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# The mammalian faunas of Pakefield/Kessingland and Corton, Suffolk, UK: evidence for a new temperate episode in the British early Middle Pleistocene

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**Abstract**

It has been recognised for some time that early Middle Pleistocene mammal faunas in Britain can be divided into an earlier group with *Mimomys savini* (e.g. West Runton Freshwater Bed—WRFB), and a later group with *Arvicola terrestris cantiana* (Boxgrove, Westbury, Ostend), representing two or more temperate/interglacial stages. On the basis of the available early Middle Pleistocene non-marine molluscan faunas, Meijer and Preece (in: C. Turner (Ed.), The Early Middle Pleistocene in Europe, Balkema: Rotterdam, 1996, pp. 53–82.) and Preece (Quaternary Science Reviews 20 (2001)) recognised three biostratigraphic groups, representing at least three temperate stages. These are largely compatible with the vertebrate faunas, but new evidence presented here strongly indicates that Pakefield/Kessingland represents an additional, hitherto unrecognised temperate stage with *Mimomys savini*, younger than the WRFB but older than Little Oakley, Boxgrove and Westbury.New exposures and finds from the Cromer Forest-bed Formation at Pakefield, Suffolk have prompted a fresh look at the palaeontology of Pakefield/Kessingland and also Corton, which has a similar lithostratigraphic and biostratigraphic sequence. The large-mammal fauna (at least in part pollen substage II) includes *Hippopotamus* sp., *Palaeoloxodon antiquus*, and *Megaloceros dawkinsi*—none of which has so far been found in the WRFB—strongly suggesting that the Suffolk sites represent a distinct stage. Further, no records of 'southern' European plant, invertebrate or vertebrate taxa have been found in the WRFB, whereas the plants *Trapa natans* and *Salvinia natans*—indicating summers warmer than now—are known from Pakefield/Kessingland and Corton, providing corroborative evidence for a stage distinct from the Cromerian *s.s.* 

## 1. Introduction

Oxygen isotope curves show that the early Middle Pleistocene (ca. 780,000–450,000 BP, approximately equivalent to Oxygen isotope stages (OIS) 19–13) was a period of complex climatic change, and this complexity is becoming increasingly apparent in the terrestrial record (Turner, 1996a, b). This period corresponds to the "Cromerian Complex" of the Netherlands, in which at least four temperate stages have been recognised (e.g. Zagwijn, 1996).

In Britain, early Middle Pleistocene deposits and vertebrates are known principally from the classic Cromer Forest-bed Formation (CF-bF) (Norfolk and Suffolk), Little Oakley (Essex), Sugworth (Berkshire), Boxgrove (Sussex), and the cave at Westbury-sub-Mendip (Somerset) (Stuart, 1996).

Bishop (1982) interpreted the mammalian assemblages from the "Calcareous Group" at Westbury-sub-Mendip as distinct from, and later than, the West Runton Freshwater bed (WRFB) —the Cromerian stratotype, which is part of the CF-bF (see below). This view has been confirmed by further work on the site (Andrews, 1990; Stringer et al., 1996). The vertebrate faunas from a recent major series of excavations at Boxgrove also strongly indicate a post-Cromerian (*s.s.*) age (Roberts and Parfitt, 1999). In particular, it has been recognised for some time that early Middle Pleistocene vertebrate faunas can be divided on the basis of the species of water vole present, into an earlier group with *Mimomys savini* (e.g. WRFB) and a later group with *Arvicola terrestris cantiana* (e.g. Boxgrove, Westbury). Among other differences is the presence of *Homo* (artefacts and skeletal remains) at Boxgrove, and possibly also Westbury (putative artefacts). Sites with *Arvicola terrestris cantiana* as part of a "Cromerian" fauna appear to date from the later part of the early Middle Pleistocene, before the Anglian cold stage.

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Further complexity in the early Middle Pleistocene was clearly demonstrated by Meijer and Preece (1996) who recognised the following groupings of non-marine Mollusca indicating discrete temperate phases (oldest first): (1) West Runton WRFB, Sugworth, Kessingland; (2) Little Oakley and; (3) Sidestrand/Trimingham *Unio* Bed (CF-bF, Norfolk). The present paper proposes an additional post-WRFB, pre-Boxgrove/Westbury temperate stage on the basis of the mammalian assemblages from the CF-bF of Pakefield/Kessingland and Corton.

## 2. Cromer Forest-bed formation

Along the North Sea coast of Norfolk and Suffolk a complex and spatially varied sequence of freshwater and marine sediments occurs, underneath the glaciogenic deposits of the Anglian stage that make up most of the sediments exposed in the cliffs (Fig. 1). These ''Forest Bed'' deposits have been famous for their fossil mammal remains since the early part of the 19th century (Newton, 1882; Stuart, 1996). In his comprehensive work on the 'Pre-glacial' succession, West (1980) divided the sequence into an older Norwich Crag Formation ('Weybourne Crag' of Reid, 1882, 1890) and a younger CF-bF. Within the latter he recognised the following stages, based on pollen and lithostratigraphy (oldest first): Pastonian (temperate); Beestonian (cold); Cromerian (temperate); and Anglian (cold, glaciation). Studies of in situ mammalian assemblages in comparison with sites from elsewhere in Europe (Mayhew and Stuart, 1986; Lister, 1993, 1996, 1998) indicates that the Pastonian belongs to the Early Pleistocene, whereas the other deposits are mostly or entirely of early Middle Pleistocene age. The two groups of deposits are separated in time by at least a million years, indicating a major stratigraphic hiatus within the CF-bF (Lister, 1996, 1998). In the last two decades, continuing work on the molluscs and vertebrates of the CF-bF and elsewhere, has provided evidence for additional temperate phases within the early Middle Pleistocene (Meijer and Preece, 1996; Turner, 1996a, b; Preece, 2001; Stringer et al., 1996; Roberts and Parfitt, 1999).

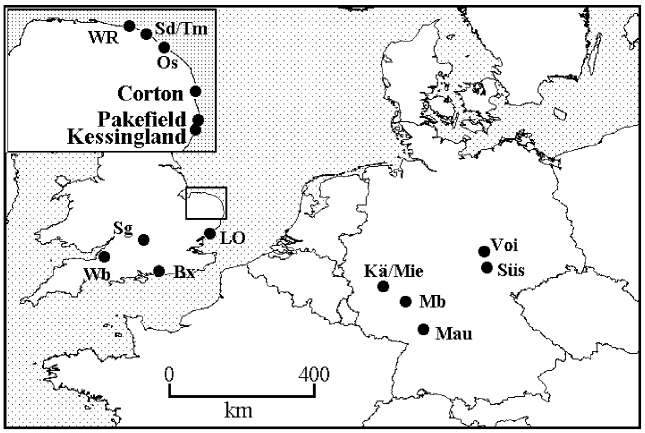



Fig. 1. Location of early Middle Plesitocene sites mentioned in the text. England: WR, West Runton; Sd/Tm, Sidestrand/Trimingham; Os, Ostend; Sg, Sugworth; LO, Little Oakley; Wb, Westbury-sub-Mendip; Bx, Boxgrove. Germany: Kä/Mie, Kärlich/Miesenheim; Mb, Mosbach; Mau, Mauer; Voi, Voigtstedt; Süs, Süssenborn.

The, WRFB, on the Norfolk coast, is the stratotype for the Cromerian temperate stage, and by far the most intensively studied CF-bF site (West, 1980, 1996; Stuart, 1996). Interest in the site has been further enhanced by the discovery and excavation 1990–1995 of a nearly complete skeleton of the mammoth *Mammuthus trogontherii* (Stuart, 1992a, 1997; Ashwin and Stuart, 1996). The exceptionally rich vertebrate faunal list so far includes over 40 mammalian taxa, plus fishes, amphibians, a snake and birds. The sediments also contain pollen, plant macrofossils, non-marine molluscs, ostracods, and beetles, all of which are currently being reassessed or studied more extensively as part of the West Runton Elephant Project. The WRFB vertebrate assemblage is essentially from Cromerian pollen substage II (IIa and IIb). The palaeobotanical evidence (West, 1980) indicates temperate woodland, and areas of grass and herbs, with alder carr, reedswamp and aquatic vegetation close to the depositional site.

All the fossil groups in the WRFB indicate a temperate climate, much as today, with a notable absence of taxa in which the northern limit of distribution today is well to the south of the British Isles. For example, there is no record of *Emys orbicularis* (European pond tortoise) which is present in most temperate small-vertebrate assemblages in Britain (Stuart, 1979, 1982, 1995; Gleed-Owen, 1999), nor of *Trapa natans* (water chestnut) and *Salvinia natans* (floating water fern), although both occur widely elsewhere in the CF-bF (West, 1980). Given the intensity of research on the WRFB it is very unlikely that any of these would have been missed, and their absence appears very significant (see later).

