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Antarctic Drilling Recovers Stratigraphic Records From the Continental Margin

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The Antarctic Geological Drilling (ANDRILL) program—a collaboration between Germany, Italy, New Zealand, and the United States that is one of the larger programs endorsed by the International Polar Year (IPY; http://www.ipy.org)—successfully completed the drilling phase of the Southern McMurdo Sound (SMS) Project in December 2007. This second drill core of the program's campaign in the western Ross Sea, Antarctica, complements the results of the first drilling season [*Naish et al.*, 2007] by penetrating deeper into the stratigraphic section in the Victoria Land Basin and extending the recovered time interval back to approximately 20 million years ago.

The primary objectives of ANDRILL (http://www.andrill.org/) were to recover stratigraphic records from the Antarctic continental margin that document key steps in Antarctica's Cenozoic (0- to 65-million-year-old) climatic and glacial history, and in the tectonic evolution of the Transantarctic Mountains and the West Antarctic Rift System [*Harwood et al.*, 2006]. These two ANDRILL stratigraphic drill cores are guiding the understanding of the speed, size, and frequency of the past 20 million years of glacial and interglacial changes in the Antarctic region. The drill cores will help to establish, through their correlation to existing records and their integration with climate and ice sheet models, how these local changes relate to regional and global events.

Each of the two ANDRILL projects involved more than 120 individuals, 80 of whom worked in Antarctica during each austral spring/summer field season. In helping to fulfill IPY's mission, ANDRILL is working to attract and train the next generation of Antarctic geoscientists and educators through research opportunities and through its education and outreach program (http://andrill.org/education/). In addition, ANDRILL is developing new drilling technology and scientific software designed to improve core visualization and data management (e.g., Corelyzer visualization tool and Paleontological Stratigraphic Interval Construction and Analysis Tool; http://www.apple.com/science/profiles/andrill/).

Southern McMurdo Sound Project

The SMS Project's AND-2A drill core was located (Figure 1) approximately 25 kilometers from the United States' McMurdo Station and from New Zealand's Scott Base on a floating sea ice platform (~8.5 meters thick) above water approximately 380 meters in depth (77°45.488'S, 165°16.613'E). After a 7-week setup period (to transport the rig and camp to the drill site, erect the structures, and melt the access hole through the sea ice), coring took place from 10 October through 30 November 2007, when the drill bit penetrated to beyond the target depth of 1000 meters below sea floor (bsf) and reached a total depth of 1138.54 meters bsf [*Florindo et al.*, 2008]. The drilling and engineering team—coordinated through ANDRILL's Operations Management Office—extended beyond the target drilling depth and delivered an excellent quality core with 98% recovery. Initial results from the core characterization phase of this project will be published in 2009 in a dedicated issue of *Terra Antartica* [*Harwood et al.*, 2009].

A primary goal of the SMS Project was to recover sediment from the middle Miocene (16–14 million years ago), which has long been regarded as a fundamental time interval in the development of modern Antarctic ice sheets [*Zachos et al.*, 2001; *Shevenell et al.*, 2004]. This time period encompassed a change from the warm middle Miocene climatic optimum (MMCO), approximately 17.5–14.5 million years ago, to the onset of major cooling between approximately 14.5 and 13.5 million years ago and the formation of a quasi-permanent ice sheet in East Antarctica.

The SMS Project successfully cored the MMCO and recovered three distinct stratigraphic intervals from the lower Miocene to Pleistocene (1.8 million years ago) that are separated by disconformities:

1. An early Miocene interval (1138.54 up to ~800 meters bsf) encompassing an expanded stratigraphic section that shows a pattern of cyclicity similar to that from coeval intervals of the Cape Roberts Project CRP-1 and CRP-2/2A drill cores [*Davey et al.*, 2001].

