Meded. Werkgr. Tert. Kwart. Geol. | vol. 24 (1-2) | pp. 147-156 | 5 figs, 1 tab. | Leiden, June 1987

AGE, CORRELATION AND PALEOECOLOGY OF THE ST. ERTH BEDS AND THE CORALLINE CRAG OF ENGLAND

by

D. Graham Jenkins & S.D. Houghton,
Department of East Sciences,
Open University, Milton Keynes, England

Jenkins, D. Graham & S.D. Houghton. Age, correlation and paleoecology of the St. Erth Beds and the Coralline Crag of England. — Meded. Werkgr. Tert. Kwart. Geol., 24 (1-2): 147-156, 5 figs, 1 tab. Leiden, June 1987.

Recent work on planktonic Foraminifera and calcareous nannofossils in the St. Erth Beds and Coralline Crag has refined the age designations. The St. Erth Beds were deposited in the Late Pliocene between 2.1 and 1.9 Ma and the Coralline Crag deposits between 3.6 and 2.3 Ma. Both deposits were laid down in relatively shallow water, but the Coralline Crag paleotemperature range was 10-18°C as opposed to the subtropical 18-24°C range of St. Erth Beds.

Dr D. Graham Jenkins and Dr Simon D. Houghton, Department of Earth Sciences, The Open University, Walton Hall, Milton Keynes, MK7 6AA, England.

Contents:

SAMENVATTING

Ouderdom, correlatie en paleooecologie van de St. Erth Beds en de Coralline Crag in Engeland.

Recent onderzoek van planktonische foraminiferen en kalkschalig nannoplankton van de St. Erth beds en de Coralline Crag in Engeland heeft een nauwkeuriger ouderdomsbepaling mogelijk gemaakt. De St. Erth beds werden afgezet in het Laat Plioceen, tussen 2.1 en 1.9 millioen jaar geleden en de Coralline Crag tussen 3.6 en 2.3 millioen jaar. Beide afzettingen zijn gesedimenteerd in betrekkelijk ondiep water. De temperatuur tijdens de afzettingen van de Coralline Crag bedroeg 10-18°C. De St. Erth Beds daarentegen ontstonden in een subtropisch klimaat met een temperatuur van 18-24°C.

INTRODUCTION

The basic work for this paper is derived from planktonic Foraminifera (Jenkins, 1982; Jenkins et al., 1986; Jenkins et al., in press), and the reader is referred to these papers for the taxonomy and illustrations of the species, and from nannofossils (Houghton & Jenkins, in prep.). The locations of the St. Erth Beds and the Coralline Crags are shown in fig. 1.

ST. ERTH BEDS

Planktonic Foraminifera

Fifteen species of planktonic Foraminifera have been recorded in the St. Erth Beds (Jenkins, 1982; Jenkins et al., 1986). The key species that provide the age for the St. Erth Beds are *Globorotalia inflata*

