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A physical record of the Antarctic Circumpolar Current: Late Miocene to recent slowing of abyssal circulation

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ABSTRACT

Sediments recovered from a drift deposit lying along the Pacific margin of the Antarctic Peninsula, (ODP Leg 178, Site 1095) provide a physical record of the Antarctic Circumpolar Current since late Miocene time. Determination of the strength of the magnetic fabric, anisotropy of magnetic susceptibility, provides a proxy for current strength. Fabric strength declines throughout the record from high values in the late Miocene; a pronounced step occurs between 5.0 and 5.5 Ma, and values decrease more gradually since about 3.0 Ma. The mass accumulation rate of terrigenous sediment derived from the Antarctic Peninsula indicates stabilization of the Antarctic Peninsula Ice Cap prior to about 8.5 Ma.

1. Introduction

The Southern Ocean lies south of 50° S latitude and its easterly circulation (the Antarctic Circumpolar Current, or ACC) is unimpeded by land. This unique geography and oceanography at the southern extent of the Earth's ocean conveyor (Broecker, 1991) make it especially important in the mixing and global distribution of water, heat, and nutrients from all other oceans. Deep, cold, northern-source water (North Atlantic Deep Water, or NADW) moves south along the bottom of the western Atlantic basin until it joins the ACC. Deep water forms off the Antarctic continent in the Weddell and Ross Seas to create Antarctic Bottom Water (AABW), which flows east and north. In addition to deep water, high latitude surface waters from the Pacific, Indian, and Atlantic Oceans are mixed by the ACC, creating intermediate water masses and the Pacific Deep Water (Wright et al., 1991; Sun and Watts, 2002).

Flow of the modern ACC initiated when tectonically-controlled gateways opened between East Antarctica and Australia (Tasmanian gateway) around 33.5 Ma (Exon et al., 2004;Kennett and Exon, 2004; Stickley et al., 2004),) and between South America and the Antarctic Peninsula (Drake Passage) (Berggren and Hollister, 1977; Barker and Thomas, 2004). Timing for the opening of Drake Passage is problematic, as the location and movement of several small continental blocks in the vicinity of the passage are not precisely known. Lawver and Gahagan (2003) state Drake was definitely open by 28.5 Ma, and was probably open to deep water circulation as early as 30 Ma (Barker and Burrell, 1977; Barker and Thomas, 2004). Other recent estimates place this opening at approximately 24 Ma, near the time of the Oligocene–Miocene boundary (Pfuhl and McCave, 2005; Lyle et al., 2007).

The ACC is the only current on Earth extending from the sea surface to the sea floor, flowing from west to east and unimpeded by any landmasses. Although mainly wind-driven, two jets carry the majority of the flow (130 Sv) (Barker and Thomas, 2004). Closer to the Antarctic Peninsula, the Antarctic Counter Current flows northeast to southwest forming, a sub-polar gyre (Camerlenghi et al., 1997a; Giorgetti et al., 2003). Bathymetrically guided currents along the ocean bottom often carry sediments and deposit them in the form of sediment drifts that extend along the flanks of topographic highs. These drift deposits accumulate at relatively high rates and commonly provide a continuous history of sedimentation, including records of changes in current intensity (Joseph et al., 1998; Hall et al., 2001; Joseph et al., 2002). Two sediment drifts along the Pacific continental slope of the Antarctic Peninsula were drilled as part of Leg 178 of the Ocean Drilling Program (ODP) to study the glacial history of Antarctica and the Southern Ocean (Fig. 1; Barker and Camerlenghi, 1999). Here we examine the record found at ODP Site 1095 which provides a direct, semi-quantitative record of current flow for the past 9.5 million years.

Our primary tool in this reconstruction is magnetic fabric analysis, the anisotropy of magnetic susceptibility (AMS). Magnetic fabric reflects the degree to which sediment grains are aligned by currents and therefore is a proxy for current strength as demonstrated by the work of Ellwood and Ledbetter three decades ago (Ellwood and Ledbetter, 1977; 1979; Ellwood et al., 1979). In the past several years

