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The Radwaste Paradox

Political pressures push for a speeding up of the geologic disposal program, but technical considerations may call for a slowing down

Early explorers and settlers of the Colorado Plateau, in coming to a deep bathtub-shaped valley just east of what is now the Colorado-Utah state line, were astonished at how the Dolores River, a tributary of the Colorado, cuts across the valley and through its steep walls at right angles. They called this place "Paradox Valley," and the much larger geologic province in southeastern Utah and southwestern Colorado of which the valley is a part was to become known as the Paradox Basin. As it happens, the Paradox Basin is one of the places where the U.S. Department of Energy (DOE) is looking for a site for a deep-mined repository for high-level radioactive waste. This seems appropriately symbolic because the geologic disposal problem has increasingly taken on the aspect of a political and technical conundrum, replete with real or seeming contradictions and paradoxes.

A central paradox is that, while the concept of sequestering long-lived wastes in mined repositories is attractive intuitively, the very efforts made to confirm the suitability of particular rock formations give rise to further uncertainties, at least in the early years of the site investigations. Overcoming these uncertainties, which are arising in every rock type and at virtually every site under investigation, takes time and may in some cases require the stretching out of schedules. But under the radwaste legislation approved by Congress last month (see box) the present DOE schedule for site selection and licensing could be accelerated by more than 2 years. The new law contemplates that, barring certain discretionary extensions, repository construction will start as early as 1989.

This is 6 years away and many people in Congress and the nuclear industry find it hard to understand why it should take any longer than that to find a suitable site and begin excavating a mine and getting rid of the waste. The scientific and technical questions associated with deep geologic disposal of radwaste—especially heat-generating high-level waste—are sufficiently specialized and obscure that for most people it seems that, as the saying goes, "you can't appreciate the problems until you get there."

Top DOE officials have themselves sought to push the geologic disposal program to a faster pace than the one DOE was following at the end of the Carter Administration. "I've tried to see that the schedule is accelerated," Deputy Secretary of Energy Kenneth Davis told *Science*, adding that a congressional mandate for a still faster schedule "could be helpful." In his view, it is likely that not just one but several of the sites under investigation will be usable. "I don't see a problem," he said. "My expectation is that it will be a question of which one to choose, not which one is acceptable."

Public health and safety does not require early disposal

DOE and the nuclear industry are feeling pressure from Congress and the public to demonstrate final disposal of radwaste. Public health and safety does not require early disposal; indeed, with passage of time the radioactive decay of the shorter lived fission products reduces the waste's heat and makes ultimate disposal easier. The pressure to move quickly is political and stems from the fact that, with the nuclear enterprise now in its fourth decade, it is an acute embarrassment that the waste problem has not been solved.

These circumstances seem to have produced what are in a sense two facets to the geologic disposal program. One is the difficult, time-consuming, brow-mopping research and development effort that the DOE staff people and contractors are struggling to carry out in the field. The other is the self-confident, briskly paced program that the nuclear industry and its supporters in Congress and the higher echelons of DOE see as vital to the industry's political needs and ultimate survival.

The National Waste Terminal Storage (NWTS) program, as the DOE geologic disposal effort for commercial high-level waste is known, is large and far-flung, especially compared to radwaste disposal programs abroad. In Germany, which has gone further than any other foreign country in its efforts to establish a radwaste repository, the geologic investigation has focused exclusively on one rock type, salt, and on one site, the Gorleben salt dome of Lower Saxony. By contrast, DOE, to hedge its bets and to meet the requirements of the Nuclear Regulatory Commission (NRC), is investigating multiple rock types and multiple sites. Moreover, the sinking of large exploratory shafts at three sites is a prerequisite to the filing of a repository permit application. The shafts will allow lateral entry into and testing of the rock formation at the repository horizon.

