

## The Geopolitics of Nuclear Waste

*A scientist's contention that the United States is building its waste site in a region of unstable hydrology has unleashed a flood of controversy, but it has won few supporters*

YUCCA MOUNTAIN, A BLEAK VOLCANIC RIDGE in the Nevada desert, emerged from obscurity in the 1980s when it was chosen as a potential graveyard for the intensely radioactive waste produced by U.S. nuclear plants. In 1987, Congress decided to strike all other candidates from the list and, as waste accumulates in utility storage ponds, this remote and unpopulated hillside has become an epicenter of controversy.

The program to build a waste repository at Yucca Mountain, run by the Department of Energy (DOE), has been criticized by virtually every Nevada politician. Now DOE scientists at the site have also been drawn into a bitter and paralyzing debate about risks to public health, focused at the moment on some arcane aspects of local geology. DOE has been told that it must find a place where deadly waste canisters can be buried without disturbance for 10,000 years. It is hard to find anything that remains unchanged for that long, and the attempt to use science to "prove" that Yucca Mountain will remain dry and stable for 10 millennia is causing trouble.

The big item at the moment is the risk of flooding. The debate on this concern is likely to erupt again in the next few weeks as DOE releases the latest of several expert reviews of a disturbing theory developed by one of DOE's own staffers in Las Vegas, an engineering geologist named Jerry Szymanski. DOE paid for this study after Szymanski criticized an earlier (and negative) review of his ideas as biased.

Szymanski thinks the proposed \$15-billion repository would sit on top of an intensely active structure that, if altered by an earthquake, would send a slug of groundwater up from deep in the mountain into the waste storage area. The canisters in it, if still hot, would produce steam and possibly break, leaking radionuclides to the outside world.

Szymanski's theory, and particularly his methods of promoting it, have upset a lot of people. It has already been slammed in two formal reviews and has virtually no support among geologists. Some are openly hostile.

For example, John Stuckless of the U.S. Geological Survey, coordinator of geochemical studies for Yucca Mountain, dismisses the Szymanski thesis, saying, "it reminds me of clinical ecology," a dubious medical specialty that links cancer to all kinds of manufactured products, including common plastic. "The guy's a moving target," adds Douglas Rumble, a geochemist at the Carnegie Geophysical Laboratory in Washington, D.C. He says Szymanski has never published any peer-reviewed articles and seems to change his arguments each time he's challenged.

But other researchers in DOE and the USGS praise Szymanski for coming up with original ideas about the geology of the "basin and range" in southwestern Nevada. Most, however, are highly skeptical that a flood could occur at Yucca Mountain's repository level, more than 300 meters above

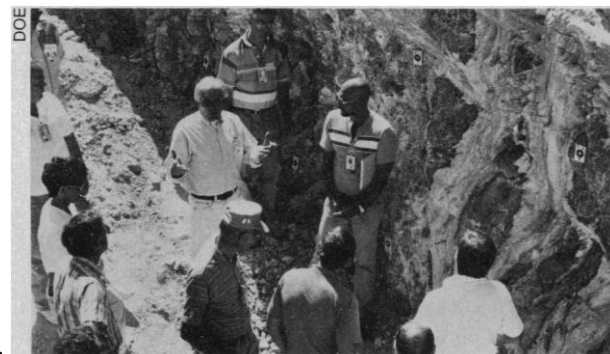
the other way and "trying their level best to defend the indefensible." Asked for his opinion of the plan to put radioactive waste in Yucca Mountain, Price replied, "The only worse thing that I can think of would be tipping it down the volcanoes in Hawaii."

Carl Gertz, DOE's director of the Yucca Mountain project, says he intends to resolve the controversy by submitting it to a thorough, objective peer review. He has already spent more than \$1 million on peer review and is not yet close to solving his problem. The definitive study is likely to be performed by a 17-member panel at the National Academy of Sciences, chaired by C. Barry Raleigh of the University of Hawaii. It's due by the end of the year.

