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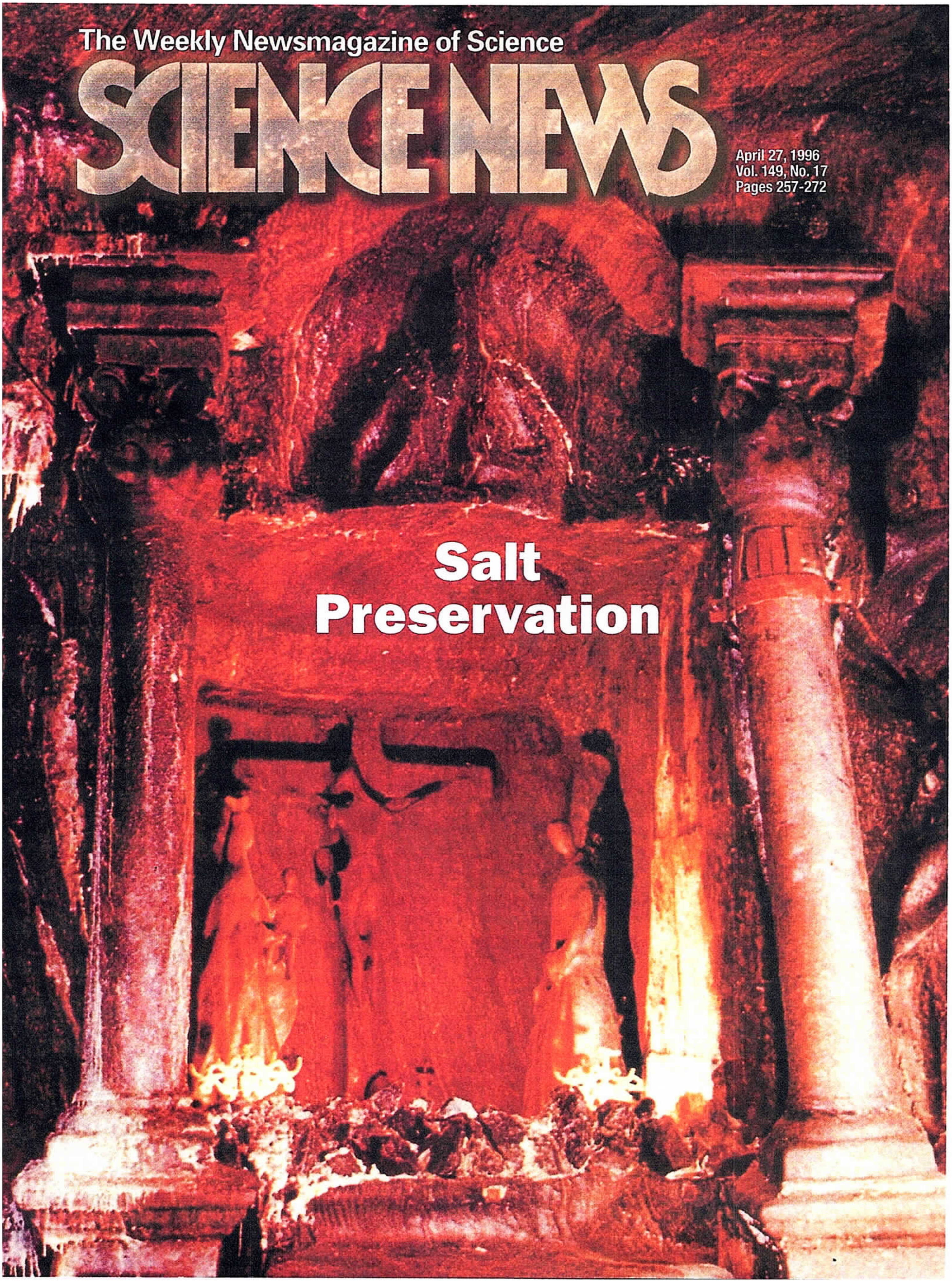
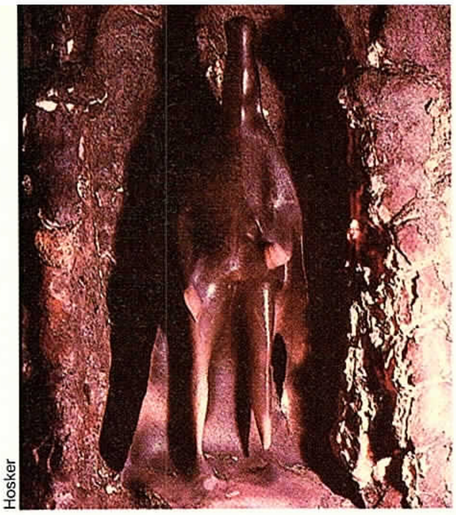


