Global Warming Underfoot

Holes in the ground hold untapped climate riches

By RICHARD MONASTERSKY

Early in the 19th century, French physicist Jean Baptiste Joseph Fourier realized that the Earth had a story to tell. The plot reached back into the planet's distant past, but the saga was there for all to see, essentially written in stone.

Fourier, who studied the way heat travels, recognized that the Earth's interior served as a recordkeeper, storing information about past temperature changes on the surface. To trace those long-ago events, one could examine boreholes drilled deep into the ground, he reasoned.

Today, more than 170 years later, dozens of geoscientists are probing the underground archives in an attempt to settle some major questions about global warming. "People think there is a real storehouse of information available in the records of borehole temperatures," says Henry N. Pollack of the University of Michigan in Ann Arbor, who organized a symposium on the subject at last December's meeting of the American Geophysical Union (AGU).

He and his colleagues "read" the history of Earth's climate shifts by lowering thermometers into boreholes that reach 100 meters or more below ground. If the climate at the surface has warmed or cooled in the last several centuries, the change shows up on the borehole temperature record.

To understand the technique, consider what happens to the ground in winter. As air temperatures drop, Earth's surface cools. But it takes time for the cold to work its way deep into the ground. Farmers have long recognized this fact, and the old maxim, "Springtime drives the frost deeper," describes how buried pipes often survive the winter only to freeze in the spring, months after the coldest days of the year.

Seasonal warmings and coolings do not seep more than a few meters into the ground. But longer climate changes, lasting decades or centuries, can creep more than 100 meters below the surface.

These major shifts manifest themselves as strange kinks in a record of borehole temperatures. Geoscientists ordinarily would expect a thermometer to detect progressively higher temperatures as it descended into a borehole, since Earth's interior is hotter than its surface. But a shift in climate will warp the steady trend toward increasing temperatures. The depth of that deviation serves as a sort of clock, indicating when the climate warmed or cooled: Information about the most recent events lies closest to the surface because it has not had time to reach deep into the ground.

The current interest in climate change represents an about-face for researchers working with borehole temperature records, who have traditionally viewed evidence of past climate shenanigans as little more than a nuisance. That's because they have generally used borehole temperatures to measure the heat flowing away from the planet's interior. Like static blocking out a song on the radio, the climate signal from the surface only complicated their heat-flow data. Researchers have long avoided this interference by focusing their studies deeper in the borehole, where the climate signal fades out.

Geophysicist Arthur H. Lachenbruch turned that attitude around with a 1986 research paper. After studying boreholes in the Alaskan Arctic for more than half a century, Lachenbruch became convinced that the Earth had something to say in the emerging scientific debate over global warming. In the Nov. 7, 1986 SCIENCE, he and B. Vaughn Marshall reported that borehole records showed a staggering 2°C to 4°C warming in the northern section of Alaska during this century.

The researchers, both from the U.S. Geological Survey in Menlo Park, Calif., could not say whether that change represented the onset of greenhouse warming, but they did hint that the Arctic would be a likely place to look for the first sign of this much-anticipated climate change. Their paper sparked the interest of other geophysicists, who began persuing borehole temperature data in other regions, looking for evidence of climate change.

Some researchers worry, however, that potential misinterpretations of borehole data could give the appearance of a climate change when none had occurred.

In the eastern United States, for instance, many boreholes seem to show warmings because they were drilled in open, tree-free spots, says geophysicist David D. Blackwell of Southern Methodist University in Dallas. These meadows receive more sunlight than the surrounding shady forest, creating patches of abnormally warm ground. Boreholes drilled at such sites offer a skewed picture of climate history, Blackwell says. Many boreholes in the West pose a similar problem because they were drilled on the treeless, south side of hills, which receive more sunlight than nearby areas.

Some skeptics also question whether holes outside the Arctic can yield useful information about climate change. The Arctic is special, they note, because its permafrost remains frozen year-round and does not permit the flow of subsurface water; in more temperate locales, seeping groundwater can alter the borehole temperature record so that it no longer provides a faithful indication of changes in the surface conditions.

New findings suggest, however, that such problems don't mar all borehole measurements taken outside the Arctic. At the December AGU meeting, researchers described successful borehole studies of sites in North America, Africa and even within the glacial ice cap of Greenland. Careful selection of the boreholes enabled them to avoid data biases created by forest clearings or hills, says Blackwell. And in many sites without permafrost, water flow isn't an issue because the boreholes are located in rocks impermeable to underground water seepage, Lachenbruch says.

Several research teams have compared their borehole evidence with records of air temperatures for the same regions and discovered that the two sources told a consistent story. In Africa, Pollack found that boreholes in one part of Zambia showed little temperature change over the last century — a finding that matches air-temperature records for the region. At several sites in Namibia, 2,000 kilometers to the southwest, boreholes indicated a total warming of about 0.6°C over the past 100 years or more, again matching mete-

orological records for that country.

Borehole researchers say their data can provide important climate information that complements findings from other sources. Until now, scientists searching for signs of a global warming have focused mostly on records of air and sea-surface temperatures. But those records don't cover the globe evenly, because remote regions often lack reliable historical archives of temperature. Moreover, most of the usable records reach back no more than a century, and many cover only the last 50 years.

Boreholes, in contrast, portray the last several centuries. Many were drilled in remote areas by companies searching for minerals. According to Pollack, temperature records exist for more than 10,000 boreholes around the world.