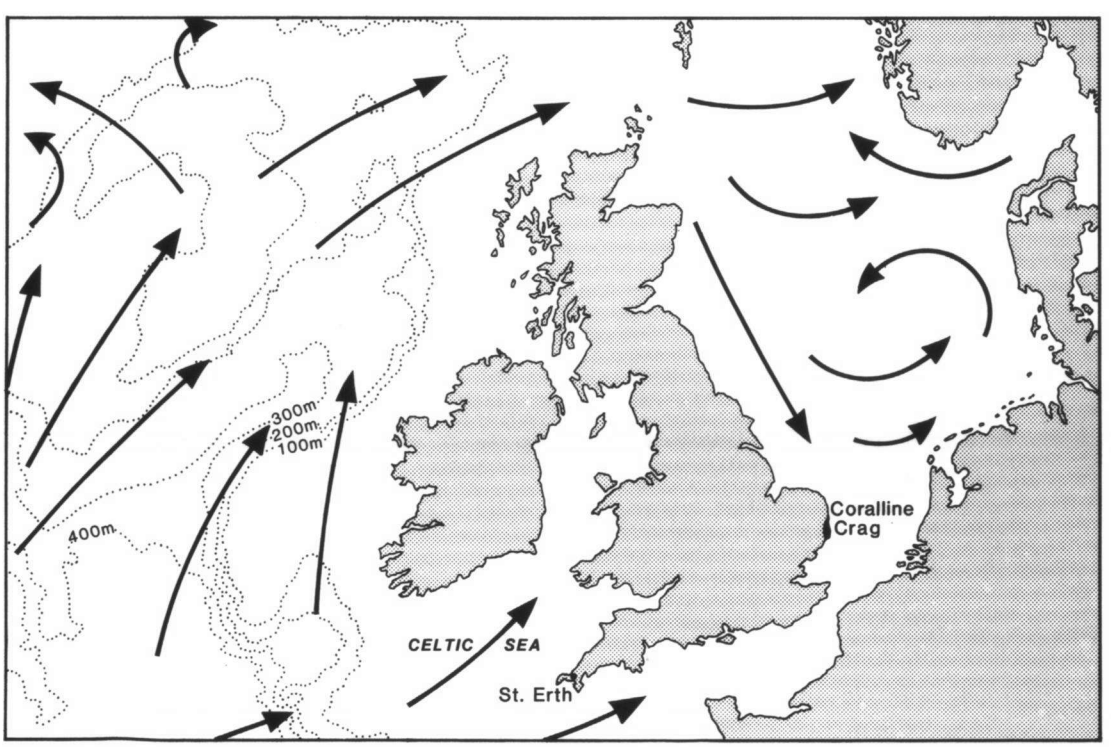

Fig. 1. Location of the St. Erth Beds and the Coralline Crag.

(d'Orbigny), *G. praehirsuta* Blow, *G. tosaensis* Takayanagi & Saito, *Pulleniatina primalis* Blow & Banner, *Neogloboquadrina humerosa* (Takayanagi & Saito) and dextrally coiled *N. pachyderma* (Ehrenberg). The overlap of the ranges of these species places the fauna in the Late Pliocene G. inflata Zone (see fig. 2). According to Weaver & Clement (1986) *G. inflata* made its first appearance in the North East Atlantic at 2.1 Ma and since the St. Erth Beds do not contain *G. truncatulinoides* (d'Orbigny) which first appeared at 1.85 Ma (Berggren et al., 1967; Berggren et al., 1985) it can be assumed that the sediments were deposited between 2.1 and c. 1.9 Ma.

Nannofossils

Seventeen species of calcareous nannofossils have been recorded from the St. Erth Beds (Houghton & Jenkins, in prep.) These assemblages are dominated by the small placoliths *Dictyococcities productus, Reticulofenestra minuta* and *R. minutula*. The absence from the nannoflora of *Gephyrocapsa oceanica* Kamptner s. lat., which has a FAD of 1.56 Ma (Rio, 1982; Rio et al., in press), delineates the youngest possible age for the sediments. Because discoasters were not observed in the assemblages the exact lower age of the St. Erth Beds cannot be delineated on the basis of nannofossils. However, the occurrence of small gephyrocapsids (FAD = 3.6 Ma; Rio, 1982) and *Pseudoemiliania lacunosa* (FAD = 3.4-3.6 Ma; Gartner, 1973; Rio, 1982) allows the St. Erth Beds to be placed within the Late Pliocene (NN 16-NN 18 zones).

Paleoecology

The presence of the extant species *Globigerina bradyi* (Wiesner), *G. bulloides* d'Orbigny, *Globigerinita glutinata* (Egger), *Globigerinoides triloba* (Reuss), *Globorotalia inflata* (d'Orbigny) and dextrally coiled *Neogloboquadrina pachyderma* (Ehrenberg) and *Turborotalita quinqueloba* (Natland) places the fauna in the modern Transition Faunal Province of Bé (1977) with a temperature range of 10-18°C. There is a

