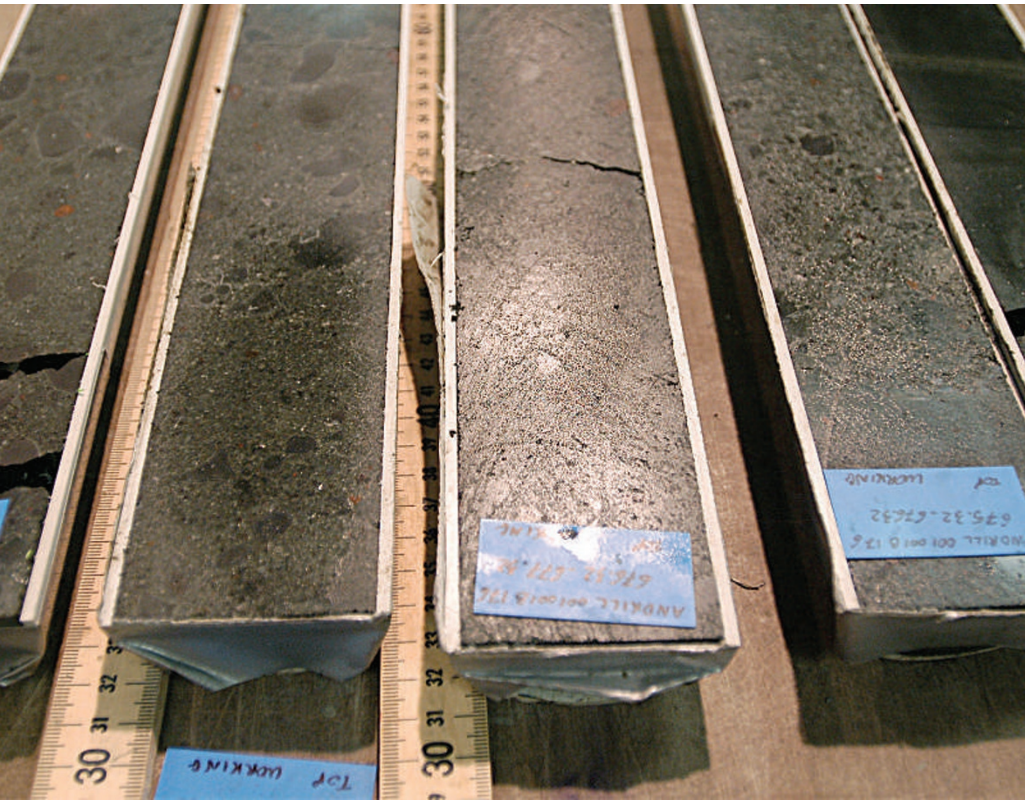


P. WEST/NSF

School of rock

The rocks of Antarctica are obscured literally, and sometimes scientifically, by its ice. But drilling efforts are now showing what we can learn from the hard stuff. Alexandra Witze reports.

When it comes to Antarctica's history, ice cores get all the glory. Large-scale ice-drilling efforts, such as Europe's EPICA and Russia's Vostok cores, capture headlines and the lion's share of people and funding. After all, these cores contain air bubbles that are hundreds of thousands of years old, a frozen time capsule from Earth's icy past.

But buried beneath the thick layers of ice, the rocks of Antarctica have far older stories to tell. Trapped within layers of mud and sand are geological records stretching back millions of years. As Antarctica's ice teams continue to hunt for the oldest ice their drills will reach (see page 126), a smaller band of rockhounds is on a similar quest to plug the gaps in the geological record.

The team now has a core that promises fresh insight into how Antarctica's ice waxed and waned over the past few million years. On 26 December, a US$30-million international project called ANDRILL pulled up the final piece of a core from beneath the Ross ice shelf (see map, page 127). Previous coring efforts have offered peeks into Antarctica's deep history — back as far as 34 million years when the continent was first covered in ice. But the new core fills a gap in the ice shelf's history, and sets a new Antarctic record for drilling depth.

