIe Higher loams	up to 1m	South-west only
IIId **Upper Gravel**	2m	Most of site
IIIc **Upper Loam**	1m	Most of site
IIIb Channel deposits 'Upper Sands'	0-2m	Localised channel-fill
IIIa Soliflucted clay	0-1m	South-west only
Phase II		
IIb **Upper Middle Gravel**	1.5-3m	Most of site
IIa **Lower Middle Gravel**	0.5-2m	Most of site
Phase I		
Ie Weathered surface of Lower Loam	0.5m	Wide channel-fill
Id **Lower Loam**	2-2.5m	Wide channel-fill
comprising the following subdivisions:		
Weathered Lower Loam		
Top of Lower Loam		
Lower Loam main body		
Lower Loam sandy horizon		
Base of Lower Loam		
Ic **Lower Gravel** 'midden complex'	0-0.75m	Localised
Ib **Lower Gravel**	up to 5m	Wide channel-fill
Ia **Basal Gravel**	0-0.5m	Localised

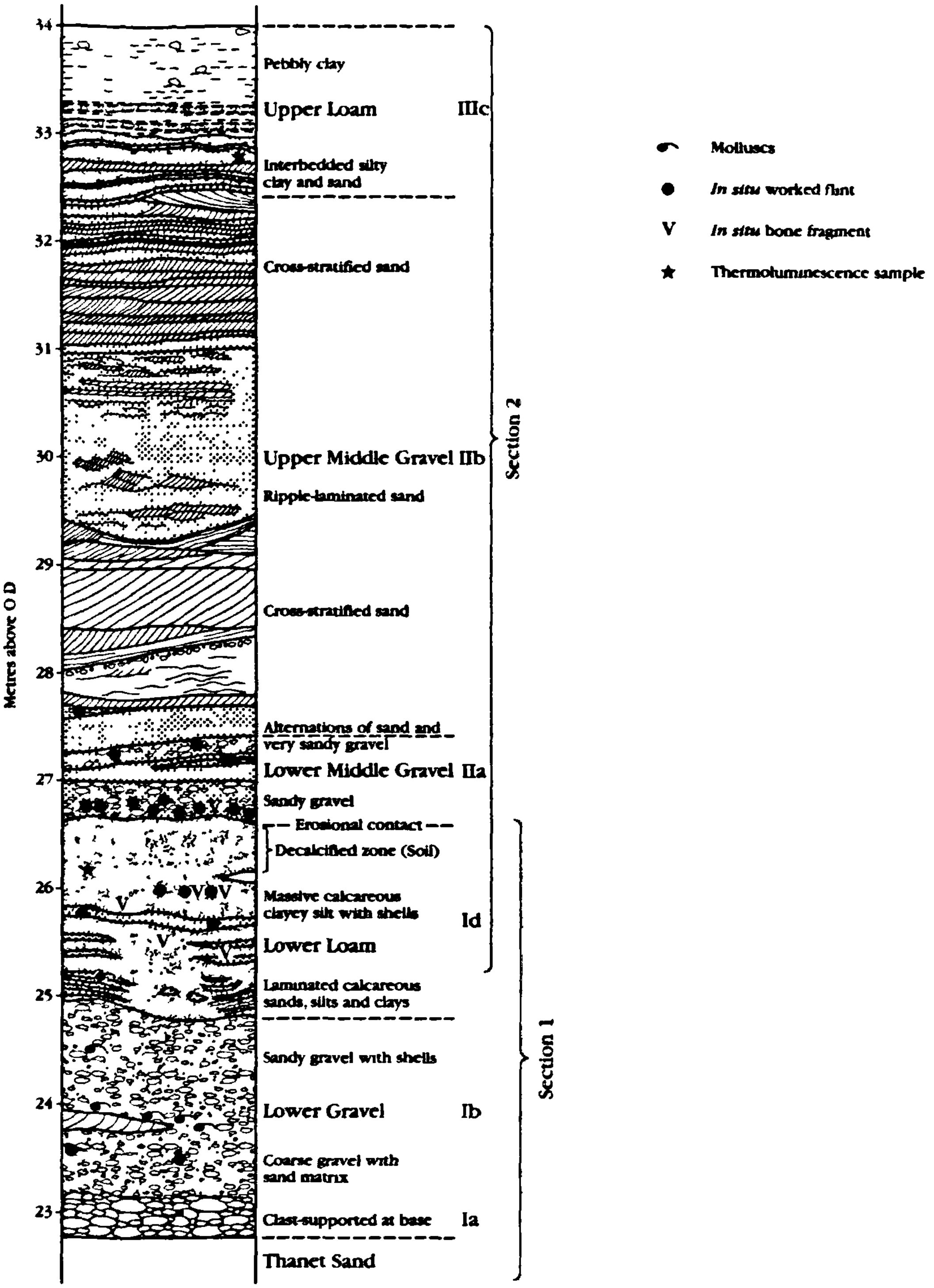


Figure 4.6 The sequence at Swanscombe, based on the GCR sections (from Bridgland 1994).

Phase I:

The initial period of fluvial deposition at the site is represented by the basal part of the Lower Gravel, henceforth referred to as the Basal Gravel (Ia). The Basal Gravel lines the floor of a channel cut into Thanet Sand to the south and Chalk to the north, at *c.* 22m O.D. It consists of up to 0.5m of poorly-sorted, unbedded flint gravel (with Palaeogene pebbles) in a brown, sandy-clay matrix (Ashton *et al.* 1995). In Conway *et al.* (1996), it is subdivided into two units (called Lower Gravel units '3' and '4', in order to distinguish them from the main body of the Lower Gravel, which is referred to as units '1' and '2'.).

The Basal Gravel was originally interpreted by Marston (1937) as a solifluction deposit, a view supported by Paterson (1940) and Conway (1969, 1970, 1996), the latter citing poor sorting and the presence of 'nests' of thermally fractured pebbles, sharp splinters of flint and striated worked flints as evidence of a periglacial origin. However, this was challenged by Kerney (1971) on the basis of molluscan remains collected from near the base of the gravel, which indicate a fully temperate climate. As indicated above, it is quite possible that these conflicting results have arisen from the observation of sections in different parts of the site. In contrast to the two previous interpretations, Bridgland *et al.* (1985) concluded that this basal layer might indeed date from the final part of the periglacial episode that preceded the deposition of the overlying interglacial deposits but considered the deposit to be fluvial in origin. Bridgland *et al.* (*ibid*) were unable to find any fossil material in this layer (again, probably as a result of local lithological differences and lateral variation in the sediments).

Although early authors describe a large quantity of mammalian remains from the Basal Gravel, these remains are apparently not present in museum collections. Dewey (1932) mentions a tusk of *Palaeoloxodon antiquus* about 2m in length, although he notes that the remains were extremely friable. Furthermore, during the installation of a railway line in the 1930s, immediately to the east of part of Waechter's future excavations, three wagon-loads of bones were reportedly removed from the bottom of the Lower Gravel (Conway 1996). Today, only a handful of bones from this unit, of a restricted number of species, are found in the Natural History Museum. However, since the Basal Gravel is unquestionably a cold stage deposit (whatever its origin) and has been observed to be unfossiliferous (Bridgland *et al.* 1985), it seems unlikely that the molluscan remains and the quantities of bone described above, including temperate species such as *P. antiquus*, were genuinely recovered from this unit. A far more likely explanation is that the organic remains were collected from an area where Unit Ia was locally absent and where the fossiliferous Lower Gravel (Unit Ib) lay directly on top of Thanet Sand.

The Lower Gravel proper (Ib) consists of up to 5m of coarse, sandy, horizontally-bedded and fining-upward gravel, which occupies a broad channel excavated in the Thanet Sand (Wymer 1968; Conway and Waechter 1977; Bridgland 1994). It is divided by a band of chalk and clay clasts in a sand and fine gravel matrix, below which only fragmentary shells occur, but above which articulated bivalves are present (Bridgland *et al.* 1985; Ashton *et al.* 1995). Molluscan and mammalian remains from this member are indicative of fully interglacial conditions, with a combination of both open and closed environments (Sutcliffe 1964; Kerney 1971; Stuart 1982; Schreve 1996). Most of the mammalian remains are rather battered and abraded, indicating the prevalence of a high-energy fluvial regime, particularly near the base of this member. Pollen extraction from the gravel has been somewhat problematic, although the results largely corroborate the faunal evidence and suggest the Early Temperate stage (zone II) of an interglacial (Hubbard 1996). Abundant flint artefacts, comprising cores and flakes, are also present.

The 'Midden Complex' (Ic) is a localised bed, channelled into the upper part of the Lower Gravel, which consists of a concentration of bones, pebbles, shells and artefacts within thin alternating bands of sand, silt and fine gravel (Chandler 1928; Marston 1937; Conway 1996). It was originally described as part of the overlying Lower Loam (Conway 1970; Waechter 1970) until a 'distinct stratigraphic break' was recognised between the 'midden' deposits and the Lower Loam (Conway 1971, 60), thereby suggesting that the 'midden' was in fact part of the underlying Lower Gravel. Waechter's initial interpretation of the 'midden' as having been emplaced by human activity (Waechter 1969) has been refuted by subsequent studies, which show that most of the accumulation is the natural product of fluvial transport (Ashton *et al.* 1995; Ashton and McNabb 1996).

The Lower Loam (Id) occupies a channel, approximately 200m wide and aligned SW-NE, cut into the Lower Gravel to a depth of 2.5m (Conway and Waechter 1977). The 'Loam' itself consists principally of horizontally-bedded, yellowish-brown, alternating bands of sand and/or silt, with significant clay and carbonate components (Ashton *et al.* 1995). It is partly laminated, with frequent channelling and lenticular bedding (Bridgland 1994). Although Ashley-Montagu (1949) had pronounced the Lower Loam archaeologically sterile, the Waechter excavations (1968-1972) concentrated on the excavation of this member and demonstrated that it contained rich mammalian and molluscan remains of a temperate character, together with unabraded and slightly-rolled flint artefacts. The fine-grained nature of the Lower Loam suggests a low-energy depositional environment, with virtually still (if not stagnant) water. Deposition was apparently interrupted on several occasions by phases of channel cutting and infilling, and by temporary relatively-dry land surfaces with desiccation features, over which a small network of streams flowed (Conway 1969, 1996; Conway and Waechter 1977). Concentrations of fauna and artefacts were found to be associated with these dessiccation levels.

In the present study, the mammalian remains from the Waechter excavations have been related to one of five horizons within the Lower Loam (from top to bottom: weathered Lower Loam, the top of Lower Loam, the main body of the Lower Loam, the Lower Loam sandy horizon and the base of Lower Loam), depending on their recorded position within this member, according to Waechter's original field notebooks (Schreve 1996). This has enabled a detailed picture of the mammalian fauna to be constructed, during the various phases of deposition and weathering of the Lower Loam. Pollen was also extracted from within the Lower Loam, although its interpretation has been subject to considerable dispute (see below) (Hubbard 1972; Mullenders, in Wymer 1974; Turner 1985; Hubbard 1996).

The upper 0.5m of this member, the 'weathered surface of the Lower Loam' (Ie) is decalcified and is thus accorded separate status fr m the remainder of the underlying Lower Loam (Conway 1996). Smith and Dewey (1913) first noted that the top of the Lower Loam was an old land surface, as did King and Oakley (1936) and Marston (1937), on the basis of the presence of white-patinated flakes and land molluscs. Signs of soil development on top of the land surface are also apparent (Zeuner 1959; Conway

1969, 1972; Kemp 1985), thereby indicating the presence of an important hiatus, following deposition of the Lower Loam. Also present on the eroded surface of the Lower Loam is a trampled surface with a large number of mammalian footprints, associated with terrestrial Mollusca (Waechter 1970; Conway and Waechter 1977; Conway 1985; Davies and Walker 1996).

Phase II:

The second phase of fluvial deposition at Swanscombe is marked by the aggradation of the Lower Middle Gravel (IIa), which rests on the eroded surface of the weathered Lower Loam at *c.* 26m O.D. This member is deposited over most of the site and consists of loose sandy gravel, interbedded with minor layers of sand (Bridgland 1994). A 'lag' deposit at the base of this member comprises coarse flints and occasional fragments of bone (Conway and Waechter 1977; Bridgland *et al.* 1985). The Lower Middle Gravel varies in thickness from 0.5 to 2m thick (Dewey 1932; Chandler 1928; Bridgland 1994; Conway 1996) as a result of an erosional phase prior to the deposition of the Upper Middle Gravel (IIb). Its absence from parts of the site is probably the result of collapse, following solution of the underlying Chalk (Conway 1972), rather than as a consequence of complete erosion, as suggested by Marston (1937) and Wymer (1968). Sandy horizons within the Lower Middle Gravel have yielded molluscan remains which are strikingly different in character from those found in the Lower Gravel. These include *Theodoxus serratiliformis*, *Viviparus diluvianus*, *Valvata naticina*, *Belgrandia marginata*, *Corbicula fluminalis* and *Pisidium clessini* (Kerney 1971), two of which (*Theodoxus serratiliformis* and *Pisidium clessini*) first appear, very rarely, at the top of the Lower Loam (Meijer and Preece 1995). Certain members of this assemblage have central European distributions at the present day and were thus termed a 'Rhenish' fauna, thought to indicate a connection with the Rhine system at this time (Kennard 1938, 1942a, b). Similar 'Rhenish' faunas have been recovered from other sites in south-east England, including Clacton-on-Sea (Kerney 1971; Turner and Kerney 1971)(4.4) and Tillingham in Essex (Roe and Preece 1995), thereby emphasising fluvial exchange between England and the continent during this period (Meijer and Preece 1995). Mammalian remains from the Lower Middle Gravel are also present, although relatively poorly-preserved. Many from the earliest collections are also marked simply 'Middle Gravels' and are thus impossible to differentiate from material from the Upper Middle Gravel.

The Upper Middle Gravel (IIb) comprises a series of cross-bedded and ripple-laminated beds, predominantly of sand but with subordinate silt and gravel horizons (Bridgland 1994). In his account of the finding of the fragments of hominid skull, Marston (1937) describes a phase of erosion and channelling between the Lower and Middle Gravels, in which a channel cut through the Lower Middle Gravel, Lower Loam and Lower Gravel to within 0.3m of the Thanet Sand and was infilled with Upper Middle Gravel. This contrasts markedly with the observations made by Smith and Dewey, Chandler and Conway, none of which were able to confirm the presence of such a channel, although the erosional nature of the Lower Middle Gravel contact with the Upper Middle Gravel was established (Conway 1996). However, Wymer (1964), Dewey (1959) and Conway (1996) all report the presence of areas of sediment slumping and associated small-scale faulting. These are the result of solution subsidence and thus the probable source of Marston's confusion.

The molluscan fauna from this member is rather sparse and dominated by aquatic species (Kerney 1971). Significantly, *T. serratiliformis* and *C. fluminalis* are still present, although much rarer than in the Lower Middle Gravel. Mammalian remains are considerably more abundant and are generally indicative of temperate conditions. However, small mammals were also recovered from silt bands within the Upper Middle Gravel and of these, *Lemmus lemmus* (Norway lemming) was thought to indicate a cooling of climate (Schreuder 1950). In the 1982 GCR sections, it was observed that the cross-stratified sands that form the highest part of the Upper Middle Gravel were interbedded with brown silty laminae. The latter became progressively thicker until they predominated and the sands disappeared at around 33m O.D. This was interpreted as the transition from the Upper Middle Gravel and Upper Loam facies (Bridgland *et al.* 1985). However, previous records 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). A lack of consensus therefore remains as to whether the transition from the Upper Middle Gravel to the Upper Loam is gradational or whether there is a significant (visible) break in the sequence (Bridgland 1994). Deposits above the Upper Middle Gravel have therefore been assigned to a separate phase (Phase III) of the Swanscombe succession.

Phase III:

Dines *et al.* (1938) record the presence of a wedge of soliflucted material (a clayey diamicton) (member IIIa) between the Upper Middle Gravel and the Upper Loam. This was interpreted as the first of a series of cold-climate deposits which mark the final aggradational phase of the Swanscombe sequence (Conway and Waechter 1977). However, the significance of such wedges of colluvial material, adjacent to a former valley side, is uncertain in terms of the severity of climate or the length of time represented (Bridgland 1994). Better evidence for the onset of cold climate conditions comes from a channel (IIIb), about 75m wide and 2m deep, cut into the Upper Middle Gravel and infilled with horizontally-bedded, fine loamy sands (the 'Upper Sands' of Conway, 1996) with thin seams of silty clay (Bridgland 1994; Conway 1996). Ice-wedge casts 10-30 cm in depth, micro-faulting and cryoturbation structures are present at several levels, leading to their interpretation as having accumulated under periglacial conditions (Bridgland 1994; Conway 1996).

The Upper Sands pass conformably into the Upper Loam (IIIC) (Conway and Waechter 1977). The latter consists of poorly-bedded to massive silty clay, brown or red-brown with scattered flints (Bridgland 1994). It has formerly been interpreted as an overbank (floodplain) deposit, thought to mark the final phase of the Boyn Hill Terrace aggradation (Dines *et al.* 1938). However, new exposures of this unit, seen by the author in May 1997 at Southfleet Road, Swanscombe, reveal the Upper Loam to be both finely-bedded and (with the exception of some pebbles at the base) stone-free. This would consequently imply a fluvial mode of deposition. White-patinated artefacts have been reported from the very base of the Upper Loam (Dewey 1919, 1930), thereby providing additional evidence of a possible hiatus between the Upper Middle Gravel and the Upper Loam. The Upper Loam has yielded no faunal remains, although sparse pollen spectra have been obtained by sieving large samples of the deposit. These have been considered indicative of temperate woodland conditions and thought to represent the early-temperate (zone IIb) and post-temperate (zone III) phases of an interglacial (Hubbard 1996). Unabraded flint knapping debris and white-patinated handaxes of twisted ovate type (a type not previously recorded in the lower levels of the site) were also recovered from this member (Conway and Waechter 1977).

The Upper Gravel (IIId) was first described by Smith and Dewey (1913) as a stiff clay, up to 2m thick, with pockets of coarse, angular gravel. It has been widely regarded as a solifluction deposit, an interpretation supported by evidence that periglaciation affected the surface of the Upper Loam before the deposition of the Upper Gravel. Further supporting evidence of intensely cold conditions apparently came from a record of *Ovibos* (musk ox) from near the base of this gravel (Conway and Waechter 1977) (but see later). Patinated, twisted ovate handaxes, thought to have been derived from the Upper Loam, are also recorded (Wymer 1968; Conway and Waechter 1977). The Upper Gravel passes upwards, with a reduction in the number of pebbles, into a loose, clayey silt with scattered pebbles (the 'Brickearth' of previous authors). This appears to represent the deeply-weathered and disturbed upper part of the Upper Gravel (Conway 1996). Minor accumulations of horizontally-bedded loamy sand (Higher Loams, IIIe) are recorded from above the Upper Gravel in the south-western part of the site, extending the sequence to nearly 35m O.D. (Conway and Waechter 1977; Conway 1996). These deposits have probably been washed or soliflucted over the bluff at the edge of the former floodplain but appear to be of little significance to the fluvial record at the site (Bridgland 1994). A few worked flakes were recovered from this deposit but no faunal material (Conway 1996).

4.2.4. Palaeontology

The mammalian assemblage from Swanscombe forms an extremely important part of the British Middle Pleistocene fossil record, although until this study, no comprehensive account existed on the collection in its entirety. The following list of mammalian species (see below) has been compiled from material in the Natural History Museum in London, the British Geological Survey Museum at Keyworth, Dartford Museum and the Harrison Zoological Museum, Sevenoaks. The collections are largely the work of A.T. Marston, A.S. Kennard, B.O. and J.J. Wymer and J. d'A. Waechter, with occasional specimens collected by M.A.C. Hinton, R.H. Chandler, K.P. Oakley, L.S.B. Leakey, C.T. Trechman, C.B.M. McBurney, M.P. Kerney and J.D. Clayden. The total number of specimens examined was 1622. The results of the present study indicate that 33 mammalian species can be reliably identified at Swanscombe, a number which exceeds any other British late Middle Pleistocene site. The present study also identified the first record of the extinct small mole *Talpa minor* at Swanscombe (Schreve 1996) and verified the presence of the extinct 'ass' *Equus hydruntinus*, absent from previously published faunal lists by Sutcliffe (1964) and Wymer (1985). A number of reidentifications were made, including a cervical vertebra (Natural History Museum London, no registered number) of lion (*Panthera leo*) from the Basal Gravel, previously identified as deer.

The Waechter collection has also been examined and described in detail for the first time as part of this study, providing the first published records from the site of common mole (*Talpa europaea*), macaque monkey (*Macaca sylvanus*), European beaver (*Castor fiber*) and wild cat (*Felis silvestris*) from the Lower Loam (Schreve 1996). In addition, further specimens of cave bear (*Ursus spelaeus*) and wild boar (*Sus scrofa*) were identified among the numerous fragments collected by Waechter. Bulk samples from the Lower Gravel and Lower Loam, collected in 1985 by A.P. Currant of the Natural History Museum, London, were processed for small vertebrate remains. These yielded a single first lower molar of wood mouse (*Apodemus sylvaticus*) from the Lower Gravel (sample 17). A coprolite fragment (indeterminate species) was also recovered from the Lower Loam of Waechter's Section H.

Species List (Mammalia) from Barnfield Pit, Swanscombe, Kent

Insectivora

Talpa cf. *europaea* L., common mole

Talpa minor (Freudenberg), extinct small mole

Primates

Macaca sylvanus (L.), Barbary macaque

Homo sp., hominid (bones and artefacts)

Lagomorpha

Oryctolagus cuniculus L., rabbit

Rodentia

Castor fiber L., European beaver

Trogontherium cuvieri Fischer, extinct giant beaver

Lemmus lemmus (L.), Norway lemming or *Myopus schisticolor* (Lilljeborg), wood lemming

Clethrionomys glareolus (Schreber), bank vole

Arvicola terrestris cantiana (Hinton), extinct water vole (primitive morphotype)

Microtus agrestis (L.), field vole

Microtus arvalis (Pallas), common vole

Microtus agrestis (L.) or *Microtus arvalis* (Pallas), field or common vole

Microtus oeconomus (Pallas), northern vole

Microtus (*Terricola*) *subterraneus* (De Selys Longchamps) (*Pitymys arvaloides* Hinton), European pine vole

Microtus sp., indet. vole

Apodemus sylvaticus (L.), wood mouse

Carnivora

Canis lupus L., wolf

Ursus spelaeus Rosenmüller and Heinroth, cave bear

Martes cf. *martes* L., pine marten

Felis silvestris Schreber, wild cat

Panthera leo (L.), lion

Proboscidea

Palaeoloxodon antiquus (Falconer and Cautley), straight-tusked elephant

Elephantidae sp., indet. elephant

Perissodactyla

Equus ferus Boddaert, horse

Equus hydruntinus Regalia, extinct stenonid 'ass'

Stephanorhinus aff. *etruscus* (Falconer), 'Etruscan'-type rhinoceros

Stephanorhinus hemitoechus (Falconer), narrow-nosed rhinoceros

Stephanorhinus kirchbergensis (Jäger), Merck's rhinoceros

Stephanorhinus sp., indet. rhinoceros

Artiodactyla

Sus scrofa L., wild boar

Megaloceros giganteus (Blumenbach), giant deer

Dama dama clactoniana (Falconer) and *Dama dama* ssp. indet., fallow deer

Cervus elaphus L., red deer

Capreolus capreolus (L.), roe deer

Cervidae sp. indet., deer (size of *Dama* or *Cervus*)

Bos primigenius Bojanus, aurochs

Bison cf. *priscus* Bojanus, bison

Bovidae sp., indet. large bovid

Table 4.4 below provides a breakdown of the species list into numbers of specimens per species (including specimens that are marked 'Swanscombe' but lack any further stratigraphic data), also expressed as a percentage of the total mammalian assemblage from the site. Minimum numbers of individuals have also been calculated (these figures do not include specimens that cannot be assigned to a stratigraphic horizon).

Species	Number of specimens	Percentage of total assemblage (%)	Minimum number of individuals (M.N.I.)
Insectivora			
T. cf. *europaea*	1	0.06	1
T. minor	1	0.06	1
Primates			
M. sylvanus	1	0.06	1
Homo sp.	3	0.18	1
Lagomorpha			
O. cuniculus	73	4.5	15
Rodentia			
C. fiber	3	0.18	2
T. cuvieri	1	0.06	1
L. lemmus or *M. schisticolor*	1	0.06	1
C. glareolus	1	0.06	1
A. t. cantiana	40	2.46	8
M. agrestis	1	0.06	1
M. arvalis	2	0.12	1
M. agrestis or *M. arvalis*	11		4
M. oeconomus	4	0.24	2
M. (T.) subterraneus	2	0.12	2
Microtus sp.	43	2.65	5
A. sylvaticus	6	0.36	3
Carnivora			
C. lupus	9	0.55	4
U. spelaeus	11	0.67	7 (1 juv., 6 adults)
M. cf. *martes*	2	0.12	2
F. silvestris	1	0.06	1
P. leo	10	0.61	4
Proboscidea			
P. antiquus	71	4.37	21 (4 juv., 17 adults)
Elephantidae sp.	42	2.58	10 (1 juv., 9 adults)
Perissodactyla			
E. ferus	59	3.63	6
E. hydruntinus	3	0.18	2
S. aff. *etruscus*	3	0.18	1
S. hemitoechus	5	0.3	2
S. kirchbergensis	30	1.84	10 (2 juv., 8 adults)
Stephanorhinus sp.	28	1.72	11 (1 juv., 10 adults)

cont'd.../...

Species	Number of specimens	Percentage of total assemblage (%)	Minimum number of individuals (M.N.I.)
Artiodactyla			
S. scrofa	12	0.73	5 (1 juv., 4 adults)
M. giganteus	6	0.36	4 .
D. d. clactoniana and *D.d.* ssp. indet.	319	19.66	30
C. elaphus	65	4	15
C. capreolus	2	0.12	1
Cervidae sp.	408	25.15	24 (2 juv., 22 adults)
B. primigenius	72	4.43	11
B. cf. *priscus*	19	1.17	6
Bovidae sp.	251	15.47	2

Table 4.4 Breakdown of the mammalian species list from Swanscombe, showing numbers of specimens per species, the percentage of the total assemblage per species and minimum numbers of individuals.

4.2.5. Palaeoenvironmental and palaeoclimatic interpretation

Table 4.5 below shows the number of specimens per species for each stratigraphic unit at the site. The stratigraphic units are as follows: UMG= Upper Middle Gravel, LMG= Lower Middle Gravel, MG= undifferentiated Middle Gravels, LL= Lower Loam, LL/LG junc.= junction of the Lower Loam and Lower Gravel, LG midden= Lower Gravel 'midden', LG= Lower Gravel, BG= Basal Gravel. As stated above, it should be noted that all material marked from the 'Basal Gravel' is probably from the Lower Gravel. A more detailed breakdown of the species present in the five subdivisions of the Lower Loam (see above) is provided in the Appendix.

N.B. This table does not take into account material for which the stratigraphic horizon at the site is unknown. Hence, for example, *T. cuvieri* and *C. glareolus* are not shown, since only a single specimen of each is known from Swanscombe but unfortunately unprovenanced.

Species	UMG	LMG	MG	LL	LL/LG junc.	LG midden	LG	BG
T. cf. *europaea*	-	-	-	1	-	-	-	-
T. minor	-	-	-	1	-	-	-	-
M. sylvanus	-	-	-	1	-	-	-	-
Homo sp.	3	-	-	-	-	-	-	-
O. cuniculus	1	-	-	52	8	1	3	1
C. fiber	-	-	-	2	-	-	-	-
L. lemmus or *M. schisticolor*	1	-	-	-	-	-	-	-
A. t. cantiana	1	-	-	35	1	-	2	-
M. agrestis	-	-	-	-	1	-	-	-
M. arvalis	2	-	-	-	-	-	-	-
M. agrestis or *M. arvalis*	8	-	-	-	-	-	-	-
M. oeconomus	1	-	-	-	3	-	-	-
M. (T.) subterraneus	-	-	-	1	1	-	-	-
Microtus sp.	38	-	-	-	1	-	-	-
A. sylvaticus	3	-	-	2	-	-	1	-
C. lupus	1	-	-	3	-	1	-	2
U. spelaeus	-	-	-	3	1	2	3	2
M. cf. *martes*	-	-	-	1	-	-	1	-
F. silvestris	-	-	-	1	-	-	-	-
P. leo	2	-	1	3	-	-	-	1
P. antiquus	4	1	7	2	-	6	16	23
Elephantidae sp.	2	-	3	3	3	2	17	4
E. ferus	17	-	18	3	-	-	3	10
E. hydruntinus	-	-	1	-	-	-	-	1
S. aff. *etruscus*	-	-	-	-	-	-	-	3
S. hemitoechus	-	-	-	-	-	2	-	2
S. kirchbergensis	3	1	1	1	-	1	4	17
Stephanorhinus sp.	-	-	-	4	1	3	10	8
S. scrofa	-	-	-	6	3	-	-	2
M. giganteus	1	1	1	1	-	-	-	1
D. dama ssp. indet.	6	2	7	-	-	-	-	-
D. d. clactoniana	-	-	-	77	4	40	45	93
C. elaphus	7	-	3	15	2	3	18	14
C. capreolus	-	-	-	-	-	-	-	1
Cervidae sp.	12	2	8	131	34	48	69	86
B. primigenius	15	1	16	2	1	-	17	13
B. cf. *priscus*	6	1	2	-	-	-	6	3
Bovidae sp.	66	7	67	11	4	14	14	44

Table 4.5 Number of specimens per species for each stratigraphic unit at Swanscombe.

Table 4.6 below shows the percentage provided by each species of the total assemblage in each stratigraphic unit at the site.

Species	UMG	LMG	MG	LL	LL/LG junc.	LG midden	LG	BG
T. cf. *europaea*	-	-	-	0.27	-	-	-	-
T. minor	-	-	-	0.27	-	-	-	-
M. sylvanus	-	-	-	0.27	-	-	-	-
Homo sp.	1.5	-	-	-	-	-	-	-
O. cuniculus	0.5	-	-	14.36	11.76	0.81	1.31	0.3
C. fiber	-	-	-	0.55	-	-	-	-
L. lemmus or *M. schisticolor*	0.5	-	-	-	-	-	-	-
A. t. cantiana	0.5	-	-	9.66	1.47	-	0.87	-
M. agrestis	-	-	-	-	1.47	-	-	-
M. arvalis	1	-	-	-	-	-	-	-
M. agrestis or *M. arvalis*	4	-	-	-	-	-	-	-
M. oeconomus	0.5	-	-	-	4.41	-	-	-
M. (T.) subterraneus	-	-	-	0.27	1.47	-	-	-
Microtus sp.	19	-	-	-	1.47	-	-	-
A. sylvaticus	1.5	-	-	0.55	-	-	0.43	-
C. lupus	0.5	-	-	0.82	-	0.81	-	0.6
U. spelaeus	-	-	-	0.82	1.47	1.62	1.31	0.6
M. cf. *martes*	-	-	-	0.27	-	-	0.43	-
F. silvestris	-	-	-	0.27	-	-	-	-
P. leo	1	-	0.74	0.82	-	-	-	0.3
P. antiquus	2	6.25	5.18	0.55	-	4.87	6.98	6.94
Elephantidae sp.	1	-	2.22	0.82	4.41	1.62	7.42	1.2
E. ferus	8.5	-	13..33	0.82	-	-	1.31	3.02
E. hydruntinus	-	-	0.74	-	-	-	-	0.3
S. aff. *etruscus*	-	-	-	-	-	-	-	0.9
S. hemitoechus	-	-	-	-	-	1.62	-	0.6
S. kirchbergensis	1.5	6.25	0.74	0.27	-	0.81	1.74	5.13
Stephanorhinus sp.	-	-	-	1.1	1.47	2.43	4.36	2.41
S. scrofa	-	-	-	0.27	4.41	-	-	0.6
M. giganteus	0.5	6.25	0.74	0.27	-	-	-	0.3
D. dama ssp. indet	3	12.5	5.18	-	-	-	-	-
D. d. clactoniana	-	-	-	21.27	5.88	32.52	19.65	28.09
C. elaphus	3.5	-	2.22	4.14	2.94	2.43	7.86	4.22
C. capreolus	-	-	-	-	-	-	-	0.3
Cervidae sp..	6	12.5	5.92	36.18	50	39.02	30.13	25.98
B. primigenius	7.5	6.25	11.85	0.55	1.47	-	7.42	3.92
B. cf. *priscus*	3	6.25	1.48	-	-	-	2.62	0.9
Bovidae sp.	33	43.75	49.62	3.03	5.88	11.38	6.11	13.29

Table 4.6 Percentage provided by each species of the total assemblage in each stratigraphic unit at Swanscombe.

Reconstruction of the palaeoenvironment at the time of deposition of the very earliest deposits at Swanscombe is problematic, due to the different interpretations of the various workers (*i.e.* whether the Basal Gravel is of soliflucted or fluvial origin). Despite reports of abundant mammalian remains from the very base of the gravel (Conway 1996), only a handful of specimens from the Waechter excavations, marked 'base of solifluction' survive today, which apparently can be related to this unit. These include fallow deer, red deer, indeterminate cervids and large bovids, species which are very broadly indicative of a temperate mixed woodland/grassland habitat. However, given the temperate character of these mammalian remains, it seems most likely that the specimens actually came from the Lower Gravel, in an area of the site where the true Basal Gravel was locally absent. The same may be said of the molluscan remains, allegedly from the Basal Gravel, which also suggest fully temperate conditions (Kerney 1971). A wide range of specimens marked 'Basal Gravel' exist in the Marston and Kennard collections but these almost certainly also came from the main body of the Lower Gravel itself. For the purposes of the present discussion, the Basal Gravel and Lower Gravel assemblages will therefore be treated as one.

The Lower Gravel has yielded a mammalian assemblage which is indicative of fully temperate climatic conditions. At the present day, the fallow deer is characteristic of temperate deciduous or mixed woodland (Corbet and Harris 1991) and Pleistocene occurrences have similarly been entirely restricted to woodland interglacial episodes. Although caution must be exercised since the *clactoniana* subspecies is now extinct, it would not be unreasonable to assume that the remarkable abundance of fallow deer in the Lower and Basal Gravel (138 specimens of 560, 23.87% of the combined Lower and Basal Gravel assemblage) strongly suggests the presence of local deciduous woodland in the vicinity and also of a temperate climate. This is further enhanced if one includes the 155 specimens of indeterminate cervid of red or fallow deer size in the Lower/Basal Gravel, most of which are probably *Dama*, given the ratio of identified red:fallow deer specimens. This is supported by the presence of other 'woodland' taxa, such as *A. sylvaticus* (1 specimen), *S. scrofa* (2 specimens) and *C. capreolus* (1 specimen). Although the numbers of specimens of these three species is small, it is important to bear in mind that the Lower Gravel is extremely poor in small mammal remains because of the coarse nature of the deposit and that wild boar and roe deer are relatively rare as Pleistocene fossils (see Chapter 3). However, the substantial presence of large grazing or part-grazing herbivores (39 specimens of *P. antiquus* plus 21 indeterminate elephant remains, 13 specimens of *E. ferus*, 2 specimens of *S. hemitoechus*, 21 specimens of *S.*

kirchbergensis, 1 specimen of *M. giganteus* and 30 specimens of *B. primigenius*) from this horizon also indicates the proximity of large areas of open grassland.

The molluscan remains from the Lower Gravel are fully temperate in nature and consist of predominantly freshwater species, with a few land snails (Castell 1964). The aquatic species include *Valvata piscinalis*, *Bithynia tentaculata*, *Lymnaea peregra*, *Potomida littoralis*, *Sphaerium corneum*, *Pisidium amnicum*, *P. henslowanum*, *P. nitidum* and abundant *Ancylus fluviatilis*, considered to be indicative of a swift-flowing river with a stony bed (Castell 1964). The palynological record from the Lower Gravel is patchy and erratic, as one would expect of a coarse waterlain deposit. However, the occurrence of *Hedera* (ivy) is thought to indicate a mild climate in an early temperate phase of an interglacial (Hubbard 1996). The Lower Gravel 'Midden' contains a virtually identical mammalian assemblage to the main body of Lower Gravel, reflecting similar environmental conditions.

The mammalian assemblage from the Lower Loam is again wholly consistent with a temperate climate and regional mixed deciduous woodland. The present study demonstrates that according to the mammalian evidence, the landscape appears to have been more densely forested at this time than previously, with abundant fallow deer and an increase in the number of woodland species (*M. sylvanus*, *C. fiber*, *S. scrofa*). At the same time, the number of open grassland species in the Lower Loam has decreased dramatically, with only three specimens of *E. ferus*, three of *B. primigenius*, six of elephant and six of rhinoceros represented out of 430 specimens (combined assemblages of the Lower Loam and Lower Loam junction with Lower Gravel). *M. giganteus*, a species needing relatively open conditions, is apparently absent. The microtine rodent remains recovered from the junction of the Lower Loam with the Lower Gravel are part of a probable pellet accumulation, given the presence of associated bones and teeth of single individuals. The species represented most abundantly is *M. oeconomus*, which favours damp, grassy conditions. They are therefore only appropriate for regional, as opposed to local, palaeoenvironmental reconstructions. No direct palaeoclimatic information is provided by the mammalian remains from the Lower Loam with the possible exception of the moles *T. europaea* and *T. minor*, which are both adapted to a fossorial existence and thus require a habitat where the ground is not subject to permanent or seasonal freezing. The proximity of slow-flowing water is attested to by the presence of *A. terrestris cantiana* and *C. fiber*.

The molluscan assemblage from the Lower Loam is also indicative of slowly moving or stagnant water with reed swamps, supporting a marsh-dwelling community including *Succinea*, *Vertigo* and *Zonitoides nitidus* (Castell 1964). Compared to the Lower Gravel, there is a marked decrease in the number of freshwater snails and an increase in terrestrial species, such as *Vallonia* sp., *Pupilla muscorum* and *Helicella crayfordensis*, which typically inhabit dry, warm grasslands. Species such as *Ena montana*, *Clausilia* and *Discus ruderatus* suggest the presence of calcareous woodland nearby (Castell *ibid*). The ostracod fauna from the Lower Loam is also characteristic of a low-energy, still water environment and is dominated by *Scottia browniana*, a species today characteristic of marshy fen environments (Robinson 1996). A brackish water influence is however suggested by the remains of migratory and marine stenohaline fish, including the Atlantic salmon (*Salmo salar*), possibly indicating deposition in an estuarine, intertidal zone (Irving 1996). Remains of piscivorous birds, including great cormorant (*Phalacrocorax carbo*) and osprey (*Pandion haliaetus*) have also been recovered from this horizon (Parry 1996). The pollen record is interpreted as reflecting the presence of a mixed oak forest, dominated by alder and with some hazel (Hubbard 1996). At approximately 60cm from the top of the Lower Loam, there is a change from *Alnus* (alder) domination to a predominance of grass and herb pollen. This is thought to record a change of pollen catchment regime (Hubbard *ibid*), although Turner (1985) considers the differences likely to result from the oxidisation of the upper levels of the Lower Loam, rather than from any significant vegetational change.

The Lower Middle Gravels are extremely poor in mammalian remains, with only a single specimen of each of the following species represented from the basal 'lag' of this bed: *P. antiquus*, *S. kirchbergensis*, *D. dama*, *M. giganteus*, *B. primigenius* and ?*Bison priscus*. Many of the specimens from the older collections are however simply marked 'Middle Gravels' and although it is possible that some of these may have come from the Lower Middle Gravel, most probably originated from the more prolific Upper Middle Gravel. Given the paucity of evidence and the fragmentary and heavily rolled nature of the material, any attempt to use the mammalian remains from this horizon for palaeoenvironmental reconstruction must be considered suspect. The molluscan record from the Lower Middle Gravel is more informative and reflects similar conditions to those in the Lower Gravel, with the important addition of the 'Rhenish' suite. The presence of these 'southern' species implies a warm climate (Castell 1964). Pollen concentrations in the Lower Middle Gravel are low but still reflect temperate conditions. Grasses and herbs contribute 75% of the pollen, although this may again be a consequence of the prevailing pollen catchment regime (Hubbard 1996).

The Upper Middle Gravels are much richer in mammalian material (200 specimens) and reflect a return to more open (but still temperate) conditions. The large bovids and *E. ferus* are by far the most abundant large mammal species recovered (77 and 17 specimens respectively), together with smaller numbers of *P. antiquus* (4 specimens), *S. kirchbergensis* (3 specimens), *C. elaphus* (7 specimens) and *M. giganteus* (1 specimen), which suggest the proximity of large tracts of open grazing. The total number of *Dama* specimens in the Middle Gravels as a whole is only 15, contrasting sharply with the figures from the Lower Gravel and Lower Loam and emphasising the decline in deciduous woodland. Rodent remains, collected by Marston from a silt bed within the Upper Middle Gravels and re-examined during the present study, include *M. agrestis*, *M. arvalis* and *M. oeconomus*, all inhabitants of rough, damp grassland at the present day. An interesting occurrence in the Upper Middle Gravel is that of Norway lemming, *Lemmus lemmus* (Schreuder 1950), which given its current arctic distribution would appear to be somewhat inconsistent with the rest of the mammalian assemblage. It is possible however, that the specimens in question may be wood lemming, *Myopus schisticolor*, since this species is indistinguishable from *Lemmus* in the fossil state (see Chapter 3). The palaeoecological significance of both the Norway and wood lemming has already been discussed (see 4.1) and it seems likely that *Lemmus*/*Myopus* appeared in conjunction with the closing phases of interglacials and the development of more open vegetation. This corresponds well with the predominance of open grassland voles in the rodent assemblage from the Upper Middle Gravel. The molluscan fauna from this unit is sparse and dominated by aquatic species (Kerney 1971). The pollen evidence is equally scanty but is apparently comparable with conditions in the Lower Middle Gravel (Hubbard 1996). No mammalian remains have been recorded from the Upper Loam. Preliminary studies of pollen from this unit indicate that temperate conditions still prevailed through the bulk of this horizon (presence of pollen from the thermophile *Hedera* and frost-sensitive *Ilex* (holly)). A single sample from the top 50 cm of the

Upper Loam shows an abrupt increase in *Carpinus* (hornbeam), suggesting an unconformity and deposition during the post-temperate phase of an interglacial (Hubbard 1996). No mammalian remains have been recorded from the Upper Gravel, with the exception of musk ox (*Ovibos moschatus*) (Conway and Waechter 1977). Unfortunately, the specimen in question was never figured and its present location is unknown. Its reported presence in the Upper Gravel is however a good indication of cold climatic conditions.

4.2.6. Biostratigraphy and correlation

Traditionally, the Swancombe deposits have been correlated with the Hoxnian Stage and have long been regarded as a stratigraphical representative for that interval in the Thames valley (King and Oakley 1936; Sutcliffe 1964; Kerney 1971). This correlation has been based primarily on biostratigraphic comparisons of the Swanscombe pollen, molluscan and mammalian records with those of Clacton-on-Sea (4.4), assigned to the Hoxnian Interglacial on palynological grounds (Pike and Godwin 1953; Turner and Kerney 1971). However, as already stated, the differentiation of Swanscombe and Hoxne (4.1) into two interglacials (Stage 11 and 9 respectively) on the basis of aminostratigraphy (Bowen *et al.*, 1989) has cast doubts on these correlations. The position of Swanscombe as the highest (and therefore oldest) temperate-stage deposits within the Lower Thames terrace sequence, and the presence of Anglian till and outwash gravel directly beneath these temperate sediments, securely establishes the Swanscombe interglacial as the first post-Anglian temperate stage and thus supports a Stage 11 correlation (Bridgland 1994; Figure 2.8). Other sites in the Lower Thames valley, such as Purfleet (5.1) and Grays (5.2), have been assigned by Bridgland (1994) to the second post-Anglian interglacial, correlated with Stage 9. Having established the diagnostic characters of the mammalian assemblage of the Hoxnian Interglacial in the previous section, that information will first be compared with the evidence from Swanscombe and then with the evidence from various localities attributed to Stage 9 (see Chapter 5).

Mammalian studies

The Swanscombe mammal assemblage will be considered in detail below and its composition used to define the characteristic components of the first post-Anglian interglacial mammal fauna in Britain. This will then be compared with evidence from the Hoxnian Interglacial.

The mammalian assemblage from Swanscombe differs from that of the immediately pre-Anglian early Middle Pleistocene in the absence of the shrews *Sorex runtonensis* and *Sorex* (*Drepanosorex*) *savini* and the vole *Pliomys episcopalis*. The interglacial as represented at Swanscombe also records the first appearance in the British Isles of the field vole *Microtus agrestis*, the cave bear *Ursus spelaeus* and two species of rhinoceros that are not found in the preceding Cromerian Complex: Merck's rhinoceros (*Stephanorhinus kirchbergensis*) and narrow-nosed rhinoceros (*Stephanorhinus hemitoechus*) (Figure 4.7). Of these, *S. kirchbergensis* is by far the dominant species, constituting 43.54% of the identified rhinoceros specimens (n= 35), with *S. hemitoechus* making up 11.29%.

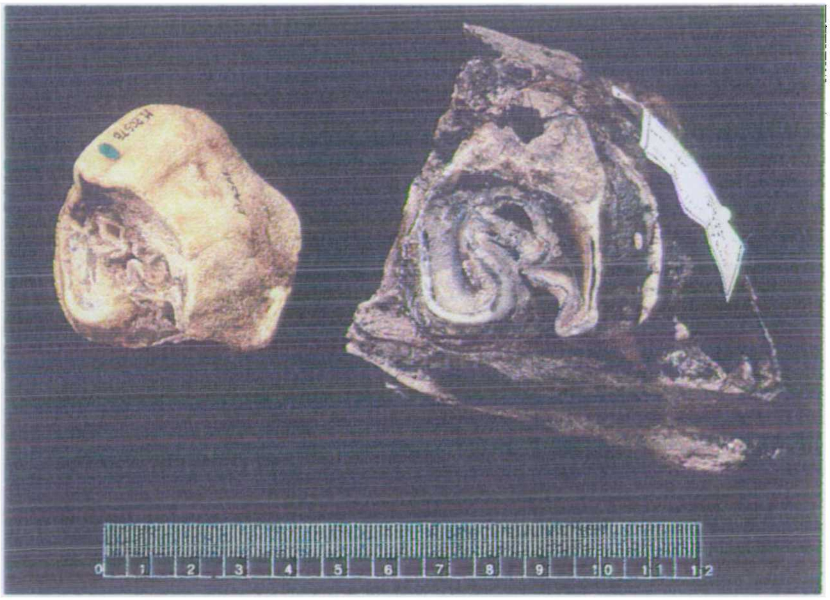


Figure 4.7 Left M3 of *Stephanorhinus hemitoechus* (M20578, N.H.M.L.), Basal Gravel, Swanscombe (left) shown against a left M3 of *S. hemitoechus* from Clacton (27840, N.H.M.L.) (right).

The Swanscombe interglacial also witnesses the first appearance in Britain of the extinct stenonid 'ass' *Equus hydruntinus*. In addition to their small size, the three specimens of *E. hydruntinus* from Swanscombe exhibit further characteristics typical of the species, for example an extremely short protocone (6.32 mm) in a left upper cheek tooth from the Middle Gravel, a deep postprotoconal groove in a left upper cheek tooth fragment from the Basal Gravel and a particularly deep ectoflexid in an unprovenanced left lower cheek tooth. The presence of *E. hydruntinus* at Swanscombe is certainly the earliest occurrence of this species in Britain, if not in Europe, since the next earliest record is from the site of Lunel-Viel in France, thought to be about 300 000 years old (Eisenmann 1992). The giant deer *Megaloceros giganteus* also makes its first appearance in Britain during the Swanscombe interglacial. As noted by Sutcliffe (1964), the giant deer from Swanscombe appear to be somewhat smaller than the Late Devensian animals from Ireland. Although the Swanscombe sample is too small for statistical treatment, comparison of the four measurable specimens from Swanscombe with corresponding elements from the Late Devensian of Ireland strongly suggest a significant difference in size, with the Swanscombe specimens close to, or below the lowermost end of the Irish range (Lister 1986). A further feature of potential biostratigraphic significance within the Swanscombe *Megaloceros* sample has also been noted by Lister (1986, 1994). Measurements in the Swanscombe giant deer of the width of the brow tine base where it inserts on the beam, suggest that the Swanscombe animals may have had unusually broad, plate-like brow tines (see Chapter 3). This feature is visible in the *M. giganteus* from Steinheim in Germany, attributed to the Holsteinian Interglacial, but has never been observed in any later giant deer (Lister 1994).

Swanscombe also marks the first occurrence of the aurochs (*Bos primigenius*) in Britain. The extreme shortness of the *Bos primigenius* horn cores from the site has already been remarked upon by Sutcliffe (1964), a feature which may have led Kennard (1942b) to mistake them for *Bison.* The horn cores in question are also elliptical in cross-section, in contrast to the rounded cross-section of *Bos* horn cores from later sites, such as Ilford (Uphall Pit) (6.2). This character may be of biostratigraphical significance. Also present in enormous numbers in the Basal and Lower Gravels and the Lower Loam is the large sub-species of fallow deer, *Dama dama clactoniana*, which (at the present state of knowledge) is thought to be unique to this interglacial and therefore of especial biostratigraphic significance. Only fallow deer from the three horizons listed above can be certainly ascribed to *D. d. clactoniana*, since none of the specimens from the Middle Gravels has the part of the antler above the second tine (the critical diagnostic feature) preserved (Lister 1986). Mean body size of these animals is estimated to be around 78kg (Lister 1986, Lister, in Singer *et al.* 1993), compared to 50kg in Recent British

Dama (Chapman and Chapman 1975). In addition, an idiosyncrasy of the third lower premolar has been observed to occur in 5 out of 12 cases in the Swanscombe sample, whereby the metaconid fuses with the entoconid quite high in the crown (Lister 1981, 1986) (Figure 4.8).

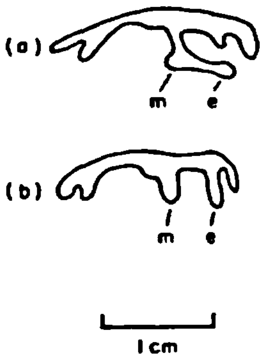


Figure 4.8 Right p3 occlusal pattern of a Swanscombe fallow deer, Lower Loam (Natural History Museum London, M49713) (a), in comparison with a Recent specimen, Takeley Forest (University Museum of Zoology, Cambridge, H17.174). e = entoconid, m = metaconid (from Lister 1986).

This feature is apparently absent in samples of Last Interglacial and Recent British fallow deer and may therefore be of significance as a temporal marker. Sutcliffe (1964) recorded over 500 specimens of fallow deer from Swanscombe and although this number was not found again in the present study, remains of *Dama* are still the most common of the large herbivores at the site. However, if one includes the total of indeterminate cervid specimens (most of which are certainly *Dama*, given the ratio of *Dama* to *Cervus* in the identifiable material), the number of *Dama* specimens reaches 727. They are most numerous in the Basal and Lower Gravels and the Lower Loam (269 specimens) but fall dramatically in numbers in the Middle Gravels (only 15 specimens).

In addition to the extinctions and first occurrences of the species listed above, which distinguish it from the preceding Cromerian complex, the Swanscombe interglacial is particularly characterised by an abundance of large herbivore taxa. Elephants are represented by a single species, *Palaeoloxodon antiquus*, again most common in the Basal and Lower Gravels. Hopwood (in King and Oakley 1936, 60, footnote) records a primitive form of mammoth from Swanscombe, although there is no evidence for this determination in the collections. As noted by Sutcliffe (1964), a series of 'Ilford type' mammoth teeth (M11563-11577) were presented to the Natural History Museum in 1914 by the Associated Portland Cement Company Ltd. These specimens are labelled 'Swanscombe' but have no further stratigraphic data. The fact that their state of preservation is completely different tothat found at Barnfield Pit would suggest that they do not belong in the Swanscombe collection. One of the specimens (M11584) is covered in periglacial 'Coombe rock' and it therefore seems likely that these teeth may have come from the nearby later sites of Northfleet (6.5), where this deposit and teeth of this type are frequently encountered.

