ATMOSPHERIC SCIENCE

Digging in the Mire for the Air of Ancient Times

Bogs are proving to be invaluable archives of airborne contaminants, as a 4000-year record of mercury deposition in a Spanish bog shows

BERN—Back in the 1500s, a visitor decried Ireland's "foul and stinking" bogs, reflecting the prevalent European view of bogs as squishy nuisances. Over the centuries, bogs and moors have been the background for fog-shrouded horror tales, wastelands to be drained for farms, or the raw material for peat cutters. Ecologists have long argued that this reputation is undeserved, for bogs provide critical habitats for numerous threatened species. Now, researchers from Spain to Switzerland to Scotland are giving bogs a new scientific cachet.

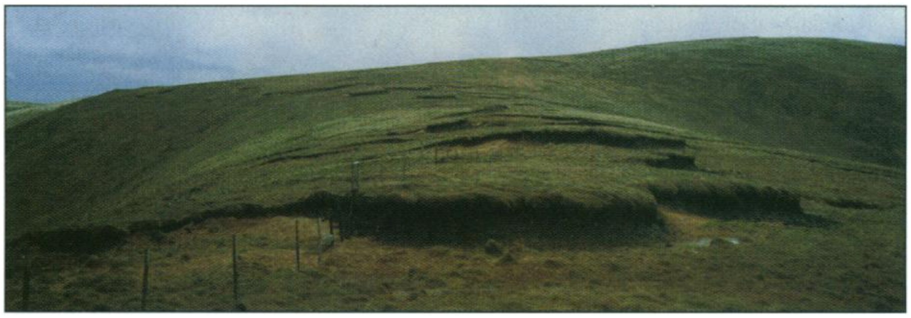
Certain types of peat bogs have proven to be living archives of trace metals, capturing year-by-year records of these atmospheric contaminants from the rain and snow that fall on the surface. The records reflect human activities such as mining; recent results have shown that they also open a window on temperature and humidity trends over thousands of years. In some ways, bogs are "the ideal archive for studying atmospherically delivered pollutants," says Peter Appleby of the University of Liverpool. Because peat layers are compact, bog researchers can uncover a 10,000-year archive by digging down several meters—a fraction of the depth needed to get an equivalent record from cores of polar ice. And bogs, unlike ice, are common in temperate latitudes, revealing past atmospheric conditions there.

"I'm amazed by how much useful data is emerging now from peat bogs," says geochemist William Shotyk of the University of Bern's Geological Institute, who with Appleby and other colleagues has analyzed nearly 15,000 years of atmospheric lead deposition at a bog in Switzerland's Jura mountains to derive a record of lead mining and smelting extending back to before the Roman empire (*Science*, 11 September 1998, p. 1635). In the most recent example, chemist and soil scientist Antonio Martínez-Cortizas and fellow researchers at the University of Santiago de Compostela in Spain have found that a peat bog in northwestern Spain preserves a long-term record of atmospheric mercury levels. As they report on page 939 of this issue, they were able to distinguish human contributions to the record from natural mercury sources such as volcanoes, and they also learned how temperature affects mercury deposition, enabling them to use mercury levels as a new tool for reconstructing the region's climate.

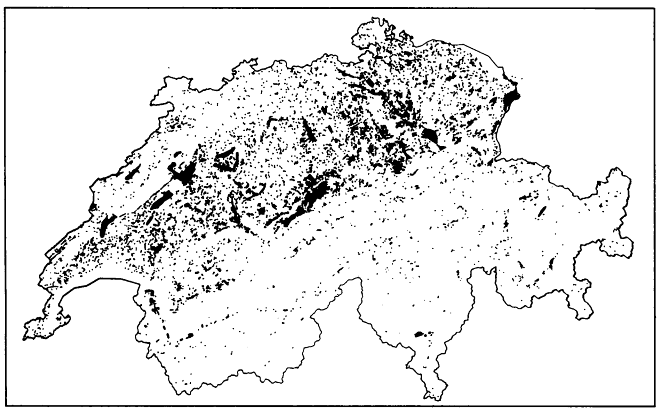
Martínez-Cortizas and his colleagues, like other bog researchers, chose an "ombrotrophic" bog. Such bogs—about a fifth of the total—are fed only by rainwater or snow and not by streams, so that they accumulate trace metals from the atmosphere rather than from the surrounding watershed. The Spanish researchers drilled 2.5-meter-deep cores of the peat with borers, cut the cores into thin slices, and carbon-dated the layers. Peat acts as a sort of filter that chemically fixes mercury, lead, and some other metals, locking them in place even as rainwater percolates through the peat. So by analyzing the mercury concentrations within each layer, the Spanish scientists were able to assemble a record of mercury deposition over time.

