Late Pliocene-Quaternary Biostratigraphy and Climatic Change in DSDP 208, Lord Howe Rise

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Abstract

Site 208 from Leg 21 of the Deep Sea Drilling Project contains a well preserved and almost complete sequence of Pliocene and Pleistocene planktic foraminifera and calcareous nannoplankton. The upper 42.5 m of sediment has been analysed at 50 cm intervals. Several major cold episodes are recognised. The strongest occur at 39 m, 27 m and about 11 m. The first of these may represent the onset of major continental glaciation in the Late Pliocene, about 3.0 m.y. ago. Oceanic palaeotemperatures were found to vary by at least 8° C, implying a latitudinal water mass movement of about 10°. The biostratigraphy has strong affinities with Tropical zonations, except that two species whose extinctions are used elsewhere as datum planes were found to occur here much higher in the sequence. They were Globorotalia multicamerata *and* Globigerinoides fistulosus. *Four coiling reversals were found in* Pulleniatina obliquiloculata *in the Pleistocene and were apparently unrelated to climate. Dates for these reversals agree closely with those found elsewhere. They may be useful datum points for Early Pleistocene correlation.*

Introduction

The purpose of this paper is to outline the results of a study of the planktic foraminifera in the upper part of DSDP well, Site 208. Because of its location this site was expected to be ideal for correlation between temperate and tropical foraminiferal biostratigraphies and for investigating the pronounced series of climatic changes which began in the Late Pliocene. In the southern hemisphere the distribution of planktic foraminifera is strongly latitude- and temperature-dependent, and so a study of foraminiferal abundance in sediment cores can be useful in the determination of oceanic palaeotemperatures. This was carried out using published data on zonation and temperature ranges in the plankton (Bé and Tolderlund, 1971; Eade, 1973) and in the sediments (Belyayeva, 1969; Kustanowich, 1963). Much climatic data were obtained, particularly for the period 3.2 m.y. to 1.0 m.y. ago, for which there was little information available previously. The results obtained must be interpreted with some caution as local ecologic factors can cause some variation in abundance of individual species, and their temperature tolerances may have changed during the interval studied.

Data

DSDP Site 208 is at Lat. 26°06'S, Long. 161°13'E, on the eastern side of the Lord Howe Rise in the Tasman Sea. It is ideally located because with climatic change the subtropical and temperate water masses fluctuate north and south past it. Furthermore, because of its shallow depth (1500 m) distance from land (500 km) and elevation above the general level of the Tasman Sea (300 m), the fauna is exceptionally well preserved, abundant and not mixed with terrigenous or turbidite material.

The well penetrated 594 m of sediment, the lowermost units being of Late Maastrichtian age. This study is concerned with the top 42.5 m, of Late Pliocene through Pleistocene age. The materials recovered were nanno-foram and foram-nanno oozes containing traces of aeolian quartz but no clay. Samples were available at 50 cm intervals. No core was recovered between 18-22 m, 31-35.5 m and 42.5-44 m. There was no magnetic stratigraphy available. The sedimentation rate was 1.05 cm/1000 yr for the Late Pliocene, giving one sample per 50,000 yr, and 1.5 cm/1,000 yr in the Pleistocene, giving one sample every 35,000 yr.

Splits of the greater-than- 250 μm fraction containing about 500 specimens were used for the foraminiferal analysis. All planktic specimens were identified and counted. Identification, nomenclature and taxonomy were based on the work of Parker (1962, 1967) and Bé (1967. Relative abundance curves were obtained for all species. These have been combined into ecologic water mass zones following the scheme of Bé and Tolderlund (1971).