2. An approximately 600 meter thick early and middle Miocene interval (~800 to 223 meters bsf), which includes the warm MMCO, with a lithological variation

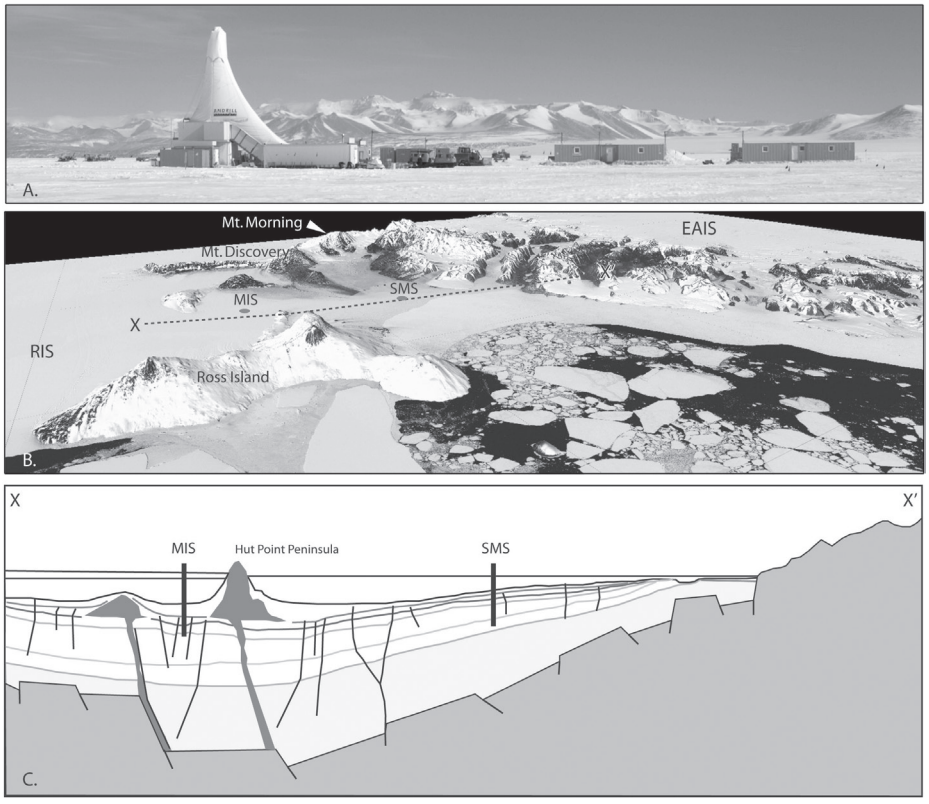

Fig. 1. Images of Antarctic Geological Drilling (ANDRILL) drill sites in McMurdo Sound, Antarctica. (a) The ANDRILL drilling rig and science labs at the Southern McMurdo Station (SMS) Project site. The Transantarctic Mountains are in the distance (photo by S. Nielsen). (b) Oblique view of the McMurdo Sound region (looking southwest) showing the location of the SMS Project drill site (on sea ice) and McMurdo Ice Shelf (MIS) Project drill site (on the Ross Ice Shelf (RIS)) and the locations of volcanoes at Mount Morning, Mount Discovery, and Ross Island. LANDSAT image mosaic of Antarctica (LIMA) scene of the McMurdo Sound region, Antarctica, courtesy of NASA, U.S. Geological Survey, British Antarctic Survey, and U.S. National Science Foundation, with modifications made by the Antarctic Geospatial Information Center and the ANDRILL Science Management Office. (c) East to west cross-section profile through the Victoria Land Basin and the coastal margin of the Transantarctic Mountains showing schematic stratigraphic sequences, fault lines, and igneous intrusions of the McMurdo Volcano Group (red). The selection of two offset drill holes to sample different portions of the Victoria Land Basin resulted in the recovery of an expanded composite stratigraphic section. Original color image appears at the back of this volume.

reflecting changes in sea level, glacial proximity, and climate change. Sediments deposited close to or beneath grounded glaciers alternate with fine-grained sediments, which provide clear evidence for cycles of ice advance and substantial retreat during climate transitions to warmer times. Macrofossils and terrestrial palynomorphs preserved in these strata suggest the persistence of conditions significantly warmer than present during an extended period of the middle Miocene when the western Ross Sea resembled modern climate conditions of Patagonia or southwestern New Zealand. The absence of fossil algae (diatoms) in many fine-grained lithologies suggests that coastal marine environments were dominated by high sediment input, with substantial river runoff and coastal turbidity.

3. A late Miocene to Pliocene interval (with poor age constraint between 14 and 2 million years ago), thinner (223–0.0 meters bsf) but correlative to parts of the expanded section recovered by the McMurdo Ice Shelf (MIS) Project [*Naish et al.*, 2007]. Shallow marine and terrestrial deposits dominate the SMS section up to approximately 1.5 million years ago, when the basin deepened rapidly.

