

CHAPTER 6

THE PALAEOENVIRONMENTAL POTENTIAL OF ARCHAEOLOGICAL SECONDARY CONTEXTS

1. INTRODUCTION

The preceding two chapters have been primarily concerned with the lithic component of archaeological data from fluvial secondary contexts. However, the evidence from many British Pleistocene sites indicates that fluvial sediments are capable of yielding a wide range of palaeoenvironmental data (Briggs *et al.* 1985, 1990; Keen 1990; Bridgland 1994; Preece 1995; Conway *et al.* 1996; Howard *et al.* 1999; West 1999; Roe 2001; Schreve 2001a; *et al.* 2002; & Bridgland 2002). The focus of this chapter is therefore an assessment of the potential for the palaeoenvironmental reconstruction of Middle Pleistocene fluvial landscapes from secondary context data sets. This assessment is not simply an identification of the main categories of biological data and a highlighting of their potential applications (previously and comprehensively documented elsewhere, e.g. Lowe & Walker 1997; Evans & O'Connor 1999; Dincauze 2000), although these issues are summarised here. The key theme addressed in this chapter concerns the spatio-temporal resolution of these palaeoenvironmental data sets and the mapping of them against the varying scales of early human behaviour in time (e.g. an afternoon's knapping activity, a seasonal settlement, or ten generations of sustained occupation) and space (e.g. throughout regional river systems, around a river estuary, or within the micro-environment of a floodplain backwater). This highlights the fundamental question of whether palaeoenvironmental reconstructions are *relevant* to the discussion of hominid behaviour or whether spatio-temporal associations between these data sets (biological and 'archaeological') simply cannot be demonstrated for secondary contexts.

The chapter does not focus upon a specific case study locality (unlike chapters 2 and 4), since the goal is to assess the generic potential of these data sets. A initial review of the extant literature (e.g. Keen 1990; Bridgland 1994; Preece 1995; Lowe & Walker 1997; Evans & O'Connor 1999; West *et al.* 1999; Coope 2001; Schreve 2001a, 2001b, & Thomas 2001, *et al.* 2002; Thomas 2001) indicates the major (vertebrates, coleoptera, non-marine molluscs, ostracods, and pollen) and minor (chironomids and testate amoebae) categories of biological evidence that can occur within fine-grained and organic deposits, sandwiched within fluvial sedimentary sequences (the archaeological secondary contexts of this project). The overall significance of these data for palaeoenvironmental reconstruction and as Pleistocene biostratigraphical markers is reviewed in Section 2. The relative potential of the different data sources is also assessed on the basis of their frequency of occurrence in the geoarchaeological record and the logistics of sampling and sample processing (Section 3). The modelling of the data's spatio-temporal resolutions (Section 4) stresses the physiological behaviour of the floral and faunal species, issues of secondary context site formation (also discussed in Chapters 2, 5, and 7), scales of hominid behaviour and the current range of research questions prevalent in Palaeolithic studies (e.g. models of colonisation and occupation; land-use and subsistence behaviour; 'single' behavioural episodes).

It is recognised that in many instances the occurrence of biological data is more often associated with fine-grained, temperate climate sediments (e.g. at Purfleet (Schreve *et al.* 2002)) than with coarse-grained, cold climate sediments. Nonetheless, it is stressed that all of these deposits fall under the definition of secondary contexts as outlined in the original project design:

⁷ 'Archaeological' is used here to refer to the cultural debris of hominid activity (e.g. stone tool technology).

*“For the purposes of this project, **secondary contexts** are defined as fluvial aggregate deposits situated on river terrace and river floodplain landforms. These deposits incorporate gravels, sands, silts and clays. These fluvial aggregate deposits in secondary contexts are hereafter referred to as secondary contexts.”*

(Hosfield 2002: 3)

Specifically therefore, this assessment of the potential of palaeoenvironmental data from archaeological secondary contexts explores four themes:

- The identification of biological data sources with the potential for reconstructing riverine palaeoenvironments.
- The relative potential of the different data sources, based on the frequency of their occurrence within the geoarchaeological record and the logistics of sampling and sample processing.
- The spatio-temporal resolution of the different biological data sources, mapped against different scales of hominid behaviour.
- The relationships between palaeoenvironmental data and the current questions prevalent in studies of Pleistocene hominids.

2. BIOLOGICAL DATA SOURCES

Biological data sources cover a wide range of types, including vertebrates, coleoptera, non-marine molluscs, ostracods, pollen, chironomids, and testate amoebae (e.g. Stuart 1982; Keen 1990; Bridgland 1994; Preece 1995; Lowe & Walker 1997; Evans & O'Connor 1999; West *et al.* 1999; Coope 2001; Schreve 2001a, 2001b, & Thomas 2001, *et al.* 2002; Thomas 2001). These are summarised here in turn.

2.1 Vertebrates

Vertebrate fossils are a diverse data set, encompassing the remains of large (macrofauna) and small (microfauna) mammals, birds, fish and reptiles. In comparison with other lines of palaeoenvironmental evidence, vertebrate remains are the most durable, with preservation possible in all but the most acidic soils. As such, vertebrate remains have been recovered from a variety of Quaternary contexts, including cave sediments, lacustrine and marine sediments, fluvial sediments (in particular river terrace sequences), and peat bogs (Lowe & Walker 1997).

The depositional environment inevitably influences the way in which palaeoenvironmental data are extracted from vertebrate assemblages. In low energy settings, such as lacustrine sediments, there is a greater possibility of micro-fossil material (e.g. fish and amphibians) being preserved, which are considered to be highly representative of the local environmental conditions. While the remains of larger mammals can also be recovered from lacustrine settings, these are most likely to represent animals that have drowned after becoming trapped in the lake bed (Coope & Lister 1987). In contrast, higher energy contexts, such as fluvial deposits, can represent a more diverse bio-spatial catchment, although fish and amphibian remains are still generally considered to represent the immediate environmental conditions, and can often dominate assemblages. Large mammal remains are relatively common, though often as single bones rather than articulated skeletons, and their physical condition can provide an indication of their taphonomic history (Shipman 1981). Small mammal remains are common within a range of Pleistocene sediments. Waterside species can provide valuable palaeoenvironmental data of local significance, although Mayhew (1977) has suggested that their population numbers can be artificially inflated by predator accumulation of their remains. Finally, their rapid evolution during the Quaternary promotes their usage as biostratigraphical markers.

Due to the diversity of vertebrate data, the palaeoenvironmental reconstructive potential of each of the main classes of vertebrate remains will be considered in turn:

2.1.1 Mammalian Evidence

Mammalian remains are of prime palaeoenvironmental and biostratigraphic significance due to the rapid turnover of many mammalian lineages (the origination and extinction of species) and the quantifiable evolutionary trends exhibited by many of these lineages during the Pleistocene (Lister 1992; Schreve & Thomas 2001). Additionally, mammalian evidence can be used to track the repeated climatic changes that affected Europe during the Pleistocene:

“The intensive and repeated environmental changes that affected Europe during this period led to major disruptions in the geographical distributions of mammalian species, thereby providing the potential for each successive climatic cycle during the late Middle Pleistocene to give rise to a different suite of mammals”

(Schreve 2001b: 1693)

Inferences about palaeoclimate are based on the known distributions of extant species, and their climatic and habitat preferences and tolerances. For example, during the Last (Ipswichian) Interglacial species such as *Hippopotamus amphibius*, *Emys orbicularis* (pond tortoise) and *Crocidura* cf. *suaveolens* (lesser white-toothed shrew) were all present in southern Britain. Currently the hippopotamus is known only in tropical Africa, the pond tortoise in the Mediterranean and southeast Europe and the lesser white-toothed shrew from southern Europe (Stuart 1979), hence the presence of these species in Britain during the Last Interglacial suggests that the climate was warmer then than it is today.

As the life spans and associated climatic and environmental sensitivities of large and small mammals operate on very different scales (and therefore data resolutions) mammalian assemblages are commonly divided on size grounds.

1. Large Mammals: large mammals, identified to species level, will provide relatively gross information about regional climate and habitat (Dincauze 2000). Generally, large mammals are more tolerant of environmental change and require less locally specialised habitats than small mammals. The ranges of large mammals typically cover much larger geographical areas than those of small mammals, and may encompass several micro-habitats, leading to the generation of much more generalised palaeoenvironmental reconstructions.

The reproductive cycles of large mammals are much slower than those of small mammals, and are therefore correspondingly slower to demonstrate evolutionary diversity. However, large mammals can also be used provide information about the age of the site they were recovered from. Certain species, referred to as ‘indicator species’, are known to only be present in certain locations (e.g. Britain) at certain times. For example, within Britain, the cave bear species *Ursus spelaeus* and *Dama dama clactoniana*, a large subspecies of fallow deer, are unique to the first post-Anglian interglacial (Schreve 2001b).

From a taphonomic perspective the bones of large mammals are more likely to survive fluvial transportation than those of small mammals. However, while this increased survival potential means they are perhaps more likely to be recovered, it can also mean that this recovery may take place some distance from the location (and therefore the habitat and environment) where the animal lived and died. And as with all sources of palaeoenvironmental data, serious consideration must be given to the depositional context and associated degree of derivation large mammal assemblages have been subjected to.

2. Small Mammals: small mammal remains (e.g. Sutcliffe & Kowalski 1976), in particular those of rodents, are commonly recovered from Pleistocene sites and are regarded as providing palaeoenvironmental data at a higher resolution than that obtained from large mammals. The environmental tolerances of small mammals are much lower than those of large mammals, therefore small mammal remains can be utilised in local palaeoenvironmental reconstructions. Small mammal remains are also unaffected by human or large carnivore predation and therefore assemblages are considered to be more representative of environmental and climatic factors than

those of larger mammals.

Due to their size and perceived fragility, small mammal remains do not survive fluvial transportation, and generally therefore when they are recovered from Pleistocene contexts they are not considered to have travelled far from their original (death) location. Species lists of small mammals recovered from a site can therefore provide a means of determining what local environmental condition(s) and habitat(s) prevailed.

2.1.2 Birds, Fish & Reptiles

Bird bones are extremely fragile, and do not survive well in either fluvial or lacustrine deposits. Their remains are not commonly recovered from Pleistocene contexts and this may simply reflect their fragility, or rather a historical research bias towards mammalian remains. Where present, and identifiable to species level, avian fossils can assist in broad palaeo-environmental reconstructions on the basis of the presence of 'warm' or 'cold' climate species (Lowe & Walker 1997). Fish remains are also extremely fragile, though when recovered from aquatic Pleistocene sites they can provide detailed palaeoenvironmental information, as the species recovered provide an indication of both aquatic temperature and flow conditions. Herpetofaunal (reptilian) remains have not commonly been recovered from Pleistocene contexts, due to the dominance of fluvial sediments. The nature of the depositional environment greatly affects the herpetofauna, and few European reptilian (or amphibian) species are associated with large rivers, suggesting that Quaternary fluvial sediments are unlikely to preserve herpetofauna.

2.1.3 Summary of vertebrate remains

This brief review highlights the biological diversity and different data resolutions preserved in vertebrate remains. As a general rule of thumb, the larger the vertebrate the coarser the palaeoenvironmental data that they preserve. There has been an increasing realisation that rather than relying on single proxy lines of evidence, for example large mammals, palaeoenvironmental reconstructions and biostratigraphies are more robust when they incorporate multi-proxy lines of evidence. Each class of vertebrate remains represents a different biological scale of resolution, and by combining the environment(s) indicated by as many classes of data as are available, reconstructions are more likely to be representative of the mosaic nature of genuine environments.

2.1.4 Multi Proxy approaches and MAZ

A multi-proxy approach also enhances the robusticity of biostratigraphic interpretations. The development of distinctive suites of chronologically discrete animals by Schreve (1997, 2001a, 2001b, 2002), rather than a reliance on the presence or absence of single indicator species, has enhanced the applicability and resolution of mammalian biostratigraphy.

Mammalian biostratigraphy has long been applied to Pleistocene assemblages. The extensive climatic and geographical changes which occurred in Britain during the Pleistocene would have had a major impact on faunal migratory behaviour. Potentially, each successive climatic cycle within the Middle Pleistocene could have generated a different and unique suite of mammals. Early biostratigraphies (e.g. Curren 1989; Sutcliffe 1976) demonstrated that the mammalian record preserved evidence of three post-Anglian interglacials, more cycles of climatic change than had been previously acknowledged within the original terrestrial sequences of Britain as proposed by the Geological Society (Mitchell *et al.* 1973).

During the 1990's the marine oxygen isotope record confirmed the biostratigraphic observation that the degree of cyclical climatic change undergone during the Quaternary was greater than had transitionally been acknowledged. Terrestrial evidence for four post-Anglian interglacials within the British sequence is now widely accepted (Bowen *et al.* 1989) and the correlations between the MIS record and the terrestrial record continues to be enhanced, particularly through analysis of fluvial terrace sequences (e.g. Bridgland *et al.* 1989; Maddy *et al.* 1991, 1995; Bridgland 1994). These terrace sequences, in particular those of the Thames which are well dated and fossil-rich, provide a chronological framework within which to apply relative dating techniques such as the identification of chronologically discrete faunal suites.

Examination of mammalian assemblages recovered from the Thames terrace deposits by Schreve (2001b) has led to the identification of three distinctive temperate-climate assemblages, referred to as mammalian assemblage zones (MAZ's) and believed to correspond with three discrete climatic cycles between the Anglian glaciation (MIS-12) and the Ipswichian Interglacial (MIS-5e). It is suggested that these MAZ's correspond with marine isotope stages 11 (the Swanscombe MAZ), 9 (the Purfleet MAZ) and 7 (the Ponds Farm/Sandy Lane (Aveley) MAZ) — Figure 225.

