British Tertiary Stratigraphy

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Chapter 8

The Neogene of eastern England

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INTRODUCTION TO THE NEOGENE

The Neogene period comprises the Miocene and Pliocene epochs that span from the top of the Palaeogene at around 23.8 Ma BP (Berggren *et al.*, 1995) to the Pliocene–Pleistocene boundary, which marks the base of the Quaternary sub-era.

The end of the Miocene saw the culmination of a general global cooling and increase in ice volume that had begun in the Middle Miocene.

The Pliocene was characterized by a series of glacially induced warm/cool oscillations with associated eustatic rises and falls of sea level (Krantz, 1991). The mid-Pliocene (*c.* 3 Ma) in particular, was a time of peak global warmth with temperatures at least 5°C warmer than at present and at least 3°C warmer than the last interglacial (Dowsett and Loubere, 1992). This warming event was associated with the uplift and closure of the Central American isthmus to surface water circulation at around 3 Ma before present. This may in turn have led to an intensification of the Gulf Stream (Dowsett *et al.*, 1992; Willard *et al.*, 1993) which therefore brought greater warmth to north-west Europe, estimated in the north-east Atlantic to have been up to 6°C warmer in winter and summer than at present (Dowsett *et al.*, 1996). Temperatures at low latitudes were relatively unaffected and therefore temperature gradients in the North Atlantic would have been much less steep than today (Cronin, 1991a).

The mid-Pliocene sea-level maximum has been estimated at 35 ± 18 m(i.e. 17–53 m) above present levels by Dowsett and Cronin (1990) which implies significant ice-cap melting (Dowsett *et al.*, 1996). Wardlaw and Quinn (1991) estimated a more modest range of +20–25 m.

The Bering Straits opened during mid-Pliocene times allowing species of northern Pacific origin to migrate into Europe. Species of North Pacific origin are found in the Late Pliocene Red Crag formation of eastern England (Carpenter, 1865; MacNeil, 1965; Strauch, 1972; Funnell, 1996). The earliest stratigraphical occurrence of such species in the North Atlantic region occurs in the Neogene sequence of Iceland, which dates back to about 3.4 Ma before present (Cronin, 1991b). Temperatures cooled slowly from 3 Ma until, at around 2.4 Ma (2.48 Ma if adjusted to take account of recent revisions of the geomagnetic polarity time-scale; Cande and Kent, 1995), the first evidence of major ice rafting seen in deep sea cores in the North Atlantic (Shackleton *et al.*, 1984) represents the onset of a significant climatic deterioration and glacioeustatic regression which has traditionally been used to mark the Pliocene–Pleistocene boundary in north-west Europe. The effect of the increased ice volume at this time has been estimated to have caused a eustatic regression of up to 80–90 m below present (Krantz, 1991) which would have had a marked effect on the environment and sedimentation within the shallow epicontinental North Sea Basin.

THE PLIOCENE–PLEISTOCENE BOUNDARY

Since the International Geological Congress in London in 1948, the Pliocene–Pleistocene boundary in Britain has traditionally been placed either at the base of (Baden-Powell, 1950; Boswell, 1952; Lagaaij, 1952) or within (Movius, 1949; Van der Vlerk, 1950) the Red Crag of East Anglia. The placing of this boundary was based on the first appearance of elephant and horse within the Red Crag and the general indications of climatic deterioration inferred from the molluscan fauna (Harmer, 1900b, 1902). The first indication of climatic deterioration was regarded as the key factor in defining the boundary (Oakley, 1949). The discovery that the Red Crag in the Stradbroke borehole was normally magnetized (Van Montfrans, 1971) implied that at least part of the formation could be correlated with the Gauss normal chron and was therefore of Pliocene age. The Red Crag therefore occupies a key position in the definition of the Pliocene–Pleistocene boundary in British stratigraphy.