Meanwhile, other forces converging on Yucca Mountain will soon draw attention to the scientific arguments over the site. For one, state officials in Nevada, who have been using every obstacle at their command to block the project, are withholding the permits DOE needs to finish its exploratory research. The state also has filed suit in federal court to stop the program on constitutional grounds. Though the appeals court last year rejected its arguments unanimously, the final word may come down from the Supreme Court in the next month or two. Now the Bush Administration reportedly has included in its energy plan a section that would remove Nevada's authority to issue (or deny) environmental permits at Yucca Mountain, handing it over to a federal agency instead.

The scientific dispute has been simmering since 1987, when Szymanski, an expert on nuclear plant siting with a master's degree from the University of Warsaw, released a paper describing his theory. As he says, his ideas are "very novel" and "unorthodox." The tectonic and convective forces beneath Yucca Mountain, he claims, are so volatile that they could rearrange the geology of the site in a relatively short time, during the 10,000-year lifetime of the repository. This is a "certainty," in his view. He argues that there is good evidence that a catastrophic rise in the water table could occur and that, in fact, it has occurred in the past.

To grasp the situation, Szymanski argues, one must understand a set of interacting



**Trench warfare.** Do calcite deposits in trench 14 come from ancient groundwater or rainwater?

the present water table, deep in a parched desert.

A handful of researchers do take Szymanski seriously, however. Neville Price, for example, one of two people nominated by Szymanski to serve on a five-person independent panel reviewing his claims for DOE, gives his unreserved support. For 20 years Price taught structural geology at Imperial College, London, and is now an oil company consultant associated with University College, London. Price says that he and Szymanski's other panel nominee, seismologist Charles Archambeau of the University of Colorado, are "absolutely convinced" that Szymanski is right. The other three members of the panel, says Price, are leaning



thermal and hydrologic forces at work in the rocks under the desert. He maintains that Yucca Mountain now sits on what he calls a local "sink." The extensional (pulling apart) stress in its rocks is exceptionally high, the fractures are open and capable of absorbing large quantities of water, the water table is low, and the flux of heat from deep in the earth is suppressed. Adjacent to it, he says, are "source" regions, where all these conditions are essentially reversed: the stress is low, the water table is high, and convective heat moves upward more vigorously, producing higher temperatures near the surface. Szymanski contends that there is nothing permanent about the spatial location of a sink or source region; that, in fact, they move about the topography depending on conditions in the underlying rock. He also claims to be able to identify these regions by the distinctive "fingerprints" produced by the ratio of certain isotopes in local deposits.

Yucca Mountain, Szymanski says, though now a sink, has been a source in the past and will be a source again in the future. If it changes from one condition to the other within the next 10,000 years, he argues, the proposed repository site—now more than 300 meters above the present water table—will almost certainly be swamped.

Szymanski put these ideas together as he was coordinating some geological studies for the Yucca Mountain program and wrote them up in a 322-page report. In December 1987, he sent copies to Gertz and a colleague working for the state of Nevada, who passed it along to then Governor Richard Bryan (Democrat). Bryan had run for office as an opponent of the repository and since then has been elected to the U.S. Senate on the same platform. When he got Szymanski's unreviewed paper, he called in the press and distributed it, using it as ammunition in his campaign against DOE.

Scientists at DOE and the Geological Survey, some of them with decades-long experience in the complex geology of the Southwest, were furious. They are still angry, and some of their outrage surfaced last month in *Eos*, the journal of the American Geophysical Union. AGU president G. Brent Dalrymple of the U.S. Geological Survey blasted the press, Szymanski, and Szymanski's allies in a

front-page editorial. Popular accounts portray Szymanski as a lone, "little guy fighting the big, dumb bureaucracy," Dalrymple claimed. But, he wrote, in this case the loner "bypassed the conventional routes" for testing hypotheses and gaining scientific support. Instead, he "released his findings to the popular press and to those politicians eager to be rid of any waste disposal site." Dalrymple adds that "dozens of scientists have reviewed [Szymanski's] work and found little merit in it."