The four appropriate zones are: Subpolar, Transition, Subtropical and Tropical. Each species is assigned to the zone in which it reaches its greatest abundance in the plankton at the present time. The following modifications were made using data from Eade (1973): *Globorotalia truncatulinoides* and *G. crassaformis* were assigned to the Subtropical zone. Because cosmopolitan species such as *Orbulina universa* do not fit into this scheme, a fifth category, *Others,* was created and all ubiquitous and extinct species except *Globorotalia tosaensis* were assigned to it. The latter species was referred to the Transition group, on the grounds that it was known to prefer somewhat cooler conditions than its descendant, *G. truncatulinoides, e.g. see* Kennett (1970).

Smear slides were made from the less-than-63 μm fraction of each sample, and examined for discoasters. Coccoliths were abundant in all slides but were not studied here. There were no siliceous microfossils present.

Results

Biostratigraphy and faunal variation are shown in Figure 1. The dominant species are *Globorotalia inflata* (generally 30-60% of total fauna), *Globigerinoides ruber, G. sacculifer, Globorotalia crassaformis* (below 35 m), and *G. tosaensis* (37 m to 10 m). Other species such as *G. truncatulinoides* and *Pulleniatina obliquiloculata* occasionally total as much as 10-15%, but are usually less abundant.

(a) Biostratigraphy

Below 39 m, about 50% of the foraminiferal fauna is in the Subtropical zone; a further 25% is Tropical. In some fluctuations the Tropical component of the fauna is as high as 40%. Over the interval as a whole the fauna would then be described as Subtropical bordering on Tropical. Similarly between 39 m and 25 m the fauna is described as Intermediate or Transitional, though at 27 m it is Intermediate-Subpolar. Between 25 m and the top the fauna is again Subtropical.

There are major fluctuations at 37 m, 27.5 m, 25 m, 16 m and 11-9 m. The biostratigraphy has strong affinities with Tropical zonations *e.g.* Hays *et al.* (1969) Berggren (1973), except for minor details which are discussed below. Correlation with the Temperate zonation of Jenkins (1971) is weak, as a number of his key species are not present, and his biostratigraphy for the Pleistocene and Pliocene is based largely on coiling changes (in *Globigerina pachyderma*) rather than on biostratigraphic events.

The foundation of the zonation given here is: (1) The evolutionary transition from *Globorotalia crassaformis* to *G. tosaensis* and (2) The evolutionary transition from *G. tosaensis* to *G. truncatulinoides.* These events define the bases of zones N21, N22 respectively of Blow (1969), and have been dated palaeomagnetically at 3.0 m.y. and 1.85 m.y. (Berggren 1973). At site 208 these transitions occurred at 38.5 m and 27 m. Hays *et al.* (1969) suggest that coiling changes in *Pulleniatina* spp. including *P. obliquiloculata,* are independent of climatic change, and hence can be used as datum planes in the Pliocene and Pleistocene. These workers found four such reversals in the Pleistocene and dated them (by extrapolation from known palaeomagnetic events) at 1.6 m.y., 1.25 m.y. 0.95 m.y. and 0.85 m.y., respectively.

Four reversals were found here and dated at 1.5 m.y., 1.15 m.y., 1.00 m.y., and 0.85 m.y., using an average sedimentation rate of 1.5 cm/1,000 yr for the Pleistocene. These reversals could become valuable Early Pleistocene datum planes. They do not appear closely related to climatic changes.

The disappearance of *Globoquadrina altispira* is simultaneous with the appearance of *Globorotalia tosaensis* and indicates that Blow's (1969) N20 zone is not present. The absence of this zone has been reported previously (Berggren, 1973); it appears that this zone is either not viable or is extremely short.

G. multicamerata disappears at 23 m (about 1.6 m.y.), whereas Berggren (1973) defines a datum plane on its disappearance simultaneous with *Globoquadrina altispira* at about 2.8 m.y. *Globigerinoides fistulosus* was persistent between 42.5 m (3.2 m.y.) and 13.5 m (0.9 m.y.) but was not found above this point. Again Berggren (1973) dates its disappearance at 1.65 m.y.