In an effort to resolve inconsistencies with the recommendations of the 1948 Congress (Oakley, 1949) a proposal for a Pliocene–Pleistocene stratotype section at Vrica, Italy, was eventually agreed by the IUGS Commission on Stratigraphy (ICS) (Aguirre and Pasini, 1985). The Pliocene–Pleistocene boundary was defined as the base of a bed of silty marly claystone conformably overlying sapropelic bed 'e'. This bed lies a little above the top of the Olduvai subchron (C2n in Figure 8.1) which was chronologically placed at 1.67 Ma, and, therefore, from an estimation based on sedimentation rates, the Pliocene–Pleistocene boundary was inferred to be at 1.64 Ma before present. Recent revisions

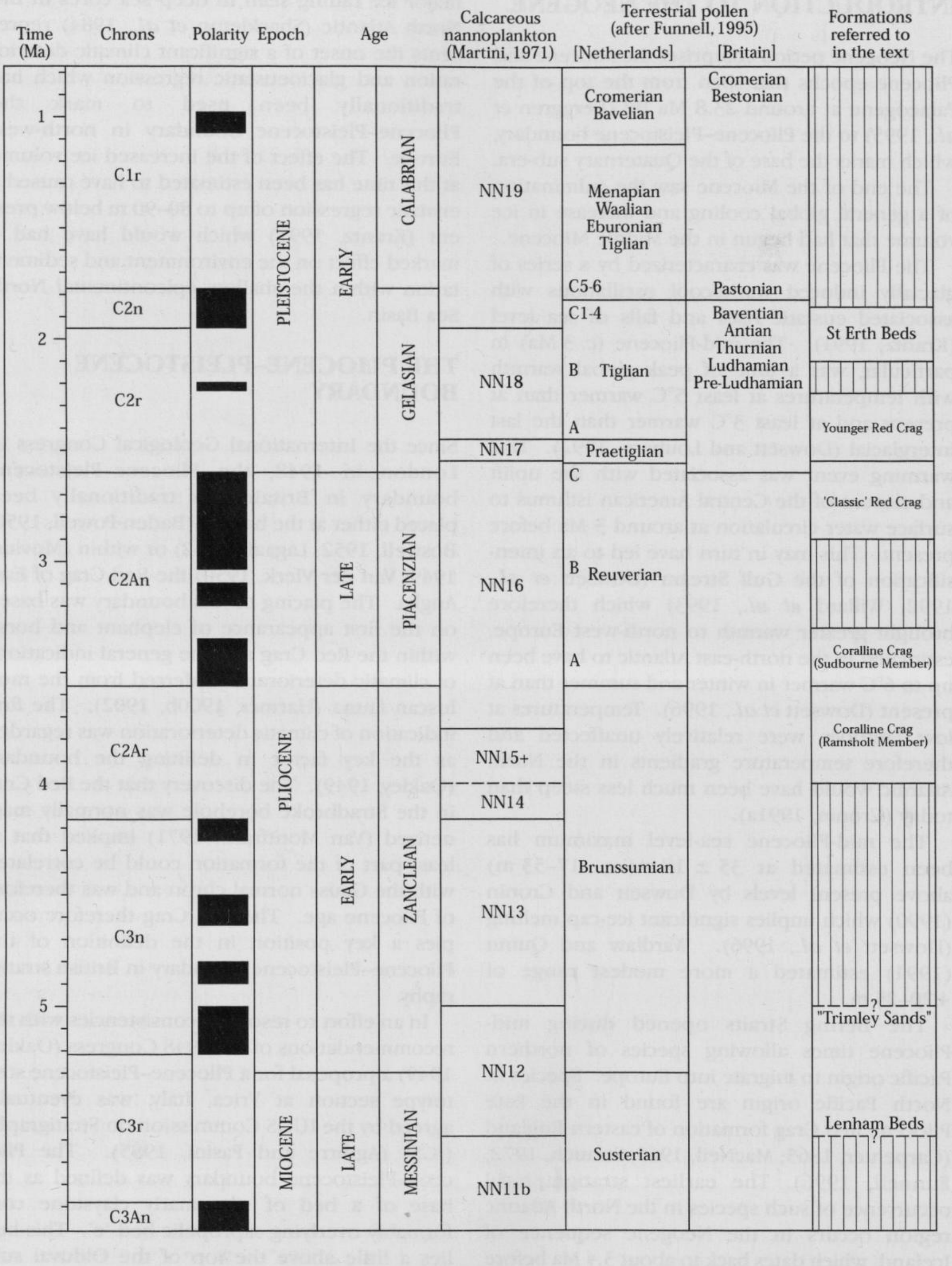

Figure 8.1 Stratigraphical position of UK Neogene Formations. Standard Neogene Chronology after Berggren *et al.* (1995). For the purposes of this volume the Plio-Pleistocene boundary has been placed at the base of the Gelasian stage. The Olduvai subchron is C2n and the Gauss normal polarity chron is C2An. The Gauss/Matuyama boundary lies between C2An and C2r.

of the geomagnetic polarity time-scale (Cande and Kent, 1995) place the top of the Olduvai subchron at 1.77 Ma and therefore, by implication, the Pliocene–Pleistocene boundary would be at approximately 1.74 Ma.

Objectors to this definition in northern Europe (e.g. Zagwijn, 1992) point to difficulties in the recognition of this boundary in sequences elsewhere and believe that a climatic definition, which was specifically rejected by the Commission, offers a more workable solution. The climatic deterioration observed in sequences throughout north-west Europe and the northern Atlantic also corresponds closely with the Gauss–Matuyama palaeomagnetic boundary (C2An/C2r in Figure 8.1) and consequently there have been proposals to place the Pliocene–Pleistocene boundary at this horizon (e.g. Partridge, 1997) which is given an age of 2.581 Ma by Cande and Kent (1995).

The implications of placing the Pliocene–Pleistocene boundary in Britain at or close to the top of the Olduvai subchron is that this is stratigraphically much higher than that traditionally used. The normally magnetized Olduvai subchron appears to be represented in deposits of Baventian or even Pastonian age in East Anglia (Funnell, 1995) (Figure 8.1) and therefore deposits previously regarded as being of early Pleistocene age would now be considered as Pliocene.