Many geologists who have read Szymanski's papers agree that the significance of his forecast has been exaggerated, even though his description of the forces in the basin and range makes sense. But the USGS experts argue that there is almost no evidence to support his claim that there will be a large, long-term shift in the water table. Mathematical models created at the Sandia

may be scarce, Archambeau, one of Szymanski's supporters, says he knows of two earthquakes that produced over a cubic kilometer of fluid—in Japan and near the Nevada-California border—within the past 25 years by "seismic pumping." This phenomenon is usually short-lived, but even a short gush such as this could damage the Yucca Mountain repository if it were large enough. However, Archambeau could not cite any well-established cases in which the water table had shifted hundreds of meters as a result of an earthquake—as it would have to do to fulfill Szymanski's prediction for long-term flooding of the repository. On the other hand, Archambeau claims that Death Valley, California, which is near Yucca Mountain, is full of high-elevation springs and may represent what Yucca Mountain would look like after a shift in the sink/source locations.

As proof that the water table was high at

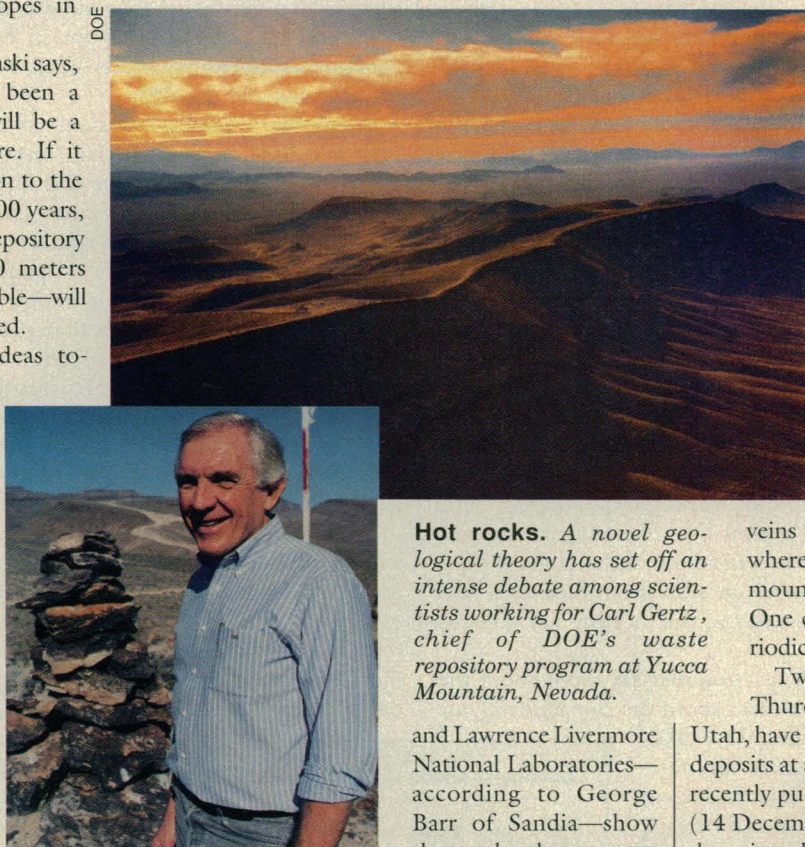
Yucca Mountain in the past and could be high again, Szymanski has focused attention on a series of calcium carbonate and opal veins exposed in an exploratory pit, known as "trench 14," near the top of the mountain. Here, he has told many people, is clear evidence that groundwater had once covered most of the hillside, leaving behind some thick mineral deposits. Price also insists that these veins are an "unequivocal" sign that groundwater flowed through the area. "The structures of the

veins that I saw in trench 14 and elsewhere are like the veins I have seen in mountains in areas around the world.... One can explain them in terms of periodic upwelling of fluids."

Two researchers, Jay Quade and Thure Cerling of the University of

Utah, have an alternative explanation for the deposits at a high elevation: rainwater. They recently published their evidence in *Science* (14 December 1990, p. 1549). By sampling deposits where the source of water is well known, they established a set of isotope values that they could use to identify carbonates created by deep groundwater, those created by trapped or "perched" water at a high elevation, and those created by rainwater. They then demonstrated that the carbonates in trench 14 match up with local perched or rainwater deposits and not with the groundwater deep below Yucca Mountain.

