THE DECLINE AND EXTINCTION OF UPPER PLIOCENE DISCOASTERS: A COMPARISON OF TWO EQUATORIAL PACIFIC OCEAN RECORDS

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Abstract: High-resolution records of Upper Pliocene *Discoaster* abundances were analysed from two ODP (Ocean Drilling Program) Sites, Site 677 (1°N, 84°W) and Site 806 (0°N, 159°E). Both sites are in the equatorial Pacific Ocean, but almost 13,000 km apart. A high-resolution oxygen isotope stratigraphy from Site 677 has formed the basis of a revised, orbitally-tuned timescale. This timescale was extrapolated to Site 806 using biostratigraphic datums. The *Discoaster brouweri* records at both sites prior to its extinction at 1.95 Ma (isotope Stage 72) document a dramatic reduction in abundance between 2.15 and 2.12 Ma (isotope Stages 82 and 80, respectively). The *Discoaster triradiatus* acme (2.15-1.95Ma) coincides with this interval of low *Discoaster* abundance but is still clearly discernible. Site 677 in the eastern Pacific is affected by the cold Peru Current. It is suggested that the advection of cooler water intensified during glacial isotope Stage 82, causing increased upwelling and lower sea-surface temperatures, which suppressed *Discoaster* production. Site 806, in the western Pacific is affected by divergence related to the equatorial currents, rather than by a cool boundary current system, so surface-water temperatures are relatively stable on a glacial-interglacial scale. The decline in *Discoaster* abundance in the western equatorial ocean, during isotope Stage 80, is, therefore, more likely to be attributable to the position of equatorial divergence and corresponding changes in the thermocline and nutricline. The decline in abundance patterns observed in the two equatorial Pacific sites are also evident in records from the equatorial Indian and Atlantic Oceans, although the reduction in *Discoaster* abundances in these two regions are less extreme.

Introduction

The genus *Discoaster* first appeared in the oceanic record in the late Palaeocene. The last two species, *Discoaster brouweri* and *Discoaster triradiatus*, became extinct in the late Pliocene, just prior to the Olduvai Subchron at 1.95 Ma (e.g., Takayama, 1970; Rio, 1982; Backman & Shackleton, 1983; Driever, 1988). A number of studies have concluded that discoasters favoured warm water-masses (e.g., Haq & Lohmann, 1976; Bukry, 1978; Backman & Pestiaux, 1987) and that their abundance decreased markedly with increasing latitude. Cyclic fluctuations of discoasters, especially in records from the tropics (Chepstow-Lusty *et al.*, 1989, 1991, 1992), pointed to the importance of a factor other than temperature, which was suggested to be productivity pressure.

Study of Hole 806C provided high-resolution data (Backman & Chepstow-Lusty, 1993) from this extreme western Pacific site, influenced by a low-intensity upwelling regime. This can be compared with Site 677 in the far eastern Pacific, located within a major upwelling area (Figure 1, Table 1). Site 806 is located on the Ontong Java Plateau, which is a broad, shallow, mid-ocean highland in the western equatorial Pacific. The sediments from Site 806 consist of foraminifer/nannofossil ooze. Site 677 is situated in the eastern equatorial Pacific between the Ecuador and Panama Fracture Zones (Becker *et al.*, 1988), and is characterised by pelagic, siliceous/ calcareous nannofossil ooze. Both sites are above the CCD and have very good carbonate preservation, hence *Discoaster abundances* are unlikely to be influenced by diagenesis. Discoasters are useful for quantitative studies since they are less prone to dissolution than planktonic foraminifera and most placoliths (Lohmann & Carlson, 1981). The semi-quantitative counting technique and taxonomy employed here follows that of Backman & Shackleton (1983).

The goal of this work is to compare the *Discoaster* abundance records from Sites 677 and 806 using a common timescale. The time interval investigated is approximately

Table 1

Hole Location	Depth	Reference
806C	0°N 159°E	2,521 Kroenke, L. W., Berger, W. H., Janacek, T. R., *et al.*, 1991
677A	1°N 84°W	3,461 Becker, K., Sakai, H., Merrill, R.B. *et al.*, 1988