In Italy, the placing of the Pliocene–Pleistocene boundary in the Vrica section left an interval between the top Piacenzian stratotype and the base of the Pleistocene which was not represented in any stratotype section, and therefore an additional stage, the Gelasian, was proposed to be equivalent to the Late Pliocene (Rio, *et al.*, 1994). Consequently the Piacenzian becomes equivalent to the Middle Pliocene. If applied in Britain, deposits of pre-Ludhamian to ?early Pastonian age, traditionally regarded as early Pleistocene, would be placed in the Late Pliocene Gelasian Stage.

For the purposes of this volume the Pliocene–Pleistocene boundary is considered to be at the Gauss–Matuyama geomagnetic boundary (Figure 8.1) which is close to the traditionally accepted position in Britain and consequently the Gelasian is depicted as of early Pleistocene age. Deposits in East Anglia stratigraphically above this horizon but below the now accepted stratotype section in Italy, are considered elsewhere in the GCR series (Allen *et al.*, in prep).

The St Erth Beds of Cornwall have traditionally been regarded as being of Pliocene age (e.g. Mitchell *et al.*, 1973a) but evidence from planktonic foraminifera indicates an age of between 1.85 and 2.1 Ma (Jenkins and Houghton, 1987), considered here to be of early Pleistocene age, and consequently these deposits are not included in this volume. An outline account is given in Campbell *et al.*, (1998). Deposits of unequivocal Neogene age are therefore of limited extent in Britain and are confined largely to eastern England.

THE NEOGENE OF EASTERN ENGLAND

During Neogene times the North Sea occupied an area similar to that at the present time, although its extent varied with transgressive/regressive cycles. The main depocentre lay along the axis of the subsiding Rhine Graben and consequently thick and fairly continuous Neogene sequences are preserved in the Netherlands. In contrast, eastern England lay on the western margin of the basin and therefore the Neogene deposits here consist mostly of thin sequences of shallow marine and marginal marine sediments deposited during regional highstands and separated by long stratigraphical gaps.

