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Pliocene–Pleistocene diatom biostratigraphy of nearshore Antarctica from the AND-1B drillcore, McMurdo Sound

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ABSTRACT

The near-shore open-marine diatom record recovered in the ANtarctic geological DRILLing (ANDRILL) McMurdo Ice Shelf Project (MIS) AND-1B drillcore, McMurdo Sound, Antarctica, advances our understanding of the marine conditions present in the southern Ross Sea during the Pliocene and early Pleistocene. This diatom history is recorded within alternating diamictite and diatomite that reflect alternating glacial activity and high marine primary productivity. The diatomite units were deposited in a continental shelf open-marine setting during periods of reduced ice cover in West Antarctica. A new diatom biostratigraphic scheme spanning the last ca. 5 Ma is proposed for the Antarctic near-shore area, based on prior work from high latitude drillcores. Four new zones are proposed for the Pliocene/Pleistocene, with eight in total for the new zonal scheme, utilizing *Actinocylus fasciculatus*, *Actinocyclus maccollumii*, *Fragilariopsis bohatyii*, *Rouxia antarctica*, and *Thalassiosira fasciculata* as new zonal markers. The early Pliocene shares the most assemblage commonality with that of the Southern Ocean with greater numbers of endemic species observed in the late Pliocene and early Pleistocene; a group of related *Fragilaripsis* species characterizes much of this later part of the time column. Two new species are proposed, *Fragilariopsis tigris* sp. nov. Riesselman and *Thalassiosira teres* sp. nov. Winter; a formal name is also proposed for another species, *Rhizosolenia harwoodii* sp. nov. Winter. The new zonation is tied to a robust chronology utilizing diatom biostratigraphy, volcanic $^{40}Ar/^{39}Ar$ ages and magnetostratigraphy.

1. Introduction

The ANDRILL McMurdo Ice Shelf Project drillcore AND-1B recovered 1284 m of sediment from beneath the McMurdo Sound Ice Shelf. Of this, the upper 585 m provides the most complete proximal sedimentary glacial–interglacial record for the high latitude Pliocene (4.9–2 Ma) from the Antarctic continental shelf (Naish et al., 2009). Initial field-based analysis recognized that the Southern Ocean (SO) biostratigraphic zonation was not fully applicable to the material recovered (Harwood and Maruyama, 1992; Zielinski and Gersonde, 2002; Scherer et al., 2007). This resulted from low abundance of some key marker species and truncated age ranges for other species. To establish a reliable biostratigraphic framework for the continental shelf, the Southern Ocean biostratigraphic zonation must then be modified. Here we present the biostratigraphy of the AND-1B drillcore employing a scheme using both established Southern Ocean zonal diatom datums as well as new marker species.

The Southern Ocean diatom biostratigraphic framework has been developed and refined through core recovery from multiple DSDP and ODP Legs. Deep Sea Drilling Project (DSDP) Leg 28 recovered the first drillcores from the Antarctic continental shelf in the Ross Sea, but with limited success (Hayes et al., 1975). This Leg was the starting point for many successive Antarctic drilling seasons. The Ocean Drilling Program (ODP) continued with Antarctic drilling, initially focusing on off-shore marine sites, including Legs 113, 114, 119, 120, 177, 178, 183 and 188 in the Southern Ocean and Legs 178 and 188 which recovered cores from the Antarctic continental shelf. Cores drilled on the continental shelf during ODP Leg 188 in Prydz Bay had slightly better recovery than those of Leg 178 (Leg 188 Site 1166–18.6% vs. Leg 178 Site 1100–15.95%, Site 1102–22.04%, Site 1103–12.3%, respectively), but none approached the 98% attained by both ANDRILL drilling seasons (Barker et al., 1999; O'Brien et al., 2001; Naish et al., 2007; Harwood et al., 2008–09) and prior Cape Roberts Project (CRP) drilling (Davey et al., 2000) in the western Ross Sea.

Biostratigraphic work from the deep ocean has resulted in different biostratigraphic schemes applied north and south of the Polar Frontal

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Zone (Zielinski and Gersonde, 2002), due to species ecological preferences and habitat differences. Furthermore, in the modern Southern Ocean it is evident that environmental differences exert a strong influence on diatom distribution; assemblages occupying the neritic sea-ice zone are very different from those observed in the open ocean (Kellogg and Truesdale, 1979; Cunningham and Leventer, 1998; Armand et al., 2005; Crosta et al., 2005). The rapidly changing depositional environment reflected in the alternating diatomite/diamictite sequences preserves different assemblages of diatom species than are observed in the Southern Ocean during the mid-Pliocene through early Pleistocene. The environmental control on diatom distribution suggests the need for separate (or modified) biostratigraphic schemes for the continental shelf versus open ocean. Magnetostratigraphy from the AND-1B drillcore suggests good correlation with known age ranges for some species present in the Southern Ocean (Wilson et al., 2007).

At sites closer to the continent, a series of drillcores recovered with land and sea-ice drilling rigs along the southern Victoria Land margin in the McMurdo Sound contain a very proximal record for the Cenozoic of the western Ross Sea. These include cores recovered during the Dry Valley Drilling Project (DVDP) (Powell, 1981), McMurdo Sound Sediment and Tectonic Studies (MSSTS) (Barrett, 1986), Cenozoic Investigations in the western Ross Sea (CIROS)-1 and -2 (Barrett, 1989; Barrett and Hambrey, 1992) and the Cape Roberts Project (CRP)-1, -2 and -3 (Cape Roberts Science Team, 1998, 1999, 2000). Previously recovered sediments of correlative age from this area have generally been thin intervals of diatom-rich muds averaging 7 m in thickness, quite different from the diatomite in AND-1B. The new biostratigraphy of this record will help improve age constraints for these previous cores.

