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Deglacial ocean and climate seasonality in laminated diatom sediments, Mac.Robertson Shelf, Antarctica

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Abstract

The palaeoceanography and climate history of the East Antarctic Margin (EAM) are less well understood than those of West Antarctica. Yet, the EAM plays an important role in deep ocean circulation and the global ocean system and has likely done so in the past. Deglacial-age marine sediments from the EAM provide clues about its past role during this critical period of rapid climate change. Several deep basins across the EAM such as Iceberg Alley (~67°S, 63°E) on the Mac.Robertson Shelf (MRS) accommodate thick marine sequences that archive the deglaciation in the form of diatom-rich, continuously laminated (varved) sediments. These laminated sediments are pristinely preserved and contain seasonal and long-term information on the cryospheric and palaeoceanographic changes associated with the rapid retreat of the glacial ice sheet across the MRS. We present results of microfabric analysis of the lower ~2 m of deglacial varves from jumbo piston core JPC43B (Iceberg Alley). Backscattered electron imagery (BSEI) of polished thin sections and scanning electron microscope secondary electron imagery (SEI) of lamina-parallel fracture surfaces are used to analyze the varves. One hundred and ninety-two laminations are investigated and their nature and temporal significance are discussed in terms of seasonal deposition and cyclicity of diatom species. Our high-resolution palaeodata record exceptionally high diatom production and silica flux associated with the retreat of the East Antarctic Ice Sheet, and seasonal sea-ice changes along the EAM. This information is invaluable for assessing cryospheric-oceanographic variation and, therefore, the local and regional response to this period of rapid climate change. Varves are made up of lamina couplets comprising (i) thickly laminated to thinly bedded orange/orange-brown very pure diatom ooze dominated by *Hyalochaete Chaetoceros* spp. vegetative cells and resting spores, and (ii) brown/blue-grey terrigenous angular quartz sand, silt and clay with an abundant mixed diatom flora. The colour variation between these two types of lamination is striking. Using floristic and textural information we interpret the diatom oozes as spring flux and the terrigenous laminae as summer flux. Each couplet pair represents one annual cycle and reflects seasonal changes in nutrient availability and

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stratification associated with the cyclical advance and retreat of seasonal sea-ice. The diatom oozes can reach up to ~7.5 cm in thickness indicating enormous silica flux to the sea floor associated with ice sheet retreat.

Keywords: Deglaciation; Diatoms; East Antarctic Margin; Marine varves; Sea-ice; Seasonality

1. Introduction

Ice-cores and ocean sediments archiving the last deglaciation provide intriguing insights into the timing and nature of this rapid climate transition from the last glacial to the present interglacial (e.g., Duplessy et al., 1981, 1986; Mix and Ruddiman, 1985; Blunier et al., 1998; Petit et al., 1999; Bennett et al., 2000; Jouzel et al., 2001; Morgan et al., 2002; Shemesh et al., 2002). A clear understanding of the natural processes and responses involved in the step-wise, rapid switch from one climate state to the other is of prime interest (e.g., Broecker and Denton, 1989; Renssen et al., 2001). Although there is still some debate, it is apparent that the Southern Ocean (and, therefore, Antarctica) may have been influential in the Northern Hemisphere deglacial climate system (e.g., Broecker, 1998). For example, 3-dimensional ocean circulation models indicate that mass transport of relatively warm Southern Ocean waters into the Atlantic during the last two deglacial periods may have abruptly 'kick started' the Atlantic thermohaline circulation out of a weak glacial mode and into a strong interglacial mode (Knorr and Lohmann, 2003). However, reliable field data necessary for addressing these past interhemispheric phase relationships and teleconnections are only really available from well-dated high-resolution archives. Extraordinarily rich archives of climate and palaeoceanographic change with seasonal resolution exist in deep inner shelf basins in the circum-Antarctic (e.g., Leventer et al., 2001, 2003; Domack et al., 2003).

The East Antarctic Margin (EAM) has received less attention in palaeoceanographic studies than West Antarctica, yet its role in deep ocean circulation and the global ocean–climate system is significant. For instance, a significant volume of shelf-derived Antarctic Bottom Water (definition by Orsi et al., 1999) originates along the Wilkes-Adélie coast (140–150°E) (Orsi et al., 1999; Rintoul and Bullister, 1999). In February–March 2001, cruise NBP01-01 of the RVIB *Nathaniel B. Palmer* cored the EAM from the George V and Terre Adélie coasts to the Edward VIII Gulf (inset Fig. 1) recovering thick deglacial to Holocene seasonally laminated (varved) diatom-rich sediments from several deep inner shelf basins (Domack et al., 2003; Leventer et al., 2001, 2003). Superficially, these sediments appear similar in lamination style and composition to those described from West Antarctica (e.g., Pike et al., 2001; Leventer et al., 2002; Maddison et al., in press) and, therefore, have the potential to provide seasonal-scale deglacial climatic information for the EAM. All NBP01-01 core sites recovering varved diatom-rich sediments (inset Fig. 1) share: (1) a similar geomorphological setting, that of a deep basin on the shelf, and (2) a similar lithostratigraphy, that of a glacial diamict overlain abruptly by the deglacial varved diatom-rich sediments (e.g., Leventer et al., 2003). The varved sediments grade into homogeneous, intermittently laminated, diatomaceous clays and muds of Holocene-age. The geochemistry and diatom content of the Holocene records have been previously described (Sedwick et al., 2001, 1998; Taylor and McMinn, 2001 and references therein) from short cores (~2–4 m length) collected during several earlier expeditions (Sedwick et al., 1998, 2001). The thickness of the deglacial varved sediments recovered during NBP01-01 is related to basin geometry and surrounding water depth. Diatoms are the main biogenic constituent of the varved sediments and are useful indicators of palaeoceanographic change, particularly in the Antarctic region where biogenic carbonate is relatively scarce, and opal flux is high. In typical open ocean settings of the Southern Ocean, rapid opal dissolution and grazing pressures mean that diatom thanatocoenosis on the sea-floor barely resembles the biocoenosis in the overlying surface waters. However, in localised regions where diatom productivity is exceptionally high and sedi-