Although a good palaeobotanical record is available for much of the CF-bF (West, 1980, 1996), very few mammalian remains have been recovered in situ from most localities, so that the provenance of most material is equivocal (Lister, 1996; Stuart, 1996). For nearly 200 years most fossils have been collected loose from the beach and foreshore, having washed out of the cliffs, and their stratigraphic provenance can only be inferred indirectly. The notable exceptions to this situation are the WRFB, from which many vertebrate remains have been recorded in situ, and Pakefield/Kessingland and Corton, where a number of finds are recorded in situ and others can be related to specific horizons within relatively simple sequences.

## 3. Site descriptions and pollen stratigraphy

### 3.1. Pakefield/Kessingland

The stratigraphy of the cliff exposures at Pakefield and Kessingland was described by Blake (1877, 1890) with accompanying detailed sections (Blake, 1884). A century later, detailed descriptions of the stratigraphy, and pollen and plant macrofossil analyses were given by West (1980), although exposures were very poor in the 1960s and 1970s and the sections had to be dug out by hand. Fortunately, within the last few years renewed coastal erosion has re-exposed the cliff sections at Pakefield (Fig. 2), revealing a sequence very similar to that seen by Blake.

The cliffs are capped by chalky till, overlying current-bedded glaciogenic outwash sands (Corton Beds) (Fig. 2), both belonging to the Anglian cold Stage. The oldest (marine) deposits, recorded in boreholes and seen in places at the base of the cliff, have been assigned to the Early Pleistocene (West, 1980). Most of the deposits exposed in the base of the cliff and on the foreshore are of early Middle Pleistocene age.

On the foreshore, Blake (1884, 1890) saw well-stratified sands and gravels, "ferruginous and indurated in places" with "numerous mammalian remains". The restricted lateral extent of this deposit strongly suggests one or more river channel fills.

Above the gravels, and currently visible in the cliff face, is the "Rootlet Bed". This is a grey to reddish-brown compact silt with carbonate nodules ("race"), occasional rootlets, and mammal remains. This is much more extensive than the underlying bed and is interpreted as an overbank deposit ("alluvium" of West, 1980, Table 32, p. 195). Blake (1890) describes it as an "unstratified homogeneous greenish-grey clay, up to 10 ft (3 m) thick, with race, small flints and mammal remains". He records thousands of vertical rootlets, 0.25–1.5 in (ca. 6–38 mm) diameter, penetrating downwards as much as 6 ft (1.8 m) from the top of the bed—evidence of vegetation growing on the floodplain. The overlying dark laminated muds and silts (West's Beds g,h) occupy a broad channel cut into the Rootlet Bed (Bed d) (West, 1980, Fig. 46)

Blake describes a "*Unio* Bed"—ferruginous flint gravel "with many *Unio* (valves united) and other Mollusca"—underlying black laminated beds "at the southern end of the basin-shaped hollow south of Lighthouse Gap" (national grid reference TM 537 884). The Mollusca studied by Meijer and Preece (1996) appear to have been collected from similar deposits at Kessingland at the end of the 19th century or beginning of the 20th century. The *Unio* Bed, occurring between the Rootlet Bed and overlying laminated beds, has been rediscovered recently (April 2000) by Parfitt. It contains small-vertebrate remains and poorly preserved molluscan shells.

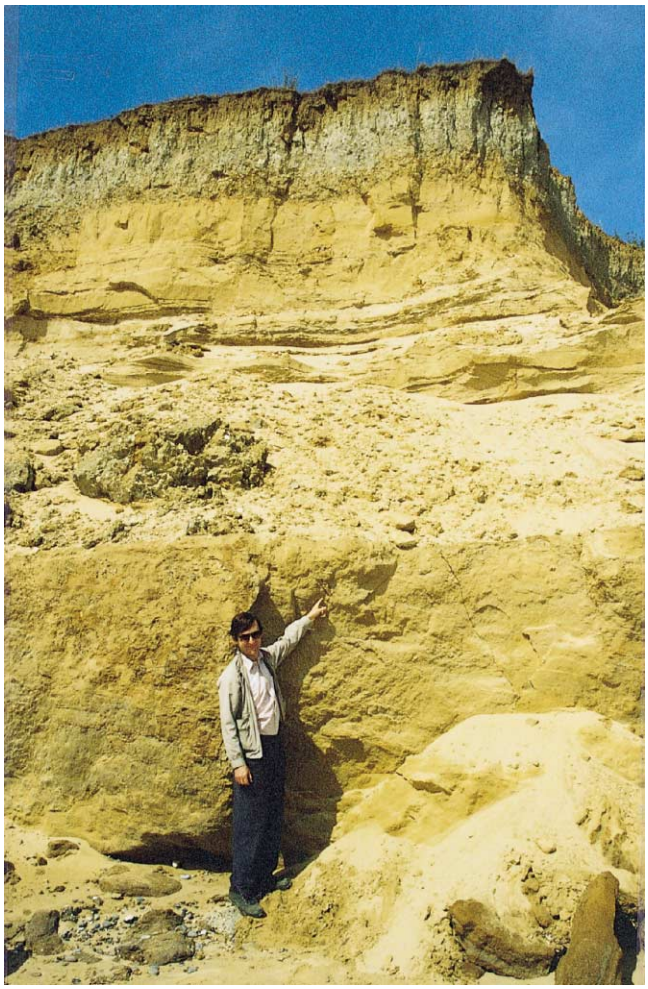


Fig. 2. Section at Pakefield, 1997. Rootlet Bed at base of cliff with overlying glaciofluvial sands and till. Figure (AML, 1.75 m) is pointing to in situ antler fragment of red deer, *Cervus elaphus*.

Blake also recorded a black silt, which yielded sparse small vertebrates, in a "slight basin-shaped hollow in the lower part of the Rootlet Bed" 120 yards (ca. 110 m) north of the flagstaff at Kessingland, (at ca TM 536862) (Blake, 1884).

Table 1 summarises West's (1980, pp. 86–89) account of the sequence, incorporating data from Blake (1877, 1890) and observation of the sections available to Spring 2000.

The pollen from the Rootlet Bed (West's Bed d) was poorly preserved with many corroded grains, so that the original composition has been distorted by differential preservation. *Pinus* and Gramineae are the main taxa present, with low amounts of *Ulmus* and *Quercus*. West compared the assemblage to that of the Rootlet Bed at Corton (substage IIb, see below).

The organic laminated silts of Bed g contain an assemblage with high *Pinus* and *Alnus*, and substantial

Table 1
Pakefield/Kessingland—early Middle Pleistocene sequence (modified from West, 1980)

| Bed | Description | Thickness (m) | Pollen substage | Vertebrates |
|---|---|---|---|---|
| i | Corton beds | | | |
| h | Laminated silty clays—tidal | 0.8 | | |
| g | Laminated silty organic muds, with wood | 1.8 | IIIa | |
| | Unio bed | 0.3 | | Small vertebrates |
| d | Rootlet bed | 3.5 | II (?) | Large mammals |
| | Organic silt at Kessingland | | | Small vertebrates |
| c | Red-brown sand and gravel (ferruginous) | 2.0 plus | | Large mammals |

Table 2
Corton—early Middle Pleistocene sequence (modified from West, 1980)

| Bed | Description | Thickness (m) | Pollen substage | Vertebrates |
|---|---|---|---|---|
| j | Till | | | |
| i | Sand with drift mud | 0.5 | | |
| h | Laminated silty clays—tidal | 1.4 (3 m Blake) | IIIa, IIIb | |
| f | Organic muds | 0.16 | IIb, IIIa | |
| e | Rootlet bed | 2.3 | IIb | large mammals |
| d | Detritus mud | 0.2 | IIa | |

*Quercus*, *Ulmus*, *Carpinus* and *Corylus*, very similar to that of the lower part of Bed h at Corton, and similarly assigned to substage IIIa (West, 1980). The rich macrofossil assemblage notably includes the warm indicators *Trapa natans* (water chestnut) and *Salvinia natans* (floating water fern) (West, 1980, Table 31 pages 193–4).

### 3.2. Corton

At Corton, the stratotype for the Anglian Stage (Mitchell et al., 1973), early Middle Pleistocene deposits again occur beneath glaciogenic deposits. The stratigraphy of these "pre-glacial" deposits was recorded by Blake (1884, 1890) and West (1980, pp. 81–85), but this part of the section is now inaccessible due to the construction of sea defences. The sequence (Table 2) is very similar to that of Pakefield/Kessingland, except that at Corton there is no record of ferruginous gravels underlying the Rootlet Bed.