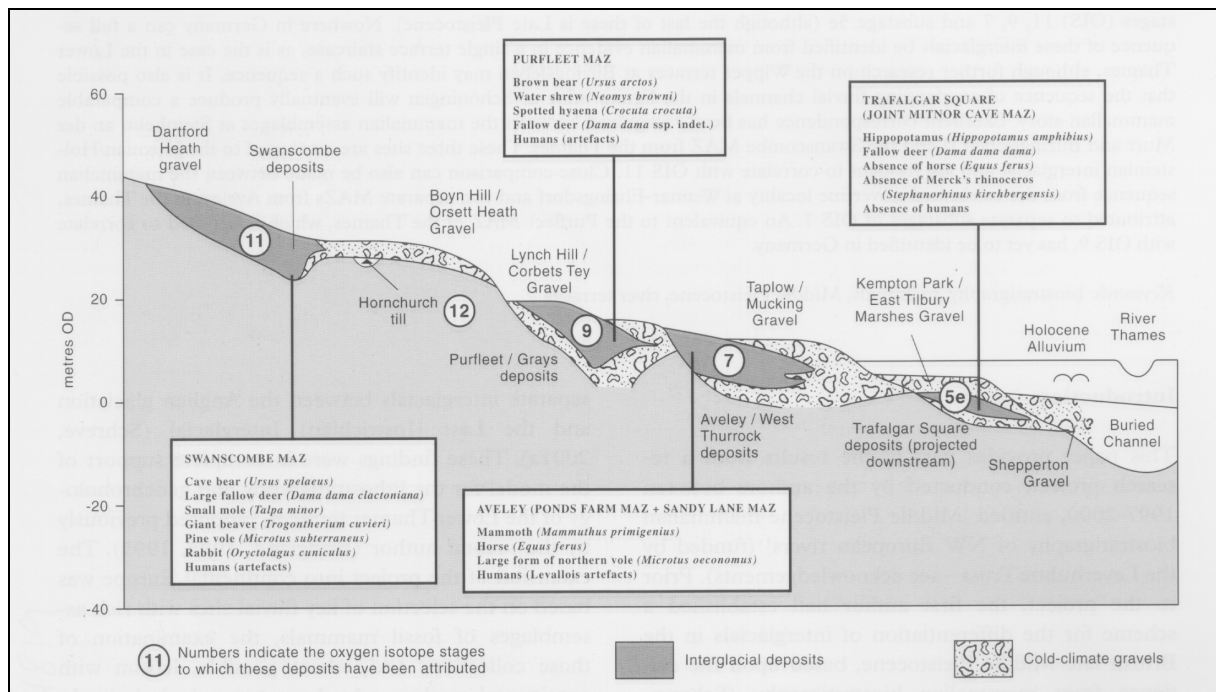


Figure 225: selected mammalian assemblage characteristics and their attribution to MAZs (Schreve & Bridgland 2002: Figure 1)

Each of the MAZ's has been identified on the basis of a series of consistent multi-species correlations. Each of these mammal assemblage zones can therefore be clearly separated from each other and from assemblages of the Last Interglacial. They represent a move away from previous reliance on single 'indicator' species and are therefore a more robust modelling technique, less prone to excavation- or recovery-related distortions. The recognition that discrete MAZ's can be identified for each interglacial provides a means of independently dating faunal assemblages from sites outside of the Thames terrace sequence in which they were originally identified. This wider applicability of the MAZ's has been demonstrated by Schreve & Bridgland (2002) in a recent analysis of key German fluvial assemblages. Correlation between the British and German sequences had previously proved problematic, as the German fluvial sequence is not preserved in the classic staircase formation of the Thames terraces, but rather fluvial gravels are instead preserved as isolated remnants. Schreve & Bridgland's (*ibid.*) examination of the faunal assemblages recovered from key German localities such as Steinheim, Bilzingsleben and Thüringen showed strong similarities with the MAZ's identified within the Thames. This correlation indicates that these faunal groupings are both robust and widely applicable within similar latitudes. In addition to providing corroboration to the MAZ methodological groupings, this study has also facilitated independent dating of highly significant German Pleistocene localities, for example on the basis of excellent correlation with the Swanscombe MAZ both Steinheim an der Murr and Bilzingsleben II have been attributed to MIS-11, the Hoxnian/Holsteinian interglacial (*ibid.*).

Detailed analyses of the faunal assemblages from Swanscombe and Aveley (both located in the Lower Thames valley) by Schreve (2001b) have shown that the mammalian record can be used to identify environmental and climatic oscillations within single interglacial events. Despite their differences in age (Swanscombe is assigned to MIS-11, and Aveley to MIS-7), both sites and therefore both interglacial

stages, show consistencies in their patterns of environmental progression (*ibid.*). An example of this progression is outlined below with reference to Swanscombe.

The Swanscombe sequence clearly represents the first post-Anglian temperate event, but has also been the subject of debate regarding the actual number of climatic events preserved (King & Oakley 1936; Evans 1971; Mullenders, in Wymer 1974; Hubbard 1982; Conway *et al.* 1996). Bridgland (1994) considers that the entire Swanscombe sequence represents a single interglacial (MIS-11), a view supported by both shell aminostratigraphy (Bowen *et al.* 1989) and mammalian evidence (Schreve 2001b). However, within this single interglacial, a series of five small-scale, intra-stage climatic oscillations can be identified. This includes three temperate events, delineated by cold phases as indicated by depositional hiatuses or lithology (*ibid.*). During the first depositional break multi-proxy evidence suggests sea levels low enough to reconnect Britain to the Continent and this is reflected in a marked faunal change above and below this horizon.

The Lower Gravel and Lower Loam are considered to represent the earliest warm episode (Phase I) within MIS-11, with mammalian fauna indicating fully temperate, mixed or deciduous woodland and open grassland habitats. *Dama dama clactoniana*, a woodland indicator species, dominates during this phase of the interglacial (Schreve 2001b). The sequence then preserves evidence of a significant hiatus in fluvial deposition, low sea levels and Continental reconnection (Zeuner 1959; Conway 1969). Within the Lower Middle Gravel the fauna is of the 'Rhenish' type and has been considered to indicate fluvial exchange between the Thames and the Rhine. The fauna of the Lower and Upper Middle Gravels is associated with the second warm phase (Phase II) and indicates temperate conditions, but of a more open nature. This is attested to by the pronounced decrease in woodland indicator species such as fallow deer, coupled with an increase in open species such as *Equus ferus* (horse) (Schreve 2001b). The Phase II deposits are followed by the cold climate Upper Sands (Phase IIIb). The fauna from temperate Phase III remain unknown at this time. In summary therefore, the Swanscombe sequence was laid down during a single interglacial, correlated to MIS-11. Both lithostratigraphic and mammalian evidence indicate multiple temperate events. Mammalian evidence indicates the change between Phase I and Phase II to more open conditions, perhaps reflecting increasingly continental climatic conditions brought about by the marine transgression.

It can therefore be demonstrated (Schreve 2001b) that not only does mammalian evidence allow the distinction between different interglacials during the Middle Pleistocene, they can also be used to distinguish environmental and climatic oscillations within them. The interglacials of MIS-11 (Swanscombe) and MIS-7 (Aveley) both demonstrate fully temperate, wooded conditions, followed by a period of temperate, open grassland habitats. At both locations two (possibly three) distinct warm episodes can be recognised, though it currently remains unclear whether some of these phases should be considered as amalgamations (*ibid.*). Mammalian evidence can therefore be demonstrated to display intra-stage variability, and can be utilised as a proxy chronology.

2.1.5 Conclusions

Mammal assemblage zones provide a detailed means of correlating the faunal assemblages from multiple sites. As they rely on the conglomeration of multiple mammalian species (both large and small) they provide a more robust set of climatic and chronological indicators than single indicator species. It can be demonstrated that the discrete MAZ's identified were present not only within the Thames valley (e.g. Schreve 2001a) and other major British river systems (Bridgland & Schreve 2001) but they can also be identified within continental Europe (Schreve & Bridgland 2002). As these discrete assemblages have been demonstrated for each interglacial (Schreve 2001a), their wider European presence can therefore provide a means of correlation and an independent dating technique (e.g. Koenigswald & van Kolfschoten 1996). Finally, mammalian evidence, as demonstrated by Schreve (2001b) can also be utilised to examine the terrestrial record for evidence of the small scale climatic oscillations present in the MIS record, potentially providing independent chronological schemes.

2.2 Coleoptera

Coleoptera (beetles) are one of the most diverse groups of macroscopic invertebrates occurring in Quaternary deposits (Lowe & Walker 1997: 192; Evans & O'Connor 1999: 140). They are the most important of the insect orders, with over 300,000 known species, of which 3,800 occur in Britain alone (Lowe & Walker 1997: 192). They occupy all of the planet's biomes except for the sea (although some do occur within the inter-tidal zone), and can be found in the vast majority of freshwater and terrestrial ecological niches (Evans & O'Connor 1999: 140). Fortunately, several aspects of coleoptera aid their usage in palaeoenvironmental research (Lowe & Walker 1997; Evans & O'Connor 1999; Coope 2001):

- Beetles, like other insect species, have remained morphologically constant throughout the last two million years of the Quaternary period (Lowe & Walker 1997: 194–195; Coope 2001: 1718).
- Evidence from living and fossil beetle assemblages suggests that the ecological preferences of the majority of species also underwent relatively little change during the Quaternary. This is indicated in Britain by the similarity of warm-adapted insect assemblages from different interglacials, widely separated in time (Lowe & Walker 1997: 195). Indirect geological and palaeobotanical evidence also suggests that the majority of fossil beetle species were associated with similar types of environments to those that they occupy in the present (*ibid.*: 195). Therefore, the coleoptera appear to demonstrate physiological stability during the Quaternary (*ibid.*: 195; Coope 2001: 1718).
- The complexity of the fossil enables identification to the level of the species (Coope 2001: 1718). Dead beetles disintegrate into the component parts of the exoskeleton: the head, thorax, elytra (wing cases), legs and abdominal sclerites. The first three of these are both robust enough for common preservation and variable enough to enable identification to a high degree (Evans & O'Connor 1999: 140).
- Many species of beetle are stenoptic, showing marked preferences for very restricted environmental niches or conditions (Lowe & Walker 1997: 192; Evans & O'Connor 1999: 140).
- Beetle species change their geographical ranges on a large scale and extremely rapidly in response to environmental changes, especially those of the thermal climatic (Lowe & Walker 1997: 192; Coope 2001: 1718).
- They are not readily eroded from one deposit and re-deposited in another. This is due to the fact that the fossil insect cuticle is readily attacked and destroyed by bacteria and fungus, and so coleoptera are rarely found as derived fossils (Coope 2001: 1718).

The classical application of coleopteran fossils has been in the fields of palaeoenvironmental and palaeoecological reconstruction, with particular emphasis upon climatic change (Lowe & Walker 1997: 196–199; Evans & O'Connor 1999: 141; Schreve & Thomas 2001: 1580). The morphological and physiological stability of beetles enables the present day ecological requirements and preferences of different species to be used in palaeoenvironmental reconstructions. However, there are exceptions to the rule of morphological and physiological stability. *Hypnoides rivularis* (Gyll) has its modern southern limit across Fennoscandia at about 60°N, yet occurs in several British sites (including the Lateglacial Windermere Interstadial) in association with temperate species (Lowe & Walker 1997: 195). In such cases, it is possible that the species has changed its ecological tolerances and could therefore be misleading as a palaeoenvironmental indicator if and when found in isolation. The importance of examining the association of species within the total assemblage is therefore stressed, not least because of the varying mobility of different beetle species. Some taxa are relatively sedentary and therefore provide small-scale data, while others are highly mobile and may therefore be incorporated into alien assemblages (Evans & O'Connor 1999: 140).

Overall however it is clear that for many species, their geographical ranges correspond with well-defined climatic zones and especially with summer temperature thresholds. Those species with narrower (stenotherms) rather than broader (eurytherms) ranges of climatic tolerance are inevitably more important in palaeoclimatic research as they enable more precise climatic inferences to be made (Lowe & Walker 1997: 196). The use of beetles as climatic proxies is not without difficulties however, since it can never be definitively established that a species has colonised the entire climatic range for which it is suited, or that

past distributions were wholly in equilibrium with the prevailing climatic conditions. Coope (1977) however has argued that the speed and scale of changes in species' geographical distributions (in response to climatic change) during the Quaternary indicates that coleoptera were able to colonise new, available habitats extremely quickly. Therefore, where species' range limits coincide with climatic boundaries, the relationship has been used to derive quantitative palaeotemperature estimates.

A second major problem concerns the potential for fossil assemblages to contain species representing a variety of different climatic ranges. Coope (1987) has shown that British assemblages may consist of species falling into eight different categories, ranging from Southern European to Eastern Asiatic. The conversion of these complex assemblages into palaeoclimatic information has relied primarily upon two methods:

- The range overlap method. The modern geographical distributions of the assemblage species are plotted, and the zone of overlap between them is identified. Modern climatic data from within the zone are then used to reconstruct the palaeoclimate. This method works best with large numbers of stenothermic species, but also faces some major problems. It is possible that a species does not occupy its full potential geographical range, and that some taxa may only temporarily co-exist during transitional phases of adaptation to new climatic conditions. This latter problem can result in ephemeral fossil mixes, which have no modern analogue (non-analogue assemblages). It is particularly relevant in the interpretation of fossil insect assemblages from sediments that accumulated during an episode of abrupt climatic change (reflecting the rapid response times of insects to climatic conditions). It is therefore vital to be able to distinguish between temporary and stable associations of beetles (Lowe & Walker 1997: 197).
- The mutual climatic range (MCR) method. This approach plots the climatic parameters for each beetle species in the assemblage, utilising modern distribution maps and meteorological data. The climatic parameters (temperature of the warmest and coldest months and an index of seasonality) provide a best fit estimate of the mutual climatic conditions within which the mix of fossils existed. As previously, the method is most successful for assemblages with large numbers of stenothermic species. By ignoring geographical ranges (which are often too broad and ignore a range of other factors), this method can reduce complex geographical ranges to simple climatic summaries, reflecting the fact that the diverse geographical locations occupied by a species are often linked by common climatic characteristics. It also does not matter if the species doesn't occupy its full (potential) geographical range, so long as some of the boundaries are reached (Lowe & Walker 1997: 197–198). The MCR method has been extensively applied to the study of the last-glacial/interglacial transition (Ponel & Coope 1990; Lemdahl 1991; Walker *et al.* 1993).

