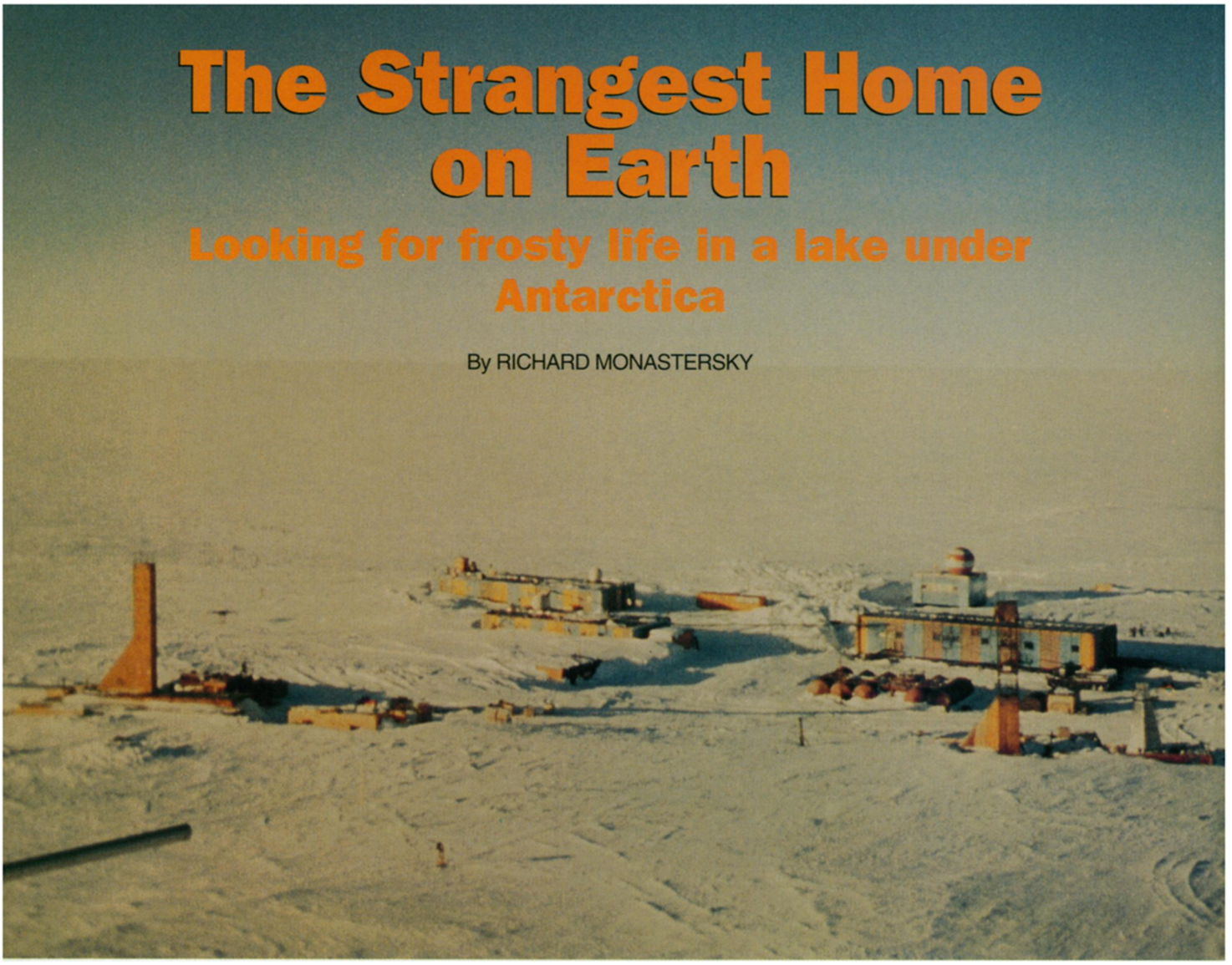
The Strangest Home on Earth

Looking for frosty life in a lake under Antarctica

By RICHARD MONASTERSKY



Sowers

A flight over the eastern portion of Antarctica crosses territory so monotonous it could lull an insomniac into unshakable slumber. For thousands of kilometers in all directions, a thick sheet of ice coats every bit of real estate, even the tips of the tallest peaks. Hour after hour, varying shades of white pass beneath the plane, with no hint of any other hue.