It appears that the extinction of *G. tosaensis* at 10.5 m may be a useful Late Pleistocene datum in Temperate and Subtropical zones, where conditions are most suitable for this species. *G. tosaenis* disappears here at 0.7 m.y., which is as

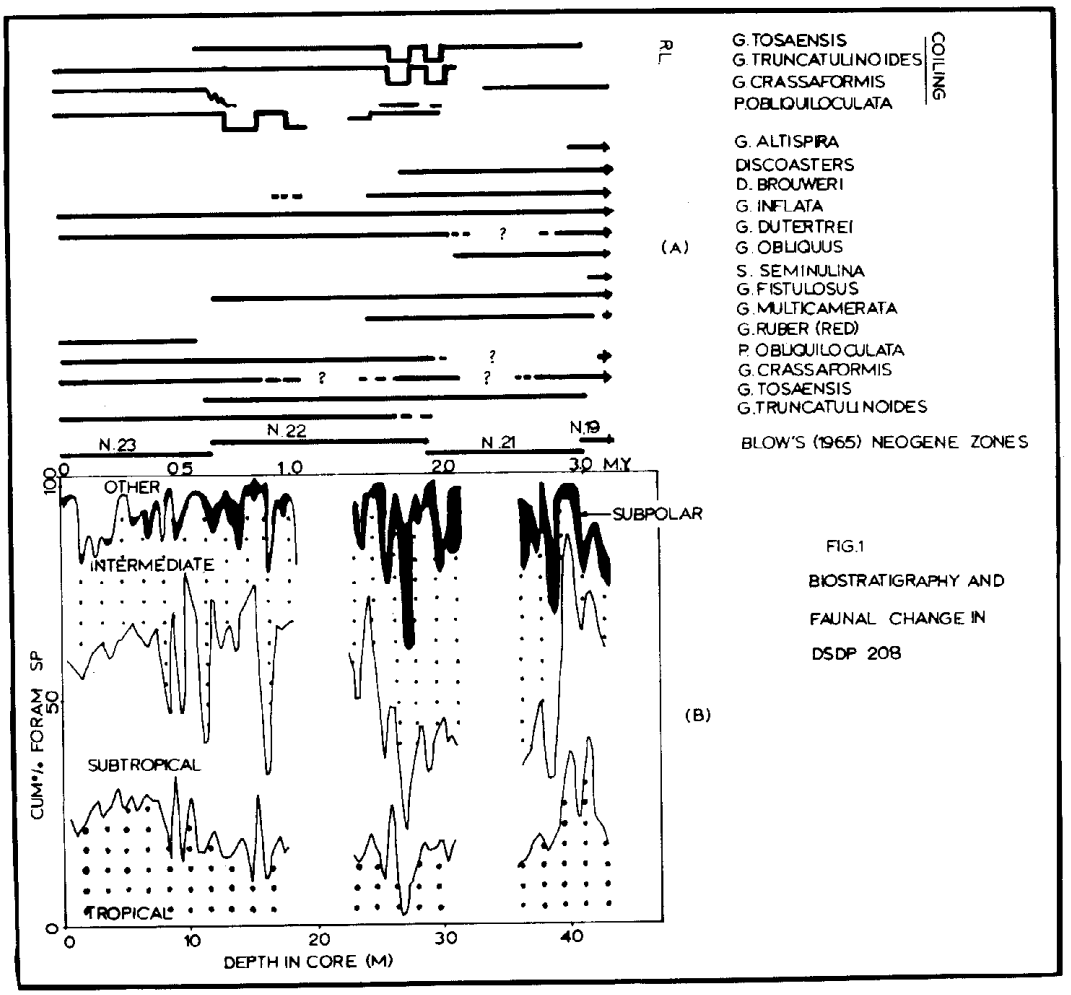

FIG.1
BIOSTRATIGRAPHY AND FAUNAL CHANGE IN DSDP 208

FIGURE 1(a)
Chart showing the stratigraphic ranges of the important foraminiferal species in the upper part of DSDP 208. Dashed lines indicate that the species is present intermittently. Coiling reversals in *Globorotalia* spp. are from right to left

FIGURE 1 (b)
Inset: Relative abundance of each of the foraminiferal ecologic zones. *e.g.* where there is 30% Subpolar, this indicates that 30% of the total fauna at this time consists of Subpolar species

high in the sequence as has been recorded elsewhere (Blow, 1970; Hays *et al.*, 1969).

