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Marine Micropaleontology 54 (2005) 213–247
MARINE MICROPALEONTOLOGY
www.elsevier.com/locate/marmicro

Late middle Eocene to late Oligocene radiolarian biostratigraphy in the Southern Ocean (Maud Rise, ODP Leg 113, Site 689)

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Received 12 May 2004; received in revised form 1 December 2004; accepted 2 December 2004

Abstract

We propose a new biostratigraphic scheme comprising the *Eucyrtidium spinosum*, *Eucyrtidium antiquum* (new), *Lychnocanoma conica* (emended), *Clinorhabdus robusta* (emended) and *Stylosphaera radiosa* (emended) Zones, in ascending order, in Eocene to Oligocene sediments drilled on Maud Rise in Southern Atlantic Ocean (Site 689, Ocean Drilling Program Leg 113). The bases of these zones are defined by the lowermost occurrences of *E. spinosum*, *E. antiquum*, *L. conica*, *C. robusta* and the uppermost occurrence of *Axoprunum irregularis* (?), respectively. From correlation to the magnetostratigraphic data, the *E. spinosum*, *E. antiquum*, *L. conica*, *C. robusta* and *S. radiosa* Zones are assigned to the late middle Eocene through late Eocene (Subchrons C17n2 to C13r), earliest Oligocene (C13n to C11n), late early Oligocene (C11n to C10n2), early late Oligocene (C10n1 to C8r) and latest Oligocene (C8r to C7An), respectively. The four boundary datum levels and supplementary datum levels such as the lowermost occurrences of *A. irregularis* (?), *Dicolocapsa microcephala* and *Lithomelissa challengerae* may be recognized in other ODP sites in the Southern Ocean. The first occurrence of *E. antiquum* approximates the Eocene–Oligocene boundary in Southern Ocean but the last occurrences of many species such as *Periphaena decora*, *D. microcephala* and the *Lithomelissa sphaerocephalis* group are commonly diachronous between high latitude sites. Two new species, *Theocyrtis* (?) *triapenna* and *Spirocyrtis parvaturris*, are described.

Keywords: radiolaria; biostratigraphy; Eocene to Oligocene; Southern Ocean

1. Introduction

The Eocene–Oligocene interval was a critical climatic period in earth history being the transition from the warm early Cenozoic hothouse to the glacial late Cenozoic icehouse. During the 10 m.y. from the middle Eocene to the early Oligocene, the deep ocean

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doi:10.1016/j.marmicro.2004.12.002

waters and the surface waters at high latitude cooled (e.g., Zachos et al., 2001), and this cooling was reflected in faunal turnover of marine and terrestrial biota (e.g., Prothero and Berggren, 1992; Prothero et al., 2003). Benthic foraminiferal δ^{18}O and Mg/Ca records obtained from deep sea sediments recovered by the Ocean Drilling Program (ODP) indicate that Antarctic icesheet initiation and/or enlargement, with or without ocean cooling, occurred near the Eocene–Oligocene boundary (e.g., Kennett and Stott, 1990; Barrera and Huber, 1991, 1993; Mackensen and Ehrmann, 1992; Zachos et al., 1992, 2001; Diester-Haass and Zahn, 1996; Lear et al., 2000; Billups and Schrag, 2003; Barker and Thomas, 2004). A positive shift in benthic foraminiferal δ^{18}O values just above this boundary was named the Oi1 event (Miller et al., 1991) and occurred at the same time as opening of the Tasmanian gateway, an increase in surface water productivity and a change from calcareous microfossil rich sediment to more biosiliceous one (Kennett et al., 1975; Kennett, 1977; Diester-Haass, 1992, 1995, 1996; Diester-Haass and Zahn, 1996; Salamy and Zachos, 1999; Shipboard Scientific Party, 2001). Siliceous microfossils (diatoms and radiolarians) increased in abundance and species diversity in the Southern Ocean during this 10 million year period in the middle Eocene–early Oligocene (Harwood and Maruyama, 1992; Caulet, 1991; Takemura, 1992), whereas calcareous microfossils became less diverse and endemic, and finally dominated by cool-water species (Stott and Kennett, 1990; Huber, 1991; Berggren, 1992; Wei and Wise, 1990a; Wei et al., 1992; Persico and Villa, 2004). Hence, siliceous microfossils are useful for biostratigraphy in the Southern Ocean during the Eocene–Oligocene transition.

Pioneering research of Paleogene Antarctic radiolarians (Chen, 1974, 1975; Petrushevskaya, 1975) described many Eocene and Oligocene species in the Australasian sector of the Southern Ocean (Deep Sea Drilling Project (DSDP) Legs 28 and 29, respectively). Weaver (1983) reported on Paleogene radiolarians from the Falkland Plateau, southwestern Atlantic (DSDP Leg 71). For the Atlantic sector of the Southern Ocean, Barker et al. (1988) reported the upper Eocene to Oligocene radiolarian faunas at Sites 689 and 690 of ODP Leg 113 and suggested that they were similar to those from the Australasian sector. Caulet (1991) reported on Indian Ocean radiolarian faunal change from upper Eocene through lower Oligocene and described several Paleogene species (Sites 738 and 744, ODP Leg 119; Kerguelen Plateau). Apel et al. (2002) described mainly lower lower Oligocene radiolarians of Site 1138, ODP Leg 183 (Kerguelen Plateau).

All these studies described the species composition of upper Paleogene radiolarian faunas in the Southern Ocean, but they did not propose an Antarctic Paleogene radiolarian zonal scheme. Abelmann (1990) first presented an upper Oligocene radiolarian biostratigraphy (the *Cyrtocapsella robusta* and overlying *Stylosphaera radiosa* Interval Zones) for Maud Rise Sites 689 and 690 (ODP Leg 113). Takemura (1992) defined three radiolarian zones, the *Eucyrtidium spinosum*, the *Axoprunum irregularis* and the *Lychnocanoma conica* Zones for the middle Eocene to upper Oligocene on Kerguelen Plateau (Indian Ocean Sites 748 and 749, ODP Leg 120). Takemura and Ling (1997) summarized the upper Eocene to Oligocene radiolarian biostratigraphy in the Southern Ocean based on correlations between the Subantarctic Atlantic Ocean (Sites 699, 702 and 703; ODP Leg 114) and the Kerguelen Plateau, Indian Ocean (Sites 748 and 749 of ODP Leg 120).

We propose a new radiolarian biostratigraphy for the upper middle Eocene through upper Oligocene recovered at ODP Hole 689B (Maud Rise, Weddell Sea, Southern Ocean; Fig. 1). At least 500 radiolarian specimens were counted for each sample, and for all slides complete scans were conducted, in which several hundreds to thousands specimens were included. We calibrated the geological ages of these radiolarian datum levels using the paleomagnetic polarity data of Spieß (1990) and the revised version of Ramsay and Baldauf (1999) (Table 1). We use the name ‘Southern Ocean’ for the ocean that is presently to the south of the Subtropical Convergence, and subdivided into the Antarctic and Subantarctic subareas by the Antarctic Polar Front (Fig. 1).

2. Materials and methods

2.1. Materials

The Paleogene sequence at Site 689 is in total about 163 m thick and consists of the lower part of