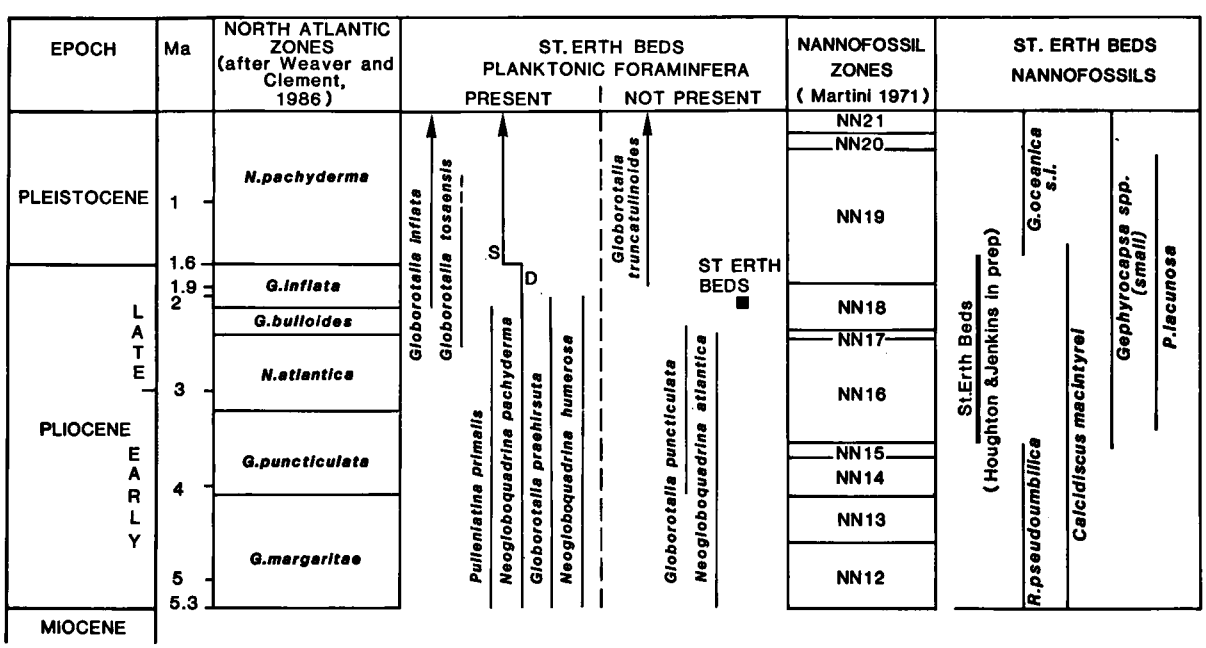

Fig. 2. Age and correlation of the St. Erth Beds.

subtropical faunal province element in the fauna indicated by the extant *Globigerina falconensis* Blow and fossil *Globorotalia tosaensis* Takayanagi & Saito and *Pulleniatina primalis* Banner & Blow.

The high diversity nannoflora (17 species) coupled with the occurrence of species such as *Oolithotus fragilis* (Lohmann) Okada & McIntyre, *Ceratolithus rugosus* Bukry & Bramlette and *Umbellosphaera tenuis* (Kamptner) Paascho all suggest deposition in warm shallow seas. Recent sediments from the shelf of the Celtic Sea contain eight or more species (Houghton, 1986). Elevated temperatures for the Late Pliocene shelf environment are also suggested from the abundance of well-preserved didemnid (Tunicata, sea-squirt) spicules in the St. Erth Beds (Houghton & Jenkins, in prep.) Fossil didemnid spicule concentrations are restricted to carbonate-rich environments in tropical and subtropical seas.

On the basis of the contained diverse nannoflora and sea-squirt spicule facies, the St. Erth Beds are postulated to have been deposited in a sub-tropical water mass (18-24°C) which 'bathed' the Celtic coasts of North-West Europe.

There is an unresolved problem as to whether the St. Erth fauna and flora represent a northward shift of a gyre of the Gulf Stream thus bringing warm waters into the Cornwall area of the Celtic Sea, or records a general warming of the ocean. Examination of the oxygen isotope curve for the Late Pliocene (fig. 3) shows that in the period 1.9-2.1 Ma there were relatively warm periods marked by low values of $\delta^{18}O$ when there was considerable melting of the ice caps.

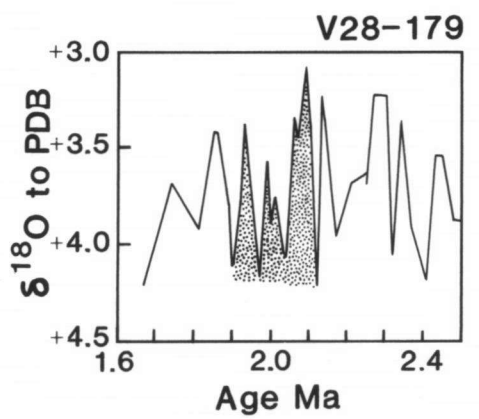

Fig. 3. Oxygen isotope record of part of the Late Pliocene in core V28-179 (after Shackleton, in Jenkins et al., 1985).

THE CORALLINE CRAG

Planktonic Foraminifera

Nine species of planktonic Foraminifera have been found in the Coralline Crag of Suffolk and the broad age range of the beds is based on the joint stratigraphic ranges of *Globorotalia puncticulata* (Deshayes) and *Neogloboquadrina atlantica* (Berggren). The first appearance of *G. puncticulata* was at 4.1 Ma and the extinction of *N. atlantica* was at 2.4 Ma (Weaver & Clement, 1987) in the North Atlantic as shown in Fig. 4.