More recently, Coope (2001) has argued for the use of coleopteran fossils as biostratigraphical indicators. This application is supported by the potential for species-level identification, the large numbers of species and the possibility for stochastic fossil faunas, the rapidity and scale of their geographical ranges (resulting in highly contrasting glacial and interglacial assemblages), and the rarity of fossil derivation (see above for further discussion of all of these points).

Coope's (2001) analysis of coleopteran assemblages from southern Britain and their role in the biostratigraphy of marine isotope stages 5 and 7e is briefly described here. The analysis highlighted coleoptera assemblages from 14 different interglacial sites, all of which were post-Hoxnian in date (Aveley, Sandy Lane Quarry, Essex; Bobbitshole, Suffolk; Deeping St James, Lincolnshire; Elsing BGS borehole, Norfolk; Histon Road, Cambridge; Itteringham, Norfolk; Marsworth, Buckinghamshire; Shropham, Norfolk; Stanton Harcourt, Oxfordshire; Stoke Goldington, Buckinghamshire; Strensham, Worcestershire; Tattershall Thorpe, Lincolnshire; Trafalgar Square, London; and Woolpack Farm, Cambridgeshire). All 14 assemblages had broadly similar implications for the local environment, indicating fairly open country, with deciduous woodland at some distance from the sedimentary site. The sites were typically pools or abandoned floodplain channels, with abundant, lush grass or reed vegetation.

The 14 assemblages were divided by Coope into two groups: group A included highly characteristic assemblages that were attributed to the Ipswichian interglacial (on stratigraphic and other independent palaeontological grounds), and specifically to MIS-5e and the early part of the interglacial (the *Pinus-Quercetum mixtum-Corylus* pollen zone Ip II of West (1977)); while group B included assemblages from deposits that pre-dated the Ipswichian interglacial and which have been assigned to MIS-7. The group B assemblages are markedly different from those of group A. The exotic species from group A are missing in the group B assemblages (most notably the dung beetles), while two characteristic group B species (*Oxytelus gibbulus* and *Stomodes gyrosicollis*) are absent from the group A assemblages. These two species act as useful, but not unique biostratigraphical markers. Overall therefore, these coleopteran assemblages have assisted in the distinction of MIS-5e and MIS-7 deposits, although further work (particularly with respect to the beetle faunas of the late Ipswichian) is required.

2.3 Molluscs (*non-marine*)

Non-marine molluscs are some of the most common fossils remains recovered from terrestrial Quaternary sediments (Lowe & Walker 1997: 202; Figure 226). The two key classes are the Gastropoda (snails, or univalves) and the Bivalvia (mussels and clams). After early taxonomic work in the 18th and 19th centuries, molluscs began to be utilised as palaeoclimatic indicators and for dating geological events, in the late 19th and 20th centuries. Compared to other terrestrial and freshwater fossil groups, molluscs boast a number of advantages (Lowe & Walker 1997: 203; Evans & O'Connor 1999: 141):

- Specimens have a high degree of taxonomic resolution and can nearly always be identified to species, supporting detailed palaeoenvironmental interpretation (Lowe & Walker 1997: 203).
- Shells occur in oxidised sediments that typically lack other fossil remains such as pollen or coleoptera (Lowe & Walker 1997: 203).
- Specimens are large enough to be recognised in the field, enabling a general appreciation of the palaeoecology to be gained on site. This can assist in the development and implementation of sampling strategies for other fossil groups (Lowe & Walker 1997: 203).
- The present day ecology and geographical distribution of molluscs is extremely well understood, indicating that molluscs often occur in distinctive species associations that reflect particular habitats (Lowe & Walker 1997: 203; Evans & O'Connor 1999: 141).
- Molluscs are characterised by rapid generation times and population turnover rates, which combined with their sensitivity to local changes in the physical and chemical environment, makes them valuable indicators of micro-scale environmental change (Lowe & Walker 1997: 203; Evans & O'Connor 1999: 141).
- However, molluscs (which are preserved as their shells) are composed of calcium carbonate, and are therefore only well preserved in alkaline conditions (Evans & O'Connor 1999: 141).

The predominant application of mollusc shells has been in the reconstructions of palaeohabitats and the study of environmental change (e.g. Kerney 1968; Sparks & West 1970). These approaches have emphasised the respective division of freshwater and terrestrial species into groups that demonstrate common habitat preferences (Lowe & Walker 1997: 205):

- Freshwater molluscs:
 - 'Slum' group: individuals tolerant of poor water conditions, ephemeral or stagnant pools, and considerable changes in water temperature (e.g. the water snail *Lymnaea truncatula*).
 - 'Catholic' group: molluscs that tolerate a wide range of habitats, except for the worst slum conditions (e.g. *Lymnaea peregra*).
 - Ditch group: species found in ditches with clean or slowly moving water, and abundant growth of aquatic plants (e.g. *Valvata cristata*).
 - Moving water group: molluscs found in larger bodies of water, including moving streams and large ponds where water is stirred by current and wind (e.g. *Valvata piscinalis*).

- Land molluscs:
 - Marsh species (e.g. *Vallonia pulchella*).
 - Dry land species (e.g. *Pupilla muscorum*).
 - *Vallonia* species: indicate open, un-wooded land surfaces.
 - Woodland species.

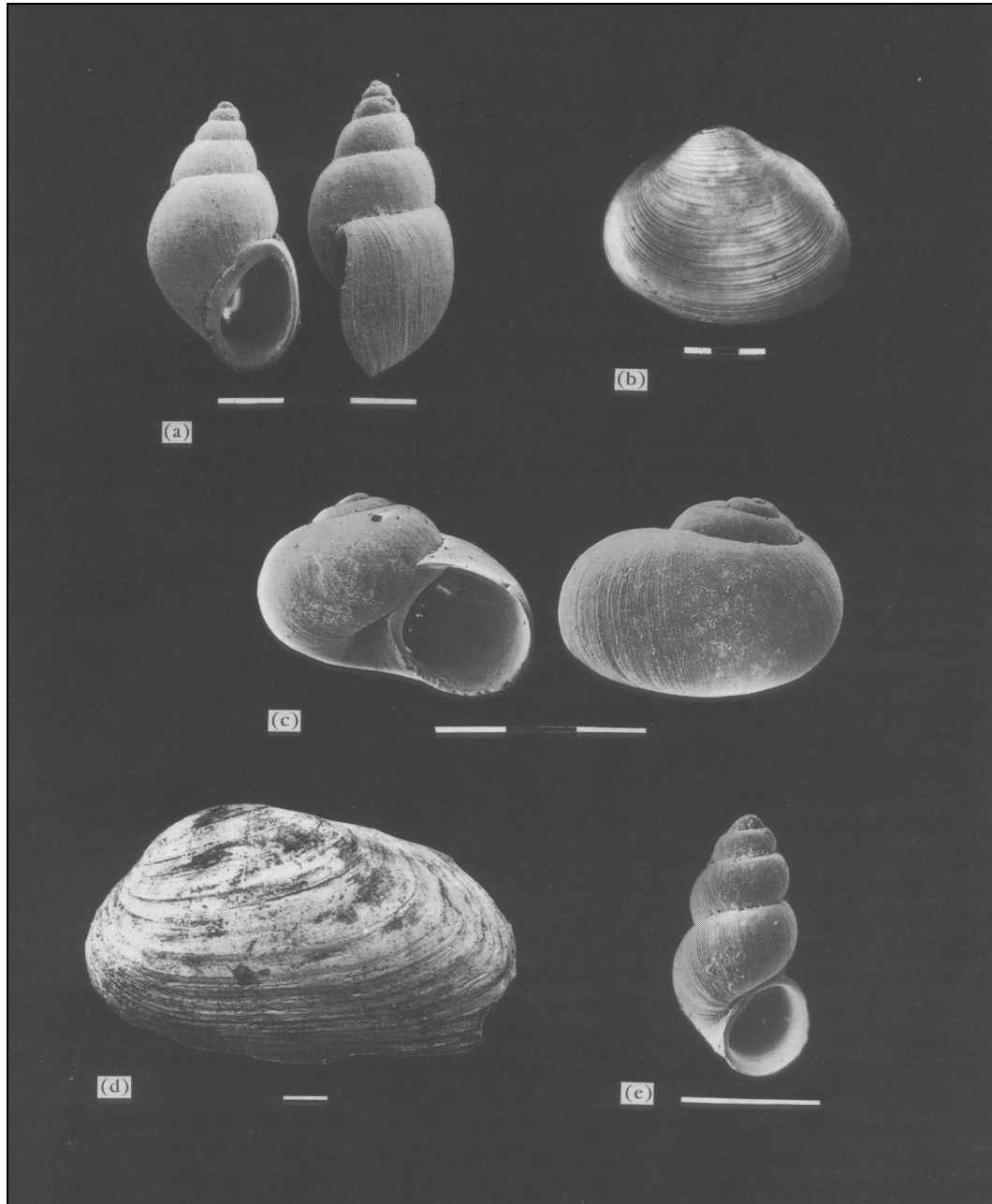


Figure 226: characteristic molluscs from the Little Oakley sands & silts (Bridgland 1994: 308)

Studies of environmental change have indicated that the primary influence upon molluscan assemblage variability during the late Quaternary was local habitat conditions. For the land taxa, the degree and type of vegetation cover was especially critical, and these molluscs could also indicate whether land conditions were dry or marshy. In contrast, the freshwater assemblages indicated rates of movement and the degree of oxygenation of water bodies (Lowe & Walker 1997: 206). Although the initial work in palaeoclimatic reconstruction focused upon indicator species (e.g. Kerney 1968; Sparks & West 1970), more recent approaches (e.g. Rousseau 1991) have developed transfer functions based on training sets of modern

molluscan assemblages and their relationships with modern climatic variables (Lowe & Walker 1997: 207).

More recently, attention has been turned to the potential of molluscan assemblages as biostratigraphical indicators (Preece 2001; Keen 2001). Preece (2001) for example has argued that the view of a single-interglacial Cromerian is a huge over-simplification, and that molluscan and vertebrate evidence suggests there may be as many of five distinct stages conflated into the Cromerian Complex. For the late Middle Pleistocene Keen (2001) has developed a non-marine molluscan biostratigraphy, which was comparable with mammalian, coleopteran and lithostratigraphic evidence, although it is at odds with extant pollen biostratigraphies. The biostratigraphy distinguishes the Ipswichian interglacial (MIS-5e) from the MIS-7 interglacial on the basis of the presence/absence of taxa now exotic to the UK, including *Belgrandia marginata* and *Corbicula fluminalis*. The faunas utilised by Keen were from fluvial deposits with similar facies, thus making the assemblages directly comparable with one another. Although flood-formed fluvial assemblages consist of species from multiple ecological niches in the river and floodplain (causing some interpretive problems), this homogenising of molluscs from different environments enables the comparison of faunas of the same or different ages.

The interglacial fluvial assemblages consisted primarily of very similar sets of species that were forced out of the UK in each cold stage and returned in each interglacial. Critical for the biostratigraphical scheme however, was the extinction of small numbers of species during the Middle Pleistocene. This enabled individual temperate stages to be characterised by a combination of species extinctions and the presence/absence of species (Keen 2001: 1658). Fluvial faunas for sub-stage 5e revealed a number of distinctive features:

- Molluscan taxa consisted largely of species that are present in southern Britain today, combined with a small number of exotic species, the most important of which is *B. marginata*.
- The assemblages commonly occur with mammal fauna containing *Hippopotamus amphibius*, a diagnostic species of sub-stage 5e.
- The assemblages also occur in association with a diagnostic coleopteran fauna, whose non-British elements have a predominantly Mediterranean distribution today.
- Plant macrofossils are indicative of summer temperatures 4°C higher than today.
- In general, the presence of *B. marginata* appears to be biostratigraphically significant and indicates an MIS-5e age.

In comparison, the MIS-7 faunas indicate a number of contrasts:

- The presence of *C. fluminalis* (although in association with Ipswichian-type pollen) appears to indicate MIS-7 age for sites in the Upper Thames, the Warwickshire/ Worcestershire Avon and the upper reaches of the Wash drainage.
- However, this pattern is more complicated in the Wash margins and the Lower Thames, where it is suggested that stage 7 faunas feature both species (*C. fluminalis* and *B. marginata*), at least in some areas. Keen (2001) suggests three possible explanations for this pattern:
 - That there was a biogeographical boundary across the Thames, between the Thames and the Avon, and between the upper and lower reaches of the Wash. However, this seems highly unlikely given the uniformity of modern faunas in the southern half of Britain today.
 - That faunas with *C. fluminalis* and *B. marginata* together, and with only *C. fluminalis* represent separate sub-stages of MIS-7. This is a possibility (and is potentially supported by the recent work of Schreve (2001a) at Aveley), but cannot be definitively evaluated at the current time.
 - That *B. marginata* occurs as a result of re-working from earlier deposits, in certain favourable circumstances (this is the explanation supported by Keen (2001)).
- The stage 7 faunas are also characterised by the last appearance of *P. clessini* prior to its extinction.

