The diatom record of the ANDRILL – McMurdo Ice Shelf project drillcore

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Summary The inaugural drilling season of ANDRILL, recovered a 1,285 m core, AND-1B, with ~99% recovery. The core contains a superb record of Antarctic continental shelf sediments, providing an unparalleled record of climate change through a critical interval in Earth history. The upper c. 600m of core, reflecting Pliocene and early Pleistocene deposition, is composed of alternating glacial diamictites and diatomites, with episodic volcanic facies. The diatomites document extended periods of open marine conditions with reduced ice, in an area currently covered by a thick ice shelf. The diatomites reflect high biosiliceous productivity, and most reflect warmer than present conditions with variable sea ice and ice rafting. Many likely represent an absence of a large ice shelf, whereas diamictites reflect glacial advances. Analysis of the diatom assemblages will result in a new biostratigraphic zonation for the Antarctic continental shelf and high resolution paleoenvironmental reconstructions.

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Introduction

The Pliocene and pre-late Pleistocene history of the Ross Sea and the Antarctic ice sheet has been much discussed and debated in numerous high profile scientific publications (e.g., Webb et al., 1984; Webb and Harwood, 1991; Sugden et al., 1993; Hall et al., 1997; Wilson, 1995; Francis et al., 2007). Most of these interpretations are based on sparse and highly incomplete records, often with controversial chronologies. The marine stratigraphic record of the Antarctic continental shelf is highly incomplete and truncated due to late Pleistocene glacial advances. These stratigraphic limitations have severely limited opportunities to establish a compelling record of ice sheet history during these key time intervals.

The ANDRILL – McMurdo Ice Shelf Project Core AND-1B was drilled south of Ross Island, through 85 m of the Ross Ice Shelf and 840 m of water, with the aim of recovering core from the crustal moat created by subsidence of Ross Island. This paper is a summary of the initial characterization of the diatom assemblages and diatom-based biostratigraphy and paleoenvironmental interpretation, based on the ANDRILL-MIS Initial Report (Scherer et al., in press). Detailed paleoenvironmental and biostratigraphic research, including the development of a new diatom biozonation for the Pliocene through early Pleistocene, will be published following additional research.

Site surveys suggested that ponding of sediments and minimal ice sheet grounding in this moat may have permitted the preservation of a Pliocene and Pleistocene stratigraphy. The highly successful drilling bore out the scientific prospectus, resulting in continuous recovery of thick successions of upper Miocene, Pliocene and lower Pleistocene sediments, including thick sequences of Pliocene diatomaceous marine sediments and cycles of glacial advance and retreat. Thirteen diatomaceous units (DUs), most of them nearly pure diatomite, have been defined in the upper c. 600m of sediment (Fig. 1). The defined units range in thickness from 75 cm (DU-I) to nearly 96 m of continuous diatomite (DU-XI). Diatomaceous sediments constitute 48.4% of the upper 600 m of recovered core (53.0%, excluding volcanic facies). Diatomaceous units include both diatomite and diatomaceous muds, but diatomites, containing nearly pure biogenic silica with little terrigenous material, dominate.

Most diatomaceous facies are true diatomites, containing a very strong dominance of diatoms and a paucity of terrigenous input, indicative of very high primary productivity with variable sea ice. The diatomites are lithified and variably bioturbated or laminated (Fig. 2). The lower c. 700 m of core contain few diatoms. Diatoms tend to be highly fragmented in the diatomites, with breakage patterns consistent with compaction (Scherer et al., 2004), though at least some of the fragmentation may be primary; a result of grazing in the water column by zooplankton (Gersonde and Wefer, 1987). Unlike the marine diamictites common in Ross Sea piston cores (Sjunneskog et al., 2005), most AND-1B diamictites contain very few diatoms.