The pollen spectra from Bed d, with *Alnus*, *Quercus*, *Ulmus*, and *Pinus,* are assigned to substage IIa (West, 1980, p. 83). Substage IIb, with abundant *Quercus*, *Ulmus*, *Tilia* and *Corylus*, is represented in the upper part of the Rootlet Bed (Bed e), and in the lower part of Bed f. Plant macrofossil assemblages from both horizons include abundant *Salvinia natans*. The upper part of Bed f and the lower part of the silty clays of Bed h are characterised by an assemblage high in *Carpinus*, *Quercus*, *Ulmus* and *Corylus*—substage IIIa. Plant macrofossils again include *Salvinia natans*.

### 3.3. Correlation of Pakefield/Kessingland with Corton

The overall similarity of stratigraphic sequence, pollen biostratigraphy and mammalian faunas strongly argues that the Rootlet Bed at both Pakefield/Kessingland and at Corton are of the same age, and very probably represent the same river floodplain deposits. It can be inferred that the Rootlet Bed was deposited in a temperate phase of the early Middle Pleistocene, (a pollen substage II). The presence of *S. natans* and *T. natans* in the Rootlet Bed and in the succeeding laminated silts/clays indicates mean July temperatures higher than now.

The ferruginous gravels at Pakefield/Kessingland have a very similar mammalian fauna to that of the Rootlet Bed at these sites and at Corton (Table 3), and it appears likely that they are not significantly older than the Rootlet Bed, probably dating from the same temperate phase.

## 4. Vertebrates from Pakefield/Kessingland and Corton

Many mammalian remains have been recovered from the sands and gravels ("ferruginous gravel") at Pakefield/Kessingland, from the Rootlet Bed at Pakefield/Kessingland (where it immediately overlies the gravel) and from the Rootlet Bed at Corton (Figs. 3–11). At Corton the CF-bF exposures are now covered by sea defences, and the finds in museum collections—apparently all from the Rootlet Bed—date from the late 19th and early 20th centuries. Many fossils from Pakefield/Kessingland were found during the same period. Since 1994 much significant new material, has been recovered both from the Rootlet Bed, and especially from the underlying gravels.

Contemporary accounts are very useful in establishing the provenance of 19th century finds. They clearly show that, as at West Runton, but unlike most other CF-bF material, many of the fossils were either collected in situ, or could be reliably attributed to specific horizons.

Gunn (1891, p. 60) describes "an abundance of elephantine and cervine remains" in deposits beneath the Rootlet Bed at Pakefield. Blake (1890, pp. 17–21) gives graphic descriptions of the beds and fossil finds, and on the accompanying horizontal section (Sheet 128) marks the precise positions at which several specimens were found.

Table 3
Mammals recorded from Pakefield/Kessingland and Corton[a,b]

| Mammalia | Pakefield/Kessingland gravel | Pakefield/Kessingland Rootlet bed | Numbers of specimens | Corton Rootlet bed | Numbers of specimens |
|---|---|---|---|---|---|
| **Rodentia** | | | | | |
| *Mimomys savini* | | RB | 1 | | |
| *Castor fiber* | | + | 1 | | |
| *Trogontherium cuvieri* | | + | 2 | | |
| **Carnivora** | | | | | |
| *Homotherium sp.* | g, + | | 2 | | |
| *Panthera leo* | | + | 1 | | |
| *Canis lupus* | | + | 4 | | |
| *Crocuta crocuta* | + | + | 2 | RB | 1 |
| *Ursus sp.* | g | | 3 | | |
| **Proboscidea** | | | | | |
| *Mammuthus trogontherii* | g, + | RB | 22 | RB | 4 |
| *Palaeoloxodon antiquus* | + | | 3 | | |
| **Perissodactyla** | | | | | |
| *Equus sp. (large)* | g, + | + | 5 | | |
| *Equus altidens* | g, + | + | 3 | | |
| *Stephanorhinus hundsheimensis* | + | RB[1] | 41 | RB | 5 |
| **Artiodactyla** | | | | | |
| *Hippopotamus amphibius* | g, + | + | 4 | | |
| *Sus scrofa* | + | + | 4 | RB | 1 |
| *Megaloceros verticornis* | g, + | + | 47 | RB | 1 |
| *Megaloceros savini* | g, + | RB | 19 | RB | 1 |
| *Megaloceros dawkinsi* | + | | 1[3] | | |
| *Dama dama (cf.)* | | + | 2 | | |
| *Cervus elaphus* | g, + | RB[2] | 3 | | |
| *Bison sp.* | g, + | + | 22 | RB | 1 |

[a] Sources: Blake, 1884, 1890; Harmer, 1899; Newton, 1882, 1883; original study of material in collections of Natural History Museum, London (NHM), Norwich Castle Museum (NCM), University Museum of Zoology, Cambridge (UMZC), Yorkshire Museum (YM), the British Geological Survey (BGS), and private collections of Mutch, Stewart and Durbidge.

[b] Key: RB, 'Rootlet Bed' on museum label; RB[1], collected in situ by Durbidge, c, 1994; RB[2], collected in situ by authors, 1996; g, collected by Mutch or Stewart, 1994–1998. +, allocated by preservation type[3], several additional antler bases are suggestive of *M. dawkinsi* but *M. verticornis* cannot be ruled out. Specimen counts are representative but not exhaustive, and include specimens not allocated to bed.

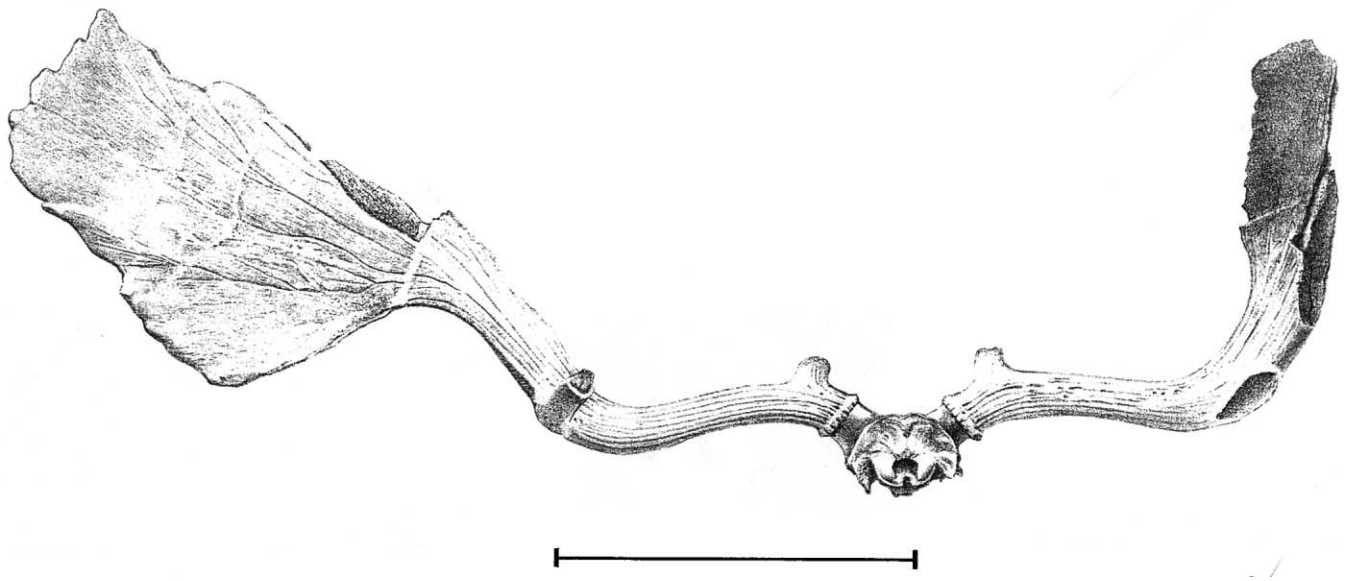


Fig. 3. *Megaloceros verticornis* skull and antlers in posterior view, Pakefield, NHM M11352, from Harmer (1899, Pl. XXI). Scale bar 50 cm.