Other large herbivores at Swanscombe include a relatively large form of caballine horse (*Equus ferus*). One specimen in particular (an upper molar from the Basal Gravel, Natural History Museum London, no registered number) (Figure 4.9) is especially robust and reminiscent of the large pre-Anglian forms, such as *E. mosbachensis*. The remaining specimens however show no particular morphological traits of biostratigraphic significance.

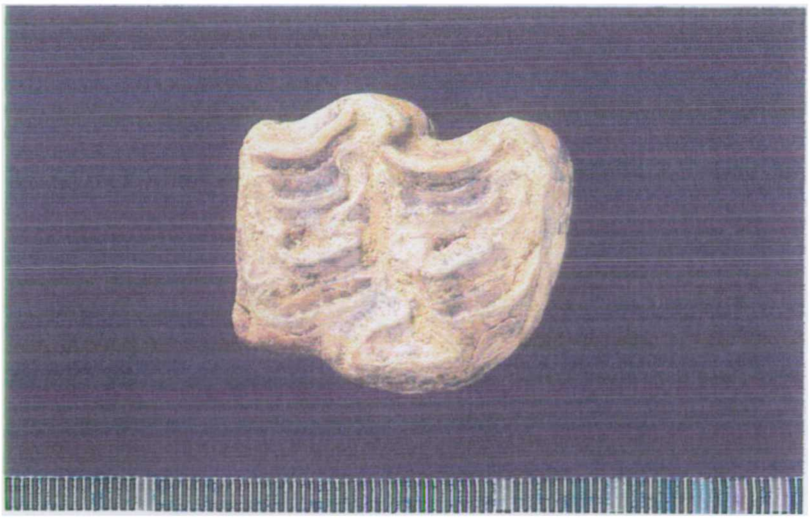


Figure 4.9 Right upper molar of *Equus*, Basal Gravel, Swanscombe.

An interesting addition to the two species of rhinoceros listed above is the presence in the Lower Gravel of three associated upper teeth (M18968, M20586 and M20580) which agree closely in size and morphology with the Etruscan rhinoceros, *Stephanorhinus etruscus*, or *S. hundsheimensis*, as later forms of *S. etruscus* have been called (Fortelius *et al.* 1993) (Figure 4.10).

Figure 4.10 Associated left P3-M1, *Stephanorhinus* aff. *etruscus*, Lower Gravel, Swanscombe.

The significance of an Etruscan-type rhinoceros at Swanscombe has recently been discussed by Currant (1996), since this species is unknown at any other post-Anglian site. Currant (*ibid*) concluded that reworking of these specimens from an earlier deposit is unlikely and suggested three possible alternatives: either that Swanscombe may pre-date the Anglian glaciation, or represent an intra-Anglian temperate phase, or that a post-Anglian form of *S. etruscus* is present in Europe. Since the entire sequence at Swanscombe is indubitably post-Anglian, on the basis of the position of the Boyn Hill terrace above Anglian till, and there is no evidence of a return to severely cold conditions in any part of the sequence (implying that parts of the sequence are of interstadial status), the third option seems by far the most plausible. The rhinoceroses are a particularly complex taxonomic group and the notion that only two species of *Stephanorhinus* co-existed in Britain after the Anglian has perhaps concealed the true identity of this third species. It must be emphasised however, that finding in itself is quite insufficient to imply correlation of Swanscombe with other sites containing *S. etruscus/hundsheimensis*, such as Boxgrove, the latter being clearly part of the Cromerian Complex in terms of its overall mammalian faunal composition (Roberts *et al.* 1995).

Red deer (*Cervus elaphus*) remains occur at low to moderate abundance in the Basal and Lower Gravels, the Lower Loam and the Middle Gravels. Lister (1986) figures two antler tops (M49725 and M49726, now missing from the collections) from the Basal Gravel which clearly show the Swanscombe red deer to be of the coronate subspecies, *C. e. elaphus*, as opposed to the Cromerian *C. e. acoronatus*. Furthermore, the red deer is of particularly small size during the Swanscombe interglacial (Lister, in Singer *et al.* 1993), so much so that there is considerable overlap with the large fallow deer, a situation that also prevails at Clacton (Lister 1986).

The primate remains at the site include the Barbary macaque (*Macaca sylvanus*). This species is not known to occur in deposits of OIS 7 or later age, thus corresponding to the age of the sequence at Swanscombe pre-dating this cut-off point. With respect to the find of *Homo* from the Upper Middle Gravels, the closest match to the Swanscombe specimen is widely regarded as the more complete skull from Steinheim, recovered from gravels believed to date from the Holsteinian Stage, generally held to equate with the British Hoxnian Interglacial (Turner 1970).

The Carnivora are comparatively abundant at Swanscombe and include some relatively rare species, such as pine marten (*Martes martes*) and the only record of wild cat (*Felis silvestris*) (Figure 3.37) from the British late Middle Pleistocene. Lion (*Panthera leo*) is the most abundantly represented predator at Swanscombe, with wolf (*Canis lupus*) and cave bear (*Ursus spelaeus*) (Figure 3.31) also well-represented. Of the carnivores, *U. spelaeus* is the only species of significance as a biostratigraphic indicator, since it is unknown from deposits in the Lower Thames later than those at Swanscombe. The remains of *C. lupus* from Swanscombe are rather small in size, visually approaching the size of the small early Middle Pleistocene *C. l. mosbachensis* from Westbury-sub-Mendip (Somerset) and Boxgrove (West Sussex). However, since local populations of wolves tend to adapt according to their prey size, this is probably not a character of biostratigraphic significance or worthy of subspecific status. It is more likely that the Swanscombe wolves were targeting small and medium-sized prey or possibly scavenging, thereby leaving the larger prey for the lions. During the Swanscombe interglacial, the spotted hyaena *Crocuta crocuta*, which is present in the preceding interglacial at Boxgrove and Westbury-sub-Mendip, is apparently absent. To this may be added the hippopotamus (*Hippopotamus amphibius*), which is also absent from this interglacial. The large size of the collections gives such negative evidence considerable weight.

The extinct giant beaver (*Trogontherium cuvieri*) is a rare but biostratigraphically significant element of the Swanscombe assemblage, since it is not found in Thames terrace deposits which post-date this interglacial. *Trogontherium* coexisted with the European beaver (*Castor fiber*) at Swanscombe but probably exploited a different ecological niche (Mayhew 1978). With regard to the small mammal fauna, three species of biostratigraphic importance are present in the Swanscombe deposits: the extinct small mole *Talpa minor* and the European pine vole (*Microtus* (*Terricola*) *subterraneus*), neither of which are found in Thames deposits post-dating this interglacial, and the water vole, *Arvicola terrestris cantiana*. Although the Swanscombe sample size of first lower molars of water vole is small (n=4), some general points may be made regarding the biostratigraphic significance of this species. All the remains are referable to the primitive morphotype, *A. t. cantiana* (= *A. cantiana* Hinton), with the enamel of the trailing (convex) edges being markedly thicker than that of the leading (concave) edges of the molars. The molars are also of small size (Figure 3.20; Tables 3.3 and 3.4), again conforming to their relative antiquity. None of the Swanscombe specimens retain the primitive ancestral *Mimomys* fold but this would only be expected at low frequency and the small sample size explains its absence at Swanscombe. The presence of rabbit (*Oryctolagus cuniculus*), a fairly abundant species at Swanscombe may also prove to be of biostratigraphic significance in identifying post-Anglian mammalian assemblages of comparable age to Swanscombe, since this species has yet to be reliably identified in any younger late Middle Pleistocene interglacial deposit.

Having considered the Swanscombe mammalian assemblage as a whole, it is now possible to pick out certain key indicator species which may be regarded as diagnostic of the first post-Anglian interglacial in Britain, tentatively correlated with OIS 11. These are:

- *Talpa minor*, extinct small mole
- *Oryctolagus cuniculus*, rabbit
- *Trogontherium cuvieri*, giant beaver
- *Microtus* (*Terricola*) *subterraneus*, European pine vole

- *Ursus spelaeus*, cave bear
- *Dama dama clactoniana*, extinct large form of fallow deer

None of the species listed should be taken in isolation as OIS 11 indicators, but in combination, these species form a consistent, coherent group that can be repeatedly observed at other British localities. Most importantly, none of these species have been recognised in Thames valley deposits post-dating the Swanscombe interglacial and so in circumstances where a post-Anglian context can be unequivocally demonstrated, the presence of any one of the above-named species is sufficient to strongly suggest contemporaneity with Swanscombe and thus to imply correlation with OIS 11.

Malacological studies

The molluscan fauna from Swanscombe has provided strong evidence for correlating the sequence with the Hoxnian Interglacial (Castell 1964; Kerney 1971). By comparing the molluscan faunas from Swanscombe and Clacton (4.4), Kerney (1971) was able to correlate the various fossiliferous parts of the Swanscombe sequence with the Hoxnian pollen biozones established at Hoxne (4.1) by West (1956) and recognised at Clacton (Turner and Kerney 1971). Kerney attributed the Phase I deposits at Swanscombe to biozone Ho II and the basal Phase II deposits to subzone Ho IIIb, considering the transition from biozones II and III to be missing from the sedimentary record at Swanscombe, as a result of the hiatus at the top of the Lower Loam. The proposed contemporaneity of the Swanscombe and Clacton sequences appears to be extremely solid, given that some elements of the 'Rhenish' suite are found only at these two sites and are unknown from any later British deposits. Furthermore, several members of the 'Rhenish' fauna have recently been found at Tillingham in deposits also assigned to subzone Ho IIIb (Roe and Preece 1995). Elsewhere in NW Europe, several of the 'Rhenish' species also have their last appearance during the Holsteinian (Meijer and Preece 1995).

Palynological studies

The Swanscombe sediments were originally correlated with the Hoxnian Interglacial, largely on the basis of other lines of evidence and despite the effective absence of a good palynological record from the site. Pollen assemblages have since been obtained from much of the sequence, although early interpretations of these led to suggestions of considerable stratigraphic complexity, with as many as three climatic cycles being recognised (Mullenders, in Wymer 1974; Hubbard 1982). For example, the vegetational change at the top of Lower Loam was originally thought to reflect cooler, more open conditions, and was attributed to a post-Hoxnian temperate interval (Mullenders, in Wymer 1974; Hubbard 1982), an interpretation which clearly had important implications for the dating of the higher parts of the Swanscombe succession. However, these interpretations failed to gain much credence, since they were based on such low concentrations of pollen and the possibilities of modern contamination or of differential preservation due to weathering and oxidisation were not properly addressed (Bridgland *et al.* 1985; Turner 1985).

However, a recent reassessment by Hubbard (1996) of the palynological evidence from the site has now placed the entire sequence within a single (Hoxnian) interglacial, an interpretation which is much more consistent with other lines of evidence. Thus the Lower Gravel and Lower Loam are attributed to Ho IIb, the Lower Middle Gravel to an unspecified substage of Ho II, the Upper Middle Gravel also to Ho IIb and the Upper Loam to Ho III (Hubbard 1996). Even so, given the paucity of pollen at the site, these interpretations can be regarded only as tentative. Of perhaps greater significance in terms of the age of the site is the presence of a pollen grain of the unidentified plant 'Type X' in the Lower Gravel (Turner 1970) and of further 'Type X' and glochidia of the water fern *Azolla filiculoides* in the Lower Loam (Hubbard 1996), since these species are unknown from deposits later than the Hoxnian *sensu lato.*

4.2.7. <u>Discussion and conclusions</u>

Swanscombe is a complex multi-phase site. The sequence clearly represents at least the first immediately post-Anglian temperate stage and much discussion has ensued as to the number of climatic episodes actually represented there (King and Oakley 1936; Evans 1971; Mullenders, in Wymer 1974; Hubbard 1982). Conway (1996) has proposed the following correlation of the Swanscombe sequence with the Oxygen Isotope record: the Basal Gravel to Upper Middle Gravel inclusive with OIS 11, the Upper Sand with OIS 10, the Upper Loam with OIS 9 and the Upper Gravel with OIS 8.

At first glance, although this would appear to accommodate some of the recognised complexities within the deep ocean record, the scheme is untenable if one accepts that the entire sequence at Swanscombe is of fluvial (Thames) origin. Following deposition of the Upper Loam at Swanscombe, during OIS 10, the Thames cut down to the level of the Corbets Tey Formation, where it deposited interglacial sediments during the succeeding temperate stage (OIS 9) (Bridgland 1994). It is therefore clearly impossible for the Thames to be simultaneously depositing material some 20 m higher at nearby Swanscombe during this period. The only means by which fluviatile sediments of OIS 10-8 age may be emplaced above the OIS 11 sequence at Swanscombe is by a river other than the Thames and there is no evidence to support this.

The view of Bridgland (1994), that the entire Swanscombe sequence represents one interglacial, equivalent to OIS 11 (423 000 - 362 000 years B.P.), is supported here. Additional corroborative evidence has come from aminostratigraphy of shells from all four main fluviatile members at the site (Ib, Id, IIa and IIb), which also suggests that the entire aggradation occurred during a single temperate episode (Bowen *et al.* 1989). Although the revised palynological model of Hubbard (1996) now includes the entire Swanscombe sequence within one interglacial, a major problem with the botanical definition of an interglacial period (as determined by Turner and West 1968) is that it allows only for unimodal development of the floral sequence. Thus, the model cannot accommodate the short-term, sharp fluctuations of climate that are visible in the Oxygen Isotope curve. No isotope stages are uniformly 'warm' or 'cold' and at least two short-lived cold periods are represented within OIS 11. One would therefore expect to see a palaeotemperature curve for this interglacial rising to three peaks of warmth separated by cooler troughs but whereas the palaeobotanical evidence cannot be reconciled with this, the mammalian evidence can.

It is proposed here that erosion of the channel into which the Phase I deposits are aggraded took place at the end of the Anglian cold stage. Deposition of the Basal Gravel presumably also occurred at this time or shortly afterwards. The Lower Gravel and Lower Loam are considered to represent the first warm peak of OIS 11 (substage 11e). The large body of mammalian and other faunal evidence supports fully temperate conditions during this period, with the development of mixed deciduous woodland and the presence of abundant grassland. The break in fluvial deposition at the top of the

Lower Loam is thought to reflect a cooling of climate during substage 11d, during which sea level would have been lowered, thus permitting the establishment of a fluvial connection with the Continent and the immigration of the 'Rhenish' suite of molluscs. A return to fully temperate conditions is marked by the deposition of the Lower and Upper Middle Gravels of Phase II (substage 11c). The mammalian remains suggest that this period was characterised by more open conditions than witnessed previously. This is followed by a second cold phase (substage 11b) represented by the Upper Sands and the presence of ice-wedge casts, micro-faulting and cryoturbation structures. The Upper Loam records the final temperate peak in the Swanscombe sequence (OIS substage 11a), although the floral and faunal character of this phase is unknown.

To conclude, the mammalian assemblage from Swanscombe contains six species of biostratigraphic significance which may be used to identify the first post-Anglian interglacial in Britain (OIS 11) and to identify further sites of this age. Other elements of this group show certain stages in their morphological evolution which are also of biostratigraphic value. The entire Swanscombe sequence is the product of deposition by the Thames during a single interglacial, although the picture of climatic fluctuations within this stage is considerably more complex than previously accepted, with three potential warm peaks recognised. The composition of the mammalian fauna shows some interesting changes which correspond to the various temperate substages and may prove useful in establishing the different nature of each.

4.2.8. Comparison of the mammalian biostratigraphic evidence from Swanscombe with Hoxne

The evidence presented above outlines the characteristic aspects of the mammalian fauna of the Swanscombe interglacial, considered to be the first post-Anglian interglacial and to correlate with OIS 11 (Bridgland 1994). Comparison of this evidence with that from Hoxne (4.1) reveals a number of strong similarities. Both sites record the first occurrence in Britain of *S. hemitoechus*, *M. giganteus* and *B. primigenius*. Swanscombe also witnesses the first appearance of *U. spelaeus* and *S. kirchbergensis*. None of these species is known from the preceding Cromerian Complex. Although the subspecific identity of the Hoxne fallow deer is unknown, the body size of the Hoxne sample compares well with the large *D. d. clactoniana* from Swanscombe, thereby suggesting that the Hoxne fallow deer may also be the *clactoniana* subspecies. The dental idiosyncrasy seen in almost half of the Swanscombe third lower premolars has not been observed in the Hoxne sample, but since the sample numbers only one specimen, the absence of this feature is perhaps not surprising.

Of special importance is the presence at Hoxne of *T. minor*, *T. cuvieri* and *M.* (*T.*) *subterraneus*. These species are also found at Swanscombe but are not known from any later interglacial deposits in either the Thames valley or elsewhere in Britain. This evidence strongly suggests contemporaneity of the Swanscombe sequence with the Hoxnian Interglacial and consequently places an upper age limit on the Hoxnian Interglacial of Stage 11. Wymer (1985) favours a complex scenario at Hoxne whereby both OIS 11 and 9 are represented, Stage 11 by the Lower Sequence and Stage 9 by the Upper Sequence. This hypothesis may be rejected on the basis of the mammalian biostratigraphic evidence from Hoxne, which shows that the critical Stage 11 indicators at the site, namely *T. minor*, *T. cuvieri* and *M.* (*T.*) *subterraneus*, are all present in Bed 4 of the Upper Sequence (see Table 4.3). This would therefore suggest that the Hoxne temperate-climate deposits were laid down during a single interglacial episode but does not however preclude the possibility of multiple short-term climatic fluctuations within this interglacial.

It is proposed here that strong parallels may be drawn between the Lower Sequence at Hoxne and the Phase I deposits at Swanscombe (Lower Gravel and Lower Loam) and between Beds 4 (Stratum C) and 5 of the Upper Sequence at Hoxne and the Phase II deposits at Swanscombe (Middle Gravels).

Mammalian remains from the Lower Sequence at Hoxne (4.1) are rather sparse but include two species that are only known from temperate episodes in the Pleistocene, the extinct giant beaver and straight-tusked elephant, in addition to red deer of small body size (Lister 1986, Lister, in Singer *et al* 1993). Mammalian remains from the Phase I deposits at Swanscombe are much more abundant and also contain straight-tusked elephant and small red deer (although the sample size is too small to compare the Hoxne and Swanscombe red deer statistically). The single find of giant beaver from Swanscombe is unfortunately unstratified. At both sites, these early temperate deposits are separated from the remainder of the sequence by a depositional hiatus, probably corresponding to a phase of climatic cooling during which sea level fell. Bed 4 Stratum C and Bed 5 of the Upper Sequence at Hoxne are much more fossiliferous and thus easier to compare with the Phase II deposits at Swanscombe. Both sites reflect a return to temperate climatic conditions but with a more open environment. Horse becomes an increasingly important species (38.46% of the faunal assemblage from Stratum C at Hoxne, 13.33% in the Middle Gravels at Swanscombe). A relatively unusual interglacial element, in the form of Norway lemming (?wood lemming) is also recorded at both sites. Human presence appears to have been more common during this phase, perhaps in response to an opening-up of the environment and an increase in herd animals. An Acheulean industry is common to both sites during this time period.

A point of difference between Hoxne and Swanscombe is the size of the red deer, which is notably larger at Hoxne (4.1). This has been interpreted as reflecting a difference in age between the two sites, albeit probably a small one, such as between successive zones of an interglacial (Lister, in Singer *et al.* 1993). The present study has revealed this to be the case, since the red deer remains from Hoxne, on which the measurements were based, were from the Upper Sequence. These were compared with red deer remains from Swanscombe, 84% of which are from the Phase I deposits. Exact contemporaneity would therefore not be expected, since the Hoxne Upper Sequence and Swanscombe Phase I deposits are potentially from separate temperate peaks within Stage 11. Evidence of ensuing cold conditions is present in Beds 6-9 of the Upper Sequence at Hoxne and in the Upper Sands of Phase III at Swanscombe. A further period of temperate-climate conditions is suggested by the Upper Loam at Swanscombe, although no such evidence exists at Hoxne, probably because the depositional basin had by that time become completely infilled.

Comparison with the Swanscombe sequence and with the marine isotope record therefore suggests that the first two temperate peaks of the Stage 11 interglacial are present at Hoxne, separated by, and then followed by a period of colder conditions. These are tentatively correlated with OI substages 11e and 11c for the temperate episodes and 11d and 11b for the cold-climate episodes.

In conclusion, mammalian biostratigraphy provides compelling evidence for the contemporaneity of the temperate deposits at Swanscombe with the Hoxnian

Interglacial, as represented at the type-site. As will be demonstrated in Chapter 5, major differences occur between the mammal fauna of the Hoxnian Interglacial and that from sites attributed to Stage 9 in the present study. Correlation of the Hoxnian Interglacial with OIS 11 is therefore suggested and it is consequently proposed that sites assigned to this age on the basis of mammalian biostratigraphy be henceforth referred to as Hoxnian.

4.3. DIERDEN'S PIT (GREENHITHE SHELL PIT), INGRESS VALE, GREENHITHE, KENT (TQ 595748)

4.3.1. Location of the site

Dierden's Pit, Ingress Vale is situated opposite the Ingress Arms public house, approximately 430 metres north-west of Barnfield Pit, Swanscombe and separated from the latter by a narrow dry valley, the Ingress Vale (Figure 4.11). The site is now built over and was occupied for many years by stables (Davis 1953).

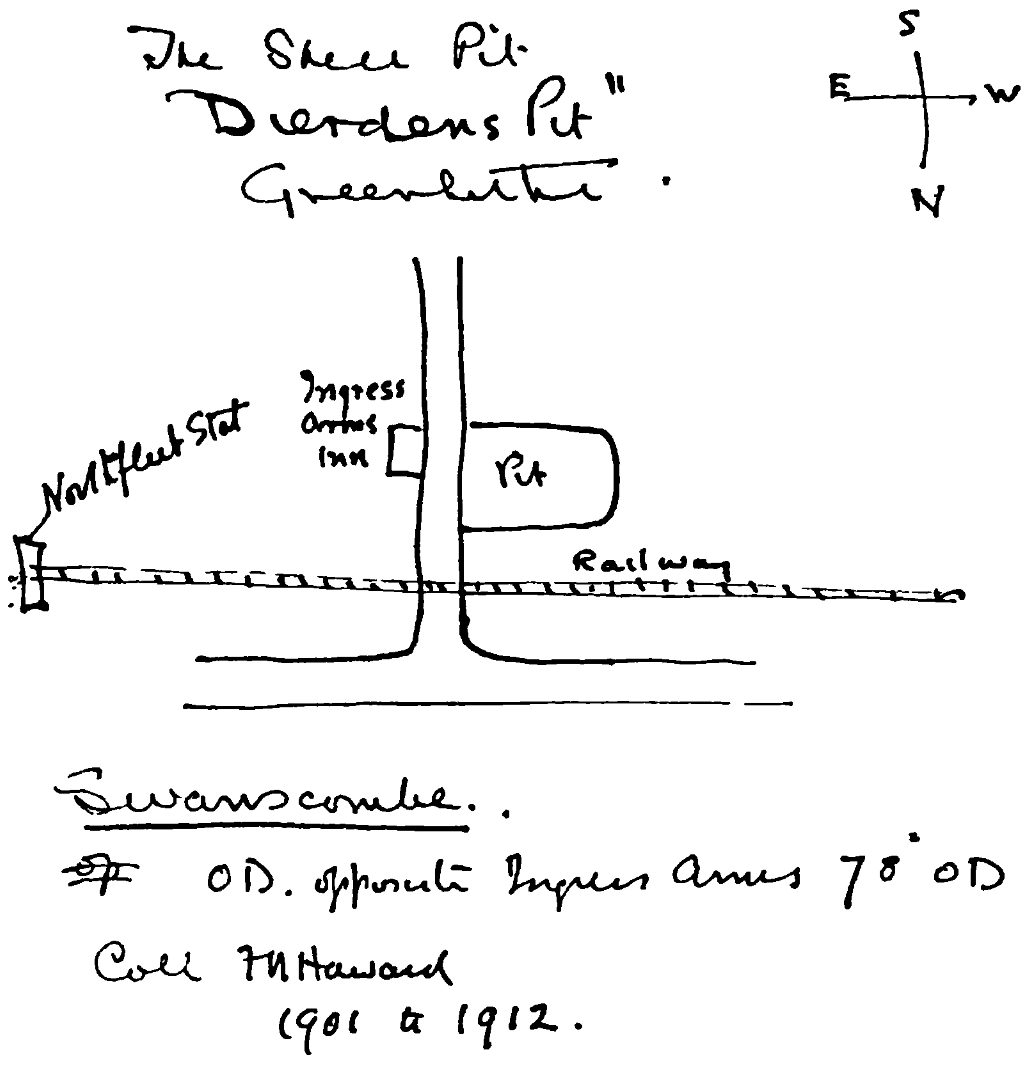


Figure 4.11 Location map of Dierden's Pit, Ingress Vale, Greenhithe (after Davis, MS map in Department of Palaeontology, Natural History Museum, London).

4.3.2. History of research

The first report of the site is by Stopes (1900), who described the opening of a new pit by Mr Dierden in the high terrace gravel of the Thames near Swanscombe in April 1899. The site was remarkable for its extremely rich shell bed, which ultimately yielded 47 species of molluscs (Stopes 1900; Kennard and Salter 1901; Kennard and Woodward 1901, 1903; Davis 1953). Of particular note was the abundance of *Theodoxus serratiliniformis*, one of the components of the so-called 'Rhenish suite' of Mollusca, thought to indicate confluence of the Thames and Rhine systems during the Middle Pleistocene (Kennard 1938). Literally "millions" of shells of *Valvata piscinalis* forma *antiqua* were also recorded (Davis 1953), together with abundant *Viviparus diluvianus*, a species that is only otherwise known from the Clacton Estuarine Beds (Bridgland 1994) (4.4). Mammalian remains (including a rare occurrence of dolphin) and sharp, patinated handaxes were also reported from the shell bed (H. Stopes 1900; C. Stopes 1903; Newton 1901; Kennard 1916). The main faunal collections were made by A.S. Kennard, M.A.C. Hinton, J.P. Johnson and G. White between about 1900 and 1905. Most significantly, these include the type specimen of the water vole *Arvicola terrestris cantiana* (Hinton and White 1902). In 1913, excavations were undertaken by Smith and Dewey (Dewey and Smith 1914, Smith and Dewey 1914), who recovered five hundred flakes within a small area of the shell bed. The pit closed towards the end of that year, at which point buildings were constructed upon the site (Carreck, in Sutcliffe 1964). Further references to the mammalian remains are in Hinton (1926a) and Sutcliffe (1964).

4.3.3. Geological background and provenance of mammalian remains

Information on the stratigraphic succession at Ingress Vale is rather limited, since the pit closed early this century and consequently had no extensive history of investigation, as at nearby Barnfield Pit (4.2). Stopes (1900) and Kennard and Woodward (1901) describe a section comprising of 14 feet (4.26m) of stratified sands and gravels, resting on a Chalk at 78 feet O.D. (23.77m) and capped by a thin layer of clay. Shells were reportedly present throughout 10 feet (3.04m) of the sequence, together with rarer mammalian remains. Correlation of these deposits with the more complex sequence in Barnfield Pit has always been problematic. Dewey and Smith (1914) and Smith and

Dewey (1914) compared the faunal remains and artefacts from the Ingress Vale shell bed with material from the Lower Gravel at Barnfield Pit, a correlation which is also supported by the altitudinal relations of the two sites (Wymer 1968). Kennard and Woodward (1916) also recognised that the beds belonged to the high terrace of the Thames and proposed correlations with Barnfield Pit, although this view was challenged by Abbott (1916), who suggested that the Pleistocene deposits at Ingress Vale were unconnected with the River Thames and were instead formed by a stream during the Pliocene. A reassessment of the molluscan assemblage from Ingress Vale by Kerney (1971) assigned the shell bed to the 'late temperate substage' of the interglacial on the basis of the presence of the 'Rhenish' suite of molluscs. Kerney (*ibid*) therefore placed the Ingress Vale shell bed above the Lower Loam of Barnfield Pit but slightly earlier than the main body of the Middle Gravel. This is supported by palaeoenvironmental evidence from the mammalian assemblage from the shell bed (see below), which suggests the presence of temperate woodland, as opposed to the more open conditions implied at Barnfield Pit in the Upper Middle Gravel.

4.3.4. Palaeontology

The following species list has been compiled from material housed in the Natural History Museum, London and in the British Geological Survey Museum at Keyworth, from the collections of H. Dewey and by M.A.C. Hinton. The present study has identified 16 mammalian species at Ingress Vale, including a previously unpublished record of stoat (cf) *Mustela erminea*. Records of bank vole *C. glareolus* (Hinton 1926b) and European pine vole *Microtus* (*Terricola*) *subterraneus* (Kennard 1916) in the collections of M.A.C. Hinton and shrew (*Sorex* sp.) in the collection of Mr J. Carreck (Sutcliffe 1964) could unfortunately not be confirmed during the present study. 99 specimens were examined.

Species List (Mammalia) from Ingress Vale, Kent

Primates
Homo sp., hominid (artefacts)
Rodentia
Castor fiber L., European beaver

Trogontherium cuvieri Fischer, extinct giant beaver

Arvicola terrestris cantiana (Hinton), extinct water vole (primitive morphotype)

Microtus sp., indet. vole

Apodemus cf. *sylvaticus* (L.), wood mouse

Cetacea

Tursiops truncatus (Montagu), bottle-nosed dolphin

Carnivora

Canis lupus L., wolf

cf. *Mustela erminea* L., stoat

Panthera leo L., lion

Proboscidea

Palaeoloxodon antiquus (Falconer and Cautley), straight-tusked elephant

Elephantidae sp., indet. elephant

Perissodactyla

Equus ferus Boddaert, horse

Stephanorhinus hemitoechus (Falconer), narrow-nosed rhinoceros

Stephanorhinus kirchbergensis Jäger, Merck's rhinoceros

Stephanorhinus sp., indet. rhinoceros

Artiodactyla

Sus scrofa L., wild boar

Dama dama ssp. indet., fallow deer

Cervus elaphus L., red deer

Cervidae sp., indet. deer

Bos primigenius Bojanus, aurochs

Bovidae sp., indet. large bovid (*Bos* or *Bison*)

Table 4.7 below provides a breakdown of the species list into numbers of specimens per species, also expressed as a percentage of the total mammalian assemblage from the site. Minimum numbers of individuals have also been calculated.

Species	Number of specimens	Percentage of total assemblage (%)	Minimum number of individuals (M.N I.)
Rodentia			
C. fiber	1	1.01	1
T. cuvieri	1	1.01	1
A. t. cantiana	7	7.07	2
Microtus sp.	6	6.06	2
A. cf. *sylvaticus*	11	11.11	3
Cetacea			
T. truncatus	1	1.01	1
Carnivora			
C. lupus	3	3.03	1
cf. *M. erminea*	3	3.03	1
P. leo	1	1.01	1
Proboscidea			
P. antiquus	5	5.05	2
Elephantidae sp.	1	1.01	1
Perissodactyla			
E. ferus	3	3.03	1
S. hemitoechus	1	1.01	1
S. kirchbergensis	1	1.01	1
Stephanorhinus sp.	2	2.02	1
Artiodactyla			
S. scrofa	5	5.05	2
D. dama ssp. indet.	14	14.14	1
C. elaphus	9	9.09	4
Cervidae sp.	17	17.17	2
B. primigenius	4	4.04	1
Bovidae sp.	3	3.03	1

Table 4.7 Breakdown of the mammalian species list from Ingress Vale, showing numbers of specimens per species, the percentage of the total assemblage per species and minimum numbers of individuals.

4.3.5. Palaeoenvironmental and palaeoclimatic interpretation

The mammalian assemblage from Ingress Vale is very similar to that from the Phase 1 deposits at Barnfield Pit, Swanscombe (4.2), in particular the Lower Loam, in terms of its implied environmental conditions. The range of mammals may be considered indicative of optimal climatic conditions and the presence of temperate deciduous or mixed woodland. This is attested to by the predominance of woodland indicators, such as fallow deer (*Dama dama*), wild boar (*Sus crofa*), wood mouse (*Apodemus sylvaticus*) and European beaver (*Castor fiber*), which make up 31.31% of the assemblage. The record of stoat (cf. *Mustela erminea*) is the only one known from the British Middle Pleistocene. This species today inhabits areas where there is plenty of ground cover and avoids open areas (Corbet and Harris 1991). The presence of open grazing is suggested by the occasional specimens of larger herbivores (5 specimens (out of 99) of *Palaeoloxodon antiquus*, 3 specimens of *Equus ferus*, 1 specimen of *Stephanorhinus hemitoechus* and 4 specimens of *Bos primigenius*), while the proximity of slow-flowing water is indicated by the *Arvicola terrestris cantiana* and *Castor fiber*. The presence of bottle-nosed dolphin (*Tursiops truncatus*) has previously been claimed as evidence for proximity to the contemporary coast (Kerney 1971). However, given the absence of other indications of a marine influence at the site, it seems far more plausible that this represents the strandline death of an individual that swam upriver (Stuart 1982). The molluscan remains from the shell bed are fully temperate in character and consist predominantly of freshwater species. Many of the examples of *Unio* spp. are still articulated, thereby suggesting that the depositional environment was relatively gentle (Kennard and Salter 1901).

4.3.6. Biostratigraphy and correlation

As outlined above, the Ingress Vale shell bed has been broadly correlated with the deposits from Barnfield Pit, Swanscombe (4.2), although there has been little agreement over precisely which part of the Barnfield Pit sequence the shell bed represents. However, much of the earlier dissent over probable correlations stemmed from conclusions based on artefact typology (for example Marston, in Kerney 1959b), which are now recognised to be suspect.

Mammalian studies

The mammalian assemblage from Ingress Vale is notable for its extremely close correspondence with that from the neighbouring site of Barnfield Pit, Swanscombe (4.2). A post-Anglian age for the Ingress Vale shell bed is indicated by the presence of three species which are not found in the preceding Cromerian complex: Merck's rhinoceros (*S. kirchbergensis*), the narrow-nosed rhinoceros (*S. hemitoechus*) and aurochs (*B. primigenius*). The small sample of water vole remains (n=7) from Ingress Vale is particularly noteworthy, since it includes the holotype of *Arvicola terrestris* *cantiana* (~ *Microtus intermedius*) (M48392), first described by Hinton and White (1902). They differentiated this molar from later remains of *Arvicola* on the basis of its small size but also stated (incorrectly) that it still possessed roots. The holotype itself belongs to a juvenile individual so observations on the patterns of enamel differentiation cannot be made (this feature is developed only in adult animals). However, in the two other specimens of adult *Arvicola* from the site, the enamel of the trailing edges of the molars is thicker than that of the leading edges, as one would expect in *A. t. cantiana*. Remains of *A. t. cantiana* are diagnostic of an age between the later part of the Cromerian complex and OIS 9. An upper age limit for the Ingress Vale deposits is provided by the presence of the extinct giant beaver (*Trogontherium cuvieri*). This important biostratigraphic indicator demonstrates that the deposits cannot be any younger than the Hoxnian Interglacial, since this species has never been found in Thames terrace (or indeed other) deposits which post-date this interglacial. The missing specimen(s) of pine vole (*M.* (*T.*) *subterraneus*) in the Hinton collection would further support correlation of the site with the Hoxnian.

With regard to other elements of the Ingress Vale mammalian assemblage, comparison with the Phase 1 deposits of Swanscombe is invited on the basis of virtually identical species composition. The fallow deer from Ingress Vale cannot be assigned to subspecies, since the critical part of the antler is not preserved in any of the specimens. However, visual inspection of the Ingress Vale specimens reveals them to be relatively large and closely comparable with the large sample of *Dama dama clactoniana* from Barnfield Pit. No dental material of fallow deer was collected from Ingress Vale, thus denying the possibility of observing the idiosyncrasy of the third lower premolar that has been observed to occur frequently in the Swanscombe sample and which may serve as a temporal marker. The other species from Ingress Vale (with the exception of two rarities - the stoat (cf.) *M. erminea* and the bottle-nosed dolphin *T. truncatus*) are all found at Barnfield Pit. The remaining large herbivores are represented by straight-tusked elephant (*P. antiquus*), red deer (*C. elaphus*) and a relatively large form of caballine horse (*E. ferus*), the carnivores include lion (*Panthera leo*) and a small wolf (*Canis lupus*), and European beaver (*C. fiber*) is present in conjunction with *Trogontherium*. The Ingress Vale deposits also contain relatively high numbers of remains of wild boar *S. scrofa* (5 specimens out of 99), usually a rare fossil. Hinton (in Sutcliffe 1964) believed that the remains of pig from the site appeared to be of two ages.

Most of them he considered to be contemporary with the deposit and with the other faunal remains, but he believed that two specimens (M21975 and M21979) differed in their state of mineralisation and appeared to be derived from an older gravel.

Hinton (1915) also assigned the remains of field mouse from Ingress Vale to a new species, *Apodemus whitei*, on the basis of part of a right maxilla with teeth, which he considered to differ slightly from recent specimens of the wood mouse, *Apodemus sylvaticus*. However, the characters concerned lie within the range of variability of *A. sylvaticus* and it has therefore been concluded that there is no sound basis for regarding the form from Ingress Vale as a distinct species (Sutcliffe and Kowalski 1976). Stopes (1903) erroneously recorded the presence of reindeer (*Rangifer tarandus*) antler fragments from Ingress Vale. These were reidentified by Kennard (in Sutcliffe 1964) as *D. d. clactoniana.*

Malacological studies

The Ingress Vale molluscan assemblage contains the biostratigraphically important 'Rhenish' suite, including *Theodoxus serratiliniformis*, *Corbicula fluminalis* and *Viviparus diluvianus*. This particular combination of predominantly southern species has also been recovered from Barnfield Pit, Swanscombe (Kennard 1942b; Kerney 1971) (4.2), Clacton-on-Sea (Warren 1955; Kerney 1971) (4.4) and Tillingham (Roe and Preece 1995), all of which have been attributed to the Hoxnian Interglacial (and in the case of the first two aforementioned localities, attributed to OIS 11 in the present study).

4.3.7. Discussion and conclusions

The position of Ingress Vale in the Boyn Hill/Orsett Heath terrace of the Lower Thames suggests correlation with the nearby site of Barnfield Pit, Swanscombe (4.2) and thus implies an immediately post-Anglian age for the interglacial shell bed deposits. This is thoroughly supported by the mammalian and molluscan biostratigraphic evidence from the site. A post-Anglian age is confirmed by the presence of *S. hemitoechus*, *S. kirchbergensis* and *B. primigenius*. The presence of the primitive morphotype of water vole, *Arvicola terrestris cantiana*, is indicative of a pre-Stage 7 age for the site but further resolution is provided by *T. cuvieri*, a critical species considered in the present study to be indicative (in a post-Anglian context) of the Hoxnian Interglacial. Furthermore, the actual composition of the Ingress Vale mammalian assemblage (with the exception of the two rarities, *M. erminea* and *T. truncatus*) is a direct match for Swanscombe, a fact which can only reinforce their contemporaneity. These conclusions are paralleled in the molluscan fauna from Ingress Vale, which also suggests correlation with Swanscombe and Clacton, on the basis of the presence of the highly distinctive 'Rhenish' suite.

It is therefore proposed that the Ingress Vale shell bed deposits and their contained faunal assemblages are directly comparable with a part (or parts) of the sequence at Barnfield Pit (4.2) and should therefore be placed within the Hoxnian Interglacial, considered here to be represented by OIS 11. This position has received support from amino-acid analyses which also place the shell bed within Stage 11 (Bowen *et al.* 1989). Exactly which parts of the Barnfield Pit sequence the shell bed corresponds with has been a matter of some debate in the past, with the Lower Gravel (Dewey and Smith 1914; Smith and Dewey 1914), the Upper Middle Gravel (Marston, in Kerney 1959b) and between the Lower Loam and Middle Gravel (Kerney *ibid*) all suggested as possible correlatives. Elements of the 'Rhenish' suite first appear at the top of the Lower Loam (Phase 1) in Barnfield Pit but the main body of the suite occurs in the Lower Middle Gravel (Phase 2). On the basis of the presence of the 'fully-fledged' 'Rhenish' suite at Ingress Vale, it is here proposed that the Ingress Vale shell bed be correlated with the Lower Middle Gravel at Barnfield Pit (possibly OIS 11c). Unfortunately, the mammalian remains from the Lower Middle Gravel are too scarce to make any direct comparison with those from Ingress Vale but given the proximity of the two sites, major differences in habitat seem unlikely and the mammalian remains from Ingress Vale may therefore fulfill an important role in reconstructing the palaeoenvironment at the time of deposition of the Lower Middle Gravel.

4.4. CLACTON-ON-SEA to JAYWICK SANDS, ESSEX (TM 175143 - TM 148128)

4.4.1. Location of the sites

Clacton lies in the south-eastern corner of the Tendring Plateau in eastern Essex. The fossiliferous Pleistocene deposits are preserved to the south of the town centre in an arc which intersects the present coastline at Lion Point, Jaywick at the western end and, 2km away, to the south of the pier at the eastern end (the West Cliff section) (Figure 4.12).

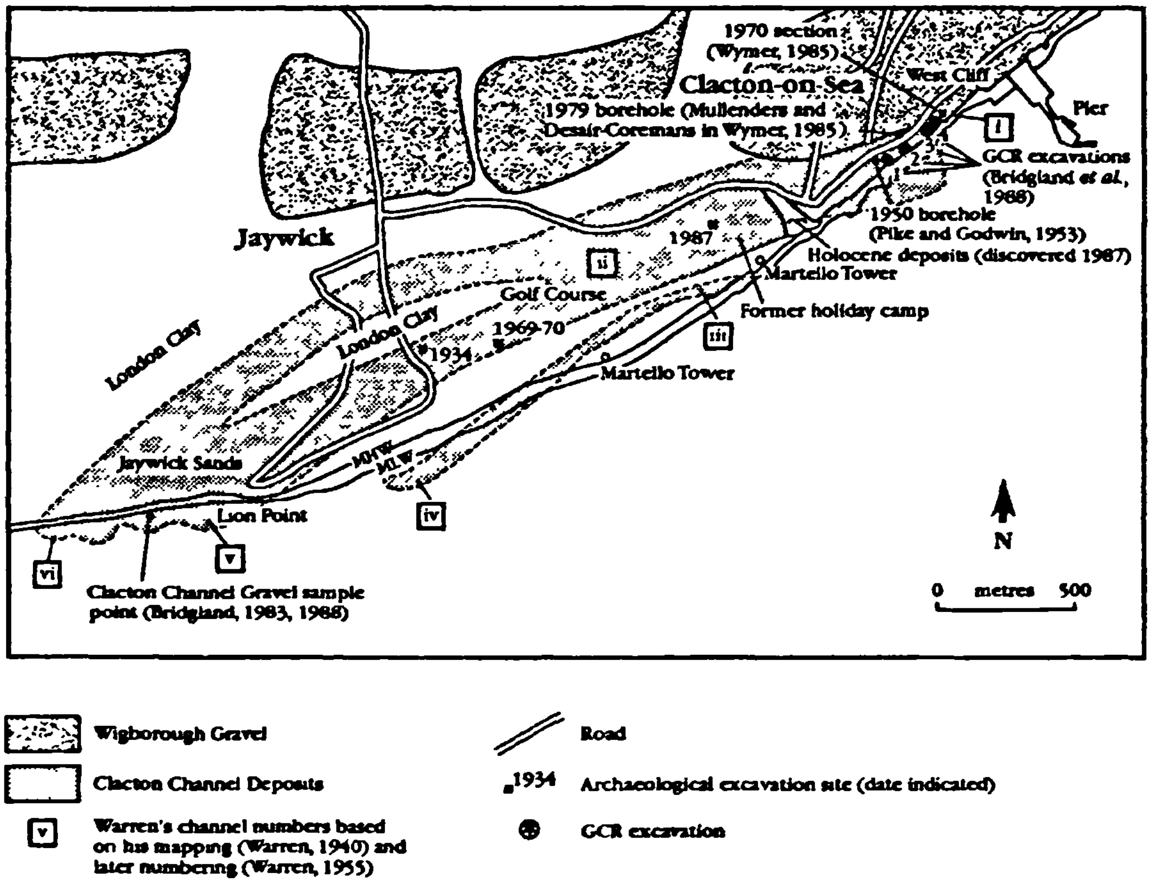


Figure 4.12 Location of sites in the Clacton area (modified from Bridgland 1994).

4.4.2. History of research

The geological, palaeontological and archaeological significance of Clacton has been recognised for more than 150 years. The channel deposits were first discovered in the West Cliff in the late 1830s by the local collector John Brown of Stanway, who subsequently published a number of reports on the deposits themselves and their fossil content (Brown 1838, 1839, 1840, 1841, 1845, 1857). Brown (1840, 1841) recorded the presence of both marine and freshwater molluscs at Clacton but noted that only freshwater shells occurred in the lowest stratum, which also yielded mammalian and plant remains. He therefore divided the sequence into seven separate beds, broadly reflecting a transition from freshwater/estuarine conditions to a fully estuarine environment. Preliminary attempts to correlate the parts of the Clacton sequence with the Red Crag were made by Wood (1848). Other early references to the site were made by his son, Wood junior, in his original description of the East Essex Gravel series (Wood 1866b), while Fisher (1868a, b) and Dalton (1880) both published descriptions and drawings of the sections which confirmed Brown's original stratigraphy. A more detailed subdivision was later proposed by Picton (1912).

Much of the early research into the site concentrated on the palaeontology and further references to the mammalian remains at Clacton appear notably in the work of Owen (1846), Dawkins (1868, 1869), Ransome (1890) and Hinton (1923b). Other faunal groups were also described in considerable detail, including ostracods (Jones 1850) and molluscs (Webb 1894, 1900; Kennard and Woodward 1897, 1923; Kennard 1924). However, the most extensive studies on the Clacton Channel deposits and their contained archaeology and fauna were undertaken by Warren (1911, 1912, 1922, 1923a, 1924, 1933, 1940, 1951, 1955, 1958). Warren recognised that part of the Clacton sequence occurs at Lion Point, Jaywick and later interpreted the Clacton and Lion Point sites as "sections across the same fluviatile channel a few miles apart" (Warren 1933, 15). As Warren demonstrated, the channel follows an arcuate course between Jaywick Sands and the West Cliff, although the full sequence of deposits is only exposed at the latter (eastern) end (Figure 4.14).

Warren (1940, 1955) ultimately mapped six small channels, the "scoured-out deeps in the bed of a wide river" (Warren 1955, 284), all of which contained temperate sediments attributed to the Clacton Channel Deposits (Figure 4.13). More recent investigation into sediments exposed at the Golf Course and at Butlin's Holiday Camp show that Channels v and i are linked and incorporate Channels ii and probably vi (Bridgland 1994). Similarly, Channels iii and iv are now known to represent two ends of a single continuous feature, entirely separated from the main channel complex by a ridge of

London Clay (Bridgland *ibid*). The main exposure at the West Cliff is referred to as Channel i.

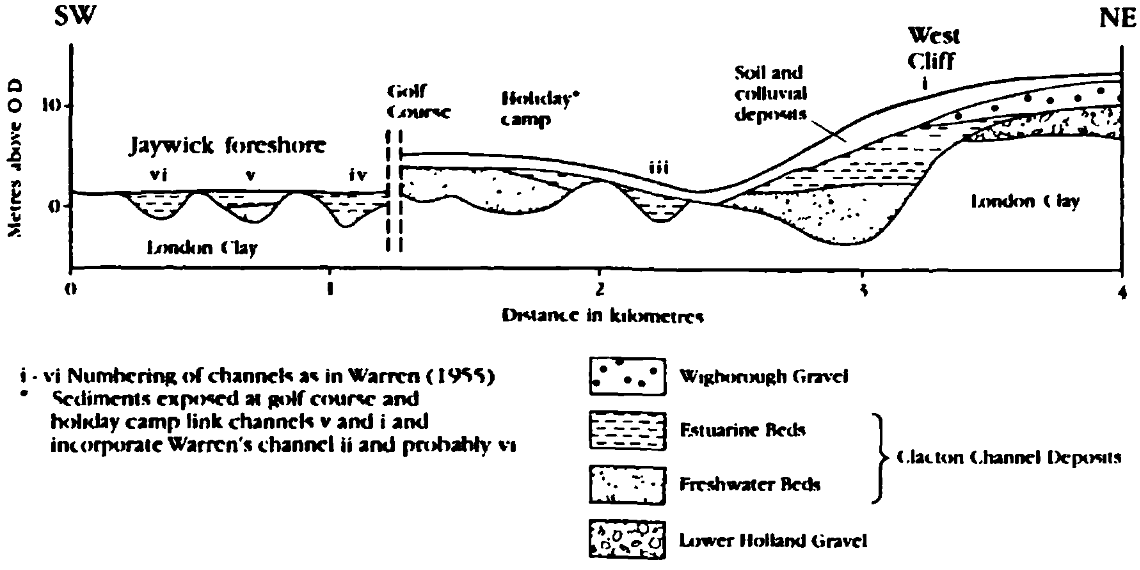


Figure 4.13 Section through the Clacton area showing the various Clacton Channel occurrences (from Bridgland 1994, after Warren 1955).

Warren designated Clacton as the type locality for the 'Clactonian', a Lower Palaeolithic industry characterised by assemblages of flakes and cores but seemingly without formal tool types such as bifaces (Warren 1912, 1922, 1926, 1933, 1951, 1958). During his studies of the foreshore exposures, he collected numerous mammalian remains and artefacts but never conducted any systematic investigations. Of particular significance was the discovery of a worked spear-point made of yew (the only wooden Lower Palaeolithic artefact of its kind in Britain), which was collected *in situ* from the estuarine deposits (Warren 1911). Two systematic archaeological excavations were subsequently carried out on the Golf Course near Jaywick Sands, the first in 1934 by K.P. Oakley and M. Leakey (Oakley and Leakey 1937) and the second between 1969-1970 by J.J. Wymer (Singer *et al.* 1973). A further investigation (the results of which are currently in press) was recently undertaken during the redevelopment of the Butlins Holiday Camp (Bridgland 1994).

In addition to yielding important archaeological and palaeontological collections, Clacton was also instrumental in the creation of the first British interglacial pollen diagram (Pike and Godwin 1953), subsequently the basis for correlation of the site with the Hoxnian Interglacial (West 1956, 1963; Turner 1973). The Clacton deposits have been widely regarded as the downstream equivalent of those at Swanscombe in the Lower Thames, the two sites having been correlated on the basis of their molluscan faunas (Kerney 1971; Turner and Kerney 1971). Most recently, attempts to correlate between the Pleistocene sequences in the Thames and East Anglia have suggested that the Clacton Channel was the product of the post-diversion Thames and that it represents an early phase of deposition by that river, following adoption of its present course through London (Bridgland 1988, 1994; Bridgland *et al.* 1988).

4.4.3. Geological background and provenance of mammalian remains

The Clacton Channel is excavated into London Clay but in the cliffs, it can also be observed to dissect the spread of sand and gravel known as the Lower Holland Gravel. On the basis of clast composition, it has been demonstrated that the Lower Holland Gravel is a pre-diversion Thames-Medway deposit, whereas the Upper Holland Gravel (which overlies, and is apparently channelled into the top of the Lower Holland Gravel) appears to date from the brief period during the Anglian glaciation when the Thames was blocked by ice and no longer reached the Clacton area (Bridgland 1988, 1994; Bridgland *et al.* 1988). This interpretation is again based upon clast composition, which indicates a predominantly Medway provenance for the Upper Holland Gravel, supplemented by small amounts of material introduced by the Anglian glaciation (Bridgland 1994). On the basis of these observations, the Holland Gravel Formation has been ascribed to the Anglian Stage and correlated with the Winter Hill Formation of the Middle Thames. The Clacton Channel deposits therefore cut through and overlie the downstream equivalent of the Winter Hill Gravel (*i.e.* the last Thames formation to be aggraded prior to the diversion of the river) (Bridgland *ibid*). The base of the Clacton Channel is estimated to descend to at least 6m below O.D. (Warren 1955) and it is consequently proposed that its erosion may have resulted from downcutting associated with the Black Park-Boyn Hill rejuvenation (D.R. Bridgland pers. comm.). The temperate sediments which infill the Channel must therefore relate to the first post-Anglian interglacial stage.

