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THE EARLIEST OCCURRENCE OF *MACOMA BALTHICA* (L.) AS A FOSSIL IN THE NORTH SEA DEPOSITS

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ABSTRACT

Macoma balthica is found first in the late Baventian of Mundesley, Sidestrand, West Runton and Sheringham, in Norfolk. It occurs by derivation in Pastonian sites close to these, but not elsewhere in the East Anglian 'Crag' succession. An hypothesis is offered, explaining this on tectonic grounds. Records of *M. balthica* from the Calabrian of Italy and the 'Icenien' of Holland are considered incorrect. A brief discussion of the paleogeography and immigration times of *M. obliqua, M. praetenuis* and *M. calcarea* is also given.

PALEOGEOGRAPHY

The *Macoma* species, *M. obliqua, M. praetenuis, M. calcarea* and *M. balthica,* appeared newly in the North Sea Basin deposits in the Pliocene and early Pleistocene time. Their points of origin and route of immigration are unknown to us. Discussion may begin with paleogeographic concepts of the later Tertiary time. There are differing claims for what the paleogeography was. Strauch (1971) considers that Atlantic and Scandic marine provinces existed. A land barrier, the Thule Province, separated them. It ran from Greenland to Europe and included Iceland, the Faroes and Britain. The Atlantic province included that part of the Atlantic Ocean which is bounded by the continental shelf of Ireland, Iceland, the southern tip of Greenland and eastern North America. Deep gulfs extended into the present Mediterranean Sea and Davis Strait. The Scandic province included what is now the Greenland and Barents seas, connecting northward with the North Eurasian Basin and extending southward into the North Sea as a narrow gulf. Other workers claim that the later Tertiary paleogeography was substantially similar to the present. The North Sea and *proto* English Channel were connected across the present Pas de Calais. There was an open connection from the North Sea to the Atlantic as at present. Spaink's findings (unpublished) on the evolution of the Astartidae would support the latter paleogeographic reconstruction. The *Macoma* evidence inclines us to keep both theories in mind. *Macoma* species were, at any rate, evolving in the North Sea and Arctic seas at this time.

MACOMA OBLIQUA (Sowerby)

In the Coralline Crag of England, which was forming during the Pliocene, is found *Macoma obliqua.* The diagnostics of this species as compared with the other species of *Macoma* mentioned here have been given and figured by Spaink & Norton (1967) and are not repeated here. *M. obliqua* is extinct today. Its Pliocene range also included the Scaldisien of the Netherlands and Belgium.

By the beginning of the Pleistocene it appears that, even if the Scandic and Atlantic provinces had been separate previously, they were now united and so were the Pacific and Arctic Oceans. The Bering Strait had been submerged during the Beringian trans-

gression (Hopkins 1967). Foraminiferal studies of the East Anglian Crag deposits (Funnell 1961) indicate that the Pas de Calais Strait became closed during the early Pleistocene. It is inferred by van Voorthuysen (1954) that tectonic movements caused rising of the land in the southern North Sea at this time. The Pas de Calais Strait was open during the time of deposition of the Waltonian and Newbournian Red Crag and the early Ludham Crag. When the Butleyan Red Crag and the Norwich Crag Series above the early Ludham Crag were being deposited, the Strait was closed. (It is not yet known whether the Ludham Crag may be correlated with any part of the Red Crag Series).

MACOMA PRAETENUIS (Leathes) and *M. CALCAREA* (Gmelin)

In the topmost Pliocene of the Netherlands and Belgium and in the earliest Pleistocene (Waltonian) of England occurs *Macoma praetenuis*. *Macoma calcarea* appears shortly afterward, in the Netherlands' 'Icenien' and the English Newbournian. *M. praetenuis* occurs also in the Icelandic succession at Tjörnes, beginning just below the currently recognised Pliocene-Pleistocene boundary (in Horizon 13/1 of Strauch (1963); *M. calcarea* was present earlier).

Macoma species also reached the Mediterranean, where in the marine Calabrian deposits Moroni (1967) found a shell named by her as *M. balthica* though on the basis of her figure we judge it to be a form of *M. obliqua*.

In the early Pleistocene North Sea Deposits there is evidence for cycles of climatic change, indicated by procession from temperate to subarctic vegetation (West 1968) and Foraminifera (Funnell 1961). After the Pas de Calais Strait finally became land, the North Sea appears to have become rather shallow and brackish in the East Anglia region. The Southeastern part (the present Netherlands and Belgium) rather soon became nonmarine. Zagwijn (1963) found that in the Western Netherlands the 'Icenien' sea receded and continental conditions began during a late cool phase (Pollen Subzone TC4c) of the Tiglian Interglacial. Zagwijn (personal communication) suggests this may be correlated with the (East Anglia) Thurnian. The East Anglian basin remained marine much longer (Spaink & Norton 1967).