The period covered by the core — from the present to more than 5 million years ago — seems to be quite active. Preliminary analysis has revealed thick layers of a greenish rock interspersed throughout the core. This is an indication of open-water conditions, suggesting that the Ross shelf retreated and then advanced at least 50 times within the past 5 million years. With this nearly unbroken record, scientists can explore the history of the shelf in unprecedented detail.

"It's going to be a benchmark that we hope we can refer to for years to come," says Ross Powell, a geologist at Northern Illinois University in DeKalb. "It may be the geological equivalent of the Vostok ice-core record." As project co-leader, Powell is understandably enthusiastic about the core, but then so are other geologists.

The Ross ice shelf, the largest in the world, is a floating extension of the even more massive West Antarctic Ice Sheet. That part of Antarctica is regarded as the most unstable and potentially prone to collapse in a globally warmed world. If the west Antarctic ice sheet melted entirely, it would raise the global sea level by about 5 metres. The Ross shelf is a tiny but important fraction of that. Its behaviour over

Martian mimics

CORBY WEST/JPL

The Phoenix spacecraft will land on Mars during the IPY. Scientists hope to compare data from the planet's northern polar region with soil measurements from an analogous 'extreme environment': the Antarctic Dry Valleys.

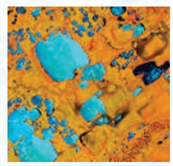
Antarctic aliens

More than 40,000 people visit the Antarctic each year — and they probably bring with them the seeds and spores of non-native species. The IPY will see the first full assessment of the environmental impact of these visitors.

Past warming

One way to predict what might happen in a warmer climate is to look back in time. The WARMPAST project will use Arctic sediment cores to reconstruct ocean temperatures for the past tens of thousands of years.

Icy lakes



LANDSAT

Scientists from Canada and Russia will pore over historical data to see how the timing of ice freezing and breaking up on Arctic lakes has changed over the past 50 years.

Changes in sea level

UK and other researchers plan to add gauges to monitor the sea level and tides in the waters around Antarctica.

Arctic greening

Climate change is likely to alter the distribution and type of plants at high latitudes. Assessing satellite data, and doing field studies to produce new vegetation maps for Russia, Alaska and Canada, will help scientists predict such changes.

Reindeer herders

The knowledge and experience of nomadic reindeer herders, accumulated over generations, will be documented to establish how herders living across Norway, Russia and Alaska can sustain their way of life.

INGER MARIE GAUP EIRA/EALÁT

Cutting edge: the ANDRILL team recovers the final part of the 1,285-metre rock core from Antarctica.

past millennia could help researchers improve their understanding of how it might respond as temperatures rise in the future.

Conditions on Earth are returning to a state that hasn't existed for millions of years, says David Harwood, a geologist and ANDRILL scientist at the University of Nebraska in Lincoln. "We have to go back to previous times in Antarctica when things were very warm, when carbon dioxide levels were higher, for an analogue of where we're heading," he says.

The history of Antarctica's ice starts about 35 million years ago, when atmospheric carbon dioxide levels and temperatures began to drop. As the globe cooled, the great ice sheet in east Antarctica began to form. Some time afterwards — perhaps as early as 30 million years ago, or as late as 5 million years ago — west Antarctica gained its ice as well. ANDRILL scientists hope to refine these timing estimates.

Until ANDRILL, Antarctic rock cores have only offered relatively short glimpses of the continent's history. Inland, researchers drilled shallow cores during the 1970s for the Dry Valleys Drilling Project — the deepest reached 300 metres. Offshore, ocean-drilling ships have collected sediment records that were scraped off the continent by the flowing ice; such debris provides clues to what Antarctica's bedrock looked like long ago. And in the broken-up sea ice that fringes the continent, icebreakers have occasionally been able to grab a quick core of similar sediments (see 'Quick-hit drilling').