Warren (1923a) originally proposed a complex subdivision for the Upper and Lower Freshwater Beds at Clacton by assigning them letters to indicate variation in lithology. He subsequently found that many of his earlier subdivisions could not be followed laterally for any great distance and adopted the more generalised sequence outlined below (after Warren 1955):

6. Surface soil and colluvium			1-3m
5. Upper bedded gravel		(Mersea Island/Wigborough Gravel ?)	2m
4. Estuarine sand with shells passing laterally into estuarine calcareous clay	=		up to 4m
		(Clacton Estuarine Beds)	up to 5m
3. Estuarine laminated clay ('peaty shale'); contains a localised lens with freshwater fauna: Warren's (1923a) 'Bed I'.	=		
2. Loamy sands and clays with much channelling		(Upper Freshwater Beds)	up to 4m
1. Clayey gravel and sand		(Lower Freshwater Beds)	up to 7m

Thicknesses vary considerably towards the northern feather-edge of the Channel (Bridgland 1994). The basal sand and gravel is typically *c.* 1m thick and the minimum thickness of the Freshwater Beds is just over 2m. The overlying Estuarine Beds extend the sequence up to *c.* 10m O.D. (Bridgland *ibid*). Within the Estuarine Beds, Warren (1923a) identified a thin (0.3m) and discontinuous bed containing only non-marine fauna. The upper part of the Lower Freshwater Beds yielded the richest collections of mammalian remains and flint artefacts, many of which bear a characteristic black peat-staining. Further fossils and flint artefacts were found in the Upper Freshwater Beds, from which the wooden spear was also excavated. Molluscs, ostracods, pollen and plant macrofossils have been obtained from both the Freshwater and Estuarine Beds, except where the latter are oxidised near the modern land surface. The complete sequence, as exposed in the West Cliff, is shown in Figure 4.14

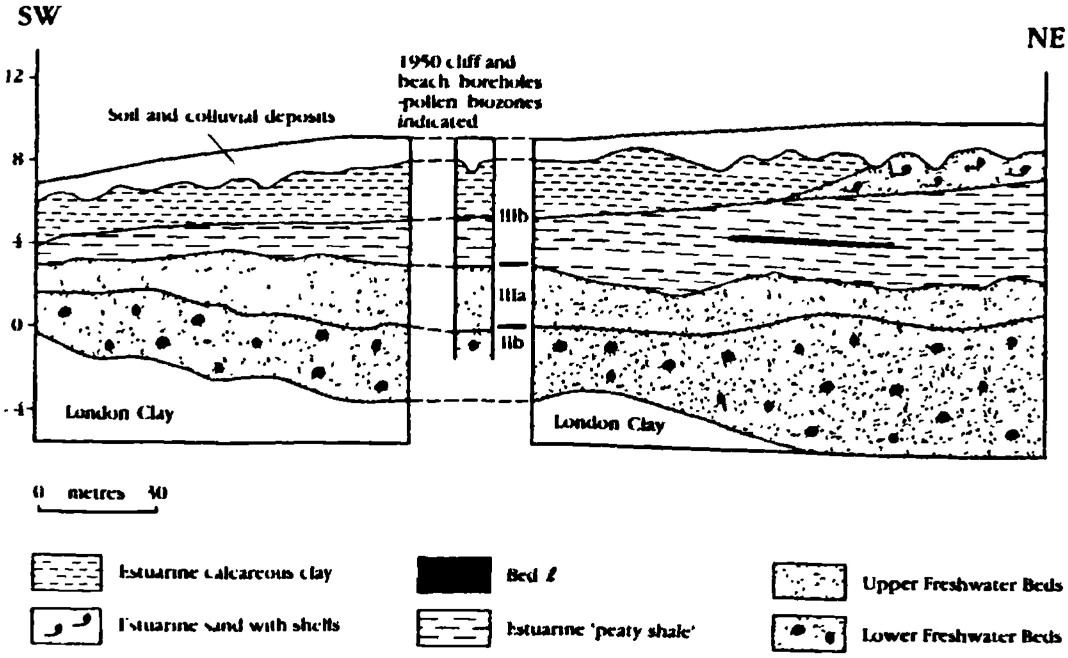


Figure 4.14 Section through the fill of the main Clacton Channel, as exposed at the West Cliff (from Bridgland 1994, modified from Warren 1955).

At the point of transition from freshwater to estuarine conditions, there is evidence for a minor non-sequence, with erosion to the lowest levels occupied by the estuarine deposits at Lion Point (Bridgland 1994). The ensuing marine transgression is not considered to have extended upstream far beyond Clacton (Bridgland *ibid*) and indeed, as the predominance of non-marine molluscs in the lower part of the Estuarine Beds suggests (Warren 1955), the sea level may have generally declined during the interval represented by the Estuarine Beds. The occurrence of a freshwater lens, Warren's 'Bed l' (see above, Figure 4.14), within the Estuarine Beds also suggests that there was a brief break in estuarine conditions, although it is possible that Bed l might result from a flood event which transported fluvial sediments into the estuarine environment (Bridgland 1994). A fall in sea level at this time is further suggested by the palaeobotanical evidence, which indicates a cooling of climate during the time of deposition of the Estuarine Beds (Pike and Godwin 1953).

4.4.4. Palaeontology

The present study has examined material from five areas at Clacton. These comprise:
1. Material probably from Channel i exposures at the West Cliff. These collections were made primarily by J. Brown in the 1850s and by S.H. Warren in the 1930s. Occasional remains were also collected by A. Savin and Sir Richard Owen.
2. Material collected by Warren from Lion Point.
3. Material collected by Warren from the Butlin's Holiday Camp.
4. Material collected by K.P. Oakley and M. Leakey from the Golf Course at Jaywick, and 5. Material collected by the University of Chicago, also from the Golf Course at Jaywick. This is the first time that the Clacton collection has been considered in its entirety.

The following list of mammalian species has been compiled from material in the Natural History Museum in London, the British Geological Survey Museum, Keyworth, Ipswich Museum, Colchester Museum and the Harrison Zoological Museum, Sevenoaks. The species lists from the individual sites have been recorded separately, so that it may be clearly be seen what was collected and where. However, the precise inter-relationships of these sites are still poorly understood and any attempt to place them in a chronological order is subject to speculation (Wymer 1985; Bridgland 1994). Nevertheless, it may be confidently stated that the above sites are all part of the main Clacton Channel and can therefore be considered parts of the same interglacial. Consequently, for the purpose of the present study, the mammalian material from the various Clacton localities will be considered as a single assemblage. Only the separate iii-iv channel fill may be of a different age (Bridgland 1994) but since only occasional bones of *P. antiquus* (a species known from all later interglacials) were recorded from here (Warren 1955), it is of no significant bearing here.

The total number of specimens examined was 952. The results of the present study indicate that 19 mammalian species can be reliably identified from the Clacton Channel deposits. These include a new, previously unpublished record of roe deer (*Capreolus capreolus*). An identification of *Megaloceros giganteus* by Oakley and Leakey (1937), on the basis of a left cubo-navicular (M15270, N.H.M.L.) is refuted, the specimen being referred to *Bos primigenius*. Dalton (1880) and later Warren (1923a) list hippopotamus, hyaena and bear from the Clacton Channel. These species have not been confirmed by the present study and it is concluded that their presence in these early lists probably resulted from misidentifications or misprovenanced material. The presence of goat in the Pleistocene deposits at Clacton can also be refuted. Owen (1846) was the first to record this species from Clacton, although the original material is now apparently lost. However, a second specimen in the collections of the Natural History Museum in London, namely a left third lower molar of a caprine (M20413), was apparently collected by Warren but is marked 'J.Wick', even though Warren never referred to the site by that name. The tooth is unlikely to have come from Oakley's excavations at Jaywick, since none of the other Oakley material is marked in that manner. It is however almost certainly from Lion Point (see below) but would therefore be an unusual component of the Clacton assemblage, if only from the point of view of palaeoenvironmental reconstruction, since wild goats are inhabitants of mountainous environments at the present day. Remains of caprines have been known from the early Middle Pleistocene at Westbury-sub-Mendip, although the Clacton tooth is rather smaller than these. Morphologically, it is also a poor match with *Capra* (ibex), *Rupicapra* (chamois) and *Hemitragus* (tahr), although it compares well with *Ovis* (sheep). In conclusion, it seems probable that the tooth is from a Holocene sheep, particularly given the proximity of a Neolithic site at Lion Point from which Warren also collected (Warren 1919). The specimen that Owen (1846) recorded may also have originally been from this locality.

Species List (Mammalia) from Clacton-on-Sea (probably mostly from Channel i), Essex

Rodentia

Castor fiber L., beaver

Arvicola terrestris cantiana (Hinton), extinct water vole (primitive morphotype)

Carnivora

Panthera leo (L.), lion

Proboscidea

Palaeoloxodon antiquus (Falconer and Cautley), straight-tusked elephant

Elephantidae sp., indet. elephant

Perissodactlya

Equus ferus Boddaert, horse

Stephanorhinus hemitoechus (Falconer), narrow-nosed rhinoceros

Stephanorhinus kirchbergensis Jäger, Merck's rhinoceros

Stephanorhinus sp., indet. rhinoceros

Artiodactyla

Sus scrofa L., wild boar

Dama dama clactoniana (Falconer) fallow deer

Cervus elaphus L., red deer

Capreolus capreolus (L.), roe deer

Cervidae sp., indet. deer

Bos primigenius Bojanus, aurochs

Bison priscus Bojanus, bison

Bovidae sp. indet. large bovid (*Bos* or *Bison*)

Species list (Mammalia) collected by Warren from Lion Point, Clacton-on-Sea, Essex

Proboscidea

Palaeoloxodon antiquus (Falconer and Cautley), straight-tusked elephant

Elephantidae sp., indet. elephant

Perissodactyla

Equus ferus Boddaert, horse

Coelodonta antiquitatis (Blumenbach), woolly rhinoceros *

Artiodactyla

Dama dama ssp. indet., fallow deer

Cervus elaphus L., red deer

Cervidae sp., indet. deer

Bos primigenius Bojanus, aurochs

Bison priscus Bojanus, bison

Bovidae sp., indet. large bovid (*Bos* or *Bison*)

* of suspect provenance, probably not from the interglacial deposits

Species list (Mammalia), collected by Warren from the Butlin's Holiday Camp, Clacton

Perissodactlya

Equus ferus Boddaert, horse

Artiodactyla

Dama dama ssp. indet., fallow deer

Cervus elaphus L., red deer

Cervidae sp., indet. cervid

Bos primigenius Bojanus, aurochs

Bison priscus Bojanus, bison

Bovidae sp., indet. large bovid (*Bos* or *Bison*)

Species list (Mammalia) from the Oakley and Leakey excavations at the Golf Course, Jaywick, Clacton-on-Sea, Essex

Rodentia

Arvicola sp., indet. water vole

Proboscidea

Palaeoloxodon antiquus (Falconer and Cautley), straight-tusked elephant

Perissodactlya

Equus ferus Boddaert, horse

Stephanorhinus hemitoechus (Falconer), narrow-nosed rhinoceros

Artiodactyla

Sus scrofa L., wild boar

Dama dama ssp. indet., fallow deer

Cervus elaphus L., red deer

Cervidae sp., indet. cervid

Bos primigenius Bojanus, aurochs

?*Bison priscus* Bojanus, bison

Bovidae sp., indet. large bovid (*Bos* or *Bison*)

Species list (Mammalia) from the University of Chicago excavations at the Golf Course, Jaywick, Clacton-on-Sea, Essex

Lagomorpha

Leporidae sp., indet. rabbit or hare

Rodentia

Trogontherium cuvieri (Fischer), extinct giant beaver

Clethrionomys glareolus (Schreber), bank vole

Microtus agrestis (L.) or *Microtus arvalis* (Pallas), field or common vole

Microtus sp., indet. vole

Proboscidea

Elephantidae sp., indet. elephant

Perissodactlya

Equus ferus Boddaert, horse

Stephanorhinus hemitoechus (Falconer), narrow-nosed rhinoceros

Stephanorhinus sp., indet. rhinoceros

Artiodactyla

Dama dama ssp. indet., fallow deer

Cervus elaphus L., red deer

Cervidae sp., indet. cervid

Bos primigenius Bojanus, aurochs

Bovidae sp., indet. large bovid (*Bos* or *Bison*)

Table 4.8 below provides a breakdown of the species list into numbers of specimens per species, also expressed as a percentage of the total mammalian assemblage. Minimum numbers of individuals have also been calculated.

Species	Number of specimens	Percentage of total assemblage (%)	Minimum number of individuals (M.N.I.)
Lagomorpha			
Leporidae	1	0.1	1
Rodentia			
C. fiber	1	0.1	1
T. cuvieri	1	0.1	1
C. glareolus	1	0.1	1
A. t. cantiana	46	4.83	3

cont'd.../...

Species	Number of specimens	Percentage of total assemblage (%)	Minimum number of individuals (M.N.I.)
M. agrestis or *M. arvalis*	1	0.1	1
Microtus sp.	2	0.21	1
Carnivora			
P. leo	3	0.31	1
Proboscidea			
P. antiquus	96	10.08	19 (3 juv., 16 adults)
Elephantidae sp.	8	0.84	2
Perissodactyla			
E. ferus	24	2.52	5 (1 juv., 4 adults)
S. hemitoechus	29	3.04	3
S. kirchbergensis	12	1.26	2
Stephanorhinus sp.	19	1.99	3 (1 juv., 2 adults)
Artiodactyla			
S. scrofa	2	0.21	2
D. d. clactoniana	254	26.68	52
C. elaphus	68	7.14	10
C. capreolus	1	0.1	1
Cervidae sp.	126	13.23	9
B. primigenius	171	17.96	14
B. cf. *priscus*	16	1.68	5
Bovidae sp.	97	10.18	9

Table 4.8 Breakdown of the mammalian species list from Clacton, showing numbers of specimens per species, the percentage of the total assemblage per species and minimum numbers of individuals.

4.4.5. Palaeoenvironmental and palaeoclimatic interpretation

Unfortunately, the early collections of fossil mammals from the different beds have been combined, making it impossible to assess environmental change throughout the sequence. However, even when considered as one assemblage, the mammalian remains from the various beds and channels at Clacton still enable some general points to be made about the palaeoenvironment. In many respects, the Clacton mammal fauna is very similar to that at Swanscombe (4.2) and reflects broadly equivalent temperate environmental conditions. As in the lower levels at Swanscombe, the Clacton mammalian assemblage is dominated by the extinct form of fallow deer, *D. d. clactoniana* (252 specimens, 26.47% of the assemblage), which strongly suggests the presence of nearby deciduous woodland. This is supported by smaller numbers of other taxa dependent on woodland, such as *C. glareolus*, *S. scrofa*, *C. capreolus* and *C. fiber*.

However, the abundance of grazing or grazing/browsing herbivores, including *P. antiquus* (96 specimens our of 952), *E. ferus* (24 specimens), *S. hemitoechus*, *S. kirchbergensis* (13 specimens), *C. elaphus* (68 specimens), *M. giganteus* (5 specimens) and large bovids (283 specimens) also indicates the proximity of areas of open grassland. A mosaic of open and woodland habitats is therefore implied. Approximately 100 species of non-marine Mollusca are known from the Upper and Lower Freshwater Beds (Kennard and Woodward 1923; Warren 1955). The most common freshwater taxa (all of which persist into the basal part of the Estuarine Beds) include *Bithynia tentaculata*, *Valvata piscinalis*, *V. cristata*, *Lymnaea peregra*, *L. truncatula*, *Gyraulus albus*, *Armiger cristata*, *Potomida littoralis*, *Sphaerium corneum*, *Pisidium amnicum*, *P. henslowanum*, *P. nitidum* and *P clessini*. These compare very closely with Swanscombe and suggest variable conditions, with both fast and slow-flowing water and some marshy habitats. The brackish water mollusc *Hydrobia ventrosa* is an important record in the Lower Freshwater Beds (Turner and Kerney 1971), indicating a tidal influence at the site. The most common terrestrial mollusc is the dry grassland species *Vallonia costata*. Four species of ostracod are also recorded, all of which inhabit ponds and rivers at the present day (Withers, in Warren 1923a). Pollen analysis of the Freshwater Beds indicates that they were laid down under temperate conditions, with mixed oak woodland in the vicinity (Pike and Godwin 1953; Turner and Kerney 1971).

The gradual inundation of the site by brackish water is clearly illustrated by the mixture of freshwater, estuarine and marine shells in the Estuarine Beds. The Estuarine Beds contain a number of freshwater species that are absent from the Freshwater Beds, including *Viviparus diluvianus* and *Corbicula fluminalis* (Kennard and Woodward 1923) but '*Paladilhia radigueli*', nowadays regarded as a brackish water species (Preece, in Bridgland 1994), is also abundant. Warren (1955) subsequently recorded small numbers of *P. radigueli* in the Freshwater Beds from the cliff-top borehole and from Jaywick. Marine species from the Estuarine Beds include *Cerastoderma edule*, *Hydrobia ulvae*, *Mytilus edulis*, *Scrobicularia plana*, *Littorina littoralis*, *Macoma balthica* and *Turritella communis* (Brown 1841; Dalton 1880; Baden-Powell, in Warren 1955). This assemblage is characteristic of a sandy mud substrate (Preece, in Bridgland 1994). *P. radigueli* and *V. diluvianus* are also present in Warren's (freshwater) 'Bed 1', which occurs within the Estuarine Beds. The pollen sequence from the Estuarine Beds was interpreted as representing a period of declining warmth, during which coniferous forests became dominant (Pike and Godwin 1953).

4.4.6. Biostratigraphy and correlation

Mammalian studies

The mammalian assemblage from Clacton is very similar to that of Swanscombe (4.2), since all the species listed above also occur in Barnfield Pit. Two of the biostratigraphically significant Hoxnian indicator species are present at Clacton, namely the giant beaver *Trogontherium cuvieri* (again found in association with *C. fiber* during this interglacial) and abundant remains of the large subspecies of fallow deer (*Dama dama clactoniana*), including the lectotype, as described by Falconer (1868). Unfortunately, no lower third premolars of *Dama* are present in the collections, so the idiosyncratic fusion in this tooth, as noted in the Swanscombe sample, cannot be commented upon. The micromammalian assemblage is very small, even despite extensive sieving of the sediments by later investigators (Singer *et al.* 1973). Certain species that one would therefore expect to find in this assemblage, such as the pine vole (*Microtus* (*Terricola*) *subterraneus*) are consequently missing. However, a small number of remains of water vole have been recovered. These are all referable to the primitive water vole morphotype, *A. t. cantiana* (= *A. cantiana* Hinton), and show a dominant *Mimomys*-type enamel differentiation (the enamel of the trailing (convex) edges being markedly thicker than that of the leading (concave) edges of the molars). This species is indicative of a pre-Stage 7 age for the deposits.

With regard to the large herbivores, the Clacton deposits are noted for their large numbers of remains of straight-tusked elephant (*P. antiquus*). The red deer from Clacton is of the 'coronate' subspecies, *C. e. elaphus*, which distinguishes it from the acoronate Cromerian complex animal. The Clacton red deer is also of small size, although not quite as small as at Swanscombe (Lister, in Singer *et al.* 1993). Roe deer (*C. capreolus*) is comparatively rare. A further point of similarity with Swanscombe is that the horn cores of *B. primigenius* from Clacton are also laterally flattened and elliptical in cross-section, in comparison to the rounded cross-sections of horn cores from later sites such as Ilford. The Carnivora are poorly represented at Clacton, with only lion (*P. leo*) recorded. Dalton (1880) and Warren's (1923a) original reports of hippopotamus and hyaena would cast doubt on a correlation with Swanscombe, although since no element of either of these species could be found in any of the collections viewed during the present study, it must be concluded that these were misidentifications.

Malacological studies

Molluscan species of biostratigraphical significance include *Belgrandia marginata*, *Valvata piscinalis* forma *antiqua*, *Viviparus diluvianus* and *Corbicula fluminalis*, all of which appear in the Estuarine Beds or at the top of the Freshwater Beds (Warren 1955; Kerney 1971). These species form part of the so-called 'Rhenish' fauna, which has also been recognised at Swanscombe (4.4) and which is thought to indicate a connection between the Thames and Rhine at this time (Kennard 1942b; Kerney 1971). The condition of some of the Clacton 'Rhenish' specimens strongly suggests that they have been reworked from an older deposit (Kennard and Woodward 1923), possibly a lower bed within the sequence that was destroyed by intraformational erosion (Bridgland 1994).

Palynological studies

The pioneering palaeobotanical study of the channel deposits, carried out by Pike and Godwin (1953), was based on a cliff-top borehole near the West Cliff (see Figure 4.12). Pollen-bearing clays and silts ascribed to the Estuarine Beds overlay polliniferous organic silty clays, attributed by Warren (1955) to the Lower Freshwater Beds. The pollen spectra from the freshwater sediments indicated the presence of temperate deciduous woodland and suggested deposition in biozone Ho IIIa of the Hoxnian Interglacial. The spectra from the Estuarine Beds revealed a period of declining warmth, with the development of coniferous forest and a particularly marked rise in *Abies* (silver fir). The Estuarine Beds were subsequently assigned to biozone Ho IIIb (Pike and Godwin 1953). Later analysis by Turner and Kerney (1971) of borehole samples from the Upper Freshwater Beds proved to contain high levels of *Quercus* (oak) and *Alnus* (alder), together with abundant plant macrofossils. These sediments were ascribed to Ho IIb (the period of optimal climatic conditions), thereby indicating that they pre-date the entire sequence in the cliff-top borehole and refuting Warren's view that the Lower Freshwater Beds were represented in Pike and Godwin's pollen sequence. Two further biostratigraphically important records from the site are those of the water fern, *A. filiculoides*, and of the unidentified palynomorph 'Type X', both of which are thought to be characteristic of the Hoxnian Stage in this country (Turner and Kerney *ibid*) but are now known to be present in more than one post-Elsterian temperate episode on the continent (Urban *et al.* 1991).

4.4.7. Discussion and conclusions

The relation of the Clacton Channel to the Thames system has been established only in recent years (Bridgland 1988, 1994). The site is widely held to represent an immediately post-Anglian (post-diversion) Thames-Medway channel, an interpretation that has been reaffirmed by palaeogeographical reconstructions, based on terrace stratigraphy, of the sequence in eastern Essex (Bridgland 1988). The drop in height between the deposits at Swanscombe (4.2) and Clacton is of the order of 27m over a distance of approximately 110km. This implies a downstream gradient of 1:4000, which is within the range of gradients observed within the fluvial terraces of the Thames and allows the Swanscombe and Clacton sediments to be contemporary deposits of the same river system (Bridgland 1988, 1994). This would be consistent with a Hoxnian age for Clacton (equivalent to OIS 11, if correlation of the Anglian with OIS 12 is correct) and would fit neatly with the wealth of mammalian and molluscan biostratigraphical evidence which points to contemporaneity with Swanscombe and Hoxne. Correlation of the Swanscombe and Clacton sequences has also been upheld by amino-acid ratios in the order of 0.3 on *Valvata* and *Pisidium* from Clacton, which place the site in OIS 11 (Bowen *et al.* 1989).

The mammalian assemblage from Clacton is extremely similar to that from Hoxne (4.1) and Swanscombe (4.2). The presence of the primitive morphotype of water vole, *Arvicola terrestris cantiana*, is indicative of a pre-Stage 7 age for the site but further resolution is provided by two critical species considered in the present study to be indicative of the Hoxnian Interglacial, namely *Trogontherium cuvieri* and *Dama dama clactoniana*. Unfortunately, amalgamation of many of the earlier collections from the various beds makes it impossible to observe changes in the faunal composition throughout the sequence, or to place the various channels in any biostratigraphic order. However, the largest collection of mammalian remains is the black, peat-stained collection, reportedly from the upper part of the Lower Freshwater Beds (Warren 1923a). This collection compares most closely in terms of species composition (particularly in the abundance of large herbivores, such as *P. antiquus*) to the mammalian assemblage from the Lower Gravel and Lower Loam at Swanscombe. It consequently possible that the minor break in the sequence observed at the top of the Freshwater Beds at Clacton corresponds with the depositional hiatus at the top of the Swanscombe Lower Loam. A lowering of sea-level during this brief period of cooler conditions would therefore allow for a fluvial connection to be established between the Thames and the Rhine and for the immigration of the Rhenish species into Britain. The mammalian material from the Clacton Estuarine Beds would thus be expected to compare closely with the upper parts of the Swanscombe sequence, although this cannot be certainly established because of the lack of stratigraphic data on the specimens.

In conclusion, the assembled stratigraphic and biostratigraphic evidence clearly indicates that the temperate channel infill at Clacton is of Hoxnian age, *i.e.* relating to the first post-Anglian interglacial, thought to equate with OIS 11. The similarity of both the Clacton molluscan and mammalian assemblages to those from Swanscombe (4.2) is clear, although precise matching of the sequences from the two localities on the basis of changes in faunal composition is difficult because of the provenancing problems at Clacton. However, from the available evidence, it seems most likely that the sequence at Clacton is rather less complete than that Swanscombe and that perhaps only the first two temperate substages of OIS 11 (11e and 11c) are represented.

4.5. BARNHAM, SUFFOLK (TL 875787)

4.5.1. Location of the site

The site at East Farm, Barnham St. Gregory, is located in a disused clay pit (formerly worked for brick-making), in a dry valley running east-west, parallel to the present course of the Little Ouse (Figure 4.15).

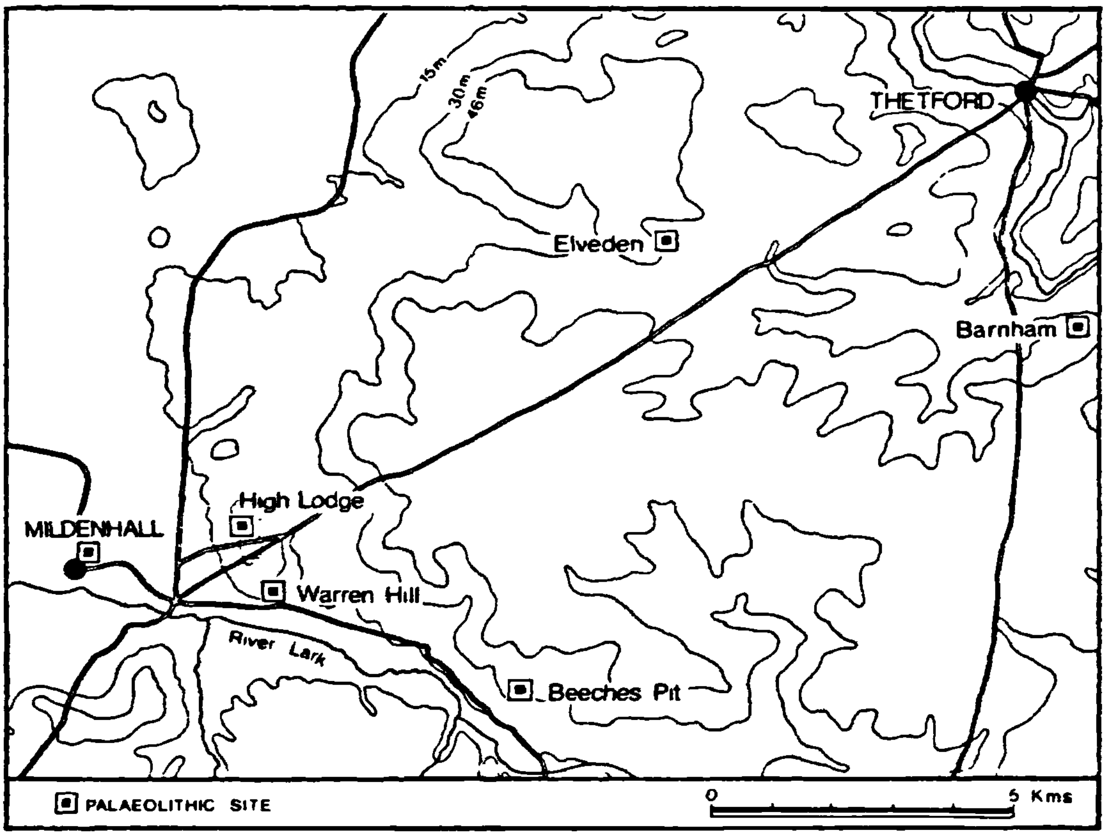


Figure 4.15 Location of Barnham (from Ashton *et al.* 1992).

4.5.2. History of research

The site is first mentioned by Whitaker in the Geological Survey Memoir of 1891. These primary observations described the exposed section as 'brown sandy loam with a black layer passing into stiff brown and grey clay' (brickearth), surrounded by '20 ft of Boulder Clay' (Whitaker 1891, 80). Whitaker made no mention of any flint artefacts, although bones and molluscs were said to have been found. The first published reports of artefacts appeared in 1913 and referred to handaxes and flakes from the brickearth

(Clarke 1913). Further artefacts were collected by Dixon-Hewitt (Clarke 1915) and by R.B. Caton (Clarke 1919). However, no controlled geological or archaeological excavations were undertaken at the brick-pit until it ceased to be worked in 1933.

The first systematic investigations were conducted by T.T. Paterson, who described a section consisting of up to 6m of brickearth, grey towards the bottom with black bands, resting upon gravels with intercalated beds of clay and silt to a depth of around 19m (Paterson 1937). Approximately 1500 artefacts in both fresh and rolled condition were subsequently recovered from the uppermost part of the gravels. Paterson identified four industries within the gravels, all in secondary context, and a fifth industry on the surface of the gravels in primary context. Further archaeological investigations at the site were undertaken by J.J. Wymer in 1979 (Wymer 1985). Between 1989 and 1994, new multidisciplinary excavations were carried out by the British Museum, under the direction of N.M. Ashton (Schreve 1993; Ashton *et al.* 1994a, b). In the 1992 season of these most recent investigations, a sequence of fossiliferous silts and clays were discovered, which were found to contain faunal material of putative Hoxnian age (Schreve 1993; Ashton *et al.* 1994a, b).

4.5.3. Geological background and provenance of mammalian remains

The history of sedimentation at the site is one of infilling, during a temperate phase, of a basin that had been previously formed in a valley cut by glacial meltwater during the Anglian Stage. The complex stratigraphic sequence has been assembled from observations of sections within four excavated areas at the site and by hand-auguring. The sequence is summarised in the composite section shown in Figure 4.16. Chalk bedrock at the base of the sequence is overlain by a chalky diamicton (present in Areas II and III), comprising chalk and flint pebbles in a poorly-sorted matrix of sand, silt and clay. Clast fabric analysis of the pebbles in this unit indicates deposition by a glacier moving in a WNW-ESE direction. This unit forms part of the regionally-extensive Lowestoft Till, which was deposited during the Anglian Stage (Perrin *et al.* 1979). In Area I, the surface of the till has been incised by a deep, steep-sided channel, into which have been aggraded approximately 20m of coarse sands and gravels (Paterson 1942). The channel and its fill are interpreted as the product of high-energy fluvial activity probably as a consequence of glaciofluvial drainage beneath or in front of an ice sheet

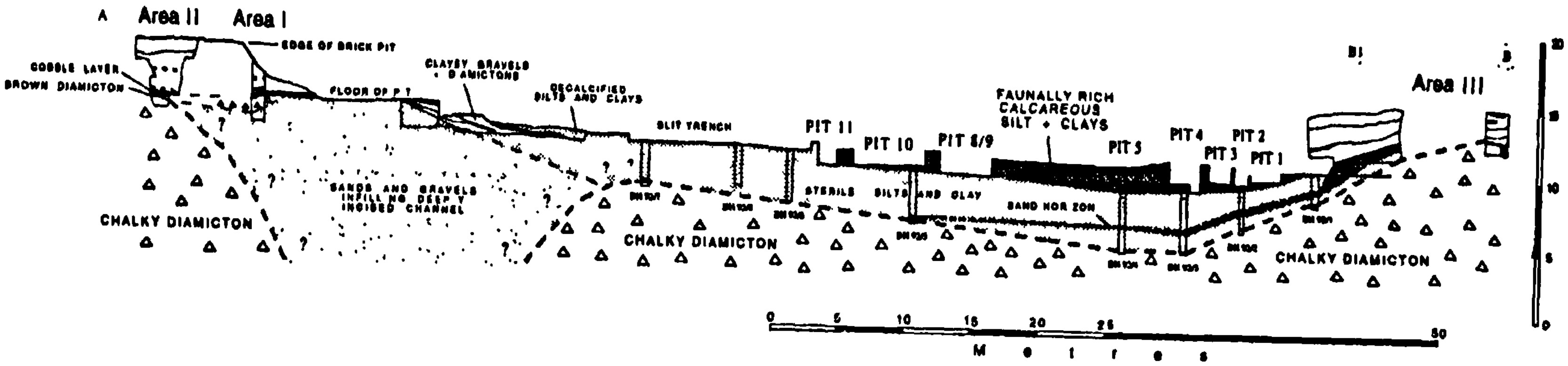


Figure 4.16 Barnham, composite geological section (from Ashton *et al.* 1994b)

(Ashton *et al.* 1994b). The channel limits are discernible in the exposures of till in Areas II and III and in a bore-hole in Area IV, generally suggesting an east-west orientation. In Area I (gravel section), on the south side of the channel, these sands and gravels are overlain by a brown diamicton. This displays a weakly-developed clast fabric consistent with down-slope movement in a NE direction, probably the result of localised gelifluction processes down the slopes which flank the channel. This unit thins towards the south and is absent across part of Area I, where the sands and gravels are directly overlain by a grey silty sand. This is thought to be the product of a slow-moving stream, which became established in the infilled channel. At the base of the grey silty sand is a 'cobble layer', consisting of large nodular flints and smaller flint pebbles. The cobbles are interpreted as a lag deposit, produced in a low-energy fluvial environment where stream flow was insufficient to transport such coarse material. It is from this cobble layer and from the overlying silty sands that most of the archaeological material has been recovered. The artefacts from the cobble band are mainly rolled and abraded, while those from the silty sands are in much fresher condition.

Neither the sands and gravels, nor the brown diamicton are present in Area III (except where the chalky diamicton is decalcified to form a brown structureless deposit). Here, the chalky diamicton is directly overlain by a 6.7m thick sequence of silts and clays, with several persistent sand facies and laminated sand and silt sequences. These can be traced laterally into Area I, where they interdigitate with and overlie the brown diamicton (Ashton *et al.* 1994b). The upper part of the silts and clays is highly fossiliferous and is considered to be the lateral equivalent of the grey silty sand in Area I, from which the flint artefacts have been recovered. The sequence is the product of deposition in still and periodically slow-flowing water. In Area I, the establishment of a stable land surface, following the infilling of the channel, is represented by a dark brown silty clay horizon, 10-20cm thick. This layer is overlain by a sequence of brown silts and clays ('brickearth'), up to 4m thick, which forms a laterally extensive unit over Areas I, II and III. This unit is probably the product of low-energy fluvial deposition, together with sheet wash from the adjacent slopes. It is completely decalcified and is overprinted with a sequence of overlapping 'welded' soils, reflecting the periodic formation of land surfaces (Ashton *et al.* 1994b). There is no evidence of a glacial episode subsequent to the deposition of the 'brickearths', as proposed by Paterson (1937, 1939, 1942).

4.5.4. Palaeontology

The mammalian remains from Barnham were unavailable for analysis during the present study. The following species list has therefore been compiled from Schreve (1993), Ashton *et al.* (1994a, b), P. Schreve (pers. comm.) and from personal observations by the author, who participated in excavations at the site between 1991 and 1993.

Species List (Mammalia) from Barnham, Suffolk

Insectivora
Sorex minutus L., pigmy shrew
Sorex sp., indet. shrew
Neomys sp., indet. water shrew
Desmana moschata L., Russian desman*
Talpa europaea L., common mole
Talpa minor Freudenberg, extinct small mole
Chiroptera
Chiroptera sp., bat
Primates
Homo sp., hominid (artefacts)
Lagomorpha
Oryctolagus cuniculus (L.), rabbit
Rodentia
Lemmus lemmus (L.), Norway lemming or *Myopus schisticolor* (Lilljeborg), wood lemming *
Clethrionomys glareolus (Schreber), bank vole
Arvicola terrestris cantiana (Hinton), water vole (primitive morphotype)
Microtus agrestis (L.), field vole
Microtus agrestis (L.) or *M. arvalis* (Pallas), field or common vole
Microtus (*Terricola*) *subterraneus* (de Selys Longchamps) (= *Pitymys arvaloides* Hinton) European pine vole
Apodemus maastrichtiensis van Kolfschoten, extinct small mouse
Apodemus sylvaticus (L.), wood mouse

Carnivora

Ursus sp., indet. bear

Panthera leo (L.), lion

Proboscidea

Elephantidae sp., indet. elephant

Perissodactyla

Rhinocerotidae sp., indet. rhinoceros

Artiodactyla

Sus scrofa L., wild boar

Dama dama ssp. indet., fallow deer

Cervus elaphus L., red deer

* P. Schreve pers. comm.

4.5.5. Palaeoenvironmental and palaeoclimatic interpretation

Changes in the composition of the vertebrate assemblage at Barnham as the channel or basin became gradually infilled are discussed in Schreve (1993). Samples taken throughout the sequence show a predominance of fish in the basal deposits, although numbers of bones are low, probably reflecting a moderate stream flow. Where terrestrial vertebrate remains occur in the lowest samples, these consist for the most part of the teeth of a restricted number of microtine rodent species. These latter are clearly allochthonous in origin and show various degrees of abrasion resulting from fluvial transportation. Further up the sequence, the depositional regime shifts to one of still or very slowly-flowing water, as attested to by the presence of fragile fish scales and an almost complete posterior skeleton of *A. cantiana* from sample 106 (Pit 4 West), which has clearly suffered little post-depositional disturbance. Towards the top of the sequence, there is a shift from a fluvial/lacustrine environment dominated by fish to more marshy conditions, as witnessed by a sharp increase in the numbers of reptiles and amphibians. The depositional regime remained extremely slow. The input of mammalian remains also increases steadily towards the top of the sequence. These changes in faunal composition are wholly consistent with field observations that the channel or basin became infilled over time.

Fish remains are most abundant at the base of the grey silts and clays (Schreve 1993) and include migratory species, such as salmonids and the eel (*Anguilla anguilla*), which indicate at least a seasonal fluvial link. These species are thought to be typical post-glacial colonisers. Further up the sequence, the assemblage is dominated by Cyprinids, including bream (*Abramis brama*), roach (*Rutilus rutilus*), tench (*Tinca tinca*) and rudd (*Scardinius erythropthalmus*), and their associated predator, the pike (*Esox lucius*). The Cyprinids reflect the presence of still or slow-flowing water and require summer water temperatures of at least 18° C for spawning (Wheeler 1969).

The Barnham herpetofauna is remarkably rich (Ashton *et al.* 1994b) and is rivalled only by that from Cudmore Grove, Essex, in terms of species numbers and diversity. The European pond terrapin (*Emys orbicularis*) is indicative of the presence of a pond or slowly-flowing water with abundant aquatic vegetation (Arnold and Burton 1978). Damp grassland adjacent to the water source is attested to by the presence of warty and palmate newts (*Triturus cristatus* and *T. helveticus*), moor frog (*Rana arvalis*), common frog (*R. temporaria*) and grass snake (*Natrix natrix*). Nearby well-vegetated, damp habitats with plenty of ground cover are indicated by the smooth newt (*T. vulgaris*), common toad (*Bufo bufo*) and slow worm (*Anguis fragilis*), while the natterjack toad (*Bufo calamita*) and Aesculapian snake (*Elaphe longissima*) would have favoured a drier, more open habitat (Arnold and Burton *ibid*). Four of the Barnham herpetiles are absent from Britain at the present day: the common tree frog (*Hyla arborea*), the moor frog, the pond terrapin and the Aesculapian snake. Based upon their present day range, they suggest that the climate during this interglacial was slightly warmer than the present day, with mean July temperatures higher than 17-18°C.

The mammalian remains suggest a similar range of environments. The presence of deciduous or mixed woodland with thick ground cover is suggested by the bank vole (*C. glareolus*), wood mouse (*A. sylvaticus*) and pygmy shrew (*S. minutus*). Fallow deer (*D. dama*) and wild boar (*S. scrofa*) are also characteristic of temperate woodland. Locally open vegetation is indicated by the field vole (*M. agrestis*), the European pine vole (*M. (T.) subterraneus*) and the rabbit (*Oryctolagus cuniculus*). Aquatic habitats are indicated by the water vole (*A. t. cantiana*) and water shrew (*Neomys* sp.), which frequent the well-vegetated banks of rivers and lakes with still or slow-flowing water.

The molluscan remains from the fossiliferous silts and clays consist mostly of opercula of *Bithynia tentaculata* (indicative of a wide range of freshwater habitats), with fragments of *Valvata* and *Pisidium* spp. A fragment of clausilid was also recovered, suggesting an interglacial woodland fauna (Ashton *et al.* 1994b). Pollen preservation is poor, although sparse pollen of Graminae (grasses), *Plantago* (plantain) and *Centaurea* (cornflower) and moss spores (*Lycopodium*, *Sphagnum*, *Filicales*) have been recovered from the top of the solifluction deposits in Area I. These suggest an open environment (Ashton *et al.* 1994b).

4.5.6. Biostratigraphy and correlation

Mammalian studies

The interglacial deposits at Barnham appear to relate to a temperate stage, immediately post-dating the Anglian glaciation and which is traditionally referred to as the Hoxnian Interglacial. Extensive sieving for microvertebrate remains has yielded a substantial small mammal assemblage, of which three species are of biostratigraphic significance in the determination of the age of the Barnham deposits. The water vole at Barnham is of the primitive morphotype, *A. t. cantiana*, with continuously-growing molars and a dominant *Mimomys*-type enamel pattern, thereby indicating an age no later than Stage 9. However, the common-place persistence of the ancestral '*Mimomys*' fold in the Barnham *Arvicola* sample (Schreve 1993) would suggest that the site is older rather than younger, *i.e.* more likely to be of Hoxnian age, as opposed to Stage 9.

An upper age limit for the deposits is indicated by the presence of the extinct small mole, *Talpa minor* and the European pine vole, *Microtus* (*Terricola*) *subterraneus*, which are unknown from British faunas after the Hoxnian Interglacial (OIS 11). Since the site can be proved to rest directly on top of Anglian till, the presence of these two critical OIS 11 indicator species is compelling evidence that the temperate deposits at Barnham are representative of the first post-Anglian interglacial. Rabbit (*O. cuniculus*) and Norway lemming (*Lemmus lemmus*) (or wood lemming, *Myopus schisticolor*), which are also found at Swanscombe (4.2) (and at Hoxne (4.1) in the case of lemming), may also prove to be of biostratigraphic value in supporting this correlation. The large mammalian remains from Barnham are few in number and can only be identified to family or genus level in some cases. No complete antlers of fallow deer have been recovered from Barnham, so the presence of *D. d. clactoniana* cannot be verified. Similarly, the remains of bear consist only of a single ?upper anterior premolar (Schreve 1993) and cannot therefore be assigned to species level. The presence of lion (*P. leo*) has been confirmed on the basis of a single astragalus (Schreve *ibid*).

4.5.7. Discussion and conclusions

To conclude, the Anglian Lowestoft Till at the base of the Barnham sequence provides a *terminus ante quem* for the interglacial deposits. The lithological evidence points to a continuity of deposition, following the end of the glaciation and this is matched by the mammalian evidence, which suggests that the temperate-climate deposits represent the first post-Anglian interglacial, *i.e.* Hoxnian Interglacial, equivalent to OIS 11. This is based upon the presence (in a clearly post-Anglian context) of two OIS 11 indicator species, *T. minor* and *M. (T.) subterraneus*, and supported by the morphological stage of the *A. t. cantiana* remains. In this respect, the Barnham mammalian assemblage is an extremely close match with sites such as Hoxne (4.1), Swanscombe (4.2) and Clacton (4.4). Amino acid ratios of 0.29 and 0.31 on *B. tentaculata* from Barnham also correspond closely with those from Swanscombe and Clacton, thereby also placing the site within OIS 11 (Ashton *et al.* 1994b). No attempt is made here to further refine the position of Barnham within Stage 11, based upon comparisons with the detailed records of climatic fluctuations established at Swanscombe; suffice to say that infilling of the basin is likely to have begun immediately following retreat of the ice. This may have been achieved within a relatively short time (? one isotopic substage) and since there is no apparent evidence of a return to cold or warm conditions above the brickearth at Barnham, it seems likely that the temperate-climate deposits at this site correspond with just one warm peak in the much more complex sequence at Swanscombe.

4.6. BEECHES PIT, WEST STOW, SUFFOLK (TL 798719)

4.6.1. Location of the site

Beeches Pit is an old brickyard, which fell into disuse before 1890. The site lies approximately 2.5 km ESE of Icklingham Church, in west Suffolk (Figure 4.15).

4.6.2. History of research

Beeches Pit is first mentioned in the Geological Survey Memoir of 1891. Sections recorded by S.B.J. Skertchly around 1877 reveal up to 12 feet (3.5 metres) of "loams with carbonaceous seams...with shells of *Cyclas* (*Sphaerium*), *Pisidium*, *Bulimus* (? *Bithynia*), *Helix* and *Succinea*" overlying chalky boulder clay (Whitaker *et al.* 1891, 79). Flint artefacts and mammalian bones were also recorded. Skertchly also claimed that further boulder clay lay above the loams, although this point was disputed by others. In 1967, new excavations were undertaken at the site by G. de G. Sieveking, on behalf of the British Museum, with the primary aim of recovering *in situ* Lower Palaeolithic implements. In the process of the investigation, an interglacial tufa containing an unusual molluscan assemblage was discovered (Kerney 1976). New sections were presented to the Quaternary Research Association in 1991 (Preece *et al.* 1991) and since 1992, further systematic excavations have been undertaken by J. Gowlett of Liverpool University. The artefacts at the site consist of flakes (some refitting) and bifaces (Gowlett, in Roberts *et al.* 1995).

4.6.3. Geological background and provenance of mammalian remains

The sequence at Beeches Pit records the infilling of a narrow channel, cut into a chalky diamicton. Glacio-fluvial deposits, 1-1.5 metres thick, are present at the base of the channel. These are overlain by finer-grained tufaceous silts and clays, previously thought to suggest deposition on a slope, associated with a springline (D.R. Bridgland, lecture given at the 'English Palaeolithic Reviewed' Conference, Society of Antiquaries, 28.10.94; Roberts *et al.* 1995). However, the recent discovery of a hearth feature within these deposits now suggests that the slope may be post-depositional (D.R. Bridgland pers. comm.). The following sequences are from the new exposures in the north and west faces of the pit, as described by Preece *et al.* (1991). The location of these exposures is shown in Figure 4.17.

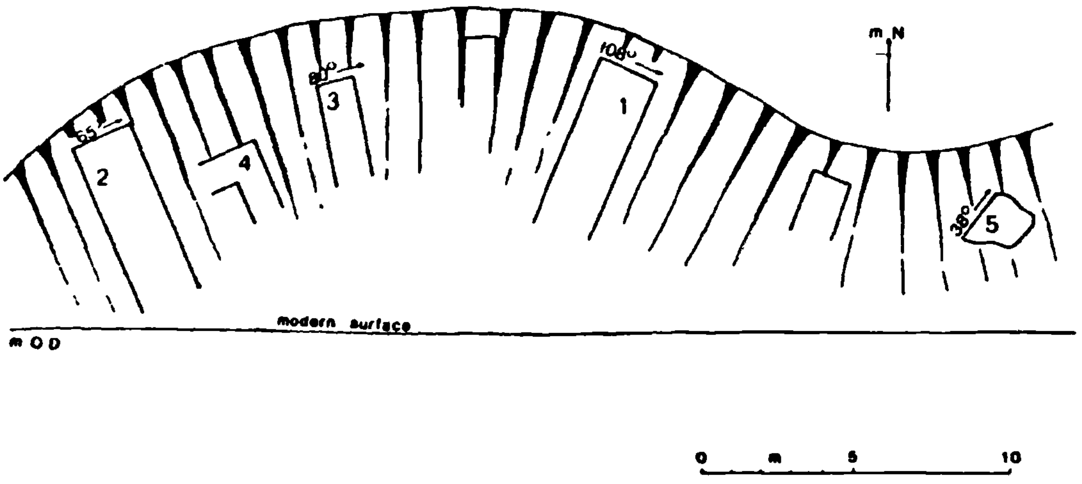


Figure 4.17 Location plan of cuttings in the north-western part of Beeches Pit (from Preece *et al.* 1991).

A thick sequence of very pale brown to pale yellow calcareous, tufaceous deposits, overlain by a diamicton unit containing abundant flint clasts in a brown clayey sand matrix was revealed in Cutting 1. This latter unit contains pockets of sandy sediment and shows evidence of solution disturbance and bioturbation by modern tree roots and soil formation. Tufaceous material was also recorded in Cutting 5. The following stratigraphic sequence was identified from the exposures in Cutting 2 (Figure 4.18):

Unit 7: diamicton with flint clasts in a clayey sand matrix
Unit 6: brownish yellow (10YR 6 6) silty sand with occasional shells
Unit 5: dark yellowish brown (10YR 4/4) sandy silty clay with occasional chalk pellets up to 2 cm in diameter
Unit 4: very dark greyish brown (10YR 3/2) organic clay
Unit 3: brown/dark brown (10YR 4 3) organic clay, containing mammalian remains
Unit 2: mottled brown (10YR 5 3) organic silty clay
Unit 1: chalky diamicton

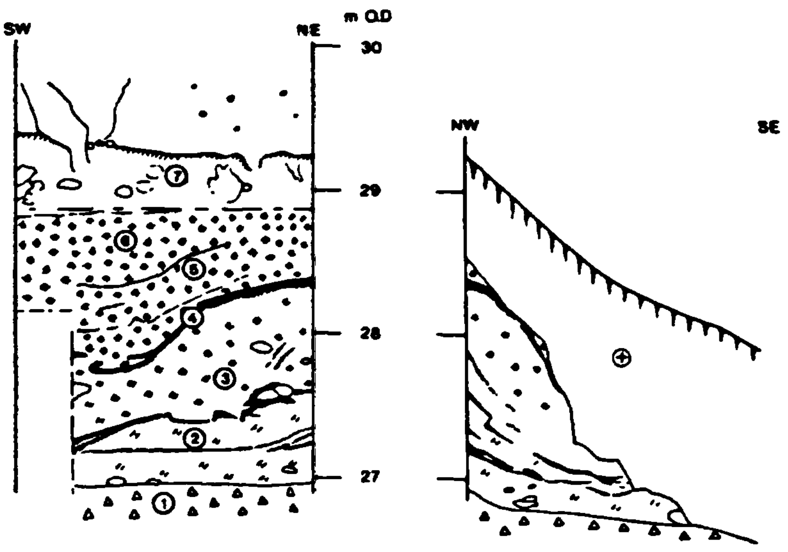


Figure 4.18 Stratigraphic sequence in Cutting 2, Beeches Pit (from Preece *et al.* 1991).

Cutting 2 clearly demonstrates that the entire sequence overlies a chalky diamicton, which is considered to be a glacigenic unit and is attributed to the Anglian Lowestoft Till (Perrin *et al.* 1979). The sections in Cutting 2 also indicate that units 2-4 thin and disappear rapidly to the north. It is therefore difficult to establish the precise stratigraphic relationship between these units and the tufaceous deposits in Cutting 1, but preliminary investigation of the area between Cuttings 1 and 2 suggest that the organic clays stratigraphically overlie the tufaceous deposits, although there may be some interdigitation (Preece *et al.* 1991).

4.6.4. Palaeontology

The mammalian remains from Beeches Pit were unavailable for analysis during the present study. The following species list has therefore been compiled from Preece *et al.* (1991) and from personal observations made during visits to the site by the author in the course of the University of Liverpool excavations.