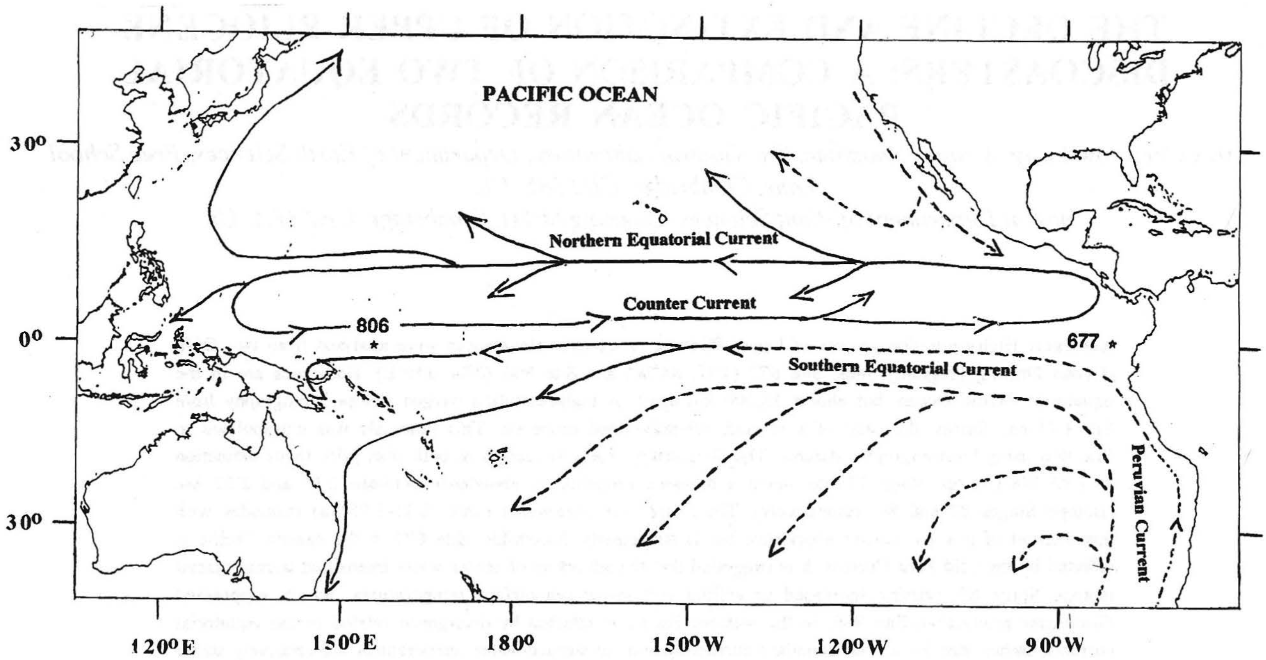

Figure 1: Location map of ODP Sites 677 and 806 with schematic representation of warm (solid line) and cold (dashed line) surface currents.

the 700 kyrs preceding the extinction of the discoasters (1.95-2.65 Ma) and the closely-spaced samples analysed (10 cm intervals) correspond to a temporal resolution of around 3 kyrs for both sites.

Age models

Detailed work at Site 677 has provided an orbitally-tuned oxygen isotope stratigraphy and high-resolution *Discoaster* abundance record (Shackleton *et al.*, 1990; Chepstow-Lusty, 1990). The age model for Site 677 is discussed fully in Shackleton *et al.* (1990). At Hole 806C, the extinctions of *D. brouweri*, *D. triradiatus* and *D. pentaradiatus* are well defined, as is the base of the *D. triradiatus* acme (Backman & Chepstow-Lusty, 1993). The *D. triradiatus* acme is located using the percentage abundance of *D. triradiatus* within the combined *D. triradiatus* and *D. brouweri* assemblage (Backman & Shackleton, 1983). Prior to the acme *D. triradiatus* usually forms <1% of the *D. brouweri* plus *D. triradiatus* assemblage, whilst during the acme it usually forms over 20% of the assemblage. The acme begins at Site 806 with a distinctive peak in *D. triradiatus*, similar to that observed at Site 607 (Chepstow-Lusty *et al.*, 1989). It is assigned the age of 2.15 Ma in accordance with the orbitally-tuned oxygen isotope stratigraphy for Site 607 (Raffi *et al.*, 1993). The age for the last appearance datum of *D. pentaradiatus*, at 2.52 Ma, follows the oxygen isotope chronology of Jansen *et al.* (1993) from Hole 806B. There is a core break before the distinctive decline in abundance of *D. brouweri*, but samples analysed adjacent to this gap indicate that the abundances are genuinely suppressed either side of this hiatus. Table 2 summarises the control points for Hole 806C.

