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Late Oligocene climatic changes: Evidence from calcareous nannofossils at Kerguelen Plateau Site 748 (Southern Ocean)

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Abstract

Palaeoecological changes in nannofossil assemblages in the Southern Ocean during Oligocene times are examined through high-resolution, quantitative analyses of samples from Ocean Drilling Program (ODP) Site 748 (Kerguelen Plateau). We quantitatively characterized the palaeoecological preference of groups of species and compared their general trends with those determined at Maud Rise (ODP Sites 690 and 689) (Persico, D., Villa, G., 2004. Eocene–Oligocene calcareous nannofossils from Maud Rise and Kerguelen Plateau (Antarctica): palaeoecological and palaeoceanographic implications. Marine Micropaleontology 52, 153–179). We then attempt a correlation between the main assemblage variation and sea-surface temperature (SST) changes in the Southern Ocean at this time. Relatively stable, cool conditions are interpreted to have persisted from earliest to late Oligocene times, when an increase in abundance of temperate-water taxa is recorded, both at Maud Rise and Kerguelen Plateau, before the Mi-1 event. This reveals a climatic event that probably involved both sites, and which is comparable to that indicated by the global oxygen isotope curve ([Miller, K.G., Wright, J.D., Fairbanks, R.G., 1991. Unlocking the Ice House: Oligocene–Miocene oxygen isotopes, eustasy, and margin erosion. Journal of Geophysical Research, 96, 6829–6848; Zachos, J., Pagani, M., Sloan, L., Thomas, E., Billups, K., 2001. Trends, rhythms, and aberrations in global climate 65 Ma to present. Science, 292, 686–693.]). In the uppermost Oligocene at Site 689, the temperate-water taxa index ([temperate/temperate+cool]*100) increases from 25.2 Ma. Similarly, at Site 748, the temperate-water taxa index indicates an increase in SST in the late Oligocene, from about 26.5 Ma, at the base of Chron C8n.2n, which is offset by about 1 m.y. between the two areas. The reason for this time difference can probably be found in the location of Site 748 with respect to Site 689, and in the palaeoceanographic setting, taking into account that Site 748 lies north of a deep water passage that separates Kerguelen Plateau from Antarctica, and north of the present day front of the Antarctic Circumpolar Current. The presence of warm-water taxa, exclusively at Site 748, corroborates this hypothesis.

Keywords: Calcareous nannofossils; Oligocene; Palaeoecology; Biostratigraphy; Southern Ocean

1. Introduction

The Oligocene was a time of climatic deterioration that saw the initiation of continent-wide ice sheets on Antarctica and the formation of the Antarctic circumpolar current (ACC). Cool Oligocene conditions are confirmed by glacigene deposits recovered from the Antarctic margin by the Cape Roberts Project off the Victoria Land coast (CRP; Naish et al., 2001) and Ocean Drilling Program (ODP) Leg 188 in Prydz Bay (Florindo et al., 2003), and also from the global deep-sea record $\delta^{18}O$ (e.g., Zachos et al., 2001).

Calcareous nannofossil records from ODP Sites 689 and 690 indicate a dominance of cool-water taxa for most of the Oligocene in the Southern Ocean (Persico

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and Villa, 2004). However, the presence of terrestrial palynomorphs recovered from the Antarctic margin drillholes (e.g., CIROS: Mildenhall, 1989; CRP: Raine, 1998; Raine and Askin, 2001) suggested mean annual temperatures that were warmer than present-day conditions. Roberts et al. (2003a) in a recent revision of the chronology of the CIROS-1 drillhole, also concluded that Antarctica was not deeply refrigerated during the late Oligocene, until after the Mi-1 $\delta^{18}O$ event, using the terminology of Miller et al. (1991).

Composite deep-sea $\delta^{18}O$ records also indicate climatic amelioration in the Late Oligocene from 26 to 24 Ma. This has been attributed to deep-sea warming, coupled with a collapse of the Antarctic ice sheet (e.g., Miller et al., 1987; Zachos et al., 2001). However, the magnitude of the late Oligocene warming is larger in the composite record of Zachos et al. (2001) than has been documented at any one site (Lear et al., 2004; Pekar et al., 2005), and a recent benthic $\delta^{18}O$ record from the tropical Pacific (Lear et al., 2004) does not indicate substantial warming at ~25 Ma. Further, both Lear et al. (2004) and Pekar et al. (2005) suggest that the much of late Oligocene warming inferred by Zachos et al. (2001) may be an artifact of the compilation. Nevertheless, they recognize a decreasing ice volume between 27 and 24 Ma before the ice growth which culminated with Mi-1.