- Overall therefore, the presence/absence of *P. clessini*, *C. fluminalis* and *B. marginata* give a clear biostratigraphic signature to the stage 7 deposits and faunas.

In contrast with the stage 5e and 7 faunas, the stage 9 and 11 faunas cannot be comprehensively characterised, primarily due to the small number of sites. However, the three stage 11 sites which have yielded fluvial faunas are highly distinctive, containing the so-called “Rhenish Fauna” (named for its supported connection with the Rhine during stage 11) which includes *B. marginata* and *C. fluminalis*, and other exotic fauna (*T. serratilineiformis*, *V. naticina* and *U. crassus*). In fact, the major molluscan biostratigraphic index for stage 11 is the terrestrial assemblage (found at Beeches Pit, Suffolk and Hitchin, Hertfordshire), although unfortunately this highly distinctive terrestrial fauna has not yet been found at enough sites to be confirmed as a biostratigraphic marker.

Overall therefore, Keen’s (2001) biostratigraphic analysis of molluscan faunas indicated that:

- Fluvial deposits can be divided on the basis of their included molluscan faunas, so long as deposits from the warmest parts of each interglacial, and from similar facies, are compared.
- Sub-stage 5e faunas are easily identified, stage 7 faunas are more difficult to characterise, while stage 9 and stage 11 sites are too poorly known (despite the stage 11 “Rhenish” fauna).
- The molluscan sequence tentatively divides into four groups that match the four temperate stages of the marine isotope stage record.
- While pollen lacks the resolution to distinguish between temperate stages (e.g. “Ipswichian” pollen appears to be found in both MIS-5e and 7 and “Hoxnian” pollen in MIS-9 and 11), these stages can be separated using molluscan, mammalian and coleopteran biostratigraphies.

2.4 Ostracods

Ostracods are small, marine and freshwater crustaceans (Evans & O’Connor 1999: 144). The bulk of ostracod research has focused upon marine species, although there has recently been an increasing interest in the occurrence and ecological preferences of brackish and freshwater species (Lowe & Walker 1997: 212). Although there is a well documented fossil record (the first fossil ostracod was described in 1813) and some species have highly restricted ecological preferences (Lowe & Walker 1997: 212; Evans & O’Connor 1999: 144), there are several problems influencing ostracod analyses:

- The classification of modern ostracods is predominantly based on the soft body parts, yet these features are rarely preserved in the fossil form. Taxonomic classification is therefore based on the carapace (the outer shell, which fossilises relatively easily), but this limits the comparison of modern and fossil forms (Lowe & Walker 1997: 212–213).
- The distributions of living ostracod communities are governed by a wide range of factors, including physical parameters (water temperature, salinity and the nature of the substrate) and biological parameters (food chains and natural associations). Unfortunately, it is difficult to cite any one factor as being universally dominant (Lowe & Walker 1997: 212).
- Terrestrial ostracods typically possess thinner carapaces than the marine species, and can be easily destroyed by mechanical breakdown and chemical corrosion (Lowe & Walker 1997: 214).

Prior to the 1970’s ostracods (marine and freshwater) were little used in Quaternary studies, with the main exception being their use in the distinction of non-marine and marine sedimentary facies (Griffiths 2001: 1743). The majority of recent ostracod research however has focused upon marine specimens (e.g. Whatley 1993). Although studies of terrestrial ostracods have been limited, there has been a growing use of freshwater ostracods as palaeoenvironmental proxies since the 1970’s (Griffiths 2001: 1743). Recently, the use of transfer functions has related species distributions to variations in substrates, salinity, oxygen/anoxia and temperature. The ability of ostracods to immigrate rapidly into ponds after cold/temperate climate transitions also indicates their potential use as palaeoclimate indicators (Lowe & Walker 1997: 214).

Roe (2001) recovered ten ostracod species for borehole EH1 at East Hyde, Essex. Freshwater species dominated the assemblages of the basal gravels and sands, with high proportions of the plant-associated species *Scottia browniana* (Jones). Freshwater species decline in the overlying organic beds, with an accompanying increase in brackish water species (e.g. *C. torosa*). Above unit 3b, there were very few ostracod valves, predominantly juveniles of *C. torosa*. Overall, the East Hyde assemblages suggest a slow-flowing, well vegetated stretch of river, with restricted access to the sea. Over time, flooding or gradual sea level rise introduced deeper, more saline waters, accompanied by a more vigorous flow regime (Roe 2001: 1613).

Finally, the last few years has seen new interest in the potential of freshwater ostracods as biostratigraphic markers in the European Quaternary (Griffiths 2001). This research has highlighted patterns of ostracod speciation, migration and lineage extinction. Griffiths (*ibid.* 1744) has highlighted several highly ornate forms (e.g. *I. quinculminata*), which are robust indicators of the Hoxnian (*sensu lato*) and the Cromerian (*sensu lato*). As with most organisms, ostracod species richness follows distinct gradients. Although these are not currently fully understood, there are clearly more species per unit area in the east and south-east of Europe than in the north-west (*ibid.* 1745). The ostracods are able dispersers, with many species producing desiccation resistant eggs or having diapausing life-history stages. These are transported by other organisms (birds, fish, amphibians, and water bugs), hydrology and possibly aerial plankton. Parthenogenetic taxa are also able to establish new populations from single individuals, giving them the potential for rapid colonisation. Although ostracod colonisation processes are random, their dispersal strategies allow them to rapidly invade newly created or ephemeral habitats and to “track” their preferred environmental and climatic optima (*ibid.* 1745–1746).

It appears that most ostracods have “preferred” climatic and environmental optima, and that they “track” these back and forth across landscapes as conditions fluctuate over time. This process is particularly noticeable in the UK because of its periodic isolation from the rest of Europe, and it results in characteristically interglacial ostracod faunas:

- MIS-11 and MIS-9 faunas are extremely similar to those of modern central Europe.
- MIS-5e faunas are much more similar to those of modern UK and the Low Countries.

In general, the advantages of ostracod species as ecological and biostratigraphic markers have been greatly enhanced by recent research that has resolved many of the most problematic issues: identification, taxonomy and systematics; and the fauna of western and central Europe.

2.5 Pollen

Pollen analysis (or pollen stratigraphy) is the most widely adopted technique used for the reconstruction of Quaternary environments (Lowe & Walker 1997: 163). It involves the extraction, identification and counting of the pollen grains and spores that are incorporated and fossilised within archaeological sediments. The study of pollen has a long history within modern archaeology, and it is clear that the technique has a wide range of advantages and disadvantages (Evans & O'Connor 1999: 134). The key advantages are as follows:

- There is an extremely well-established methodology for the recovery and representation of pollen data, emphasising the importance of local and regional pollen assemblage zones (Lowe & Walker 1997: 167–169).
- Lacustrine sequences provide long, high resolution pollen sequences (Thomas 2001: 1621).
- Degraded grains (see also below) commonly indicate secondary deposition, evident in the structural modification of the exine surfaces (which occurs through re-working). Deteriorated pollen diagrams can therefore provide useful corroborative information with regards to redeposited pollen (Lowe & Walker 1997: 172).
- Despite the many problems and difficulties associated with the interpretation of pollen data (see below), the value of this data is clearly indicated by:

“the remarkable degree of consistency in the large number of pollen-based research publications that have appeared in the Quaternary literature in recent years”.

(Lowe & Walker 1997: 173)

Nonetheless, these problems and difficulties should be stressed here:

- Not all plants produce the same amounts of pollen, although this can be corrected for by the application of scaling and weighting factors to original pollen counts (Lowe & Walker 1997: 169).
- Pollen identification is hindered by a degree of taxonomic imprecision.
- Within almost any polleniferous deposit, there is likely to be a combination: of local pollen derived from the contemporary vegetation close the point of deposition; regional pollen transported over long-distances by air and water; and a residual component of re-worked pollen of various different ages (Evans & O'Connor 1999: 70–71). Evans & O'Connor (1999: 70) also stress that the processes of fluvial flooding and transport offer a mechanism by which pollen taxa not normally widely dispersed are transported over potentially large distances.
- The variable nature of pollen deposition can create considerable complications in the fossil record. Factors include the differential settling velocities of pollen in lakes and ponds, the disturbance of sediments by currents and/or burrowing organisms, and the occurrence of reworked pollen (Lowe & Walker 1997: 171). Streams and rivers can derive pollen from eroding soils and peats which may be centuries or millennia older than the contemporary, freshly deposited pollen, although patterns in exine deterioration can be used to distinguish primary and secondary pollen (Evans & O'Connor 1999: 70).
- Fossil pollen grain deterioration results from physical, chemical and biological attacks on the exine. Experimental research has indicated that grains and spores vary in their responses to oxidation and corrosion, and that this variability is partly attributable to the depositional environment. In other words, some pollen types tend to be under-represented and others over-represented in the fossil record (Lowe & Walker 1997: 172).
- It is now generally recognised that many former plant communities have no modern analogues (Lowe & Walker 1997: 172). This highlights the issue of how far pollen assemblages can be related to plant communities, and how valid are the palaeoenvironmental and palaeoclimatic inferences that are made on the basis of pollen data.
- With respect to the biostratigraphical value of pollen in Quaternary studies, it has become apparent that pollen sequences from two or more interglacials can be comparable, recording similar patterns of vegetation development (Thomas 2001: 1622).
- Finally, the fragmentary nature of many terrestrial pollen records, combined with the issue of local vegetation variability, means that single-proxy palynological schemes are difficult to apply (Schreve & Thomas 2001: 1579).

The classical focus of pollen studies has been in the reconstruction and tracing of local and regional vegetation developments. At the local level, pollen records from peat and lake cores underpin the identification of ecosystem histories, while in coastal regions pollen is used to track sea-level change, as marine transgressions and regressions are reflected by changes between saltmarsh, terrestrial, and freshwater plant communities. At the regional and extra-regional levels, pollen data enables large-scale vegetation patterns to be established and the history of individual species and entire assemblages to be tracked through time. Finally, where sufficient numbers of well-dated pollen sites exist, space-time reconstructions of palaeo-vegetation change through time can be developed, showing changes in vegetation composition and distribution (Lowe & Walker 1997: 173).

Pollen data is also used to reconstruct Quaternary climates, although increasing awareness of the complexities of pollen taphonomy (see above), and the differential migratory responses of plants (especially trees) to climate change, has highlighted the dangers of using indicator species as a basis for making palaeoclimatic inferences. More recently therefore, focus has been placed on the development of pollen response surfaces, which provide a quantitative measure of the dependence of broad-scale vegetation patterns upon climate (Lowe & Walker 1997: 175).

Thomas (2001) has recently assessed the problems and potential associated with the development of a pollen biostratigraphy for the British Quaternary. This work is grounded in the pioneering work of Pike & Goodwin (1953) and West (1956, 1957), who argued that the various warm stages of the Pleistocene were apparently characterised by different patterns of vegetation development. Pollen (and macroscopic plant remains) therefore became the basis for the reconstruction of regional vegetation histories, and three Middle and Late Pleistocene interglacials (the Cromerian, Hoxnian and Ipswichian) were recognised (Mitchell *et al.* 1973). However, it has since been demonstrated that pollen sequences for different interglacials can be comparable, a realisation that has been partially due to the oxygen isotope record's demonstrated that the pollen-based glacial/interglacial scheme was an over-simplification (Thomas 2001: 1622). It is now clear for example, that pollen records with a 'Hoxnian' signature can originate from more than one interglacial.

Therefore, with respect to the pollen record and its overall potential as a biostratigraphical marker, Thomas (2001: 1625) has highlighted a series of key current issues:

- It is critical to recognise biostratigraphical signals that are significant at regional and not just local levels, if palynology is to be used to identify and distinguish interglacials. In this respect, regional variations in taxa abundance (e.g. the abundance of *Carpinus* in East Anglia and its scarcity in the Midlands) may be of considerable value.
- Boreal forest pollen assemblages from early or late interglacial sub-stages show strong similarities between different interglacials, and may indeed be undiagnostic.
- High resolution lacustrine sites are extremely difficult to link into established stratigraphical frameworks (e.g. the river terrace sequences), although these links may be achieved through the use of other proxies (e.g. mammals and molluscs).
- A large proportion of UK Middle and Upper Pleistocene palynological sequences are from fluvial contexts. Unfortunately, the polleniferous fluvial and estuarine sites are unlikely to yield sufficient length of record, or quality of resolution, to enable the distinction of interglacials with similar pollen signatures.

2.6 Plant macro-fossils

The distinction between plant macro and microfossils is made on the basis that macrofossils are visible to the naked eye. Plant macrofossils can potentially survive in a variety of depositional environments, though they are most commonly recovered from lacustrine, fluvial and peat deposits where anaerobic conditions prevail. Nonetheless, the preservation of plant macrofossils is highly variable and the occurrence of plant macrofossils within Quaternary deposits is best described as sporadic. For example, many polleniferous deposits do not contain plant macrofossils, and where they do occur it may only be at very low densities. However, where plant macrofossils are preserved it is usually possible to identify them, to species level.

Where plant macrofossils are preserved they are usually locally derived. This makes them useful in local palaeoenvironmental and ecological reconstructions (e.g. Watts 1978) but of limited value in wider, regional analyses. At a local scale, macrofossil remains can be valuably employed to clarify the local distributions of species generally over-represented in pollen diagrams such as *Pinus*.