Species List (Mammalia) from Beeches Pit, Suffolk

Insectivora

Sorex minutus L., pygmy shrew

Sorex sp., indet. shrew

Neomys sp., indet. water shrew

Primates

Homo sp., hominid (artefacts)

Rodentia

Clethrionomys glareolus (Schreber), bank vole

Arvicola terrestris cantiana (Hinton), extinct water vole (primitive morphotype)

Microtus agrestis (L.) or *M. arvalis* (Pallas), field or common vole

Microtus (*Terricola*) *subterraneus* (de Selys Longchamps) (= *Pitymys arvaloides* Hinton) European pine vole

Microtus sp., indet. vole

Apodemus cf. *sylvaticus* (L.), wood mouse

Carnivora

Ursus sp., indet. bear

Artiodactyla

Cervidae sp., indet. deer

Bos primigenius Bojanus, aurochs

Bovidae sp., indet. large bovid (*Bos* or *Bison*)

4.6.5. Palaeoenvironmental and palaeoclimatic interpretation

The tufaceous deposits at Beeches Pit are remarkable for their extraordinarily diverse molluscan remains, a mix of extinct species and taxa whose modern ranges do not overlap at the present day. Central European forest species are represented by *Acicula polita, Ruthenica filograna* and *Clausilia pumila,* S.E. European species by *Acicula diluviana* (= *Platyla similis*), western Pyrenean woodland species by *Lamnifera pauli* and western Atlantic species by *Zenobiella subrufescens* and *Leiostyla anglica* (Preece *et al. ibid*). However, the most unusual occurrence is that of *Retinella* (*Lyrodiscus*) *skertchlyi,* a species whose nearest living relatives are now restricted to the Canary Islands. The presence of woodland species indicates that the tufa formed in a temperate forest, in association with pools probably fed by springs. Several aquatic species suggest the presence of deep water nearby. Remains of three-spined stickleback (*Gasterosteus aculeatus*), newt (*Triturus* sp.) and frog (*Rana* sp.) confirm the proximity of a water source (Preece *et al.* 1991).

The mammalian assemblage from the lower part of unit 3 (brown/dark brown organic clay) of Cutting 2 is fully temperate in character and is dominated by bank vole (*Clethrionomys glareolus*) and wood mouse (*Apodemus sylvaticus*), which make up 63.6% of the rodent assemblage. The remaining 36.4% is made up by grassland voles (*Microtus* spp.). This reflects the proximity of woodland or bushy habitats with dense ground cover to the site. In contrast, the assemblage from the upper part of unit 3 is dominated by species of *Microtus* (75% of the rodent fauna), with *Apodemus* scarce and *Clethrionomys* absent. This difference in the relative abundance of the rodent taxa is thought to represent a change in the local vegetation cover from woodland scrub to grassland conditions (Preece *et al. ibid*). Mammalian remains were also collected from the tufaceous deposits of Cutting 5 and reflect the presence of temperate woodland.

4.6.6. Biostratigraphy and correlation

Mammalian studies

The mammalian remains were not available for analysis in the present study and the conclusions drawn here are based entirely on published records. Three species are of biostratigraphic importance in the determination of the age of the Beeches Pit deposits. The presence of aurochs, *Bos primigenius*, indicates that the deposits post-date the Anglian glaciation, since this species is unknown from the preceding Cromerian Complex. The water vole at Beeches Pit is described in Preece *et al.* (1991) as being of a primitive morphotype with continuously-growing molars and a dominant '*Mimomys*'-type enamel pattern. It is therefore referable to *A. t. cantiana* and is indicative of an age between the late Cromerian Complex (Cromerian Interglacial IV) and OIS 9. An upper age limit for the deposits is however indicated by the European pine vole, *M.* (*T.*) *subterraneus*, which is unknown from British faunas after the Hoxnian Interglacial. In these respects, the mammalian assemblage from Beeches Pit bears strong similarities to those from sites such as Hoxne (4.1), Swanscombe (4.2) and Barnham (4.5). However, apparent differences in the tooth morphology of *Arvicola terrestris cantiana* from Beeches Pit and from the nearby site of Barnham are thought by Parfitt (in Roberts *et al.* 1995) to indicate that the two sites are of different ages. Both sites are nevertheless referred to the Hoxnian Interglacial in the present study. It is therefore possible that either they may represent different temperate peaks of this complex interglacial, or that the SDQ data from water vole molars is misleading as a biostratigraphic indicator (see Chapter 3).

Malacological studies

The highly-distinctive molluscan assemblage from the Beeches Pit tufa is closely comparable with that from the interglacial tufa at Hitchin, Hertfordshire (Kerney 1959a; Holyoak *et al.* 1983; Preece *et al.* 1991) (4.8). In Britain, several species (including *R. skertchlyi*) are known only from these two localities and there is seemingly little doubt that they are identical in age. However, the nature of the facies itself means that direct correlations with other British interglacial sites are difficult, although some affinities with the assemblages from the Middle Gravels at Barnfield Pit, Swanscombe (4.2), have been noted (Preece *et al.* 1991). Nevertheless, similar '*Lyrodiscus*' faunas have been reported from various continental sites, including St. Pierre-lès-Elbeuf, Vernon and Arrest in France and Hörlis in Germany. These deposits have all been correlated with OIS 11 (Rousseau and Puisségur 1990; Rousseau *et al.* 1992).

Palynological studies

Turner (in Wymer 1985, 133) regards the tufaceous deposits as Hoxnian in age, although in recent excavations, the sediments failed to yield well-preserved pollen in sufficient quantities to interpret meaningfully (Preece *et al.* 1991).

4.6.7. Discussion and conclusions

Evidence for the age of the Beeches Pit deposits comes from two sources: the relation of the temperate deposits to the underlying glacigenic sediments and the biostratigraphy. Since the fossiliferous deposits lie stratigraphically above Anglian till, they are presumably of post-Anglian age. This having been established, the presence of the European pine vole (*M.* (*T.*) *subterraneus*) is sufficient to demonstrate that the sediments were deposited during the Hoxnian Interglacial, *i.e.* the first pre-Anglian interglacial stage, equated with OIS 11. This is supported by the distinctive molluscan assemblage, which has noted affinities with that from the Middle Gravels at Swanscombe (Kerney 1971) (4.2) and with a number of continental sites that have been attributed to the Holsteinian Interglacial (Preece *et al.* 1991).

4.7. COPFORD, ESSEX (TL 962242)

4.7.1. Location of the site

The site lies in a former brickpit (now no longer accessible) about 800m north-west of Stanway church (Figure 4.19).

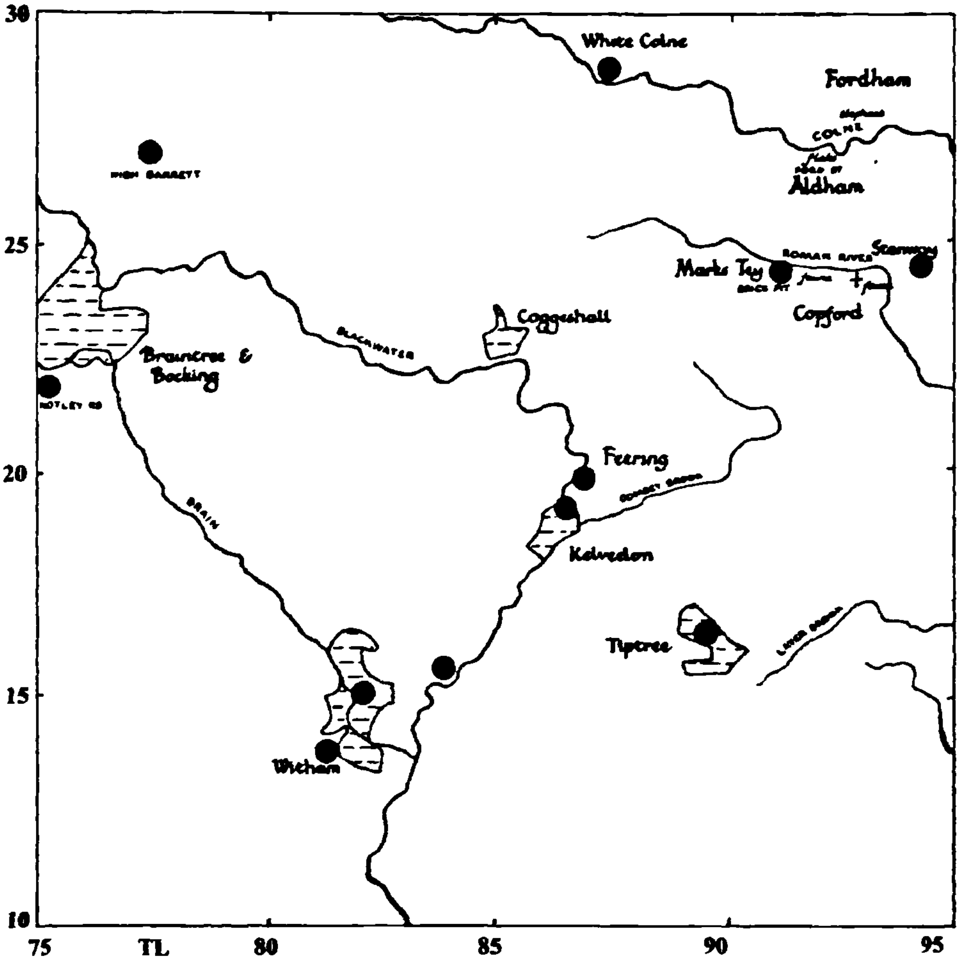


Figure 4.19 Location of Copford (modified from Wymer 1985).

4.7.2. History of research

The first published reference to the site, its geological sequence and fauna is by John Brown of Stanway (Brown 1834). By the time of his writing, three extensive workings had been opened for the commercial extraction of brickearth (Brown's 'western, eastern and southern' sections) and Brown himself undertook further casual excavations and borings in the winter of 1835-6 (Brown 1836). The mammalian remains were recovered in the process of digging for a blue clay, "a most excellent material for white bricks, chimney pots & c., for which it is extensively used" (Brown 1834, 437). Of particular note was the richness of the molluscan fauna (69 species at the time of his writing), although it was remarked that fossil mammals were relatively scarce (Brown 1852). Later work by Dalton (1880) recorded that 'a number of large bones, vertebrae and tibiae' had been found as early as 1764 at Stanway Manor House, immediately to the south of the Copford pit. The molluscan remains were further discussed by Kennard and Woodward (1897). No palaeoliths have been recorded from the site (Wymer 1985).

4.7.3. Geological background and provenance of mammalian remains

The interglacial beds occupy a basin in the underlying Anglian till, which extends for nearly half a mile in an east-west direction and for at least quarter of a mile north-south (Wymer 1985). The following section was recorded by Brown (1852) (Figure 4.20), with additional descriptions from Brown (1834):

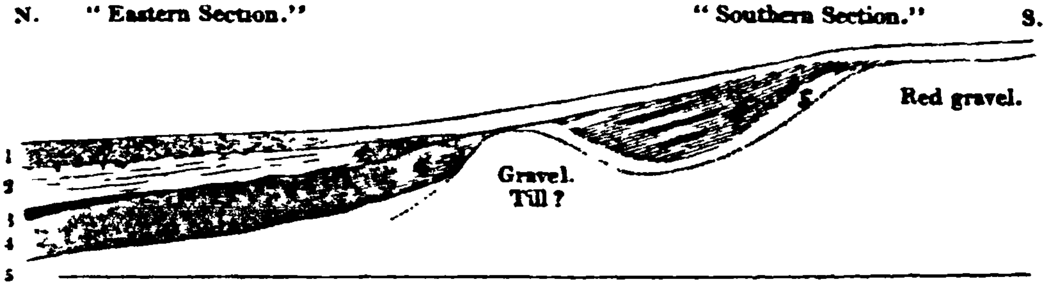


Figure 4.20 Schematic cross-section of the Copford deposits (from Brown 1852).

1. Brown clay with gravel (rounded and angular flints, quartz boulders etc), iron-stained, passing towards the south into

1'. Brown sandy loam

2. White calcareous shell-marl, alternating with ferruginous sands (furrowed surface), containing bones and shells, 1-6ft (0.3m-1.8m)

2'. The same, passing into clay, rich in shells

3. Lignite stratum ('vegetable bed'), containing shells and plant remains, varying from 3-12 in. to 6-7ft. (0.075m-0.3m to 1.8-2.1m) Remains of *Bos* and antlers found immediately above lignite.

4. Blue mica-rich, calcareous clay (brickearth), not laminated, containing bones and shells, 11ft (3.3m)

4'. Yellow clay with 'race', not laminated, 6ft (1.8m)
4". Laminated yellow and blue clays
5. Grey sandy gravel, shells and drifted fossils
5'. Sandy gravel

Brown proposed that the site represents 'an ancient freshwater lake, being more than a mile in extent from east to west, and about three-quarters of a mile in a north and south direction' (1852, 187). He observed that Bed 5 (sandy gravel) appeared to be part of the (Anglian) till and considered Bed 4 to be a modification of that deposit, on the basis of its far-travelled organic and mineral contents. Mammalian remains reportedly came from three horizons at the site. Brown (1834) recorded a horse molar from Bed 1 and a horn core and scapula of *Bos*, elephant bones and deer antlers from the bottom of the shell-marl (Bed 2') where it met the top of the lignite stratum (Bed 3). Bed 4 yielded remains of further elephant, red deer, bear, aurochs and giant beaver.

4.7.4. Palaeontology

The following species list has been compiled from material in the Natural History Museum, London. The present study has confirmed the presence of 4 mammalian species, on the basis of 17 specimens, all collected by J. Brown. Brown (1852) also listed remains of elephant and horse, although these have not been relocated in museum collections in the present study, together with additional specimens of giant beaver, aurochs and red deer which are also now apparently missing.

Species List (Mammalia) from Copford, Essex

Rodentia
Trogontherium cuvieri Fischer, extinct giant beaver
Carnivora
Ursus sp., bear
Artiodactyla
Cervus elaphus L., red deer
Bos primigenius Bojanus, aurochs

Table 4.9 below provides a breakdown of the species list into numbers of specimens per species, also expressed as a percentage of the total mammalian assemblage. Minimum numbers of individuals have also been calculated, although these must be taken as incomplete, given that some of Brown's original specimens are missing.

Species	Number of specimens	Percentage of total assemblage (%)	Minimum number of individuals (M.N.I.)
Rodentia			
T. cuvieri	1	5.88	1
Carnivora			
Ursus sp.	1	5.88	1
Artiodactyla			
C. elaphus	14	82.35	3 (1 juv., 2 adults)
B. primigenius	1	5.88	1

Table 4.9 Breakdown of the mammalian species list from Copford, showing numbers of specimens per species, the percentage of the total assemblage per species and minimum numbers of individuals.

4.7.5. Palaeoenvironmental and palaeoclimatic interpretation

The restricted mammalian assemblage prevents the drawing of detailed conclusions as to the nature of the palaeoenvironment, although the presence of the giant beaver (*Trogontherium cuvieri*) would seem to confirm the proximity of a slow-flowing or standing water source. *T. cuvieri* is also thought to be indicative of a temperate environment, since all stratified records of this species are from interglacial or Lower Pleistocene temperate stages (Stuart 1982). The presence of fresh water is also attested to by molluscan remains, including *Lymnaea truncatula*, *Valvata piscinalis* and *Bithynia tentaculata*. Although only 16 large mammal remains have been recovered, the availability of grassland adjacent to the water source may safely be assumed from the presence of large grazers, such as red deer (*Cervus elaphus*) and aurochs (*Bos primigenius*). Various species of terrestrial molluscs from Copford are also present in the collections of the British Geological Survey. These include *Cepaea nemoralis*, *Oxychilus cellarius*, *Vertigo pygmaea*, *Planorbis planorbis*, *Columella edentula*, *Helicigona lapicida*, *Oxyloma pfeifferi* and *Clausilia bidentata*. These molluscs are undubitably interglacial in nature but may be of Holocene age and therefore unrelated to the Pleistocene sequence, given the presence of Holocene deposits in the vicinity (R.C.

Preece pers. comm.).

4.7.6. Biostratigraphy and correlation

Mammalian studies

Two species are of biostratigraphic value in the consideration of the age of the Copford interglacial deposits. The presence of aurochs (*B. primigenius*) indicates that the site post-dates the Anglian glaciation, since this species is unknown from the preceding Cromerian complex. An upper limit for the age of the deposits is provided by the giant beaver (*T. cuvieri*), a species which may be considered diagnostic of the Hoxnian Interglacial, where a post-Anglian context can be definitely proved. A further point of similarity with the Hoxnian Interglacial comes from analysis of the Copford red deer, which were demonstrated to be of particularly small size, just as at Swanscombe (4.2) and Clacton (4.4) (Lister 1981).

Palynological studies

Turner (in Wymer 1985) attributes the organic deposits to the Hoxnian late-temperate zone Ho IIIb.

4.7.7. Discussion and conclusions

The interglacial deposits at Copford are clearly stratified above Anglian till and may therefore be considered to post-date the Anglian glaciation. This is confirmed by the presence of aurochs (*B. primigenius*), a species unknown in Britain prior to the Hoxnian Interglacial. Having thus established a post-Anglian context for the fossil mammal remains, the occurrence of the Hoxnian indicator, the giant beaver (*T. cuvieri*), is sufficient to demonstrate that the Copford deposits relate to the first post-Anglian interglacial and should accordingly be correlated with sites such as Hoxne (4.1), Swanscombe (4.2) and Clacton (4.4).

4.8. HITCHIN LAKE BEDS and HITCHIN TUFA DEPOSITS, HITCHIN, HERTFORDSHIRE

4.8.1. Location of the sites

The sites relating to the Hitchin 'Lake Beds' are located beneath the southern side of the town of Hitchin in north Hertfordshire (Figure 4.21). Mammalian fossils have come from several localities, including sections at two former brickpits, Jeeve's Pit (also known as the Folly or Highbury Pit) (TL 193282) and Ransome's Pit (TL 187285). Palaeobotanical information has also come from boreholes at Charlton Lane (TL 18852774) and Maydencroft Manor (TL 18282760). The lacustrine deposits are distinct from interglacial tufa deposits at Oughton Head Lane (TL 52172299), located 1.6km to the west of Hitchin, on the eastern flank of a chalk valley containing the source of the River Oughton.

4.8.2. History of research

The presence of Palaeolithic flint implements at Hitchin was reported as early as 1877 (Anon. 1877), following the sinking of a test pit in Ransome's Brickyard by Joseph Prestwich and Sir John Evans. However, it was not until some years later that descriptions of the interglacial deposits themselves were published by Hill (1891, 1900, 1908, 1912) and Reid (1897), from sections exposed in Ransome's and Jeeve's Pits. Further references to the archaeological finds are provided by Evans (1896) but the majority of information on the geological, implementiferous and fossiliferous nature of the deposits derives from the investigations carried out by Clement Reid (Holmes 1897; Reid 1897, 1901). On the basis of borehole data, Reid determined a sequence of interglacial deposits resting on top of till and glaciofluvial gravels and overlain by a thick 'brickearth' containing Lower Palaeolithic artefacts. The interglacial deposits consisted of a fossiliferous silty clay, overlain by discontinuous shelly *Chara* marl. Reid interpreted the silty clays as lacustrine, while the marl was thought to represent deposition in shallow pools (Reid 1901). The combined evidence from the topographic situation of the site, the sedimentary sequence, the plant remains, mammalian fossils and associated Lower Palaeolithic artefacts led Reid to propose

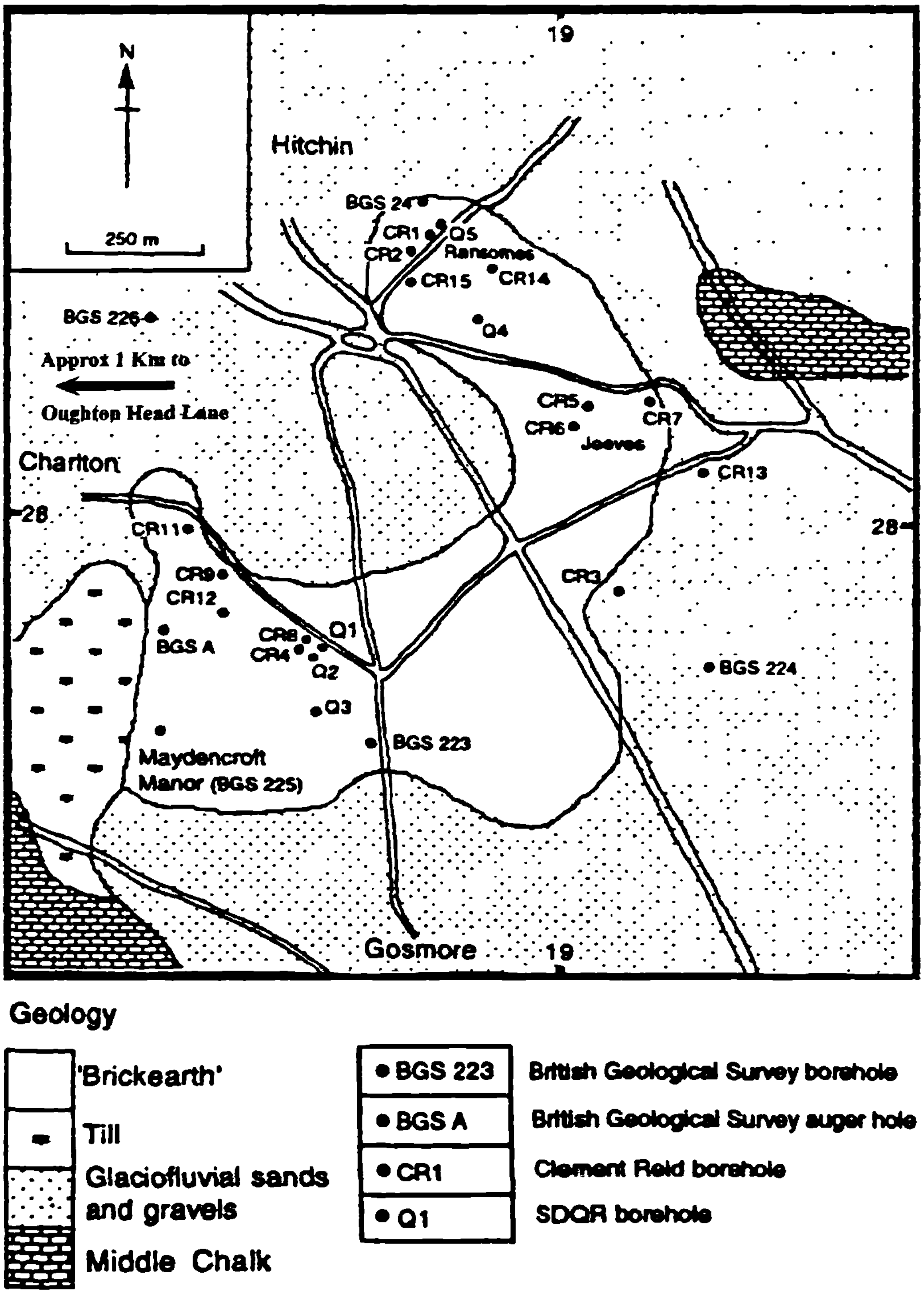


Figure 4.21 Location of sites in the Hitchin area (modified from Boreham and Gibbard 1995).

correlation of the Hitchin sequence with that of Hoxne, Suffolk (Reid 1897). Sections at the original excavations remained open during the 1960s but by 1970, the pits had been closed and the land developed for housing and as the town cemetery.

In 1971, in an attempt to relocate the Hitchin Lake Beds, two boreholes (Q1 and Q2) were put down by P.L. Gibbard in an old brickpit on the south side of Charlton Lane, Hitchin, close to the position of Reid's CR4 and CR8 boreholes (see Figure 4.21). The boreholes successfully located blue-grey chalky till at the base of the sequence, overlain by organic silty clay deposits, from which pollen samples were taken (Gibbard 1974). During remapping of the area in 1992, a further series of boreholes were put down by the British Geological Survey (BGS), including one (BGS 225) near Maydencroft Manor, which penetrated an organic deposit, overlying a light-grey, chalk-rich till and capped by orange-brown 'brickearth'. Pollen analyses from borehole BGS 225 were also undertaken (Boreham and Gibbard 1995).

A separate site, distinct from the Hitchin Lake Beds but potentially relating to the same interglacial, was discovered in 1943 during the excavation of a pipe trench between Bedford Road, Hitchin, and the new well at Oughton Head. The exposures at Oughton Head Lane revealed a layer of peat (approximately 18cm thick) and a white, tufaceous layer, up to 45cm thick and containing a large number of terrestrial Mollusca and remains of badger and small mammals (Kennard 1943; Wiggs 1943). This site was later re-investigated by Kerney (1959a).

4.8.3. Geological background and provenance of mammalian remains

In the area of the Hitchin-Stevenage gap, sediments attributed to the Hoxnian interglacial are represented by lacustrine deposits in basin-like depressions in Anglian till, lying between 85 and 110 m O.D. Two tills of Anglian age have been identified in the Vale of St. Albans, the Ware and Eastend Green Tills (Gibbard 1977). The Ware Till (and its equivalents) are believed to represent an early ice advance through the Hitchin Gap towards the south and south-east, while the later Eastend Green Till is thought to represent the main ice advance over the chalk scarp of the Chilterns to the north (Hopson *et al.* 1996). The ice advances incised a series of extremely deep channels in the Hitchin area, which acted as conduits for subglacial drainage, although it has also been suggested that they originated as tunnel valleys, formed by subglacial erosion (Boswell 1914; Woodland 1970). The presence of a deep, drift-filled channel at Hitchin was recognised in the nineteenth century and was first proposed by Hill (1908, 1912). The channel runs approximately north-south and is eroded to -100 metres O.D. in some parts (Hopson *et al.* 1996). A second channel, a little to the west, is present at Oughton Head (TL 168304) (Figure 4.22).

The sequence of glacial deposits at the base of the main Hitchin channel is summarised as follows (from Hopson *et al.* 1996):

7. Glaciofluvial outwash deposits (= part of Westmill Lower Gravel in the St. Albans area)
6. 1st Anglian ice advance: deposition of the Priory Till (= Ware Till of St. Albans), a lodgement till.
5. Period of ice retreat and formation of proglacial lakes. Deposition of glaciolacustrine sediments and subglacial fluvial deposits, believed to represent deposition in 'finger lakes' in front of the ice margin and Charlton Till, incorporating waterlain and flow tills, with some lodgement till.
4. Glaciofluvial outwash deposits (= Westmill Upper Gravel of St. Albans).
3. Main Anglian ice advance: deposition of Maydencroft Till (= Eastend Green Till of St. Albans).
2. Ice retreat and formation of periglacial lakes: deposition of Vicarsgrove Till (waterlain and flow tills).
1. Glaciofluvial outwash and initiation of postglacial fluvial deposition.

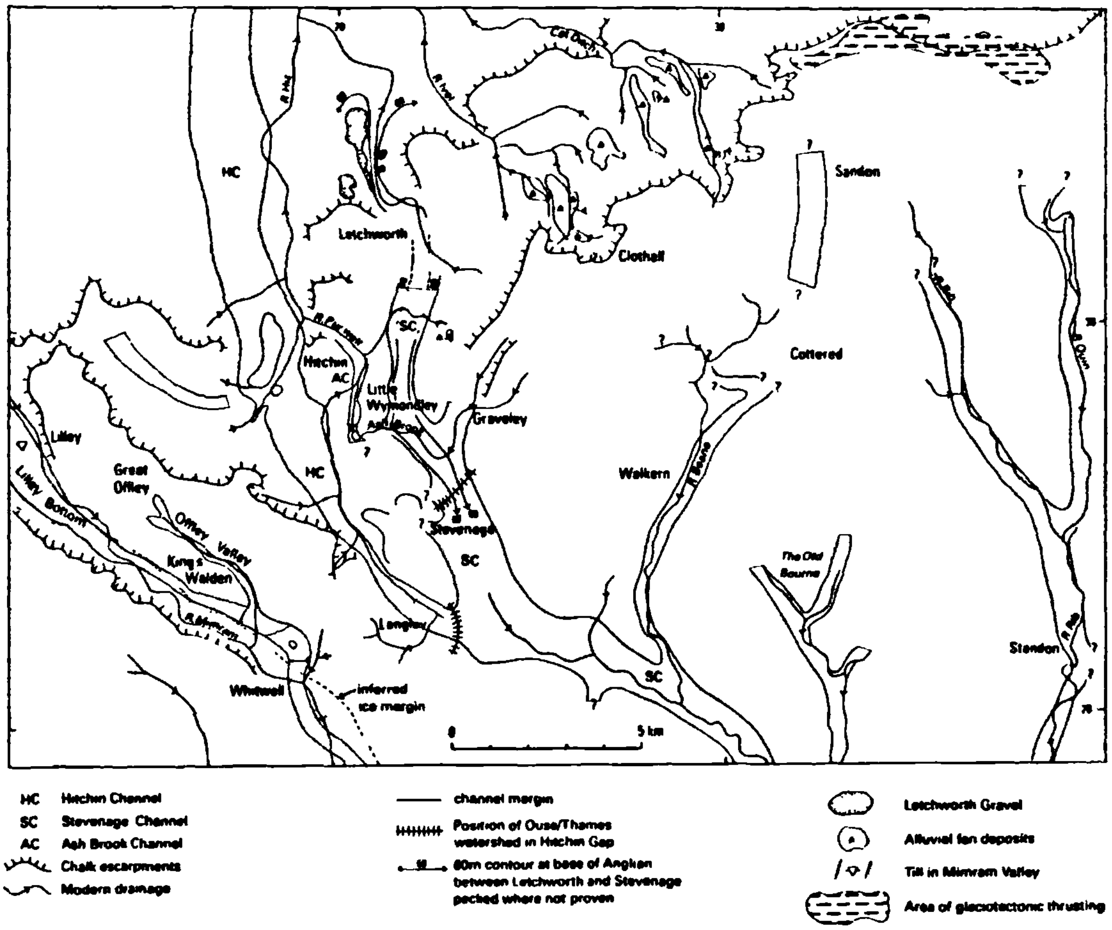


Figure 4.22 Location of buried channels in the Hitchin area (modified from Hopson *et al.* 1996).

Reid proved the following geological sequence in a series of boreholes through the buried Hitchin channel (composed from Holmes 1897; Reid 1897, 1901):

6. Yellow brickearth and small stones, containing Palaeolithic implements 14½ feet (4.35m)
5. Yellow and white *Chara* marl and silt, containing plant remains (seeds and fruits), vertebrate remains, ostracods and freshwater molluscs, 2 feet (0.6m)

--hiatus ?

4. Yellow loam and small chalk pebbles (alluvial deposit), 6 inches (0.15m)
3. Chalky boulder clay, 9 feet (2.75m)
2. Loamy, chalky gravel (base of the boulder clay), 2 feet (0.6m)
1. Gravelly sand (boring stopped by large stones), 8 feet (2.40m)

The sequence of channel-fill deposits in the Hitchin area is shown in Figure 4.23.

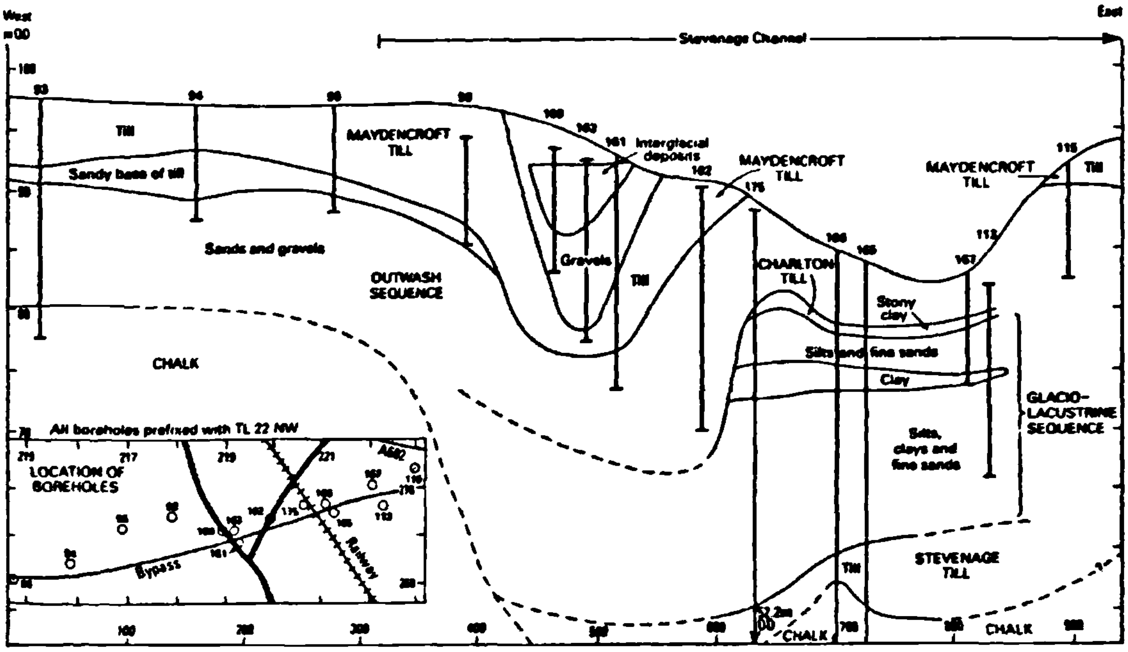


Figure 4.23 The sequence of channel-fill deposits in the Hitchin area (from Hopson *et al.* 1996).

Similar sequences were proved in boreholes Q1 and Q2 at Charlton Lane (Boreham and Gibbard 1995). The original landsurface was at approximately 79m O.D., although some 5 m of 'brickearth' had already been removed from the site. In borehole Q1, till was reached at 7.25 m below the ground surface, while in borehole Q2, till was attained at 5.73 m.

Sequence of sediments at Charlton Lane (Q1), from Boreham and Gibbard (1995).

Above 150 cm	Made ground
150-200 cm	Red-brown clay with pebbles
200-245 cm	Light brown silty clay
245-325 cm	Red mottled clay
325-370 cm	Dark brown silty clay
370-400 cm	Brown silty clay with shell and plant fragments
400-470 cm	Grey silty clay marl with shell fragments
470-500 cm	Grey-brown organic silty clay

500-575 cm	Grey silty clay with *Rutilus* tooth
575-675 cm	Dark grey silty clay with shell and plant fragments
675-725 cm	Dark grey clayey silt
Below 725 cm	Blue-grey chalky sandy diamicton (till)

Although modern excavation and building work has made it impossible to demonstrate that the lacustrine sediments at Charlton Lane are continuous with those at Jeeve's Pit, some 700 m to the north-east, the continuity is almost certain.

The Pleistocene sediments filling the basin beneath southern Hitchin therefore appear to represent the infilling of a kettle-hole that formed at the end of the Anglian glaciation. During the early part of the succeeding interglacial, the lake became infilled by sedimentation, probably as the result of a stream supplying argillaceous material flowing into the depression. The basin seems to have evolved from a lake into a shallow pond complex and possibly later into part of the stream floodplain during the second half of the interglacial (Gibbard and Boreham 1995). Both Hill (1891) and Reid (1897, 1901) noticed that the lake clays were locally decalcified beneath the *Chara* marl, suggesting local drying-out and possibly even weathering of the exposed surface of the sediment prior to emplacement of the marl. The cessation in sedimentation of the organic sediments on the basin margin and the accompanying change from the accumulation of predominantly inorganic lacustrine sediments in the basin centre to shallow-water, marl-dominated pond sediments marks a significant change in the sedimentary environment. This may have occurred either because the aforementioned stream or streams were entering the basin, or through regional lowering of the water level, or through a combination of both factors (Gibbard 1974). The isolated nature of the marl deposits may result from deposition in a number of pools or might indicate erosion of this horizon before deposition of the overlying 'brickearth' (Gibbard 1974).

Throughout the area, the lake sediments are obscured by thick 'brickearth' deposits, consisting of decalcified, indistinctly-bedded, yellow, red or brown clayey or sandy silts with pebbles increasing towards the base (Hill 1891; Reid 1897). The brickearth was originally up to 10 m thick (proved in borehole Q5, Boreham and Gibbard 1995, see Figure 4.21) and is considered to have been deposited in the valley by a combination of aeolian, colluvial and fluvial processes under periglacial conditions (Boreham and

Gibbard 1995). Later downcutting of the stream is thought to have initiated the River Hiz and its tributaries, since the location of of the Middle Pleistocene deposits on the present interfluves between Ippollitts Brook and the Hiz indicates that they are unrelated to the modern drainage system.

The sequence at Oughton Head Lane is described by Kerney (1959a) as follows:

D. Coarse flint gravel in brownish loamy sand, containing patches of material derived from Bed C and many glacial erratics. This bed is interpreted as a meltwater gravel, 1½ feet (0.45m)

....unconformity

C. Calcareous tufa or travertine, very variable in texture and containing mammalian remains and a rich temperate non-marine molluscan fauna. The tufa is interpreted as having accumulated in marshy pools fed by springs, when the climate was sufficiently warm to maintain a constant supply of water and to bring about calcium carbonate precipitation. The lower part of this bed is marly and grey, the upper is granular and crumbly in texture. Considerable post-depostional displacement has occurred, since the shells are flattened and crushed, 9 inches - 1foot 3 inches (0.23m - 0.57m)

B. Light-brown calcareous sandy clay or brickearth, with occasional flint and chalk pebbles. Contains a temperate molluscan fauna. The sediments resemble slack-water deposits, although virtually all the mollusc species are terrestrial. This bed may therefore be partly hillwash, accumulating under gentle solifluction in a temperate climate. At the top, the brickearth becomes whiter and more calcareous, grading into and interdigitating with the overlying tufa, 2 feet (60cm)

A. Very variable, ungraded series of alternating fine sandy gravels with glacial erratics and brown and grey calcareous loams. Non-fossiliferous. Interpreted as glacial outwash from a nearby ice sheet, estimated minimum 10 feet (3m)

4.8.4. Palaeontology

The following species list from the Hitchin Lake Beds has been compiled from material in the British Geological Survey Museum at Keyworth and Hitchin Museum. Thirty-six specimens were examined. The present study has confirmed the presence of 10 mammalian species, including new records of *E. ferus* and *S. kirchbergensis*. A single molar of *M. primigenius* has also been recorded from the Folly Pit, although the relationship of this specimen to the interglacial deposits is unclear. The putative record of *M. giganteus* (Stuart, in Boreham and Gibbard 1995) has not however been verified. Species listed from the Hitchin tufa at Oughton Head Lane by Wiggs (1945), Kerney (1959a) and Holyoak *et al.* (1983) include:

Meles meles L., badger
Clethrionomys glareolus (Schreber), bank vole
Microtus (*Terricola*) *subterraneus* De Selys Longchamps (– *P. arvaloides* Hinton), European pine vole
Arvicola terrestris cantiana Hinton, water vole (primitive morphotype)
Apodemus sp., indet. mouse

These remains were unfortunately unable to be located during the present study.

Species List (Mammalia) from the Hitchin Lake Beds, Hertfordshire

Rodentia
Microtus cf. *arvalis* (Pallas), common vole
Carnivora
Ursus sp., indet. bear
Proboscidea
Palaeoloxodon antiquus (Falconer and Cautley), straight-tusked elephant
Mammuthus primigenius (Blumenbach), woolly mammoth
Elephantidae sp., indet. elephant
Perissodactyla
Equus ferus Boddaert, horse
Stephanorhinus cf. *kirchbergensis* (Jäger), Merck's rhinoceros
Stephanorhinus sp., indet. rhinoceros
Artiodactyla
Dama dama ssp. indet., fallow deer
Cervus elaphus L., red deer

Capreolus capreolus (L.), roe deer
Cervidae sp., indet. deer
Bos primigenius Bojanus, aurochs
Bovidae sp., indet. large bovid (*Bos* or *Bison*)

Table 4.10 below provides a breakdown of the species list into numbers of specimens per species, also expressed as a percentage of the total mammalian assemblage. Minimum numbers of individuals have also been calculated.

Species	Number of specimens	Percentage of total assemblage (%)	Minimum number of individuals (M.N.I.)
Rodentia			
M. cf. *arvalis*	1	2.77	1
Carnivora			
Ursus sp.	1	2.77	1
Proboscidea			
P. antiquus	2	5.55	1
M. primigenius	1	2.77	1
Elephantidae sp.	1	2.77	1
Perissodactyla			
E. ferus	1	2.77	1
S. cf. *kirchbergensis*	2	5.55	1
Stephanorhinus sp.	1	2.77	1
Artiodactyla			
D. dama ssp. indet.	1	2.77	1
C. elaphus	6	16.66	2
C. capreolus	4	11.11	2
Artiodactyla			
Cervidae sp.	2	5.55	1
B. primigenius	5	13.88	1
Bovidae sp.	8	22.22	2

Table 4.10 Breakdown of the mammalian species list from Hitchin, showing numbers of specimens per species, the percentage of the total assemblage per species and minimum numbers of individuals.

4.8.5. Palaeoenvironmental and palaeoclimatic interpretation

Plant remains from the lacustrine deposits include a wide variety of aquatic plants, such as white water lily (*Nymphaea alba*) and common water plantain (*Alisma plantago-aquatica*) and marshland species, such as water mint (*Mentha aquatica*) and corn sowthistle (*Sonchus arvensis*). These point to fully temperate conditions. The presence of dry, grassy ground around the pool is indicated by species such as musk thistle (*Carduus nutans*) and self heal (*Prunella vulgaris*) (Gibbard 1974). The actions of large herbivores is thought to be at least partly responsible for the prevailing open, grassy conditions around the site (Boreham and Gibbard 1995). However, leaves of *Quercus* (oak) indicate temperate forest in the immediate vicinity (Boreham and Gibbard *ibid*). Freshwater molluscs, including *Lymnaea peregra*, *Valvata piscinalis* forma *antiqua*, *V. cristata*, *Bithynia tentaculata*, *Anodonta* sp. and *Ancylus lacustris* have been recovered from the *Chara* marl deposits (Kennard 1943) and fish remains, including perch (*Perca fluviatilis*), pike (*Esox lucius*), roach (*Rutilus rutilus*), rudd (*Scardinius erythropthalmus*) and tench (*Tinca tinca*) have also been recorded (Reid 1898). These species are indicative of relatively slow-flowing rivers and lakes at the present day. The pike spawns in winter in water not less than 5° C, while tench and rudd require minimum summer temperatures of 18° C for spawning (Wheeler 1969). Ostracods from the *Chara* marl are indicative of a temperate freshwater pool or lake with still or very slowly-flowing water. Many of the species occur in Britain at the present day (Chapman 1897). Insect remains are also recorded (Reid 1897), although the horizon from which they come is not specified. The mammalian remains, although few in number, are broadly indicative of a mosaic of habitats, including both open grassland and woodland. The large herbivores (*Equus ferus*, rhinoceroses, elephant and large bovids) are likely to have grazed the area around the lake, while the presence of fallow and roe deer suggests the presence of nearby temperate deciduous or mixed woodland.

The tufaceous deposits at Oughton Head Lane, Hitchin are remarkable for their extraordinarily diverse molluscan remains, which include a mix of extinct species and taxa whose modern ranges do not overlap at the present day. Central European forest species are represented by *Acicula polita*, *Ruthenica filograna* and *Clausilia pumila*, S.E. European species by *Acicula diluviana* (¯ *Platyla similis*), western Pyrenean woodland species by *Lamnifera pauli* and western Atlantic species by *Zenobiella subrufescens* and *Leiostyla anglica* (Preece *et al.* 1991). However, the most unusual occurrence is that of *Retinella* (*Lyrodiscus*) *skertchlyi*, a species whose closest living relative is now restricted to the Canary Islands. The presence of woodland species indicates that the tufa formed in a temperate forest, in association with pools probably fed by springs. A marshy environment next to the springs is suggested, although species such as *Valvata piscinalis* and *Bithynia tentaculata* require a fair-sized body of permanent, preferably flowing, water. The land molluscs are indicative of a highly calcareous area, covered with deciduous woodland or thick scrub, giving plenty of shade. Open grassland molluscan species are virtually absent (Kerney 1959a). The mammalian remains from the tufa are also indicative of woodland conditions, in particular the presence of *C. glareolus*, *Apodemus* sp. and *Meles meles*. The proximity of a water source is confirmed by the occurrence of *A. t. cantiana*.

4.8.6. Biostratigraphy and correlation

Mammalian studies

The mammalian assemblage from the Hitchin Lake Beds is extremely small but nevertheless contains three species of biostratigraphic significance. The presence of *Bos primigenius* and *Stephanorhinus kirchbergensis* indicates a post-Anglian age for the deposits, while the occurrence of *Equus ferus* suggests that the site is not of Last Interglacial (Ipswichian) age. Unfortunately, there is nothing else in the mammalian assemblage that can assist in further refining the dating of the interglacial represented in these deposits, since no diagnostic indicator species have been recovered. However, the overall composition of the mammalian fauna from the Lake Beds compares most favourably with sites such as Swanscombe (4.2) and Clacton (4.4), in particular the combination of horse, straight-tusked elephant, Merck's rhinoceros and fallow deer. The subspecific identity of the fallow deer is unknown, since the single antler (HG/2252) from the Lake Beds is incomplete. Similarly, the single canine fragment of bear (HG/2254) cannot be identified to species level. In both cases, the availability of more material would make specifc identifications possible. The small size of the Hitchin red deer, comparable to that found at Swanscombe and Clacton (Lister 1981), also suggests that the Lake Beds may be of Hoxnian age.

The upper premolar of *Equus ferus* (HG 2253) is particularly large and robust (occlusal length: 1: 31.36mm, occlusal width: 26.18mm, length of protocone: 12.34mm) and in this respect, is reminiscent of the equid upper cheek tooth from the Basal Gravel at Swanscombe (4.2) (see Figure 4.9). A single specimen of woolly mammoth (*Mammuthus primigenius*) (HG 1706) was apparently collected from the Folly Pit, although it is unfortunately not recorded whether it came from the interglacial deposits themselves or from the cold stage deposits that pre- and post-date the temperate episode.

In conclusion therefore, the limited mammalian assemblage from the Hitchin Lake Beds is considered to be most probably of Hoxnian age and thus representative of the first post-Anglian interglacial, a correlation that is reinforced by the palaeobotanical evidence (see below).

The mammalian remains from the Hitchin tufa deposits are much more age-diagnostic, although the deductions drawn here are based upon published records, since the present whereabouts of the original material could not be ascertained. The presence of the primtive morphotype of water vole, *A. t. cantiana*, suggests an age for the deposits between the end of the Cromerian complex and OIS 9 inclusive. The occurrence of the pine vole, (*M.* (*T.*) *subterraneus*, however places an upper limit on the age of the fauna of OIS 11. Taken together with the biostratigraphic evidence from the molluscan fauna (see below), the mammalian remains strongly suggest an age for the Hitchin tufa of approximately 400 000 years B.P.

Malacological studies

The highly-distinctive molluscan assemblage from the Hitchin tufa is closely comparable with that from Beeches Pit (Kerney 1959a; Holyoak *et al.* 1983; Preece *et al.* 1991) (4.6). In Britain, several species (including *R. skertchlyi*) are known only from these two localities and there is thus little doubt that they are identical in age, although the possibility that the similarities are facies-controlled must be taken into account. Similar '*Lyrodiscus*' faunas containing have been reported from various continental tufas, including St. Pierre-lès-Elbeuf, Vernon and Arrest in France and Hörlis in Germany. These deposits have all been correlated with OIS 11 (Rousseau and Puisségur 1990; Rousseau *et al.* 1992).

Palynological studies

The Hitchin Lake Bed deposits have been assigned to the Hoxnian Interglacial, on the basis of the palynological evidence (Gibbard 1974). Deposition within the lake began during the late Anglian, as witnessed by the herb-dominated assemblage characterised by moderate frequencies of *Hppophaè*, followed by the development of *Betula* woodland during the early Hoxnian, and a rise in thermophilous tree pollen. The sequence at Charlton Lane records only the development of *Betula* woodland and appears to span a shorter time period than the sequence at Maydencroft Manor (Boreham and Gibbard 1995). The deposits at Charlton Lane appear to be the direct equivalents of the basal silty clays and *Chara* marl described by Reid and are assigned to biozone Ho II. Additionally, a sample of *Chara* marl from Jeeve's Pit, collected by R.G. West in 1954 (West 1955), has yielded pollen spectra characteristic of thermophilous woodland, which has been assigned to subzone Ho IIc (Boreham and Gibbard *ibid*). It appears that either sedimentation ceased at this point (possibly to due water level fluctuations), or that later interglacial deposits were weathered and eroded.

4.8.7. Discussion and conclusions

The age of the organic deposits in the Hitchin Lake Beds is indicated by their stratigraphical position and contained biological remains. These deposits directly overlie unweathered Anglian Lowestoft Till and associated meltwater sediments, thereby implying that the basin formed immediately following decay of the Anglian ice. The pollen spectra record the transition from the late Anglian into the early Hoxnian interglacial, thus also indicating a continuity of deposition. The stratigraphic and palynological evidence consequently place the Hitchin Lake Beds within the Hoxnian Interglacial, correlated in the present study with OIS 11. The mammalian remains confirm a post-Anglian, pre-Last Interglacial age for the deposits but are otherwise limited as biostratigraphic indicators. However, the assemblage bears most close resemblance to that from Swanscombe (4.2) and would certainly not be inconsistent with a Hoxnian age. In conclusion, the combined lines of evidence suggest an approximate age for the Hitchin Lake Beds of 400 000 years B.P. Evidence for the age of the Hitchin tufa is derived from molluscan and mammalian biostratigraphy, both of which also suggest an immediately post-Anglian age for the deposits. The molluscan fauna compares very closely with that from Beeches Pit (4.6), a site demonstrated in the present study to be of Hoxnian (OIS 11) age, and from various continental sites also attributed to OIS 11. The mammalian assemblage from the tufa also supports this correlation, since it contains the important biostratigraphic indicator, *M.* (*T.*) *subterraneus*, which is unknown in Britain after the first post-Anglian interglacial.

4.9. HICKS BRICKYARD (WOODSTON), FLETTON, PETERBOROUGH, CAMBRIDGESHIRE (TL 190955)

4.9.1. Location of the site

The interglacial deposits known as the Woodston Beds are preserved on the south side of the city of Peterborough, to the south of the River Nene (Figures 4.24 and 4.25).

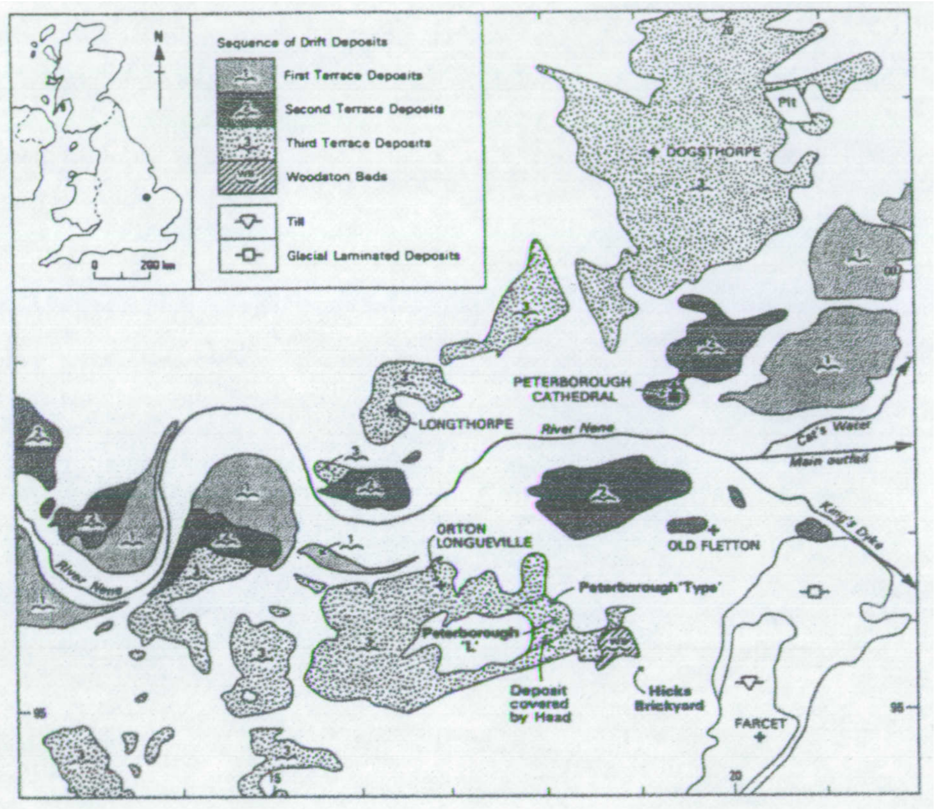


Figure 4.24 The Peterborough area showing the distribution of Pleistocene deposits and the locations of Hicks Brickyard, Peterborough 'Type' and Peterborough 'L' sections (from Horton *et al.* 1992).