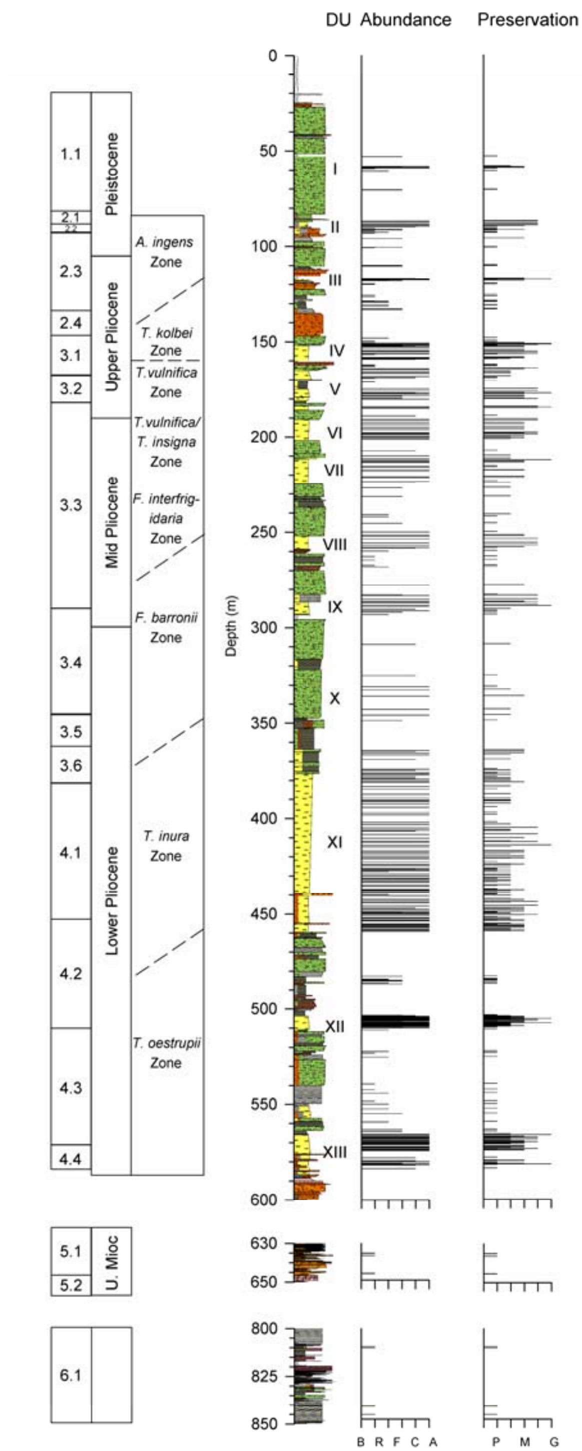

Figure 1. Lithostratigraphic units, age, correlation to the existing Southern Ocean diatom zonation, downcore depth in m, lithologic log, diatom units (DU), diatom abundance (Barren, Rare, Few, Common, Abundant) and diatom preservation (Poor, Moderate, Good) for the upper 600 m, plus some Miocene diatom occurrences in AND-1B. Yellow is diatomite, green, diamictite, grey, mudstone, and orange, volcanics.

Lower Pleistocene and Pliocene diatomaceous units

Diatomites contain a variable concentration of diatoms that are interpreted as characteristic of cold water with significant summer sea-ice, whereas other units contain little evidence of sea-ice, and are interpreted as reflecting warmer than present sea surface temperatures. The concentrations of ice-rafted detritus (IRD) varies significantly among the diatomaceous packages (Fig. 2).

Initial core characterization and biostratigraphic interpretation revealed eleven Pliocene and two Pleistocene diatomaceous units in AND-1B, which does not include the upper 23 m of the sediment column (Fig. 1). This extraordinary record of diatomaceous sedimentation beneath the current northern margin of the Ross Ice Shelf records a history of dynamic fluctuations in the Ross Ice Shelf and West and East Antarctic ice sheets. Detailed interpretation of this record will require extensive investigation and interpretation based on a diverse dataset, including quantitative diatom assemblage evaluation.

As with earlier Antarctic continental shelf drilling, which recovered Oligocene and lower Miocene strata (Olney et al., 2007), direct application of the standard Southern Ocean biostratigraphic zonation for the Pliocene and lower Pleistocene is limited in AND-1B, due to ecologic exclusion and diachrony of many of the open ocean biostratigraphic markers. Consequently a new diatom zonation for the Antarctic continental shelf is under development. The new zonation will be applicable to the circum-antarctic nearshore zone and land-based sections indicative of higher than present sea-level (e.g., Harwood et al., 2000), and will greatly improve biostratigraphic interpretation of discontinuous or displaced diatomaceous deposits. Certain intervals, most notably the lower Pleistocene DU-II and the thick lower Pliocene unit (DU-XI) contain diatom assemblages that suggest a considerable influence of pelagic waters, with little summer sea ice, as suggested by the abundance of "subpolar" taxa such as *Thalassionema nitzschiodes*. The diatom assemblage of lower Pleistocene DU-II closely resembles that of the lower Pleistocene carbonate unit recovered as part of the Cape Roberts Project (Bohaty et al., 1999). Lower Pliocene diatom units (XII and XIII) include typical sea ice taxa that are nearly absent in the thick overlying diatomite unit.