Beneath the boring white blanket lies half a continent of virtually uncharted territory—a *terra nova* so completely hidden that scientists have little clue what riches await discovery. Only 3 years ago, Russian and British glaciologists identified an immense lake—one of Earth's largest and deepest—buried beneath 4,000 meters of ice immediately below Russia's Vostok Station (SN: 6/29/96, p. 407).

When the team announced the find, many other researchers sniffed that the lake was little more than a curiosity, says glaciologist Martin Siegert of the University of Bristol in England, one of the lake's discoverers. As more details have emerged, however, a growing number of scientists have picked up the scent, with dozens of investigators now panting to explore the feature, known as Lake Vostok.

"This is a very exciting opportunity to learn about our planet, the history of our planet, perhaps even analogues to life on other planets," says David Karl, a microbiologist at the University of Hawaii at Manoa in Honolulu who cochaired a conference last fall on Lake Vostok. "It was pretty amazing how uniform the interest is," he says.

Cut off from the rest of Earth for a million years or more, Lake Vostok may harbor ancient species of microbes, unknown to science, that are able to withstand conditions at the edge of survivability. Moreover, a thick layer of sediment at the bottom of the lake could hold novel clues to the planet's climate going back tens of millions of years.

The mysterious body of water inspires even otherworldly interest: NASA hopes to use the lake to test methods for detecting life on other planets.

In August, the National Science Foundation—which runs U.S. operations in Antarctica—decided that it would fund an airborne survey of the lake, a first step toward eventually drilling into the water. This week, some 60 scientists gathered in Cambridge, England, to start planning an international expedition to explore the lake and capture samples of its residents, if any exist.

Along with the potential rewards come a host of challenges. Researchers must find a way to penetrate the icy covering without introducing any microorganisms or pollutants into the sealed-off water.

"We know absolutely nothing about subglacial lakes. If we're going to work on them, we must assume that we are going to take extreme measures to avoid any sort of contamination," says Cynan Ellis-Evans of the British Antarctic Survey in Cambridge, who led this week's meeting.

Vostok Station holds the uncomfortable distinction of having recorded the coldest temperature on Earth. Thermometers there measured –89.6°C in July 1983, and the average temperature hovers down around –55°C.

It's the thick ice, strangely, that enables a lake to survive in such a frozen environment. "The 3 kilometers or so of ice acts effectively as an insulating blanket that protects the bedrock underneath the ice from the cold temperatures above," says Siegert. Geothermal heat coming from the planet's interior keeps the lake from freezing and warms the lowest layers of ice.

The tremendous weight of the ice sheet also plays a role in maintaining the lake. Beneath 4 km of glacier, the pressure is intense enough to melt ice at a temperature of –4°C.

These factors have helped lakes develop across much of the thickly blanketed East Antarctica. To date, Siegert and his colleagues have detected more than 70 hidden lakes in the small portion of the continent they've examined so far.

Lake Vostok is the largest of these, stretching 280 km from south to north and some 60 km from east to west, roughly the size of Lake Ontario but twice as deep. At the station, which sits at the southern end of the lake, the water depth appears to be 500 m, according to seismic experiments carried out by Russian researchers.

The first clues to Lake Vostok's existence came in the 1970s, when British, U.S., and Danish researchers collected radar observations by flying over this region. The radar penetrates the ice and bounces off whatever sits below. When researchers found a surface as flat as a mirror, they surmised that a lake must exist underneath the ice. Gordon de Q. Robin of the University of Cambridge reported the subglacial water, but the data didn't reveal whether there was a single giant lake or several separate ones.

It took a view from space to define the lake better. Using radar data collected by ERS-1 satellite measurements, J.K. Ridley of University College London found that ice was much smoother and flatter above the lake than it was above the surrounding mountainous regions. In 1993, he charted the northern end of the lake, but the available data did not resolve the southern portion near Vostok Station.

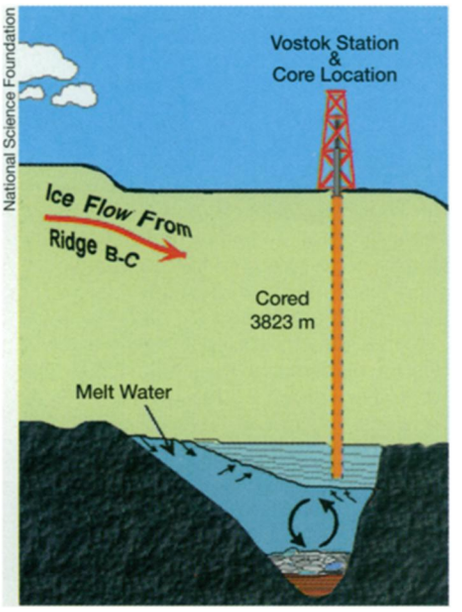
Three years later, Siegert analyzed an improved set of satellite radar data without ever setting foot on the Antarctic continent. Along with Robin, Ridley, and other researchers, Siegert fully mapped out the dimensions of the lake using the satellite, radar, and seismic measurements.