Technologically, it is much harder to drill through the thin layer of sea ice that surrounds the continent, or beneath the thicker ice shelves such as the Ross. In the late 1990s, the international Cape Roberts Project tried this for the first time, drilling through sea ice into the sea floor. A severe storm cut one of the seasons short, but the team managed to collect short cores dated to between 34 million and 17 million years ago (T. R. Naish *et al. Nature* **413,** 719–723; 2001). That took scientists back to the formation of the east Antarctic ice sheet, but couldn't tell them what had happened more recently.

Shelf help

ANDRILL aims to fill in that gap. "No one has ever tried to recover a long sedimentary record from under an ice shelf," says the project's other co-leader, Tim Naish of the Institute of Geological and Nuclear Sciences in Lower Hutt, New Zealand. The 200-plus consortium of researchers, run by the United States, New Zealand, Germany and Italy, has allocated two field seasons for drilling two separate cores: the one just completed through shelf ice, and another to be drilled through thinner sea ice.

For this season's work, which began in November near the New Zealand Scott base, the drilling company had to devise a hot-water system to get through the 85 metres of ice shelf, and keep it from refreezing around the pipe. The solution was a giant metal 'doughnut' filled with hot water that continuously ran up and down the drill shaft, keeping the surrounding ice melted enough for operations.

Drilling was tricky at first. Tides cause the ice shelf to flex up and down by about a metre per cycle, and sideways by about half a metre per

Quick-hit drilling

There are obvious advantages to using a drill rig and drilling for as long as you can — a very long continuous core, for instance.

But there are lots of places in the Antarctic where drill rigs just aren't feasible, either as fixed platforms such as ANDRILL or onboard ocean-drilling vessels that work offshore. In particular, the broken-up sea ice around the edges of the continent makes it difficult for core-seekers to get to where they want to go. They may know exactly where the sediments they seek are, but they can't get to the spot because of dangerous ice floes.

Overcoming that problem is the point of the SHALDRIL drilling platform. It uses icebreakers to swoop into the region of interest, fending off sea ice as they go, and retrieves short cores from the sea floor. "The object is to give you a lot more mobility," says John Anderson, a geologist at Rice University in Houston, Texas, and co-leader of the project.

But the 'drill and run' strategy hasn't always worked. The first SHALDRIL cruise, in 2005, aboard the US icebreaker *Nathaniel B. Palmer*, successfully acquired cores at sites along the Antarctic peninsula. But the following year, the second cruise ran into major problems with sea ice (J. B. Anderson *et al. Eos* **87,** 402, 408; 2006). Thick ice floes battered the icebreaker, making it impossible to retrieve the planned cores. Instead, the team grabbed short samples quickly from various locations and left.

Although the team currently doesn't have funding for a third cruise — or even to study the cores it has already retrieved — Anderson says he hasn't given up on SHALDRIL as an alternative drilling platform. "We won't see the day when a conventional drill ship can go into these ice-covered areas," he points out, adding that he is getting plenty of interest from other scientists in the approach. **A.W.**

P. WEST/NSF

Chilled out: the ANDRILL rig on the Ross ice shelf in Antarctica.

day. And stronger-than-expected ocean currents bent the pipe surrounding the drill as it stretched more than 900 metres through the ice shelf and the water below, before finally entering the sea floor. But after two months of non-stop drilling, the team recovered 1,285 metres of rock.

The core, now stored in the freezers of the Antarctic geologic repository at Florida State University in Tallahassee, has yet to reveal all its secrets. The first challenge, says Powell, is pinning down its age. The top half of the core seems to cover the past 5 million years, and that's what contains the 50-plus cycles of ice-shelf collapse. The sediments show repeated layers of ground-up rock debris scraped off the continent by glaciers, interspersed with the open-water greenish ooze rich in the marine organisms known as diatoms. The transitions between the glacial sediments and the open-water ooze seem to be quite sharp, says Powell — suggesting that they took place relatively quickly.

