Magical realism

WISSARD project poised to explore subglacial Lake Whillans

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It's taken a bit of magic — not to mention an incredible effort by scientists, engineers and support personnel — but the WISSARD project is poised to explore one of the last frontiers on the planet.

The biggest research program of the post-International Polar Year (IPY) era for the U.S. Antarctic Program, WISSARD brings together more than a dozen principal investigators to delve into a subglacial lake buried nearly a kilometer below the ice sheet.

The official name — Whillans Ice Stream Subglacial Access Research Drilling — only offers a hint about what this $10 million interdisciplinary project funded by the National Science Foundation hopes to accomplish over the next two years.

"We're going into the unknown — one of the last frontiers — which makes it really exciting," said John Priscu, WISSARD chief scientist and professor at Montana State University. "We've got every discipline involved. I think we've put together the best [people]."

The project is actually made up of three components, an alphabet soup of acronyms that captures the various research goals within WISSARD. Priscu also leads GBASE, for Geomicrobiology of Antarctic Subglacial Environments, which covers various aspects of the subglacial ecosystem – including the examination of life in this lightless, low-temperature, nutrient-poor environment.

"We're ready for almost anything," Priscu said of the search for life underneath the ice sheet.

Next up is LISSARD, Lake and Ice Stream Subglacial Access Research Drilling, which will focus on the interplay between the ice sheet and subglacial waterworks below, particularly how the water influences the behavior of the ice and its march to the sea.

"Basically, it provides a lubrication for ice motion," explained Slawek Tulaczyk, a professor at the University of California, Santa Cruz, and lead PI for LISSARD.

The third component has the fiercest acronym, RAGES, for Robotic Access to Grounding-zones for Exploration and Science, a project that proposes to delve eventually downstream of Lake Whillans where the water, ice and bedrock meet in a dynamic dance of streaming, melting and freezing.

A professor at Northern Illinois University, Ross Powell is the lead PI for RAGES and is the third member of the scientific triumvirate for WISSARD. His group has been involved in designing and developing some of the scientific instruments that will be involved in sampling the lake.

"There's complexity in developing the technology to do that," Powell said in what could be considered something of an understatement.

A subglacial wetlands

There's certainly nothing understated in what WISSARD proposes to accomplish in its multiyear study, particularly in the opening chapter that begins with the 2012-13 summer field season.

Even now, U.S. Air Force C-17 Globemaster III aircraft are hauling equipment and personnel from Christchurch, New Zealand, to McMurdo Station on Ross Island. By early December, scientists, engineers and support personnel plan to test the entire WISSARD system on the nearby McMurdo Ice Shelf.

The dress rehearsal includes everything from the complex hotwater drill system that will bore a hole through the ice sheet, to the instruments that will collect water and sediment samples from Lake Whillans, to the clean-access protocols that will help ensure the research doesn't contaminate the lake.

Then it will be time to pack it all up and haul sleds of equipment across the Texas-sized Ross Ice Shelf to the field site on the eastern edge of the West Antarctic Ice Sheet.

"The United States has a history of working there," said Priscu of a region where ice streams, faster-moving rivers of ice within the ice sheet, drain into the Ross Ice Shelf.

For example, remote sensing work by WISSARD colleagues like Helen Fricker at the University of California, San Diego, led to the discovery of an extensive subglacial waterworks system connected to the lakes. The satellites revealed the subtle rise and fall of the ice, as water filled and drained the lakes below.

"The subglacial environment is like a wetland, with the rivers coming through … with fairly large but shallow lakes that flow into other lakes," Priscu explained.

Land o' lakes

Lake Whillans is one of about a half-dozen subglacial lakes known to exist under the ice streams near the Ross Ice Shelf. A series of previous studies — some directly in support of WISSARD, others predating it — have found that Lake Whillans is about 60 square kilometers but only about 10 meters deep.

In particular, WISSARD's geophysical team has worked over the past few years to provide the borehole science group with unequivocal data on lake hydrology and morphometry.