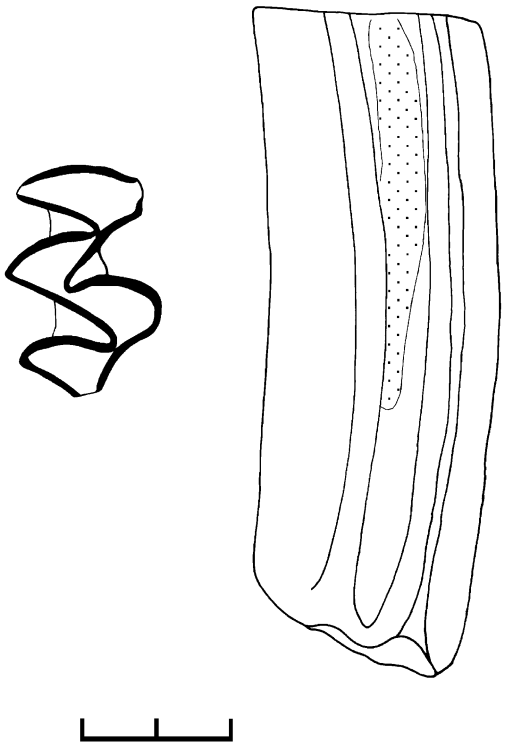


Fig. 4. *Mimomys savini* right $M^2$ from the Unio Bed at Pakefield, in occlusal and lateral views (drawings by Parfitt). The dotted area indicates extent of crown cementum. Scale bar 2 mm.

On the foreshore at Pakefield and Kessingland, Blake (1884, 1890) saw well-stratified sands and gravels, "ferruginous and indurated in places." He records the main area of exposure as extending continuously along the shore for more than 100 yards (ca. 91 m), and for 30–40 yards from the base of the cliff to low water mark. This bed was then, as now, usually covered by modern beach deposits, but when occasionally scoured out by waves during gales many bones were found scattered along the shore, while others were exposed in situ. The bed was also seen at other points along the section. Blake (p. 15) recorded that "numerous mammalian remains are generally procurable." These included "various bones, etc. of *Bos*, *Cervus verticornis*, *Elephas antiquus*, *Equus* and *Rhinoceros*."

Overlying the sands and gravels, Blake (p. 19) reported that "Many mammalian remains occur in places, scattered throughout the unstratified greenish-grey stiff homogeneous clay forming the Rootlet-Bed." "A tooth and jaw of *Rhinoceros etruscus*, and many fragments of bones and antlers of a species of *Cervus* were found, and the precise position where each specimen was obtained is marked on the published Section."

At Corton, Blake indicated that "Horns, teeth or bones of the following Mammalia have been obtained from the Rootlet-bed, *Cervus verticornis* (base of antler), *Elephas antiquus* (4 fine teeth), *Hyaena crocuta*, *Rhinoceros etruscus*, etc.

From a "black silt in the lower part of the Rootlet Bed" at Kessingland, Blake (1884, 1890) obtained bones and teeth of "*Arvicola intermedius*" (the name assigned to remains of the extinct water vole *Mimomys savini* from the WRFB—Newton, 1882), *Perca* (perch) scales and an *Esox* (pike) pre-operculum.

Finally, Harmer (1899) described a particularly spectacular find from the Rootlet Bed at Pakefield—a skull with attached (abnormal) antlers of *Megaloceros verticornis* (Fig. 3), plus associated atlas and axis vertebrae. According to the University Museum of Zoology Cambridge (UMZC) catalogue, they were found in November 1897 at the base of the cliff after a landslip, implying that they came from the Rootlet Bed. The unabraded, dark glossy preservation is consistent with this provenance. The finds are now at the Natural History Museum. The UMZC report for 1898 records that the bones were found by two men, 'one of whom has since died, and the pieces in his possession have so far failed to reach the museum'. It appears that more of the skeleton had been present at the site.

This material, collected by Blake, Gunn, Harmer and others, formed a substantial part of the museum collections examined in the present study. Most of the elephant molars identified by Blake as "*Elephas antiquus*", including the "four fine teeth" from Corton, are now referred to *Mammuthus trogontherii* (Fig. 5). Early Middle Pleistocene material previously identified as *Rhinoceros etruscus* has been referred to *Stephanorhinus hundsheimensis*, although it is possible that some of the material may prove to represent '*Stephanorhinus* species A' recognised by Parfitt (1998) at Boxgrove. Other spectacular fossils include antlers of the giant deer *Megaloceros savini* (Fig. 6), and a complete mandible of the sabre-toothed cat *Homotherium latidens* (Backhouse, 1886; Fig. 7)

Blake (1890) noted that many of the bones from the Rootlet Bed at Pakefield and Kessingland were too fragile to be recovered, and it appears that many of the fossils found there today do not survive either, and most go unrecorded.

From about 1994 Mutch, Stewart and Durbidge have found a number of bones in the gravels at Pakefield.- Fossils found recently in the Rootlet Bed at Pakefield, and seen by the authors, include *Stephanorhinus hundsheimensis* (cheek teeth) and *Cervus elaphus* (part of antler) (Table 3). Of particular importance is the identification by Parfitt (Personal commication, June 2000) of *Mimomys savini* molars (Fig. 4) from the newly-rediscovered *Unio* Bed at Pakefield.

In addition to those finds recorded in situ, many of the fossils in museum collections from Pakefield/ Kessingland can be assigned to either the Rootlet Bed or the underlying gravels on the basis of their

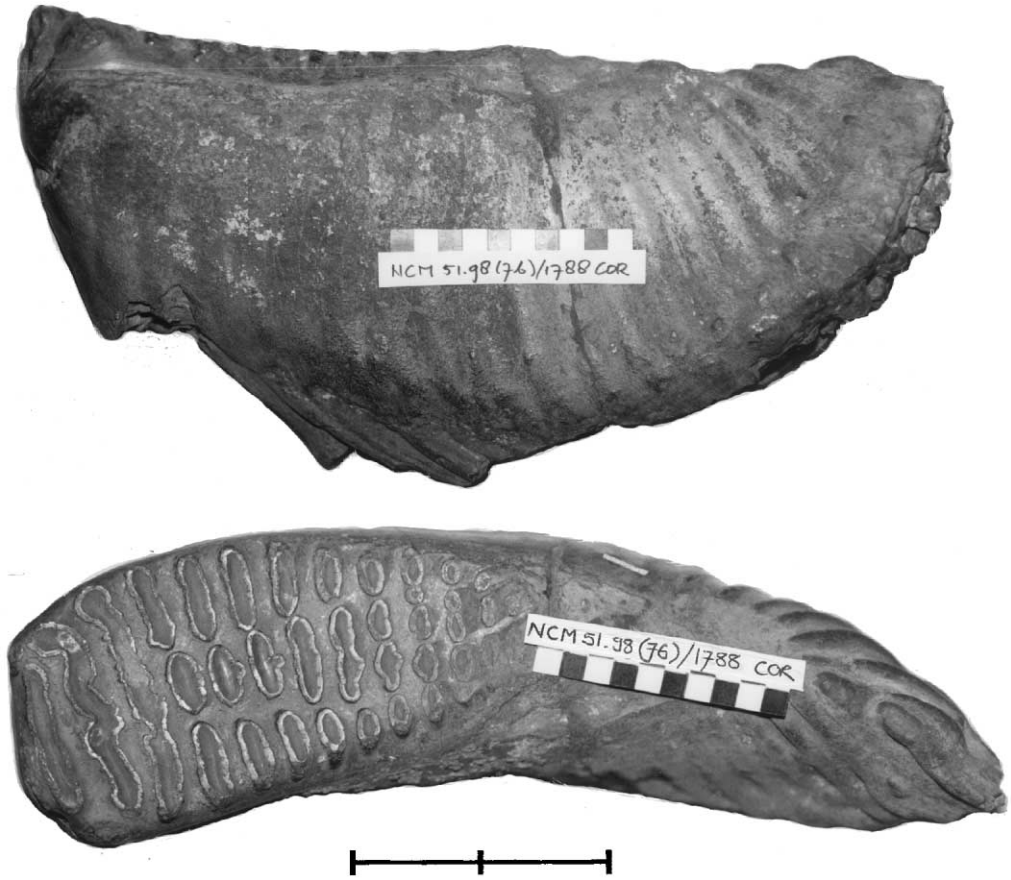



Fig. 5. *Mammuthus trogontherii* left lower $M_3$, NCM 51.98 (76)/1788, one of a complete set of four molars excavated from the Rootlet Bed at Corton (Blake, 1890). Scale bar 10 cm.