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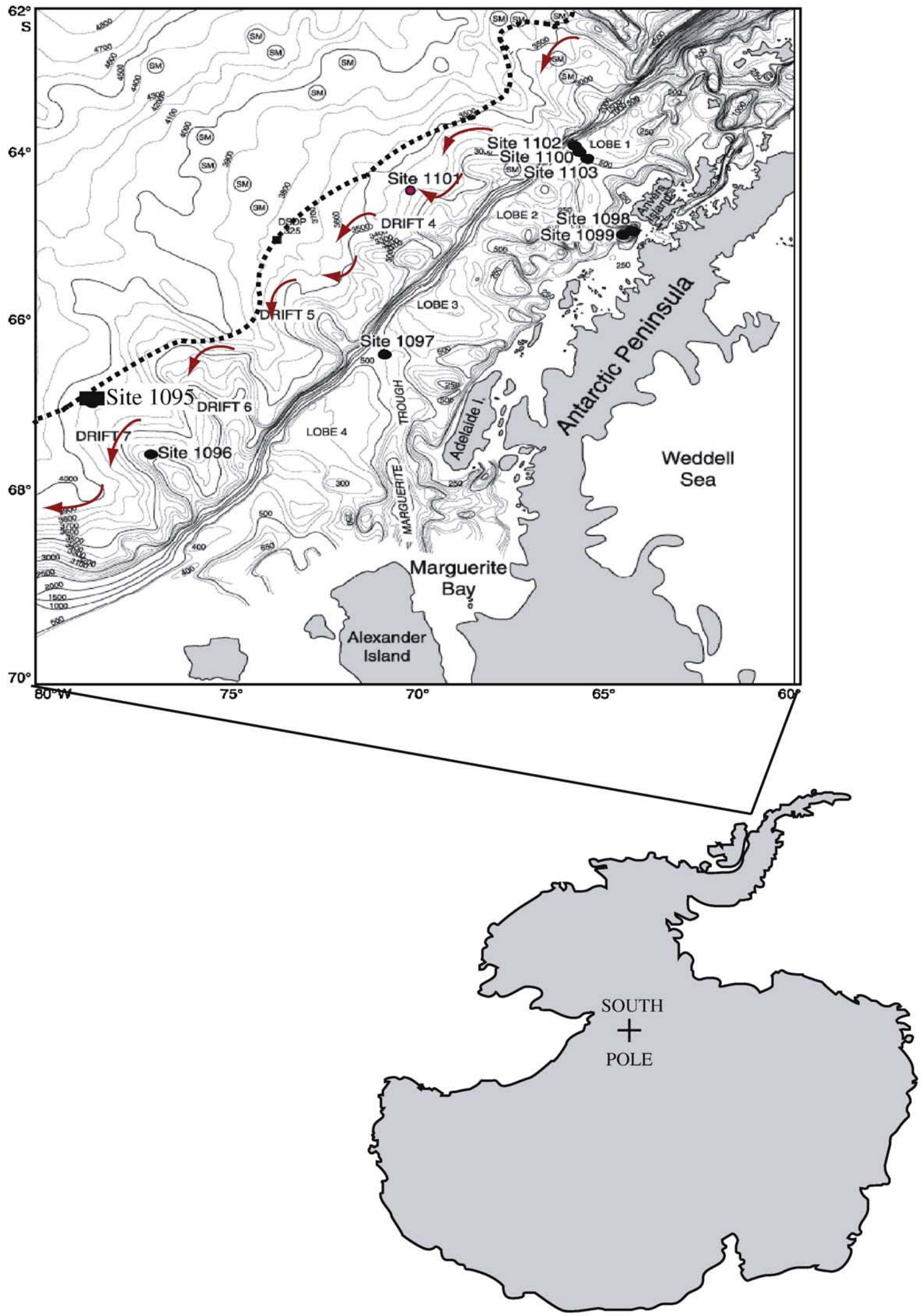

Fig. 1. Location of Site 1095. Dotted line shows southern ACC front, arrows show the path of the bottom current (from Uenzelmann-Neben, 2006).

we have refined this technique (Joseph et al., 1998) and applied it to drift deposits on the Kerguelen Plateau, southern Indian Ocean (Joseph et al., 2002) and in the North Atlantic Ocean (Hassold et al., 2006). These previous studies indicate a slowing of abyssal circulation since late Miocene time.

2. Setting, sediments, and methods

The Antarctic Peninsula is a long, narrow plateau, extending from 63° S to 74° and merging into West Antarctica (Fig. 1). Elevation varies from roughly 900 m in the north to 1750 m or higher southward of