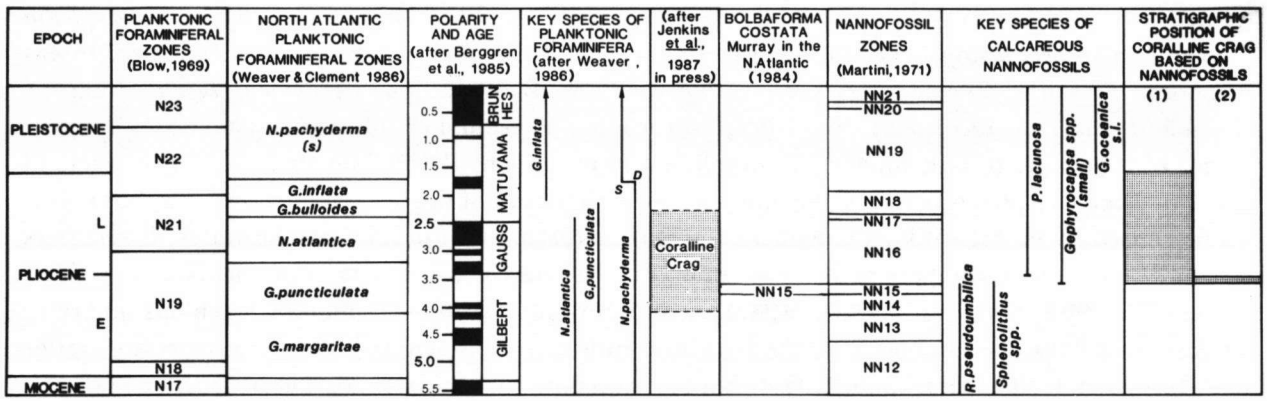

Fig. 4. Age and correlation of the Coralline Crag; (2) based on LAD of *Sphenolithus* spec.

G. puncticulata evolved from *Globorotalia sphericomiozea* Walters in the Early Pliocene in the Southern Hemisphere (Jenkins, 1975; Scott, 1980; Kenneth & Srinivasan, 1983; Jenkins & Srinivasan, 1985) but there is no record of this evolutionary transition in the North Atlantic (see Poore, 1978; Weaver, 1986). The *G. puncticulata* appearance in the North Atlantic is therefore cryptogenic and consequently later than in the Southern Hemisphere.

There are a number of morphological features which can be used to distinguish *G. puncticulata* from its immediate descendant species *G. inflata* (d'Orbigny) (see Malmgren & Kennett, 1981). According to these authors *G. puncticulata* has 4.0-3.6 chambers in the final whorl in contrast to *G. inflata* which has 3.6-3.25. The Coralline Crag specimens have an average of 3.9 chambers in the final whorl and this compares with a range of 4.05 to 3.93 in the Early to Late Pliocene of DSDP site 609B of NE Atlantic (for further details see Jenkins et al., in press). It is therefore quite clear that the Coralline Crag was deposited before the cryptogenic appearance of *G. inflata* in the North Atlantic reported by Weaver (1986) at 2.1 Ma.

Sinistrally coiled *Neogloboquadrina atlantica* is the commonest species in the Coralline Crag and its extinction at 2.4 Ma appears to be a good marker (Weaver, 1986). Nevertheless evidence was printed by Jenkins et al. (1986) that the extinction was diachronous, being earlier in the lower latitudes.

The age of the Coralline Crag is therefore between the first appearance of *G. puncticulata* at 4.1 Ma and the extinction of *N. atlantica* at 2.4 Ma.

Nannofossils

Sixteen species of calcareous nannofossils are described from two localities of the Coralline Crag at Ramsholt Cliff and Sutton Knoll (table 1). Three species are dominant in the Crag samples: *Coccolithus pelagicus, Calcidiscus leptoporus* and *Reticulofenestra minutula*. Common species include *Braarudosphaera bigelowii, Pseudoemiliania lacunosa, Reticulofenestra minuta* and *Helicosphaera sellii*. The other species generally form less than 1.0% of the assemblages. Preservation of the nannofossils ranges from good to poor with frequent evidence of overgrowth of the placolith assemblages. The coccoliths show little signs of etching on crystal sutures.

Previous nannofossil investigations on the Coralline Crag (Hamilton & Hojjatzadeh, 1982) have yielded disappointing results. Nannofossil assemblages described from Orford and Sutton Knoll con-