As the preservation and ease of identification of plant macrofossils is highly variable, perhaps the best application of this dataset is in conjunction with pollen analyses to produce detailed reconstructions of Quaternary vegetation patterns:

“when used in conjunction, therefore, plant macrofossil analysis and pollen analysis offer a more secure basis for palaeoecological inference than either technique used in isolation”

(Lowe & Walker 1997: 189)

2.9 Other sources of data

Lowe & Walker (1997: Chapter 4) highlight a range of other biological data types, including chironomidae, diatoms, foraminifera, marine micro-flora and micro-fauna, chrysophytes, cladocera, coral polyps, fungal remains, and testate amoebae. None of these categories of biological evidence are discussed further here, as they all represent environments and/or sediments which are not incorporated within the secondary contexts that are the focus of this work.

3. POTENTIAL OF BIOLOGICAL DATA SOURCES

This assessment is based on a range of factors, including the sampling logistics for each of the major data categories, the preservation potential within different sediment types, and an analysis of their occurrence within a sample set of secondary context archaeological deposits, as documented by Bridgland (1994) for the Quaternary of the Thames.

3.1 Sampling logistics

3.1.1 Mammals

Considerable care should be taken in the excavation of bone-bearing deposits, reflecting the variety of conditions in which bones can be found. Mapping, surveying, field descriptions, sketches and photography should precede the removal of bone fragments from the sediment matrix. In some cases it is possible to remove larger bones by hand, which should be left to dry out prior to cleaning with brush or water. In many cases however, bones (even those quite heavily mineralised) are brittle, and treatment with a penetrative plastic solution (e.g. polyvinyl acetate in toluene) may be necessary prior to removal of the matrix. If the bones are wet, especially those that are markedly decalcified, an emulsion of the plastic solution may be necessary, so that the strengthening material will penetrate the bone fibres. Very small bones and teeth (e.g. those of rodents) can usually only be recovered through sieving or screening of the sediment matrix, following the removal of the larger bones by hand (Lowe & Walker 1997: 228).

3.1.2 Coleoptera and other insect remains

Typically, flotation techniques are required for the extraction of fossil insect remains from sediment matrix. Following Lowe & Walker (1997: 192), disaggregation of the sediment using water or sodium carbonate solution breaks the sediment down into slurry. After sieving (300 µm), the residues remaining in the sieves are mixed with kerosene, after which water is then added enabling the insect remains (along with plant macro-fossils if these are present in the sediment) to float to the surface. The floating fraction is decanted, washed and sorted in alcohol, prior to microscopic collection and identification.

3.1.3 Non-marine (and marine) molluscs

Molluscan remains can be collected by hand from open sections in the field. However, they are best extracted under laboratory conditions as hand-picking of individual shells inevitably results in samples that are biased towards larger specimens. Following Lowe & Walker (1997: 203–204), bulk samples from sections or cores should be air dried and immersed in water, with a small quantity of a dispersive agent (e.g. H₂O₂ (Hydrogen Peroxide) or NaOH (Sodium Hydroxide)) being added if there is organic material present. The ‘froth’ (which contains the snails) is decanted through a 0.5 mm sieve and the process is repeated several times until no more snails are present in the froth, at which point the residual slurry is poured into a second 0.5 mm sieve. Both sieves are dried and the residues passed through another set of sieves (1 mm, 710 µm and 2411 µm) for ease of sorting, after which molluscan remains are removed by hand and/or brush under microscopic conditions.

3.1.4 Ostracods

Ostracods are commonly collected from lacustrine and marine sediments, under laboratory conditions. Following Lowe & Walker (1997: 212), deposits are typically disaggregated in water (although occasionally hydrogen peroxide may be required), sieved and dried. Ostracod carapaces and valves can be picked out by hand, using a very fine brush, under microscopic conditions.

3.1.5 Pollen

Samples containing fossil pollen can be taken from cores, or from sections exposed in river banks, cliffs, road cuttings and building excavations. Samples must be sealed air-tight and are usually kept in a cool store (at *c.* 1–3°C) to prevent desiccation and microbial attack. This also protects the samples from contamination by pollen circulating in the atmosphere (especially during the pollen and spore production seasons). In the laboratory, following sediment dispersal, sieving and/or chemical flotation (density separation), samples should be chemically treated in a variety of ways to remove as much of the sediment matrix as possible. Lignins and cellulose can be reduced in volume, if not entirely removed, by oxidation and acetolysis. Minerogenic sediments may be removed by either digestion in hydrofluoric acid, or be separated off by differential centrifugation or by floating the organic detritus (including pollens) out of the matrix using a ‘heavy liquid’. Carbonates and calcareous sediments are treated with hydrochloric acid. The residues containing the pollens and spores may then be stained with an organic dye (e.g. safranin) which enhances the surface detail of some grains, prior to microscopic identification and counting of the grains and spores (Lowe & Walker 1997: 165).

3.2 Preservation Potential and Sediment Types

Evans & O’Connor (1999: 80–81) provide a valuable summary of soil and sediment types, depositional environments and their associated environmental indicators (summarised here in Table 50). Table 50 indicates, unsurprisingly, that anoxic environments (whether acidic or basic) provide favourable preservation conditions for the widest range of biological evidence (bone, insects, pollen, macroscopic plant remains, wood, and charcoal). However, such peats and organic sediments are relatively rare within Pleistocene secondary contexts (although certainly not unknown), and are also unfavourable to the preservation of molluscs and ostracods. It is clear that acid (favouring soil pollen, charcoal, and phytoliths preservation), basic (favouring bone, molluscs, charcoal, and ostracods) and neutral (promoting charcoal and sometimes bone and shell preservation) oxic environments are more widely distributed, although their preservation potential is less all-encompassing with respect to the different biological data categories.

| Depositional environment | Main soil/sediment type | Some typical situations | Environmental indicators |
|-------------------------------|--|---|--|
| Acid, pH usually < 5.5, oxic | Podsoles & other leached soils | Heathlands, upland moors, some river gravels | Soil pollen, charcoal, phytoliths |
| Basic, pH usually > 7.0, oxic | Rendsinas, lake marls, tufa, alluvium & shell-sand | Chalk & limestone areas, valley bottoms, karst, machair | Molluscs, bones, charcoal, ostracods |
| Neutral, pH 5.5–7.0, oxic | Brownearths & gleys, river gravels | Clay vales & other lowland plains | Charcoal, sometimes bone & shell |
| Acid or basic, anoxic | Peats & organic deposits (e.g. lake sediments) | Urban sites, wetlands, river floodplains | Insects, macroscopic plant remains, pollen, bone, wood, charcoal |

Table 50: soil & sediment types, depositional environments and environmental indicators (Evans & O’Connor 1999: 80)

3.3 Case Study

Although the previous discussions provided a general background to variable preservation conditions, it provided relatively little specific detail with respect to the fluvial sediments that are the focus of this report. By contrast, Bridgland’s (1994) synthesis of the Quaternary of the Thames provided an excellent resource for assessing the relative abundance of different biological data within fluvial secondary contexts. The presence/absence of different biological data categories at each of 39 sites was documented, along with the main sediment types recorded at each site (Table 52). Although it is clear that the preservation of different data categories can be strongly influenced by soil and sediment types (Section 3.2 above), the 39 sites cover a wide range of geographical localities (Figure 227) and this minimises (without wholly removing) the effects of localised preservational biases.

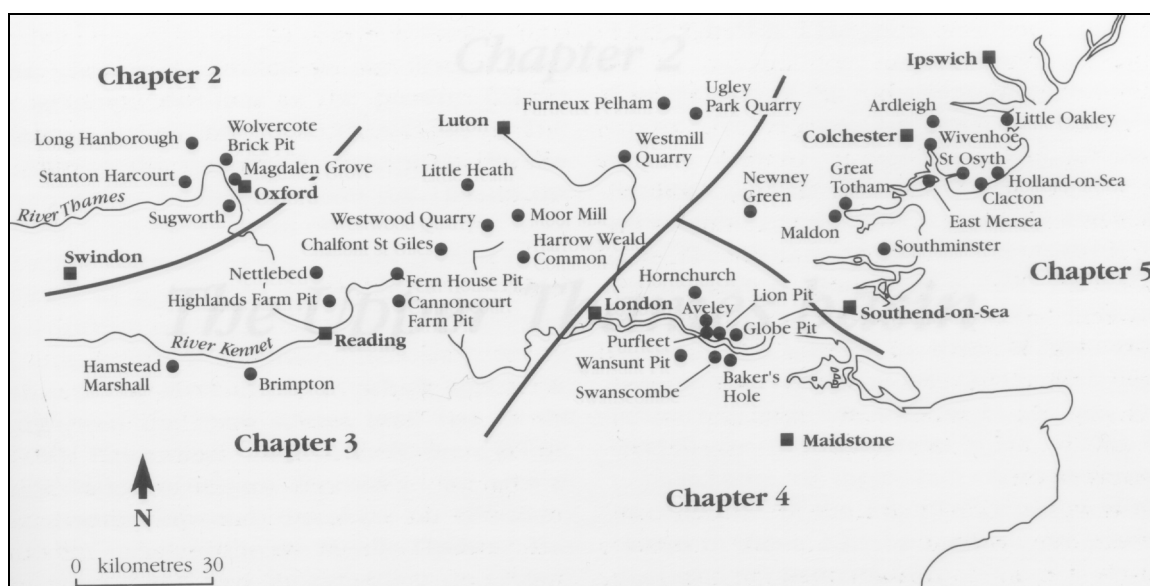


Figure 227: Thames Quaternary sites (Bridgland 1994: Figure 1.4)

The presence/absence of the data categories are summarised in Table 51, and indicate that the most common categories of biological evidence recovered from the Thames Quaternary sites are large mammals (20%), molluscs (primarily non-marine species, 16%) and pollen (15%; Figure 228). Small mammals (10%), ostracods (10%), coleoptera (8%) and plant macro-fossils (12%) are also relatively common, while birds, fish, amphibians and reptiles were only rarely recovered.

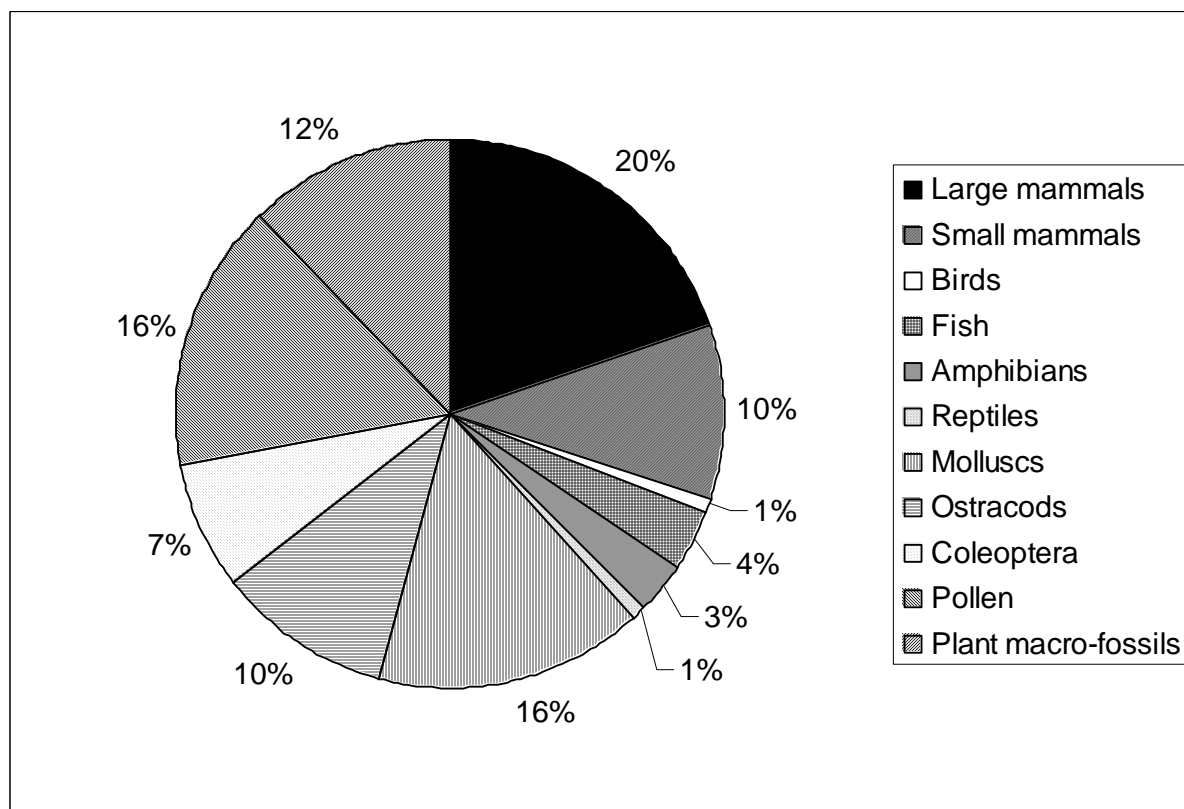


Figure 228: biological data recovered from 39 Thames Quaternary sites (after Bridgland 1994)

| Data Type | Present | Absent |
|---------------------|---------|--------|
| Large mammals | 21 | 18 |
| Small mammals | 11 | 28 |
| Birds | 1 | 38 |
| Fish | 4 | 35 |
| Amphibians | 3 | 36 |
| Reptiles | 1 | 38 |
| Molluscs | 17 | 22 |
| Ostracods | 11 | 28 |
| Coleoptera | 8 | 31 |
| Pollen | 16 | 23 |
| Plant macro-fossils | 13 | 26 |

Table 51: occurrence of biological data types in 39 Thames Quaternary sites (after Bridgland 1994)

It is clear from the review that the recovery of certain categories of biological data correlates to specific sediments and deposits. For example, pollen, plant macro-fossils and insects (e.g. coleoptera) were predominantly recovered from organic deposits and other fine-grained, low energy sediments (e.g. pollen has been recovered from the Swanscombe lower loams (Bridgland 1994: 193–218), laminated silts, sands and clays at Purfleet (*ibid.* 218–228), and (along with plant macro-fossils) from the organic silty-clays at Wivenhoe gravel pit (*ibid.* 313–317). Small mammals and other small vertebrates (e.g. birds, fish, amphibians and reptiles) were also typically recovered from organic and fine-grained deposits (e.g. organic clays and silts at Great Totham), reflecting their vulnerability to physical and chemical destruction in higher energy fluvial deposits.