"Thanks to the excellent work by our geophysical team, we now know more about the basin characteristics of Subglacial Lake Whillans than we do about lakes in the McMurdo Dry Valleys, which have been studied for more than 30 years," Priscu said.

Several hundred subglacial lakes have been identified since they were first discovered in the 1970s. Researchers with the British Antarctic Survey (BAS), including colleagues from the United States, published an inventory in 2005 that tallied 145 subglacial bodies of water. The number is believed to be about double that today.

The largest and most famous remains Lake Vostok, which Russian scientists penetrated earlier this year after decades of drilling through the East Antarctic Ice Sheet, originally as part of ice-core research. A recent analysis from samples of lake ice stuck to the drill did not find any signs of life from Vostok, located more than 4,000 meters below the ice. That hasn't surprised scientists, who say the sample was likely contaminated by petroleum-based fluid used to cool the drill and keep the hole open.

Three different environments

This year the Russians are expected to sample Lake Vostok properly. Meanwhile, BAS scientists are en route to subglacial Lake Ellsworth in West Antarctica for similar studies. The serendipitous timing of the three subglacial drilling programs has prompted some media to dub the scramble to access these heretofore inaccessible places as an international space-race-type competition.

Priscu insists that's not the case, noting that all three lakes are different in nature. For instance, scientists believe both Lake Vostok and Lake Ellsworth are isolated bodies of water, while Whillans is an "active" lake.

"These are deep lakes without a lot of water coming in and out. The lakes on the Whillans ice plain are very river dominated," he said.

Tulaczyk conceded that the United States didn't want to be left behind in the realm of subglacial research, but echoed Priscu's comments about the differences between the three lake systems. For example, Vostok is believed to be ancient, possibly on the scale of millions of years old. Meanwhile, Lake Ellsworth is located in an old, deepened fjord, and has possibly been isolated for hundreds of thousands of years.

"Scientifically, they're really complementary," he said of three projects.

In fact, a Russian scientist has been invited to observe the WISSARD effort this year, and collaborations have been under way with the BAS researchers, according to Priscu.

"We're trying to keep it open," he said. "We don't want it to be a race, and I think this is a really good way to keep the spirit of Antarctica in terms of its international aspects."

Language lessons

While most of the scientists with WISSARD are American, it doesn't mean they always speak the same language. A multitude of disciplines is represented within the program, from biologists to glaciologists to geologists.

The focus on ensuring that the lake environment remains as pristine as possible — equipment and instruments will be zapped with UV radiation and the drill water treated and filtered to commercial standards — means that the biology is at the forefront of the WISSARD project.

That's a little different from previous projects of this scale, such as the ANDRILL (ANtarctic Geological DRILLing) program that Powell helped lead that recovered sediment cores from below the seafloor to learn about Antarctica's glacial and geological past.

"The microbiology component is much more important," Powell said. "It's been good learning the different ways scientists approach their science."

Tulaczyk agreed that the interdisciplinary nature of the project — mainly supported by the Antarctic Integrated System Sciences (AISS) program within NSF's Office of Polar Programs (OPP) — has been both a learning experience and a challenge as the program was developed.

"We are working together rather than against each other," he said. "Our scientific goals have always revolved around this idea that water is the substance that connects the glaciology, geology and microbiology, because you need water to support the kind of life we have on Earth."

Life is The Thing

And what will that life look like?

Well, no one is expecting to need flamethrowers, ala the popular *The Thing* movies. If life exists in these subglacial realms — and most researchers believe they will find evidence — it will be on the microscopic scale, most likely bacteria that have developed strategies to cope in lightless, likely nutrient-poor environments, according to Priscu.

"These organisms will be obtaining a lot of their energy from the minerals in the rocks," Priscu said. "This is what we think we'll see. This is what we see in Blood Falls, under the Taylor Glacier."