Interpretation

Although the sites are approximately 13,000 km apart, and affected by very different oceanographic conditions, there are obvious parallels to be observed, since similar and marked fluctuations in abundance occur at certain intervals. It is apparent that the intense glacial corresponding to isotope Stage 96 had an impact on *D. brouweri* abundances that can be correlated between both sites. However, the preceding glacial isotope Stages 98 and 100 are of a similar

Table 2

Hole 806C				
Datum	**Age (Ma)**	**Depth (mbsf)**	**Event**	
D. brouweri & *D. triradiatus*	1.95	39.30	Extinction	
D. triradiatus	2.15	43.15	Abundance Increase	
D. pentaradiatus	2.52	53.80	Extinction	

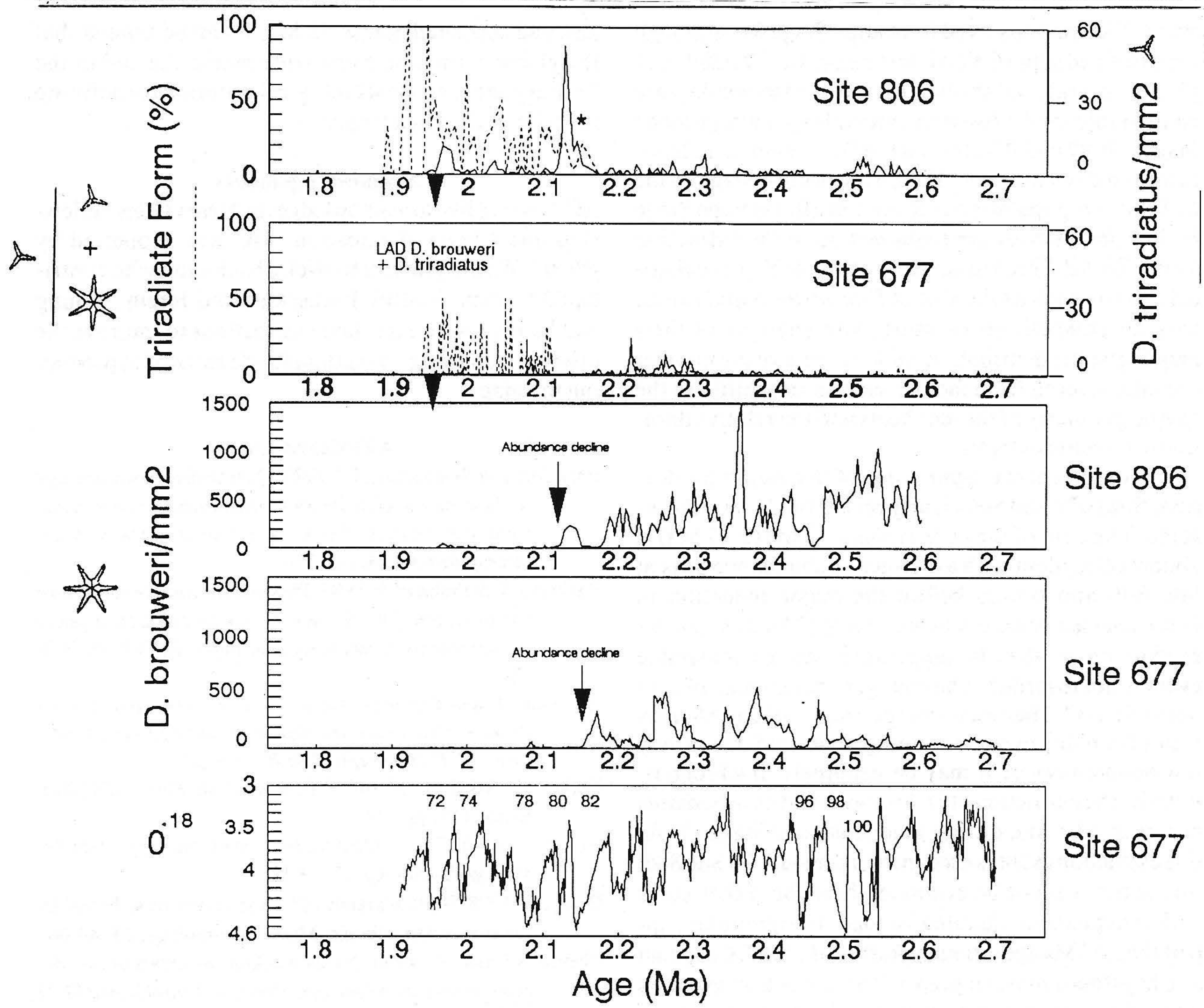

Figure 2: Abundance plots of *D. brouweri, D. triradiatus* and the *D. triradiatus* acme for Sites 677 and 806 versus the orbitally tuned oxygen isotope stratigraphy for Site 677. * indicates the increase in *D. triradiatus* abundance used as a control point for constructing the age model at Site 806.

magnitude in the isotope record but only at Site 677 is *Discoaster* production greatly suppressed, whilst abundance patterns remain largely unaltered at Site 806. Quaternary palaeoceanographic reconstructions, inferred from the composition of planktonic foraminiferal faunas, have shown that surface ocean circulation patterns are modified in response to prevailing glacial or interglacial conditions (CLIMAP, 1976). The CLIMAP results indicate that the difference between modern and glacial (18,000 B.P.) biogeographic patterns within the low latitude Pacific Ocean is much more pronounced in the eastern region of the equatorial divergence. Therefore, the differences observed in the Upper Pliocene *Discoaster* abundances from the eastern (Site 677) and western (Site 806) Pacific Ocean are probably a result of contrasting regional oceanographic responses to climatic change.