The diatom assemblages of AND-1B include many well-documented species, but also include numerous taxa that require further taxonomic investigation. The upper Pliocene is characterized by an abundant and diverse assemblage characteristic of relatively cold waters, dominated by *Fragilariopsis* spp. Figure 3 illustrates the diversity and variability of *Fragilariopsis* spp. Many of these taxa are easily assigned to known species, but many will require careful taxonomic investigation. Similar problems exist among *Rouxia* spp., (Fig. 4) which are occasionally abundant though not as diverse as *Fragilariopsis*.

Miocene mudstones: Diamictites and altered diatomites

The lower c. 700 m of core is dominated by mudstones and diamictite. Diatoms are largely absent, though very rare examples of poorly preserved diatoms do occur in certain mudstone units (Fig. 5). Some of the mudstones may reflect subglacial or sub-ice shelf sediments, but many are interpreted as diagenetically altered diatomites, based on the occurrence of open ocean foraminifera and rare and poorly preserved diatoms, including siliceous casts of large Coscinodiscids down to nearly 1,200 mbsf. Some diatoms are tentatively identified as characteristic Miocene forms, though few can be identified unequivocally. Poor preservation of biosilica is expected given that the opaline skeletons rarely preserve following burial beneath more than 500 – 600 m of sediment, or heating to > 35°C.

Conclusions

The rich diatom record of the AND-1B core will provide detailed information for reconstructing Pliocene and early Pleistocene climate change and ice sheet history, and provide new diatom biostratigraphic control for the Antarctic continental shelf. Detailed analyses by the on-ice and off-ice science team are underway.

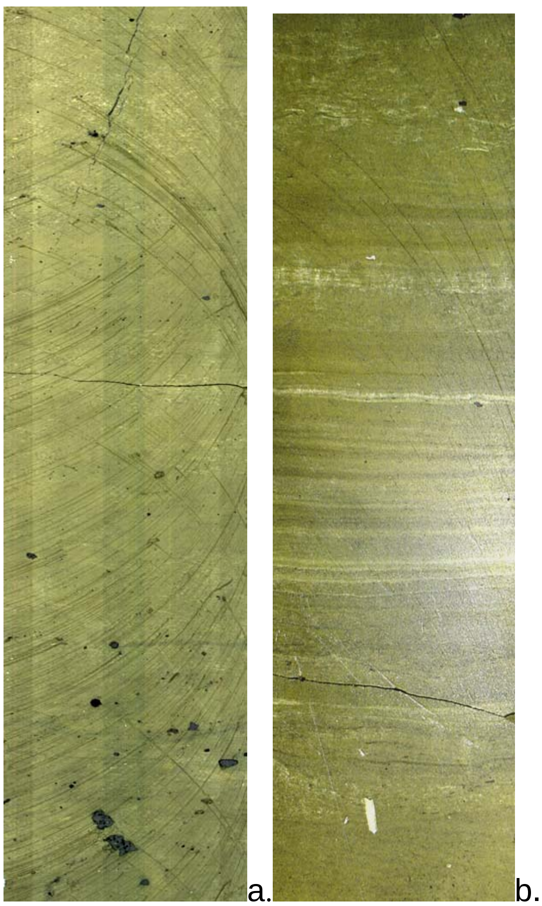

Figure 2. Core photographs. (a) Part of lower Pleistocene DU-II, c. 87mbsf. Note bioturbation and decreasing IRD content through the 20 cm core section. (b) Section of the very thick Upper Pliocene DU-XI, c. 426 mbsf. Note fine, primary laminations and scarcity of IRD. Laminations are nearly pure diatoms, but few are true monospecific layers. The curved marks on the surface of the images are an artifact of core cutting.