By contrast, only mammalian fauna (typically large mammals) and molluscs were recovered from the coarser-grained (and higher energy) fluvial gravels sediments, and in many of these cases, the molluscs were actually recovered from silt and sand lenses within those gravels. This is particularly well illustrated at the Long Hanborough gravel pit, where non-marine mollusc assemblages were sampled from distinctive silt and fine-sand lenses within the gravel unit (*ibid.* 49–58; Figure 229). By contrast, mammalian fauna has often been recovered from gravel units, such as the Stanton Harcourt gravel, which yielded a cold-climate assemblage including *Mammuthus primigenius*, *Coelodonta antiquitatis*, *Bison priscus* and *Equus ferus* (*ibid.* 65–79).

Rather unsurprisingly, it is those sites consisting only of fluvial gravel sediments (e.g. Harrow Weald Common, Chalfont St Giles Brick Pit, and Ferneux Pelham Gravel Pit) that most typically yield no biological evidence. However, it cannot be taken as a simple relationship, and it is noticeable that some sites including organic sediments (e.g. Priest's Hill, Nettlebed) have produced relatively little biological data, emphasising the importance of the local depositional environment and soil chemistry.

A specific assessment of the relationships between biological data and sediment types is presented for ten sites that have yielded a wide range of biological data (Table 53): Great Totham (Loft's Farm Pit), Clacton, Cudmore Grove (East Mersea), Little Oakley, Swanscombe (Barnfield Pit), Purfleet, Globe Pit (Little Thurrock), Aveley (Sandy Lane), Wolvercote, and Stanton Harcourt (*ibid.*). It is immediately apparent that silts, clays and sands tend to preserve the widest range of biological data, while gravels typically preserve only large mammals (the absence of smaller vertebrates reflects taphonomy and sampling processes) and molluscs.

In summary, it is clear that the recovery of the different categories of biological evidence reflects a combination of several factors: soil and sediment chemistry; the depositional environments (e.g. high and low energy settings); the preservation of organic and/or fine-grained sediments within fluvial sequences; and the nature of the archaeological sampling. Given these variables, it should be clear that the potential range of biological data will vary considerably, but a case study synthesis of Bridgland (1994) does suggest that large mammal fauna and molluscs may be the most commonly encountered types of data within purely coarse-grained, fluvial gravel deposits and sequences. Naturally, the presence of finer-grained and organic sediments within those sequences will potentially increase the range of biological data, although regional soil conditions can still limit the available evidence, as at Broom (Chapter 2).

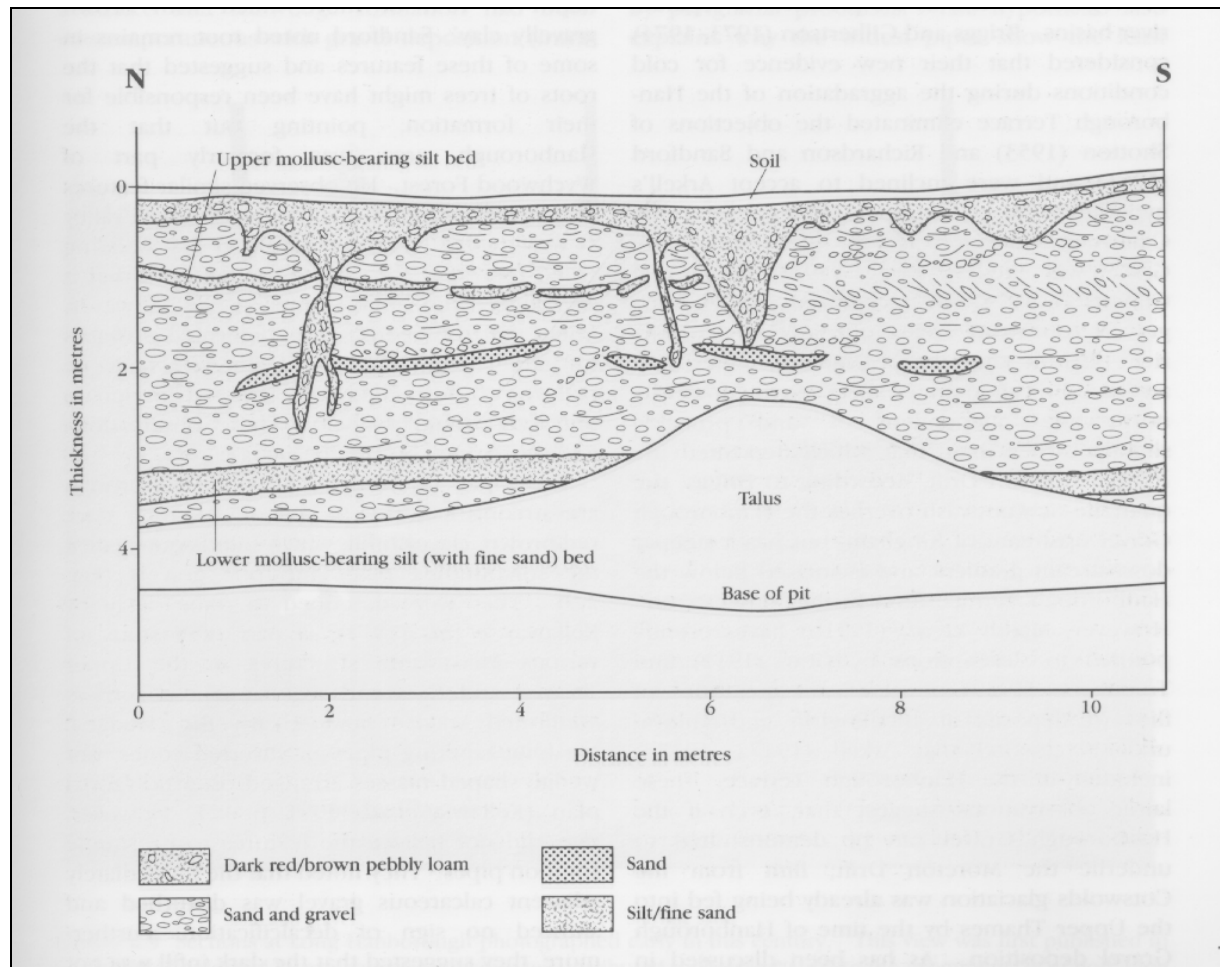


Figure 229: Long Hanborough Gravel Pit (East Face). Note the mollusc-bearing silt beds (Bridgland 1994: Figure 2.8)

| Site | Sediment types | Vertebrates | | | | | | | | | | |
|---|--|---------------|---------------|-------|------|------------|----------|----------|-----------|------------|--------|---------------------|
| | | Large mammals | Small mammals | Birds | Fish | Amphibians | Reptiles | Molluscs | Ostracods | Coleoptera | Pollen | Plant macro-fossils |
| Sugworth Road Cutting Long Hanborough Gravel Pit Wolvercote Channel Stanton Harcourt Gravel Pit Magdalen Grove Little Heath Harrow Weald Common Priest's Hill, Nettlebed Chalfont St Giles Brick Pit Ferneux Pelham Gravel Pit | Gravels, sands, silts & clays | YES | YES | NO | NO | NO | NO | YES | YES | YES | YES | YES |
| | Gravels (incl. silt & sand lenses) | YES | NO | NO | NO | NO | NO | YES | NO | NO | NO | NO |
| | Gravels, sandy-gravels, silty-clays & peats | YES | NO | NO | NO | NO | NO | YES | NO | YES | YES | YES |
| | Gravels, sands, silts & organic sediments | YES | NO | NO | NO | NO | NO | YES | NO | YES | YES | YES |
| | Gravels & silty-sands | YES | NO | NO | NO | NO | NO | YES | NO | NO | YES | NO |
| | Gravels, sands & clays | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| | Gravels | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| | Gravels & interglacial organics | NO | NO | NO | NO | NO | NO | NO | NO | NO | YES | NO |
| | Gravels | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| | Sandy-gravel | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| Westwood Quarry | Gravels (incl. clay-enriched & iron-stained horizon) | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| Westmill Quarry | Tills, gravels & sands | NO | NO | NO | NO | NO | NO | NO | YES | NO | NO | NO |
| Moor Hill Quarry | Till, gravels & glacio-lacustrine sediments | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| Ugley Park Quarry | Till, gravels & sands | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| Highlands Farm Pit | Gravels | YES | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| Cannoncourt Farm Pit | Gravels & sands | YES | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| Fern House Gravel Pit | Gravels | YES | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |

| Site | Sediment types | Vertebrates | | | | | | | | | | Plant macro-fossils |
|--|--|---------------|---------------|-------|------|------------|----------|----------|-----------|------------|--------|---------------------|
| | | Large mammals | Small mammals | Birds | Fish | Amphibians | Reptiles | Molluscs | Ostracods | Coleoptera | Pollen | |
| Brimpton Gravel Pit | Gravels, sands, silts & organic muds | NO | NO | NO | NO | NO | NO | YES | NO | YES | YES | YES |
| Hornchurch Railway Cutting | Till & gravels | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| Wansunt Pit, Dartford Heath | Gravels, silts & clays | YES | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| Swanscombe (Barnfield Pit) | Gravels, sands & loams | YES | YES | NO | NO | NO | NO | YES | NO | NO | YES | YES |
| Purfleet (Bluelands, Greenlands, ESSO & Botany Pits) | Gravels, brickearths & coombe deposits | YES | YES | NO | NO | NO | NO | YES | YES | NO | YES | YES |
| Globe Pit, Little Thurrock | Gravels & brickearths | YES | YES | NO | NO | NO | NO | YES | YES | NO | YES | YES |
| Lion Pit, Tramway Cutting (West Thurrock) | Gravels, sands, silts & silty-clays | YES | NO | NO | NO | NO | NO | YES | YES | NO | YES | NO |
| Aveley, Sandy Lane Quarry | Sands, silty-clays & peaty-clays | YES | YES | NO | YES | NO | NO | YES | YES | YES | YES | YES |
| Northfleet (Ebbsfleet Valley): Baker's Hole Complex | Gravels & fine-grained sediments | YES | YES | NO | NO | NO | NO | YES | NO | NO | NO | NO |
| Newney Green Quarry | Till, outwash gravels & cover-sands | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| Ardleigh (Martells Quarry) | Gravels & organic sediments | NO | NO | NO | NO | NO | NO | NO | NO | YES | YES | YES |
| Little Oakley | Gravels & channel sediments | YES | YES | NO | YES | YES | YES | YES | YES | NO | YES | NO |
| Wivenhoe Gravel Pit | Gravels & organic silty-clays | NO | NO | NO | NO | NO | NO | NO | NO | YES | YES | YES |
| St. Osyth | Ice-sheet outwash sediments & gravels | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| Gravel Pit | | | | | | | | | | | | |
| Holland-on-Sea Cliff | Ice-sheet outwash sediments & gravels | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |

| Site | Sediment types | Vertebrates | | | | | | | | | |
|-------------------------------|---|---------------|---------------|-------|------|------------|----------|----------|-----------|------------|--------|
| | | Large mammals | Small mammals | Birds | Fish | Amphibians | Reptiles | Molluscs | Ostracods | Coleoptera | Pollen |
| Holland-on-Sea Cliff | Ice-sheet outwash sediments & gravels | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| Clacton | Gravels, sands & clays (channel-fill sediments) | YES | YES | NO | NO | NO | NO | YES | YES | NO | YES |
| Cudmore Grove, East Mersea | Gravels & channel-fill estuarine sediments | YES | YES | YES | YES | YES | NO | YES | YES | NO | YES |
| Southminster, Goldsands Road | Sandy-gravels, sands & clayey-sands | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| Maldon Railway Cutting | Tills, gravels & sandy-silts | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| East Mersea Restaurant Site | Gravels, sandy-silts & clay-silts | YES | YES | NO | NO | NO | NO | YES | YES | NO | NO |
| East Mersea Hippopotamus Site | Gravel & silts (incl. sand & gravel stringers) | YES | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| Great Totham (Lofts Farm Pit) | Gravels, silts & organic clays | YES | YES | NO | YES | YES | NO | YES | YES | YES | YES |

Table 52: presence / absence of biological data types for 39 Quaternary sites from the Thames (after Bridgland 1994)

| Data types | Sediment type | | | | | |
|---------------------|----------------|------|------|------|------|-------|
| | Gravels | Sand | Silt | Clay | Peat | Loams |
| Large mammals | YES | YES | YES | YES | NO | YES |
| Small mammals | NO | YES | YES | YES | NO | YES |
| Fish | NO | YES | YES | YES | NO | NO |
| Birds | NO | NO | NO | YES | NO | NO |
| Reptiles | NO | YES | YES | NO | NO | NO |
| Amphibians | NO | YES | YES | YES | NO | NO |
| Molluscs | YES | YES | YES | YES | NO | YES |
| Ostracods | NO | YES | YES | YES | NO | YES |
| Coleoptera | NO | NO | YES | YES | YES | NO |
| Pollen | ? ⁸ | YES | YES | YES | YES | NO |
| Plant macro-fossils | NO | NO | YES | YES | YES | NO |

Table 53: occurrence of biological data in different sediment types, from the sites of Great Totham (Loft's Farm Pit), Clacton, Cudmore Grove (East Mersea), Little Oakley, Swanscombe (Barnfield Pit), Purfleet, Globe Pit (Little Thurrock), Aveley (Sandy Lane), Wolvercote and Stanton Harcourt (after Bridgland 1994)

4. SPATIO-TEMPORAL RESOLUTION OF BIOLOGICAL DATA

The review of the key biological data sources (Section 2) indicated two contrasting scalar approaches to the issue of reconstructing fluvial palaeoenvironments:

- High resolution reconstruction, based on biological material that is highly sensitive to palaeoclimatic change and other aspects of palaeoenvironmental variation (e.g. coleoptera and molluscs).
- Low resolution reconstruction, based on biological material that is less sensitive to palaeoclimatic change and other aspects of palaeoenvironmental variation (e.g. large mammal fauna and pollen).