Channell et al. (2003) report on low resolution stable isotope data from ODP Site 1090 for the late Oligocene, down to 26.3 Ma, while the high resolution record for this site only extends back to ~25 Ma (Billups et al., 2002). However the superimposition of these late Oligocene sparse data onto the composite $\delta^{18}O$ record of Zachos et al. (2001) reveals that the warming trend shown at ODP Site 1090 slightly precedes that shown by the composite curve. Also, uppermost Oligocene samples from Site 689 indicate a decrease in abundance of nannofossil cool-water taxa, in favor of an increase of temperate-water taxa (Persico and Villa, 2004) at about this time. This warming trend is not seen as inconsistent with the presence of a significant Antarctic ice sheet in the late Oligocene, which is well established from CRP drilling on the Antarctic margin (Naish et al., 2001), and indicated by deep-sea isotope records (Pekar et al., 2002, 2005).

As with most other Palaeogene intervals, previous nannofossil records that span the Oligocene lack the sampling density needed to resolve palaeoecological changes on time scales of 10^5 years. Few detailed micropalaeontological data are available for interpretation of sea-surface temperature (SST) in the late Oligocene in the Southern Ocean. We present here the abundance variations of nannofossil palaeoecological groups at ODP Site 748 in an effort to improve the resolution of late Oligocene palaeoclimatic changes and their effects in open-ocean high latitude sedimentary sequences, and to correlate them with the Antarctic continental margin record. Several studies of Southern Ocean sections have used calcareous nannofossil biostratigraphy and palaeoecology in the Palaeogene and have demonstrated the important role of these microfossils for palaeoclimatic and palaeoceanographic reconstructions (e.g., Wei and Wise, 1990a,b; Bralower, 2002; Persico and Villa, 2004). In this work, using the classification previously obtained for nannofossil palaeoecological groups, and with previous classifications (Wei and Wise, 1990a,b; Wei, 1991; Wei et al., 1992; Monechi et al., 2000; Persico and Villa, 2004), we compare trends in nannofossil assemblages observed at Kerguelen Plateau and Maud Rise, and propose a correlation between main assemblage variations and SST changes in the Southern Ocean at this time.

2. Materials and methods

ODP Hole 748B (Leg 120) is located on the southern Kerguelen Plateau, in the Southern Indian Ocean (Fig. 1). We analysed the interval from 66.61 m below sea floor (mbsf) to 95.40 mbsf, taking samples at 10 cm intervals from u-channels studied by Roberts et al.

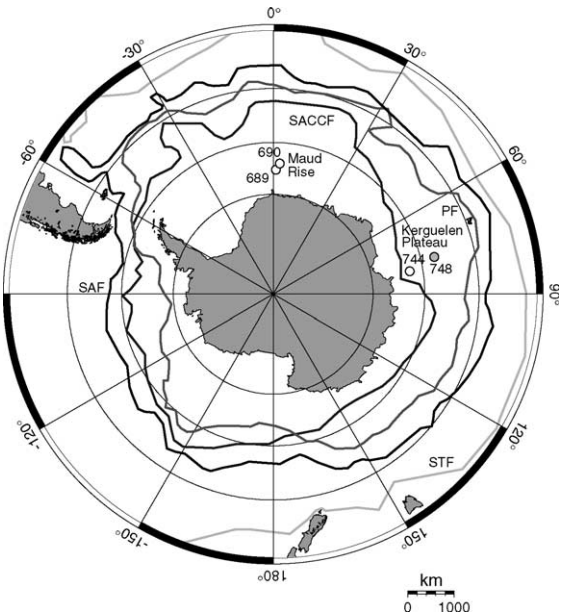

Fig. 1. Map of ODP Site 748 (shaded dot) on Southern Kerguelen Plateau, and other ODP sites on Maud Rise. Oceanic fronts as reported according to Barker and Thomas (2004): Southern Antarctic Circumpolar Current Front (SACCF); Polar Front (PF); Southern Antarctic Front (SAF); South Tropical Front (STF).