Salt Preservation

A Salty Heritage

Licking the problem of Poland's melting treasures

By JANET RALOFF

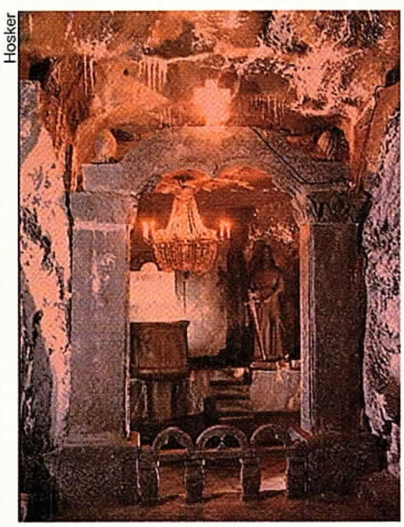

Hosker

Once-crisp features on some of the oldest sculptures, dating from the 1600s, have totally disappeared.

In the 6 centuries preceding widespread mechanical refrigeration, a succession of Polish monarchs enhanced their fame, wealth, and cultural glory by trading in salt. This natural food preservative, extracted from a vast, crown-owned mine near Kraków, was sometimes as costly as gold. In fact, the mine often provided one-quarter or more of the king's annual revenues.

Though the miners derived great prestige from their labors, the human cost of obtaining this subterranean treasure was high. In the 16th and 17th centuries, some 10 percent of the workforce at the Wieliczka (vye leech´ ka) mine died each year from methane explosions, collapsed shafts, and exhaustion.

Not surprisingly, workers there started each shift by invoking God's protection. Indeed, beginning in 1689, the mine employed a priest to hold daily masses in one of the earliest excavated salt chambers. This small, vaulted room was named St. Anthony's Chapel for the patron saint of metal miners.


Hosker

Stalactites mar St. Anthony's ceiling.

Wieliczka's managers also encouraged crews and, later, outside artists to decorate the mine's dark interior. Over the centuries, the resulting freestanding statues, bas-relief carvings, and immense chandeliers—all carved from salt—have gained worldwide artistic and cultural renown. In fact, few who emerge from the mine describe the effect of these carvings as anything less than awesome and breathtakingly beautiful.

In the last century, however, the earliest and some of the most valuable of the carvings—those adorning altars and niches within St. Anthony's Chapel—have melted into featureless blobs. So severe was the deterioration that in 1978 the Wieliczka mine became one of the first eight entries on the United Nations' inventory of endangered world cultural heritage sites. Since that time, 461 other sites have been added to the list.

"Sadly, none have been removed by virtue of having been saved," notes Robert Milne of the World Heritage Center at the U.N. Educational, Scientific, and Cultural Organization (UNESCO) in Paris.

Now, an international team of scientists, after a detailed analysis, has proposed a technological fix for Wieliczka's dissolving artwork. If that hardware—now on order—arrests the erosion of the St. Anthony's carvings, Milne told SCIENCE NEWS, this salt mine could very well become the first World Heritage site to be removed from the endangered list.

The international program to save Wieliczka's carvings was jump-started in June 1989, when a team of scientists who had been attending a Kraków symposium on air pollution and historic monuments made a field trip to the mine. Susan Sherwood, then an archaeologist with the U.S. National Park Service, was stunned by the experience.

"The Wieliczka salt mines are perhaps the most amazing cultural resource in the world," she says. The 265 million cubic feet of excavated passages descend almost 1,100 feet under ground. Along this route, miners have cleared more than 2,000 galleries. A number of these rooms, some as large as cathedrals, contain extensive carvings that range from the whimsical to the pious, from the historical to the mythological. Throughout are gleaming walls, floors, and ceilings—of naturally dark salt.