These scalar differences function at both spatial and temporal scales. For example, not only do beetles and molluscs change their geographical ranges rapidly in response to environmental change (high resolution spatial data) but they also have rapid generation times and population turnover rates, thus providing high resolution temporal data.

However, with respect to palaeoenvironmental reconstructions, the robusticity of biological data and their susceptibility to destruction during fluvial transport is also a critical factor. Thus molluscs, beetles, ostracods and small mammals tend to be preserved in close proximity to their death environment and provide valuable data for local habitat reconstruction. By contrast, large mammals and pollen are far more susceptible to long range transport and are therefore often only reliable as indicators of regional and sub-regional palaeoenvironments.

Most importantly, it is clear from the previous discussions of biological data types (Section 2) and their occurrence within the geoarchaeological record (Section 3), that many types of evidence occur most commonly within sediments that often yield *in situ* archaeology and would therefore be described as archaeological primary contexts. Classic examples include the Swanscombe lower loam, where a thin horizon (thought to represent a sub-aerial surface) contains conjoinable flint flakes (Bridgland 1994: 206); and the gravel/clay interface at the Clacton golf course site, which yielded mint and conjoinable artefacts (Bridgland 1994: 342); while primary context archaeology is also associated with fine-grained and organic sediments at several other British Lower Palaeolithic sites (e.g. Boxgrove (Roberts & Parfitt 1998), Beeches Pit (Gowlett & Hallos 2000), Barnham (Ashton *et al.* 2000a) and Elveden (Ashton *et al.* 2000b)). This clearly raises a number of important issues: principally whether such biological data should be discussed within an assessment of archaeological secondary contexts.

⁸ This reflects the doubts expressed regarding the occurrence of pollen in the lower gravels at Swanscombe (Bridgland 1994: 197).

This project defined secondary contexts as the range of fluvial sediments (gravels, sands, silts, and clays) that are deposited within fluvial sedimentary sequences upon river terrace landforms. All of these sediments reflect fluvial processes, albeit at markedly different scales of magnitude and energy. If some of those sediments contained primary context archaeology (e.g. conjoinable knapping scatters within fine-grained silts), then the relevant sediments and the archaeology would be defined as being in primary context, as the archaeological materials had not been transported since they were discarded by hominids. Such archaeological 'sites' are therefore outside of the remit of this project. However, if the sedimentary sequence was as outlined below, how would it be defined?

(Top of sequence)

Fluvial gravels, containing re-worked, derived bifaces

—

Fluvial, organic clays, containing a coleoptera assemblage

—

Fluvial silts, containing a mollusc assemblage

—

Fluvial gravels, containing derived bifaces

(Base of sequence / bedrock surface)

Clearly, the gravels at the base and top of the sequence represent an archaeological secondary context, as the sediments and the archaeology (in this hypothetical example) demonstrate clear evidence of derivation (transportation and deposition) under high energy, fluvial conditions. The key question is whether the fine-grained silts and organic clays (and their biological contents) can be (or should be) associated with the gravels (and bifaces) as part of an archaeological secondary context? Moreover, if they are regarded as part of the same secondary context, then how can the material be related?

With regard to the first question, it is clear that the biological and archaeological data cannot be directly associated as they do not occur within the same sedimentary unit. However, Bridgland's (1994, 1995, 1996, 1998, 2000, 2001) climatically-driven, cyclical model of terrace formation does provide a framework within which these data can be bracketed: namely, the marine isotope stage (or stages) within which the sediments were deposited. The biological and archaeological data still cannot be directly related, but the materials represent un-associated examples of archaeological behaviour and palaeo-environmental conditions within the bracketed time-span of the sedimentary unit (an archaeological secondary context). We would therefore argue that all such data falls under the investigation of archaeological secondary contexts, and within the remit of this project. This therefore leads into our second question: can any links be drawn between the various categories of biological and archaeological data that occur within those secondary contexts? This is critically dependent upon the different minimum temporal and spatial scales that can be assigned to the data.

Based on the assessment of the different biological data types, we propose two classifications for their spatial and temporal resolution:

4.1 Spatial resolution

Macro-scale: large mammal fauna, pollen (the regional component) and arboreal macro-fossils (especially trunk material).

↑↓

Micro-scale: small mammals, small vertebrates, molluscs, ostracods, pollen (the on-site component), coleoptera, and plant macro-fossils.

In this context, macro-scale refers to a regional spatial unit, as represented by river system catchments. Will these can obviously vary in size (e.g. compare the River Thames with the River Axe), the key points are that the material has derived from a wide range of fluvial palaeohabitats and from a comparably-sized catchment to any derived archaeological artefacts. This latter point has obvious implications for the

interpretation of hominid behaviour, and is returned to below. The incorporation of large mammal fauna, arboreal macro-fossils, and the regional component of pollen assemblages within the macro-scale group reflects the robusticity of this material and their potential for long distance transport by water (fauna and wood) and air and water (pollen). By contrast, micro-scale refers to 'site'-based spatial units. While it is impossible (and fruitless) to try and discuss specifically-sized spatial areas, these scales can be viewed as reflecting specific micro-habitats and landscapes (e.g. the Barnham channel and floodplain (Ashton *et al.* 2000a) or the Boxgrove landsurface (Roberts & Parfitt 1998)). These data support the high resolution reconstruction of individual palaeohabitats, which may or may not contain the archaeological evidence of hominid behaviour. The inclusion of small mammals, small vertebrates, molluscs, ostracods, coleoptera, pollen (the on-site component) and plant macro-fossils reflects the general fragility of this material and the taphonomy of their deposition (Section 2).

4.2 Temporal resolution

Macro-scales: large mammal fauna.

↑↓

Intermediate scales: pollen, molluscs.

↑↓

Micro-scales: small mammals, small vertebrates, ostracods, pollen (on-site component), coleoptera, and plant macro-fossils.

In this context, macro-scales refer to marine isotope stages, or marine isotope sub-stages, reflecting the broader environmental tolerances of large mammal species, low turnover rates and generation times, and the relatively coarse biostratigraphical signatures of large mammal associations (Schreve 2001a, 2001b). Moreover, the presence within high energy fluvial contexts and varied physical conditions of large mammal fauna indicates their ability to withstand extensive re-working and derivation. The occurrence of large mammal fauna within a specific fluvial sediment (especially coarse-grained gravels) is therefore not a high resolution temporal indicator (i.e. death did not necessarily occur immediately prior to the deposition of the sediment). This contrasts markedly with the fragile micro-fauna (e.g. coleoptera, ostracods, small mammals and other small vertebrates), whose intact preservation tends to indicate a short time period (and limited transport and derivation) between death and the sedimentary accumulation event.

The classification of pollen and molluscs within the intermediate group reflects a range of factors. For pollen, the robusticity of the material indicates its potential for surviving re-working episodes, and ultimately being deposited in pollen assemblages where the 'fresh' pollen is centuries or even millennia younger. In the case of molluscs, their apparent occurrence within coarser-grained gravel and sand deposits (e.g. Bridgland 1994) suggests a degree of robusticity and the potential to survive re-working episodes within high energy contexts.

These classifications are clearly intended as guidance rather than a hard rule. For example, certain elements of large mammal fauna are far more robust than others (e.g. limb bones compared to cranial material), while small mammal fauna may be preserved over several phases of derivation and re-working in exceptional circumstances. However, the physical conditions of this material (e.g. fauna, shells, pollen exine) can often be employed as an indicator of atypical levels of derivation and re-working in time and space.

Overall therefore, macro-scale (as defined above) palaeoenvironmental reconstructions are primarily dependent upon large mammal faunal assemblages within secondary contexts. These species associations have been widely employed to reconstruct broad-scale environments and climatic conditions. For example, in the Aveley (Sandy Lane) mammal assemblage zone (MAZ) the predominance of species such as woolly mammoth and horse suggests an open grassland environment, while decreasing numbers of straight-tusked elephant and Merck's rhinoceros suggest a reduction in woodland coverage (Schreve 2001b: 1701–1702). These reconstructions inevitably cover large spatial areas, reflecting the broad ecological tolerances of many large mammal species, the large ranges of individual species, and their wide

geographical distributions (Schreve has traced her MAZ's into western and central Europe (Schreve & Bridgland 2002)). The reconstructions also span long time periods (e.g. MIS stages and sub-stages), reflecting the difficulties in assessing the time depth of derived fossils⁹, and the relatively stable, non-ephemeral nature of large mammal communities. In effect therefore, these reconstructions are essentially time-averaged, and yield a reliable overview of the mammal fauna (associated with a specific terrace unit for example), although it must be remembered that it will not detect micro-variations in space and time. This has been demonstrated by Schreve (1997, 2001a, 2001b, & Bridgland 2002), whose development of mammal assemblage zones has documented the repetitive occurrence of distinctive faunal assemblages and species associations. These species associations minimise the dangers associated with the employment of single indicator species, which are particularly prevalent in secondary contexts subject to re-working.

Finally, it is stressed that when dealing with large mammal fauna, the potential role of hominids in the accumulation of the material needs to be acknowledged. However, the focus upon species associations and the range of other mechanisms leading to the accumulation of mammals within fluvial sediments (e.g. non-hominid carnivore predation, old age, disease, drowning) should limit the impact of hominid bias, although certain species may be over-represented.

Macro-scale palaeoenvironmental reconstructions can also make potential use of pollen assemblage zones from organic deposits within secondary context sequences, with specific reference to the reconstruction of regional vegetation development, palaeo-climatic conditions, and broad scale climatic change. However, in light of the major taphonomic complexities associated with pollen assemblages, and the typically low resolution, fragmented pollen sequences from fluvial secondary contexts (Thomas 2001), it is suggested here that regionally-derived pollen data from fine-grained deposits within fluvial secondary contexts will typically be strongly time and space-averaged. This is also true for arboreal macro-fossils occurring within both fine and coarse-grained fluvial sediments. Overall, these data may reveal broad patterns in palaeoclimate and regional vegetation types, although temporal trends in vegetation development will be difficult to detect. The nature of fluvial sequences and the problems of pollen taphonomy also highlight the dangers of utilising single indicator species to document palaeoclimatic change.

In contrast, micro-scale palaeoenvironmental reconstructions are primarily dependent upon a range of biological data (small vertebrates, molluscs, ostracods, coleoptera, pollen), from a wide range of coarse and fine-grained secondary contexts. These data can provide a wide range of extremely high resolution data, indicating local environmental conditions and short-term change (e.g. fish species can indicate aquatic temperature and flow conditions, beetle distributions vary in response to vegetation, substrate types, hydrology and/or micro-climate, while terrestrial mollusc species vary in response to vegetation cover and soil saturation levels). However, it is apparent from the extant literature that the time-spans associated with particular micro-habitat conditions and/or with climatic change are rarely explicitly stated (if they are known at all):

“Overall, the assemblages from East Hyde are typical of a slow-flowing, well-vegetated stretch of river which had restricted access to the sea. Through time, flooding or gradual sea-level rise brought deeper, more saline waters to the site, accompanied by a more vigorous flow regime.”

(Roe 2001: 1613, our emphasis)

“Examination of the lithological and palaeontological evidence indicates that the Purfleet deposits were laid down by a river of substantial size, with water depths of at least 5m. There are indications of saline influence, although very muted, suggesting that the site lay only a short distance upstream from the inner end of the contemporary estuary. A gradual freshening of the water is however indicated upwards through the profile.”

(Schreve *et al.* 2002: 1455, our emphasis)

⁹ Interpretative caution is strongly recommended where a fossil shows evidence of extremely severe evidence of abrasion and fluvial modification (Schreve pers. comm.).

No criticism is intended of these authors, it is simply apparent that geochronological estimates of high resolution habitat change are extremely rare (see Roberts & Parfitt 1998 for an example). Unfortunately, from an archaeological perspective, drawing direct associations between specific palaeoenvironmental habitats and sets of archaeological debris is an extremely attractive goal. However, unless primary context archaeology is recovered from the sediments yielding the biological data, these associations cannot be made (and primary context archaeology is not the focus of this research).

