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Iron oxide tracers of ice sheet extent and sediment provenance in the ANDRILL AND-1B drill core, Ross Sea, Antarctica

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ABSTRACT

The AND-1B drill core recovered a 13.57 million year Miocene through Pleistocene record from beneath the McMurdo Ice Shelf in Antarctica (77.9°S, 167.1°E). Varying sedimentary facies in the 1285 m core indicate glacial–interglacial cyclicity with the proximity of ice at the site ranging from grounding of ice in 917 m of water to ice free marine conditions. Broader interpretation of climatic conditions of the wider Ross Sea Embayment is deduced from provenance studies. Here we present an analysis of the iron oxide assemblages in the AND-1B core and interpret their variability with respect to wider paleoclimatic conditions. The core is naturally divided into an upper and lower succession by an expanded 170 m thick volcanic interval between 590 and 760 m. Above 590 m the Plio-Pleistocene glacial cycles are diatom rich and below 760 m late Miocene glacial cycles are terrigenous. Electron microscopy and rock magnetic parameters confirm the subdivision with biogenic silica diluting the terrigenous input (fine pseudo-single domain and stable single domain titanomagnetite from the McMurdo Volcanic Group with a variety of textures and compositions) above 590 m. Below 760 m, the Miocene section consists of coarse-grained ilmenite and multidomain magnetite derived from Transantarctic Mountain lithologies. This may reflect ice flow patterns and the absence of McMurdo Volcanic Group volcanic centers or indicate that volcanic centers had not yet grown to a significant size. The combined rock magnetic and electron microscopy signatures of magnetic minerals serve as provenance tracers in both ice proximal and distal sedimentary units, aiding in the study of ice sheet extent and dynamics, and the identification of ice rafted debris sources and dispersal patterns in the Ross Sea sector of Antarctica.

1. Introduction

The Antarctic Drilling (ANDRILL) Program is a multinational collaborative effort between Germany, Italy, New Zealand, and the United States, which has thus far conducted two field seasons in the western Ross Sea (Naish et al., 2009; Fielding et al., 2011). ANDRILL is the most recent in a series of collaborative international drilling programs whose goals include recovery of ice proximal records in order to study the dynamics of the Antarctic Ice Sheet (AIS), its fringing ice shelves and outlet glaciers at tectonic to modern timescales, including the earliest formation and subsequent evolution of the AIS, its volume and areal extent, causes and effects of ice sheet and shelf collapse, behavior of the AIS during past episodes of global warmth, and the feedbacks between the Antarctic cryosphere and the global climate system. This information will aid in predicting how the Antarctic cryosphere may respond to future climate change, particularly with regard to the rate and amplitude of sea level rise. Determining this information from distal sites alone is challenging where the Antarctic signal is convolved with local environmental and tectonic processes, and for which the AIS is manifested as a single entity rather than as discrete signals of West Antarctic Ice Sheet (WAIS), East Antarctic Ice Sheet (EAIS), and Antarctic Peninsula Ice Cap (APIC) evolution.

Our study focuses on results from the AND-1B succession, which was recovered during the austral summer of 2006–07 at the McMurdo Ice Shelf site at 77.9°S, 167.1°W (Fig. 1). The McMurdo Ice Shelf is a portion of the Ross Ice Shelf that occupies McMurdo Sound between Ross Island,