Archambeau is not persuaded. He sees no reason why trench 14 carbonates must match the signature of present-day groundwater beneath Yucca Mountain. He says that other



**Hot rocks.** A novel geological theory has set off an intense debate among scientists working for Carl Gertz, chief of DOE's waste repository program at Yucca Mountain, Nevada.

and Lawrence Livermore National Laboratories—according to George Barr of Sandia—show that under the most ex-

aggerated assumptions, the long-term changes will be no more than "tens of meters" up or down. Furthermore, says Isaac Winograd, an early student of this area known to some as the USGS "guru" on Yucca Mountain, the historic record indicates that no earthquake has shifted the water table by more than about 10 meters in this area of the Southwest. More important, Winograd says, even these fluid excursions don't last long, perhaps a year at most. "Szymanski tends to ignore geologic time," he says.

While the evidence for large water flows



groundwaters in the region have an isotopic signature like the trench 14 carbonates, and he suggests that in the past, when these carbonates were formed, Yucca Mountain may have been gushing with groundwater of a different kind—the kind that is typical of a Szymanski source zone.

Though Archambeau and Price have helped give Szymanski's theory credibility, it has yet to pass muster in formal peer reviews. In fact, it has flunked the two reviews completed so far. The first was conducted by a group of experts retained by the state of Nevada and the second by a panel of federal scientists chaired by William Dudley, Jr., of the USGS. Though only the DOE-USGS

review has been made public, *Science* has obtained, among others, a critique performed for the state by University of Nevada seismologist James Brune. In it, Brune comments that Szymanski's thesis seems "unlikely" and appears to be "scientifically unsound." Yet he writes that the possibility that it is correct "cannot be discounted."

Brune judged the discussion of earthquakes to be especially weak because it leaned on a theoretical model developed by a Bureau of Mines geophysicist named Brian Brady. In the early 1970s, Brady proposed his own method for predicting earthquakes and then, in an infamous case, went on to apply it. He forecast that a major quake would hit a town

in Peru on a specific day. It caused an international flap and a local panic, and when the day came, there was no quake. Brune says that an analysis performed by Clarence Allen of the California Institute of Technology found Brady's theory to be "completely untenable." The fact that Szymanski relied so much on it, Brune wrote, "casts a great deal of doubt on the validity of this part of the report."

Asked if he had read these comments and written any response, Szymanski told *Science* he had not bothered. He dismissed them as the work of contractors, whom he speaks of as "fleas." However, Brune was pleased to see that Szymanski's final draft—a sprawling 911 pages long—omits the Brady references.

## Flap Erupts Over Dioxin Meeting

Everything about dioxin is so politically charged, even the science, that the organizers of a Banbury Center dioxin conference last fall expected their meeting would generate some controversy. But no one anticipated the furor that erupted in early February when participants learned that a public relations firm hired by the Chlorine Institute, which helped pay for the conference, was circulating a "consensus" summary of the meeting. The document, not surprisingly, supports the industry line on dioxin.

"I'm outraged," says Ellen Silbergeld, a toxicologist at the University of Maryland, who insists that the press materials—which none of the participants approved—misrepresent her views. "I agreed to participate based on my previously held high regard for Banbury and Cold Spring Harbor," she wrote in a letter to Banbury Center director Jan Witkowski. "I did not expect to be manipulated by industry or government spokespeople." Silbergeld sent copies of her letter to all the participants and to the press.

"It was basically mishandled," sighs Witkowski, who admits to a degree of naïveté in dealing with such a "highly politicized" issue as dioxin. He has just written a letter to all the meeting participants explaining that the Banbury Center in no way authorized the press materials that were sent out. "I am very sorry that what was intended to help promote the goals of the meeting has gone so awry," he wrote.