Prior to the recovery of the AND-1B drillcore, development and application of Antarctic diatom biostratigraphy from coastal and continental-shelf deposits was restricted to these punctuated and brief records exposed on land and recovered in near shore drill cores. The strata recovered in ANDRILL's inaugural season preserve an unprecedented record of diatom populations and evolution on the continental shelf, upon which a biostratigraphic scheme for coastal Antarctic regions can be based. An excellent record of Late Neogene diatoms is present in the upper 585 m of the AND-1B drillcore, often in sufficient abundance to qualify as diatomite (Scherer et al., 2007). The diatomaceous and diatomite units are interbedded within a cyclical sedimentary sequence of diamictite, mudstone, sandstone and volcaniclastic sediments (Krissek et al., 2007). Many glacial surfaces of erosion are present within these sequences, commonly at the base of and within diamictite units. AND-1B contains more than 13 intervals of diatomaceous mud and diatomite representing open-marine deposition in the southern Victoria Land Basin. These diatom-bearing units vary in thickness from less than 1 m in the youngest Pleistocene interval to >60 m of continuous lower to mid-Pliocene diatomite, averaging 20 m in thickness.

2. Regional setting

The ANDRILL McMurdo Ice Shelf AND-1B drill site is located in southern McMurdo Sound at 77.89°S, 167.09°E, in ~850 m water depth, in the southern end of Victoria Land Basin and on its eastern flank (Fig. 1). The core was drilled from the McMurdo Ice Shelf to the southeast of McMurdo Station/Scott Base on Ross Island and to the north–northwest of White Island. The targeted sediments accumulated in a basin surrounding Ross Island, thought to result from crustal loading and flexure associated with the growth of Mt. Erebus and the other Ross Island volcanoes (Horgan et al., 2005).

Diatomaceous sediments of this age exist in other areas around the Antarctic continent, some preserved in ice-free areas on land and some in other drillcore material. Several other cores exist in the same region as AND-1B, Dry Valley Drilling Project cores DVDP-10 and DVDP-11 both drilled in 1974 at the mouth of Taylor Valley and Cenozoic Investigations in the Western Ross Sea drillcore CIROS-2 drilled in 1984 from Ferrar Fjord (McGinnis, 1981; Barrett, 1985). These cores combined contain the near-shore section of the climatic history recorded in AND-1B. Their sediments are, at best, diatom-rich mud units but they document the same interglacial intervals represented in the AND-1B diatomite units (Winter and Harwood, 1997; Winter et al., this volume).

On the other side of the continent, subaerially exposed marine sediments of the Sørsdal Formation in the Vestfold Hills region of East Antarctica represent the time interval equivalent to Diatom Unit 11b (DU-11b) (Whitehead et al., 2001; Scherer et al., 2007). A younger set of strata in the Bardin Bluffs Formation in the Amery Oasis of the northern Prince Charles Mountains record ice-distal and ice-free sedimentation in the late Pliocene and early Pleistocene (Whitehead

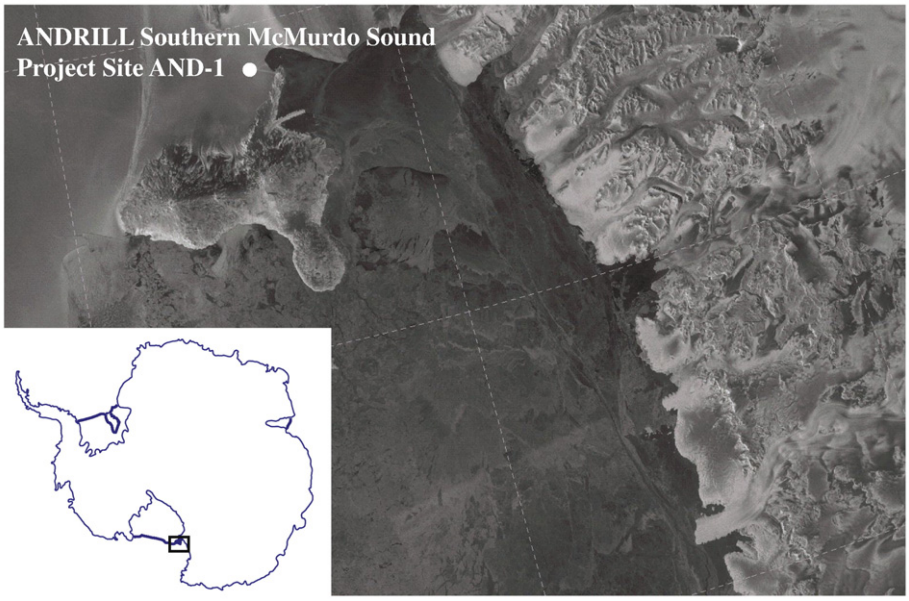

Fig. 1. Map of the southern Ross Sea and McMurdo Sound region. The circle indicates the location of the ANDRILL MIS AND-1B drillsite (locate in or near Regional Setting).