From a setting proximal to ice sheet influence and sea level change, the AND-2A drill core will be instrumental in guiding interpretations from the deep-sea chemostratigraphic records and coastal sequence stratigraphic records of glacioeustasy. New ANDRILL results are vital to the Antarctic Climate Evolution scientific research program of the Scientific Committee on Antarctic Research (http://www.ace.scar.org/) [*Florindo and Siegert*, 2009], whose objective is the integration of new Antarctic geological and paleoclimatic data into climate and ice sheet models. Empirical data generated from ANDRILL studies will help calibrate these climate and ice sheet numerical models, enabling new constraints to be placed on estimates of ice volume variability, sea level change, terrestrial and marine paleotemperature, and the timing of the development and paleodistribution of terrestrial and marine biota in Antarctica.

Future Work and Broader Implications

The ongoing study of the AND-2A drillhole data and core samples will provide an important calibration and chronostratigraphic framework for the broad network of seismic profiles for the Ross Sea, coordinated by the Antarctic Offshore Stratigraphy Project (e.g., see http://www.scar.org/publications/reports/19/). The SMS site is well connected to the grid of seismic lines in the western Ross Sea; hence, the AND-2A drill core will provide excellent chronostratigraphic control for regional seismic surfaces, for interpreting regional stratal architecture, and for dating Cenozoic subsidence and rifting history.

With uncertainties about the future behavior of Antarctic ice sheets and resultant sea level change, programs such as ANDRILL—which provide historical data on climate and ice sheet changes that can be fed into numerical models—are important. The ANDRILL program will use stratigraphic records to determine the behavior of ancient ice sheets and to understand factors driving past ice sheet, ice shelf, and sea ice growth and decay. This new knowledge will enhance our understanding of Antarctica's potential responses to future global climate changes.

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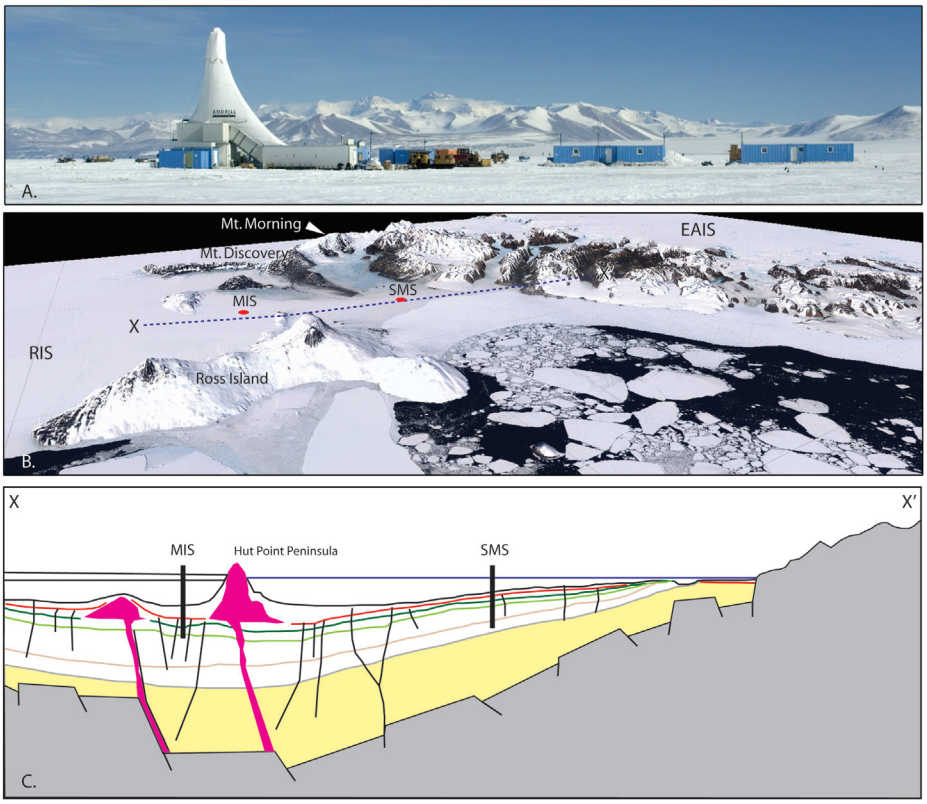

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