The major abundance decline at Site 677, during glacial isotope Stage 82 (2.15Ma), is believed to represent an increase in equatorial upwelling, possibly amplified by the effects of the cool Peru Current moving northwards up the western coast of South America. Planktonic foraminiferal records from ODP Site 846 have documented analogous glacial-interglacial shifts in the intensity of the eastern boundary current system throughout the late Quaternary (Le *et al.*, 1995). At Site 806, the major abundance decline occurs later, at 2.12 Ma, corresponding to glacial isotope Stage 80. Circulation in the western part of the Pacific, where there is no advection of cool surface-waters originating in higher latitudes, is dominated by upwelling driven by equatorial divergence. Any increase in the intensity, or proximity, of divergence will have modified the regional temperature, nutrient, and upper water-structure characteristics. This is likely to have affected *Discoaster* production, because of their preference for warm, low-nutrient waters. It may be that the different age estimates for the decline in *Discoaster* abundance document significant circulation differences and climatic responses between the equatorial eastern and western Pacific. However, caution is required because, while the Site 677 age model is rigorously constrained, the age model for Site 806 is constructed by interpolation between three control points and would benefit from independent chronostratigraphic data. In the equatorial Atlantic and Indian Oceans, at ODP Sites 662 and 709 (Chepstow-Lusty *et al.*, 1992; Chapman & Chepstow-Lusty, in prep.), a marked abundance reduction is likewise observed in isotope Stage 82, although the sustained suppression is less emphatic. Variability in glacial-interglacial shifts in the oxygen isotope data are comparable for the two time intervals spanning isotope Stages 78-82 and 96-100, but the *Discoaster* abundance records differ markedly. Following isotope Stage 96 the *D. brouweri* population recover, but after isotope Stage 80 low abundances are sustained up to the extinction event. This difference could be attributable to ecological criteria such as the size of *Discoaster populations*, varying competition pressure, and changes in their biogeographic distribution, which in turn relate to wider climatic forcing from factors such as variability in the spatial geometry of the ice sheets and the relative duration of climatic extremes.

In spite of the suppression of *Discoaster* production, Sites 677 and 806 clearly record the *D. triradiatus* acme. The base of the *D. triradiatus* acme (2.17 Ma) is almost coincident with a distinctive abundance peak at Site 806 and occurs before the major reduction in *Discoaster* abundance, whereas at Site 677 the *Discoaster* production is already suppressed and a comparable event is not recorded. The younger age estimate of 2.12 Ma at Site 677, between isotope Stages 79 and 80, may result from this event remaining unnoticed due to very low abundances or it may be genuinely diachronous. Finally, the extinction of *D. brouweri* and *D. triradiatus* occurs at 1.95 Ma, during glacial isotope Stage 72. As this extinction event is used in the age model for Site 806, this datum cannot be evaluated here, but other cores with independent, detailed isotope stratigraphies support the 1.95 Ma age estimate (Raffi *et al.*, 1993; Chapman & Chepstow-Lusty, in prep.). The extinction event, is marked by the end of continuous distribution; occurrences of single or very few specimens above the extinction event are considered to be reworked. The pattern seen here of some 200kyrs of suppressed abundances prior to extinction is worth noting. It clearly shows that an abrupt abundance drop near a last occurrence level cannot be assumed to be the extinction level.

Although both *D. brouweri* and *D. triradiatus* abundance records exhibit variability in relation to climatic change, they also appear to record two major thresholds of temperature reduction and nutrient increase in the equatorial Pacific. The first threshold, at isotope Stage 82 in the eastern Pacific, did not take effect until isotope Stage 80 in the western Pacific and marked the onset of cooler temperatures associated with upwelling, cold currents or equatorial divergence. The extinction of the discoasters is believed to signify an intensification of these conditions resulting in greater environmental pressure and declining population sizes, which may have allowed other phytoplankton species to outcompete them. The morphology of *D. triradiatus* (only three arms) was the final modification in a lineage that had been continually reducing skeletal calcification and the number of arms (Bukry, 1971). The increase in *D. triradiatus* may represent the last observed adaptive response of *Discoaster* to the accentuation of glacial-interglacial climatic variability during the late Pliocene. Since the discoasters favoured stable, warm conditions and had speciated across 55 Ma, it can be argued that thisglobal extinction event truly marks the end of the Tertiary and is an ideal biological criterion for defining the base of the Quaternary.

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