As a graduate student in the Priscu Lab, Jill Mikucki (now at the University of Tennessee-Knoxville and a PI on GBASE), discovered a chemotrophic microbial community underneath Taylor Glacier while investigating Blood Falls. The waterfall-like feature is stained red because it draws water from an iron-rich pool, where the bacteria apparently dwell. Such light-starved organisms live off of inorganic compounds to fix carbon.

"I think we'll see a moderately diverse microbial community," Priscu said. Beyond that?

"Who knows?" he responded, noting that it's possible slightly more complex life may be dwelling in the subglacial ecosystem. Geothermal activity upstream of the Lake Whillans ice plain could support a more energetic and robust environment, he said.

"It's time to go down there and bring a sample to surface and actually look at it," he said.

In hot water

Easier said than done.

Much will have to go according to plan in a place that usually doesn't allow for a large margin of error. Much will depend on the success of the test on the McMurdo Ice Shelf in December. That will be the first trial of the entire system, which features a complex hotwater drill system designed and operated by the University of Nebraska-Lincoln (UNL).

"The design and procedures all have to be integrated to make this work seamlessly," said Frank Rack, executive director of the ANDRILL Science Management Office at UNL and lead for the hotwater drilling operation.

The new system uses a combination of off-the-shelf components, equipment salvaged from the IceCube Neutrino Observatory project at the South Pole, and some custom-made pieces from a variety of stateside vendors, according to Rack.

The design had to take many factors into consideration, Rack explained. It had to be mobile, as the idea is to traverse, or drive by tractor, much of the equipment to and around the field sites over the course of several years. It had to be integrated with a clean-access system to sanitize the water and equipment that will enter the borehole through which various science instruments will be deployed. And, of course, it had to stand up to Antarctica's tough environment.

"We set out to keep it containerized," Rack said. "The design is geared toward making it plug and play."

Keep in clean

The scientists certainly aren't playing around when it comes to keeping Lake Whillans and the rest of the subglacial system below the ice sheet from contamination.

"It's a serious issue, but it does add huge complexities to the whole operation as well," said Powell, whose team had to develop instruments that could be cleaned and sanitized before descending into the borehole.

Of course, the motivation to maintain the pristine environment is equal parts conservation and research-driven.

"Many of these challenges are not just unique to the WISSARD project. They're common to all subglacial access [projects],” said Brent Christner, an associate professor at Louisiana State University and PI on GBASE, during a presentation on the WISSARD clean access strategy during this summer’s meeting of the Scientific Committee on Antarctic Research (SCAR) in Portland, Ore.

Christner said WISSARD is using proven technologies used by the food and pharmaceutical industries. Water entering the borehole will pass through filtration modules, as well as be subjected to ultraviolet radiation and pasteurization. That should take care of about 99.99 percent of the cells in the water, he said.

“We actually passed E. Coli cultures through this system to ensure the system killed or removed them,” he said.

The hotwater drill equipment and science instruments will also be treated to eliminate particles and microbes from reaching the lake water.

“We do not want to alter these systems by either introducing microbiological or chemical contamination that will change the properties of these pristine subglacial environments,” Christner emphasized.

Taking a closer look

What that environment looks like and its properties will be assessed by a variety of instruments that have been developed or modified specifically for the WISSARD program.

One key piece of equipment is called the Micro-Submersible Lake Exploration Device (MSLED), a slim submersible designed by collaborator Alberto Behar at NASA’s Jet Propulsion Laboratory (JPL). MSLED sports chemical sensors and a high-resolution imaging system to scope out the environment below the ice.

“This is a piece of equipment that I’m very excited about,” Tulaczyk said. He explained the imagery collected by MSLED will be important for examining the morphology of the lake basin to understand how it was formed and its origin. It will also help answer questions from the age of the basin to how the water is entering and leaving the lake.

“All of these questions can be addressed by that camera on MSELD,” Tulaczyk said.

Getting real *in situ* water samples to analyze and to make a variety of measurements down through the lake water column will fall to a suite of instruments known by yet another acronym, IPSIE, for Instrument Package for Sub-Ice Exploration.