The intensity of Silbergeld's reaction may say more about the extreme sensitivities over dioxin than about the culpability of any of the parties involved, all of whom have taken some heat. The flap nevertheless illustrates what can go wrong when the roles and agendas of sponsors and participants aren't clearly spelled out.

What Silbergeld, who was formerly with the Environmental Defense Fund, finds most disturbing about the events is the "violation of process." And she has found an unexpected ally in Vernon Houk, director of the Center for Environmental Health and Injury Control at the Centers for Disease Control. Houk is in almost total disagreement with Silbergeld on the dangers of dioxin—he believes that they have been vastly overrated. Yet Houk told *Science* that he, too, is "disturbed" by the publicity campaign. "I don't think it is fair to

represent consensus when none was really sought," says Houk. Silbergeld's view is also supported by a number of the other participants, albeit with somewhat less emotion, who say they feel manipulated and misused.

When the Chlorine Institute, an industry trade group, approached Banbury director Jan Witkowski early last year about holding a dioxin meeting, he had no inkling it would turn out differently from the 15 or so other meetings the center runs each year, some of which are also sponsored by industry. And to the Chlorine Institute, the time was ripe for another look at dioxin's risks, given shifting sentiments among at least some scientists that dioxin may be less dangerous than previously believed. Chlorine Institute officials thus believed that a scientific meeting could be "beneficial to our interests, particularly our interest in the paper industry," explains Joe Walker, the institute's head of communications. Walker is referring to the enormous pressure the paper industry is now under to reduce the amount of dioxin that arises as a by-product in the bleaching process.

The Chlorine Institute lined up Robert Scheuplein of the Food and Drug Administration to run the meeting. He then asked Michael Gallo, a toxicologist at the Robert Wood Johnson Medical School in New Jersey, and Cornelius A. van der Heijden, a regulatory official in the Netherlands, to chair the meeting with him. From then on, the Chlorine Institute studiously kept itself out of the picture, say both Witkowski and the meeting organizers.

The three organizers picked all participants, with one exception: George Carlo, who was invited as an observer for the institute at its request. Carlo, an epidemiologist and lawyer who heads the Health and Environmental Sciences Group in Washington, D.C., is a regular consultant to the institute.

The meeting itself went surprisingly well; indeed, some agreement was reached by people from opposite sides of the dioxin debate on a number of issues. For example, there was nearly unanimous agreement that, in light of a new understanding of dioxin's molecular actions, the Environmental Protection Agency should take another look at how it assesses the risk of this chemical. Several people, most notably the meeting organizers, speculated

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—JAN WITKOWSKI

The Dudley report, issued by DOE in July 1989, was just as harsh as Brune's analysis. The summary said that while some reviewers found Szymanski's ideas "constructive" and "stimulating," "most doubt that there is sufficient technical basis to warrant pursuing the author's hypotheses further." The authors singled out one problem in particular that others have complained about since—namely, that the thesis provides no numerical model that can be used to estimate the magnitude, frequency, or duration of the events Szymanski postulates.

Szymanski did not respond in detail to these criticisms, either, but said they are typical of the kind that come from people

who have been trained to think about geology and hydrology in static terms and are hostile to new ideas. "I do not want to be presumptuous," he said, "but prior to Charles Darwin, people had the idea that species remain unchanged; Darwin showed that they evolve. The situation is similar with hydrology."

Although Szymanski has taken a couple of heavy blows in the first rounds of peer review, the debate has not yet run its full course. Judging by the kind of arguments Price and Archambeau are using now—comparing the veins in trench 14 with even thicker (and relatively young) deposits elsewhere on Yucca Mountain—DOE and the

USGS may have to collect a lot more information on the quality, size, and location of carbonate deposits in the area before they will be able to present a complete case on the origin of the material in trench 14.

Meanwhile, the DOE staff continues to plug away at the massive "site characterization" effort at Yucca Mountain, costing about \$1 million a day. Gertz says the government is prepared to continue in this investigative mode, spending up to \$4 billion, until it is satisfied that it has laid to rest all reasonable concerns about safety. That is a huge financial investment. But at least it is paying for some intriguing geological research. ■ ELIOT MARSHALL

that such a reexamination would reveal that EPA overestimates how risky dioxin is—though others, like Silbergeld, rejected that idea (*Science*, 8 February, p. 624).