Fig. 6. *Megaloceros savini* right skull fragment and antler, Kessingland, NCM 61.18 (3064), in anterior view. Scale bar 10 cm.

preservation (Table 3). The fossils recently collected from the Rootlet Bed are from pale oxidised silts, and are pale yellowish-brown in colour, unabraded, and fragile. Museum collections include material with this preservation type, and also dark shiny unabraded fossils that appear to have come from dark unoxidised parts of the Rootlet Bed. Fossils collected recently from the underlying gravels are tougher, rust-coloured and permineralised (iron oxides, hydroxides), and generally have adhering ferruginous sand and gravel. Some are clearly abraded and many show corrosion and pitting of the surface. Material in museum collections with this type of preservation can also rather confidently be assigned to the gravels. However, a number of fossils show intermediate preservation type, pale and unabraded, but with adhering ferruginous sand. These may originate from sandy parts of the Rootlet Bed.

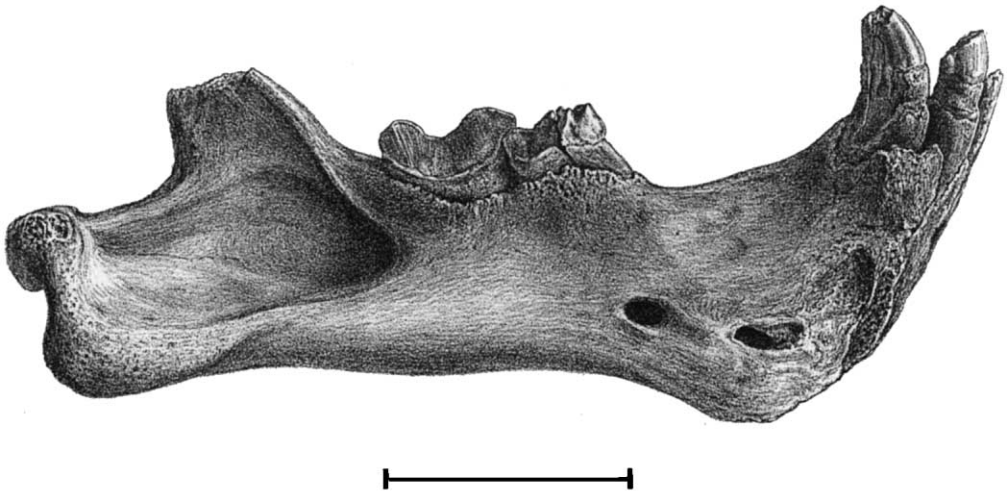


Fig. 7. Homotherium latidens right mandible, from Backhouse (1886). Scale bar 10 cm.

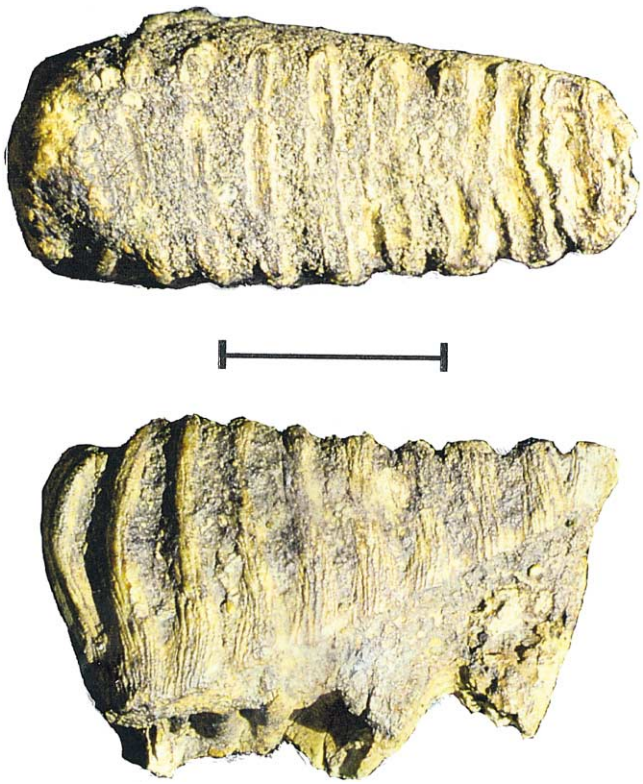


Fig. 8. *Palaeoloxodon antiquus* right $dP_4$ from Kessingland, Leiden Museum. Scale bar 5 cm.

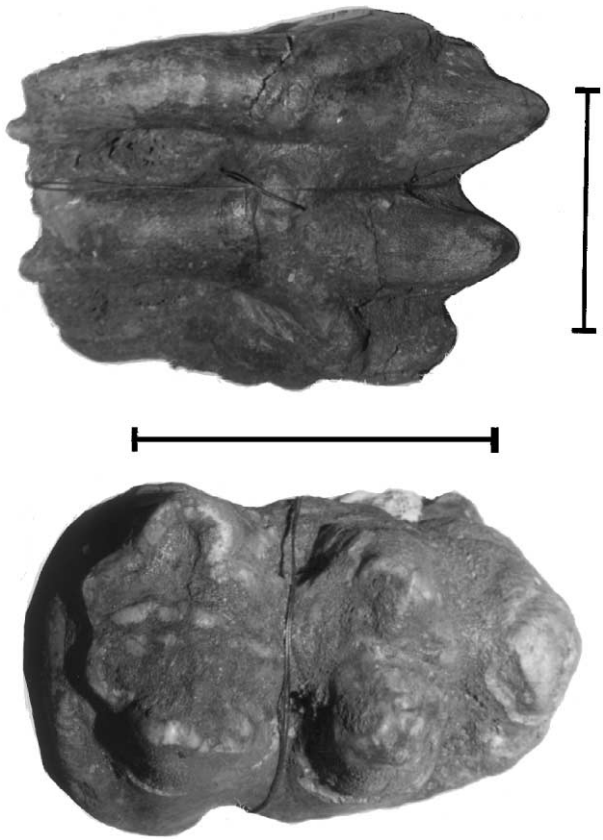


Fig. 9. *Hippopotamus* sp. $M_3$, Kessingland, NCM 38.09 (3513). Scale bar 5 cm.

## 5. Palaeoecology of Pakefield/Kessingland and Corton

The pollen assemblage from the Rootlet bed at Corton (substage IIb) (West, 1980) shows around 95% arboreal pollen with high *Pinus* and *Alnus*, and significant *Picea*, *Betula*, *Ulmus*, *Quercus*, *Tilia*, and *Corylus*. Non-arboreal taxa include Gramineae, Cyperaceae and Chenopodiaceae, plus fern spores. Fen/reedswamp helophytes predominate among the plant macrofossils, which also include trees—*Alnus* and cf. *Betula*, and aquatics—*Stratiotes*, *Typha*, abundant *Azolla filiculoides* and *Salvinia natans*. The presence of *S. natans* (distribution map in Keen et al., 1999) and *T. natans* in the laminated beds at Pakefield/

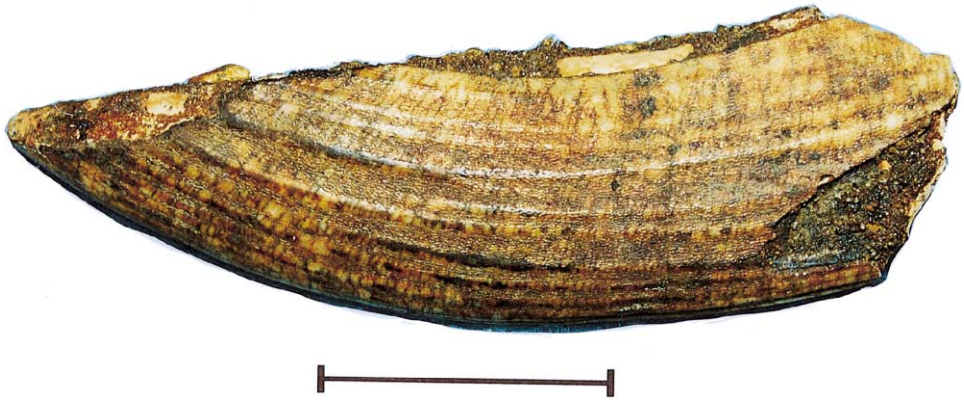


Fig. 10. *Hippopotamus* sp. Part of left canine, Pakefield gravel, private collection J. Stewart. Scale bar 5 cm.

Fig. 11. *Megaloceros dawkinsi* left skull fragment and antler base, Kessingland, NCM 256, in anterior view. Scale bar 10 cm.

Kessingland, and of *S.natans* in the Rootlet Bed at Corton indicates summer temperatures higher than today. The sparse non-marine mollusc fauna from the Rootlet Bed at Corton indicates marshy ground (Sparks in West, 1980, p. 84). Differences between the pollen assemblages from the Pakefield/Kessingland Rootlet Bed and at Corton were attributed to selective weathering of pollen grains at the former and to local facies variations.