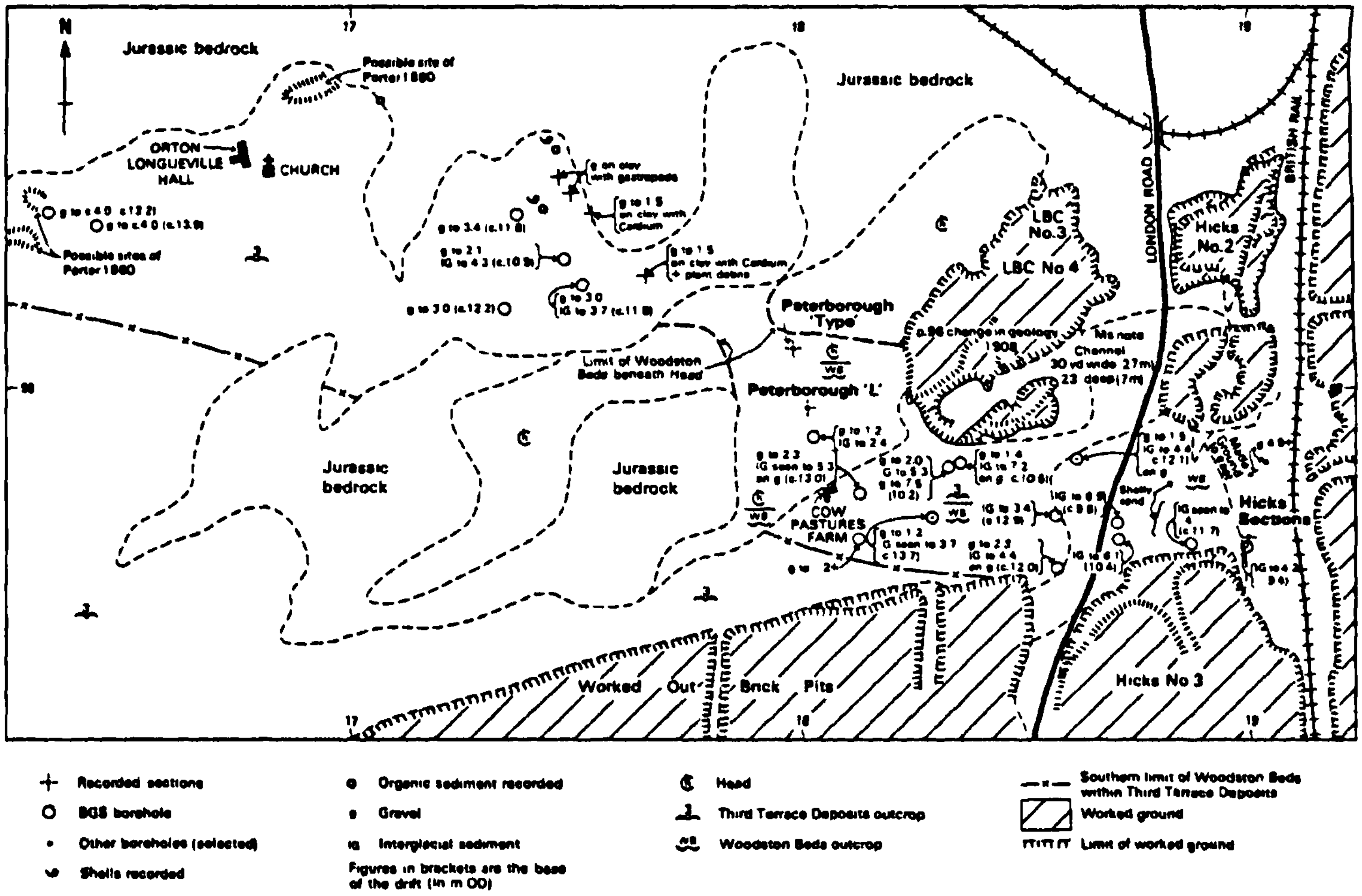


Figure 4.25 Location of the Hicks sections, Peterborough 'Type' Peterborough 'L' sections and other pits mentioned in the text (from Horton *et al.* 1992).

4.9.2. History of research

Gravel pits near Orton Longueville Hall (see Figure 4.24) were recorded by Trimmer (1854). The sequence described was up to 4.20m thick and consisted of a basal gravel containing freshwater and brown clay' yielding freshwater and terrestrial Mollusca, which was capped in turn by a second bed of gravel. This sequence was confirmed by Porter (1861) and Judd (1875) in two pits to the west and to the north-east of Orton Longueville Hall (TL 163964 and TL 169967 respectively), which also yielded mammalian and molluscan remains (see Figure 4.25). Expansion of the brickyards in the nineteenth century led to the opening of two new pits, probably Hicks No. 1 (TL 189960) and Plowman's Pit (TL 193960). These exposed the infill of a Pleistocene river channel, 27.5m wide by 6.9m deep, cut into Boulder Clay and running east-west (Leeds 1956; Sabine, in Horton *et al.* 1992). Mammalian bones were recorded from the channel sediments. A second channel up to 15m deep was revealed in the London Brick Company Pit No.4 (Kendall 1913) (see Figure 4.25). This channel was cut into Oxford Clay and ran from north-west to south-east. The section consisted of 6-7.5m of rubble and boulders at the base, overlain by up to 9m of sands, marls, clays and gravels. The channel fill contained 58 species (in roughly equal proportions) of freshwater and marine mollusca (Kendall *ibid*; Kennard and Woodward 1922).

In 1968, the Greater Peterborough area was mapped by the British Geological Survey and new exposures investigated. Material from two boreholes (known as Peterborough 'Type' and 'L') was examined and the presence of the tripartite stratigraphic sequence confirmed. Preliminary accounts of this work are given in Horton *et al.* (1974a) and Horton (1981). In 1986, a further excavation in Hicks Brickyard was conducted for the specific purpose of recovering palaeontological material (Horton *et al.* 1991, 1992) (see Figure 4.25). The term 'Woodston Beds' was coined for the fluviatile and estuarine silty clays, silts and fine sands that are found to overlie beds of gravel and ultimately Jurassic bedrock in this area (Horton *et al.* 1974a).

4.9.3. Geological background and provenance of mammalian remains

The oldest Pleistocene deposits in the Peterborough district are glacio-lacustrine sediments which underlie, and in rare instances overlie, chalky Lowestoft Till. These are believed to represent sedimentation in pro-glacial lakes during the Anglian glaciation. Small outcrops of glacial sand and gravel, probably outwash from the Anglian ice sheet, also occur to the west and south-east of Peterborough (Davey 1991). The Woodston Beds represent the oldest interglacial deposits in the district. They are succeeded by, and possibly interdigitate with, gravel deposits which form the Third Terrace of the River Nene, the highest (and oldest) of three river terraces (Horton *et al.* 1991, 1992).

The history of sedimentation at the site is of deposition in the channel and estuary of a large slow-flowing river, during temperate conditions. Fluvial sedimentation occurred, initially with deposition of gravel as channel bars, and then accumulation of quiet-water sediments with evidence of episodic current activity, suggesting overbank deposition. Although freshwater conditions predominated, a progressively more important tidal input is apparent, culminating in brackish conditions with tidal channels, mud flats and possibly salt marsh at the maximum extent of the marine transgression. Subsequently, fluvial sedimentation returned, initially in quiet-water environments but eventually to deposit the sands and gravels of the Third Terrace of the River Nene.

As stated above, the tripartite succession recorded by earlier investigators is confirmed, although one or other of the three elements may be locally absent, thereby suggesting that there was a great variety of depositional environments. This would be consistent with the normal variability of depositional conditions on a river floodplain or in a tidal estuary (Horton *et al. ibid*). The sequence in the Hicks 86 section is shown in Figure 4.26.

Throughout their outcrop, the Woodston Beds overlie Jurassic bedrock. The base of the formation ranges in altitude from 5.2m to 14.7m above O.D., whereas the top lies at *c.* 13m to 16.3m above O.D. (Horton 1981). The following information on the stratigraphic succession is summarised from Horton *et al.* (1992). Gravel is usually present at the base of the sequence, varying in thickness from a few centimetres to over 2m and commonly containing lenses and beds of sand and clay-rich layers. Palaeobotanical and molluscan remains are common, either dispersed throughout the gravel or concentrated in the form of felted plant debris or in shell-rich bands. Mammalian remains may be present but are uncommon. The gravel is overlain by

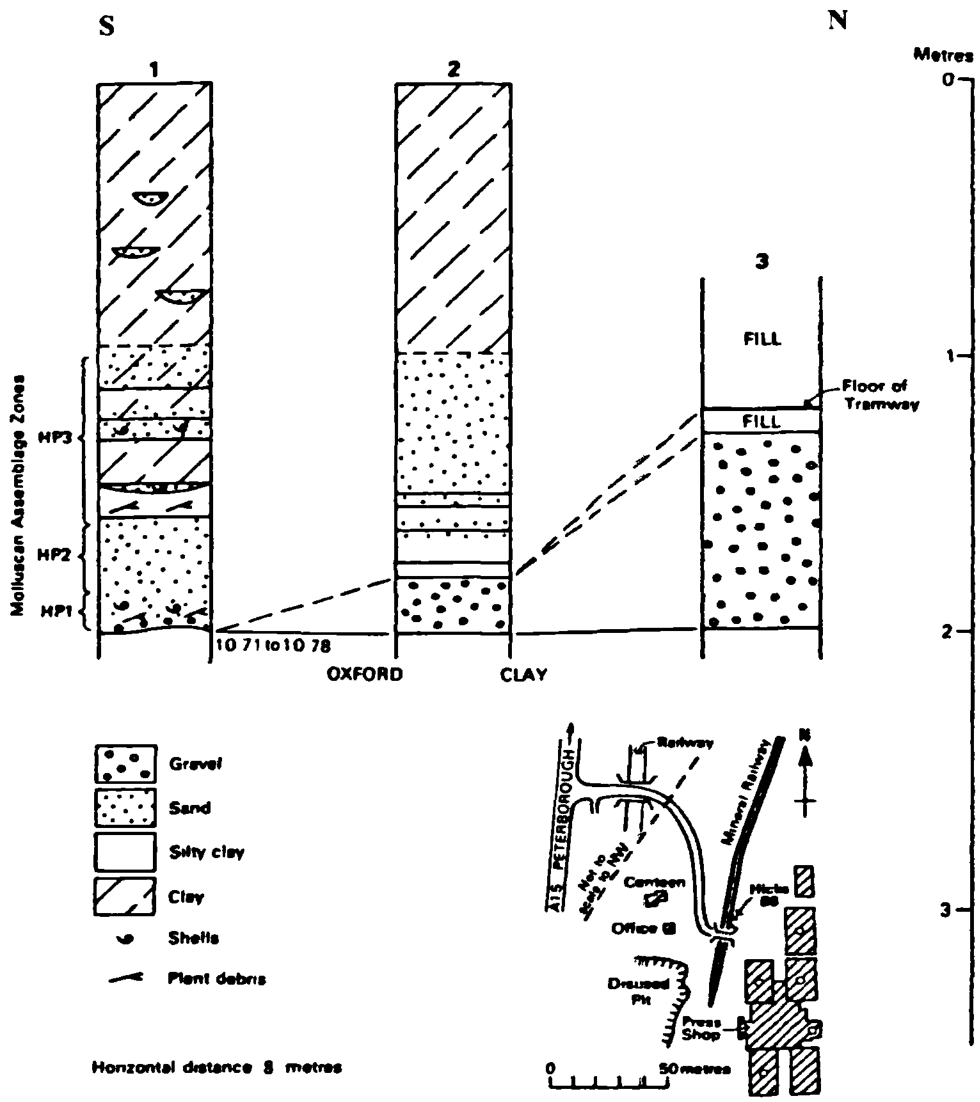


Figure 4.26 The stratigraphic succession and location plan, Hicks 86 section (modified from Horton *et al.* 1992).

mainly fine-grained fluvial sediments, indicative of deposition outside the confines of the channel. These include silts, characteristic of backwater deposition, and sands in lens-shaped bodies and graded and laminated sheets, suggestive of higher-energy flows on the floodplain. Thin seams of gravel are locally present. Fossil material is generally encountered and is preserved in very rich horizons. These fluvial sediments form the middle element of the tripartite succession. They pass (apparently conformably) upwards into similar deposits which, on the basis of their contained fauna, are of estuarine origin. Evidence of backwater deposition and of the cutting and filling of minor channels is also present but the amount of reworking changes from place to place and suggests varying proximity to the main flow of water in the estuary. These sediments are commonly oxidised and wholly or partly decalcified towards the top, nearing the ground surface. The uppermost element of the tripartite succession is gravel, observed to be at least 1m thick in places.

4.9.4. Palaeontology

The mammalian remains from Woodston were not seen during the present study. The following species list has therefore been compiled from Horton *et al.* (1992).

Species List (Mammalia) from Woodston (Hicks 86 section), Peterborough, Cambridgeshire

Insectivora
Talpa sp., indet. mole
Rodentia
Clethrionomys glareolus (Schreber), bank vole
Arvicola terrestris cantiana (Hinton), water vole (primitive morphotype)
Microtus (*Terricola*) *subterraneus* (de Selys Longchamps) (= *Pitymys arvaloides* Hinton) pine vole
Microtus sp., indet. vole
Apodemus sylvaticus (L.), wood mouse
Artiodactyla
Bovidae sp., indet. large bovid (*Bos* or *Bison*)

4.9.5. Palaeoenvironmental and palaeoclimatic interpretation

The molluscan assemblage from the Woodston Beds comprises 91 non-marine taxa and 11 brackish/marine taxa (Horton *et al.* 1992). The basal part of the succession is dominated by species which inhabit large rivers, such as *Valvata piscinalis* and *Bithynia tentaculata*. The occurrence of *Ancylus fluviatilis*, *Pisidium henslowanum* and *P. moitessierianum* also confirms the presence of well-oxygenated moving water. Freshwater ostracods were also recovered. Further up the sequence, the assemblage contains a greater percentage of still-water and weed-dwelling species, such as *Valvata* *cristata*, *Armiger crista* and *Acroloxus lacustris*, before returning to conditions of moving water, characterised by the *V. piscinalis B. tentaculata* fauna. The land-snail fauna is dominated by shade-demanding species, with dry, predominantly calcareous grassland and damp, marshy habitats also represented.

The brackish water indicator, *Hydrobia ventrosa*, appears in the upper part of the Hicks 86 section, thereby suggesting an increase in salinity in the Woodston Beds river prior to a marine transgression. Examination of the Peterborough 'L' section molluscan and ostracod fauna reveals a gradual increase in brackish indicators (such as the ostracod *Cyprideis torosa*) from around 11m O.D. with truly marine species present at 12.2m O.D. (*Ostrea edulis*, *Cerastoderma edule*, *Scrobicularia plana*, *Littorina littorea*, *Spisula elliptica* and *Mytilus edule* and the brackish water hydrobiid, *Hydrobia ventrosa*). Three peaks of marine influence are apparent from the Peterborough 'L' section, separated by brief freshwater incursions, possibly the result of floods or longer periods of marine regression. Marine molluscs are found up to a height of 14.1m O.D., thus indicating the prevalence of marine conditions to at least this level (Horton *et al. ibid*).

Certain taxa among the land snails have a rather different distribution at the present day, *C. pumila* (southern Sweden, Denmark and eastern Germany), *V. alpestris* (known only from Cumbria and north Wales in Britain, otherwise in central Europe and Scandinavia), *Perforatella rubiginosa* (western Germany and the Netherlands) and *T. callicratis* (south coast of England and south-east France). This implies that either the present-day ranges of these species are different, or that more continental or southern European climatic conditions were in operation during the deposition of the Woodston Beds.

The coleopteran fauna from the base of the succession is dominated by species requiring well-oxygenated water with a stony substrate (Horton *et al.* 1992). The presence of water meadows adjacent to the river is attested to by the presence of *Donacia semicuprea*, which feeds on the sweet grass *Glyceria aquatica*. This plant would have been particularly attractive to herbivorous mammals, the dung of which provided food for at least four species of dung beetle. Marshy riparian environments, some dry grassy areas and light woodland are also suggested by various species of carabid beetle. The insect assemblage is indicative of fully temperate conditions, with a climate rather warmer than southern England today and possibly more continental.

The mammalian remains suggest a similar range of environments. The co-occurrence of bank vole (*Clethrionomys glareolus*) and wood mouse (*Apodemus sylvaticus*) is suggestive of woodland habitats (Currant 1986). Locally open vegetation is suggested by the pine vole (*Microtus* (*Terricola*) *subterraneus*) and the proximity of slow-flowing water by the water vole (*Arvicola terrestris cantiana*). The presence of mole (*Talpa* sp.) implies a temperate climate, since this species cannot tolerate permanently or seasonally frozen ground.

The pollen spectra from the sections in Hicks Pit are indicative of mixed oak forest, dominated by *Ulmus* (elm), *Quercus* (oak) and *Alnus* (alder) and rich in *Betula* (birch), *Pinus* (pine), *Fraxinus* (ash) and *Picea* (spruce). Tree pollen never falls below 72% of total land pollen throughout the sequence and low herbaceous pollen values indicate an almost complete forest cover. Small areas of open ground are suggested by grasses and by infrequent occurrences of open-ground plants, such as *Artemsia* (mugwort) and *Plantago* (plantain). The only evidence for vegetational change is a slight upward increase in *Pinus* and some decline in *Ulmus* and *Quercus*. Plant macrofossils, especially of alder and yew (*Taxus*), and fragments of wood, particularly of oak, were also recovered. The palaeobotanical evidence therefore suggests fully interglacial conditions during the deposition of the Woodston Beds, with closed canopy forest and small areas of grassland in proximity to the site. The occurrence of *Najas minor*, which has a currently southern and eastern European distribution, suggests a climate warmer than at present, while the occurrence of *Hedera* (ivy) and *Ilex* (holly) indicates a climate with winters not significantly colder than at present (Horton *et al.* 1992).

4.9.6. Biostratigraphy and correlation

Mammalian studies

Two species are of biostratigraphic significance in the determination of the age of the Woodston Beds. The presence of the primitive morphotype of water vole (*A. t. cantiana*) places the Woodston Beds between the end of the Cromerian complex and

OIS 9, while the European pine vole (*M.* (*T.*) *subterraneus*) indicates that the beds cannot post-date the Hoxnian Interglacial, since this species has never been recovered from any younger deposits.

Malacological studies

The molluscan assemblage from the Woodston Beds has proved inconclusive as far as an age determination is concerned. This is primarily due to a lack of sites with a comparable depositional environment on which to base any correlations. The ostracod evidence has proved similarly unsatisfactory as far as establishing the age of the deposits (Horton *et al. ibid*).

Coleopteran studies

The insect fauna from the Woodston Beds has been noted to have strong affinities with that from the type locality of the Hoxnian Interglacial (4.1). In both cases, the distinctive species *Hydraena latebricola* is present and these are to date the only two sites from which this species has been recovered. It is therefore concluded that the Woodston Beds are of Hoxnian age (Horton *et al. ibid*).

Palynological studies

The palynological evidence from the Woodston Beds suggests a Hoxnian age for the deposits. This is based upon the characteristics of the pollen assemblages, such as the high values of *Ulmus* in the mixed oak forest, the consistent occurrence of *Tilia* (lime), the low curve for *Picea* before the rise of *Carpinus* (hornbeam) and the consistent occurrence of *Ilex*, and also on the presence of two biostratigraphically significant species, Type 'X' and the water fern *Azolla filiculoides*, both of which are not known from deposits younger than the Hoxnian *sensu lato*. The Woodston Beds are therefore assigned to pollen zone Ho II of the interglacial. The progressive upward decline of *Ulmus*, the high *Alnus* content and the increase in *Corylus* are suggestive of subzone Ho IIc, although Horton *et al.* (*ibid*) regard the correlation as tentative, since the high non-arboreal pollen phase present in Ho IIc at Marks Tey and Hoxne (4.1) is not represented at Woodston. However, it seems highly likely that the difference in facies between the lake sites of Marks Tey and Hoxne and the fluvial estuarine environment at Woodston can explain this apparent absence at the latter locality.

Sea levels

The age of the Woodston Beds has important implications for the understanding of sea level changes during the Middle Pleistocene. The marine incursion in the Woodston Beds is at *c.* 11m O.D. and extends to at least 14.10m O.D., although the upper limit of marine conditions is not firmly established due to decalcification and erosion at the top of the sequence. The only other site in the Wash basin to have yielded evidence of Hoxnian sea levels is the Nar Valley (Ventris 1985; West 1987). Here, palynological evidence suggests the onset of marine conditions during subzone Ho IIc, where marine deposits occur at 2.5m O.D., reaching a maximum sea level of *c.* 23m O.D. in Ho III. This implies a 10m difference in the height of the marine transgression from the north side of the Wash to the south. Several explanations have been put forward for these differences by Horton *et al.* (1992). First, they may reflect a possible height difference between the two localities in the Hoxnian. Second, it is possible that the form of the proto-Nene estuary resulted in higher spring tide levels than in the Nar Valley. Third, differential uplift or tectonic warping may have occurred between the Nene and Nar Valleys in the Hoxnian or subsequently or fourth, the two sites may not be contemporary.

The Hoxnian deposits at Clacton (4.4) show a marine trangression at 3m O.D. and continuing estuarine conditions to 9m O.D. (Turner and Kerney 1971). This height range is much closer to that of the marine episode at Woodston, although the transgression at Clacton occurs at a lower level. The possibility of differential warping must therefore also be considered.

4.9.7. Discussion and conclusions

As outlined above, the possibility of factors such as differential warping prevents any correlation of the Woodston Beds with other sites on the basis of sea level heights. The age of the deposits is therefore indicated primarily by their contained biological remains. The pollen spectra are characteristic of zone II of the Hoxnian Interglacial (possibly subzone IIc) and contain biostratigraphically significant species such as Type 'X' and *A. filiculoides*, which provide an upper age limit for the deposits of Hoxnian *sensu lato.* Comparisons of the beetle fauna also show strong similarities with Hoxne itself (4.1). However, the attribution of the Woodston Beds to OIS 9 on the basis of amino acid ratios (Horton *et al.* 1992) would appear to conflict with the mammalian evidence, which strongly advocates correlation with the Hoxnian Interglacial and thus with OIS 11. This is based on the presence in the Woodston Beds of the European pine vole *M.* (*T.*) *subterraneus*, an important biostratigraphic indicator which is unknown in Britain after the first post-Anglian interglacial. The place of the Hoxne interglacial deposits within the British Pleistocene succession has already been discussed (see Chapter 2 and 4.1) and it is concluded here that, as with Hoxne, the interglacial represented by the Woodston Beds is that of the first post-Anglian temperate stage, equated with OIS 11. The validity of the amino acid ratios from the Woodston Beds is therefore called into question.

4.10. Summary of evidence from the Hoxnian Interglacial

The following species have been recognised as diagnostic of the Hoxnian Interglacial (Stage 11), wherever a post-Anglian age can be unequivocally demonstrated: *Talpa minor*, *Trogontherium cuvieri*, *Pitymys subterraneus*, *Oryctolagus cuniculus* and *Ursus spelaeus*. *Dama dama clactoniana* is also considered to be an important Hoxnian indicator, although the absence of antlers of *Dama* in museum collections attributed to either the Cromerian Complex or to the Stage 9 interglacial makes identification of the stratigraphic range of this subspecies difficult. In conclusion therefore, the presence of *D. d. clactoniana* is to date known only from the Hoxnian, although its use as a Hoxnian indicator is best taken in support of the other taxa named above. The Hoxnian Interglacial also marks the first occurrence in Britain of *Microtus agrestis*, *Equus hydruntinus*, *Stephanorhinus kirchbergensis*, *Stephanorhinus hemitoechus*, *Megaloceros giganteus* and *Bos primigenius*, but species from the immediately pre-Anglian period, including *Sorex* (*Drepanosorex*) *savini*, *Sorex runtonensis*, *Pliomys episcopalis*, *Megaloceros verticornis* and *Ursus deningeri* are absent, presumably becoming extinct (at least in Britain) during the Anglian. Other important absences from the Hoxnian Interglacial include *Crocuta crocuta* and *Hippopotamus amphibius*.

CHAPTER 5. THE "STAGE 9 INTERGLACIAL"

5.0. Introduction

This chapter will examine the mammals of the "Stage 9 interglacial". Seven sites are reviewed in this section: Purfleet (Essex), Grays (Essex), Cudmore Grove (Essex), Belhus Park (Essex), Pershore (Worcestershire), Wolvercote (Oxfordshire) and Barling (Essex). The location of these sites is shown in Figure 5.1.

The "Stage 9 interglacial" is a newly-recognised interglacial, which was originally identified in the oxygen isotope record as the second of four post-Anglian temperate episodes (the Anglian glaciation being correlated with Stage 12, see Chapter 2). The existence of terrestrial deposits that can be attributed to Stage 9 has been upheld by the model for terrace succession in the Thames, proposed by Bridgland (1988, 1994). This model recognises four major post-Anglian gravel formations in the Lower Thames, of which the second, the Corbets Tey (Taplow) Gravel Formation, contains interglacial sediments correlated with Stage 9 (Bridgland *ibid*). Further support for the "Stage 9 interglacial" has come from other terrace studies, which have consistently demonstrated the presence of four separate post-Anglian temperate episodes, in the Avon (Maddy *et al.* 1991) and Severn valleys (Bridgland *et al.* 1986; Maddy *et al.* 1995). Results from aminostratigraphy (Bowen *et al.* 1989) are also consistent with four post-Anglian interglacials. The "Stage 9 interglacial" is therefore taken to refer specifically to the un-named interglacial episode after the Hoxnian (cf. Stage 11) and before the "Stage 7 interglacial" and the Ipswichian.

The following section will first examine the evidence from Purfleet in order to establish the nature of the mammal fauna of the "Stage 9 interglacial" and to identify species of biostratigraphic significance. This information will then be compared with mammalian evidence from the other above-named localities. Since the Hoxnian type-site has also been assigned to Stage 9 on the basis of aminostratigraphy by Bowen *et al.* (1989) (although this attribution is not supported by the present study), comparisons will be made with the mammal fauna of the Hoxnian Interglacial.

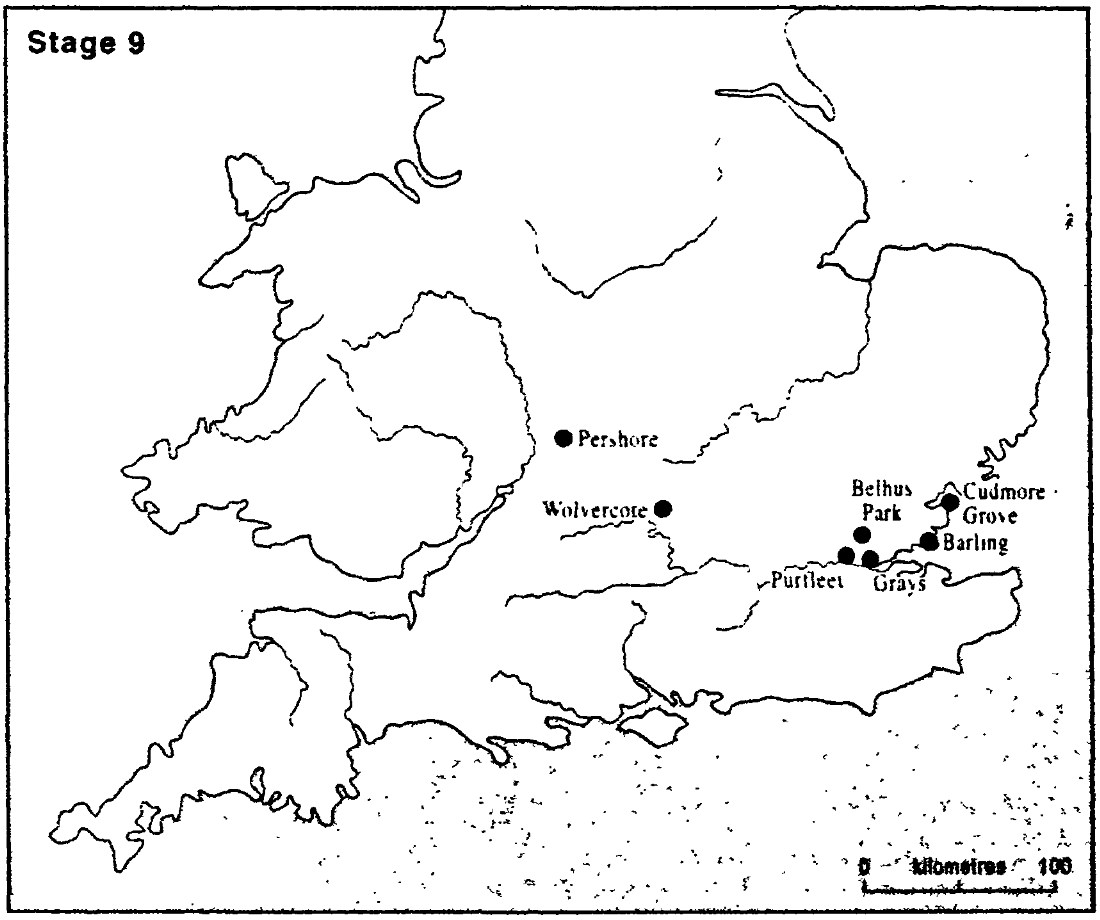


Figure 5.1 Location of sites assigned to the “Stage 9 interglacial”.

5.1. PURFLEET, ESSEX

5.1.1. Location of the sites

Four adjacent quarries are located within the Purfleet Chalk Pits S.S.S.I.: Greenlands, Bluelands, Botany and Esso Pits (Figure 5.2). The Pleistocene sediments exposed in these pits abut the northern side of the Purfleet Anticline and lie to the south of the Mar Dyke stream, a westward-flowing tributary of the River Thames. The first three pits are disused Chalk quarries with the Pleistocene deposits forming the upper part of the section only. The Esso Pit is a small gravel working within a compound formerly used by the Esso company for underground oil storage. The first three localities have yielded mammalian remains, all four contain archaeological material.

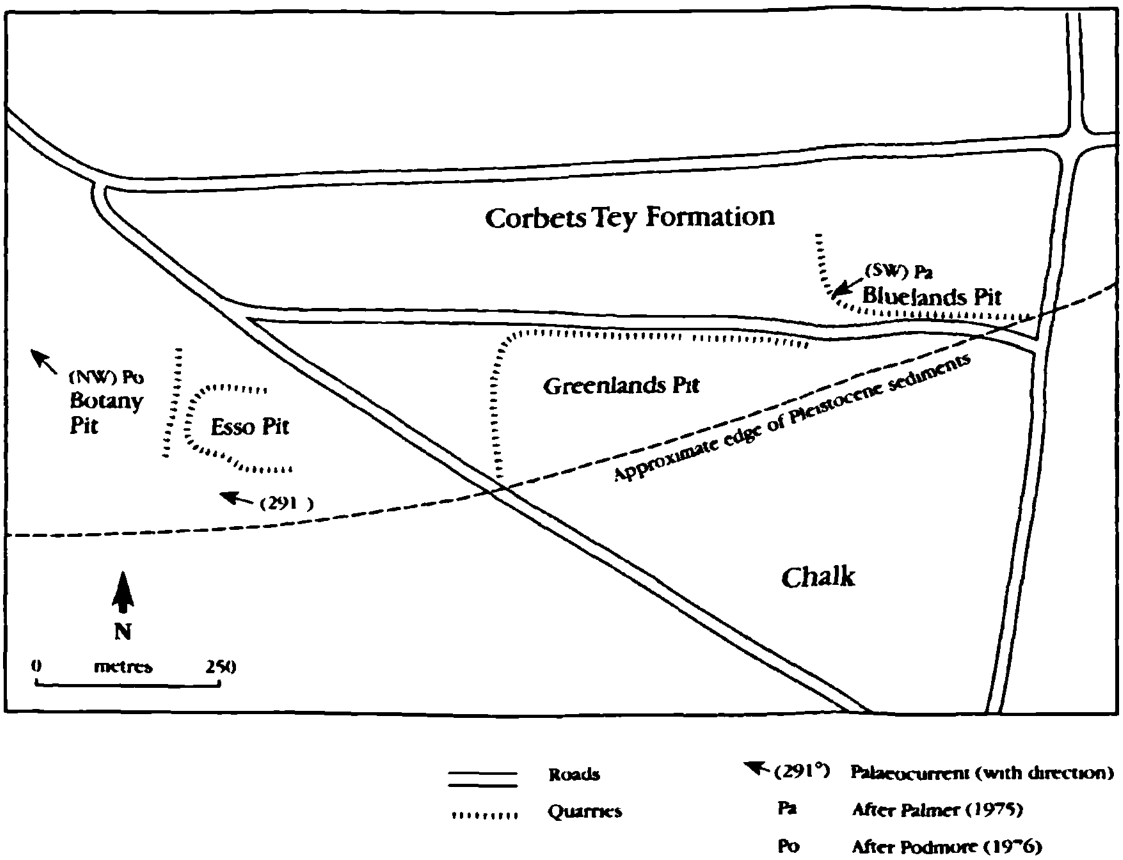


Figure 5.2 Location of sites in the Purfleet area (from Bridgland 1994).

During the course of the present study, new multidisciplinary excavations were undertaken by the author in the north-east corner of Greenlands Pit, approximately 2km NNW of the Thames (Figures 5.3 and 5.4).

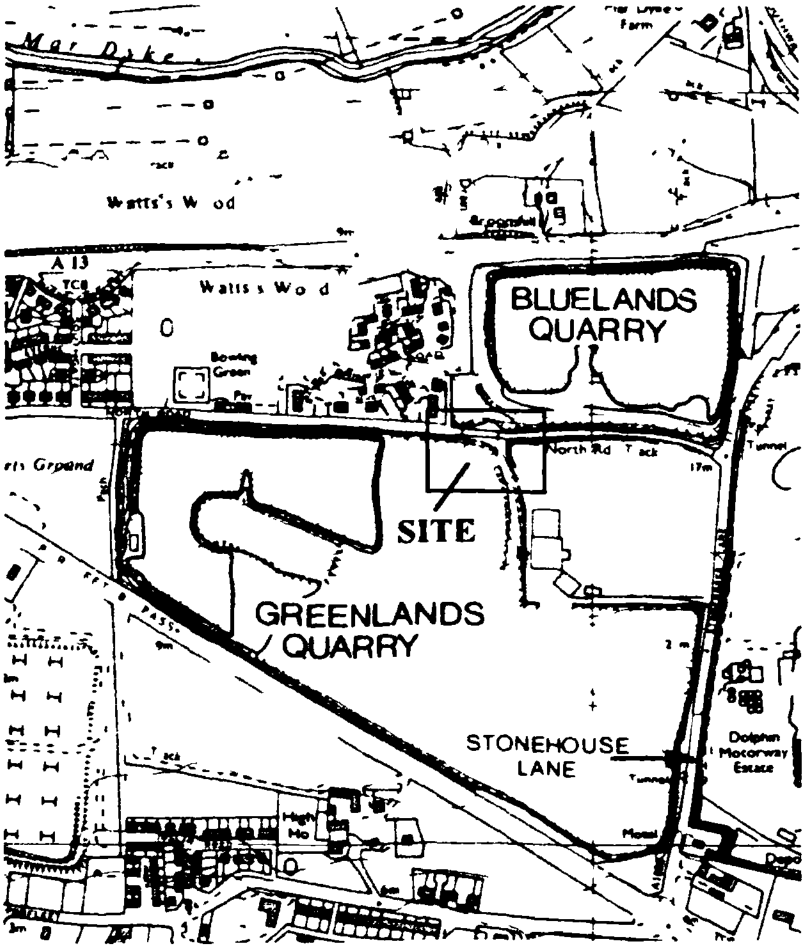


Figure 5.3 Location of author's excavations in Greenlands Pit, Purfleet (modified from Ordnance Survey).

5.1.2. History of research

The earliest reference to deposits in the Purfleet area is in the Dartford memoir of the Geological Survey (Dewey *et al.* 1924), although the first archaeological investigation was not undertaken until the early 1960s, when removal of the terrace gravels above the Chalk in Botany Pit, south-west of the present Purfleet bypass, revealed a rich Palaeolithic assemblage in the feather edge of the gravels. An archaeological excavation and collecting operation was undertaken by A.J. Snelling (in Wymer 1968), which recovered a wide range of flint artefacts, including handaxes, 'chopper-cores' and flakes of Clactonian type, together with 'proto-tortoise-cores', exemplifying the early use of the Levallois flint-knapping technique. Greenlands Quarry was also opened in the early 1960s and provided extensive exposures revealing the presence of rich shell beds, from which an extensive molluscan fauna and occasional mammal bones were collected (Snelling 1975).

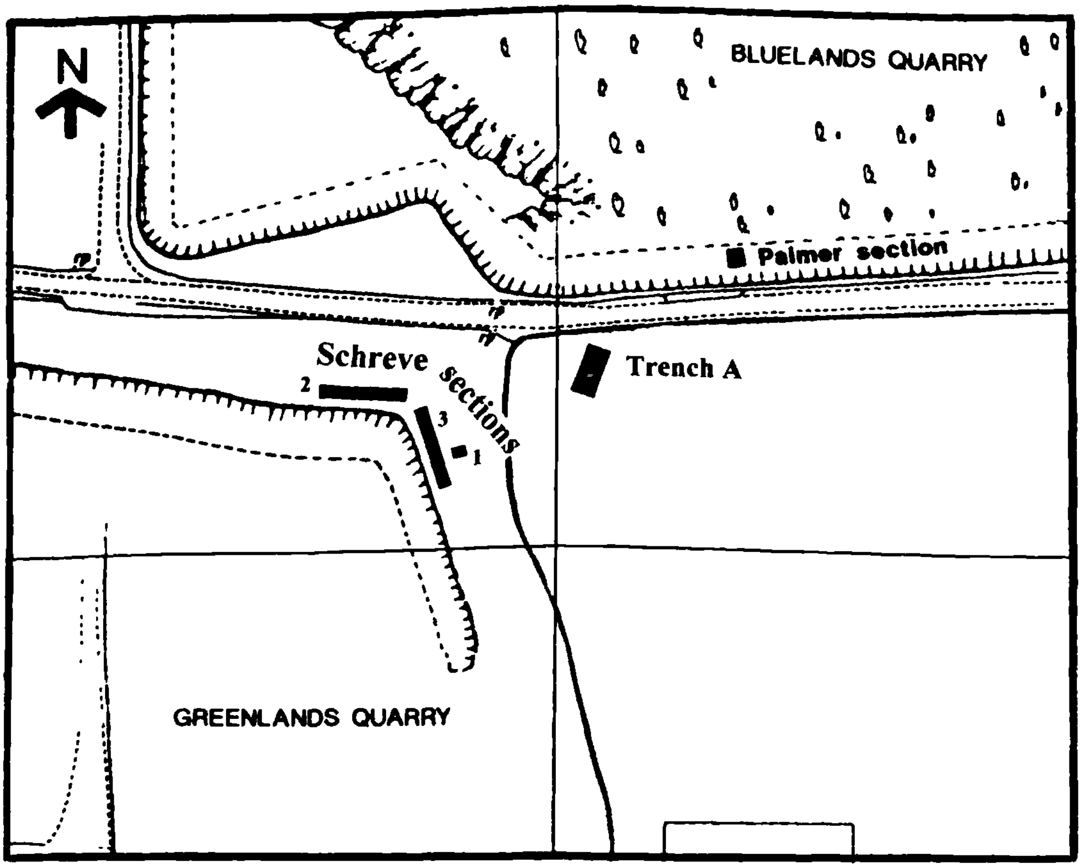


Figure 5.4 Location of the author's sections in Greenlands Pit, Palmer's section on North Road and Essex County Council's Trench A off Stonehouse Lane, Purfleet (modified from Bridgland and Allen 1994).

In the 1970s, it was discovered that flint artefacts were also present within the terrace deposits at both Greenlands Pit and the adjacent Bluelands Pit, and a series of small-scale controlled excavations were subsequently undertaken by Palmer (1975), on either side of the former North Road (now a footpath). Reappraisal of Palmer's collections suggested that a highly significant stratigraphical sequence of different artefact types might be represented in the terrace deposits at Purfleet, with simple flakes and cores in the lower deposits and a Levallois industry in the highest sediments. All parts of the

Purfleet sequence have yielded handaxes, thereby suggesting that hand-axe manufacture was common to both periods (Wymer 1985). The Botany Pit sediments with their Levallois artefacts are presumed to correlate with the upper part of the Greenlands/Bluelands sequence. The early exposures at Purfleet demonstrated that some of the sediments were both fossiliferous and of interglacial nature. In addition to significant molluscan, ostracod and small vertebrate assemblages (Palmer 1975; Snelling 1975; Allen 1977; Hollin 1977; Holman and Clayden 1988), rather restricted pollen spectra were also recovered, from which it was tentatively suggested that the sediments dated from the Ipswichian Interglacial, pollen zone IIb (Hollin 1971; 1977).

It is uncertain when excavation of the small Esso Pit was undertaken, as no published descriptions have been found. However, a small excavation was undertaken there under the auspices of the Geological Conservation Review in 1986 (Bridgland 1994). This revealed deposits comparable to those in Botany Pit and yielded several Palaeolithic artefacts, although no faunal remains were recovered (Bridgland *ibid*).

In 1993, a series of trial trenches were excavated by the Field Archaeology Group of Essex County Council on the site of a proposed warehouse development on the west side of Stonehouse Lane, Purfleet (TQ 570585). Vertebrate remains and lithic artefacts were recovered during the course of these excavations (Bridgland and Allen 1994; Bridgland *et al* 1995b).

Between September 27th-30th 1995, two sections were cut by hand by the author in the north-east corner of Greenlands Pit, Purfleet, prior to a visit by the Quaternary Research Association on October 14th 1995. The location of the sections is shown in Figures 5.3 and 5.4. Although previous workers, including Wymer (1968, 1985), Hollin (1971, 1977) and Palmer (1975), had assigned Purfleet to the Ipswichian interglacial, the recent publication of the Purfleet interglacial deposits as Stage 9 in age by Bridgland (1994) suggested that the site might be considerably older than previously accepted. Bridgland's interpretation was however contested by Gibbard (1994), who continued to regard the deposits as Ipswichian. The primary purpose of the author's excavations was therefore to collect a mammalian assemblage from a sound stratigraphic context at Purfleet and then to test each hypothesis. It was hoped that sufficient material would be collected in order for a full-scale comparison to be made with sites such as Hoxne (4.1) and Swanscombe (4.2), considered in the present study to be both of OIS 11 age) and to establish a 'type assemblage' for OIS 9, should Bridgland's correlation be borne out by the mammalian biostratigraphic evidence. Following on from this, it was anticipated that excavation of the Purfleet site would provide an excellent opportunity for testing, in a much more wide-ranging way, the four-interglacial scheme proposed by Bridgland (1994) and the applicability of aminostratigraphy to that scheme.

It was decided to site the new sections in the hope of locating the feather edge of the terrace formation, thereby maximising the potential for exposing *in situ* Palaeolithic occupation areas at the former river margin. Section 1 was abandoned when it bottomed out into chalky solifluction deposits 2.20m below the surface and Section 2 (TQ 56877885) then became the main focus of attention. Despite the somewhat precarious position of the excavation above a sheer drop to the quarry floor, a 4.5 m deep by 1m wide section was cut, exposing a sequence of bedded gravels, silts and sands stratified above an orange sand, containing abundant molluscan remains. Preliminary investigation of the shell bed revealed it to be equally rich in fossil vertebrate remains, including fish, herpetiles and mammals. Of particular significance was the discovery of a first phalanx of macaque monkey (*Macaca sylvanus*) (Figure 5.8), together with white-toothed shrew (*Crocidura* sp.), since both species are rare in the British Pleistocene record. Two worked flint flakes and a core were also recovered from the gravels overlying the shell bed. On the strength of these findings, a four month programme of further research was carried out at the site by the author in 1996.

The 1996 excavations enlarged Section 2 to a width of 4m and exposed the entire geological sequence down to the Chalk bedrock. In order to gain better access to the working face, a ramp was built up from the floor of the pit against the chalk face and approximately 1.5m of overburden was then removed by mechanical excavator. A 4x3m grid was set up in the trench and area excavation of the fluviatile sediments was then undertaken by hand. At the same time, clearing began of a new face (Section 3), immediately to the east of Section 2. This led to the fortuitous discovery of the channel margin, thereby confirming that the excavations were right on the bank of the former Thames. In the final stages of the excavation, the ramp in front of Section 2 was removed and further machining undertaken to expose the lowermost part of the geological sequence down to the Chalk.

In addition to the larger mammalian remains recovered during excavation by hand of the fossiliferous shell bed, 150 bulk samples (140 weighing approximately 20 kg each, 10 smaller bags from a column sample) were removed from the shell bed. Samples were wet-sieved, using a 0.5 mm mesh size and the dried residues then scanned for faunal remains and microdebitage under a low-power microscope. Thirty-four bulk samples (515.4 kg) were processed for the purposes of the present study and a preliminary species list is given below.

5.1.3. Geological background and provenance of mammalian remains

The geological interest of the Purfleet Chalk Pits lies in the occurrence there of Pleistocene fluviatile sediments, overlying the Chalk. The Pleistocene deposits are banked against the northern flank of the Purfleet Anticline, an east-west trending structure that causes the Upper Chalk to outcrop in a ridge between Purfleet and Grays. The area to the north of this Chalk ridge is now drained by the Mar Dyke, a westward-flowing tributary that joins the Thames at Purfleet, and which dissects the Pleistocene deposits on the northern side of the anticline. This has led to speculation in the past that the Purfleet deposits form a terrace of the Mar Dyke, rather than the Thames (Dewey *et al.* 1924; Wymer 1968, 1985; Palmer 1975). Furthermore, studies of bedding structures within the gravels revealed evidence for deposition by currents flowing towards the west and south-west, clearly contrary to the present-day direction of flow of the Thames (Palmer 1975; Podmore 1976). It was therefore concluded that the deposits were in fact laid down by the tributary Mar Dyke stream during the Ipswichian Interglacial and not by the main river Thames (Wymer 1968, 1985, Palmer 1975, Gibbard 1995b).

However, recent reconstructions of Lower Thames palaeodrainage do not support this view, and the Purfleet sediments are now considered to occupy an abandoned loop of the former River Thames and to be part of the Lynch Hill/Corbets Tey Formation (Bridgland 1988, 1994; Gibbard, in Gibbard *et al.* 1988). The Purfleet deposits are aggraded up to *c.* 15m O.D. and thus form part of the middle terrace of the Thames, occupying an intermediate position between the high terrace deposits of Swanscombe (4.2) and the lower middle terrace deposits of Aveley (6.1) (Figure 2.8). A wide-ranging study of the Pleistocene deposits by Bridgland (1988, 1994) has indicated that during the late Middle Pleistocene, the Thames occupied a more sinuous course across the area now drained by the Mar Dyke. It flowed eastwards from London to Ockendon, where it curved to the south-west. Flowing towards the south-west or west-south-west, it then passed through Stifford to the Purfleet area, where it turned once more towards the east (Figure 5.5). This reconstruction explains why the Corbets Tey Gravel between Ockendon and Purfleet occupies the Mar Dyke valley and why it is banked against the north side of the Purfleet Anticline (Bridgland 1994).

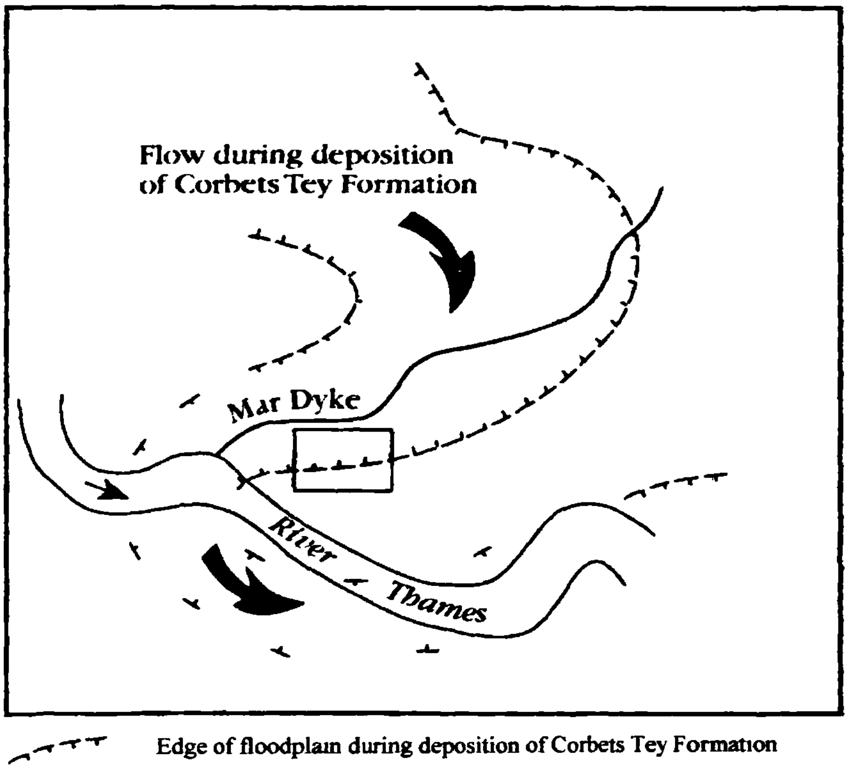


Figure 5.5 Diagram of the direction of flow of the Thames during deposition of the Corbets Tey Formation. Boxed area refers to area shown in Figure 5.4 (from Bridgland 1994).

Following deposition of the Corbets Tey Gravel, the Ockendon-Stifford loop was cut off by the river. The next terrace in the sequence, the Mucking Formation, follows the modern, shorter route of the river, passing to the west of Aveley. The Corbets Tey Formation is so well preserved in this abandoned section because the loop was never re-occupied by the Thames in later times. It is also apparent that the Mar Dyke probably formed in this part of the valley, following its abandonment by the Thames. Upstream of the Corbets Tey Gravel outcrop, the Mar Dyke is entirely devoid of gravel. There is therefore nothing to indicate that this stream is of sufficient antiquity to have deposited any part of the Purfleet sequence, nor that it ever laid down substantial pre-Holocene sediments (Bridgland 1994).

The earliest geological descriptions are from Botany Pit and record sands and current-bedded gravels, banked against Chalk, which were observed to pass laterally into 'Coombe rock' in the southern part of the pit (Wymer 1968). Sections in Greenlands Pit were also described by Snelling (1975), who recorded over 7.5m of Pleistocene deposits overlying Chalk and Chalk rubble in the north face. Snelling (*ibid*) noted approximately 0.5m of basal gravel above the Coombe rock, this in turn overlain by laminated shelly clays and sands and finally by alternating gravels and clays. Later observations of the sections in Greenlands and in the adjacent Bluelands Pit were made by Palmer (1975), Hollin (1971, 1977), Lonsdale (1978) and Wymer (1985). These descriptions broadly confirm the sequence described by Snelling (1975), although Hollin (1971, 1977) noted that the main shell-bearing bed occupied a channel cut into clayey, laminated deposits. Hollin (1971) considered these laminated beds to be of tidal origin, related to a sea level of 6m or higher early in the Last Interglacial, following an Antarctic ice surge.

The following description is of the geological sequence in Section 2 of the author's 1996 excavation in Greenland's Pit (see Figures 5.6 and 5.7).