Only then—some 20 years after it was first suspected—did the lake start to garner attention outside the narrow field of glaciology. When NATURE splashed the news of Vostok on its cover in 1996, biologists started wondering whether the buried lake could harbor exotic new species.

At the time that people first found hints of Lake Vostok, there was little reason to suspect it might harbor any life. "The most exciting advance since the 1970s is the understanding that life on this planet can occur, and indeed thrive, in extremely difficult environments," Siegert says.

If microbes do populate the lake, they may be some of the hungriest organisms ever discovered. "Lake Vostok has the potential to be one of the most energy-limited, or oligotropic, environments on the planet," says microbiologist Edward F. DeLong of the Monterey Bay Aquarium Research Institute in Moss Landing, Calif.

For the lake's residents, the only hope for a sizable meal would come from below. Russian investigators have speculated that the lake floor has hot springs



The drilling project at Vostok Station penetrated the thick ice sheet but stopped short of the lake below. The ice in this part of Antarctica flows slowly across the narrow end of the lake. The melting and freezing of the ice's bottom layer may generate currents in the water.

spewing out hydrothermal fluids stocked with reduced metals and other sorts of chemical nutrients.

They base their argument on the shape of the lake. Its elongated outline and substantial depth resemble Lake Baikal in Siberia, which sits in a geologically active rift zone. At this site, Earth's outer shell is pulling apart, allowing molten rock to rise close to the surface and feed hydrothermal springs.

Geologists, however, have always painted the exact opposite picture of East Antarctica. The scant geological evidence available for this region indicates that the crust is old and dead.

Without a stream of nutrients seeping up from the deep Earth, the only potential source of energy lies above the lake. The ice sheet above the water is creeping from west to east at a rate of roughly 4 m per year. The lowermost layers of ice melt when they come in contact with the lake, liberating trapped gases and bits of crushed-up rock.

Indirect evidence for this glacially slow delivery system comes from drilling operations at Vostok Station, where Russian and French researchers have pulled up cylindrical ice samples—about as wide as a coffee can—of ice down to within 120 m of the lake surface. In January 1998, the team ceased its work to prevent contaminating the lake with the diesel fuel used to lubricate the drill.

In the lowest part of the hole, the scientists found a 200-m-thick layer of ice containing giant crystals. This and other properties indicate that the ice formed as the lake water froze to the bottom of the glacier. Researchers suspect that the bottommost ice melts as it passes over the western edge of the lake and then water freezes onto the ice sheet as it moves over the eastern portion of the lake underlying Vostok Station.

What comes out of the melting ice is guesswork at the moment because geologists know so little about East Antarctica. If the glacier recently passed over sedimentary rock before reaching the lake, it could be supplying organic compounds useful to microorganisms.

It also could be seeding the lake with a continuous source of new residents. S.S. Abyzov of the Russian Academy of Sciences in Moscow has found bacteria, yeasts, fungi, algae, and even pollen grains in the Vostok ice core down to depths of 2,750 m—three-quarters of the way to the bottom. At least some of these organisms are alive and capable of growing, he reported last year.

Karl is currently examining ice from the 3,600-meter depth for signs of viable microbes. Because ice from that depth formed from frozen lake water, it contains a sample of whatever was floating at the surface of the lake. The results from this analysis may indirectly indicate whether anything survives in the lightless body of water.

If denizens of Lake Vostok don't succumb for lack of food, they could easily suffocate. Because of the intense weight bearing down from the ice sheet above—340 times atmospheric pressure—the water contains almost no dissolved oxygen, carbon dioxide, methane, or other gases.

According to calculations, gas molecules should reside in crystal cages of ice, forming a structure called a clathrate. Some of these may create a slushy zone floating at the top of the lake, while others could sink to the floor.

Despite the apparent odds against life, biologists place their bets on the bacteria. "I would be surprised if there were no microbes in Vostok rather than the other way around," says Karl.