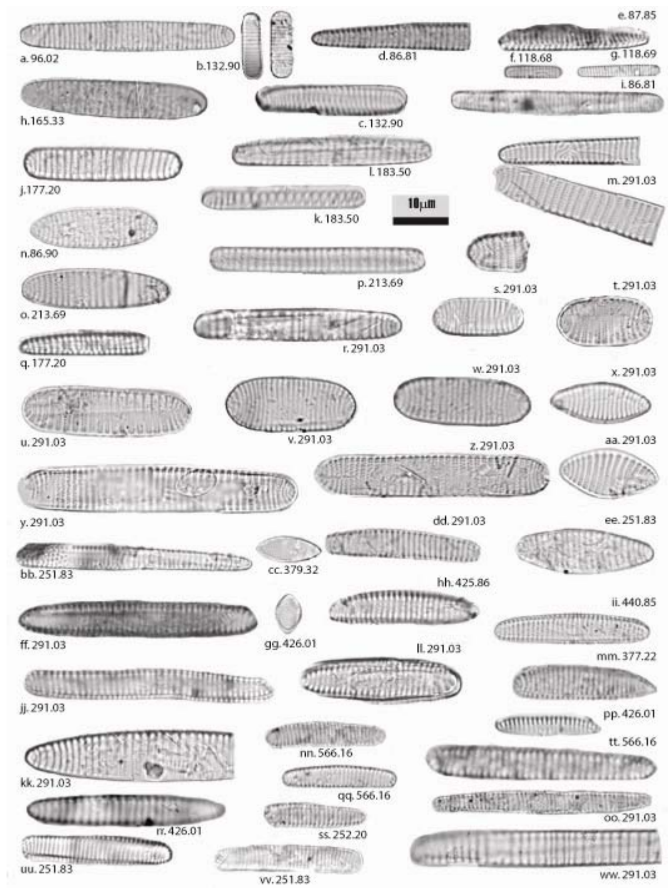

Figure 3. Diverse *Fragilariopsis* spp. in AND-1B, upper 600m. Analysis of this species complex will allow documentation of morphologic diversity and evolution. Labels represent sample depth (mbsf). Scale bar is 10 µm

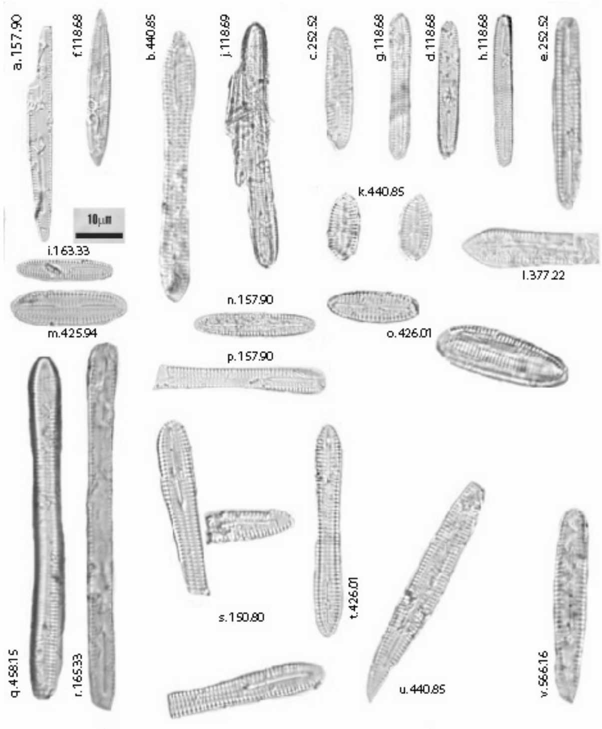

Figure 4. Morphologic variation among *Rouxia* spp. in AND-1B, upper 600m. Labels represent sample depth (mbsf). Scale bar is 10 µm.

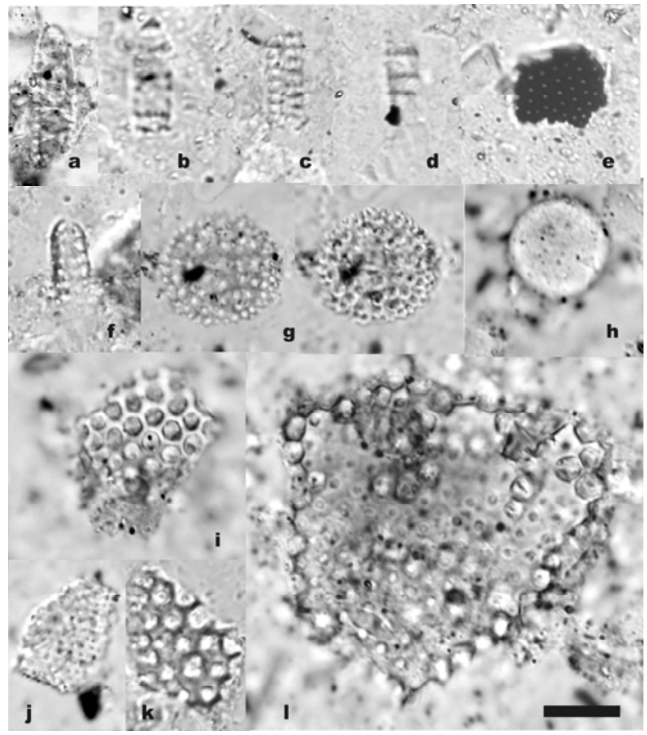

Figure 5. Recrystallized diatoms from altered diatomites of the lower 700 m in the core. These represent the best examples found. Diagenesis includes alteration to opal-CT and replacement as casts by pyrite or redeposited silica.

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