To the south, uplift of the Weald–Artois Axis which began in Lutetian times (Lake and Karner, 1987) had severed connection between the North Sea Basin and the English Channel and it is unlikely that this connection was restored until Pleistocene times. Certainly it is unlikely that any connection existed through the area of the modern Dover Straits until that time (Gibbard, 1995). The evidence for a connection between the London Basin and the Hampshire Basin across southern England, as for instance suggested by Wooldridge and Linton (1938), is based on the occurrence of deposits at relatively high altitudes at Netley Heath and Rothamsted which lie to the north of the Wealden axis. There are no marine deposits of unequivocal Neogene age on the UK mainland south of this axis. If there was a Neogene seaway between the two basins it apparently left no deposits in the Hampshire Basin. Recently published palaeogeographical reconstructions either do (e.g. Funnell, 1996), or do not (e.g. Murray, 1992), show such a connection. The faunal evidence

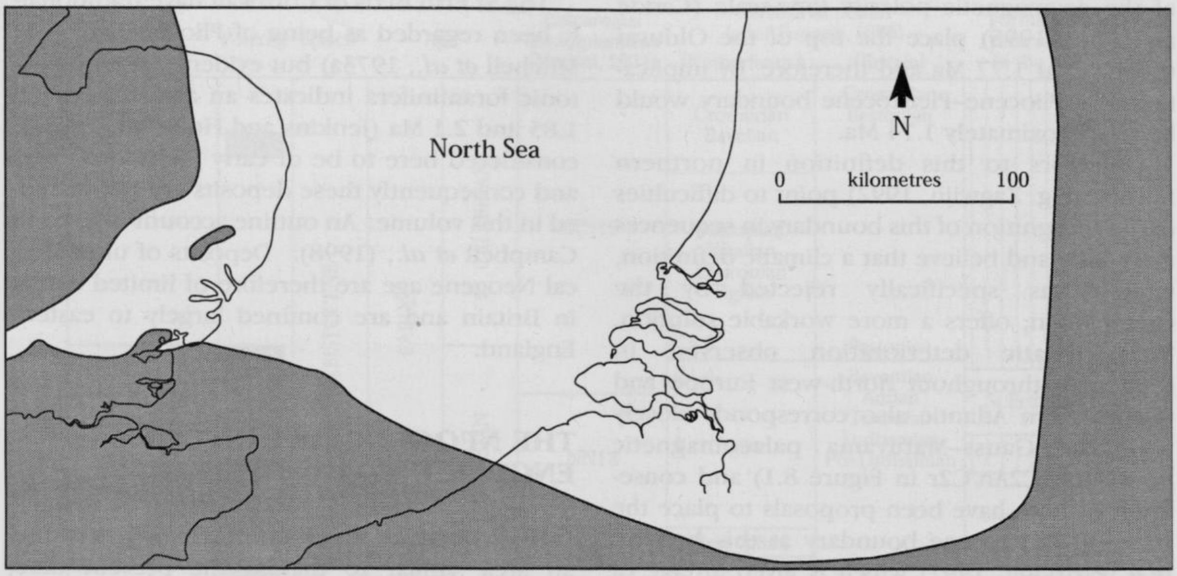

Figure 8.2 Palaeogeography of the southern North Sea during Pliocene times.

for a southern connection is also equivocal. Lagaaij (1963) believed that, during the mid-Pliocene, the warm-water bryozoan *Cupuladria canariensis* and other thermophilic fauna migrated with water masses entering the North Sea Basin from the north in much the same way as modern currents bring warmer water from the Gulf Stream around the north of Scotland. Houghton (1991) noted that the diverse coccolith fauna of the mid-Pliocene of eastern England contrasts with the lack of coccoliths in the southern North Sea at the present time. These two observations are consistent with the possibility of an enhanced Gulf Stream during mid-Pliocene times (Dowsett *et al.*, 1992; Willard *et al.*, 1993). Wood *et al.* (1993) believed a northern route for migration of thermophilic species during the late Pliocene to be unlikely because of a cold-water thermoclinal barrier. However, it is also likely that any connection across southern England would have been very shallow and would thus have provided an even greater ecological boundary, particularly to planktonic species. On, balance therefore, it appears unlikely that there was direct communication between the southern North Sea and the English Channel during Neogene times (Figure 8.2).