tained a limited assemblage of *Coccolithus pelagicus, Calcidiscus leptoporus, C. macintyrei, Helicosphaera carteri, Pontosphaera multipora* (Kamptner) Roth, *Braarudosphaera bigelowii* and *Sphenolithus* spec. It was supposed that the delicate species typical of the Late Pliocene (i.e. *Ceratolithus rugosus* Bukry & Bramlette and *Discoaster* spec.) "have been lost leaving a residual of solution-resistant long ranging forms of little stratigraphic interest" (Hamilton & Hojjatzadeh, 1982). The absence of discoasters in the Coralline Crag deposits is not thought here to be the result of dissolution or reworking, but rather to be caused by ecological factors which control their distribution in northern latitudes. Discoasters are not a common component of Late Pliocene nannofossil assemblages in the North Atlantic (Backman, 1984; Takayama & Saito, 1986) and adjacent coastal areas (Houghton & Jenkins, in prep.) In fact, Late Pliocene samples from the North Atlantic have characteristic discoaster/coccolith-ratios of 1/10,000 or 1/5,000 (Backman, 1984). Because coccoliths are much scarcer in near-shore and shelf sediments than in the open ocean, discoasters are likely to be of little value in biostratigraphic studies of the Pliocene record of Europe. Evidence against carbonate dissolution in the Coralline Crag sediments is provided by the occurrence of moderately diverse coccolith assemblages with unetched crystal sutures.

Previous nannofossil studies on the Coralline Crag (Hamilton & Hojjatzadeh, 1982) did not resolve the age of the deposits. The sediments at Sutton Knoll were tentatively given a Late Pliocene age, based on the occurrence of *Calcidiscus macintyrei.*

Many of the species found in the Coralline Crag are long-ranging forms and are similar to those found in the St. Erth Beds. The absence of *Gephyrocapsa oceanica* s.lat. indicates that the sediments are

Coccolith species	Sutton Knoll	Ramsholt Cliff 1	2	3	4	5
Braarudosphaera bigelowii (Gran & Braarud) Deflandre	F	C	C	C	C	C
Coccolithus pelagicus (Wallich) Schiller	A	A	A	A	A	A
Calcidiscus leptoporus (Murray & Blackman)	A	C	C	C	C	C
Calcidiscus macintyrei (Bukry & Bramlette) Loeblich & Tappan	R	R	-	-	-	R
Pseudoemiliania lacunosa (Kamptner) Gartner	C	C	C	C	C	C
Reticulofenestra minuta Haq	R	-	R	-	R	R
Reticulofenestra minutula (Gartner) Haq & Berggren	A	C	C	C	C	C
Reticulofenestra haqii Backman	-	F	F	F	F	F
Dictyococcities productus (Kamptner) Gartner)	F	F	F	F	F	F
Gephyrocapsa spec. (small)	R	F	F	F	F	F
Helicosphaera carteri (Wallich) Kamptner	F	-	-	-	F	F
Helicosphaera sellii Bukry & Bramlette	C	C	C	C	C	C
Pontosphaera japonica Takayama	F	F	F	F	F	F
Syracosphaera pulchra Lohmann	F	F	F	F	F	F
Rhabdosphaera clavigera Murray & Blackman	R	-	R	-	-	R
Sphenolithus spec.*	R	R	-	-	-	R

* includes both *Sphenolithus abies* Deflandre and *S. neoabies* Bukry & Bramlette.

Table 1. List of coccolith species recorded from the Coralline Crag.
Samples 1-5 taken from an excavation at Ramsholt Cliff (main pit and grid reference TM 299 428), dug and logged by John Bishop; 1 = 0.45 m, 2 = 0.95 m, 3 = 1.45 m, 4 = 1.95 m and 5 = 2.45 m (all heights refer to metres above bore of excavation).
A = abundant (> 10%), C = common (10.0-1.0%), F = frequent (1.0-0.1%), R = rare (< 0.1%).

older than 1.56 Ma (Rio, 1982; Rio et al., in press). The presence of *Pseudoemiliania lacunosa* (FAD 3.4-3.6 Ma; Gartner, 1973; Rio, 1982) and scarce small gephyrocapsids (FAD 3.6 Ma; Rio, 1982) shows that the sediments are younger than 3.6 Ma. A suggested age range of ± 2 million years represents a relatively large time-slice for a thin sequence of beds (c. 25 m thick). However, there is also evidence (provided by the occurrence of small *Sphenolithus* species and the absence of *Reticulofenestra pseudoumbilica* (Gartner) Gartner, which suggests that the Coralline Crag might represent a still much narrower time-slice. Studies on the extinction of *Sphenolithus* species indicated that they have a LAD at c. 3.47 Ma, some 0.1 Ma after the extinction of *R. pseudoumbilica* at 3.56 Ma (Backman & Shackleton, 1983). Taken on this evidence alone this would suggest that the Coralline Crag has an age represented by the period between the extinction datums of *Sphenolithus* spec. and *R. pseudoumbilica*. The LAD of *R. pseudoumbilica* marks the top of the NN 15 Zone, therefore on the basis of the *Sphenolithus* occurrence the Coralline Crag would be placed at the very base of NN 16 (D. surculus Zone).