The IPSIE suite is based on the sort of instruments used by oceanographers and limnologists to measure various properties of seawater, such as salinity and temperature. In this case, however, the various sensors and water-collection bags have to be stacked vertically to slip through the 800-meter-deeep, 30-centimeter-wide borehole in the ice sheet.

“That’s required a bit of technology development – just trying to design it so all of the instruments can be linked to each other and synchronized,” Powell said.

The various instrument units can be swapped and reordered depending on the science goals, according to Powell. The unit at the very bottom features a water pump that can circulate lake water through the instruments above. A fiber optic cable allows the team to send instructions to the instruments down in the lake cavity while their data are streaming real-time to the surface. A crane will be on site to help raise and lower the instrument suite.

Getting the dirt

Water isn’t the only sample the scientists hope to draw out from nearly a kilometer below the ice sheet. They want to get a little dirty, too.

That will require various coring instruments to collect sediments from the lake floor. Shallow cores will capture water at the crucial interface between the water and top layer of sediments, where biological activity may occur.

Longer cores up to five meters long will capture a glaciological and geological record that researchers hope pushes past the Last Glacial Maximum (LGM), when the ice sheets reached their most recent maximum extent about 20,000 years ago. Powell said there is some reason to speculate the sedimentary record may dip into the last ice age and to a previous warm period known as an interglacial about 120,000 or so years ago.

“We don’t know what sort of record we’ll get,” he said. “The intriguing thing there is that it relates to the sensitivity of the West Antarctic Ice Sheet. When did it last retreat? When was it fully gone? That’s what we’re hoping to address with the longer record.”

Such records are hard to obtain in the continental margin where the WISSARD team will core because of the hard glacial till that resists traditional coring techniques, according to Powell. In response, the team developed a new technology, a percussion corer, which uses a 1,000-kilogram weight to drive the core barrel into the lake floor.

“It pounds its way into the sediment,” Powell said. A hydraulic motor that runs the weight can the be switch to pump water into a narrow space within the core barrel to help eject the instrument when it has collected the mud, rock and till.

Learning more

The window for this ambitious project is about two weeks in January 2013. The WISSARD camp will be a busy place during that time, with more than 40 people expected to be in the field at once. Aircraft will be coming and going. A handful of journalists and teachers will also be on site to communicate the results of the project to the world.

And results are expected to come quickly, if the lake can be penetrated safely and cleanly. Two high-tech labs, built from shipping containers, will be on site for the researchers to use to analyze water and sediment samples.

“We’ll be able to bring the samples up and immediately start cultures, and rate measurements. We’ll be able to do it right there,” Priscu said.

A second field season is planned for 2013-14, with the focus shifting to the subglacial system that feeds and drains Lake Whillans. A proposal is pending with the NSF to support a succession of the RAGES project in future years.

But this year the WISSARD team has one goal: Drilling into Lake Whillans, one of the last remaining mysteries of polar science.

“We don’t know what’s there. We don’t know what to expect. What if it’s all mud? We don’t know,” Priscu said. “We know more about going to Mars.”

NSF-funded research in this story: John Priscu, Mark Skidmore and Andrew Mitchel, Montana State University, Award No. 0838933; Slawek Tulaczyk, University of California-Santa Cruz, Award Nos. 0839142, 0838947; Ross Powell and Reed Scherer, Northern Illinois University, Award Nos. 0839107, 0839059; Ross Virginia and Jill Mikucki, Dartmouth College, Award No. 0838896; Brent Christner, Louisiana State University, Award No. 0838941; Jeffrey Severinghaus and Helen Fricker, University of California-San Diego Scripps Institution of Oceanography, Award No. 0838885; Robert Jacobel, Saint Olaf College, Award Nos. 0838855, 0838854; Sridhar Anandakrishnan, Pennsylvania State University, Award No. 0838763, 0838764; Susan Schwartz, Andrew Fisher and

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