It is stressed however that these high resolution biological data sources may be used within biostratigraphical models (e.g. Thomas 2001; Keen 2001; Preece 2001; Coope 2001). These may potentially assist in macro-scale palaeoenvironmental reconstructions, both through indicating broad palaeoclimatic patterns (e.g. the summer temperature contrasts between MIS-5e and MIS-7), and by facilitating comparisons with high resolution data from other sites. However, it is clear that there are still considerable biostratigraphical conflicts between the different categories of biological data, and the need for multi-proxy, rather than single-proxy, approaches is therefore stressed:

“A possible correlation of the Cassington sequence with the Upton Warren Interstadial Complex on the basis of the Mollusca...[is] refuted by the pollen [and] is also contradicted by the coleopteran fauna”

(Maddy *et al.* 1998: 228)

Having highlighted the spatio-temporal resolutions of the available biological data, the final goal concerns the mapping of hominid behaviours against the reconstructed palaeo-environments. Four types of hominid behaviour are identified, at two key scales:

- On-site activity (micro-scale behaviour). This primarily covers tool production and subsistence activities (e.g. carcass butchery), reflecting those activities that are most commonly recognised in the archaeological record (e.g. Roberts & Parfitt 1998; Ashton *et al.* 1998; Ashton *et al.* 2000; Gowlett & Hallos 2000). It is of course acknowledged that these activities do not represent the full range of hominid daily existence.
- Technological change (macro-scale behaviour). This relates to the appearance of new technological innovations in the archaeological record (e.g. the appearance of Levallois technology in late MIS-9 and early MIS-8) and/or changes in technological practise (e.g. the shift from Clactonian to Acheulean during MIS-11 and MIS-9 (White & Schreve 2000). It is recognised that technological change also occurs at the micro-scale (the scale of individual technological innovations), although this is extremely difficult to detect. White's (1998b) analysis of changing biface shape at Swanscombe in response to landscape transformation and variations in raw material supply clearly operates at the sub-marine isotope stage level, but it still does not reach micro-scales as defined here.
- Demographic change (macro-scale behaviour). Evidence of demographic change is difficult to detect and verify, even at macro-scales, during the Middle Pleistocene, although recent research utilising artefact densities as a population proxy (Hosfield 1999; Ashton & Lewis 2002) has begun to suggest the presence of robust patterns.
- Responses to climatic change and perception of environments (micro and macro-scale behaviours). It is suggested that hominid responses to environmental change (e.g. climatic, vegetational) are more likely to have operated at similar spatial and temporal scales to the large mammalian fauna, although their specific sensitivity to micro-changes (e.g. in flora and micro-fauna) remains an unknown factor.

A preliminary mapping of these behaviour types and scales against the palaeoenvironmental data is therefore proposed:

- On-site knapping and subsistence activities (micro-scale): where the archaeological debris of these behaviours is in primary context, they can be directly mapped against any micro-scale biological data within the same sedimentary unit (which as outlined above is likely to be multi-proxy and high resolution). However, we are not dealing with archaeological primary contexts. Where the

archaeological debris is derived, not only is the behavioural information of lower resolution, but it also cannot be directly mapped against the biological data¹⁰. This is true whether the biological data occurs in the same sedimentary unit as the archaeology, or in other units within a secondary context sequence. The biological data and reconstructed (high resolution) habitats can be discussed with respect to the archaeology, but only as examples of the *types* of environments within which the hominid behaviour *may* have occurred. In a similar manner, macro-scale palaeoenvironmental data can also be mapped against these types of micro-scale archaeological debris, but only as an indicator of generic, rather than specific, environmental conditions (i.e. direct associations can obviously not be demonstrated, reflecting the time and space-averaged nature of both sets of data).

- Technological change (macro-scale): this is most commonly represented through changes in lithic technology at the marine isotope stage or sub-marine isotope stage level (e.g. Conway *et al.* 1996; White & Schreve 2000), and the data typically consists of time-averaged assemblages. As previously, these data cannot be directly mapped against high resolution biological evidence, due to the spatio-temporal contrasts. The latter data can only be employed as an example of the multiple possible habitats and environmental conditions that existed during the timespan over which the archaeology was deposited. However, the archaeology can be indirectly associated with the low resolution biological evidence, based on their complementary scales (both data sets are time and space-averaged palimpsests, encompassing regional and extra-regional space and marine isotope stage-time). The biological data provides a low resolution, large scale image of mammalian communities and palaeolandscapes over defined time-spans (e.g. MIS-10 or MIS-11e), against which changes in hominid technology and behaviour can be tested at the MIS and sub-MIS scale:

For example, in an extension of the hypothetical example represented above (and reproduced below), the lower gravels represent MIS-11c (older) and the upper gravels represent MIS-11a (younger):

Fluvial gravels (MIS-11a): derived, twisted ovate bifaces & straight-tusked elephant/woolly rhinoceros fauna

—

Fluvial, organic clays, containing coleoptera

—

Fluvial silts, containing molluscs

—

Fluvial gravels (MIS-11c): derived, pointed bifaces & horse/red deer fauna

These gravels are exposed at multiple locations throughout a regional river catchment, and in all locations where bifaces are present, the MIS-11a bifaces are dominated by twisted ovates, while the MIS-11c bifaces are characterised by points. The MIS-11a fauna is dominated by straight-tusked elephant and woolly rhinoceros, while the MIS-11c fauna is characterised by horse and red deer. Both the fauna and the archaeology are space-averaged (the smallest definable analytical spatial unit is the river catchment, although bones and artefacts will have been transported over a range of different distances) and time-averaged (the smallest definable analytical temporal unit is the MIS sub-stage associated with the gravel deposits). A regional scale analysis therefore enables change in biface technology (from MIS-11c to MIS-11a, across the river catchment) to be tested against changes in large mammal fauna (from MIS-11c to MIS-11a, across the river catchment). In the above example, an association could potentially be made between the marked faunal and technological changes, if the analysis assumes that the respective sets of artefacts and fauna are associated with the individual sedimentary events (see Chapter 7 for further discussion of this issue).

¹⁰ The physical condition of both faunal and lithic materials may indicate varying probabilities of association, but it is stressed that association still cannot be *demonstrated*.

- Demographic change (macro-scale): this has been recently demonstrated through MIS variations in artefact density, within fluvial secondary contexts (Ashton & Lewis 2002). As with the technological change data (see above), three key points are evident:
 - These palimpsest data sets cannot be directly mapped against high resolution biological evidence, due to the contrasts in the spatio-temporal scales.
 - The high resolution biological data can only be employed as an example of the multiple possible habitats and environmental conditions that existed during the timespan (MIS in the work of Ashton & Lewis (2002)) over which the fluvial secondary context archaeology was deposited.
 - The archaeology can be indirectly associated with the low resolution biological evidence, utilising their shared time and space-averaged palimpsest structures. The low resolution biological data (defined by MIS-units) provides an environmental framework against which changes in hominid demography can be tested. Such possible connections (e.g. between technology, hunting strategies, social structures, environments and biota) have been more fully explored by Ashton & Lewis (2002).
- Responses to climatic change and perception of environments (micro- and macro-scale): this aspect of hominid behaviour is intended to highlight elements of Palaeolithic societies which are typically ignored in favour of tool making and subsistence activities. The premise is relatively simple: that as another social mammal, hominids may well have perceived and reacted to environmental and climatic change at broadly similar spatio-temporal scales to the large mammalian fauna. Since macro-scale data (e.g. Schreve's MAZ's) provides a range of data regarding mammalian distributions at the MIS and MIS sub-stage scales, it is argued that hominids could potentially be mapped against these patterns to explore trends in Palaeolithic occupation and migration (e.g. the apparent abandonment of Britain during MIS-6). Finally, it is noted that hominids may also have been sensitive to the high resolution environmental and climatic changes evident in micro-flora and fauna, although the scalar contrasts between micro-scale palaeoenvironmental data and secondary context archaeology do not permit the direct investigation of this potential relationship.

The above discussion highlighted issues of data scales and their implications for the applications and potential of palaeoenvironmental data within assessments of archaeological secondary contexts. The final section briefly expands this theme with respect to current research questions in British Palaeolithic studies.

5. PALAEOENVIRONMENTAL DATA, PALAEOLITHIC QUESTIONS & CONCLUSIONS

A brief review of the extant literature regarding current British Palaeolithic research suggests a core of key themes to which the interrogation of archaeological secondary contexts is relevant:

- The earliest occupation of 'Britain' during the Pleistocene (e.g. Roberts *et al.* 1995; Roebroeks 1996, & van Kolfschoten 1995; Roberts & Parfitt 1998; Wymer 1999; Rose *et al.* 2001).
- Patterns of colonisation and demography during the late Middle Pleistocene (e.g. Hosfield 1999; White & Schreve 2000; Ashton & Lewis 2002).
- Palaeolithic technology and hominid behavioural repertoires (e.g. Roberts & Parfitt 1998; White 1998a, 1998b; Gamble 1999; Wenban-Smith 1998, *et al.* 2000; White 2000, & Schreve 2000).
- The geochronological frameworks of the Middle and Late Pleistocene (e.g. Maddy *et al.* 1998; Bridgland 1998, 2000, 2001; Maddy *et al.* 2001; Schreve 2001a, 2001b; Bridgland & Schreve 2001; Current & Jacobi 2001; Preece 2001; Coope 2001; Keen 2001; Schreve & Bridgland 2002; Schreve *et al.* 2002).

With respect to these key themes and archaeological secondary contexts, where and how can the palaeoenvironmental data resource be applied? This review of the resource has indicated that the data covers a wide range of spatial and temporal scales, from stenoptic beetles to continent-ranging mammoths. These data scales mirror the variable and wide-ranging resolutions evident in archaeological

material from the Middle and Late Pleistocene. The applications of palaeoenvironmental data therefore range from high resolution, small-scale and multi-proxy reconstructions of micro-habitats and local environments (e.g. Roe 2001; Schreve *et al.* 2002), to the low resolution, large scale mammal assemblage zones of Schreve (1997, 2001a, 2001b). In the case of the earliest occupation and geochronological frameworks themes outlined above, the applications of the palaeoenvironmental data are easily defined:

- Earliest occupation theme: linking biostratigraphically significant species (or assemblages of species) to the occurrence of otherwise undated archaeological materials within MIS and sub-MIS-scale secondary archaeological contexts. This has been previously demonstrated for primary context sites (e.g. the presence of *Stephanorhinus hundsheimensis*, *Ursus deningeri*, and *Arvicola terrestris cantiana* in the archaeological sediments at Boxgrove (Roberts & Parfitt 1998)) but could also potentially be applied to archaeological secondary contexts.
- Geochronological frameworks theme: linking biostratigraphical models to existing frameworks (e.g. absolute dating and/or terrace stratigraphy models). While it is clear that different schemes are sometimes contradictory (e.g. mammalian and coleoptera data are currently at variance with pollen biostratigraphies (Keen 2001)), these biostratigraphical approaches offer multi-proxy data and potential sub-MIS stage resolution (e.g. Schreve 2001a).

However, the application of these data to themes 2 (colonisation and demography) and 3 (technology and behaviour) is more difficult to identify. This is primarily due to the significant contrasts between the spatio-temporal scales of the various data sets. As discussed in Section 4, it is suggested here that the direct applications of high resolution palaeoenvironmental data are limited with respect to secondary context archaeology. While the derived archaeological data provide valuable time-averaged insights into technology and demography, the cultural debris cannot be demonstrably associated with the reconstructed habitats. In other words, while the archaeology provides direct evidence of hominid presence (within coarse timescales), that presence cannot be related to specific local habitats and environments. Those environments can only be presented as examples of the range of environments and habitats that were present, and which may or may not have been encountered by hominids. This last issue is specifically highlighted, since it is often not made explicit within multi-proxy investigations of Quaternary sequences.

However, low resolution palaeoenvironmental data can be indirectly linked at the scalar level with secondary context archaeology. This reflects their comparable scales of magnitude (e.g. river system catchments incorporating derived artefacts and fluvially transported mammal remains into time-averaged fluvial sedimentary sequences). These data are inevitably low in resolution and coarse-scale, but provide robust indications of broad trends, both in hominid technology and mammal/tree species distributions, although it is stressed that this data mapping does *not* assume that encounters between hominids and specific flora/fauna associations occurred. Such data are nonetheless extremely valuable as they can be employed to test multi-MIS changes in hominid demography, extra-regional colonisation, and technology, and explore potential relationships between hominid behaviour and the environment. They therefore highlight the importance of both regional data sets and macro-analysis approaches.

In conclusion, this module initially highlighted four goals:

- The identification of biological data sources with the potential for reconstructing fluvial palaeoenvironments: these currently cover a wide range, primarily vertebrates (including large and small mammals, fish, amphibians and birds), molluscs (non-marine), ostracods, coleoptera, pollen, and plant macro-fossils. It is also apparent however that new sources of palaeoenvironmental data are becoming available, reflecting new technological and methodological developments. These include Cladocera (a freshwater crustacean (the water flea)), Chironomids (non-biting midges), and testate amoebae (Evans & O'Connor 1999: 145; Charman 2001).
- The relative potential of the different data sources: based on the relative fragility of the different materials and their variable survival potential during re-working episodes, it was apparent that

mammals and molluscs are more likely to be recovered from archaeological secondary contexts than any other type of palaeoenvironmental data. This reflects their greater durability and assumes (Chapter 2) that high energy sediments (e.g. fluvial gravels) constitute the bulk of the deposits within these secondary contexts. However, it is also clear that where fine-grained and organic sediments are preserved, a wide range of biological data may be recovered (although taphonomic factors are still important). Finally, it was clear that local sedimentary regime variations were of greater significance than sampling strategies with regard to the diversity of biological data recovered.

- The spatio-temporal resolution of the different biological data sources: it was clear that these varied markedly, and that secondary context archaeology cannot be directly mapped against high resolution palaeoenvironmental reconstructions. It is argued here however that secondary context archaeology and low resolution palaeoenvironmental data occur at similar scales of magnitude, and can be employed to generate comparable, low resolution models of different aspects of the Pleistocene environment.
- Relationships between palaeoenvironmental data and the current questions prevalent in studies of Pleistocene hominids: it is stressed that these relationships must be made explicit (irrespective of the specific questions), since there are fundamental scalar contrasts between the archaeological and biological data.