What excites researchers is the idea that resources in the lake are not evenly distributed. Microorganisms, just like any

business, tend to exploit inequalities in supply and demand. By living on the border between two environments, cells can extract energy as materials move from regions of plenty to paucity. For instance, bacteria may well thrive on the surface of the clathrates, taking advantage of a gradient in methane concentrations.

Clathrates have also captured the attention of climate scientists because they may contain ancient samples of oxygen and other gases, says glaciologist Todd A. Sowers of Pennsylvania State University in State College. The frozen cages of gas could have built up on the lake bottom, layer by layer, over a million years or more. By looking at the ratio of different oxygen isotopes in these clathrates, scientists should be able to trace how Earth's temperature has changed since the time that some of the earliest humans were spreading across the world.

Below the clathrate layers, Lake Vostok apparently holds vast sedimentary deposits chronicling tens of millions of years of Antarctic geology. The Russian seismic experiments indicate that sedimentary layers extend hundreds of meters below the lake floor.

In many ways, however, the bottom of Lake Vostok is even more remote than the surface of Mars.

To study the lake's sediments, scientists need to drill through the ice, sterilize the probe before entering the lake, pass the instrument through hundreds of meters of lake water, bore into the sediments below, then pull the samples back up through the ice. All this at crushing pressures.

The constraints steer engineers in opposite directions, says Joan Horvath, a project manager at NASA's Jet Propulsion Laboratory in Pasadena, who's developing plans for Lake Vostok. "To get anything through the ice, you want it to be small," she says. "However, once you get a submersible down there, it's very difficult to get something small that will operate at high pressure. In that environment, you like things to have thick walls. So, there is an inherent engineering mismatch between the two things you're trying to do."

Most concepts for a first Vostok mission don't involve collecting samples. A simpler plan calls for melting a hole through the ice and then sending a robotic submersible into the lake to analyze the water and search for hydrothermal vents. The hole would refreeze almost instantly, so the trapped instrument would send back information via a cable running up through the ice.

NASA has expressed interest in Lake Vostok because of its similarity to Europa. This moon of Jupiter appears to have a water ocean covered by a thick ice sheet, measuring perhaps tens of kilometers in depth. If hydrothermal vents roil away beneath the ice, chemical reactions on Europa could have created the molecular building blocks for life, if not life itself (see p. 219 and SN: 11/7/98, p. 296).

Vostok would be an ideal testing ground for technology that would eventually fly to Europa or places even more distant, say many scientists. "If we want to be able to search for life on other planets, this [Vostok mission] would be a drop in the bucket," says Sowers.

Though cheap compared with a Europan mission, any expedition to Vostok would represent a significant investment. Participants at the meeting this week in Cambridge discussed ways to harness support from many nations for a mission.

Researchers also debated whether it makes sense to focus on Lake Vostok to the exclusion of other ice-covered Antarctic lakes. "I'm not convinced at all that Vostok is the best place to drill," says Siegert.

Part of the problem is Vostok Station. U.S. officials are reluctant to use the aging outpost because of environmental and safety hazards there, so any expedition would have to set up a camp elsewhere on the lake. According to Siegert, "it may be sensible to drill down into a subglacial lake [that] is located quite close to a serviceable station. And also one that's relatively small so that if it's spoiled in some way, it won't be the best example of a subglacial lake."

Siegert and others have pointed out that a lake lies almost directly beneath the station run by the United States at the South Pole. Because of the facilities already there, a drilling operation near the South Pole would cost less than at the remote Vostok site.

Yet the size of Lake Vostok gives it some unique advantages. Shallower lakes may have frozen in the past few hundred thousand years, during spells when the ice sheet was thinner, says Robin Bell, a geophysicist at Columbia University's Lamont-Doherty Earth Observatory in Palisades, N.Y.

"Since Vostok is so deep, it's very unlikely that it has frozen solid since the ice sheet was built," says Bell, who cochaired last November's Vostok workshop at the National Science Foundation.

The agency recently decided to fund Bell's proposal to complete an airborne survey of Lake Vostok, which will help answer whether Earth's crust is currently tearing apart there. Bell views the agency's action as a symbol of its growing interest in sampling the lake. She says, "This isn't going to guarantee that they're going to go the whole way, but without this they weren't going to do anything."

Future missions depend in part on what Bell finds in the next 2 years while flying a gridlike pattern of traverses over the endless white expanse near Vostok Station. Despite the blankness of the surface ice, though, the geophysicist will have little trouble staying awake as her instruments plumb the depths of the alien lake below. □