> **"It's spectacular. I was surprised at the striking differences that the core brought out."**
> — Peter Barrett

Debris and ooze

Peter Barrett, a geologist at the Victoria University of Wellington in New Zealand, who was chief scientist for the Cape Roberts Project, says he was struck by the number of transitions over such a short period. "I think it's spectacular," he says of the core. "We'd talked about what they might find beforehand of course. But I was surprised at the striking differences that the core brought out."

Another major question is where the ground-up glacial deposits in the ANDRILL core came from. Studying the sediments in the core could help the team trace the material — and therefore the ice — back to its source. They might turn out to have come from somewhere else in west Antarctica, says Powell, or perhaps even as far as east Antarctica. Knowing the path the ice took could help researchers better understand how ice flows across the continent, thus aiding future models of ice flow as Antarctica warms.

Other insights could come from comparing the ANDRILL core with ice cores such as EPICA. There isn't much overlap; only the upper 80 metres or so of the ANDRILL rock represent the past 1 million years, and the whole of EPICA covers only the past 800,000 years. But comparing rock and ice records could help palaeoclimatologists correlate increases and decreases in carbon dioxide levels with what the ocean and the Ross shelf were doing at the time. "It will be very exciting to see how the records of ice-sheet changes they have are related to the changes in Antarctic temperature we have," says Eric Wolff, an ice-core specialist with the British Antarctic Survey in Cambridge, UK, and a member of the EPICA team.

The next chapter in the story will start in October, when the second leg of ANDRILL gets under way. For that, the researchers will drill through the 7-metre-thick sea ice in the southern part of McMurdo Sound, through the ocean and again into the sea floor. There, they are expected to pick up where the current core left off — probably around 7 million years ago — and extend the record to around 17 million years ago. With that, geologists hope, they will finally have a complete history of the Ross shelf.

This is key because it seems likely that Antarctica will undergo some serious changes in the future. Both atmospheric carbon dioxide levels and temperatures are projected to increase beyond historical highs over the next several centuries. "Just how long will it be before the temperature increase catches up and we watch the Ross ice shelf go away?" asks Barrett. With the Ross gone, the scenario goes, melting on the main part of the west ice sheet could accelerate. That's something neither the ice experts nor the rockhounds want to contemplate. ■

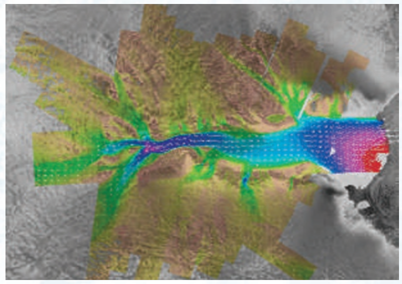
Alexandra Witze, *Nature*'s chief of correspondents for America, has been to the North Pole but not Antarctica — yet.

Warm vents

Studying hydrothermal vents on the Arctic mid-ocean ridge is a challenge as major portions of the ridge lie more than 4,000 metres under pack ice. In July and August, robotic vehicles will dive to the Gakkel Ridge to search for vents.

Satellite shots

The photographic power of Earth-observing satellites is being pooled to yield a wide range of snapshots of the world's polar regions in the highest resolution possible.



BYRD POLAR RES. CENTER/CAN. SPACE AGENCY

Solar activity

Scientists will take measurements from the polar regions to assess whether variation in the Sun's activity affects Earth's weather and climate by influencing a global electrical circuit in the atmosphere.

Particle physics

Physicists will use the IceCube observatory being built at the South Pole to search for subatomic particles called neutrinos. During the IPY, glaciologists are being invited to use the detectors to study ice flow.

Polar bears

A Danish-led team will examine contaminants in the muscles and bones of polar bears killed by Inuit hunters. Chemical analyses of the bears' body tissues could also shed light on how much climate change is stressing the animals.

B& C ALEXANDER/NHPA

Open leads

Some 200 researchers from 15 countries will study the circumpolar flaw lead — an area of open water that forms each autumn when the main Arctic pack ice pulls away from coast. With thin ice becoming more common in the Arctic seas, this region offers a glimpse of how changes to the ice affect ocean life.

Lucy Odling-Smee