West (1980) interprets these assemblages as indicating regional temperate woodland, fen and fen carr with a body of shallow freshwater.

The diverse large-mammal fauna indicates temperate forest plus areas of grass/herb on the river floodplain; and/or a mosaic of forest and open vegetation, with considerably more herb vegetation than might be inferred from the pollen spectra. *Sus scrofa* and *Dama dama* are obligate woodland species, whereas *Mammuthus trogontherii*, *Equus* spp., and *Hippopotamus* sp., and probably also *Megaloceros* spp. (large antlers), *Crocuta crocuta* and *Panthera leo* suggest that extensive open areas were also present. Such areas may well have been in part initiated and maintained by the activities of large herbivores, especially elephantids. The occurrence of hippopotamus *Hippopotamus* sp., beaver *Castor fiber*, extinct beaver-like rodent *Trogontherium cuvieri* and probably also the water vole *Mimomys savini* are consistent with the presence of a large body of water.

## 6. Biostratigraphy

### 6.1. European context

The faunas from early Middle Pleistocene sites in Germany show a broadly similar pattern to that seen in Britain (Table 4). The German sites can be divided into two groups: an earlier group with *Mimomys savini* and a later group with *Arvicola terrestris cantiana* (Koenigswald and Kolfschoten, 1996). Stratigraphical superposition of the two species of water vole is seen in the Kärlich sequence (Kolfschoten and Turner, 1996). Of the large mammals, several taxa, e.g. *Stephanorhinus hundsheimensis*, *Megaloceros verticornis*, and *Mammuthus trogontherii*, occur in both groups. However, *Megaloceros savini* and *Equus altidens* are known only

Table 4
Selected mammal records from early Middle Pleistocene sites in Germany[a,b]

| | Mimomys faunas | | | Arvicola faunas | | | |
|---|---|---|---|---|---|---|---|
| | Voi | Süss | KärF | KärG | Mie | Mau | Mb2 |
| *Homo* sp. | | | | | ✠ | ✠ | |
| *Mimomys savini*† | ✠ | ✠ | ✠ | | | | |
| *Arvicola terrestris cantiana*† | | | | ✠ | ✠ | ✠ | ✠ |
| *Panthera leo* | | | | | | + | + |
| *Homotherium* sp.† | + | + | | | | + | + |
| *Mammuthus trogontherii*† | +[c] | + | + | | + | | + |
| *Palaeoloxodon antiquus*† | | | | | | ✠ | ✠ |
| *Equus ferus*[d] | | ? | | + | | + | + |
| *Equus altidens*† | ? | ✠ | | | | | |
| *Equus suessenbornensis*† | ✠ | ✠ | | | | | |
| *Stephanorhinus hundsheimensis*† | + | + | | + | + | + | + |
| *Stephanorhinus kirchbergensis*† | | | | | | | ✠ |
| *Sus scrofa* | + | + | | | | + | + |
| *Hippopotamus* sp. | | | | | | ✠ | ✠ |
| *Alces latifrons*† | + | | | + | | + | + |
| *Capreolus capreolus* | + | + | | | + | + | + |
| *Megaloceros verticornis*† | + | + | + | + | | | + |
| *Megaloceros savini*† | ✠ | ✠ | | | | | |
| *Cervus elaphus* | + | + | + | + | + | + | + |

[a] Data from: Kahlke, 1965, 1969; Kolfschoten and Turner, 1996; v. Koenigswald and Tobien, 1987, Stuart, 1981. Key: Voi, Voigtstedt, Süs, Süssenborn, KäF, Kärlich Bed F, KäG, Kärlich Bed G, Mie, Miesenheim 1, Mau, Mauer, Mb2, Mosbach 2

[b] †Extinct taxon; ✠ present, likely biostratigraphic significance; + present; ? taxon uncertain.

[c] *Mammuthus meridionalis* and *M. trogontherii* both occur at Voigtstedt—Lister, in preparation.

[d] *Equus ferus* refers to all caballine horses, including '*E. mosbachensis*'.

from the earlier faunas, whereas *Palaeoloxodon antiquus*, *Hippopotamus* sp., *Stephanorhinus kirchbergensis* and *Homo* sp. are only recorded from the later group. The change from hornblende-dominated to pyroxene-dominated heavy mineral assemblages is an important stratigraphic marker in the sediments of the middle and lower Rhine region. The fact that Karlich G falls below this boundary, whereas Miesenheim 1 is above it, clearly demonstrates that two distinct temperate phases are represented by the German *Arvicola* faunas (Kolfschoten and Turner, 1996).

The straight-tusked elephant *Palaeoloxodon antiquus* is a potentially important biostratigraphic marker. Having evolved from *Elephas recki* of the African Plio-Pleistocene (Maglio, 1973), it was in the Levant ca. 800–700 ka (Goren-Inbar et al., 1994, 2000), from where it migrated to Europe. However, it appears not to have reached central and northern Europe until the later part of the Cromerian Complex. It is unknown both from the WRFB and from the huge sample (>1000 specimens) of elephant molars—all *Mammuthus trogontherii*—from Süssenborn, Germany (Guenther, 1969), but does appear in association with the early *Arvicola* faunas of Mosbach II and Mauer (Koenigswald and Tobien, 1987; Koenigswald, 1992; Koenigswald and Heinrich, 1999).

*Megaloceros dawkinsi* has not been recorded outside Britain. However, large megacerine remains from Isernia La Pineta, Italy, referred to *M. solihacus* (Abbazzi and Masini, 1996), are very close to this species, if not conspecific. At the same horizon, and in association with *M. solihacus*, occur *Palaeoloxodon antiquus*, *Hippopotamus* sp. and a water vole very close to the boundary between *Mimomys savini* and *Arvicola terrestris cantiana* (Koenigswald and Kolfschoten, 1996). These authors refer the fauna to the early Middle Pleistocene, although the precise age of the site is debated.

### 6.2. British sites

Our starting-point is the best-known vertebrate assemblage of the British early Middle Pleistocene—that of the WRFB. Biostratigraphically significant taxa include *Mimomys savini*, *Megaloceros savini* and *Equus altidens*. *Palaeoloxodon, Hippopotamus* and *Megaloceros dawkinsi* are notably absent (Table 5).

The limited fauna from Sugworth, Berkshire (Shotton et al., 1980; Stuart, 1980) is similar to that of the WRFB, including *Mimomys savini*, although Sugworth shows much higher percentages of woodland rodents—reflecting closer proximity of woodland to the site—and yielded one incisor of *Lemmus* (Stuart, 1996), not recorded from the WRFB. The Mollusca are also generally similar at the two sites (Meijer and Preece, 1996). Nevertheless, the presence of *Trapa natans*

Table 5
Selected taxa from British early Middle Pleistocene sites[a,b]

| Biostratigraphic Groups | 1 | 2 | 3 | 4 | ? | 5/6/7 | | |
|---|---|---|---|---|---|---|---|---|
| Sites | WR | Sg | Pk/Ks/Co | LO | Sd/Tm | Os | Wb | Bx |
| Pollen substages | II | IIIb | II* | II | IIa | IVa | | |
| **'Southern' taxa (plant, reptile)** | | | | | | | | |
| *Salvinia natans* | – | | ✠ | | | | | |
| *Trapa natans* | – | ✠ | ✠[c] | | | ✠ | | |
| *Emys orbicularis* | – | | | ✠ | | | ✠ | |
| **Mollusca** | | | | | | | | |
| *Valvata goldfussiana*† | ✠ | ✠ | ✠ | | | | | |
| *Tanousia runtoniana*† | ✠ | ✠ | | | | | | |
| *Belgrandia marginata* | – | – | | ✠ | ✠ | | | |
| *Valvata naticina* | – | – | | ✠ | ✠ | | | |
| *Tanousia stenostoma*† | – | – | | ✠ | – | | | |
| *Bithynia tentaculata* | – | – | | – | ✠ | | | |
| **Mammalia** | | | | | | | | |
| *Homo* sp. | | | | | | | ✠ | ✠ |
| *Apodemus sylvaticus* | + | + | | + | | | + | + |
| *Apodemus maastrichtensis*† | | | | ✠ | | | | ✠ |
| *Sicista* sp. | | | | | | | | + |
| *Lemmus* sp. | | + | | | | | + | + |
| *Pliomys episcopalis*† | + | + | | | | | + | + |
| *Mimomys savini*† | ✠ | ✠ | ✠ | ✠ | | – | – | – |
| *Arvicola terrestris cantiana*† | – | – | | – | ? | ✠ | ✠ | ✠ |
| *Canis lupus* | + | | + | | | | + | + |
| *Panthera leo* | + | | + | | | | + | + |
| *Homotherium latidens*† | + | | + | | | | + | |
| *Crocuta crocuta* | + | | + | cf | | | + | + |
| *Mammuthus trogontherii*† | + | | + | | | | | |
| *Palaeoloxodon antiquus*† | | | ✠ | | | ✠ | | |
| *Equus ferus*† | + | | | | | | + | + |
| *Equus altidens*† | ✠ | | ✠ | ✠ | | | | |
| *Equus cf. sussenbornensis*† | + | | | | | | | |
| *Stephanorhinus hundsheimensis*† | + | + | + | | + | | + | + |
| *Sus scrofa* | + | | + | + | | | | + |
| *Hippopotamus* sp. | | | ✠ | | | | | |
| *Alces latifrons* | + | | | | | | | |
| *Capreolus capreolus* | + | | | | | + | | + |
| *Megaloceros dawkinsi*† | | | ✠ | ✠ | | | | ✠ |
| *Megaloceros verticornis*† | + | | + | + | | | | + |
| *Megaloceros savini*† | ✠ | | ✠ | | | | | |
| *Cervus elaphus* | + | + | + | cf | | | + | + |
| *Dama dama* | + | | + | | | | + | + |