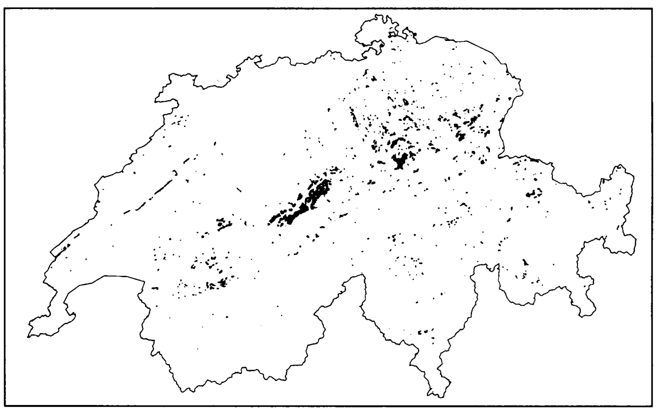
The bog they sampled is just 600 kilometers from what was the world's largest mine of cinnabar, a mercury ore. The layers of mire record a rise in mercury levels starting in the 8th century, implying stepped-up mining during Spain's Islamic period, when metallurgy flourished. They also show an earlier, gradual rise starting 2500 years ago, suggesting that the cinnabar mine may have been worked by the Celts in pre-Roman times, probably at first for the ore's colorful pigment rather than for the mercury it contains.

But the Spanish group found that mining activity—which they traced by examining 500 years of mining records—wasn't the only factor at work. "We were struck by the big increase in mercury accumulation in the bog between 200 and 600 years ago, before the industrial revolution," says Martínez-Cortizas. "Because the mine production



Buried treasure. Peat bogs like this one in northwestern Spain hold records of lead and mercury.





Peatering out. Maps of Switzerland showing bogs in 1800 *(left)* and today *(right)* reveal the effects of drainage and peat mining.

CREDITS: (TOP) UNIVERSITY OF SANTIAGO DE COMPOSTELA; (BOTTOM) SWISS FEDERAL INSTITUTE FOR FOREST, SNOW, AND LANDSCAPE RESEARCH

records do not account for that increase, we believe that the accumulation was related to the colder climate—the 'Little Ice Age,' in the 15th through the 17th centuries."

He and his colleagues think that bogs retain more mercury in cooler weather, partly because the volatile element is less prone to evaporate from the bog surface than it is at warmer temperatures. As a result, says Martínez-Cortizas, bogs contain a sort of mercury thermometer for past climates. To take advantage of it, the team is now working at another Spanish bog to dig cores deep enough to analyze between 10,000 and 20,000 years of paleotemperatures.

Elsewhere in Europe, bog specialists are finding other troves of information in the mires. In Norway, chemist Eiliv Steinnes of the Norwegian University of Science and Technology has analyzed ratios of stable lead isotopes in bogs to determine how much of the lead deposition in Norway comes from atmospheric lead emissions elsewhere in Europe. And Hansjörg Küster, a paleobotanist at the University of Hannover in Germany, is examining pollen from bog and fen sediments to reconstruct the vegetation—and hence the climate—of former times. "Pollen grains and other organic materials are well preserved in the wet soil," he says. A meter below the surface of German bogs, Küster can find pollen from Roman times; 2 to 3 meters down is Neolithic pollen.

Other researchers are trying to learn how bogs capture and preserve trace metals in the first place, which could help guide interpretations of the bog records. Chemist John G. Farmer of the University of Edinburgh, for example, has examined how humic acid, an organic acid derived from peat decay, interacts with metals, a process that can affect whether the metals remain in the bog layers where they are first deposited. And although bog research has traditionally had a European focus, a North American contribution is coming from Stephen A. Norton of the University of Maine, Orono. He has been studying atmospheric deposits of both natural and humanmade radionuclides, which could sharpen techniques for dating recent bog sediments.

Both Norton and Shotyk caution that bogs are not infallible archives. At a recent conference, Shotyk advised researchers to be sure that the bogs they analyze are truly ombrotrophic and that the trace metals being measured have not migrated through the bog, confusing the chronology. Norton adds that the accumulation of atmospheric particles in bogs is not always even and varies with each mire's "microtopography" of small hills and valleys. And Farmer says that researchers trying to reconstruct ancient environments should call on other records as well. "It is important to be able to compare environmental records from peat bogs with those from lake sediments, ice cores, tree rings, and other potential archival material," he says.