This date based on the LAD of *Sphenolithus* species is tentative and open to some criticism. Firstly the extinction of *Sphenolithus* species outside tropical areas seems to be ecologically controlled. The extinction of *Sphenolithus abies* in the Neogene of the North Atlantic cored in Leg 94 of DSDP is not synchronous (Takayama & Saito, 1986; Baldauf et al., 1986). The LAD of *Sphenolithus abies* varied with latitude, ranging from 3.45 to 4.16 Ma. Other problems arise from different workers species concept of *R. pseudoumbilica* and how the species extinction datum is defined. Takayama & Saito (1986), because of consistent reworking of *R. pseudoumbilica* in Late Pliocene sediments, used the last common occurrence of *R. pseudoumbilica* to define the NN 15/NN 16 boundary of Martini (1971). The absence of *R. pseudoumbilica* from the samples is a good indicator that the Coralline Crag is younger than NN 15 and also suggests that the *Sphenolithus* species are not reworked lower Pliocene components in the Coralline Crag nannofossil assemblages.

In conclusion, from the combined planktonic foraminiferal and nannofossil evidence, a Late Pliocene age for the Coralline Crag with a maximum range of between 3.6 and 2.3 Ma is indicated. The tentative evidence provided by the occurrence of the sphenolith species however suggests that the Coralline Crag represents only the first 0.1-0.2 Ma of the age range given above.

Hodgson & Funnell (1986) recorded the planktonic algal cyst *Bolboforma costata* Murray in the Coralline Crag. In the North Atlantic this fossil has only been recorded in NN 15 (Murray, 1984), which has an age range of 3.6-3.4 Ma (Berggren et al., 1985; see figs 4 and 5).

Paleoecology

Samples from Sutton Knoll and Ramsholt Cliff represent the Silty Sand Facies (Facies A) of the Coralline Crag (Mathers et al., 1984). This facies is thought to represent a lower energy environment than most of the Coralline Crag. The coccolith assemblages described from these localities also support this conclusion. Coccolith diversity and abundance in Recent sediments of NW Europe has been shown to be controlled by the degree of tidal mixing in the water column (Houghton, 1986). The occurrence of diverse coccolith assemblages in Facies A sediments of the Coralline Crag suggests deposition from waters of weak tidal currents (< 1.5 kts) with a well-developed thermocline. Atlantic influences must have been pronounced in the southern North Sea at this time and may have been supplied to the Coralline Crag basin either from the North around the coast of Scotland or from the South via the English Channel.

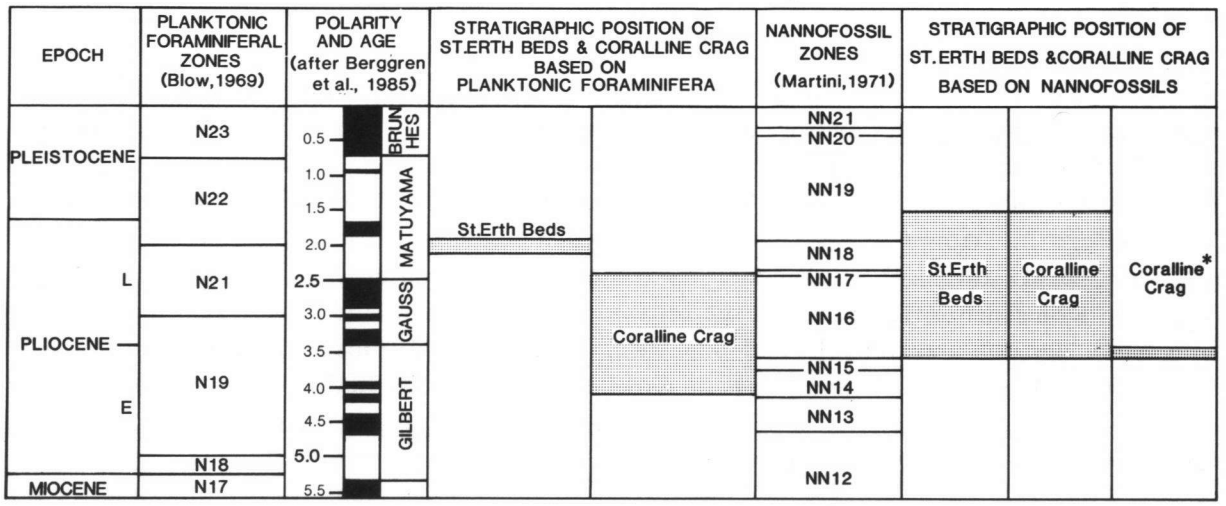

Fig. 5. Age and correlation of the St. Erth Beds and the Coralline Crag. * Based on the LAD of *Sphenolithus* spec.

