Integrated provenance characteristics of glacial-marine sediment from East and West Antarctica

S.A. Brachfeld,[1] S.R. Hemming,[2] T. van de Flierdt,[2] S.L. Goldstein,[2] M. Roy,[3] T. Williams,[2] and M. Rosig[1]

[1]Department of Earth and Environmental Studies, Montclair State University, Montclair, NJ 07043 USA (brachfelds@mail.montclair.edu)
[2]Department of Earth and Environmental Sciences and Lamont Doherty Earth Observatory of Columbia University, Rt. 9W, Palisades, NY 10964 USA (sidney@ldeo.columbia.edu) (steveg@ldeo.columbia.edu) (tina@ldeo.columbia.edu) (Trevor@ldeo.columbia.edu)
[3]Dép. des Sciences de la Terre et de l'Atmosphère, Université du Québec à Montréal, Montréal, Canada, QC H3C 3P8 (roy.martin@uqam.ca)

Summary This project investigates the sediment supplied to the Southern Ocean by the East Antarctic Ice Sheet (EAIS) and the West Antarctic Ice Sheet (WAIS), with the goal of fingerprinting the bedrock geology underlying the ice. Glacial-marine diamict and sandy mud recovered from inner-shelf basins and fjords were examined for lithic clast composition, bulk geochemistry of the < 63-micron fraction, $^{40}Ar/^{39}Ar$ ages of individual hornblende grains, and radioisotope signatures. Samples from the George V Coast have several distinctive characteristics, including abundant metamorphic lithic clasts, and high concentrations of Mn and Cr relative to Prydz Bay and Mac.Robertson Land, located further to the west. Mac.Robertson Land also displays high metamorphic content and high garnet content relative to Ross Sea tills (Licht et al., 2005). Samples from West Antarctica contain abundant felsic igneous clasts, sedimentary clasts, and monomineralic quartz and potassium feldspar. Al/Ti ratios and Fe/Ti ratios from East Antarctica range from 12-21 and 6-16, respectively. We speculate that the George V samples are iron rich due to the presence of ironstone in the source region. The George V Coast samples are Ti-poor and Al-poor relative to Prydz Bay, Svenner Channel, and Mac.Robertson Land. West Antarctic samples have lower Al/Ti ratios (7-17), and fairly constant Fe/Ti ratios between 7-10. The East Antarctic margin samples have strongly negative e_{Nd} values and old $^{40}Ar/^{39}Ar$ ages relative to West Antarctica. These characteristics may provide a means of tracing offshore sediment that was supplied to the Southern Ocean by the East Antarctic Ice Sheet.

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Introduction

A comprehensive suite of sediment provenance tracers is under construction for the purpose of evaluating Antarctic sediment transport processes and pathways, including tracking iceberg sources and drift patterns, and bottom current intensity. A means of tracing ice rafted debris deposited offshore back to its most probable source will aid in the monitoring the advance and retreat of each piece of the Antarctic Ice Sheet (Kanfoush et al., 2002; Licht et al., 2005). Identifying the provenance of fine-grained deep-sea sediment will aid in reconstructing trends in ocean circulation (Lattimer et al., 2006). This project reports on the construction of source area fingerprints using a combination of lithic clast composition, bulk sediment geochemistry, $^{40}Ar/^{39}Ar$ Ages of hornblende grains, and radiogenic isotope signatures.

Samples and methods

Ice proximal samples from the Antarctic Margin were collected from piston cores and jumbo piston cores recovered in fjords, bays, and inner shelf basins by past and recent United States Antarctic Program cruises. We targeted glacial diamict where possible, or sandy mud otherwise (Figure 1). Diamict represents sampling and homogenization over large areas, avoiding possible biasing in limited and heterogeneous outcrops, while also avoiding the competing influences of sediment redistribution by ocean currents.

Samples were sieved at 63, 500, and 2000 μm. The 500-2000 μm fraction was embedded in epoxy and thin sections were made for lithic clast identification via point counting, following the methods of Licht et al., 2005. The < 63 μm fraction was processed for bulk sediment geochemistry via Inductively-coupled Optical Emission Spectrometry (ICP-OES) analysis, using a lithium metaborate fusion flux, and for radiogenic isotopes via ICP-MS analysis. Results of $^{40}Ar/^{39}Ar$ analyses of individual hornblende grains and laser ablation U-Pb analysis of individual zircon grains are reported in Hemming et al., 2007 (this volume).