MACOMA BALTHICA (Linnaeus)

A new *Macoma* species, *M. balthica*, is first recorded from marine deposits of the late Baventian on the north coast of Norfolk. Pollen spectra in clays of this Stage indicate open heath oceanic vegetation (West 1961) and similar pollen occurs in clays associated with the *Macoma balthica* deposits. *M. balthica* is not found in Baventian deposits elsewhere in East Anglia. Preliminary findings (Beck, personal communication) of the U.E.A. Research Boreholes programme allow us to speculate that the north and south parts of the deposition basin were separated by a chalk ridge running northeast towards Halesworth (Fig. 1). The Northern Basin subsided during Ludhamian times. Both parts, except for North Norfolk, subsided during Thurnian, Antian and Baventian times. The sea level was lowered glacio-eustatically during the Thurnian and Baventian. In late Baventian times a local marine transgression in North Norfolk allowed the incursion of a marine fauna in which *M. balthica* is the most frequent species (Norton 1967). Deposits of 'Weybourne Crag' at Sheringham, Sidestrand, West Runton and grey shelly deposits with *M. balthica* in borings at Mundesley, represent this phase. The succeeding Pastonian was a time of regression on the North Norfolk coast, with deposition of thick estuarine silts. In these conditions the *M. balthica* stocks, with the rest of the 'Weybournian' fauna, retreated. Later Pastonian, and younger, 'Weybourne Crag' deposits on the North Norfolk Coast were formed by reworking of the primary Baven-

TABLE 1

East Anglia Stages (*Temperate Stages italicised*)	Pas de Calais Strait	*Macoma* arrivals	Netherlands Stages (Correlation not guaranteed)
Pastonian	Closed	(reworking)	Eburonian
Baventian	Closed	*M. balthica*	Eburonian
Antian	Closed		Tiglian in nonmarine facies
Thurnian	Closed		Tiglian in nonmarine facies
Ludhamian (top)	Closed		Tiglian in marine facies
Ludhamian (lower)*	Open		Tiglian in marine facies
Butleyan Red Crag*	Closed		no pollen in Red Crag
Newbournian Red Crag	Open	*M. calcarea*	no pollen in Red Crag
Waltonian Red Crag	Open	*M. praetenuis*	no pollen in Red Crag
Coralline Crag (Pliocene)	Open	*M. obliqua*	Scaldisian

*As mentioned in the text, the relationship between the Ludham Crag and Red Crag is not understood and this table should not be read either as correlating them, or as stating that the Pas de Calais Strait closed twice.

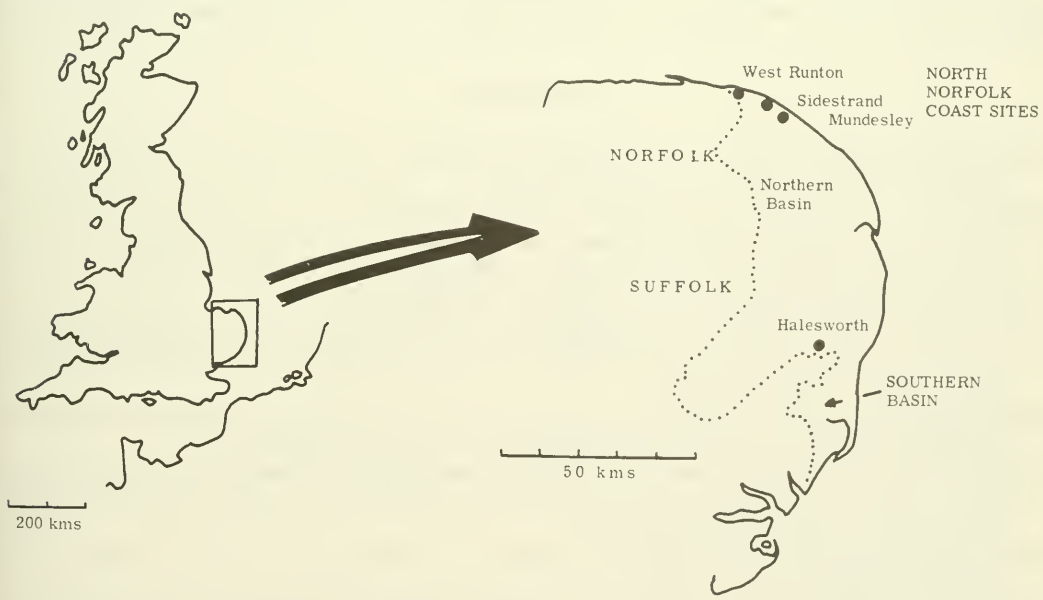

FIG. 1. Sketch-map of East Anglia showing the 2 main basins on the Crag base.

tian material. The 'Weybourne Crag' deposits are diachronous. The Pastonian sea spread over the rest of the Northern Basin and Southern Basin. Silts alone were deposited in the Northern Basin. Mollusca were living in the Southern Basin. *M. balthica* has never been found in the shelly deposits here though the molluscan assemblages at some sites (Norton 1970) show that conditions would have been suitable for it. Apparently this species had become locally extinct and did not recolonise after its short incursion in the Baventian.

Some records of *M. balthica* in the Netherlands Pliocene or Early Pleistocene were published by Lorié (1885). Heering (1950) summarises them. This gave rise to the term 'Weybournien' for the top part of the 'Icenien' (Tesch 1942). Examination of these shells (Spaink & Norton 1967) shows that all are wrongly determined. They should be *M. calcarea*, *M. obliqua* or *M. praetenuis*. A few shells are correctly determined but belong to a much younger horizon mistakenly recorded as 'Icenien'. The use of the term 'Weybournien' in the Dutch succession has therefore been discontinued, which is fortunate as we (*op. cit.*) have inferred that it cannot be placed later than Tiglian TC4c which is similar to the Thurnian in East Anglia whereas the East Anglia 'Weybourne Crag' is Baventian, Pastonian or Cromerian.

After the brief occurrence of *M. balthica* in the East Anglia Pleistocene and the Pastonian and Cromerian reworking of its shells, follows the remainder of the Cromer Forest Bed Series and the first glaciation of this region, the Lowestoftian (which may be equivalent to the Elsterian). Following the Elsterian in the Netherlands, are found the marine deposits of the Holsteinian Interglacial, in which *M. balthica* is abundant, as it has been in suitable deposits ever since.

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