Although the early to middle Miocene transgression was probably one of the most extensive of the Tertiary, and produced extensive deposits in the North Sea and continental Europe, it appears to have left little evidence in eastern England. Fossil teeth of the mid-Miocene giant shark *Carcharocles megalodon* (Figure 8.3) occur in the lag deposits at the base of Pliocene Crag formations in East Anglia (Balson, 1990a).

A period of regression during the late Miocene as a result of a major eustatic sea-level fall (Haq *et al.*, 1987) preceded a renewed transgression in the latest Miocene–earliest Pliocene. In Kent, the Lenham Beds, which may be of latest Miocene age (Figure 8.1), contain a poorly preserved fauna in decalcified ferruginous sands contained within solution pipes in the surface of Late Cretaceous Chalk. In the lag deposits at the base of the Crag deposits, sandstone cobbles ('boxstones' in the literature) that originated as concretions (Figure 8.4) are the only evidence of a former deposit of muddy marine sands, informally termed the 'Trimley Sands' (Balson, 1990a). The mollusc fauna indicates that the 'boxstone fauna' is younger and from shallower water than that of the Lenham Beds (A.W. Janssen, pers. comm., 1995).

A renewed transgression in the mid-Pliocene deposited the Coralline Crag, a formation of carbonate-rich marine sands and silty sands with an outcrop on land restricted to eastern Suffolk. The overlying late Pliocene Red Crag formation has the most extensive outcrop of any Neogene deposit in the UK and shows evidence of a shallowing-upward sequence from subtidal marine sands to intertidal sand flat deposition.

During Neogene times, therefore, the south-

Figure 8.3 Phosphatized tooth of the giant shark *Carcharocles megalodon* from the basal 'coprolite bed' of the Red Crag. (British Geological Survey specimen no. GSM 3100.) (Tooth is 133 mm long.)

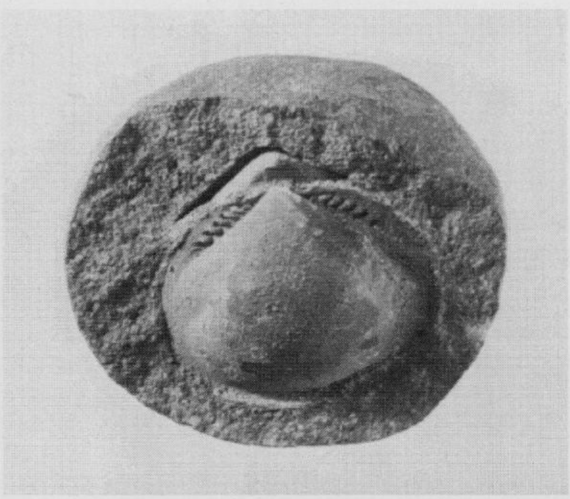

Figure 8.4 Phosphatic sandstone concretion ('boxstone') showing enclosed mould of *Glycymeris*. (Sedgwick Museum specimen C48553.) (Specimen is 74 mm across.)

ern North Sea was probably a semi-enclosed embayment that periodically inundated parts of eastern England (Figure 8.2). The deposits are dominantly of shallow marine and marginal marine facies (Coralline Crag and Red Crag) although in the east Midlands terrestrial deposits of Neogene age (the Brassington Formation) are preserved in solution subsidence hollows within Carboniferous Limestone in Derbyshire (Boulter *et al.*,1971).