Despite the lasting majesty of the statues in Princess Kinga Chapel, deep within the mine, those near the entrance, particularly in St. Anthony's Chapel, are a travesty. Indeed, notes Glen Cass, a chemist from the California Institute of Technology in Pasadena, what had once been the carefully chiseled likeness of a man "now looks like a space alien. All of its features have been eroded, leaving just an oval for a head."

Several Polish architects, convinced that air pollution was causing the problem, suggested the scientists visit the mine, Sherwood recalls. Noting the moisture evident throughout St. Anthony's Chapel, however, the scientists were dubious that pollution was the culprit. What was clear, she says, "was that this was a problem we could solve."

"We would have been happy to undertake [the research] for free," says Cass, except that "there are too many travel expenses and materials required."

On returning home, Sherwood applied for a grant from the Marie Curie Fund. Administered by the U.S. State Department, the fund uses zlotys collected in repayment of Polish debts to help finance cooperative U.S.-Polish research.

Money came through to fund two separate studies—one focusing on humidity and the other on pollution—both led by U.S. scientists.

Explains conservation chemist Roman Kozlowski of the Polish Academy of Sciences in Kraków, "at the beginning, we knew little about methods for studying microclimates," such as how temperature, humidity, or airflow may vary within a single room. But Ray Hosker knew what to do. Director of the National Oceanic and Atmospheric Administration's turbulence and diffusion laboratory in Oak Ridge, Tenn., he designed a procedure to compare such factors inside and outside the mine. Then he took portable monitoring equipment to Poland and trained Kozlowski's team to use it for a year-long analysis.

The findings confirmed that St. Anthony's Chapel has a serious moisture problem—one that apparently began around

Lynn Salmon/Caltech

Kinga Chapel's carvings, deep within the mine, remain well preserved.

the turn of the century, when mechanical ventilation systems to draw out the dangerous methane began pulling warm outside air through the mine's cool shafts at a rate of some 35,000 cubic feet per minute.

The problem was aggravated in recent decades, Kozlowski says, when commercial mining at Wieliczka was phased out in favor of an increasingly more lucrative activity—tourism. From April through October, the humid air accompanying elevator loads of sightseers, along with the increased ventilation air, quickly condenses onto the cooler salt surfaces in the upper regions of the mine. A thin layer of water forms, at times actually dripping. This seems to explain the salt stalactites on the ceiling of St. Anthony's Chapel.

Pure rock salt does not begin picking up water until the relative humidity reaches about 75 percent. Once it does, Cass says, there is an "explosive pickup" of water. While the humidity deep in the mine oscillates seasonally between about 55 and 65 percent, Kozlowski and Hosker found that the relative humidity in the chapel can reach periodic, midweek highs of 75 percent by April—and by July it stays at that level around the clock.

To investigate whether crowds of visitors—with their warm, hot breaths—might pose an independent risk to the sculptures, Kozlowski's team studied humidity changes in small chapels deep within the mine as tourist groups filed through. "We found no need to limit the number of people coming," he says, "because they are not contributing to the damage."

A second study, led by Cass, showed that the Polish architects hadn't been entirely wrong. Pollution entering with the tourists and ventilation air had blackened a few sculptures that had started out white. This pollution also accelerated the moisture buildup by changing the surface chemistry of the salt in such a way as to lower significantly the relative humidity at which it begins to dissolve. Cass, Kozlowski, and their colleagues describe their findings in the March ENVIRONMENTAL SCIENCE & TECHNOLOGY.

Salt efficiently collects sulfur dioxide, a constituent of acid rain and the polluted air in the Kraków environs. While large amounts of this gas enter with the ventilation air, Cass' team found little in the mine air, even in St. Anthony's Chapel, because the sulfur dioxide collects so quickly on salty surfaces.

A complex mix of soot and other dustlike pollutants, some of them chemical salts that are different from the sodium chloride native to the mine, also adheres to the surfaces. Although rock salt remains bone dry until the surrounding air reaches a relative humidity of 75 percent, the mix of polluting salts, such as ammonium nitrate, begins building a thin film of water on its surface at a relative humidity as low as 20 percent. By 74 percent, the polluted surfaces are clearly saturated.

