Probing Subglacial Environments Under the Whillans Ice Stream

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Water and wet sediments under ice sheets can play an important role in regulating the rate of ice stream flow in Antarctica, particularly over short time scales. Indeed, the discharge of subglacial lakes has been linked to an increase in ice velocity of Byrd Glacier by 10% for 14 months [*Stearns et al.,* 2008], and studies in West Antarctica have shown that subglacial water can significantly influence overall ice stream dynamics [*Fricker and Scambos,* 2009], particularly at the seaward margin [*Pollard and DeConto,* 2009].

The subglacial environment of Antarctica also is an unexplored component of the biosphere. Low temperatures, complete darkness, and direct isolation from the atmosphere for millions of years make this one of the most extreme environments on the planet [*Priscu et al.,* 2008]. Additionally, microorganisms beneath the ice sheet may play an important role in mineral weathering of basement rock and sediments, making them likely contributors to geochemical inputs into the surrounding ocean.

Despite the potential importance of subglacial environments, these areas have yet to be sampled in a comprehensive, integrated fashion. To address this issue, the Antarctic Integrated System Science program of the U.S. National Science Foundation's (NSF) Office of Polar Programs has funded a 6-year integrative study of subglacial environments in West Antarctica, called the Whillans Ice Stream Subglacial Access Research Drilling (WISSARD) project (http://www.wissard.org). Begun in 2009, WISSARD will assess how water beneath a West Antarctic ice stream and beneath the Ross Ice Shelf influences complex glaciological, geological, microbiological, geochemical, hydrological, and oceanographic systems (see Figure 1).

Scientific Goals

The WISSARD project will integrate surface geophysical surveys with borehole and subglacial sampling to test the overarching hypothesis that active hydrological systems connect various subglacial environments and exert major control on ice sheet dynamics, geochemistry, and metabolic and phylogenetic diversity within glacial environments. Exact selection of drill sites will be based on safety considerations and accessibility as determined through radar, seismic, and satellite data. Surface geophysical surveys will also determine regional geologic and hydrologic structures of the bed, constrain long-term history of ice flow across the region, and provide spatial context for interpretation of borehole findings.

Boreholes will be used to (1) collect samples of subglacial water, sediments, and basal ice for biological, geochemical, glaciological, sedimentological, and micropaleontological analyses; (2) measure physical and chemical conditions of an ice shelf cavity and determine their spatial variability; and (3) investigate sedimentary features and components, subglacial water discharge, oceanography, and basal ice at the seaward side of the grounding zone and within the cavity beneath the ice shelf. Subglacial access and data collection have required designing or customizing many instruments, including a submersible multisensor, a remotely operated vehicle for surveying under ice, sediment corers, thermal and geotechnical probes, and oceanographic moorings, some of which will remain as long-term observatories.

WISSARD Components

WISSARD consists of three interrelated subprojects. Lake and Ice Stream Subglacial Access Research Drilling (LISSARD) focuses on how active subglacial lakes control temporal variability of ice stream dynamics and mass balance. Robotic Access to Grounding-zones for Exploration and Science (RAGES) concentrates on stability of ice stream grounding zones, the regions of the ice sheet where conditions change from grounded ice sheet to freely floating ice shelf as the ice flows to the sea. Typically several kilometers wide, the grounding zone may be perturbed by increased thermal ocean forcing, internal ice stream dynamics, subglacial sediment flux to the grounding zone, and/or filling or draining cycles of subglacial lakes upstream. Finally, Geomicrobiology of Antarctic Subglacial Environments