The extant species in the Coralline Crag: *Globigerina bradyi, G. bulloides, Globigerinita glutinata*, dextrally coiled *Neogloboquadrina pachyderma, Orbulina universa* d'Orbigny and *Turborotalita* cf. *quinqueloba* places the fauna in the Transition Faunal Province of Bé (1977) with a temperature range of 10-18°C. The relatively low species diversity of transition faunal specimens could be due either to poor preservation of specimens in the relatively shallow water crag deposits or to the remote connection of the fauna with the North Atlantic via the northern passage (fig. 1).

The faunas and floras of the St. Erth Beds and the Coralline Crag do not provide conclusive evidence that the English Channel was open at these times in the Pliocene. Today, the high salinity (> 34.75‰) Atlantic water flowing into the southern North Sea via the English Channel does not supply any calcareous nannofossils or planktonic Foraminifera (Houghton, 1986). The tidally-mixed water column of the central and eastern English Channel acts as an ecological filter barrier for these planktonic forms.

CONCLUSIONS

Diagnostic planktonic Foraminifera and nannofossils have been used to date the St. Erth Beds as between 1.9 and 2.1 Ma and the Coralline Crag as between 2.3 (from planktonic Foraminifera) and 3.6 Ma (from nannofossils). However, the occurrence of *Sphenolithus* species may indicate that the Coralline Crag represents only the first 0.1-0.2 million years of the age range given above. Subtropical temperatures prevailed during the deposition of the St. Erth Beds (18-24°C), whereas cooler transitional temperatures of 10-18°C existed in the southern North Sea when the Coralline Crags were deposited. The occurrence of diverse coccolith assemblages in Facies A of the Coralline Crag indicates deposition from a stratified water column with pronounced Atlantic influences.

ACKNOWLEDGEMENTS

The authors wish to thank John Bishop (British Museum-Natural History) for excavating a new pit at Ramsholt Cliff and Dr J.E. Whittaker (British Museum-Natural History) for providing the samples for nannofossil studies. They are also grateful to Mr John Taylor (Open University) for drafting the figures and to Mrs SueMarshall for typing the manuscript.

REFERENCES

Backman, J., 1984. Cenozoic calcareous nannofossil biostratigraphy from the northeastern Atlantic Ocean DSDP Leg 81. In: D.G. Roberts, D. Schnitker et al. — Init. Rep. DSDP, 81: 403-427.

Backman, J., & N.J. Shackleton, 1983. Quantitative biochronology of Pliocene and Early Pleistocene calcareous nannofossils from the Atlantic, Indian and Pacific Oceans. — Marine Micropaleont., 8: 141-170.

Baldauf, J.G., E. Thomas et al., 1986. Magnetostratigraphy and biostratigraphic synthesis. Deep Sea Drilling Project Leg 94. In: W.F. Ruddiman, W.F. Kidd et al. — Init. Rep. DSDP, 94: 1159-1205.

Bé, A.W.H., 1977. An ecological zoogeographic and taxonomic review of Recent planktonic Foraminifera. In: A.T.S. Ramsey (ed.). Oceanic micropalaeontology. London, New York (Academic Press), pp. 1-100.

Berggren, W.A., D.V. Kent & J.A. van Covering, 1985. The Neogene, 2. Neogene geochronology and chronostratigraphy. In: N. Snelling (ed.). Chronology and the geological record. — Geol. Soc. London Mem., 10: 211-260.

Berggren, W.A., S.D. Phillips, A. Bertels & D. Wall, 1967. Late Pliocene-Pleistocene stratigraphy in deep-sea cores of the south central North Atlantic. — Nature, 216: 253-254.

Gartner Jr., S., 1973. Calcareous nannofossil age determinations. Deep Sea Drilling Project, Leg 13. In: W.B.F. Ryan, K.J. Hsu et al. — Init. Rep. DSDP, 13: 822-828.

Hamilton, G.B., & M. Hojjatzadeh, 1982. Cenozoic calcareous nannofossils - a reconnaissance. In: A.R. Lord (ed.). A stratigraphical index of calcareous nannofossils. Chichester (Ellis Hornwood), pp. 136-167.

Hodgson, G.E., & B.M. Funnell, 1986. Foraminiferal biofacies of the Early Pliocene Coralline Crag. In: M.B. Hart (ed.), Carbonate micropalaeoecology. Chichester (Ellis Horwood), pp. 44-73.