"At present," Cass observes, "no one really knows how much water you can tolerate in a liquid film before you begin to get runoff"—and a melting statue.

Based on these findings, "one of the senior scientists suggested the solution was just to close the mine during the height of the tourist season," Sherwood recalls. That idea was rejected because the primary reason for preserving the mine was so that people could enjoy it. Moreover, the nearly 1 million visitors who file through each year help pay for the state-sponsored mine's costly maintenance.

"We brought up the idea of dehumidifying the incoming air with a chap in Denver who specializes in air conditioning mines," Hosker says. The U.S. scientists recruited funds to fly this engineer, Wayne Fry of Fry Equipment Co., to Poland for a quick tour of Wieliczka. He hadn't been home long before he donated a detailed design of a glorified dehumidifier to patch into the mine's existing ventilation system.

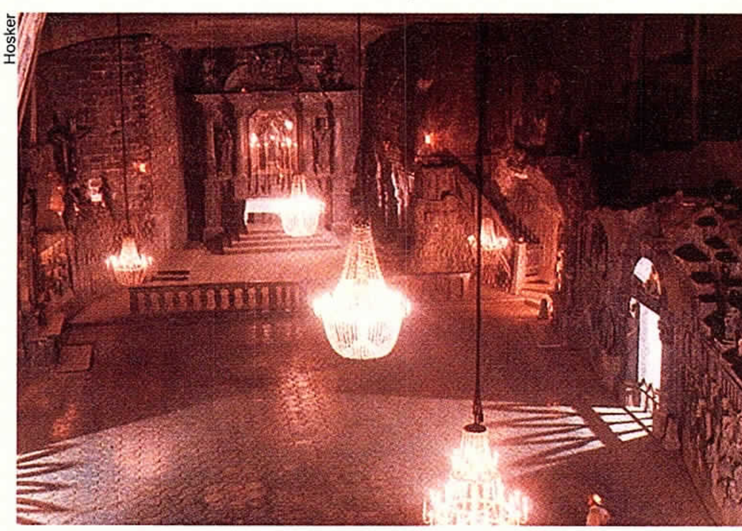
Sherwood helped raise a total of about \$100,000 from UNESCO and the Curie Fund to pay for the hardware required. The first test of the system, slated for delivery by a Polish contractor before summer, probably won't take place until next year, Kozlowski notes, because the mine anticipates making some extensive changes to its ventilation system while the new equipment is being installed.

Once the dehumidification system is up and running, however, conservators from the Academy of Fine Arts in Kraków plan to begin restoring St. Anthony's Chapel. They've already begun testing crushed salts and epoxy resins for repairing some of the badly dissolved carvings.

Was it worth the equivalent of \$100,000 and 6 years of international collaboration to establish that a wet salt mine was experiencing humidity problems? Absolutely, Kozlowski asserts. Money is one of Poland's most limited resources, and the studies financed by the Curie Fund "were a very important condition to getting that grant to buy the [dehumidification] equipment."

Moreover, Cass notes, the chemistry studies established that, because of the pollutants entering the mine, the new system will have to lower the relative humidity below that sufficient to protect pure salt. Until the pollution on the statues' surfaces was analyzed, he points out, no one could have estimated reliably how much lower that humidity needs to be.

These studies may also prove applicable to other sites, such as tombs and churches, Cass adds. Over time, chemical salt compounds—from pollution, water damage, microbes, even mortar or cement—can permeate porous building materials. If the relative humidity varies seasonally in these structures, as it often does, he says, the salt that's accumulated will alternately dissolve and recrystallize. This can damage a wall by fracturing the porous material. Salt that migrates from within a wall can also damage a fresco or other paint on the surface.



Hosker

From the chandeliers' crystal pendants to the marble-patterned floors, salt dominates in the Kinga Chapel.

At Wieliczka, everyone "got an extremely high return on every dollar that was spent on this project," maintains René Eppi, former NOAA director for international programs in central and eastern Europe. He points out that for U.S. researchers, "there was no cost other than their time."

Concludes Hosker, "I can't believe there is anyplace else like it [Wieliczka]. It's gratifying to have a little hand in preserving it." □