But the harmony was to prove short-lived. In retrospect, most participants with whom *Science* spoke say they failed to realize that the meeting was sponsored by industry, along with the EPA, even though the invitation clearly said so. And none of the participants *Science* spoke with, nor even meeting co-organizer Gallo, knew Carlo was there as the institute's observer. Silbergeld, Houk, and others say they have no problem with industry sponsorship of scientific meetings—as long as everyone's role is clear.

At the meeting Carlo heard the message the Chlorine Institute hoped he would. The institute's intention, from the outset, was that "if the conference outcome was favorable we would take advantage of it and bring it to the attention of key people in the media," says Walker. They hired Edelman Medical Communications to do just that.

Witkowski saw no problem with the institute publicizing the results of the meeting—after all, they paid for half of it—as long as it was well done. But what he thought would be a straightforward press release turned into a fiasco of crossed signals and miscommunication. For example, Gallo, Scheuplein, and van der Heijden were delighted to cooperate—and indeed, each wrote his own one-page summary of the meeting for the public relations firm. But Gallo and Scheuplein now complain that they had assumed that Edelman was representing the Banbury Center, not the Chlorine Institute.

In addition, Witkowski's only condition in agreeing to the press release was that he have final approval. As agreed, the Edelman staff sent him the cover letter to the press, which he edited to remove any references to the Cold Spring Harbor Laboratory. But in December, Edelman sent out a press packet that included, along with the statements from the three chairmen alluded to in the letter, a background paper purportedly written by Carlo that none of the organizers or participants had seen. The paper asserted, among other things, that the Banbury meeting "reinforced the notion that dioxin is much less toxic to humans than originally believed."

The cover letter also differed from the version Witkowski had approved in two important respects. First, it referred to the meeting



**No consensus.** *Ellen Silbergeld's objection to the press release won support from other participants.*

as a "consensus conference." Says Witkowski: "Just those two words set the whole framework. It was not a consensus conference. That is what is causing all the trouble." What's more, the draft he approved carried a disclaimer, which was missing from the final version, saying that the three statements were the views of the chairmen and not the conference as a whole. Meeting organizers Gallo and Scheuplein also object to the letter—essentially to the two offending words—and insist that they never saw it.

When Silbergeld got hold of the press packet from a reporter at the end of January, she exploded, writing a letter to Witkowski that took all of the parties to task. Events then took a bizarre twist when Carlo, who received a copy of Silbergeld's letter, called Witkowski to say he had not written the paper after all and had no idea how his name ended up on it.

Carlo has since launched a massive telephone campaign—calling the participants and this reporter repeatedly—to clear his name. Carlo concedes that he did work with Edelman and the Chlorine Institute in developing the paper but asserts, nonetheless, that, "No one has the right to put someone's name on a document."

Nancy Turett, senior vice president at Edelman, admits to putting Carlo's name on the paper—she says because he was so extensively involved in drafting it. "The end product is very much a reflection of what Dr. Carlo thought should be in it," says Turett, who says she assumed that the Chlorine Institute had cleared the final document with Carlo. Institute officials say, meanwhile, that they thought Edelman had gotten Carlo's permission.

Turett also takes the blame for the revised letter, calling it a simple editorial mistake. "I thought there was a consensus. There is no big agenda. It is just a cover letter." She called *Science* back to add, however, that Edelman never distributes a single word without the client's approval.

All of which leaves Witkowski at the Banbury Center shaking his head in disbelief. He realizes, much to his dismay, that this flap threatens to "poison" the entire meeting and undermine the fragile—and unexpected—agreement the group forged on the molecular action of dioxin. "That is the kind of thing you would hope would happen at a scientific meeting," says one participant who asked to remain unnamed. "It was like a little flower just starting to bloom, then along came this mess. I feel very sad." ■ LESLIE ROBERTS