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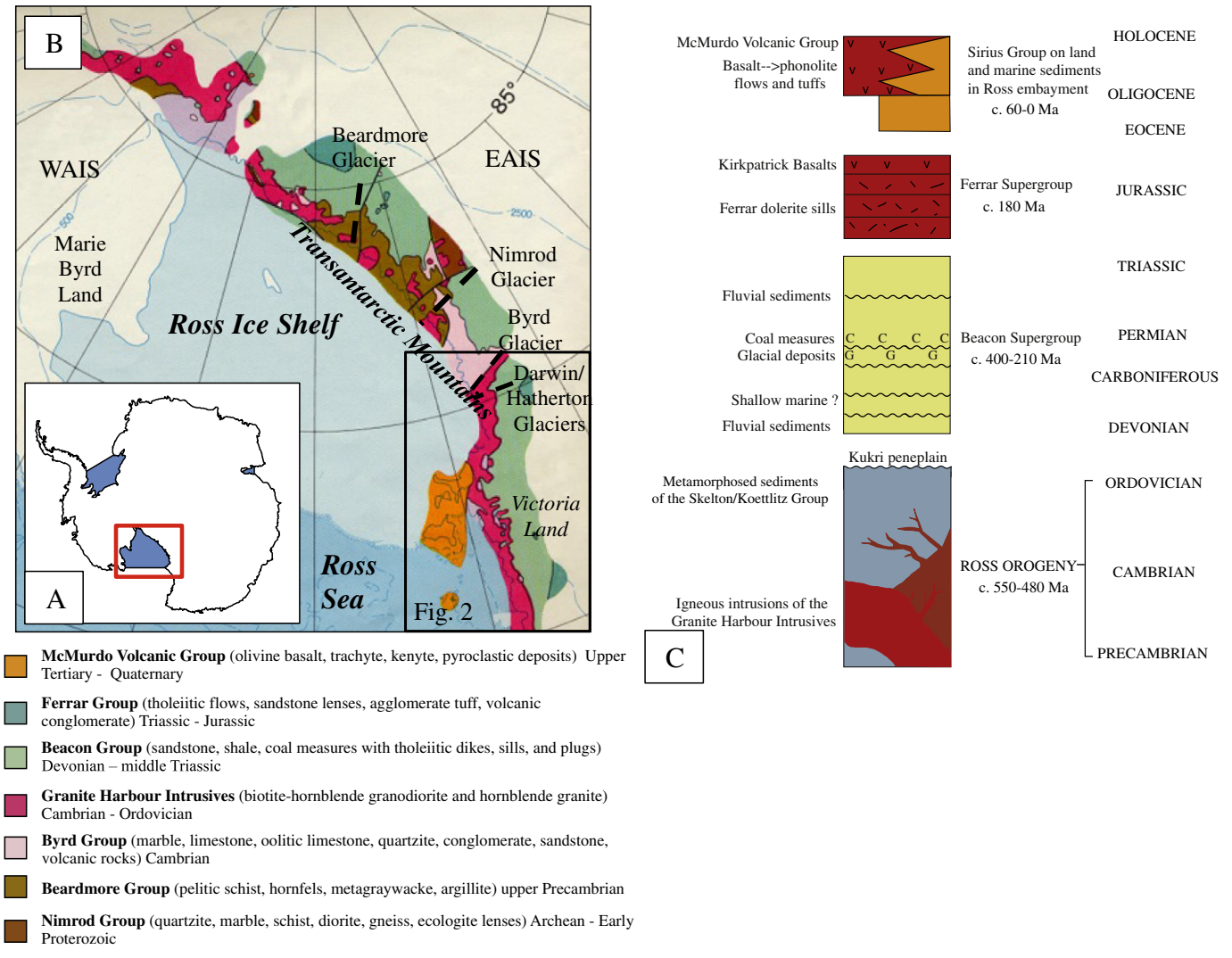

Fig. 1. A. (Inset) Location map showing the Ross Sea Embayment, Antarctica. (B) Geology of the western Ross Sea (after Licht et al., 2005). (C) Lithostratigraphic column summarizing the geologic history of the western Ross Sea.

White Island, and Black Island (Fig. 1). The AND-1B core comprises a 1285-m thick sedimentary section that was deposited in a flexural moat surrounding Ross Island, and has been dated back to 13.57 Ma (Wilson et al., 2012).

Here we examine the rock magnetic properties, iron oxide (hereafter Fe-oxide) textures and composition from the AND-1B drill core (with a focus on diamictites) and from the lithologic rock units that supply sediment to the western Ross Sea. Diamictites are deposited in sub-ice or ice-proximal environments and record the properties of the bedrock over which the ice flowed en route to the ice sheet terminus. Relative to mudstone and diatomite units in the AND-1B core, the diamictites should be free of the effects of sediment redistribution by ocean currents. We assess the Fe-oxide assemblages of diamictites to determine if they possess distinctive morphologies, compositions, and rock magnetic properties that can be used to trace sediment provenance, which would enable a means of identifying changes in ice sheet behavior such as a shift in the location or direction of ice flow through key Transantarctic Mountain (TAM) glaciers. To do this, we characterize the Fe-oxide assemblages and magnetic properties of the McMurdo Volcanic Group (MVG) and TAM lithologies to gain a better understanding of the starting mineral assemblage supplied to the Ross Sea, and compare these with Fe-oxide assemblage properties of the AND-1B diamictites.

2. Study area

The Ross Embayment sits at the boundary between East Antarctica and West Antarctica. The TAM form the western and southern boundaries of the embayment and Marie Byrd Land comprises the eastern boundary (Fig. 1). The embayment is occupied by the Ross Ice Shelf, which is fed by ice streams draining the WAIS and by outlet glaciers from the EAIS emerging from the TAM. A major goal of the ANDRILL Program is to evaluate the dynamics of the WAIS and EAIS through time. One method to monitor each ice sheet's past contribution to the Ross Ice Shelf is to trace the sediment that each ice sheet supplied to the Ross Embayment, a technique referred to as provenance tracing.

3. Provenance tracing and regional geology

The terrigenous material deposited at the AND-1B site is the product of glacial marine sedimentation processes, primarily the emplacement of diamict below grounded ice or immediately seaward of the grounding line, turbidity currents and release of debris-laden meltwater plumes seaward of the grounding line, basal melting in the sub-ice shelf cavity, and deposition of ice rafted debris (IRD) from calving and melting icebergs during open marine conditions. Clast lithology and