Houghton, S.D., 1986. Coccolith assemblages in Recent marine and estuarine sediments from the continental shelf of northwest Europe. Ph.D. thesis (Univ. of Southampton) (unpublished).

Houghton, S., & D.G. Jenkins, in prep. (1987). Subtropical Celtic Sea during the Late Pliocene.

Jenkins, D.G., 1975. Cenozoic planktonic foraminiferal biostratigraphy of the southwestern Pacific and Tasman Sea - DSDP Leg 29. In: J.P. Kennett, R.E. Houtz et al. — Init. Rep. DSDP, 29: 449-467.

Jenkins, D.G., 1982. The age and palaeoecology of the St. Erth Beds, southern England, based on planktonic Foraminifera. — Geol. Mag., 119 (2): 201-205.

Jenkins, D.G., D.Q. Bowen, C.G. Adams, N.J. Shackleton, & S.C. Brassel, 1985. The Neogene, 1. In: N. Snelling (ed.). Chronology and the geological record. — Geol. Soc. London Mem., 10: 199-210, 251-260.

Jenkins, D.G., J.E. Whittaker & R. Carlton, 1986. On the age and correlation of the St. Erth Beds, S.W. England, based on planktonic Foraminifera. — J. Micropalaeont., 5 (2): 93-105.

Jenkins, D.G., D. Curry, B.J. Funnell & M.E. Whittaker, in press (1987). Planktonic Foraminifera of the Early Pliocene Coralline Crag of Suffolk, eastern England. — J. Micropalaeont.

Jenkins, D.G., & M.S. Srinivasan, 1985. Cenozoic planktonic foraminifers from the equator to the sub-Antarctic of southwest Pacific. In: J.P. Kennett, C.C. von der Borch et al. (eds.). — Init. Rep. DSDP, 90: 795-834.

Kennett, J.P., & M.S. Srinivasan, 1983. Neogene planktonic Foraminifera, a phylogenetic atlas. Stroudsburg (Hutchinson Ross Publ. Corp.), pp. 1-265.

Malmgren, B.A., & J.P. Kennett, 1981. Phyletic gradualism in a Late Cenozoic planktonic foraminiferal lineage; DSDP site 284, southwest Pacific. — Paleobiol., 7: 230-240.

Mathers, S.J., J.A. Zalasiewicz & P.S. Balson, 1984. A guide to the geology of South-East Suffolk. — Bull. Geol. Soc. Norfolk, 34: 65-101.

Martini, E., 1971. Standard Tertiary and Quaternary calcareous nannoplankton zonation. — Proc. II. Plankt. Conf. Roma 1970, 2: 739-785.

Murray, J.W., 1984. Biostratigraphic value of Bolboforma, Leg. 81 Rockall Plateau. In: D.G. Roberts, D. Schnitker et al. — Init. Rep. DSDP, 81: 535-539.

Poore, Z., 1978. Oligocene through Quaternary planktonic foraminiferal biostratigraphy of the North Atlantic: DSDP Leg 49. In: B.P. Luyendyk, J.R. Cann et al. — Init. Rep. DSDP, 49: 447-517.

Rio, D., 1982. The fossil distribution of the coccolithophore genus Gephyrocapsa Kamptner and related Plio-Pleistocene chronostratigraphic problems. In: W.L. Prell, V. Gardner et al. — Init. Rep. DSDP, 68: 325-343.

Rio, D., J. Backman & I. Raffi, in press. Calcareous nannofossil biochronology and the Pliocene/Pleistocene boundary. In: The Neogene-Quaternary boundary. Final Report of the IGCP Project 41.

Scott, G.H., 1980. Globorotalia inflata lineage and G. crassaformis from Blind River, New Zealand; recognition, relationship and use in latest Miocene-Early Pliocene biostratigraphy. — New Zealand J. Geol. Geoph., 23: 665-677.

Takayama, T., & T. Saito, 1986. Coccolith biostratigraphy of the North Atlantic Ocean Deep Sea Drilling Project Leg 94. In: W.F. Ruddiman, R.B. Kidd et al. — Init. Rep. DSDP, 94: 651-701.

Weaver, P.P.E., & B.M. Clement, 1986. Magnetobiostratigraphy of planktonic foraminiferal datums: DSDP Leg 9ï. In: W.F. Ruddiman, R.B. Kidd et al. — Init. Rep. DSDP, 94: 815-829.

Weaver, P.P.E., 1986. Late Miocene to Recent planktonic Foraminifera from the North Atlantic: DSDP Leg. 94. In: W.F. Ruddiman, R.B. Kidd et al. — Init. Rep. DSDP 94: 703-727.

Manuscript received 9 April 1987, revised version accepted 5 May 1987.