[a] Data from: Meijer and Preece (1996); West, 1980; Lister, 1993, 1996; Stuart, 1996; Stuart and West, 1976, Bishop, 1982; Roberts, 1986, A. Turner pers. comm.; Parfitt, 1998; Preece and Parfitt, 2000; Andrews et al., 1999; this paper.

[b] Key: * Pollen substage at Pakefield/Kessingland inferred (see text); † extinct taxon; ✠ present, likely biostratigraphic significance; + present; ? taxon uncertain, –, lack of fossils probably reflecting absence from source fauna; WR, West Runton Freshwater Bed, Sg, Sugworth, Co: Corton, Pk/Ks: Pakefield/Kessingland, LO, Little Oakley, Sd/Tm, Sidestrand/Trimingham, Os, Ostend, Bx, Boxgrove, Wb, Westbury-sub-Mendip.

[c] Only from pollen substage IIIa.

(Gibbard and Pettitt, 1978) and several elements in the beetle fauna (Osborne, 1980) indicate summer temperatures warmer than those which prevailed during the deposition of the WRFB. Since the Sugworth deposits represent pollen substage IIIb, whereas the WRFB is substage II, it is not possible to make direct comparisons. The two sites could represent different phases of distinct early Middle Pleistocene temperate stages, or different phases of the same temperate stage, i.e. the Cromerian *s.s.* The latter interpretation would indicate that the warmest part of the Cromerian *s.s.* was in pollen substage III, not II.

The vertebrate and mollusc faunas from Little Oakley, Essex include *Mimomys savini*, but there are significant differences from the WRFB. The modest vertebrate fauna (substage II) includes *Megaloceros dawkinsi*, not recorded from the WRFB (Lister et al., 1990). Subsequently, Parfitt (Personal communication)

has recognised *Apodemus maastrichtiensis* in the original material. The presence of pond tortoise *Emys orbicularis* (indicating summer temperatures higher than today) further emphasises that the site is not Cromerian *s.s.* The molluscan fauna, currently unique, indicates that Little Oakley is younger than the WRFB, Sugworth and Pakefield (see below).

Westbury-sub-Mendip and Boxgrove, with *Arvicola terrestris cantiana*, appear to represent more than one temperate episode. As they are, respectively, a cave site and an open site, with very different taphonomic histories, detailed faunal comparison is difficult. Andrews et al., 1999 recognise two temperate peaks with an intervening cooler interval within the Westbury early Middle Pleistocene sequence. Parfitt (Preece and Parfitt, 2000, p. 21) considers that Boxgrove postdates the entire Westbury sequence. The evidence for this is that tundra vole *Microtus gregalis* occurs at Boxgrove, whereas only its ancestor *Microtus gregaloides* is recorded throughout the early Middle Pleistocene part of the Westbury sequence.

A modest vertebrate assemblage collected by Green from the CF-bF at Ostend, Norfolk in the early 19th century includes *Arvicola terrestris cantiana* (Stuart, 1996). Pollen analyses (Stuart and West, 1976) of the sediment matrix from several specimens indicated pollen substage IV of a temperate episode (originally thought to be Cromerian *s.s.*), but a molar of *Palaeoloxodon antiquus* yielded a substage II pollen assemblage (Lister and Peglar, unpublished).

The earlier determination of *Mimomys* molars from the Sidestrand/Trimingham *Unio* Bed (Stuart, 1996) is now thought to have been based on reworked material, probably from the Early Pleistocene. New material (19 molars) collected by Parfitt and Preece, and some of the teeth collected previously, have been identified as *Arvicola* (Preece and Parfitt, 2000; Preece, 2001). The distinctive molluscan fauna, which includes the only known occurrence of *Bithynia tentaculata* in the CF-bF, together with *Valvata naticina*, rather than *Valvata goldfussiana* present in earlier faunas, suggests that the site is younger than the WRFB, Sugworth, Kessingland and Little Oakley (Preece and Parfitt, 2000; Preece, 2001).

### 6.3. Pakefield/Kessingland and Corton

Lister (1993, 1996) tabulated the occurrence of (mostly unstratified) deer and elephantid species at the main CF-bF localities. The fauna of the WRFB is entirely of early Middle Pleistocene type, including *Megaloceros verticornis*, *Megaloceros savini* and *Mammuthus trogontherii* (Table 5). Similarly at Pakefield/Kessingland, all 75 identifiable cervid antlers belonged to species characteristic of the early Middle Pleistocene, while all 25 elephantid molars studied belong to the early Middle Pleistocene species *Mammuthus trogontherii* and *Palaeoloxodon antiquus*. At most other CF-bF localities, Early Pleistocene deer (e.g. *Eucladoceros* spp.) and elephants (*Mammuthus meridionalis*) also occur. This strongly suggested that all of the faunal material from Pakefield/Kessingland is of early Middle Pleistocene age.

However, although the mammal faunas are otherwise very similar to that of the WRFB (including *Mimomys savini*), three large-mammal taxa are present at Pakefield/Kessingland and Corton which have not been recorded so far from the Cromerian (West Runton) stratotype. These are: *Palaeoloxodon antiquus*; *Hippopotamus amphibius*; and *Megaloceros dawkinsi* (Table 5; Figs. 8–11). An important point is that the Rootlet Bed at the Suffolk sites, and the WRFB, have both yielded substage II pollen spectra, so that the apparent faunal differences cannot be attributed to different phases within the same temperate stage.

Of course it is impossible to be certain that these taxa are genuinely absent from the Cromerian *s.s.*, especially as there is only a moderate amount of large-mammal material available from the WRFB. The case for the absence of *Hippopotamus* is strongest. *Hippopotamus* remains are generally very distinctive, including fragments of teeth, yet nothing attributable to this animal has been found at West Runton. Identifiable elephantid remains from the WRFB comprise much of a skeleton including skull and mandible (West Runton elephant), a partial mandible with two molars, at least four other molars, and part of a tusk. All are attributable to *Mammuthus trogontherii*, none to *P. antiquus*. Similarly, of six WRFB *Megaloceros* antlers seen, five are *M. verticornis*, and one *M. savini*; no *M. dawkinsi* has been recorded. This is corroborated by *Megaloceros* limb bones and teeth in the collections, all of which are of large size, conforming to *M. verticornis* or possibly *M. savini*; no smaller remains attributable to *M. dawkinsi* have been seen (cf. Azzaroli, 1953). Taken together, the apparent absence of all three taxa appears convincing, especially as they are also absent from the older group of early Middle Pleistocene sites in Germany (Table 4).

In contrast, Meijer and Preece (1996) and Preece (2001) found no elements in the Pakefield/Kessingland non-marine molluscs that would distinguish them from the WRFB assemblage. However, they were only able to study sparse material collected from Kessingland in the late 19th/early 20th centuries. It would be interesting to see if differences become apparent if and when well-preserved fresh molluscan remains are collected from the Suffolk sites.