A sequence of interglacial deposits sandwiched between two cold stage deposits was exposed. Chalk bedrock is at the base of the sequence at approximately 7 m O.D., rising to 20m towards the south-east. The lowest part of the Pleistocene sequence consists of 1m of chalky 'Coombe Rock' deposits containing seams of silts and laminated sands, overlying solid Chalk bedrock. These are interpreted as solifluction deposits, indicating mass downslope movement of mobilised chalk, during a cold stage prior to the main interglacial. Clast fabric analysis of the 'Coombe Rock' indicates movement down the slope in a WNW/NW direction (P. Allen pers. comm.). The 'Coombe Rock' is overlain by a fining-upward sequence of gravels ('Basal Gravel') with occasional large flint nodules at the base. Above this layer are interglacial laminated grey silty clays, bisected by a thin band of grey and orange sands, containing densely-packed shells. The top of the clay is oxidised and is immediately overlain by the main shell bed, comprising of bedded orange sands with extremely abundant molluscan remains.

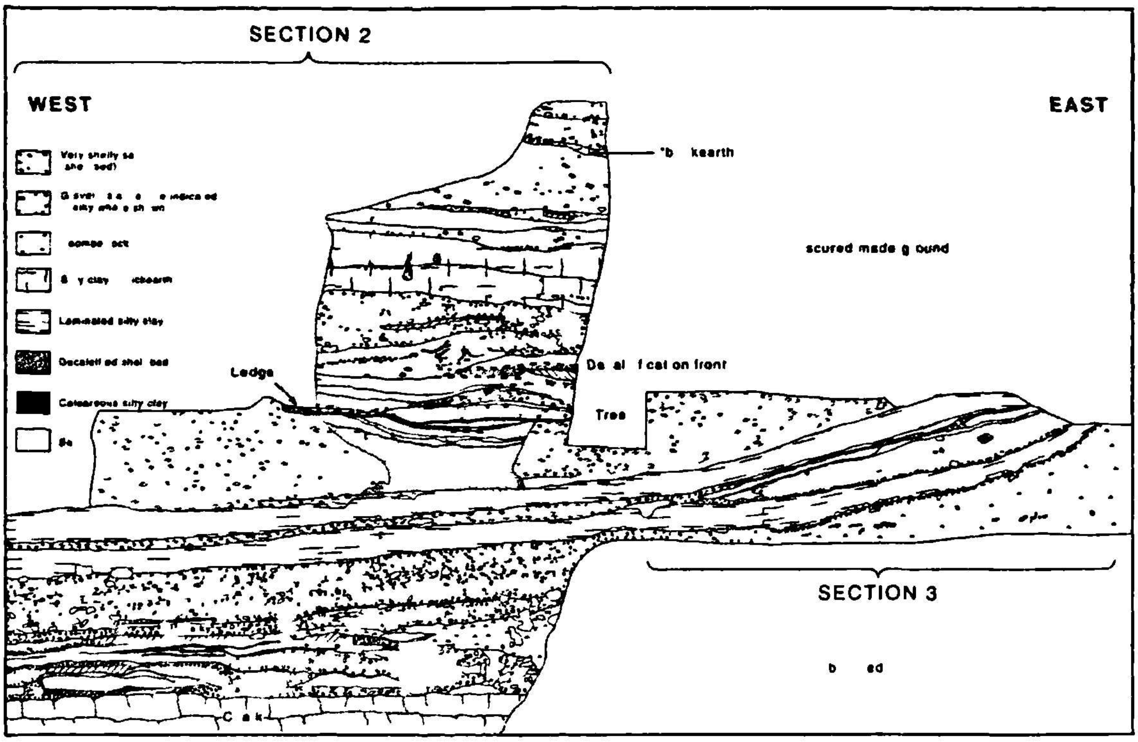


Figure 5.6 The geological sequence in Sections 2 and 3, Greenlands Pit, Purfleet (D.R. Bridgland/ University of Durham Geography Department Cartography Unit).

Figure 5.7 Sections 2 and 3, Greenlands Pit, Purfleet, showing the edge of the channel.

The shells are virtually intact (indicating deposition in relatively slow-flowing waters) but show no preferred orientation. Many of the freshwater bivalves are still articulated. Well-preserved *in situ* mammalian remains were recovered from the shell bed during the area excavation. Subsequent sieving of the shell bed for small vertebrate remains has shown that remains are dispersed throughout its depth, although the greatest concentrations are apparently in the top 20cm. Decalcified pipes were encountered in the eastern part of the shell bed.

The shell bed is overlain by a thin grey clayey-silt, above which occasional patches of banded grey and orange sands are present. These probably represent decalcified parts of the shell bed. Bones and antler were found in these sands but were in very poor and fragmentary condition. Flecks and small chunks of charcoal were also present. Above the sands are horizontally-bedded, variable gravels (here termed the 'Middle Gravel'). A layer of flint cobbles within these gravels (11.55-11.45 m O.D.) proved to be the source of a large number of palaeoliths. A total of 79 deliberately-worked flint artefacts was recovered during the excavation. The majority of these were located in or above the concentration of flint cobbles in the Middle Gravel, although occasional pieces were found in other parts of this unit, from the underlying banded sands and from the top of the shell bed. One flake was retrieved from the gravels underlying the laminated silty clays, near the base of the sequence. The majority of the finds are flakes, although thinning flakes, spalls and cores were also recovered. Of particular note is a biface (handaxe) from the upper part of the implementiferous gravels, above the main concentration of artefacts. No Levallois material was recovered, although this may be a consequence of the very limited area excavated by hand. The general condition of the pieces is fresh, although the biface shows signs of rolling and abrasion. Recording of the artefacts was carried out in three dimensions, thus permitting eventual refitting.

A brown clayey silt with pebbles overlies the Middle Gravel and is, in turn, overlain by a dark orange-brown indurated sand and a loose yellow-orange sand which shows signs of cross-bedding. The top of the sequence is marked by a return to horizontally-bedded gravels ('Upper Gravel'), indicating renewed fluvial activity and the onset of colder climatic conditions. Palaeocurrent analyses of these deposits at Botany Pit reveal that the river continued to flow in a north-westerly direction at this time (Podmore 1976).

In Section 3, the very edge of the main Pleistocene river channel has been exposed (see Figures 5.6 and 5.7). The same sequence of deposits as seen in the adjacent Trench 2, up to and including the main shell bed, is visible. No archaeological material was recovered from this section.

5.1.4. Palaeontology

The following species list has been compiled from material collected during the author's 1996 excavations at Greenlands Pit (to be deposited in the Natural History Museum, London). The list must be regarded as provisional pending completion of sieving but 14 mammal taxa have been identified to date, which substantially exceeds any previously published records and includes new records of *Macaca sylvanus*, cf. *Crocuta crocuta* (on the basis of a coprolite), *Cervus elaphus*, *Capreolus capreolus* and a large bovid. To the list have been added additional records of *Castor fiber* and *Palaeoloxodon antiquus*, collected from shell bed exposures in the 1960s by J. Hesketh (pers. comm.) and records of bat (indeterminate genus and species) and *Equus ferus*, collected in 1993 by Essex County Council's Field Archaeology Group from equivalent shell bed deposits in Stonehouse Lane, Purfleet, adjacent to Greenlands Pit (Bridgland and Allen 1994). The presence of *Homo* at the site is attested to by the abundance of flint artefacts. A second species list records mammalian remains collected in the 1960s by A.J. Snelling from the lateral equivalent of the Greenlands 'Upper Gravel' in Botany Pit, now housed in the Natural History Museum, London.

Species List (Mammalia) from Greenlands Pit, Purfleet, Essex

Insectivora
Sorex sp., shrew
Neomys sp., water shrew
Crocidura cf. *leucodon* Hermann, bicoloured white-toothed shrew
Chiroptera sp., indet. bat†
Primates
Macaca sylvanus L., macaque monkey
Homo sp., indet. hominid (artefacts)
Rodentia

Castor fiber L., European beaver*

Clethrionomys glareolus (Schreber), bank vole

Arvicola terrestris cantiana (Hinton), water vole (primitive morphotype)

Microtus agrestis (L.) or *M. arvalis* (Pallas), field or common vole

Apodemus sylvaticus (L.), wood mouse

Carnivora

cf. *Crocuta crocuta* Erxleben, spotted hyaena

Proboscidea

Palaeoloxodon antiquus (Falconer and Cautley), straight-tusked elephant†

Elephantidae sp., indeterminate elephant

Perissodactyla

Equus ferus Boddaert, horse†

Artiodactyla

Dama dama (L.), fallow deer

Cervus elaphus L., red deer

Capreolus capreolus (L.), roe deer

Bovidae sp., indet. large bovid (aurochs (*Bos*) or bison (*Bison*))

† collected by Essex County Council, Stonehouse Lane

* J. Hesketh collection

Species list (Mammalia) from Botany Pit, Purfleet (collected by A.J. Snelling)

Primates

Homo sp., indet. hominid (artefacts)

Perissodactyla

Equus ferus Boddaert, horse

Artiodactyla

Cervus elaphus L., red deer

Bovidae sp., indet. large bovid (aurochs (*Bos*) or bison (*Bison*))

5.1.5. Palaeoenvironmental and palaeoclimatic interpretation

As stated above, Hollin (1971) considered the laminated silty clay beds to be of probable tidal origin. However, sampling during the 1996 excavations for dinoflagellates and brackish-water ostracods revealed that both were apparently absent. This suggests that the fluvial environment did not have a sufficiently strong marine input at the time of deposition of these beds (S. Hall pers. comm.) and thus argues against a tidal origin for the deposits. *Candona* sp. and other freshwater ostracods have however been found within the laminated beds (Robinson, in Hollin 1971). A column sample for pollen analysis was taken from the laminated beds during the 1996 excavations. Preliminary results reveal that preservation is very poor, with only *Picea*, *Fraxinus* and grasses represented (J.J. Blackford pers. comm.). This reflects the results of Bridgland *et al.* (1995b) who found the sequence to be effectively non-polliniferous or at least unsuitable for the application of palynology. Very few of the samples were found to contain pollen and in those that did, abundances were far too low for acceptable counting (*i.e.* over 300 grains). Preservation was also described as being poor and the assemblages appear strongly distorted by an over-representation of Coniferales, due to the preferential deposition of these grains in wave-affected environments, such as estuaries, because of their greater than average buoyancy.

The mammalian assemblage from the shell bed reflects fully interglacial conditions. The small mammals are indicative of a range of habitats, including woodland, grassland and riparian environments, whilst the larger mammals, in particular macaque monkey (*Macaca sylvanus*) (Figure 5.8), beaver (*Castor fiber*), fallow deer (*Dama dama*) and roe deer (*Capreolus capreolus*) (Figure 5.9), confirm the proximity of deciduous or mixed woodland. The proximity of a body of slow-flowing water is attested to by the presence of *C. fiber*, water shrew (*Neomys* sp.) and water vole (*Arvicola cantiana*). White-toothed shrews (*Crocidura* spp.) have a predominantly southern European distribution at the present day and their presence in the deposits may therefore indicate slightly warmer climatic conditions. This is supported by the presence of *D dama* and straight-tusked elephant (*Palaeoloxodon antiquus*), both of which have been restricted to interglacial occurrences during the Pleistocene.

Figure 5.8 First phalanx of *Macaca sylvanus* (M55044, N.H.M.L.) from the author's excavations, Greenlands Pit, Purfleet (anterior view, scale in mm).

Remains of fish were also recovered from the shell bed during the 1996 excavations. These include pike (*Esox lucius*), three-spined stickleback (*Gasterosteus aculeatus*) and Cyprinids, such as tench (*Tinca tinca*), roach (*Rutilus rutilus*), rudd (*Scardinius erythropthalmus*), and perch (*Perca fluviatilis*). Fish scales have survived intact, thereby indicating a gentle depositional regime. The Cyprinids reflect the presence of still or slow-flowing lowland rivers and require summer water temperatures of at least 18° C for spawning, while the pike spawns in winter in water of not less than 5° C (Wheeler 1969). Reptile and amphibian remains were also recovered from the shell bed during the 1996 excavations and are currently being analysed. Preliminary results reveal the presence of frogs and grass snake (*Natrix natrix*), the latter indicative of damp terrestrial habitats with ample ground cover (Holman *et al.* 1990).

Ostracods are abundant in the shell bed and are dominated by *Cyprideis torosa*. Although this species is a brackish water indicator, the form found at Purfleet is an exceptionally noded one, thereby indicating that this species was living under conditions of ecological stress at the very limit of its freshwater tolerance (J Whittaker pers.

comm.). It is therefore concluded that the deposits at Purfleet represent the furthest point upriver that a brackish influence can be discerned. Analysis by D.H. Keen of molluscan remains from the shell bed, collected during the 1996 excavations, show that the assemblage is dominated by aquatic species, the most numerous being those that live in slowly-moving, large rivers (Unionidae, *Belgrandia marginata*, *Bithynia tentaculata*, *Pisidium amnicum*, *P. moitessieranum*, *P. henslowanum*, *Acroloxus lacustris* and *Corbicula fluminalis*). Species of more rapidly-moving waters, principally *Ancylus fluviatilis*, are well-represented but in smaller numbers than those of quieter conditions. Backwater species and species requiring abundant aquatic vegetation are very limited in numbers, suggesting that the assemblage was laid down in a channel too deep for much plant growth and too large for the influence of environments aside from the main channel to contribute much material (D.H. Keen pers. comm.). Preece (1988) suggests that the presence of *Margaritifera auricularia* in the Purfleet deposits indicates water depths of at least 5m for the deposition of the Greenlands sequence.

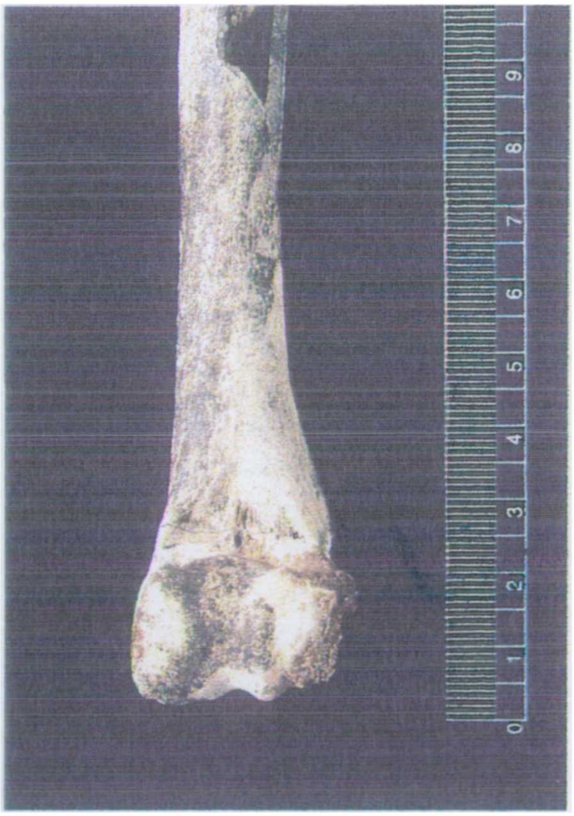


Figure 5.9 Distal left humerus of *Capreolus capreolus* from the author's excavations, Greenlands Pit, Purfleet (anterior view).

Despite the occurrence of numerous specimens of *C. torosa*, there is no indication from the Mollusca of any degree of salinity. Even species indicative of 2-3‰ salinities are apparently absent, thereby suggesting that saline influences were minimal. Preece (1995) however records the extinct hydrobiid and thus inferred brackish indicator species '*Paladilhia radigueli*' from Greenlands. The terrestrial taxa are diverse in number of species, although no one taxon is represented by more than two individuals. Marsh or swamp close to the river channel is indicated by Succineidae, *Carychium minimum* and *Vallonia pulchella* and grassland habitats by *Pupilla muscorum* and *Vallonia costata*. The majority of the remaining species indicate shaded habitats ranging from scrub (*Aegopinella nitidula* and *Nesovitrea hammonis*) to woodland (Clausiliidae, *Discus* spp. and *Helicodonta obvoluta* (D.H. Keen pers. comm.). The molluscan assemblage is strongly indicative of a fully interglacial environment, based upon the presence of thermophiles such as *C. fluminalis* and *B. marginata*, which today have modern distributions to the south and east of the British Isles.

Mammalian remains collected from the lateral equivalent of the Greenlands 'Upper Gravel' at Botany Pit by A.J. Snelling consist of horse (*Equus ferus*) (1 specimen), red deer (*Cervus elaphus*) (1 specimen) and large bovids (3 specimens). The gravel is considered to have been deposited under cooling climatic conditions and the mammalian assemblage (although very limited) is at least consistent with more open conditions. No woodland indicators are present.

5.1.6. Biostratigraphy and correlation

The complex site of Purfleet is of particular importance in the Pleistocene record of the Thames and the age of the deposits has been the subject of considerable controversy (Bridgland 1994). Snelling (1975) concluded that the interglacial deposits at Greenlands Pit were of Hoxnian age on the basis of the presence of *Valvata piscinalis* forma *antiqua*, a species unknown from post-Hoxnian sediments (Castell, in Snelling 1975) (but now considered to be of questionable biostratigraphic significance - R.C. Preece pers. comm.). However, the presence of proto-Levallois artefacts in the gravel at Botany Pit (the lateral equivalent of the Greenlands 'Upper Gravel') led him to suggest that the upper, post-interglacial part of the Greenlands sequence was of post-Hoxnian age. Palmer (1975) also supported a correlation with the Hoxnian, on the basis of comparison of the archaeological material from Purfleet with that from Middle Gravel at Swanscombe (4.2). In a reappraisal of Palmer's findings, Wymer (1985) placed the archaeological assemblages from Purfleet into stratigraphic order, with an Acheulean industry in the interglacial beds, overlain by a Levallois industry in the gravel. He therefore also concluded that the Levallois material at Purfleet post-dated the main interglacial.

An Ipswichian (Last) Interglacial age for Purfleet was favoured by Hollin (1971, 1977) on the basis of palynological evidence, a correlation supported by Gibbard (in Gibbard *et al.* 1988; Gibbard 1994, 1995b), who views the Purfleet deposits as part of a complex Ipswichian temperate stage with a marine transgression during pollen zone IIb .

The picture has been complicated still further by very high amino acid ratios on shells from Purfleet in the order of 0.34 (± 0.24) on *Bithynia* and 0.38 (± 0.07) on *Corbicula* (Bowen *et al.* 1989), which would suggest that the deposits are of Cromerian age, *i.e.* substantially older than Swanscombe (4.2), a position which clearly contradicts both the stratigraphic and mammalian biostratigraphic evidence. It is therefore considered that such anomalous ratios might result from heating, a process which is known to accelerate the epimerisation process. This may have occurred during laboratory treatment, or from natural processes following deposition of the shelly sand but before complete burial (Bridgland and Allen 1994). New samples for amino acid analysis were collected during the 1996 excavations, although the results are not yet available.

The potential significance of Purfleet as a site where an additional, previously-unrecognised interglacial might be represented was first proposed by Allen (1977), who considered that the height of the terrace deposits here and certain features of their molluscan fauna precluded correlation with either of the interglacials known at that time, the Hoxnian or the Ipswichian. The revised stratigraphical scheme for the Thames terrace sequence of Bridgland (1994) strongly advocates correlation of the interglacial deposits contained within the Lynch Hill/Corbets Tey Formation with Stage 9, the second post-Anglian interglacial (Bridgland 1994). This implies that differences should be apparent in the mammalian assemblage from Purfleet when compared to older sites in the Lower Thames valley, such as Swanscombe (4.2) and younger sites such as

Aveley (6.1) and Trafalgar Square, considered to be of Stage 7 and sub-Stage 5e ages respectively by Bridgland (1994).

Mammalian studies

A full report on the mammalian biostratigraphy of the interglacial represented at Purfleet is currently in preparation. However, enough evidence has so far been accumulated to permit the identification of species of biostratigraphic importance at Purfleet and allows demonstration that the Purfleet interglacial cannot be correlated with either the Hoxnian, Stage 7 or Last Interglacials.

The mammalian assemblage from Purfleet differs from that of the immediately preceding Hoxnian Interglacial (Stage 11), as represented by Swanscombe for example, in the absence of four small mammal species of biostratigraphic significance: the extinct small mole *Talpa minor*, the rabbit *Oryctolagus cuniculus*, the extinct giant beaver *Trogontherium cuvieri* and the European pine vole *Microtus* (*Terricola*) *subterraneus*. These species, which may be regarded as elements of the pre-Anglian mammal fauna, apparently made their last appearance in Britain during the Hoxnian and have not been recovered from any later Pleistocene site. Although their absence at Purfleet constitutes negative evidence, the extensive sieving carried out has not yielded a single specimen of any of the above species, although quantities of remains of other small mammal species were recovered. Since the environment and climate at Purfleet appear to have been similar to that described at Swanscombe (4.2) on the opposite side of the river, the presence of at least one of the above species would be expected at Purfleet if the site were also of Hoxnian age. The Purfleet mammalian assemblage is also differentiated from that of the Hoxnian Interglacial by the presence of white-toothed shrew (*Crocidura* cf. *leucodon*), which makes its first appearance in Britain during this interglacial, and by the presence of spotted hyaena (*Crocuta crocuta*) (identified at Greenlands Pit on the basis of a coprolite, Figure 5.10), which is unknown from any Hoxnian site.

Figure 5.10 Coprolite of cf. *Crocuta crocuta* from the author's excavations, Greenlands Pit, Purfleet (scale in mm).

The mammalian biostratigraphic evidence also argues against correlation of the Purfleet interglacial with Stage 7 sites, such as Aveley (Bridgland 1994) (6.1), on the basis of the presence of macaque monkey (*Macaca sylvanus*) and the primitive morphotype of water vole (*Arvicola terrestris cantiana*). Neither of these taxa has been recovered from deposits of Stage 7 age or younger. Preliminary analysis suggests that the *A. t. cantiana* from Purfleet is of a slightly more advanced form than that from Hoxnian Interglacial sites. Although bulk sieving is expected to yield further examples of first lower molars, the ancestral '*Mimomys*' fold has not been observed in any specimen so far. Although *Crocidura* is present in association with *P. antiquus* in the lower clays at the Stage 7 site of Aveley, it is immediately overlain by a *Mammuthus-Equus* assemblage typical of the later part of the OIS 7 interglacial, as outlined in Chapter 2. The mammals from Purfleet bear no resemblance to the *Mammuthus-Equus* group and contain other species already mentioned, such as *M. sylvanus*, which have never been recovered from any British site of Stage 7 or Substage 5e age. The presence of *Crocidura* at Aveley more probably reflects an early woodland period during the Stage 7 interglacial (6.1) as opposed to any age-equivalence with Purfleet and indeed, this is paralleled at other sites, such as Itteringham in Norfolk (6.3).

Correlation of the Purfleet interglacial deposits with the Last Interglacial (sub-Stage 5e), as proposed by Gibbard (1994, 1995b), is similarly implausible when one considers the mammalian evidence. *M. sylvanus*, *A. t. cantiana* and *C.* cf. *leucodon* (all recorded from Purfleet) are absent from the British Last Interglacial. Furthermore, the Last Interglacial in the British Isles is characterised by an apparent absence of humans and horses (*Equus ferus*) and by an abundance of hippopotamus (*Hippopotamus amphibius*) (Currant 1989b; Sutcliffe 1995a). In contrast, the wealth of Palaeolithic artefacts at Greenlands Pit would clearly confirm the presence of early hominids in Britain during the Purfleet interglacial, while the discovery of remains of horse in interglacial deposits of equivalent age at the adjacent site of Stonehouse Lane, Purfleet (Bridgland *et al.* 1995b) would also contradict a Last Interglacial age. Likewise, no *bona fide* hippopotamus fossils have ever been recovered from deposits of the Corbets Tey Formation (but see 5.2). On the available evidence, it therefore seems most unlikely that the deposits at Purfleet are of Last Interglacial age.

It is therefore concluded that on the basis of the evidence from mammalian biostratigraphy, the Purfleet deposits are younger than Swanscombe but older than Stage 7 or the Ipswichian. The only temperate stage in the oxygen isotope record that fits this gap is Stage 9. Having considered the Purfleet mammalian assemblage as a whole, it is now possible to determine certain key features which may be regarded as diagnostic of the mammalian fauna from the second post-Anglian interglacial in Britain, here correlated with OIS 9. These are:

- Absence of the Hoxnian indicator, *Talpa minor* (extinct small mole).
- Absence of the Hoxnian indicator, *Oryctolagus cuniculus* (rabbit).
- Absence of the Hoxnian indicator, *Trogontherium cuvieri* (extinct giant beaver). By Stage 9, this species has been entirely replaced by the modern European beaver *Castor fiber*.
- Absence of the Hoxnian indicator, *Microtus* (*Terricola*) *subterraneus* (European pine vole).

- Presence of a more advanced morphotype of water vole, *Arvicola terrestris cantiana*, with a greater number of specimens displaying undifferentiated enamel than the Hoxnian *A. t. cantiana.*
- Presence of *Crocidura* cf. *leucodon*, bicoloured white-toothed shrew
- Presence of *Crocuta crocuta*, spotted hyaena

None of the species listed should be taken in isolation as OIS 9 indicators, but in combination, these species form a consistent, coherent group that can be repeatedly observed at other British localities.

Malacological studies

Molluscan faunas from fluvial deposits in southern Britain have been divided into those with *B. marginata* only and those with *C. fluminalis* only (Keen 1990). The former group is associated with *Hippopotamus* and is generally agreed to be of Ipswichian (Last) Interglacial age (sub-Stage 5e), while sites with *C. fluminalis* as the only exotic element are associated with the mammoth-horse faunas, now generally correlated with OIS 7. Preece (1995) agrees that sites with *Belgrandia* only present are of sub-Stage 5e age but suggests that Stage 7 sites in the Lower Thames contain both *B. marginata* and *C. fluminalis.* However, Aveley (the nearest major Stage 7 site to Purfleet) (6.1) only has very small numbers of *Belgrandia* in comparison with numerous specimens of *Corbicula*, and even these are mostly abraded and possibly reworked to some degree (D H. Keen pers. comm.). This contrasts markedly with Purfleet, where *Belgrandia* is very abundant and would appear to suggest that Aveley and Purfleet are not contemporary but belong to different interglacials.

The abundant presence of the invasive coloniser *Corbicula* at Purfleet argues strongly against a Last Interglacial age for the site, since this species has never been found in direct, un-reworked association with the Last Interglacial *Hippopotamus* fauna at any site in Britain (Keen 1990; Preece 1995). Its presence at Purfleet and absence further upstream at the undisputed Ipswichian site at Trafalgar Square would be inexplicable if these two sites were of the same age. The absence of elements of the 'Rhenish Suite' of Mollusca at Purfleet also argues against correlation of the deposits with the Hoxnian Interglacial, since the similar fluviatile facies would be expected to yield the same fauna as Swanscombe (D.H. Keen pers. comm.) (4.2). Other potentially stratigraphically significant taxa in the Purfleet fauna are *Valvata piscinalis* forma *antiqua* and *Pisidium clessini*. The former was regarded by Castell (in Snelling, 1975) as a Hoxnian indicator, a conclusion not inconsistent with a Stage 9 age for Purfleet, since it is now apparent that Stages 11 and 9 often share particular faunal or floral elements. The latter seems to make its last appearance in sites now regarded as being of Stage 7 age, such as Aveley (6.1) (D.H. Keen pers. comm.) and Stutton, Suffolk (6.8) (Sparks and West 1963). Its presence at Purfleet, like that of *Corbicula fluminalis*, may indicate a pre-Ipswichian age.

It is therefore concluded that the molluscan evidence supports the Stage 9 correlation (D.H. Keen pers. comm.) proposed by the mammals.

Palynological studies

Hollin (1971, in Palmer 1975) tentatively attributes the laminated beds to the Ipswichian Interglacial, on the basis of a high percentage of *Pinus* and a low percentage of *Betula*. However, only 5 samples out of 28 yielded pollen and even in these, the pollen counts are extremely low. Given the reasons for the preferential representation of *Pinus* outlined above, any attribution of age on the basis of these results must be viewed with caution.

5.1.7. Discussion and conclusions

Most recently, the deposits at Purfleet have been attributed to the Corbets Tey Gravel Formation (Bridgland 1994), equivalent to the Lynch Hill Gravel Formation of the Middle Thames (the Lynch Hill Member of Gibbard, 1985) and to the Barling-Dammer Wick Gravel Formation of eastern Essex (Bridgland *et al.* 1993; Bridgland 1994).

The Hoxnian deposits at Swanscombe (4.2) in the higher Orsett Heath Gravel Formation are separated from the lower-level (and therefore younger) deposits at Purfleet by a period of cold (glacial or periglacial) conditions, which is represented at Swanscombe by sediments overlying the interglacial beds, at Purfleet by basal, pre-interglacial deposits and in the valley as a whole by the erosion event that caused the river to cut down to the level of the Corbets Tey Gravel. As stated above, the reinterpretation of the Lower Thames terrace sequence by Bridgland (1994) correlates the temperate, fossiliferous sediments within the Corbets Tey Formation with OIS 9 of the deep sea record, an *intra*-Saalian interglacial at around 300 000 years old and the second of four post-Anglian temperate stages. Consequently, the solifluction deposits and Basal Gravel in the Purfleet sequence are thought to represent the cold phase prior to the interglacial and to date from OIS 10, whilst the post-interglacial Upper Gravel is considered to date from OIS 8.

Mammalian biostratigraphic evidence from the Purfleet shell bed is consistent with a Stage 9 correlation. The Purfleet mammals form a distinctive group that is observable at other Early Middle Terrace localities (see later) and that cannot be correlated with assemblages from any earlier or later post-Anglian interglacial. This is based upon the absence of critical Hoxnian indicator species and the presence of white-toothed shrew (*C.* cf. *leucodon*) and spotted hyaena (*C. crocuta*). An upper age limit for the interglacial deposits is provided by the primitive morphotype of water vole (*A. t. cantiana*) and macaque monkey (*M. sylvanus*), which indicate a pre-Stage 7 age. The mammalian remains and flint artefacts from the lateral equivalent of the Greenlands Upper Gravel at Botany Pit therefore relate to the immediately post-interglacial period and may thus be correlated with the beginning of OIS 8, when conditions became cooler and more open. The Purfleet site has thus been critical in testing the recently-proposed hypothesis that dates the first use of the Levallois technique to the cold period immediately following the Purfleet interglacial, as represented by the highest parts of the Purfleet sequence (Bridgland 1994).

A sufficient body of evidence now exists to dismiss correlation of the Purfleet deposits with the Ipswichian (Last) Interglacial. This is based not only upon the topographical position of the Purfleet deposits within the revised stratigraphical scheme for the Thames terraces (Bridgland 1994) but also upon sound biostratigraphical evidence, in particular the presence at Purfleet of humans, *E. ferus* and *C. fluminalis*. In addition, the status of the Purfleet deposits as being of Thames, as opposed to Mar Dyke, origin is now well-established, given the new evidence for the former course of the river (Bridgland 1994). The molluscan remains also support a Thames origin, since they indicate the presence of a large river up to 5m deep, clearly a far more imposing body of water than the Mar Dyke at any stage in the past.

Correlation of the Purfleet interglacial deposits with OIS 9, an *intra*-Saalian interglacial as yet unnamed in the British sequence and unrecognised in the palynological record, has been proposed by Bridgland (1994) and is here corroborated by the presence of a unique fauna which post-dates the Hoxnian Interglacial (Stage 11) and pre-dates the Stage 7 interglacial.

5.2. GRAYS THURROCK, ESSEX (TQ 622781)

5.2.1. Location of the site

The palaeontological material in the Natural History Museum in London gives the recorded locality of the specimens as 'Grays Thurrock', abbreviated simply to 'Grays' in the majority of cases. Despite the existence of considerable literature concerning the deposits, there has often been confusion in the past regarding the origin of material (both palaeontological and archaeological) from sites within the modern Thurrock area since they have all collectively become known as 'Grays'. In fact, during the mid-nineteenth century, three distinct small villages existed in this part of southern Essex: West Thurrock to the west, Grays Thurrock in the centre and Little Thurrock to the east. Three pits at Grays Thurrock ('Western', 'Central' and 'Eastern'), lying just to the north of the road between Grays Thurrock and Little Thurrock and centred upon TQ 622781 made up the renowned 'Grays' brickfields, from which the faunal material studied here was recovered (Figure 5.11).

5.2.2. History of research

During the 19th century, the exploitation of large brickyards and the excavation of tramway cuttings in the chalk pits on the north bank of the Thames in the Grays district of southern Essex brought to light a remarkable series of deposits, yielding a variety of mammalian fossils in an excellent state of preservation.

As recorded by Morris (1836, 261) in the earliest account of the site, these deposits were about a quarter of a mile wide and extended east and west, filling up a valley between two ridges of irregular height; "that to the north being part of a long range of chalk hills, extending from Purfleet for seven or eight miles parallel to the river; and that to the south consisting of rubbly chalk with irregularly disposed flints, about 30ft. high..." The deposits are separated into a western half and an eastern half by a northward incut of Holocene alluvium just to the west of Grays Thurrock (Hinton and Kennard 1900). The majority of fossils were collected from the eastern brickyards where the "magnificent mammalian remains and the richly fossiliferous shell beds which made the name of Grays Thurrock famous were contained and exposed..." (Hinton and Kennard *ibid*, 344)

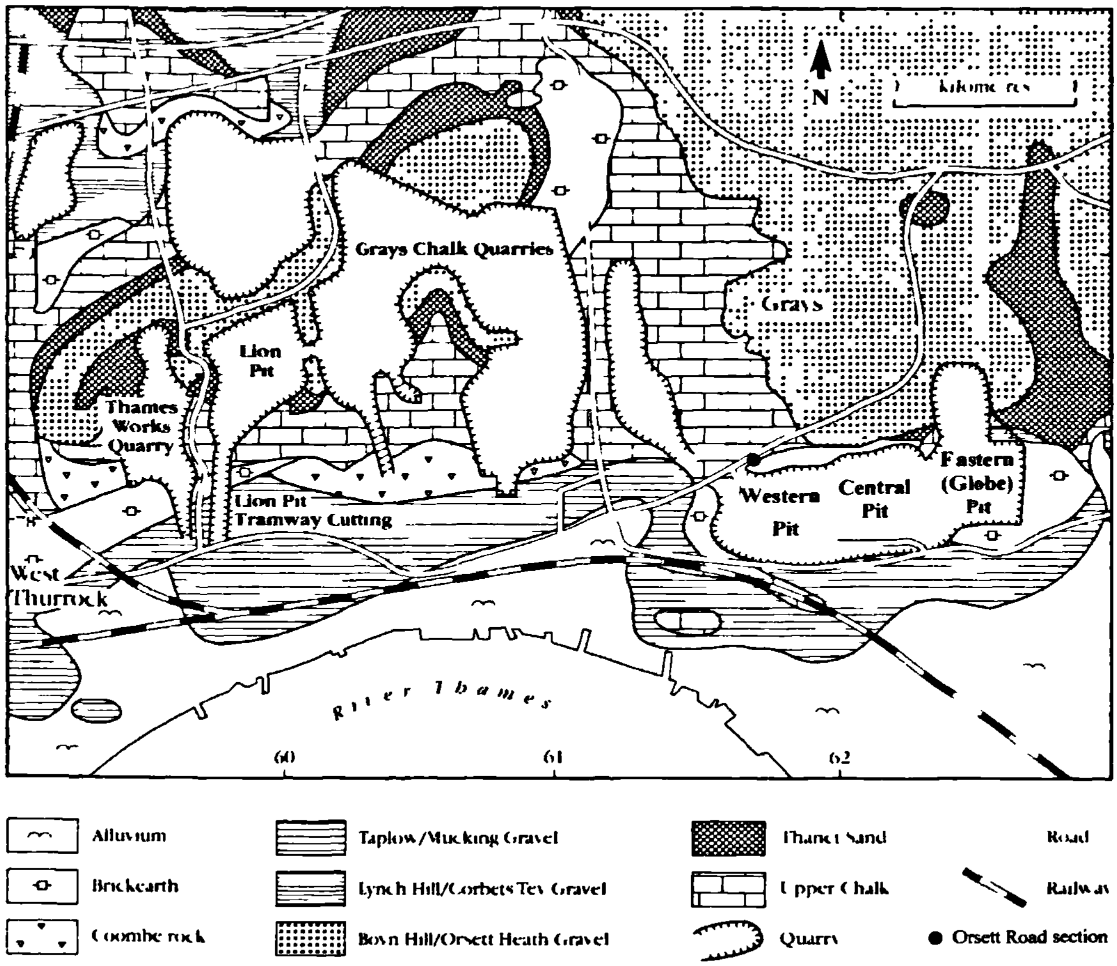


Figure 5.11 Map of the Thurrock area, showing the three Grays pits (modified from Bridgland 1994).

but even by the time of Whitaker's account in the Memoirs of the Geological Survey of 1889, the brickyards were already being described as "things of the past" (Whitaker 1889, 419). The majority of specimens held in the Natural History Museum (London) bear the name of W. Ball and were collected between 1845 and 1850. However, the quality of the mammalian remains was such that the Grays deposits were visited by the most celebrated antiquarians of the day and further specimens bear the names of Richard Owen, William Boyd-Dawkins, Hugh Falconer, John Brown of Stanway, R. Cotton and F.C.J. Spurrell. Studies of the elephant remains were carried out by Falconer (in Murchison 1868) and Adams (1877-81). The most recent material was recovered in 1900 by Hinton and Kennard from a section on the Orsett Road, Grays, which was by that time the only terrace remnant still visible. Almost all of the brickearth had long been removed for commercial purposes and very little of the deposits in the pits remains today.

Much confusion has arisen over the original locality of the 'Grays' mammal fauna. It is important to emphasise that the only material discussed here is that pertaining to the main brickfield of Grays Thurrock. The first mention of West Thurrock as a fossil mammal locality is by Abbott in 1890 and all the specimens under consideration here have acquisition dates prior to that year, with the exception of Hinton's collections from 1900, which are clearly marked from Orsett Road. Furthermore, the Geological Survey Sheet of 1861 for London shows the eastern Grays Thurrock and Little Thurrock brickfields in some detail but makes no mention of any workings at or near West Thurrock. The fossils in question labelled 'Grays' must therefore have come from the eastern brickfields and specifically from the pits in the village of Grays Thurrock. True Grays specimens display a uniformly fresh and distinctive preservation type. Furthermore, the discovery of butchery marks on almost all the faunal groups would seem to attest to their collective deposition and subsequent lack of disturbance.

5.2.3. Geological background and provenance of mammalian remains

Since the deposits at the site were simultaneously being worked in three different pits, it was possible to examine the stratigraphy over more than half a mile (Morris 1836).

The following sections were all observed and recorded by Morris (*ibid*):

Western pit (north side):

4. Loam and sand, 18ft (5.5m)
3. Ferruginous sand with angular flints and rounded chalk pebbles, 2ft (0.6m), containing numerous Mollusca (*Unio*, *Corbicula*, *Sphaerium*, *Viviparus*, *Valvata*, *Planorbis*, *Lymnaea*, *Ancylus*, *Helix*, *Pupa*, *Carychium* and *Bulimus*), fragments of bone, fish vertebra and a small tooth
2. Loam and sandy clay, 4ft (1.2m)
1. Chalk bedrock, 15ft (4.5m) below (information obtained from workmen)

The western pit yielded little in the way of faunal remains in comparison with the central pit. At the western edge of this pit is located the Orsett Road section from which various small mammal remains were recovered by Hinton and Kennard (Hinton and Kennard 1900; Hinton 1901) (see below).

Central pit:

8. Black mould, 1ft (0.3m)
7. Burnt brickearth, 2ft (0.6m)
6. Loam and reddish coloured sand with flints, the lower part waved and irregular, 5ft (1.8m)
5. Iron sand, red and yellow with horizontal patches of white, 12ft (3.6m)
4. Brown sandy clay, 10ft (3m)
3. Two beds of shells (containing the same species as in the western pit but with the addition of *Anodonta*), 2ft (0.6m)
2. Layer of lignite, reeds, leaves and blue clay with mica, 15ft (4.5m), the upper part containing abundant *Unio* and *Anodonta.*
1. Below this, a bed of gravel and sand, resting upon the 'Bullhead Bed' (a glauconite flint bed at the base of the Thanet Sand), directly on top of the chalk.

It was from the shell beds in this pit that numerous large mammal remains were recovered ("an almost entire skeleton of the elephant...remains of the hippopotamus; horns of the ox and deer; a canine tooth of the bear; and numerous other bones, more or less perfect" Morris 1836, 263). Falconer (1868), after visiting the site in 1845, records that mammalian remains were rarely found above the shell beds. He also noted that the nearly entire elephant skeleton was mostly destroyed during its excavation by the workmen, save for two last lower molars (one of which is preserved in the Natural History Museum as specimen 39370).

Eastern Pit:

The upper beds thin off, with the brown sandy clay coming to within 7ft (2.1m) of the surface. Further east, the beds completely disappear below the marsh. Like the western pit, this also yielded very little in the way of fauna.

Hinton and Kennard (1900) record the following section at Orsett Road (Figure 5.12):

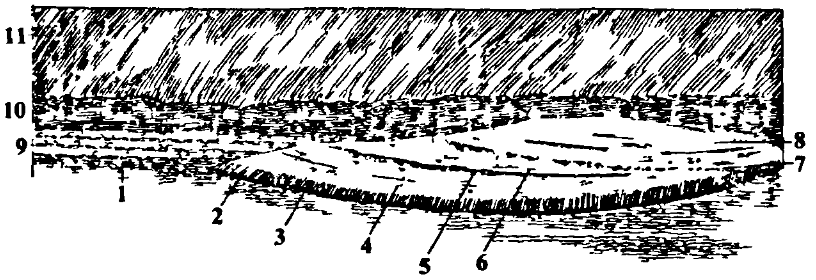


Figure 5.12 Orsett Road section, Grays (modified from Hinton and Kennard 1900).

11. Stiff brown loam, with many pebbles in the upper part, varying in thickness from 8-10ft (2.4-3m)

10. Finely-laminated blue, brown, yellow or mottled clays, containing a few shells, 3ft 6 inches (1.05m)

9. Laminated brown clay, 1ft 6 inches (0.45m)

8. Shell-beds, consisting of fine sand packed with fluviatile and terrestrial molluscs and many bones and teeth of small vertebrates, the whole interstratified with beds of gravel, varying in thickness from 0-2ft 6 inches (0-0.75m)

7. Thin seam of gravel, dipping southwards at an angle of 9°, 4 inches (0.1m)

6., 5. and 4. Shell and *Unio* beds, similar to Bed 8, 0-3 ft (0-0.9m)

3. Brown clay, 0-6 inches (0-0.15m)

2. Blue clay with shells and remains of mosses and other plants. The lower part of this bed contains much limonite, 0-9 inches (0-0.23m)

1. Finely-laminated fissile and mottled clays, containing bones of *Cervus*, *Bos* etc and shells of *Anodonta* and *Unio* in places. Race nodules frequently encountered. Seen to a depth of 12 ft (3.6m)

The upper surface of Bed 11 and the under surface of Bed 10 were observed to be polished and striated, thereby suggesting slipping between the two (Hinton and Kennard *ibid*).

The age of the deposits at Grays Thurrock has been the subject of much discussion and contention. The site itself has always been considered part of the Early Middle or

'Taplow' terrace of the Thames (Hinton and Kennard 1900), indeed Hinton (1926b) even defined Grays Thurrock as the type-locality of this terrace. Kennard (1916) and later Warren (1923a) recognised the existence of two palaeontologically and stratigraphically separate groups of deposits within the Grays area, observing that both occur at approximately the same level. Despite the potential confusion that this may have caused, Kennard (1916) was able to assign relative ages to the deposits of the Lower Thames, placing an older eastern Grays Thurrock brickearth before the Ilford brickearths of Essex (6.2) and finally those of Crayford and Erith in Kent (6.18). Within these latter, he placed a younger 'Grays' brickearth (now known to be that at West Thurrock) (6.4). The discovery of Clactonian artefacts in the Globe Pit at Little Thurrock to the east (King and Oakley 1936; Wymer 1957; Bridgland and Harding 1993) and of a Levallois industry at West Thurrock (Kennard in Dibley and Kennard 1916) further served as support for this argument. Nevertheless, following palynological work by West (1969) and Hollin (1971, 1977) (see below), the Grays deposits are even today still assigned to the Ipswichian (Last) interglacial by certain workers (for example Gibbard 1994, 1995b). With this in mind, Hollin further suggested that the Grays brickearth represents a tidal deposit reflecting estuarine aggradation to 14m O.D. in response to an Antarctic ice surge during the Ipswichian, a view which has received support from Gibbard (in Gibbard *et al.* 1988).

However, over the years a number of authors have held the view that Grays is not only older but substantially older than West Thurrock and is in fact closest in age to the deposits at Swanscombe and Clacton, traditionally assigned to the Hoxnian interglacial. This appears to stem from the work of Hinton, who considered the Early Middle terrace and the High terrace of the Thames to be close in time: "...we find that portions of the Middle Terrace deposits at Grays and Clacton are very much -I had almost said immeasurably- older than portions higher up the valley at Crayford and Erith" (Hinton 1926a, 336).

Although the celebrated fossiliferous Grays brickfields have long since disappeared, attention has focused in recent years on the neighbouring site of the Globe Pit, Little Thurrock (TQ 6251 7830) (Wymer 1957; Hart 1960; Snelling 1964; West 1969; Hollin 1977; Bridgland and Harding 1993). Wymer (1957) reported a thin remnant of sandy fluviatile gravel overlying a 'bench' of Thanet Sand at 15m O.D, from which 294 *in situ* artefacts (flakes and cores) were obtained in a highly concentrated area. No mammalian remains were ever recovered from the Globe Pit, the overlying fossiliferous Grays brickearth having been entirely quarried away in Wymer's sections. Later reports by Hart (1960) and West (1969) do however mention a shelly grey and brown sandy brickearth still present in patches above the artefact-rich gravel, although more recently, only a decalcified, feather-edge was recorded by Bridgland and Harding (1993). A further post-interglacial gravel unit was observed above the brickearth (Kennard 1916; Wymer 1985). Contrary to earlier impressions that the fluvial gravel was restricted to a 'bench' at 15m, Bridgland and Harding (1993) observed a single well-bedded *in situ* fluviatile aggradation to below 10m O.D.

The difference in height between the base of the aggradations at Grays-Little Thurrock and Swanscombe (at 23m O.D.) is a compelling argument against the two sites representing the same interglacial stage. The 1936 scheme of King and Oakley had attempted to incorporate Grays, Swanscombe and Clacton into the same stage by proposing a model of highly exaggerated incisional and aggradational phases. Their reconstruction was however founded upon typological analysis of the archaeological record at the three sites and also upon the belief that the mammalian fauna from Grays was the same age as that from Swanscombe.

Most recently, the deposits at Grays have been attributed to the Corbets Tey Gravel Formation (Bridgland 1994), equivalent to the Lynch Hill Gravel Formation of the Middle Thames (the Lynch Hill Member of Gibbard, 1985) and to the Barling-Dammer Wick Gravel Formation of eastern Essex (Bridgland *et al.* 1993, Bridgland 1994). As outlined in Chapter 2, the reinterpretation of the lower Thames terrace sequence by Bridgland (1994) correlates the temperate, fossiliferous sediments within the Corbets Tey Formation with OIS 9 of the deep sea record, an *intra*-Saalian interglacial at around 300 000 years old and the second of four post-Anglian temperate stages. Consequently, the lower artefact-rich gravel present at Little Thurrock is thought to represent the pre-interglacial aggradational phase of the Corbets Tey Formation and to date from OIS 10, whilst the post-interglacial upper gravel is considered to date from OIS 8.

5.2.4. Palaeontology

The Grays assemblage is in the unusual position of being one of the best-preserved Middle Pleistocene mammalian assemblages but at the same time, one of the least studied and until now, one of the most poorly-understood in terms of its age. The great renown of the Grays brickfields led to their mammalian remains becoming well-dispersed in museums throughout the country and the following species list has therefore been compiled from collections housed in the Natural History Museum in London, the Sedgwick Museum of Geology, Cambridge, Manchester Museum, Ipswich Museum, the British Geological Survey Museum in Keyworth, the University Museum, Oxford, the Yorkshire Museum, York and Dartford Museum. This is the first time that the Grays collection has been systematically analysed in its entirety. A total of 1579 specimens was examined during the present study and the presence of 27 mammalian species was confirmed. To this may be added *Homo*, for although no artefacts or human remains have ever been reported in association with the mammalian remains, butchery marks have been discovered on many of the large mammal bones (Figure 5.13).

Several specimens examined are considered to be of suspect provenance. These include a left third lower molar of *Mammuthus primigenius* (21681, N.H.M L.) and the associated right second and third lower molars of *Bos primigenius* (N.H.M.L., no registered number), the dark and pyritised conditions of which bears no resemblance to the uniformly fresh, pale brown preservation type of the rest of the Grays assemblage. A lower first or second incisor fragment of *Hippopotamus amphibius* (21653, N.H.M.L.) may also be of doubtful provenance. Several authors, including Wymer (1985) and Bridgland (1994) have been inclined to dismiss the record of this species from Grays, believing the provenance of the specimen to be the more recent site of West Thurrock (6.4), or the specimen to have been misidentified. However, the acquisition date of the specimen concerned shows that it was collected in 1844 at around the same time as the rest of the Grays assemblage and well before the opening of a pit at West Thurrock. Furthermore, the site at West Thurrock (6.4) is now believed to be of OIS 7 age (Bridgland 1994) and is therefore unlikely to contain *H. amphibius* in any event. The question of whether the *Hippopotamus* specimen is a genuine or an erroneous inclusion in the Grays assemblage is discussed below.

Figure 5.13 Associated right 3rd-5th metatarsals of *Ursus arctos*, showing cutmarks (21290 N.H.M.L.), Grays (anterior view).

Two reidentifications were made during the course of the present study: two axis vertebrae of *Sus scrofa*, (19834 and 18816, N.H.M.L.), previously identified as *Ursus arctos*. The majority of the rhinoceros material (which had previously only been identified to genus level) was assigned to species level. A further record of *Vulpes vulpes* was also established on the basis of a left tibia (36634b, N.H.M.L.).

Species List (Mammalia) from Grays, Essex

Insectivora
Sorex sp., indet. shrew
Neomys cf. *browni* Hinton, water shrew
Crocidura sp., indet. white-toothed shrew
Primates
Macaca sylvanus (L.), Barbary macaque
Homo sp., hominid (cutmarks on bones)

Rodentia

Castor fiber L., European beaver

Clethrionomys cf. *glareolus* (Schreber), bank vole

Arvicola terrestris cantiana (Hinton), extinct water vole (primitive morphology)

Microtus agrestis (L.), field vole

Microtus oeconomus (Pallas), northern vole

Microtus sp., indet. vole

Apodemus cf. *sylvaticus* (L.), wood mouse

Cetacea

Tursiops truncatus (Montagu), bottle-nosed dolphin

Carnivora

Canis lupus L., wolf

Vulpes vulpes L., red fox

Ursus arctos L., brown bear

Lutrinae sp., indet. otter

Crocuta crocuta Erxleben, spotted hyaena

Proboscidea

Palaeoloxodon antiquus Falconer and Cautley, straight-tusked elephant

Elephantidae sp., indet. elephant

Perissodactyla

Equus ferus Boddaert, horse

Stephanorhinus hemitoechus (Falconer), narrow-nosed rhinoceros

Stephanorhinus kirchbergensis (Jaeger), Merck's rhinoceros

Stephanorhinus sp. indet., rhinoceros

Artiodactyla

Sus scrofa L., wild boar

Megaloceros giganteus (Blumenbach), giant deer

Dama dama ssp. indet., fallow deer

Cervus elaphus L., red deer

Alces cf. *alces* L., elk

Capreolus capreolus (L.), roe deer

Cervidae sp. indet. deer

Bos primigenius Bojanus, aurochs

Bovidae sp., indet large bovid (*Bos* or *Bison*)

Table 5.1 below provides a breakdown of the species list into numbers of specimens per species, also expressed as a percentage of the total mammalian assemblage from the site. Minimum numbers of individuals have also been calculated.