Most species of discoaster, including *D. pentaradiatus* and *D. surculus* became extinct at about 27 m (1.75 m.y.). These forms are generally regarded as having become extinct at or just below the base of the Pleistocene. Berggren (1973) has dated these extinctions at 2.3 and 2.0 m.y., respectively. *D. brouweri,* which is known to persist into the Pleistocene, occurs here commonly up to 23 m (1.5 m.y.); occasional specimens are found as high as 17 m.

(b) Climatic Change

For any particular time, the palaeoclimate can be determined from Figure 1 by determining which faunal zone contains the greatest percentage of the fauna. If two adjacent zones contain approximately the same numbers of foraminifera the climate is considered to be intermediate between them. Unfortunately, there is insufficient detail in Figure 1 for fine correlation, especially in the Late Pleistocene. Here successive glaciations are known to have occurred at intervals of about 80,000 years (Ruddiman and McIntyre, 1976) and usually each glaciation had several peaks and troughs. As the sample interval in the Pleistocene is about 35,000 years it is not possible to resolve all of these events. Many may not be recorded at all or only with greatly reduced intensity. Figure 1 was compared with the oxygenisotope curve of Shackleton and Opdyke (1976) for the whole of the Pleistocene. The great detail in the upper part of their curve (sampled at 5,000 year intervals) is simply not present in the material studied here. There are a number of peaks in Figure 1, but it is not possible to correlate these with specific glaciations as described by Shackleton and Opdyke.

The curve does show several strong cooling episodes near 10 m (0.7 m.y.). An intensely cold episode has long been recognised at this time. Similarly at 1.8 m.y. there is another cold pulse, the most severe found at site 208. This event also has often been described but present opinion puts it as being much less severe than the one at 0.7 m.y. (Hays *et al.*, 1969).

A third cooling episode occurs at 38.5 m (3.0 m.y.). This event is also described in the literature and probably corresponds to the first major onset of continental glaciation at the end of the Mid-Pliocene.

Oceanic palaeotemperatures were estimated for several points, using the method of Tolderlund and Bé (1971). They state that past ocean surface temperatures can be deduced from the ratio of *Globigerinoides sacculifer* to *Globigerina bulloides.* If this is near zero, then water temperatures are near 10°C. When the ratio is 1.0 the temperature is about 18°C and when *G. bulloides* disappears the temperature exceeds 24°C. The absence of *Globorotalia menardii* and *Pulleniatina obliquiloculata* below 15°C can also provide a useful reference point.

Applying this technique, palaeotemperatures were estimated to vary from above 24°C at 39 m (3.0 m.y.) to about 16°C at 27 m. (1.8 m.y.) The average temperature was 21°C. Data presented in Rochford (1957) show that a change in Tasman Sea temperature of 8°C implies a water mass movement of about 10° of latitude or 1100 km.

Summary

This study of the foraminiferal fauna of DSDP Site 208 has shown that while the biostratigraphy is basically similar to published zonations from tropical areas, there are significant differences in the ranges of several species previously used as datum planes. Coiling reversals were found in *Pulleniatina obliquiloculata* which may be useful biostratigraphic markers. A palaeoclimate curve was constructed which shows major climate shifts at 3.0 m.y., 1.8 m.y. and 0.7 m.y. These are in good agreement with major coolings found elsewhere. A number of less intense climate shifts were also found. A palaeotemperature curve was constructed which showed a change in water temperature of over 8°C in the last three million years.

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