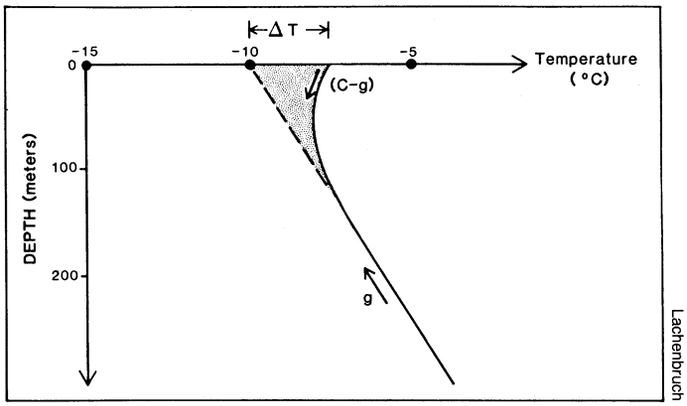
He and his colleagues are working to compile those data, trying to piece together a picture of how different parts of the world have warmed or cooled during the last century. That information can serve as a test for evaluating the reliability of computer models used to forecast future climate changes, Lachenbruch says.

Several geophysicists are trying to alert other global-warming analysts to the rich potential of borehole records, but a number of key players in climate research have yet to hear the news. Climatologist James Hansen, for instance, told SCIENCE NEWS he was under the impression that borehole records could provide useful information only in permafrost areas, and thus had limited applications. Hansen directs NASA's Goddard Institute for Space Studies in New York City, where he models climate change and tracks global air temperatures.

If heat-flow scientists have had difficulty making themselves heard, a rattling of the research coffer might draw some attention. Right now, none of the federal funding earmarked for global-change research goes to borehole studies, but that will probably change, says Ian MacGregor, acting director of the National Science Foundation's earth sciences division in Washington, D.C. Several geophysicists have recently submitted proposals for borehole work related to climate change.

The ground, they insist, has valuable messages to convey.

"If you want to know what the Earth has been doing, ask the Earth, because it remembers," Lachenbruch says. "It's quiet, but it's very knowledgeable. All we've got to do is ask it some questions." □



Throwing a curve: Because of Earth's internal heat, temperatures recorded along a borehole should increase steadily with depth, following the dotted line shown here. However, in this representation of a typical borehole in the Alaskan Arctic, a bend in the temperature record (solid line) reveals abnormally high temperatures near the surface, indicating that the climate warmed during the last 100 years.

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Several researchers say contact with Westerners has whipped up local conflicts in Africa and elsewhere since the early days of European colonialism.

More than a century ago, for example, Tuareg tribes of northern Africa limited their attacks to small-scale raids on caravans passing through their territory, says Candelario Saenz of the State University of New York at Purchase. The Tuareg extorted camels and other goods from the caravans to support their pastoral way of life, Saenz says. But when France took control of Algeria in the late 1800s, it imposed numerous restrictions on trade in the region. Tuareg groups soon entered into a period of nearly constant warfare among themselves as they competed for the rapidly decreasing supply of goods passing along traditional trade routes, Saenz says.

Another instance of Western contact helping to foment violence occurred more recently in the ethnically mixed African nation of Mauritania, says Michael M. Horowitz of the State University of New York at Binghamton, who has conducted fieldwork there for the past four years.

The completion of a large dam on the Senegal River several years ago expanded farmable floodplains and drew the promise of considerable outside investment by Western agricultural companies, Horowitz says. But the local population, long dependent on farming this fertile river valley, already occupied much of the area.

"The Mauritanian government is now killing and torturing these people to get the land," Horowitz says. "In the process, they've created 100,000 refugees and intensified violence between ethnic groups."

Whether stimulated by Western contact or not, most of the 120 wars documented since the end of World War II similarly pit large states against smaller nations or ethnic groups the states claim to represent, says Jason Clay of Cultural Survival, a public-interest organization in Cambridge, Mass.

In the aftermath of the international conflict sparked by the aggressions of the Axis powers, he notes, dictatorships and one-party states ironically solidified their power in many parts of the world, including Africa, the Soviet Union and Eastern Europe. Diverse nations and groups of people with separate languages and cultural histories were yoked to the goals of unresponsive, unelected leaders of both the political right and left, Clay says.

Moreover, those leaders socked away whatever taxes, internal resources, foreign aid and international loans they could extract for themselves, leaving the rest of the populace destitute, he maintains.

"The destruction of social and political life at the local level and the stripping away of resources by modern one-party states has led to longer, more widespread wars," Clay argues. "We'll have more violence at the regional level and the settling of old scores as states fall apart in the post-Cold War world."

Although Clay's dire prediction gathers support from the bloody Soviet crackdown on Lithuania's independence movement and the increasing tensions in other Soviet republics, anthropological research provides room for optimism, says R. Brian Ferguson of Rutgers University in Newark, N.J.

"War is not the natural human condition," Ferguson says. "Research shows that war varies over time due to factors such as trade, population growth and outside contacts."

Often, leaders must paint the enemy as inhuman in order to motivate people to kill, he says — and even then, many soldiers come out of combat with severe psychological aftereffects.

"We need to dispense with the idea that people love violence and are doomed to fight," Ferguson concludes. □