Species	Number of specimens	Percentage of total assemblage (°o)	Minimum number of individuals (M.N.I.)
Insectivora			
Sorex sp.	7	0.44	4
N. cf. *browni*	9	0.56	5
Crocidura sp.	1	0.06	1
Primates			
M. sylvanus	1	0.06	1
Rodentia			
C. fiber	8	0.5	2
C. glareolus	30	1.89	6
A. t. cantiana	86	5.44	18
M. agrestis	77	4.87	40
M. oeconomus	1	0.06	1
Microtus sp.	331	20.96	36
A. sylvaticus	30	1.89	8
Cetacea			
T. truncatus	1	0.06	1
Carnivora			
C. lupus	6	0.37	2
V. vulpes	3	0.18	1
U. arctos	104	6.58	8
Lutrinae sp.	3	0.18	1
C. crocuta	8	0.5	1
Proboscidea			
P. antiquus	53	3.35	10 (5 juv., 5 adults)
Elephantidae sp.	12	0.75	3
Perissodactyla			
E. ferus	77	4.87	7
S. hemitoechus	49	3.1	3
S. kirchbergensis	119	7.53	11 (3 juv., 8 adults)
Stephanorhinus sp.	20	1.26	2
Artiodactyla			
S. scrofa	39	2.46	4
H. amphibius	1	0.06	1
M. giganteus	13	0.82	3 (1 juv., 2 adults)
D. dama ssp. Indet.	122	7.72	25 (3 juv., 22 adults)
C. elaphus	145	9.18	11 (1 juv., 10 adults)
A. cf. *alces*	1	0.06	1
C. capreolus	14	0.88	2
Cervidae sp.	12	0.75	3

cont'd... ...

Species	Number of specimens	Percentage of total assemblage (%)	Minimum number of individuals (M.N.I.)
B. primigenius	179	11.33	14 (1 juv., 3 adults)
Bovidae sp.	15	0 94	5 (3 juv., 2 adults)

Table 5.1 Breakdown of the mammalian species list from Grays, showing numbers of specimens per species, the percentage of the total assemblage per species and minimum numbers of individuals.

5.2.5. Palaeoenvironmental and palaeoclimatic interpretation

The most distinctive aspect of the Grays mammalian assemblage is the predominance of woodland species, such as *M. sylvanus* (Figure 3.8), *C. fiber*, *U. arctos*, *P. antiquus* (Figure 3.40), *S. scrofa* (Figure 3.48), *D. dama*, *A.* cf. *alces* (Figure 3.53) and *C. capreolus*. These clearly outnumber species requiring more open environments for grazing, such as *E. ferus*, *M. giganteus* and *B. primigenius*. The dominance of woodland over open grassland species is most obviously shown in a comparison of the rhinoceros material. Merck's rhinoceros (*S. kirchbergensis*) is by far the dominant species of rhinoceros (71.08% of the identified rhinoceros remains) (Figure 3.46a, b), with *S. hemitoechus* (Figure 3.45) making up the remainder. Since the rhinoceros remains include specimens from all age classes, this difference in abundance in the fossil record may be accepted as reflecting natural population sizes with some confidence.

The small mammals are indicative of a range of habitats, including woodland/shrubby (*Crocidura*, *C. glareolus* and *A. sylvaticus*), grassland (*Microtus* spp.) and riparian/aquatic environments (*N.* cf. *browni* and *A. t. cantiana*). The single specimen of dolphin (a vertebral centrum, 20274, N.H.M.L.) is thought to represent an individual that swam up the estuary and became stranded on the banks of the Thames. Carnivore gnaw marks are present on one side of the specimen (Figure 3.27). The presence of *Crocidura* sp., *D. dama* and *P. antiquus* suggest fully temperate environmental conditions, with a climate possibly slightly warmer than at present.

Hinton and Kennard (1900) record remains of waterbirds, including goose (*Anser cinereus*), swan (*Cygnus* sp.) and great cormorant (*Phalacrocorax carbo*), together with fish, including pike (*Esox lucius*), ruffe (*Gymnocephalus cernua*), dace (*Leuciscus leuciscus*), roach (*Rutilus rutilus*), rudd (*Scardinius erythropthalmus*) and possible eel (*Anguilla anguilla*) from the Orsett Road section. Dace, roach and rudd suggest the presence of still or slow-flowing water with summer water temperatures of at least 18 C for spawning, while the pike spawns in winter in water of not less than 5 C (Wheeler 1969). Orsett Road also yielded herpetile remains, including grass snake (*Natrix natrix*), indicative of damp terrestrial habitats with ample ground cover (Holman *et al.* 1990), common frog (*Rana temporaria*) and common toad (*Bufo bufo*), preferring damp and slightly drier conditions respectively (Arnold and Burton 1978).

Mollusca seen in collections of the British Geological Survey include *Corbicula fluminalis*, *Bithynia tentaculata*, *Lymnaea palustris* and *Pisidium amnicum*. These are considered indicative of similar fluviatile conditions to those at Purfleet, indicating a large, slow-moving river.

5.2.6. Biostratigraphy and correlation

As with Purfleet (5.1), the Grays deposits have been correlated with both the traditional Hoxnian and Ipswichian Interglacials, depending on whether terrace stratigraphy, palaeontology or palaeobotany have been given priority for relative dating. Aminostratigraphic studies on this group of upper Middle Terrace sites have also proved unsatisfactory. For example, correlation of the Grays-Little Thurrock sediments with Swanscombe (4.2) has been suggested by amino acid ratios on shells from early collections (Miller *et al.* 1979; Bowen *et al.* 1989). Both sets of authors consistently obtained D:L ratios of around 0.29 on *Corbicula fluminalis* and *Bithynia tentaculata* which would place Grays-Little Thurrock, together with Swanscombe, in Oxygen Isotope Stage 11. On stratigraphic grounds alone, this correlation appears to be unlikely since the two sites lie on completely separate terraces of the Thames. Furthermore, the high amino acid ratios of 0.38 from Purfleet and considerably lower ones of 0.26 from Belhus Park (Bowen *et al.* 1989) (5.4), both neighbouring sites on the Middle Terrace, would caution again acceptance of these correlations at face value. Such a spread of dates for three adjacent sites is completely inconsistent with any logical stratigraphic or biostratigraphic interpretation. As stated above, the most recent stratigraphical scheme for the Thames terrace sequence (Bridgland 1994) advocates correlation of the interglacial deposits contained within the Lynch Hill Corbets Tey Formation with Stage 9, the second post-Anglian interglacial. Having established Purfleet as the 'type site' for the mammalian fauna of the Stage 9 interglacial, the evidence from Grays will now be considered.

Mammalian studies

Hinton supported an early age for Grays Thurrock on the basis of palaeontological grounds, believing that the Grays fauna contained "the last remnants of the Pliocene fauna" (Hinton 1926a, 338) in the form of horse, macaque, hippopotamus and pig. Similarities were drawn between the Grays fauna and that of the Cromer Forest Bed. Considerable emphasis was also placed on the evidence from the small mammals, with the species of *Arvicola* from Grays deemed to be only distantly related to the modern *A. terrestris* and bearing more resemblance to the Cromerian type (Hinton 1926a, 337, Hinton 1926b, 129-131). However, in an earlier paper in 1900, Hinton had taken an exactly opposite view on the age of the Grays *Arvicola* material, stating that the water vole molars from the Orsett Road section "all agree with recent examples in the pattern of the crowns" (Hinton and Kennard 1900, 348). He thus accepted that the teeth were closest to those of the modern *A. terrestris*, differing only in their size (which was smaller in the fossil examples). The Stage 11 Hoxnian sites of Hoxne (4.1), Swanscombe (4.2), Clacton (4.4), and Barnham (4.5) have all yielded remains of morphologically early forms of *A. cantiana*, with clearly thicker enamel on the convex edges of the salient angles (*Mimomys* differentiation) and a large percentage of specimens still displaying the primitive ancestral '*Mimomys*' fold.

At Grays however, the form of *Arvicola* is apparently from a more advanced population since a greater number of specimens now display undifferentiated enamel (*i.e.* the enamel of the cheek teeth is present in equal thickness on both the concave and the convex sides of the salient angles). This confirms the work of Koenigswald (in Sutcliffe and Kowalski 1976) who, in a study of British *Arvicola* remains, described the Grays species as 'advanced *A. cantiana*'. Koenigswald placed this transitional form in an intermediate position between Hoxnian sites such as Swanscombe and Clacton and Last

Interglacial sites such as Barrington, Cambridgeshire and Swanton Morley, Norfolk, along with Aveley (6.1), Stutton (6.8) and Crayford (6.18). Hinton (1910) also devised the name *Microtus agrestoides* for the specimens of field vole from Grays, citing 'the constant development of a fourth outer angle in the last upper molar' as a criterion for their separation from *M. agrestis*. However, the 'fourth angle' is present in a great proportion of Recent *M. agrestis* and its presence is not therefore sufficient for specific determination (Sutcliffe and Kowalski 1976).

The elephant at Grays is represented almost entirely by the straight-tusked species, *P. antiquus*. A left third lower molar of *P. antiquus* (39370) and a L m2 m3 (18966, both N.H.M.L.) were originally described by Falconer as a separate species, *Elephas (Loxodon) priscus* (Murchison 1868). Falconer compared these teeth to other remains of *E. priscus* from Monte Serbaro, near Verona, stating that they differed from *P. antiquus* in having only 12-13 plates in the last lower molar and in their remarkable resemblance to the teeth of the modern African elephant (Murchison *ibid*). However, in his memoir on *Mammuthus columbi*, written 6 years later, Falconer revised his opinion, claiming that *E. priscus* was simply a form of *P. antiquus*. A single lower third molar of *M. primigenius* is also present in the collections of the Natural History Museum, although it seems most unlikely that this specimen is from the main interglacial horizon at the site.

The Carnivora are well-represented at Grays, in particular *U. arctos* with 104 specimens out of 1579. All remains are referable to brown bear, identified on the basis of its relatively high-crowned dentition. No evidence of *U. spelaeus* (cave bear) has been found. Smaller numbers of *C. crocuta* (8 specimens) (Figure 3.35), wolf (6 specimens), fox (3 specimens) (Figure 3.29) and an indeterminate otter (3 specimens) have also been recovered. The remains of *C. lupus* from Grays are visually similar in size to the small wolf from Swanscombe (4.2). However, this is more likely to reflect a small local population (see 4.1), than to be a feature of biostratigraphic significance.

The Grays equids are represented exclusively by a relatively large caballine horse, *Equus ferus* (Figure 7.3). The extinct 'ass' *E. hydruntinus*, known from Swanscombe (4.2), has not been recorded.

No antlers have been found in the Grays assemblage which prevents a complete determination to species level of the Grays fallow deer. However, the small size of the Grays bones suggests that they do not belong to the same subspecies as that found in Hoxnian deposits and may well be referable to the modern *D. d. dama*. Figure 5.14 shows a Grays *Dama* metacarpal compared to Grays *Cervus elaphus*. The *Dama* specimen is clearly the smaller of the two, whereas at Swanscombe, the two would be of similar size. The Grays interglacial also marks the appearance in Britain of *A.* cf. *alces* (Lister 1984a) (Figure 3.53).

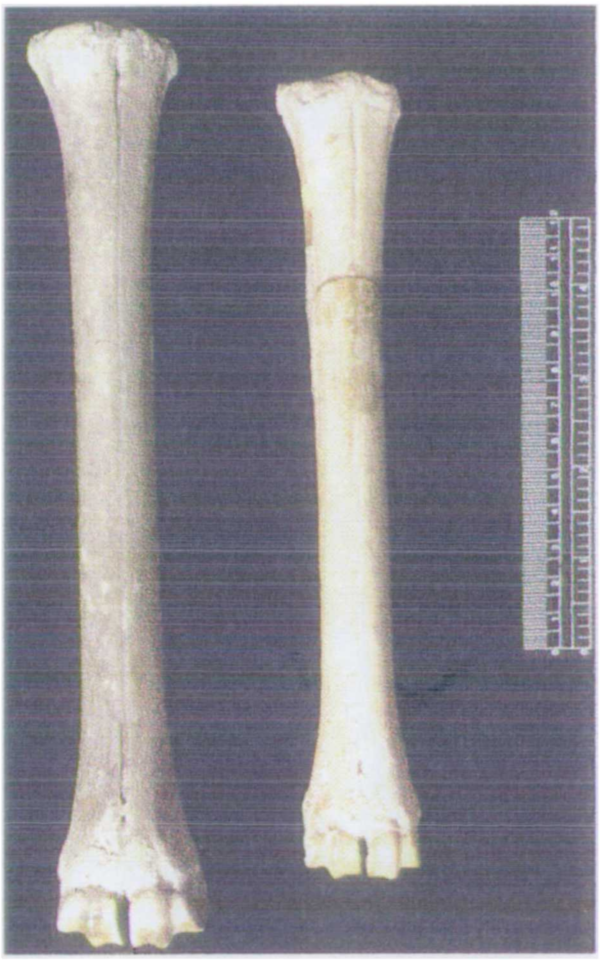


Figure 5.14 Comparison of *Cervus elaphus* left metacarpal (21296, N.H M.L.) (left) with *Dama dama* left metacarpal (21674, N.H.M.L.) (right), Grays (anterior view).

Apart from early accounts and species lists, the Grays mammals have received virtually no treatment in the literature. This unfortunate state of affairs has led to the belief that they are undiagnostic of any particular interglacial, for example "The rich mammalian fauna from the Grays and Little Thurrock brickearth...has failed to provide clear biostratigraphical evidence for the age of the deposits." (Bridgland 1994, 234).

However, detailed study has now shown that quite the reverse is true. Several lines of evidence may be put forward on palaeontological grounds which argue against correlation of the Grays mammals with the Hoxnian Interglacial. As illustrated in Currant (1989), the mammalian assemblages of Swanscombe (4.2) and Grays are only superficially similar and substantial differences between the two occur. Certainly, the Grays assemblage has elements in common with earlier temperate woodland faunas, notably the presence of large herbivores such as *Palaeoloxodon antiquus*, *Equus ferus*, *Stephanorhinus hemitoechus*, *Stephanorhinus kirchbergensis*, *Cervus elaphus* and *Bos primigenius*. However, major differences to the Hoxnian group, as typified at Hoxne (4.1), Swanscombe (4.2) and Clacton, may be witnessed in virtually all other areas. The following points are considered critical to the discussion:

- Absence of the Hoxnian indicator, *Talpa minor* (extinct small mole).
- Absence of the Hoxnian indicator, *Oryctolagus cuniculus* (rabbit).
- Absence of the Hoxnian indicator, *Trogontherium cuvieri* (extinct giant beaver). By Stage 9, this species has been entirely replaced by the modern European beaver *Castor fiber*.
- Absence of the Hoxnian indicator, *Microtus* (*Terricola*) *subterraneus* (European pine vole).
- Absence of the Hoxnian indicator, *Ursus spelaeus* (cave bear). At Grays, the bears are represented exclusively by the brown bear *Ursus arctos*.
- Absence of the extinct 'ass' *Equus hydruntinus*.
- Presence of a more advanced morphotype of water vole, *Arvicola terrestris cantiana*, with a more intermediate enamel morphology than the Hoxnian *A. t. cantiana*.
- Presence of a smaller form of *Neomys* (water shrew), compared to Hoxnian *Neomys* (see Figure 3.2; Tables 3.1 and 3.2). The Grays species is probably referable to *Neomys browni*.
- Presence of *Crocidura* cf. *leucodon*, bicoloured white-toothed shrew
- Presence of *Crocuta crocuta*, spotted hyaena

- Presence of a visibly smaller fallow deer (*Dama dama*) at Grays, compared to the large Hoxnian subspecies *Dama dama clactoniana*.
- Presence of *Alces* cf. *alces* (elk).

Some of these species (such as *Equus hydruntinus*) are rare even in the Hoxnian, but when taken together, the combined evidence from the above species provides a compelling demonstration that marked differences are present between the mammals from Grays and from Swanscombe (4.2). On biostratigraphic grounds alone, age-equivalence is therefore unlikely, if not impossible. Similarly, mammalian biostratigraphy precludes correlation of Grays with lower Middle Terrace sites, such as Aveley (6.1) and Ilford (Uphall Pit) (6.2) on the basis of the presence of *A. t. cantiana* and *M. sylvanus*.

Finally, the mammalian biostratigraphic evidence also advocates strongly against a Last Interglacial age for the Grays deposits, *contra* Gibbard (1994, 1995b). The abundance of horse, the evidence of human activity, the presence of *Crocidura, M. sylvanus* and *S. kirchbergensis* at Grays all negate an Ipswichian correlation. Mention must here be made of the single specimen of *Hippopotamus amphibius* from Grays Thurrock since it has been used to imply correlation with the Ipswichian stage. As mentioned above, the acquisition date of the specimen shows that it was collected in 1844 at around the same time as the rest of the mammals. The specimen is also not dissimilar in preservation type to the rest of the assemblage, aside from bearing some unusual grooves near the base of the tooth. In Britain, the Last Interglacial fauna is characterised by the presence of *Hippopotamus*, at seen at classic Ipswichian sites, such as Trafalgar Square in London, Barrington and Joint Mitnor Cave (Devon). Whilst the record of *Hippopotamus* from Grays therefore appears to contradict the current accepted wisdom that this species was only present in this country after the Anglian during the Last Interglacial, the possibility that occasional stray animals reached the shores of Britain during the Grays interglacial should not be so readily dismissed. Whether the *Hippopotamus* specimen is a genuine or an erroneous inclusion in the Grays assemblage remains a matter for debate. What is not in doubt is the wealth of evidence which opposes a Last Interglacial age for the rest of the mammalian assemblage.

Malacological studies

Work by Kerney (1959b) on the molluscan fauna from both Grays and Swanscombe (4.2) suggested a broadly Hoxnian age for the deposits at Grays. Many elements present in the Middle Gravels at Swanscombe also occur at Grays, for example the woodland snail *Macrogastra ventriculosa* which is restricted within the Thames system to these two localities. The abundance of *Corbicula fluminalis* at Grays must be regarded as strong evidence that the Grays deposits are not of Last interglacial age, since this species has never been found at sites that are demonstrably Ipswichian, as at Trafalgar Square (Preece 1995).

Palynological studies

As previously stated, pollen analyses were undertaken at the Globe Pit, Little Thurrock (West 1969; Hollin 1971, 1977) and whilst these indeed demonstrated that the brickearth had been deposited under interglacial conditions, it proved impossible to differentiate between the Hoxnian and Ipswichian temperate stages (West 1969). However, since brickearth at similar elevations at Aveley (6.1) and Ilford (6.2) had yielded late Ipswichian pollen sequences (West 1969; West *et al.* 1964), a similar age for Little Thurrock was proposed. This suggestion is now somewhat superseded by the widespread acceptance that the sites at Aveley and Ilford (Uphall Pit) are almost certainly not of Last Interglacial age but belong to a preceding unnamed interglacial (generally correlated with Stage 7 of the Oxygen Isotope record) and previously unrecognised in the palaeobotanical record. The palynological evidence from Grays must therefore be regarded as inconclusive as far as age determination is concerned.

5.2.7. Discussion and conclusions

In summary, the available stratigraphic and biostratigraphic evidence from Grays confirms the position of the site as being younger than the High Terrace deposits at Swanscombe (4.2) but older than the Later Middle Terrace deposits at sites such as Aveley (6.1). The similarity of the mammalian assemblage to that from Purfleet (5.1) is striking and strongly supports their correlation. The disappearance of the characteristic Hoxnian indicators (*Trogontherium cuvieri, Microtus (Terricola) subterraneus, Ursus* *spelaeus* and *Dama dama clactoniana*) and the combined presence of *Neomys browni*, *Crocidura*, a more advanced form of *Arvicola cantiana*, *Macaca sylvanus*, *Ursus arctos* and *Crocuta crocuta* are the important diagnostic characters of this interglacial. Correlation of the site with Oxygen Isotope Stage 9 is therefore suggested.

5.3. CUDMORE GROVE, EAST MERSEA, ESSEX (TM 068144)

5.3.1. Location of the site

The Cudmore Grove cliffs and foreshore are situated on the north-eastern edge of Mersea Island, Essex, near the estuary of the River Colne and within the Cudmore Grove Country Park (part of the Colne Estuary biological S.S.S.I) (Figure 5.15). Extensive coastal erosion in recent years has revealed a large channel, infilled with fossiliferous estuarine sediments of later Middle Pleistocene age, beneath terrace gravels (the Mersea Island Gravel). Two further localities in the same area, the 'Restaurant Site' and the 'Hippopotamus Site' are of Late Pleistocene Last Interglacial age and will not be dealt with here.

5.3.2. History of research

Fossiliferous deposits were first reported at East Mersea early in the present century. Dalton (1908, 136) noted the discovery of a 'dark blue mollusc-rich silt' containing estuarine species such as *Scrobicularia* and *Cerastoderma*, during the digging of a well in a gravel pit 'one mile east by north of Mersea church'. The pit Dalton described may be that located in a now-overgrown hollow at TM 065148, approximately 300 m inland from the present cliff line (Bridgland 1994). At the time of writing, Dalton would have been unaware of the potential of the Cudmore Grove exposures, since the cliffs were inactive and vegetated, and the salt marsh in front of them had been turned over to pasture (Bridgland and Sutcliffe 1995). Further accounts of shelly material were provided by Warren (1918) and Cornwall (1958), although the listing of *Hippopotamus* bones suggests that what was seen in the foreshore exposures prior to the 1980s was the Upper Pleistocene sequence mentioned above. Additional descriptions of the Cudmore Grove cliff sections were provided by Tucker and Greensmith (1973), although these make no mention of the Cudmore Grove Channel deposits later reported.

Accelerated coastal erosion at Cudmore Grove eventually exposed a large, argillaceous channel-fill in 1982 (Bridgland and Sutcliffe 1995). Organic sediments were observed outcropping at the edge of the foreshore to the east of the wood, clearly underlying the gravel exposed in the cliff. These exposures have since been markedly enhanced by

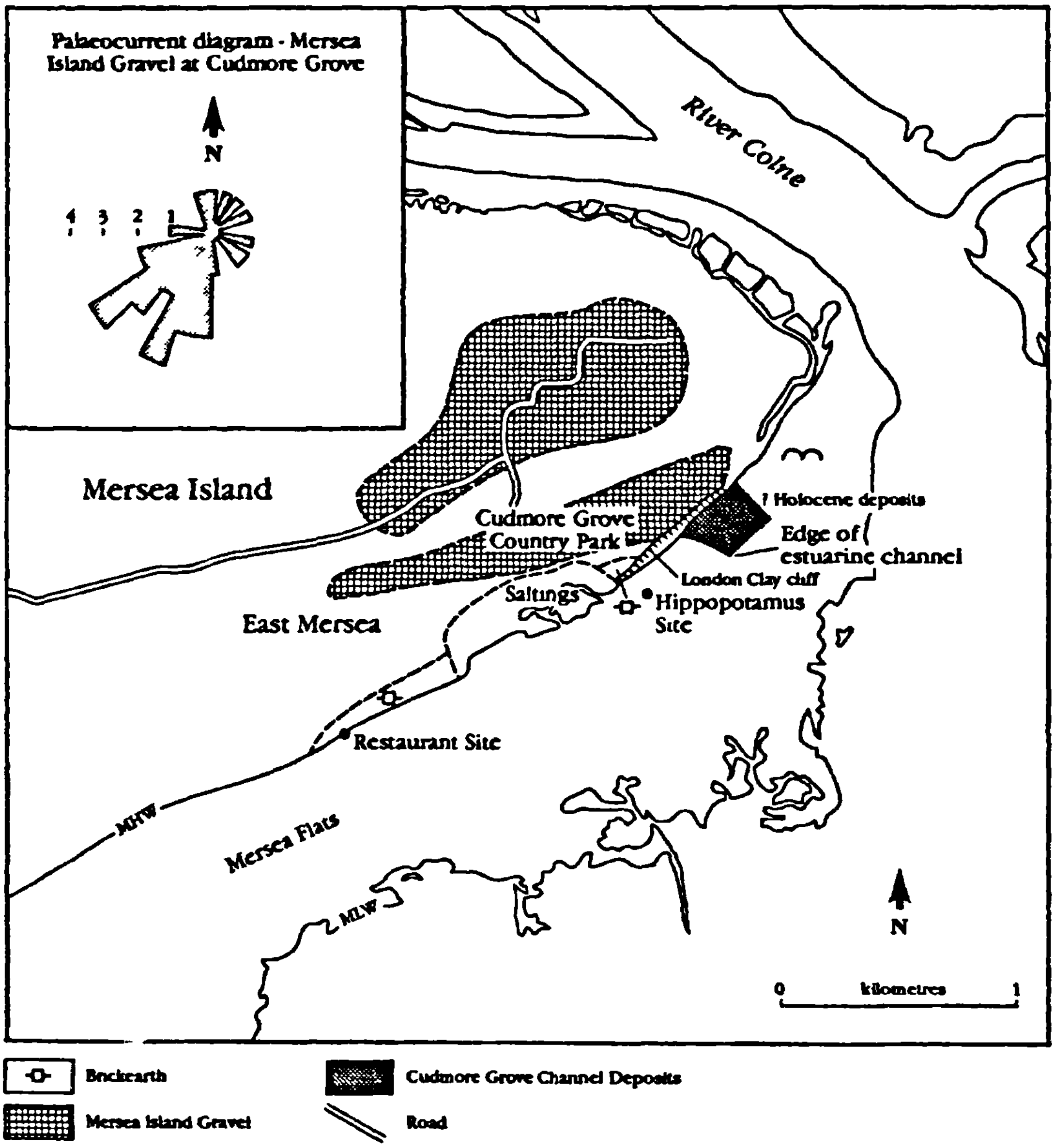


Figure 5.15 Location map of Cudmore Grove, showing the distribution of the Pleistocene deposits (modified from Bridgland 1994).

further erosion and the organic beds are now visible at the base of the cliffs as well as on the foreshore (Bridgland *et al.* 1988; Bridgland 1994; Roe 1995). Accounts of the herpetofauna and mammalian remains from the upper part of the channel-fill are provided by Holman *et al.* (1990) and Currant (in Bridgland *et al.* 1988) respectively.

5.3.3. Geological background and provenance of mammalian remains

The Cudmore Grove Channel site is of considerable stratigraphic significance since it lies in the valley of the former Thames-Medway (the Essex limb of the diverted Thames) and thus clearly post-dates the Anglian glaciation. Analysis of the gravels overlying the interglacial deposits showed them to contain material of Thames origin, including Tertiary flints from the London Basin and low levels of quartzose material from the Midlands (Bridgland 1988; Bridgland *et al.* 1988). Of equal significance was the presence of material of southern provenance, in particular Greensand chert from the Weald of Kent (Bridgland 1986). The latter had also been recorded in the High-level East Essex Gravel, pre-Anglian deposits attributed to an early, north-flowing Medway (Bridgland 1983a, b, 1988). It was therefore concluded that the gravels overlying the channel-fill at Cudmore Grove were of combined Thames-Medway origin and represented the route taken by the Thames after its diversion during the Anglian into the former Medway valley (Bridgland 1980, 1983b, 1988a). These 'Thames-Medway' gravels were assigned to the Low-level East Essex Gravel Formation (Bridgland 1988), later reclassified as a Subgroup (Bridgland 1994).

Palaeodrainage reconstructions based on the height and distribution of the Thames-Medway gravels (Bridgland 1988; Bridgland *et al.* 1993) established two routes: i. an initial post-diversion route, when the Thames-Medway is believed to have flowed north-eastwards and deposited the Southchurch/Asheldham/Mersea Island/Wigborough Gravel Formation, and ii. a later route when the river was thought to have migrated south-eastwards to drain the area between Shoeburyness and Burnham-on-Crouch, during which the Barling/Dammer Wick Gravel Formation was deposited (Bridgland 1988). Bridgland's original interpretation of the various formations thus required that the Thames-Medway course persisted across Mersea Island to Clacton until OIS 10, during which rejuvenation coincided with a southward shift in the river's course. Consequently, all interglacial deposits of post-diversion Thames-Medway origin to the north of the Dengie Peninsula were considered to date from OIS 11. The interglacial deposits at Cudmore Grove were therefore correlated with those of the Clacton Channel and held to be the downstream equivalents of the deposits at Swanscombe (Bridgland 1983a, 1988, 1994).

A series of reconnaissance borings and a deep borehole subsequently proved the following succession (from Roe 1995) (Figure 5.16):

7. Upper sand and gravels (Mersea Island Gravel)
6. Grey clays
5. Organic clays
4. Detritus muds
3. Grey silty clays
2. Basal gravels (Cudmore Grove Channel Gravel)
1. London clay

A large channel, deeply excavated into the London Clay, forms the base of the sequence. The base of the channel has been reached in a borehole in the central part of the outcrop at -11m O.D. (Roe 1995). The Cudmore Grove Channel Gravel (Bed 2), which fills the base of the channel, is up to 3m thick and consists of sand and gravels rich in angular flint. Indeed, clast lithological analysis of these gravels has revealed higher frequencies of angular flint than other Thames-Medway gravels (Roe 1995). Such frequencies are typical of the outwash-enriched gravels of the Tendring Peninsula at St. Osyth (Bridgland 1983a; Bridgland *et al.* 1988). The basal gravels also contain a high proportion of exotics, probably derived from the quartz-rich Kesgrave Group gravels of north-west Essex. This suggests that the basal gravels were deposited by a different river other than the Thames-Medway, a 'proto-Colne' or 'proto-Blackwater' that had reworked older Thames-Medway, 'outwash', 'Kesgrave' and High-level East Essex Gravel (early Medway) material (Roe 1995). This latter reinterpretation would no longer require the Cudmore Grove sediments to be part of a Stage 11 Asheldham/Clacton channel system. The overlying interglacial deposits could consequently be of any age, including OIS 11.

The basal gravels grade upwards into a thick sequence of grey silty clays (Bed 3), up to 10m thick, which form the main infill of the Cudmore Grove Channel. Four subunits are recognised within this unit (Roe 1995):

i. sandy clays, dark grey, massive, 0.5-1m

ii. silty clays, grey to grey-brown with occasional shell fragments, commonly interbedded with fine sand, *c.* 3m

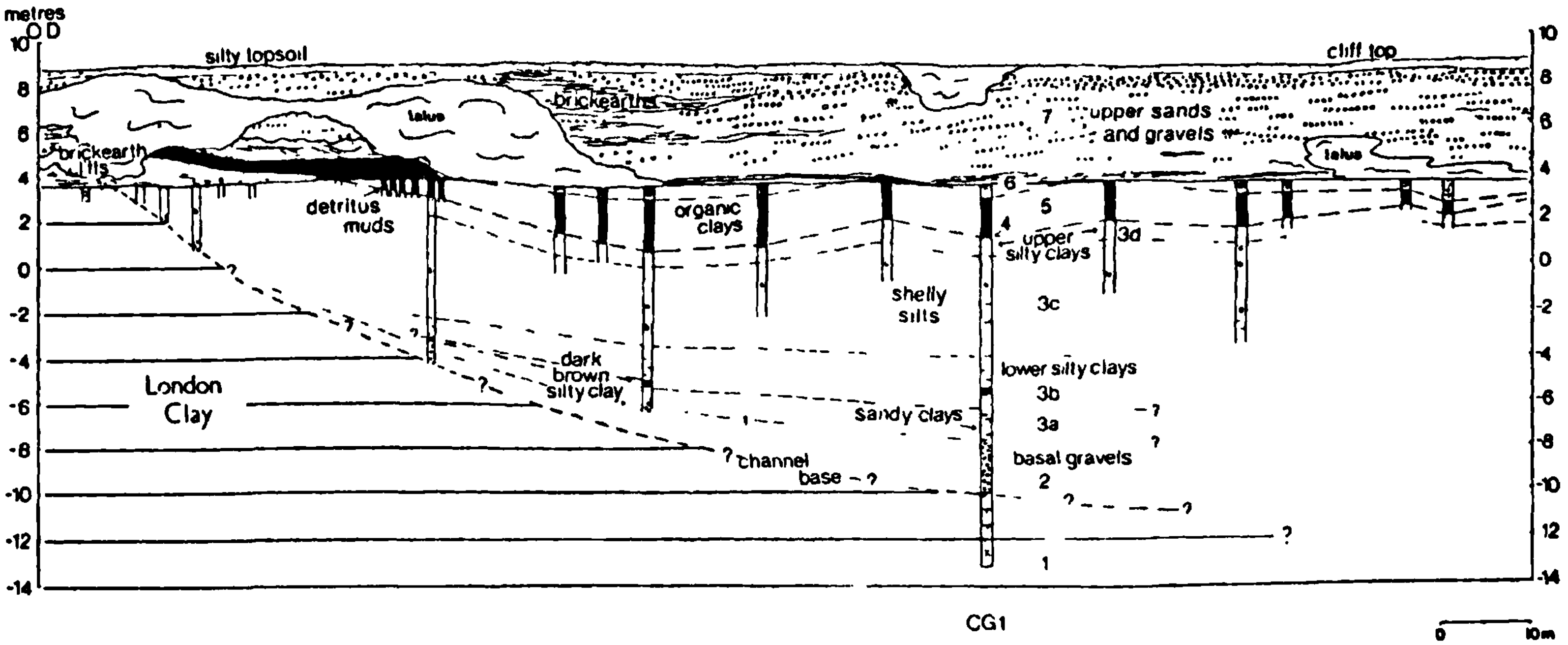


Figure 5.16 Section through the Pleistocene deposits at Cudmore Grove (from Roe 1995).

iii. shelly silts, dark grey, massive, with randomly scattered shell debris, 1-5m
iv. silty clays, green-grey with occasional fine sand laminae, *c.* 0.5m

The detrital muds (Bed 4) are restricted to the south-western part of the site, where they are occasionally exposed on the foreshore. These deposits are rich in fine grey sand and have yielded extensive vertebrate faunas and much comminuted shell material. The fragmentary nature of the shells implies some degree of transportation, thereby suggesting that this deposit may represent some kind of 'lag' (Roe 1995). Roe (*ibid*) recorded a 0.1m thickness for this bed, although earlier accounts suggest that up to 0.3m was formerly present and was widely exposed beneath the modern beach (Bridgland *et al.* 1988). The organic clays (Bed 5) that form the uppermost part of the channel infill are also restricted to the south-western part of the site, where they reach a maximum thickness of 2.5m. Here, a lower horizon of wood, interbedded with organic clay, is overlain by an upper, massive organic clay horizon with occasional wood fragments. Three large tree trunks (*Alnus* sp.) have been recorded from the lower horizon (Bridgland 1994), thereby suggesting colonisation of the infilled channel surface by alder woodland (Roe 1995). Signs of deformation (probably associated with loading) are present throughout this unit. The organic clays are overlain in part of their exposure by 0.05-0.3m of mottled grey clay (Bed 6), considered to have been deposited under slightly brackish (?lagoonal) conditions (Roe 1995) This unit may be traced laterally towards the eastern part of the cliff exposure, where it directly overlies the silty clays (Bed 3).

The argillaceous series (Beds 3-6) are capped by 4-5m of sands and gravels, reflecting a return to fluvial, braided condtions. Two main facies occur: a lower 2-3m series of cross-bedded sands and an upper 3m of mainly clast-supported gravels. The sandy beds are truncated by the gravels, which thicken towards the north-east. Palaeocurrent measurements suggest that flow in the lower sandy horizon was towards the south-east and in the upper gravel horizon towards the north-north-east. Compositionally, both beds are considered comparable to Thames-Medway gravels of the East Essex Subgroup. A slight enrichment of exotics in the upper gravel could reflect the input of additional quartzose material from a tributary joining the Thames-Medway between the Dengie Peninsula and Mersea Island, presumably a proto-Blackwater (Bridgland 1983a;

Roe 1994). The upper gravel-rich horizon shows signs of periglacial deformation, including ice-wedge casts and intrusions of London Clay 'head' (Roe 1995).

5.3.4. Palaeontology

The following species list has been compiled from material in the Natural History Museum, London and the Harrison Zoological Museum, Sevenoaks. The present study has confirmed the presence of 17 mammalian species, including a new record of horse (*Equus ferus*), collected by the author from foreshore exposures of the detritus muds (Bed 4) on 15.10.95, and previously unpublished records of common shrew (*S. araneus*), badger (*Meles meles*) and polecat (*Mustela* cf *putorius*). All other vertebrate material described below is also from Bed 4. To the list may be added *Homo*, on the basis of a Palaeolithic flake, recovered from the basal gravel (Bed 2) (Bridgland 1994). A total of 1508 specimens was examined.

Species List (Mammalia) from Cudmore Grove, Essex

Insectivora

Sorex cf. *araneus* L., common shrew

Sorex cf. *minutus* L., pygmy shrew

Neomys cf. *browni* (Hinton), water shrew

Crocidura cf. *leucodon* Hermann, bicoloured white-toothed shrew

Chiroptera

Eptesicus serotinus (Schreber), serotine bat

Primates

Macaca sylvanus (L.), Barbary macaque

Homo sp., indet. homind (artefacts)

Rodentia

Sciurus vulgaris L., red squirrel

Castor fiber L., European beaver

Clethrionomys glareolus (Schreber), bank vole

Arvicola terrestris cantiana (Hinton), extinct water vole

Microtus agrestis (L.), field vole

Microtus agrestis (L.) or *M. arvalis* (Pallas), field or common vole

Microtus sp., indet. vole

Apodemus cf. *sylvaticus* (L.), wood mouse

Carnivora

Canis lupus L., wolf

Ursus arctos L., brown bear

Meles meles (L.), badger

Mustela cf. *putorius* L., polecat

Perissodactyla

Equus ferus Boddaert, horse

Artiodactyla

Capreolus capreolus (L.), roe deer

Table 5.2 below provides a breakdown of the species list into numbers of specimens per species, also expressed as a percentage of the total mammalian assemblage from the site. Minimum numbers of individuals have also been calculated.

Species	Number of specimens	Percentage of total assemblage (%)	Minimum number of individuals (M.N.I.)
Insectivora			
S. cf. *araneus*	9	0.59	4
S. cf. *minutus*	4	0.26	2
N. cf. *browni*	38	2.51	18
C. cf. *leucodon*	1	0.06	1
Chiroptera			
E. serotinus	1	0.06	1
Primates			
M. sylvanus	1	0.06	1
Rodentia			
S. vulgaris	2	0.13	1
C. fiber	19	1.25	5 (1 juv., 4 adults)
C. glareolus	191	12.66	46 (6 juv., 40 adults)
A. t. cantiana	563	37.33	60
M. agrestis	31	2.05	19
M. agrestis or *M. arvalis*	82	5.43	47
Microtus sp.	503	33.35	106
A. cf. *sylvaticus*	42	2.78	9
Carnivora			
C. lupus	1	0.06	1
U. arctos	4	0.26	1
M. meles	1	0.06	1
M. cf. *putorius*	3	0.19	2

cont'd.../...

Species	Number of specimens	Percentage of total assemblage (%)	Minimum number of individuals (M.N.I.)
Perissodactyla			
E. ferus	1	0.06	1
Artiodactyla			
C. capreolus	11	0.72	2 (1 juv., 1 adult)

Table 5.2 Breakdown of the mammalian species list from Cudmore Grove, showing numbers of specimens per species, the percentage of the total assemblage per species and minimum numbers of individuals.

5.3.5. Palaeoenvironmental and palaeoclimatic interpretation

The palaeobotanical evidence indicates the presence of three local pollen assemblage biozones (Roe 1995):

Pinus-Betula biozone.

This zone extends from the base of Bed 3 to -3.4m O.D. and is dominated by *Pinus* and *Betula*, with low frequencies of thermophilous pollen, mostly *Quercus*. Aquatic pollen types, dominated by *Potamogeton* and *Typha latifolia* reach maximum frequencies. This assemblage is considered to reflect a quiet fluviatile channel environment, where pollen from a boreal-foreast catchment has been mixed with that of local waterside plant communities.

Quercus-Pinus biozone.

This zone is characterised by rising values for *Quercus* and declining *Pinus* and *Betula*, marking the gradual expansion of thermophilous trees in the regional forest. *Corylus*, *Fraxinus* and *Tilia* are represented, Aquatic pollen frequencies are low, possibly reflecting a rise in salinity.

Alnus-Quercus-Pinus biozone.

The abrupt changes in pollen spectra at the base of this zone coincide with the sharp lithological boundary between Beds 3 and 4 (the silty clays and the organic beds). *Alnus* and Filicales are the dominant spectra, reflecting damp woodland habitats, with *Quercus*, *Betula*, *Carpinus*, *Pinus* and *Abies* indicating drier conditions.

Molluscan remains from Bed 3 (grey silty clays) are dominated by brackish intertidal species, notably *Cerastoderma edule* and *Hydrobia ulvae*. The extinct hydrobiid ‘*Paladilhia radigueli*’ has also been recorded (Bridgland *et al.* 1988; Bridgland 1994; Roe 1995). The feather-edge of this unit has yielded a rich ostracod assemblage, dominated by a noded form of the brackish water indicator, *Cyprideis torosa*, thought to indicate low levels of salinity. Other ostracod taxa include 8 freshwater species and 3 brackish or marine species (Robinson, in Bridgland 1994).

By way of contrast, the molluscan remains from Bed 4 (detrital muds) are dominated by freshwater species, including *Valvata piscinalis*, *Corbicula fluminalis*, *Bithynia tentaculata* and *Pisidium* sp., although brackish elements, notably hydrobiids, are also present (Bridgland 1994; Roe 1995). The presence of these taxa in these proportions suggests a brackish influence, although much lower levels of salinity than in the underlying grey silty clays (Bridgland *et al.* 1988).

A rich herpetofaunal assemblage was recovered from the detrital muds, comprising 14 taxa, half of which are no longer native to Britain (Holman *et al.* 1990). The presence of still or slowly-flowing water with abundant aquatic vegetation is indicated by the European pond terrapin (*Emys orbicularis*), warty newt (*Triturus cristatus*), dice or viperine snake (*Natrix tessellata* or *N. maura*), pool frog (*Rana lessonae*) and the marsh or edible frog (*Rana ridibunda* or *R. esculenta*). Damp grassland adjacent to the water source is attested to by the presence of the moor frog (*Rana arvalis*), common frog (*R. temporaria*) and grass snake (*Natrix natrix*). Nearby well-vegetated, damp habitats with plenty of ground cover are indicated by the smooth newt (*T. vulgaris*), tree-frog (*Hyla* sp.) and slow worm (*Anguis fragilis*), while the natterjack toad (*Bufo calamita*), common toad (*Bufo bufo*) and Aesculapian snake (*Elaphe longissima* would have favoured a drier, open shrubby or open woodland habitat. The adder (*Vipera berus*) and viviparous lizard (*Lacerta vivipara*) are found in a wide range of open terrestrial habitats, including heaths, dunes, woodland, marshes and meadowland (Arnold and Burton 1978). Seven of the Cudmore Grove herpetiles do not occur in the native British fauna: the marsh or edible frog, tree frog, moor frog, pool frog, dice or viperine snake, pond terrapin and the Aesculapian snake. Based upon their present day ranges, their presence in the Cudmore Grove channel deposits suggests that the climate during this interglacial was slightly warmer than the present day, with mean July temperatures higher than 17-18 C and mild winters.

The mammalian remains suggest a similar range of environments, with woodland and aquatic species particularly well-represented. The presence of deciduous or mixed woodland with thick ground cover is suggested by the abundance of bank vole (*C. glareolus*) and wood mouse (*A. sylvaticus*), with smaller numbers of pygmy shrew (*S. minutus*) and a rare record of serotine bat (*E. serotinus*) (Figure 3.6). This is supported by large mammal taxa such as macaque monkey (*M. sylvanus*), European beaver (*C. fiber*), brown bear (*U. arctos*), badger (*M. meles*) and roe deer (*C. capreolus*) (Figure 3.54). Locally open vegetation is indicated by the field vole (*M. agrestis*), while aquatic habitats are indicated by the enormous abundance of water vole (*A. t. cantiana*) (37% of the mammalian assemblage) and the unusually good representation of water shrew (*Neomys* sp.), which frequent the well-vegetated banks of rivers and lakes with still or slow-flowing water. The presence of the bicoloured white-toothed shrew (*C.* cf. *leucodon*), which today has a predominantly southern European distribution, supports the inference that the climate may have been slightly warmer than at present.

A wide variety of avian remains have also been recovered, including garganey duck (*Anas querquedula*), gadwall duck (*A. strepera*) and little crake (*Porzana parva*), which indicate a summer as warm as central mainland Europe at the present day, while whooper swan (*Cygnus cygnus*) and smew (*Mergus albellus*) are present as winter visitors. These species suggest the presence of an open body of freshwater, with a well-vegetated margin and shallow-water plantlife. A range of passerines, including thrush (*Turdus philomelos*), great tit (*Parus major*), blue or coal tit (*P. caeruleus* or *P. ater*) and willow warbler or chiffchaff (*Phylloscopus trochilus* or *P. collybita*) indicate the proximity of (probably broadleaf) woodland (C. Harrison, letter in archive of A.J. Sutcliffe).

5.3.6. Biostratigraphy and correlation

The Cudmore Grove Channel deposits have been correlated in the past with the Hoxnian Interglacial on the basis of palynological evidence (Roe 1994, 1995) and with OIS 11 on the basis of palaeodrainage reconstructions, which suggested that the Cudmore Grove

Channel Gravel was the equivalent of the Clacton Channel Gravel (Bridgland 1983a, 1988, 1994). However, new clast lithological data now suggest that the Cudmore Grove Channel was incised by a different river to the Thames-Medway (Roe 1994, 1995), thereby removing the necessity for the Cudmore Grove deposits to be included within a Stage 11 Asheldham/Clacton channel system. Further differences, such as the height of the base of the channels (-11m O.D. at Cudmore Grove and -5m O.D. at Clacton) also suggest that the sites may be of quite different ages. In addition, at Cudmore Grove, evidence of marine conditions between -8 and -1m O.D. occurs during zone II of the interglacial. This contrasts markedly with the record at Clacton, where freshwater conditions are replaced by brackish ones at approximately 3m O.D. in zone IIIb of the interglacial (4.4). Although this does not preclude correlation of the two localities, since these differences may be accommodated in a complex sea level history, the possibility remains that the two sites date from different interglacials.

On the basis of mammalian biostratigraphic evidence (in particular the presence of *Crocidura*), the Cudmore Grove deposits have been grouped with those of Grays (5.2), the lower part of Aveley (6.1) and Itteringham, Norfolk (6.3) (Currant, in Bridgland *et al.* 1988; Currant 1989b). However, revision of the stratigraphic sequence in the Thames by Bridgland (1994) now recognises that two separate interglacials are contained within the Middle Terrace, correlated with OIS 9 and 7 and represented by Grays and Aveley respectively. *Crocidura* is present in both stages but other features of their mammalian faunas permit their separation. The most appropriate correlation for the Cudmore Grove mammalian assemblage will therefore be considered below.

Mammalian studies

As indicated above, three separate interglacials are potential correlatives for the Cudmore Grove temperate deposits: the Hoxnian (Stage 11), Stage 9 and Stage 7.

The first important point about the Cudmore Grove mammalian assemblage is that it does not contain a single one of the Hoxnian indicator species described in Chapter 7?. Thus, in the case of the small mammals, *T. minor*, *O. cuniculus*, *T. cuvieri*, and*M. (T.) subterraneus* are apparently absent. This is in spite of extensive sieving for small vertebrate remains, the recovery of an extremely large assemblage (over 1500 specimens) and the physical proximity and similar environmental conditions of the site to Clacton. Furthermore, the presence at Cudmore Grove of brown bear (*U. arctos*), as opposed to cave bear (*U. spelaeus*), and the representation of the Castoridae exclusively by the modern species *C. fiber* would suggest that Cudmore Grove is of younger age than the Hoxnian.

The distinction made by Currant (1989b) between the Hoxnian group of sites and Cudmore Grove was dismissed by Bridgland (1994), who cites differences in the levels of richness of mammalian remains as a possible reason for the distinction. Thus, Bridgland states that Grays and Cudmore Grove are both prolific sites, a fact which has artificially created strong similarities between their mammalian assemblages, while "the assemblages from Clacton and Swanscombe...are sparse by comparison" (Bridgland 1994, 356). Examination of the evidence reveals that this statement is erroneous. In the present study, 1575 specimens from 27 species were counted at Grays (5.2) and 1508 specimens from 17 species at Cudmore Grove, while Swanscombe counts 1622 specimens from 33 species (4.2) and Clacton 952 specimens from 19 species (4.4). All four sites are therefore comparable in terms of their number of specimens. The absence of the Hoxnian indicator species from Cudmore Grove thus has nothing to do with assemblage richness and everything to do with stratigraphical significance.

Comparison of the Cudmore Grove assemblage to those from Purfleet (5.1) and Grays (5.2) reveals that they are extremely similar. Of particular importance is the presence at Cudmore Grove of the bicoloured white-toothed shrew (*C.* cf. *leucodon*) and of abundant water shrew, attributed to *N. browni* on the basis of their size, which is larger than that of *Neomys* from West Runton but smaller than that of Recent *N. fodiens* (see Figure 3.2; Tables 3.1 and 3.2). The water vole remains from Cudmore Grove are attributed to *A. t. cantiana* but show a slightly more advanced morphology than those from Hoxnian sites. However, of the 256 molars of *A. t. cantiana* from Cudmore Grove, 50 (19.53%) are from juvenile individuals and are therefore unsuitable for use as biostratigraphic indicators since enamel differentiation in the molars is not fully developed. The primitive ancestral '*Mimomys*' fold is present in only 2 specimens (0.78% of the water vole sample).

A further point of comparison with Purfleet (5.1) and Grays (5.2) is that all share a characteristic mammalian assemblage with marked woodland affinities and relatively lower numbers of open grassland species, compared to Hoxnian localities. Thus for example, *C. capreolus*, which is normally poorly represented in the fossil record, is found at all three sites. Although specimen numbers of this species still remain low, its consistent presence is taken to reflect a larger population at this time compared to the Hoxnian and to indicate the development of extensive areas of broadleaf woodland. This is supported by the presence of beaver and macaque monkey, by high percentages of bank vole (almost 13% of the Cudmore Grove assemblage) and wood mouse (almost 3%) and by the presence of a diverse range of other woodland inhabitants, which are also rare in the fossil record, including *E. serotinus*, *S. sciurus* and *M. meles*. This woodland-species predominance is considered to be of significance in determining the overall nature of this interglacial and in differentiating it from the Hoxnian Interglacial. As at Purfleet, human presence at Cudmore Grove appears to be restricted to more open periods outside the main interglacial, since the archaeological material has been recovered from the basal gravel that pre-dates the temperate deposits .

The presence of *M. sylvanus* and *A. t. cantiana* provides an upper limit for the age of the Cudmore Grove Channel interglacial deposits. *M. sylvanus* is unknown from deposits younger than Stage 9 in Britain, while the *A. t. cantiana* from Cudmore Grove is differentiated from water vole remains of Stage 7 age or younger, not only on the basis of its more prımitve enamel differentiation, but also on the basis of size. The trend through time towards an increase in the length of the first lower molar in *Arvicola* is shown in Figure 3.20; Tables 3.3 and 3.4. The Cudmore Grove *Arvicola* are significantly smaller in size (mean 3.47mm ± 0.015) compared to *Arvicola* from two sites attributed in the present study to Stage 7, namely Itteringham (6.3) and Pontnewydd, Clwyd (6.25), with means of 3.62mm ± 0.035 and 3.69mm ± 0.210 respectively. The greater antiquity of the Cudmore Grove *Arvicola* specimens is consequently surmised.

It is therefore concluded that on the basis of the mammalian biostratigraphic evidence, the interglacial deposits at Cudmore Grove correlate most closely with Purfleet and Grays, equated in the present study with OIS 9. The Cudmore Grove deposits are considered to be younger than the Hoxnian Interglacial because of the absence of well-established Hoxnian indicator small mammal species and because of the replacement of *U. spelaeus* by *U. arctos*. The presence at Cudmore Grove of bicoloured white-toothed shrew (*C.* cf. *leucodon*), which is unknown from preceding British interglacial deposits, and a small form of water shrew (*N. browni*) is also of critical importance in establishing contemporaneity of the Cudmore Grove interglacial with Purfleet (5.1) and Grays (5.2). Correlation with Stage 7 is rejected on the basis of the presence of *M. sylvanus* and *A. t. cantiana.*

Malacological studies

An important feature of the Cudmore Grove molluscan assemblage is that it does not contain any element of the 'Rhenish' suite, which migrated into the Thames from mainland Europe during zone Ho III (Kerney 1971). This contrasts greatly with the evidence from Clacton, where the 'Rhenish' fauna is a major component of the zone Ho III assemblage (4.4). Although this difference would seem surprising if the sites were of equivalent age, the fact that the freshwater 'Rhenish' group prefer channels with sandy substrates has been suggested as a possible reason for their absence at Cudmore Grove (Roe 1995). The presence at Cudmore Grove of *C. fluminalis* and the extinct hydrobiid '*P. radigueli*' are considered to indicate a pre-Ipswichian age (Meijer and Preece 1995; Roe 1995).