There are, however, important differences in the plants. The aquatics *Salvinia natans* and *Trapa natans* (indicating significantly higher summer temperatures than now) are recorded from Pakefield/Kessingland (pollen assemblage substage IIIa) and *Salvinia natans*

Table 6
Records of *Salvinia natans* and *Trapa natans* from early Middle Pleistocene sites[a]

| CF-bF site with plant macrofossils | Pollen substage | *Salvinia natans* | *Trapa natans* |
|---|---|---|---|
| West Runton | Ia,Ib,IIa,IIb | | |
| Beeston | IVA | + | |
| Overstrand | IVB | + | |
| Sidestrand/Trimingham | Ib | +p | |
| | IIa | | R |
| Mundesley | IIa | +p | |
| | IIb | P | |
| | II | +p | |
| | IIIb | | |
| | IVa | | R |
| | IVc | | |
| Ostend | IVa | | + |
| | IV? | | R |
| Corton | IIb | + | |
| | IIIa | + | |
| Pakefield | IIIa | + | +R |
| Other site with plant macrofossils | | | |
| Sugworth | IIIb | | + |

[a] + plant macrofossils (West, 1980); p pollen (West, 1980); R plant macrofossil records by Reid (1882) - substages inferred by comparison with West (1980). The CF-bF sites are listed geographically from northwest to southeast. Sugworth data from Gibbard and Pettitt (1978).

from Corton (pollen assemblage substage IIb, IIIa) (Table 6). There is a clear climatic signal here, as neither occurs in the WRFB, which has no plant, invertebrate or vertebrate taxa indicative of a climate appreciably different to that of today (see above). Therefore, both the mammalian and palaeobotanical evidence from Pakefield/Kessingland and Corton argue for the recognition of an additional temperate episode, with *Mimomys savini*, distinct both from the WRFB (Cromerian *s.s.*) and the faunas with *Arvicola terrestris cantiana* from Boxgrove and Westbury (Table 5).

## 7. Conclusions

### 7.1. Summary

Taking into account both the vertebrate and mollusc evidence, the British sites can be grouped as follows (Table 5); mollusc groups follow Meijer and Preece (1996) and Preece (2001):

(A) Sites with *Mimomys*

*Group 1*: (WRFB—pollen substage II): *Equus altidens*, *Megaloceros savini*. No indicators of temperatures higher than today. (Mollusc group 1)

*Group 2*: (Sugworth—pollen substage IIIb): Sparse large-mammal fauna. *Trapa natans* indicates summer temperatures higher than today. Possibilities - same stage as WRFB, or another stage a little older or younger. (Mollusc group 1)

*Group 3*: (Pakefield/Kessingland, Corton- pollen substage II)—*Hippopotamus* sp., *Megaloceros dawkinsi*, and first appearance of *Palaeoloxodon antiquus*. *Trapa natans*, *Salvinia natans* (warmer summers). (Mollusc group 1).

*Group 4*: (Little Oakley)—Modest assemblage includes *Emys* (warmer summers), *Megaloceros dawkinsi* (Mollusc group 2).

(B) Sites with *Arvicola*

*Groups 5/6/7(?)*: (Boxgrove, Westbury, Ostend) *Emys orbicularis* (Westbury); *Palaeoloxodon antiquus* (Ostend, substage II); *Trapa natans* (Ostend, substage IVa). *Homo* sp. (Boxgrove, Westbury). *Megaloceros dawkinsi*, *Apodemus maastrichtiensis* (Boxgrove). Two or more temperate phases appear to be represented by these sites (see above).

The Sidestrand/Trimingham *Unio* Bed (Mollusc group 3) contains unrooted water vole molars that are referable to *Arvicola* (see above; Preece and Parfitt, 2000).

The main elements of biostratigraphic significance at Pakefield/Kessingland and Corton are summarised in Table 7.

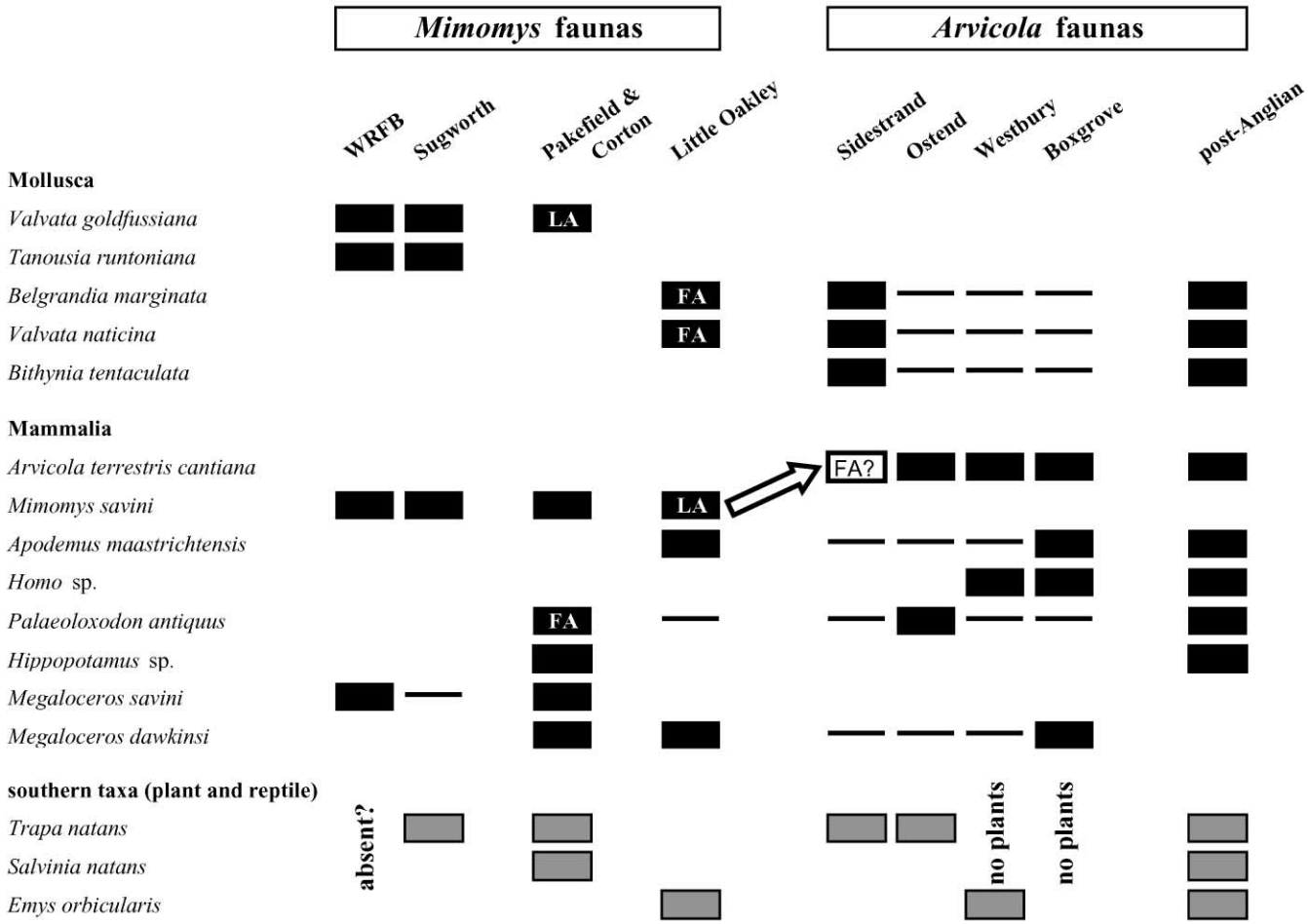
### 7.2. Concluding remarks

The recognition of a new temperate stage represented by Pakefield/Kessingland and Corton contributes to an increasing awareness of the complexity of the early Middle Pleistocene terrestrial record.

The timespan of the early Middle Pleistocene is constrained at the base by the Brunhes-Matuyama palaeomagnetic boundary (ca.780 ka; Valet and Meynardier, 1993) within OIS 19, and at the top by the onset of the Anglian stage, widely thought to correlate with OIS 12 that began at ca 450 ka (Turner, 1996b). If the latter correlation is correct, the early Middle Pleistocene spans four warm OIS—19, 17, 15 and 13. Since there is now evidence for at least six temperate episodes in the British terrestrial record, then clearly correlations with the deep sea record must be sought at the level of the warm substages.

The co-occurrence of *Mimomys savini*, *Hippopotamus* sp., *Palaeoloxodon antiquus*, *Megaloceros dawkinsi* and *Equus altidens* at Pakefield/Kessingland and Corton (Table 7) is so far unique both in Britain and continental Europe. The apparent lack of correlative sites probably reflects the complexity of the sequence in which the chances of discovering a site of a particular age is rather low.

Table 7
Summary of main elements of biostratigraphic significance at Pakefield/Kessingland and Corton in the context of other British early Middle Pleistocene assemblages[a]




[a] Key: filled rectangles—present at site; bar—not recorded so far, although presence likely as recorded from both older and younger assemblages; FA first appearance; LA last appearance; arrow indicates transition from *Mimomys savini* to *Arvicola terrestris cantiana*..

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