Despite those caveats, Shotyk sees a great future in bog research—providing that enough bogs are still available for study. In a report being published this month in the *Journal of Applied Vegetation Science*, Hans Joosten of the Botanical Institute in Greifswald, Germany, estimates that only about 1% of the former mire areas now survive in many European countries, including Germany, the Netherlands, France, and Spain. Drainage programs and peat mining have destroyed many of the rest.

Organizations such as the London-based International Mire Conservation Group have pushed worldwide programs to try to preserve bogs and other wetlands, and Shotyk is urging his colleagues to take up the cause. "The bottom line is that bogs are important for science," Shotyk says. "And we should be trying to preserve as many bogs as we can for future generations."

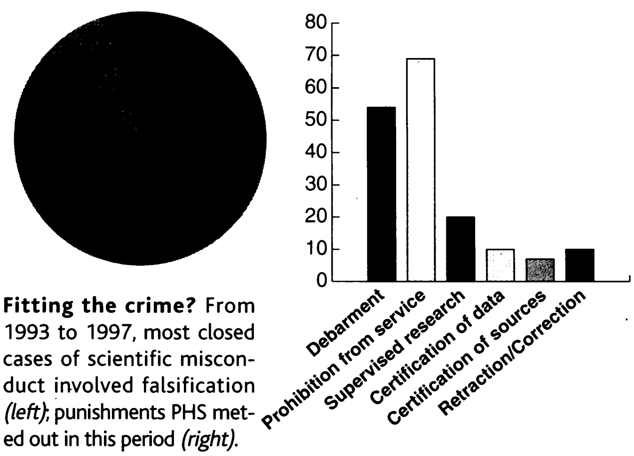
–ROBERT KOENIG

SCIENTIFIC MISCONDUCT

ORI Report Tracks Gun-Shy Feds

The gendarmes of scientific misconduct have changed their look in the last decade, with the federal government increasingly leaving the job of policing research to the universities. According to a report released this spring by the U.S. Public Health Service's (PHS's) Office of Research Integrity (ORI), universities handled 96% of the extramural misconduct cases closed in 1997, up from 64% in 1993.

This single statistic captures both the essence of a policy shift at ORI, which since 1995 has relied on university investigations whenever possible, and a greater willingness among universities to undertake their own investigations, says acting ORI director Chris Pascal. "Many more institutions are up to speed on closing investigations and could do a good job," he says. When PHS misconduct regulations were first adopted in 1989, Pascal says, universities were unsure how to navigate these uncharted waters. But educational programs run by ORI and scientific societies and the chance to learn from investigations at other universities have made the academic world more comfortable policing itself, he says.



Fitting the crime? From 1993 to 1997, most closed cases of scientific misconduct involved falsification (*left*); punishments PHS meted out in this period (*right*).

SOURCE: ORI

But not everyone views ORI's laissez-faire approach as a good thing. "ORI just turns down a lot of cases" that it should perhaps take, asserts one university official who has worked with the office, noting that since 1994 ORI's policy has been to kick back to the universities plagiarism cases involving collaborators, which the office uniformly labels as authorship disputes.

One trend apparent in ORI's report is that allegations of scientific misconduct are ebbing. The 150 investigations tracked by ORI between 1993 and 1997 grew from nearly 1000 allegations, which peaked in 1995 at 244 cases, falling to 166 in 1997. Of the cases investigated, roughly half resulted in misconduct findings. ORI also cites its own alacrity at disposing of cases, pointing to its success at clearing a backlog from its predecessor office and closing over half of inquiries within its 60-day standard; 38% of investigations, however, dragged on for over 240 days. Besides being punished by their home institutions, those found guilty of misconduct were typically barred by PHS from serving on review panels or receiving grants (see chart). Thirteen percent had to retract or correct publications, and a handful did so voluntarily.

The report also highlights a trend evident in earlier ORI studies (*Science*, 28 February 1997, p. 1255): Lab personnel lower down the totem pole are most likely to be found guilty of misconduct. This pattern held even though the accused were most often associate professors (27%), professors (19%), and postdocs (19%), with professors and deans making up the lion's share of whistle-blowers. Women were more likely than men to be found guilty—with Thereza Imanishi-Kari, the target of a decade-long investigation, a well-known exception.

–JOCELYN KAISER