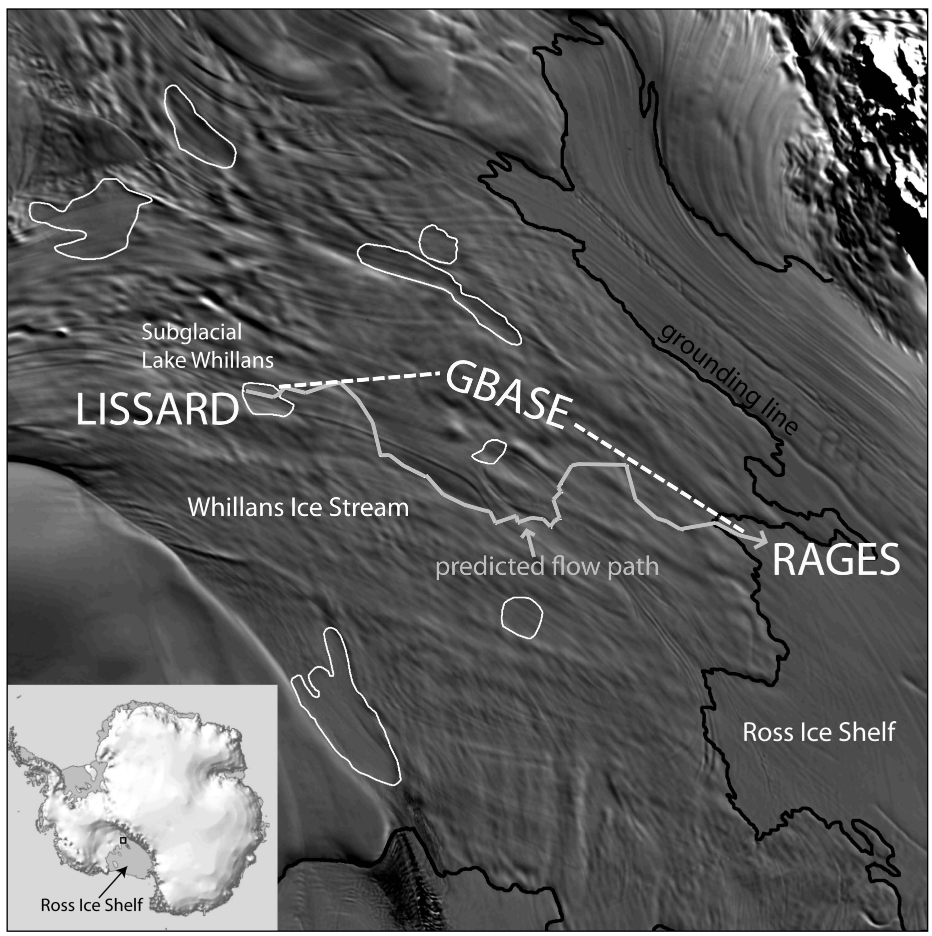

Fig. 1. Map of the Whillans Ice Stream subglacial hydrologic system (modified from Fricker and Scamos *[2009]) with annotation of the predicted flow path (light gray) of subglacial water from subglacial Lake Whillans to the grounding line (marked in black). Marked are the geographical study areas for the Lake and Ice Stream Subglacial Access Research Drilling (LISSARD), Geomicrobiology of Antarctic Subglacial Environments (GBASE), and Robotic Access to Grounding-zones for Exploration and Science (RAGES) components of the project. The white outlines indicate the locations of subglacial lakes. Inset map shows the location of Whillans Ice Stream (black square) with respect to the Ross Ice Shelf and the Antarctic continent.*

(GBASE) addresses microbial metabolic and phylogenetic diversity and associated biogeochemical rock weathering and elemental transformations in subglacial lake and grounding zone environments.

LISSARD and GBASE will target subglacial Lake Whillans, a hydrologically active lake beneath the Whillans Ice Stream (Figure 1). Through WISSARD's drilling program, access to the lake is scheduled for the 2012–2013 field season. The lake is part of an extensive hydrological system under the Mercer and Whillans ice streams that was discovered through analysis of repeat track laser altimetry data from NASA's Ice, Cloud, and land Elevation Satellite (ICESat) [*Fricker et al.*, 2007]. The discovery was based on the detection of ice surface deformation, presumed to be a response to subglacial water activity. In fact, surface expressions of two complete fill and drain cycles of the lake between October 2003 and October 2009 were observed, leading researchers to estimate that water in the lake drains and refills about every 3 years.

During the 2007–2008 field season, ice-penetrating radar surveys showed that ice thickness above subglacial Lake Whillans is only 700 meters and that the depth of water in the lake is greater than 8 meters even after lake drainage events. RAGES and GBASE will examine the Whillans Ice Stream grounding zone site because of its hydropotential linkage with subglacial Lake Whillans, and because a wedge of sediment has been detected in a zone behind the grounding line. This wedge could cause water to pool, influencing ice flow. Sampling at the grounding zone site is scheduled for the 2013–2014 season.

All WISSARD sampling sites will be accessed from McMurdo Station by tractor traverse.

Drilling Logistics

WISSARD is a complex, logistically challenging project that has required many years of planning with NSF, Raytheon Polar Services Company, and private instrument developers with funding through the U.S. National Oceanic and Atmospheric Administration and the Gordon and Betty Moore Foundation.

The current plan is to use an NSF-funded hot-water drill that can reach the subglacial environment within a day of initiating a borehole. Meltwater from the borehole will be filtered through 0.5- and 0.2-micrometer filters and passed through an ultraviolet sterilization system to reduce the number of viable cells within the fluid. Bacterial numbers will be monitored in the borehole water to ensure it remains below that in the ice sheet. This process will ensure that the subglacial environment remains pristine and that samples will not be contaminated by our drilling efforts.

Scientists intend to demonstrate a clean sampling strategy by conducting two intensive tests of this technology before making any attempt at subglacial access drilling. The first test will occur in the United States in 2010, and the second will occur during the 2011–2012 season on the Ross Ice Shelf, which will more closely approach conditions expected at the study site. This testing will demonstrate the efficacy of the filtration system, putting researchers in compliance with the Protocol on Environmental Protection to the Antarctic Treaty, which states that activities in the treaty area shall be planned and conducted so as to limit adverse impacts on the Antarctic environment and dependent and associated ecosystems.

Toward a New Chapter in Polar Science

Following more than a decade of active community planning, subglacial research has become a focus for interdisciplinary polar science. WISSARD provides an unprecedented opportunity to make direct observations and collect real-time in situ data to advance knowledge about a variety of important scientific questions in glaciology, geology, oceanography, and microbiology. Results from the project will not only test new theories about these environments but also provide important new data about the role of subglacial environments in global processes and biodiversity.

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NEWS

Report on Climate Change E-mails Exonerates Scientists

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A new report commissioned by the University of East Anglia (UEA) has largely exonerated climate scientists from the university's Climatic Research Unit (CRU) who wrote a number of controversial e-mail messages that were made public without authorization in November 2009. Critics have argued that the e-mails indicate that scientists had tampered with scientific data—including data related to land station temperatures and temperature reconstructions from tree ring analysis—subverted the peer review process, misused the Intergovernmental Panel on Climate Change (IPCC) process, and withheld data from critics.

At a 7 July news conference to release the "Independent climate change e-mails review," report chair Muir Russell said, "Climate science is a matter of such global importance that the highest standards of honesty, rigor, and openness are needed in its conduct. On the specific allegations made against the behavior of CRU scientists, we find that their rigor and honesty as scientists are not in doubt." He continued, "In addition, we do not find that their behavior has prejudiced the balance of advice given to policy makers. In particular, we did not find any evidence of behavior that might