Palynological studies

Roe (1995) attributes the lower part of the sequence at Cudmore Grove (lower part of Bed 3) to the early temperate substage of an interglacial (zone II) and the upper part of the sequence (Beds 3 and 4) to part of the late temperate substage (zone III). Correlation with the sequence at Clacton is suggested by the presence of Hoxnian indicators, such as *Abies*, the 'Type X' pollen grain and the water fern *Azolla filiculoides* (Roe, in Holman *et al.* 1990, 1994, 1995). However, it is important to note that these species have been reported from more than one post-Elsterian temperate stage at Schöningen in Germany (Urban *et al.* 1991) and the possibility that they are found in a post-Hoxnian context in Britain, especially in a previously unrecognised interglacial, must therefore be taken into account.

5.3.7. Discussion and conclusions

Evidence for the age of the Cudmore Grove deposits comes from both lithostratigraphic and biostratigraphic sources. Clast lithological data indicates that the river that incised the Cudmore Grove Channel entered the site from the west, bringing with it a rich supply of exotics and angular flint. This suggests that either the basal gravels were deposited by the Thames-Medway itself, downstream of a confluence with a substantial river reworking fluvio-glacial and Kesgrave Group sediment, or that they were deposited by a different river that had reworked older material (Roe 1995). The latter reinterpretation would thus remove the necessity to include the Cudmore Grove deposits within a Stage 11 Asheldham/Clacton channel system. This would consequently be a plausible explanation as to why there are such significant differences between the Cudmore Grove and Clacton sequences in terms of the base heights of their respective channels and their sea-level histories. Incision of the Cudmore Grove Channel by a different river other than the Thames-Medway does not however preclude correlation of the Cudmore Grove interglacial deposits with OIS 11.

The palynological evidence suggests correlation of the interglacial deposits with the Hoxnian, on the basis of the presence of *Abies*, 'Type X' and *A. filiculoides* (Roe, in Holman *et al.* 1990, 1995). However, this correlation is somewhat uncertain, given the possibility that the above 'Hoxnian' indicators may be present in a second post-Anglian interglacial. The molluscan biostratigraphic evidence is similarly inconclusive, suggesting a broadly post-Anglian, pre-Ipswichian age (Roe 1995). A much clearer indication of the age of the Cudmore Grove interglacial is provided by the mammalian remains, which reject correlation of Cudmore Grove with the Hoxnian Interglacial. The combined absence of critical Hoxnian indicator species, such as *T. minor*, *O. cuniculus*, *T. cuvieri*, *M.* (*T*) *subterraneus* and the presence of *U. arctos*, *C.* cf. *leucodon*, *N. browni* and a more advanced morphotype of water vole point strongly to correlation of the Cudmore Grove interglacial with the Lower Thames sites of Purfleet (5.1) and Grays (5.2). This would consequently place the Cudmore Grove temperate deposits in the second post-Anglian interglacial, here considered to equate with Stage 9. This is confirmed by the presence of *M. sylvanus* and *A. t cantiana*, which indicate a pre-Stage 7 age.

The attribution of Cudmore Grove to Stage 9 has important implications for the stratigraphical ranges of 'Type X' and *A. filiculoides*, since they can now be demonstrated to occur in the first two post-Anglian interglacials in Britain. This parallels evidence from the continent, where these species have been found in at least the first two post-Elsterian interglacials (Urban *et al.* 1991; Bridgland *et al.* 1996).

5.4. BELHUS PARK, ESSEX (TQ 574810)

5.4.1. Location of the site

The site was exposed during construction of the M25 motorway at Belhus Park, Essex. The mammalian remains were collected from an area excavated on the site of the Belhus Park bridge (grid reference above) in advance of laying the road.

5.4.2. History of research

Documentation of the stratigraphy and collection of specimens was undertaken by G.R. Ward, W.H. George and A.J. Snelling between November 1979 - April 1981.

5.4.3. Geological background and provenance of mammalian remains

The following description of the deposits was kindly provided by G.R. Ward (pers. comm.). At the base of the sequence is London Clay, which is overlain by terrace gravel at approximately 9m O.D. A continuous bed of grey organic clay, weathered to a brownish colour near the surface was observed to overlie the gravel. In a cutting south of the Belhus Park bridge (57468094), the organic clay was seen to be 0.8-0.9m thick. The clay contains abundant plant detritus and compressed logs of *Alnus* and *Quercus* at the base. Molluscan and vertebrate remains were also recovered from this unit. Towards the centre of the motorway cutting, the base of the organic clay was observed to descend steeply, as though occupying a channel. At this point, a seam of grey shelly gravel was present near the base of the clay, the shelly gravel being separated from the underlying terrace gravel by a brown silty clay. The shelly gravel yielded molluscan remains similar to those obtained from the base of the organic clay in the bridge excavation, but with the addition of abundant, mostly articulated valves of *Unio* spp. and *Corbicula fluminalis*. Rodent remains, plant detritus and logs of *Alnus* and *Quercus* were also recovered from the shelly gravel, but unlike in the base of the organic clay, the logs from the shelly gravel were uncompressed.

Traced northwards through the Belhus Park cutting, the organic clay was seen to be overlain by an increasing thickness of a more sandy gravel, consisting of largely rounded and angular matrix-supported flint pebbles, with well-rounded pebbles and cobbles of quartzite, pebbles of quartz, sandstones, Lower Greensand chert and Carboniferous chert (D.R. Bridgland pers. comm.). The upper sandy gravel is relatively well sorted compared to the terrace gravel and shows considerable variation in lithology, both vertically and laterally. The coarse constituents resemble those in the terrace gravel, reflecting derivation from a similar source or from the terrace gravel itself. Palaeocurrent measurements suggest flow in a southerly direction. A small cleaver in very sharp condition was found *in situ* from a lens of brown clay within the sandy gravel, approximately 1m above the organic bed. The tip of a broken handaxe (slightly rolled), two handaxes (one fresh and one rolled) and several flakes were also recovered from the sandy gravel (Wymer 1985).

The section at the Belhus Park bridge is summarised below:

Surface at *c.* 17.5m O.D.
8. Sandy gravel, well defined base, undulating, 3m + thick
7. Brownish-yellow sand, 0.04m
6. Brown and pale grey fissured clay, 0.14m
5. Pale blue-grey fissured clay, 0.08m
4. Dark grey clay, fissured in upper part, 0.51m
3. Dark grey silty clay with mollusc shells, 0.27m
2. Dark grey silty clay with angular-well-rounded flint pebbles, wood, seeds and shells, 0.23m
1. Gravel, 1m +
Bottom of excavation obscured by talus.

The Belhus Park deposits are attributed to the Corbet's Tey Gravel Formation by Bridgland (1994). The lower gravel is therefore equated with OIS 10, while the interglacial deposits are considered to be the correlatives of the Stage 9 temperate sediments at Purfleet and Grays. The overlying sandy gravel at Belhus Park is therefore attributed to OIS 8 (Bridgland *ibid*).

5.4.4. Palaeontology

The mammalian remains are currently in the care of the Passmore Edwards Museum in east London. They were unavailable for examination during the present study and the following list was provided by G.R. Ward (pers. comm., identifications by A.P. Currant).

Species List (Mammalia) from Belhus Park, Essex

Primates
Homo sp., indet. hominid (artefacts)
Rodentia
Sciurus vulgaris L., red squirrel
Clethrionomys glareolus (Schreber), bank vole
A. t. cantiana (Hinton), water vole
Microtus sp., indet. vole
Muridae sp., indet. mouse
Artiodactyla
Cervidae sp., indet. deer

5.4.5. Palaeoenvironmental and palaeoclimatic interpretation

Molluscan remains from the organic bed comprise *Pisidium* spp. including *P. amnicum*, *Bithynia tentaculata*, *Valvata piscinalis*, *Valvata* sp., *Unio* spp., *Lymnaea* spp. including *L. auricularia*, *Ancylus fluviatilis*, *Corbicula fluminalis*, *Paladilhia* sp., *Hydrobia* sp., *Cepaea nemoralis*, *Bathyomphalus contortus*, ?*Planorbis* spp., *Succinea pfeifferi*, *Sphaerium corneum*, *Segmentina* sp., *Carychium* sp., *Zonitoides nitidus*, *Nesovitrea hammonis*, *Anisus leucostoma*, *Vallonia* sp., *Retinella* sp. and *Helicella* sp. (G.R. Ward pers. comm.). These suggest an aquatic environment very simlar to that described from Purfleet, consisting of a large body of relatively slow-flowing water with a very mild saline influence. Adjacent marshland is indicated by *S. pfeifferi*.

Plant macrofossils are extremely abundant in the organic bed and include the fruits of the water chestnut *Trapa natans*, cones of *Alnus glutinosa*, seeds of *Cornus* sp., pine cones, wood, thorns, *Prunus* sp. fruitstones, birch catkins, *Rubus idaeus*, seeds of *Batracium*, seeds of *Potamogeton* sp., seeds of *Sambucus* sp., flattened reeds, stems and a small log of *Quercus* sp. Fully interglacial conditions are indicated.

The mammalian remains reflect the presence of nearby deciduous or mixed woodland, as indicated by *C. glareolus* and the rare record of *S. vulgaris* (Figure 3.9). The proximity of a body of slow-flowing water with well-vegetated margins is suggested by the presence of *A. t. cantiana*, while *Microtus* sp. is indicative of local grassland. An indeterminate snake vertebra and a fragment of carapace attributed to the European pond tortoise *Emys orbicularis* were also recovered from the organic clay. The presence of *E. orbicularis* is of particular significance in demonstrating the interglacial nature of the deposits, since this species requires mean summer temperatures of 18° C for hatching its eggs (Stuart 1979). Fish and coleopteran remains are also reported from the organic clay.

As at Purfleet (5.1), evidence of human presence, in the form of artefacts, is restricted to sediments above or below those representing the main interglacial.

5.4.6. Biostratigraphy and correlation

Mammalian studies

The only species of biostratigraphic significance in the Belhus Park assemblage is *A. t. cantiana*, which suggests a broadly pre-Stage 7 age.

Malacological studies

The presence of *C. fluminalis* is indicative of a pre-Ipswichian age (Meijer and Preece 1995).

Palynological studies

The organic clay has been attributed to subzone IIb of the Ipswichian by Gibbard (1994).

5.4.7. Discussion and conclusions

As stated above, the Belhus Park deposits have been attributed to the Corbets Tey Gravel Formation by Bridgland (1994), thereby implying contemporaneity of the interglacial deposits with those at Purfleet (5.1) and Grays (5.2). The mammalian evidence is consistent with this suggestion, partly because of the presence of *A. t. cantiana* and partly because of the general woodland affinity of the Belhus Park assemblage, which compares well with Purfleet, Grays and Cudmore Grove (5.3). The molluscan evidence is also supportive of a correlation with Purfleet, based upon the considerable similarity of the assemblages. As with *A. t. cantiana*, the presence of *C. fluminalis* in the organic deposits would apparently contradict the palynological attribution of the Belhus Park interglacial sediments to the Ipswichian. In summary therefore, the limited information from the mammalian and molluscan remains is broadly supportive of Bridgland's correlation of the Belhus Park temperate deposits with OIS 9. (D.H. Keen pers. comm.).

5.5. AVON TERRACE 5, PERSHORE, WORCESTERSHIRE (centred on SO 93874637)

5.5.1. Location of the site

The mammalian material was collected from a number of pits, centred on SO 93874637. The Avon No. 5 terrace in the Pershore area has now been completely removed by commercial extraction.

5.5.2. History of research

All material was collected by Mr P.F. Whitehead in April 1975, during excavation works by Severn Trent Water.

5.5.3. Geological background and provenance of mammalian remains

Five terraces are traditionally recognised within the catchment of the River Avon (Tomlinson 1925). The highest of these terraces (No.5) is interpreted as being the oldest and was considered by Tomlinson (*ibid*) to have been deposited as outwash from the main glaciation of the English Midlands. On the basis of faunal evidence obtained from deposits underlying the gravels of Avon No. 5, Shotton (1983b) suggested that a temperate episode was contained within the early part of this aggradation. Most recently, mapping of the Avon terraces has correlated the Pershore temperate deposits with OIS 9 and the overlying gravel with OIS 8 (Maddy *et al.* 1991, 1995; Maddy 1997) (see Chapter 2, Figure 2.9). This has received support from comparisons with the Bushley Green Terrace of the River Severn, widely believed to be the direct correlative of the Avon No. 5 terrace (Wills 1938; Bridgland *et al.* 1989) and considered to post-date the glaciation of the Midlands (Hey 1958) but pre-date the Ipswichian Interglacial as represented by Avon Terrace No. 3 (Keen and Bridgland 1986). A molluscan assemblage of cool-temperate affinities was obtained from 4m below the gravel surface of the Bushley Green Member (Bridgland *et al.* 1986). Amino acid ratios of 0.24 ± 0.01 on these Mollusca are thought to be indicative of a Stage 9 age (Maddy *et al.* 1995).

No section drawings of the deposits where the mammalian remains were collected from could be found in the Whitehead archive (Department of Palaeontology, Natural History Musem, London). However, the following section was recorded by Whitehead (1989a) during road-widening and is believed to represent similar deposits (Figure 5.17):

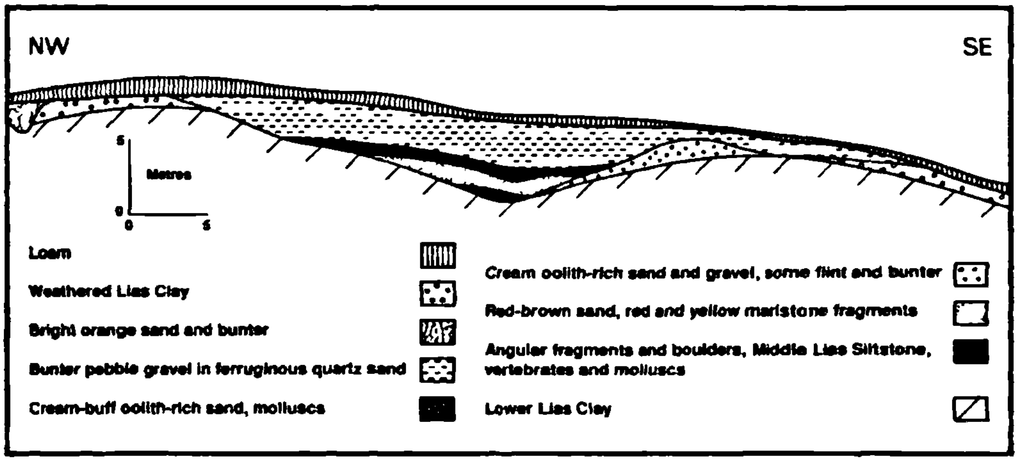


Figure 5.17 Section in No. 5 terrace of the Avon, Pershore, Worcestershire (from Whitehead 1989a).

The above section reveals a deeply-incised channel, at least 7.2m deep, in the Lower Lias Clay. The channel infill attains a height of 39m O.D. and is therefore estimated to be part of the No. 5 terrace (Whitehead *ibid*). Material collected by Whitehead is marked either ‘clay’ or ‘marlstone’, or (in the case of two specimens) ‘sand’. These deposits are assumed to equate with the two lowermost units of the channel-fill shown above. Preservation of the material is fairly fresh and the bones are creamy pale brown-grey in colour.

5.5.4. Palaeontology

The species list from Pershore is very limited, with only 2 species represented (horse and red deer). 39 specimens were examined. All material is housed in the Natural History Museum.

Species List (Mammalia) from Pershore, Worcestershire

Perissodactyla

Equus ferus Boddaert, horse

Artiodactyla

Cervus elaphus L., red deer

Table 5.3 below provides a breakdown of the species list into numbers of specimens per species, also expressed as a percentage of the total mammalian assemblage from the site. Minimum numbers of individuals have also been calculated.

Species	Number of specimens	Percentage of total assemblage (%)	Minimum number of individuals (M.N.I.)
E. ferus	37	94.87	2 (1 juv., 1 adult)
C. elaphus	2	5.13	1

Table 5.3 Breakdown of the mammalian species list from Pershore, showing numbers of specimens per species, the percentage of the total assemblage per species and minimum numbers of individuals.

5.5.5. Palaeoenvironmental and palaeoclimatic interpretation

Given the limited nature of the mammalian assemblage, few deductions can reasonably be made about the environment or climate at the time of deposition. The presence of *E. ferus* would suggest rather open conditions, while *C. elaphus* is today widely distributed in many habitats throughout western Europe. Both species have been recorded from warm and cold episodes during the Middle and Upper Pleistocene, although red deer was generally more abundant during temperate stages (Lister 1984b, 1986). Molluscan remains from the channel recorded above include *Pisidium moitessieranum* (Whitehead 1989a), characteristic of slowly-flowing water. This is supported by the presence of deep-water hydrophytes, such as *Potamogeton paelongus* and *Groenlandia densa* and by the ostracod *Limnocythere sanctipatricii* (Whitehead *ibid*). Other molluscan taxa recorded from various parts of the the No. 5 terrace include *Valvata piscinalis* and *Bithynia tentaculata* (Whitehead 1989b) (both indicative of slowly-flowing water) and limited terrestrial species, including Succineidae sp. and *Pupilla muscorum*, indicative of relatively open conditions.

5.5.6. Biostratigraphy and correlation

Mammalian studies

Unfortunately, the low species diversity prevents any age being assigned to the Pershore deposits on the basis of mammalian biostratigraphy. The presence of red deer is not indicative of any particular stage, since it has been recorded from every post-Anglian interglacial, although horse indicates that the deposits must pre-date the Last Interglacial (Currant 1989b; Sutcliffe 1995a).

5.5.7. Discussion and conclusions

Evidence for the age of the Pershore interglacial deposits is derived primarily from its position within the Avon terrace system and comparisons with its equivalent in the Severn, at Bushley Green. The mammalian remains themselves are too limited to be of any assistance in pinpointing the precise age of the deposits. However, the presence of a *Hippopotamus* fauna of Last Interglacial age in No. 3 terrace, and of interglacial deposits attributed to Stage 7, underlying Terrace No.4 at Ailstone (Warwickshire) (Bridgland *et al.* 1989), lends support to an earlier age for the Pershore interglacial. This corresponds well with amino acid ratios which suggest a Stage 9 age for both Bushley Green and its equivalent at Pershore (Maddy *et al.* 1991).

5.6. WOLVERCOTE BRICK PIT, WOLVERCOTE, OXFORDSHIRE (SP 498105)

5.6.1. Location of the site

The village of Wolvercote lies approximately 3km to the north of Oxford, on the west bank of the River Thames, south of its confluence with the River Cherwell. A large channel revealed in Wolvercote brick pit during the latter part of the 19th century is reputed to contain "the most important Palaeolithic site in the Upper Thames Valley" (Wymer 1968, 87). It is difficult to determine the precise location and orientation of the Wolvercote Channel deposits from the early descriptions of the brick pit, although it was clearly present in the southern end of the pit (Bridgland and Harding 1986). Equivalent deposits reported from temporary exposures in Banbury Road (SP 503106) by Wymer (1968) suggest a west-east trend (Bridgland and Harding 1986) (Figure 5.18).

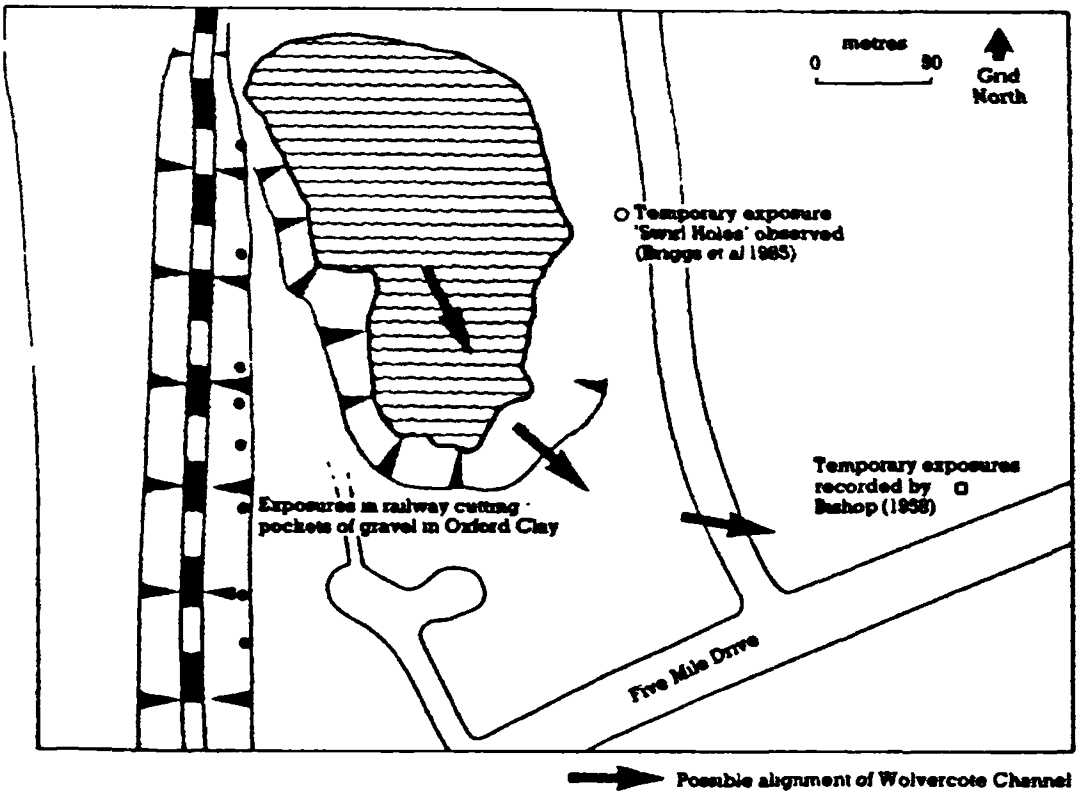


Figure 5.18 Map of the Wolvercote brick pit and the surrounding area, showing the possible alignment of the Wolvercote Channel (from Bridgland 1994).

5.6.2. History of research

Early reports of the Wolvercote Channel deposits and their contained molluscan and mammalian remains, plant macrofossils and extensive archaeological assemblage are provided by Bell (1894a, b, 1904), Pocock (1908), Sandford (1924, 1926) and Arkell (1947). Reviews of the archaeology are provided by Wymer (1968) and Roe (1981). Unfortunately, no extensive exposures of the deposits have been available since the 1930s and very little modern work has therefore been carried out. The pit is now an ornamental lake, surrounded by residential development, making reinvestigation difficult (Bridgland 1994). Temporary exposures were observed on the eastern side of the pit (Briggs *et al.* 1985; Tyldesley 1986) but an attempt to relocate the channel in a railway cutting immediately to the west revealed only Oxford Clay with pockets of gravel at the surface (Bridgland and Harding 1986). Nevertheless, despite the lack of opportunities for reinvestigation, various interpretations as to the age of the deposits have been put forward (Bishop 1958; Wymer 1968; Evans 1971; Shotton 1973a; Roe 1981; Briggs *et al.* 1985), with both Hoxnian and Ipswichian ages being proposed.

5.6.3. Geological background and provenance of mammalian remains

The Pleistocene succession in the Upper Thames may be divided into two parts (after Bridgland 1994) (Figure 5.19):

1. The older, high-level deposits of the pre-Anglian Northern Drift Group, which are devoid of calcareous clasts, and
2. More recent (*i.e.* post-Anglian) lower-level terrace gravels composed largely of local limestones.

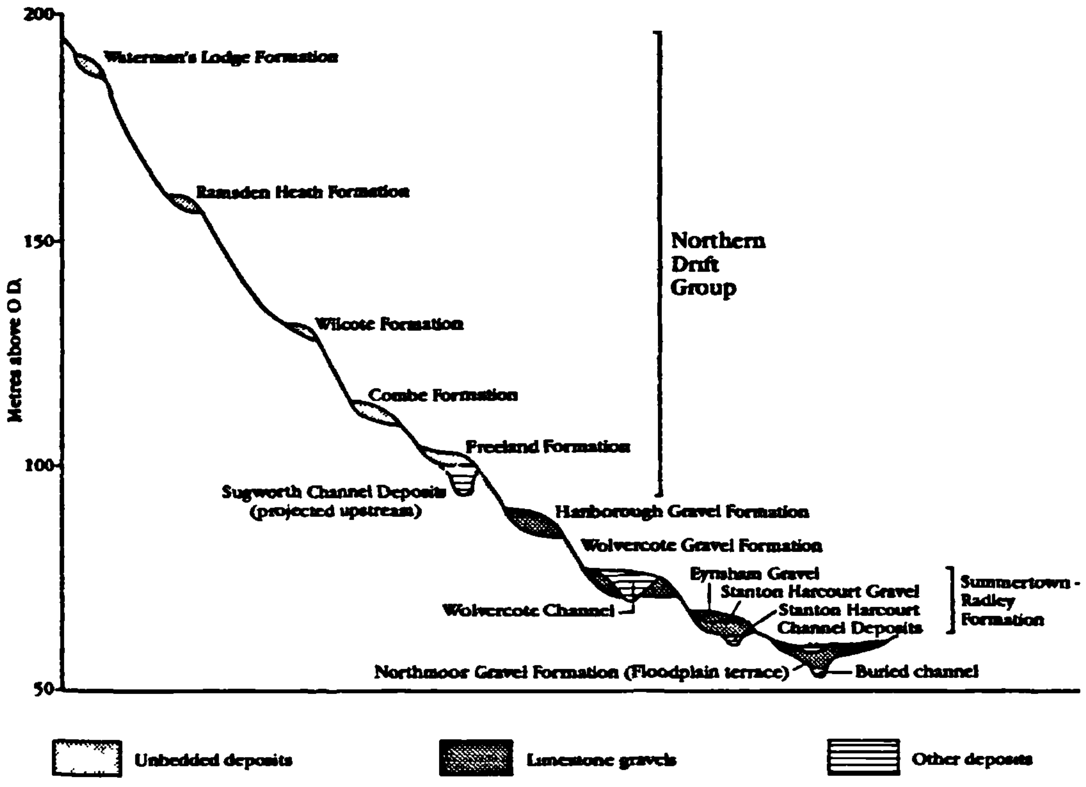


Figure 5.19 Idealised transverse section through the terrace deposits of the Upper Thames (from Bridgland 1994).

The Wolvercote Gravel Formation is thus the second oldest of the various limestone-rich terrace gravels, after the Hanborough Gravel Formation. The Wolvercote Gravel was originally suggested by Tomlinson (1929) and later Bishop (1958) to be the first deposit to contain fresh flint introduced into the basin by the glaciation of the Cotswolds. However, on the basis of comparisons of the Wolvercote Gravel with the higher Hanborough Gravel, later authors have concluded that the Cotswolds glaciation occurred between the aggradation of the two formations (Briggs and Gilbertson 1973; Briggs *et al.* 1985). The Cotswold glaciation had previously been correlated with the 'Wolstonian' (*i.e.* the British equivalent of the Saalian Stage) by Shotton (1973a, b), although re-evaluation of the sequence in the Midlands has suggested that the ice advance that reached the Cotswolds occurred during the Anglian (Sumbler 1983a, b; Rose 1987, 1989b) (see Chapter 2). This has evident implications for the age of the Wolvercote Formation, which remains extremely controversial. In addition, the veracity of the input of flint into the Upper Thames system between the Hanborough and Wolvercote Gravels has also now been called into question by Maddy *et al.* (1991), who see no justifiable basis for the separation of the Wolvercote Terrace from older terraces on lithological grounds.

Most recently, however, the Wolvercote Gravel has been equated with the Lynch Hill Gravel of the Middle Thames on the basis of downstream extrapolation of gravel profiles (Bridgland 1994).

The sequence at Wolvercote is summarised as follows (from Bridgland 1994) (Figure 5.20):

6. 'Warp sand', clayey-gravelly sand, yellow brown, in involutions, 1-2m

Wolvercote Channel Deposits, up to 4.5m and comprising:

5. Silt and clay, laminated
4. Peat, thin and localised within the base of Bed 5

Iron pan

3. Sandy gravel, current-bedded, with shells
2. Calcareous gravel, containing bones and artefacts

Wolvercote Gravel:

1. Bedded gravel, truncated by the channel deposits

Base: Oxford Clay

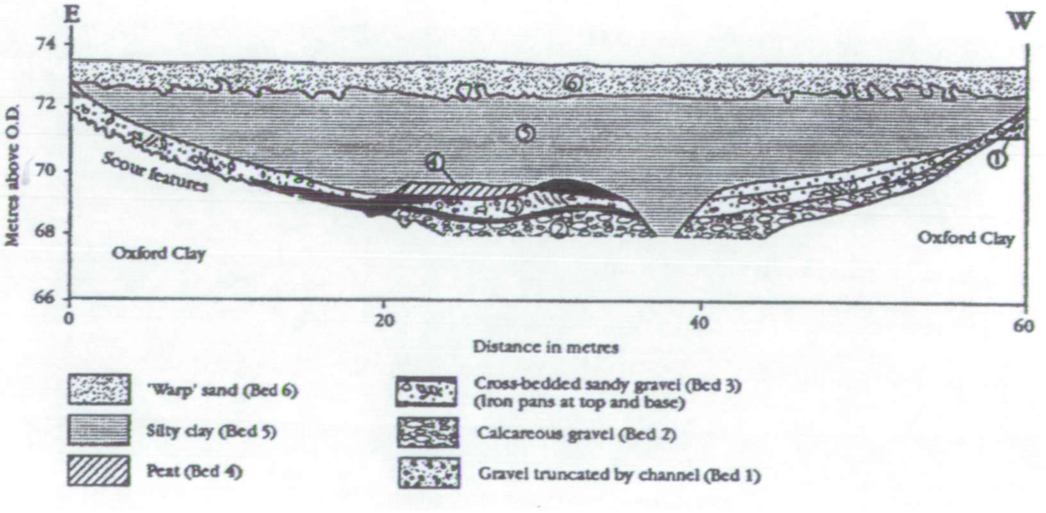


Figure 5.20 Section through the Wolvercote Channel (from Bridgland 1994, after Sandford 1924).

The gravel of Bed 1 is attributed to the Wolvercote Terrace by Sandford (1924), although Bishop (1958) considered this to be part of an older aggradation. The calcareous gravels (Bed 2), from which the mammalian bones and artefacts came, fill and overlie potholes or 'swirl-holes' in the surface of the Oxford Clay (Bell 1904; Sandford 1924; Arkell 1947). These have been interpreted as scour features. Sandford (1924) reported that many of the large vertebrate bones were found in gravel within these features. Bed 3 comprises a series of feruginous, cross-bedded sands and gravels. Certain layers, predominantly at the top and base of this unit, were cemented into iron pans. Between the iron pans, Sandford (*ibid*) recorded shelly sands and a clay lens, from which 17 species of Mollusca were recorded (Kennard and Woodward, in Sandford 1924). Bed 3 was separated from the main infill of the channel (Bed 5) by an erosive contact. A locally-present peat bed (Bed 4) at the base of Bed 5 was found to contain plant macrofossils and beetles (Bell 1894a, 1904; Reid 1899; Blair 1923; Duigan 1956). The channel sequence is capped by up to 2m thick of sand ('Warp sand') (Bed 6), showing signs of periglacial deformation which also penetrate into the top of Bed 5. This sand has been attributed to solifluction by most authors, although Sandford (1925) considered that it might result from decalcification of the underlying deposits.

5.6.4. Palaeontology

The following species list has been compiled from collections in the Manchester Museum and the Oxford University Museum. Labels on the Manchester material reveal that it was apparently collected in 1894 by Manning. Material from Oxford appears to have been collected around 1912. The present study has confirmed the presence of 7 species, to which may be added *Homo* on the basis of artefacts. The records of reindeer reported by Sandford (1924, 1925, 1926) were unable to be confirmed. Due to time constraints, only a species list was compiled and total specimen numbers per species were not counted. However, it was clear from examination of the material that the Wolvercote assemblage was dominated by horse (*E. ferus*) with red deer (*C. elaphus*) and large bovids also important.

Species list (Mammalia) from the Wolvercote Channel, Oxfordshire

Primates

Homo sp., indet. hominid (artefacts)

Proboscidea

Palaeoloxodon antiquus (Falconer and Cautley), straight-tusked elephant

Elephantidae sp., indet. elephant

Carnivora

Ursus indet. sp., bear

Perissodactyla

Equus ferus Boddaert, horse

Stephanorhinus hemitoechus (Falconer), narrow-nosed rhinoceros

Artiodactyla

Cervus elaphus L., red deer

Cervidae indet. sp., deer

Bos primigenius Bojanus, aurochs

? *Bison priscus* Bojanus, bison

Bovini indet. sp., large bovid (*Bos* or *Bison*)

5.6.5. Palaeoenvironmental and palaeoclimatic interpretation

The mammalian assemblage is considered to reflect still temperate but cooling conditions towards the end of an interglacial. This is based upon the presence of thermophilous species, such as *P. antiquus* and *B. primigenius* combined with species reflecting more open grassland conditions, such as *E. ferus*, which dominates the assemblage.

Plant macrofossils (Bell 1894a; 1904; Reid 1899; Duigan 1956) and coleopteran remains (Blair 1923) from Bed 4 indicate cool-temperate conditions (Duigan 1956), probably colder than at the time of deposition of Bed 2. This is based upon the occurrence of the arctic-alpine plant *Draba incana* (Duigan 1956), the northern weevil *Notaris aethiops* and mosses of cold climate affinities (Bell 1904). The cooling climatic conditions were also reflected in sparse pollen assemblages obtained (probably) from

Bed 5 (Briggs *et al.* 1985), which show a transition from pine-dominated forest to open conditions.

5.6.6. Biostratigraphy and correlation

The attribution of the Wolvercote Gravel to the 'Wolstonian' (that is to say, a post-Anglian, pre-Devensian cold stage, correlated with the continental Saalian), led to attribution of the temperate-climate channel deposits to the Ipswichian Interglacial (Shotton 1973a). This correlation was supported by Roe (1981), who believed that the technologically advanced nature of the Wolvercote palaeoliths indicated a Late Pleistocene age. This clearly contradicts the conventional interpretation of the terrace stratigraphy in the Upper Thames basin, which would place the Wolvercote Terrace and Channel earlier than the Summertown-Radley Terrace. A large body of evidence now exists which suggests that temperate stage deposits underlying the Summertown-Radley Terrace should be correlated with OIS 7 (6.11), consequently implying that the Wolvercote deposits pre-date this period. This conclusion was also reached by Kennard and Woodward (in Sandford, 1924) on the basis of molluscan biostratigraphical evidence. However, Sandford (1925, 1926, 1932) continued to view the Wolvercote Channel as younger than the upper part of the Summertown-Radley aggradation, a view that was also upheld by Dines (1946) and Arkell (1947), although the latter placed both within the Great (Hoxnian) Interglacial. Bishop (1958) and later Wymer (1968) believed the Wolvercote Channel to be of Hoxnian age, the former interpreting the Channel as a pre-Wolvercote Terrace feature.

Briggs (1976) presented four possible alternatives:

1. the channel post-dates the Wolvercote Gravel but pre-dates the Summertown-Radley aggradation.
2. the Wolvercote Channel immediately post-dates the upper Summertown-Radley aggradation.
3. the Wolvercote Channel is a pre-Wolvercote Terrace feature.
4. the Wolvercote Channel deposits are contemporaneous with the upper Summertown-Radley aggradation but were laid down in a steeply-sloping tributary valley and are therefore at greater elevation.

Of these, the first hypothesis is that which most closely follows conventional terrace stratigraphy by regarding the Wolvercote Channel as part of the Wolvercote Gravel Formation. It is thus inherently more likely than those models which favour complex sequences of erosion and aggradation (Bridgland 1994).

Mammalian studies

The mammalian evidence from the Wolvercote Channel is unfortunately not diagnostic of any one interglacial, since no biostratigraphically significant 'indicator' species are present. However, the abundance of *E. ferus* at the site strongly suggests that the Wolvercote Channel is not of Ipswichian age.

5.6.7. Discussion and conclusions

In the absence of sound biostratigraphical information, determination of the age of the Wolvercote deposits relies heavily upon the interpretation of the terrace sequence in the Upper Thames. Evidence for interglacial deposits of Stage 7 age lower down in the Upper Thames sequence strongly suggests that the Wolvercote Formation represents an earlier climatic cycle. If the interpretation of the Cotswolds glaciation as Anglian is upheld, the Wolvercote Channel deposits may therefore be accomodated within one of two temperate episodes between the Anglian (widely regarded as OIS 12) and the OIS 7 interglacial beneath the Summertown-Radley Terrace. Correlation of the Wolvercote Channel deposits with either Stages 11 or 9 is therefore possible.

However, the presence of reworked mammalian bones in the Hanborough Gravel indicates evidence of a post-Anglian temperate stage prior to that observed in the Wolvercote Channel. The Hanborough Gravel has been attributed to OIS 10 by Bridgland (1994) and since the Wolvercote Formation clearly post-dates the rejuvenation event that followed deposition of the Hanborough Gravel, correlation of the Wolvercote Channel deposits with Stage 9 (rather than 11) is proposed (Bridgland *ibid*). This is supported by terrace profiling between the Upper, Middle and Lower Thames, which correlates the Wolvercote Formation with the Lynch Hill Formation in the Middle Thames and the Corbets Tey Formation in the Lower Thames (Bridgland *ibid*).

5.7. BARLING, ESSEX (TQ 936893)

5.7.1. Location of the site

The village of Barling is situated approximately 500m south of the estuary of the River Roach, where it meets the sea near Foulness Island. The site is located in a gravel pit at Baldwin's Farm, Barling.

5.7.2. History of research

Very little published information exists concerning the history of research at the site, although collecting of mammalian remains apparently began early in this century (Southend Museum archival records). Several discoveries of handaxes have also been made (Wymer 1974, 1985).

5.7.3. Geological background and provenance of mammalian remains

The Barling gravel aggradation forms part of the sequence of terrace deposits classified by Wood (1866b) as 'East Essex Gravel'. These deposits primarily occupy the coastal area of eastern Essex between the estuaries of the Thames and Blackwater, although they are also present on Mersea Island and in the south-eastern corner of the Tendring Plateau (Bridgland 1994). The region is characterised by a series of gravel terraces descending south-eastwards towards the North Sea, which give way inland to higher, isolated hills capped by Bagshot Beds, Claygate Beds and frequently, high-level gravel remnants, which reach a maximum height of 76m O.D. at Hadleigh (Bridgland *ibid.*). Wood's original interpretation of the East Essex Gravels held them to be a dissected spread of marine shingle, formed in an embayment of the North Sea (Wood 1866b), although this was later dismissed by Whittaker (1889), who viewed them as a continuation of the gravels in the Lower Thames valley, laid down by a united Thames-Medway river. This was confirmed by Gruhn *et al.* (1974), who demonstrated that the gravels of this area represent the left-bank terrace deposits of a fluvial valley system whose eastern side has since been lost to the North Sea. Later remapping of the area by the Geological Survey divided the East Essex Gravel into 'Sand and Gravel of Unknown Age' (high-level deposits south of the Crouch) and four terraces, nominated 'Crouch

Terraces 1-4' - a reflection of their distribution either side of the modern Crouch estuary, rather than an implication of deposition by that river (Bristow 1985; Lake *et al.* 1986). A number of buried channels were also recognised beneath the terrace gravels by Lake *et al.* (1977), who attributed them to glacio-fluvial processes.

Recent reappraisal of these deposits (Bridgland 1980, 1983a,b, 1986, 1988) has recognised two gravel types within Wood's East Essex Gravel, based upon clast lithology and altitudinal distribution. They comprise an earlier 'High-level East Essex Gravel' series, composed almost exclusively of local and southern rocks, and a later 'Low-level East Essex Gravel', containing similar materials but with the important addition of a significant suite of exotic rocks, including *Rhaxella* chert, derived from the north and west (Bridgland 1994). Within each series, a number of separate terraces have been mapped (Figure 5.18).

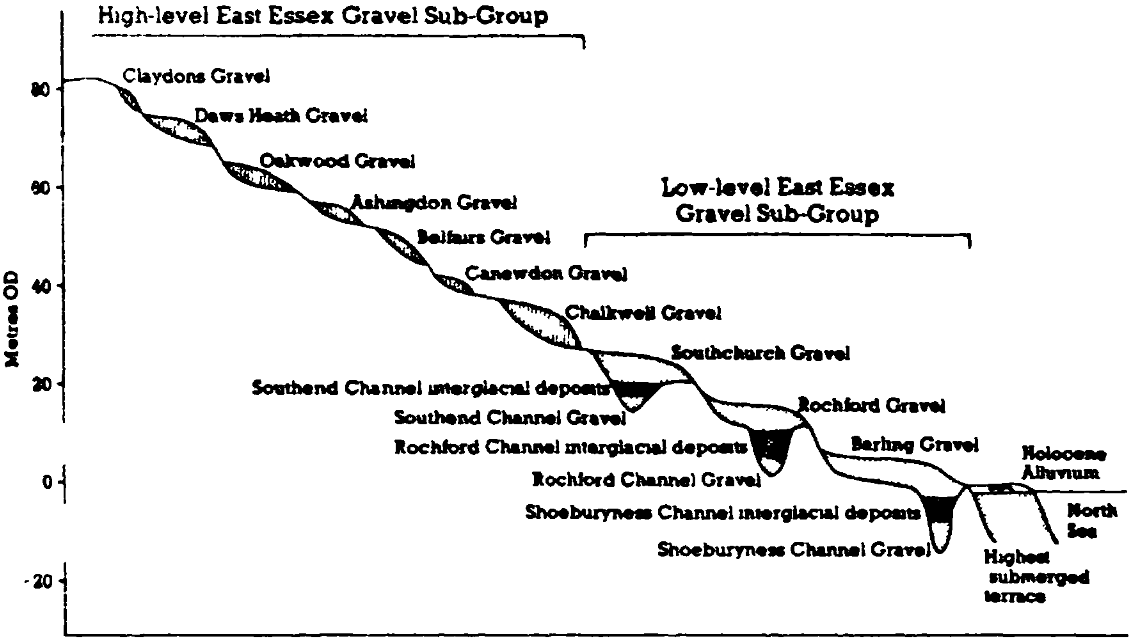


Figure 5.18 Idealised transverse section through the gravels of the Southend area (from Bridgland 1994).

The High-level East Essex Gravel is believed to be the product of an extended River Medway, laid down by that river at a time when the Thames flowed further north, prior to its diversion by Anglian ice (Bridgland 1988). The exotic lithology of the Low-level

East Essex Gravel, on the other hand, is identical to that found in the terrace deposits of the Lower Thames and thus clearly indicates deposition after the diversion of the Thames by a combined Thames-Medway (Bridgland *ibid*). As previously discussed in Chapter 2, the diverted Thames appears to have joined the pre-existing Medway valley in the area of the Thames estuary and then flowed northwards across eastern Essex, before rejoining its original pre-diversion course near Clacton (Bridgland 1980, 1983a,b, 1988, 1994). The abrupt compositional change between the High-level and Low-level East Essex Gravels provides an important stratigraphical marker, thanks to its causal link with the Anglian glaciation and the subsequent diversion of the Thames. Since the diversion of the Thames into the valley of the Essex Medway effected the change in eastern Essex from High-level (Medway) to Low-level (Thames-Medway) East Essex Gravel, the terrace gravels of the Lower Thames and the Low-level East Essex gravel must therefore be considered broad lateral equivalents (Bridgland 1988, 1994, 1995).

The buried channels first recognised by Lake *et al.* (1977) have also been the focus of recent reinterpretation (Bridgland 1980, 1983a, 1988, Bridgland *et al.* 1993; Roe 1994). Bridgland (1983a, 1988, 1994) has proposed the existence of three separate downcutting events, associated with two Low-level East Essex Gravel Formations, the Southchurch and Barling Formations. The older Southchurch Formation includes two channels, the Southend and Rochford Channels, whilst the younger Barling Formation contains only one, the Shoeburyness Channel. Each channel consists of basal gravels overlain by probable interglacial sediments (usually of apparently estuarine character) and capped by terrace gravels (Bridgland 1994). No equivalent of the Black Park/Dartford Heath Gravel has been found in the Southend area, possibly due to its steeper downstream gradient, which suggests that it may fall below the level of the Boyn Hill/Orsett Heath aggradation surface between London and Southend (Bridgland 1980, 1988). The Southchurch Formation has therefore been equated with the Orsett Heath Formation of the Lower Thames and with the Asheldham Formation of the Dengie Peninsula (Bridgland 1994, 1995). The oldest unit of the Southchurch Formation, the Southend Channel Gravel, has been traced as far northwards as Clacton and has thus been correlated with the Lower Orsett Heath Gravel, thought to have been deposited during OIS 12 (Bridgland 1988, 1994, 1995, Bridgland *et al.* 1993).

Previous work by Bridgland (1988) suggested the possibility that the temperate sediments of the Southend and Rochford Channels might therefore represent distinct interglacials, equating with OIS 11 and 9 respectively. However, it is now recognised that the Southchurch Formation is considerably more internally-complex than once realised and that the temperate deposits of the Southend and Rochford Channels probably reflect different parts of a single interglacial, namely that represented at Clacton and Swanscombe. The Southchurch Formation is consequently correlated with OIS 12-10 inclusive (Bridgland 1994, 1995).

The younger Barling Gravel Formation is now regarded as the equivalent of the Corbets Tey Formation of the Lower Thames by Bridgland (1994, 1995), thought to represent deposition during OIS 10-8. If the temperate deposits of the Shoeburyness Channel are therefore equated with OIS 9, the Barling Upper Gravel (from which the vast majority of the mammalian remains are derived) must represent OIS 8.

A single specimen of *Cervus elaphus* was recovered from *in situ* interglacial deposits below the Barling Upper Gravel, probably from Barling Hall Pit in the 1980s (D.R. Bridgland pers. comm.). The age of these interglacial deposits has yet to be established, since they may be part of either the Southchurch Formation (Rochford Channel - Stage 11?) or the Barling Formation (Shoeburyness Channel - Stage 9?).

The specimen of *C. elaphus* is dark brown in colour and very well-preserved. The remaining material from the Barling Upper Gravel is extremely poorly-preserved, all of it showing signs of significant rolling and abrasion. The paucity of complete bones and teeth is notable.

5.7.4. Palaeontology

The following species lists have been compiled from material in Southend Museum and in the Natural History Museum, London. Red deer, represented by a single specimen, is the only large mammal recorded from the Shoeburyness Channel. Small mammal remains from boreholes in the Barling area, include wood mouse *A. sylvaticus* and an indeterminate vole (*Microtus* sp.) (H.M. Roe pers. comm.). These may also be from the

Rochford or Shoeburyness Channels. Seven species have been confirmed from the Barling Upper Gravel from 243 specimens.

Species List (Mammalia) from interglacial deposits below the Barling Upper Gravel (Rochford or Shoeburyness Channels), Essex

Artiodactyla
Cervus elaphus L., red deer

Species List (Mammalia) from the Barling Upper Gravel, Essex

Proboscidea
Palaeoloxodon antiquus (Falconer and Cautley), straight-tusked elephant
Mammuthus primigenius (Blumenbach), woolly mammoth
Elephantidae sp., indet. elephant
Perissodactyla
Equus ferus Boddaert, horse
Rhinocerotidae sp., indet. rhinoceros
Artiodactyla
Cervus elaphus L., red deer
Cervidae sp., indet. deer
? *Bos primigenius* Bojanus, aurochs
Bison priscus Bojanus, bison
Bovidae sp., indet. large bovid (*Bos* or *Bison*)

Table 5.4 below provides a breakdown of the species list from the Barling Upper Gravel into numbers of specimens per species, also expressed as a percentage of the total mammalian assemblage from the site. Minimum numbers of individuals have also been calculated.

Species	Number of specimens	Percentage of total assemblage (%)	Minimum number of individuals (M.N.I.)
Proboscidea			
P. antiquus	2	0.82	1
M. primigenius	118	48.55	2
Perissodactyla			
Equus ferus	55	22.63	7 (1 juv., 6 adults)
Rhinocerotidae sp.	4	1.64	1
Artiodactyla			
C. elaphus	40	16.46	8 (1 juv., 7 adults)
Cervidae sp.	2	0.82	1
? *B. primigenius*	4	1.64	1
B. priscus	2	0.82	1
Bovidae sp.	16	6.58	2

Table 5.4 Breakdown of the mammalian species list from the Barling Upper Gravel, showing numbers of specimens per species, the percentage of the total assemblage per species and minimum numbers of individuals.

5.7.5. Palaeoenvironmental and palaeoclimatic interpretation

The single record of *C. elaphus* from beneath the Barling Upper Gravel cannot confirm or otherwise the inferred temperate nature of the deposits, since this species has been recovered from both cold and warm stages in the Middle and Late Pleistocene. The record of *A. sylvaticus* however, is a much better indication of interglacial conditions, although the identity of the channel deposits from which it was recovered is uncertain.

The mammalian remains from the Barling Upper Gravel are dominated by *M. primigenius* (48.55% of the assemblage), with significant numbers of *E. ferus* (22.63 %) and *C. elaphus* (16.46). These species would suggest a cooler, more open environment with abundant grazing. The two extremely worn and abraded molar fragments of *P. antiquus* are clearly derived from an earlier deposit and thus have little bearing on the climate at the time of deposition of the Upper Gravel.

5.7.6. Biostratigraphy and correlation

Mammalian studies

The mammalian remains from the channel deposits underlying the Barling Upper Gravel are unfortunately not diagnostic of any particular interglacial and could therefore relate to any post-Anglian temperate stage. Few correlatives exist for the mammalian assemblage from the overlying Barling Upper Gravel, since cold stage assemblages are so poorly known in Britain. Mammalian remains from the putative Stage 8 gravel at Botany Pit, Purfleet, include a similar combination of horse, red deer and large bovids, although mammoth was not recorded from this very small aseemblage (5.1). Examination of the woolly mammoth remains from Barling suggests that they represent a fully-evolved morphotype with thinly-spaced lamellae, although the fragmentary nature of the material prevented any measurements being carried out.

5.7.7. Discussion and conclusions

Having considered the available evidence, it is tentatively suggested that the mammalian remains (including woolly mammoth (apparently a fully-evolved morphotype), horse, red deer and large bovids) from the Barling Upper Gravel may represent one of the few Stage 8 assemblages known in Britain. This is on the basis of the correlation of the Barling Gravel Formation with the Corbets Tey Formation of the Lower Thames by Bridgland (1994, 1995), thought to represent deposition during OIS 10-8. The underlying temperate channel deposits may equate with either OIS 11 or 9, although nothing in the scarce mammalian assemblage can confirm this.

5.8. Summary of evidence from the "Stage 9 interglacial"

The mammal fauna of the Stage 9 interglacial is differentiated from that of the preceding Hoxnian interglacial by the absence of the small mammal Hoxnian indicator species: *Talpa minor*, *Trogontherium cuvieri* and *M.* (*T.*) *subterraneus*. *Ursus arctos* has replaced the Hoxnian *Ursus spelaeus*, *Oryctolagus cuniculus* is apparently absent and the fallow deer from deposits of this age are tentatively referred to the modern *D. d. dama*, as opposed to *D. d. clactoniana*. The Stage 9 interglacial also witnesses the first occurrence in Britain of *Crocidura* cf. *leucodon* and *Alces* cf. *alces*. The Stage 9 mammal fauna is further differentiated from that of the Hoxnian by the abundant presence of *Neomys browni*, the presence of *Arvicola cantiana* with a slightly more advanced enamel morphology and fewer specimens displaying the ancestral *Mimomys* fold, and the presence of *Crocuta crocuta*. *Panthera leo* was apparently extremely rare during this time period, with only a single record known from the Cauliflower Pit at Ilford (see Chapter 8).