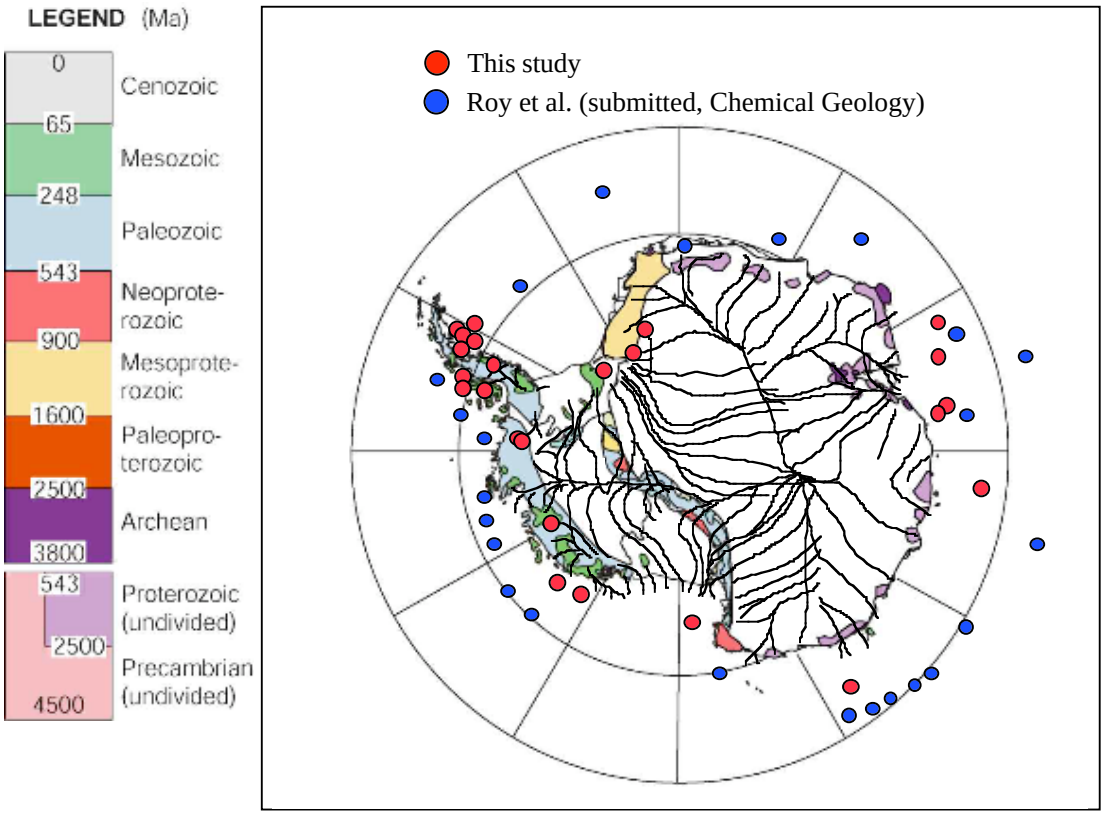

Figure 1. Locations of samples used in this study (red circles) and Roy et al., (blue circles). Geology basemap after Roy et al. (2007, submitted); Kirkham and Chorlton (1995); Dalziel (1992). Flow lines after Anderson et al. (2002).

Results

Samples from the George V Coast contain abundant metamorphic clasts (59% of the assemblage), including biotite hornfels, schist, meta-sedimentary rocks (slate and phyllite), marble, quartzite, and coarse-grained garnet-quartz-pyroxene-bearing grains that we tentatively classify as granulite. These observations are consistent with the bedrock geology information obtained from limited outcrops along the Wilkes Land Margin (see Fitzsimons, in press, and references therein). Prydz Bay and Mac.Robertson Land contain more igneous intrusive clasts and fewer metamorphic clasts, although garnets were commonly observed in the Mac.Robertson Land samples. A petrographic study of Ross Sea tills and till samples from Trans-Antarctic Mountain (TAM) outlet glaciers indicated that metamorphic clasts generally comprise < 12% of the TAM samples and < 5% of the Ross Sea tills (Licht et al., 2005). Samples from West Antarctica and the Antarctic Peninsula contain abundant igneous clasts, primarily felsic in composition, and sedimentary clasts. Monomineralic quartz and potassium feldspar grains are also common. These observations suggest that metamorphic clasts and garnet may be useful provenance indicators for ice-rafted debris derived from East Antarctica.

Major and trace element concentrations of the < 63-μm fraction were measured via ICP-OES. No chemical pretreatments were applied to the sediment prior to processing with a lithium metaborate flux. Raw intensities were calibrated to concentrations using 12 USGS rock standards. Al/Ti ratios and Fe/Ti ratios from East Antarctic samples range from 12-21 and 6-16, respectively. The George V Coast samples are Ti-poor and Al-poor relative to Prydz Bay, Svenner Channel, and Mac.Robertson Land. The George V Coast is also distinguished by higher Mn and Cr concentrations, and lower V concentrations that Svenner Channel and Mac.Robertson Land. Samples from West Antarctica have lower Al/Ti ratios of 7-17, and fairly constant Fe/Ti ratios between 7-10.

The nearshore ε_{Nd} values from the Prydz Bay and Mac.Robertson sectors are consistent with the offshore results reported by Roy et al., (Chemical Geology, submitted), although there is some variability in the 3 diamict units from NBP01-01 JCP34. However, the George V Coast samples (143 E longitude) are significantly lower than their

offshore counterparts, yielding ε_{Nd} values of -23.6 to -23.8, the lowest values yet found in our survey, and suggestive of ancient ages for the Wilkes Land craton.

Summary

A combination of provenance tracers has been applied to nearshore glacial-marine diamict samples from East Antarctica and West Antarctica. The George V Coast has several distinctive characteristics, including abundant metamorphic lithic clasts, old $^{40}Ar/^{39}Ar$ ages and high concentrations of Mn and Cr relative to Prydz Bay and Mac.Robertson Land. Mac.Robertson Land also displays high metamorphic content and high garnet content relative to Ross Sea tills (Licht et al., 2005) and relative to samples from West Antarctica. West Antarctic samples contain abundant felsic igneous clasts, sedimentary clasts, and monomineralic quartz and potassium feldspar. The East Antarctic margin samples have strongly negative ε_{Nd} values and old $^{40}Ar/^{39}Ar$ ages relative to West Antarctica. These characteristics may provide a means of identifying ice rafted debris and fine-grained sediment that was supplied to the Southern Ocean by the East Antarctic Ice Sheet and the West Antarctic Ice Sheet.

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