The multiplicity of sites and rock types in part reflects a political need to "spread the misery" by demonstrating that no one part of the nation will be expected to bear the entire burden of nuclear waste disposal. Taken overall, the NWTS program constitutes an enormous geologic research effort; its budget is now approaching a quarter of a billion dollars a year and is rising.

Furthermore, by virtue of political circumstances, the demands of the NRC and the National Environmental Policy Act, and DOE's own sense of technological caution, the department is committed to an elaborate program review process in which the agency not only solicits but pays for kibitzing by outsiders. The U.S. Geological Survey (USGS), for instance, has recently been brought into the program to a far greater extent than ever before. Similarly, most of the potential repository host states are becoming increasingly involved in the review of program plans and data pertaining to the investigation of sites within their boundaries; in some cases these DOE-state relationships have been going acrimoniously, in others more harmoniously, but with the exception of Nevada, all of the host states have chosen to enter into formal arrangements of one kind or another with DOE whereby they are supposed to receive project information regularly.

To find sites for the two repositories that are expected to be needed by early in the next century, investigations have been under way for some time in four different kinds of geologic formations in

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six states: the old basalt lava flows of the Columbia Plateau at DOE's Hanford facility in Washington; the welded tuff (another kind of volcanic rock) at the Nevada Test Site, not far from Las Vegas; bedded salt in the Paradox Basin of southeastern Utah and the Palo Duro Basin in the West Texas panhandle; and salt domes in Louisiana and Mississippi. Within a year or so field work is expected to start in the Precambrian shield granite of the upper Midwest and in the granite of the Appalachian Mountains.

The next major step in the NWTS program is to come in 1983 and early 1984 with the sinking of exploratory shafts at Hanford and the Nevada Test Site, in basalt and tuff, and at a salt site to be chosen from among the four salt locations which DOE still has under investigation. One of the three sites picked for exploratory shafts will, under the present DOE schedule (which the radwaste legislation may accelerate), be selected for a licensing application by 1988. Also, either at one of these sites or at some other, an unlicensed "Test and Evaluation Facility" for temporary storage of a few hundred waste canisters would be built and put in operation by the fall of 1989. A second repository site would be chosen in the early 1990's.

But the experience so far at the several sites suggests that the technical and political questions tend to proliferate rather than diminish as more becomes known about the geology and hydrology.

The Hanford basalt. The priority being given the Hanford basalt and the Nevada tuff has not come about because those geologic media have been known from the first to be suitable for radwaste disposal. In fact Rockwell International, the DOE contractor at Hanford, was called to account in 1981 by its Hydrology and Geology Overview Committee (a group made up largely of university-based scientists) for stating that the Hanford basalt was under study "because of the favorable geology of the site."

The committee observed: "We trust this is not a representative attitude. There is really only one solid justification for studying this site and it is the sociopolitical fact that the land is a U.S. nuclear reservation. From a hydrogeological perspective, the Columbia River Basalt Group as a whole is not well suited for a high-level waste repository. It may well be that with further data and/or careful engineering design it can be shown to be acceptable, but it cannot be stated that the 'geology is favorable.' "

The political climate for the basalt project is more or less sympathetic in the Hanford vicinity, where the people have long been familiar with things nuclear. But elsewhere in the state attitudes are reserved, to say the least. In 1980, Washington citizens voted overwhelmingly for a ballot initiative to limit or prevent nuclear waste—high as well as low level—from being shipped in from outside the state (a law that has since been declared unconstitutional). Governor John Spellman, with support from DOE, has recently established a task force to bring the basalt project under close state review.

DOE realizes that it is on its mettle to show that the basalt investigation is being conducted in a rigorously scientific manner. The participation of the USGS in this investigation has in recent months been earnestly solicited. This marks a big change from the late 1960's and early 1970's when the basalt studies were starting under ARCO, the DOE contractor at the time. The USGS scientists found ARCO so unresponsive to their suggestions and critiques that they chose to withdraw.

Now, the USGS is focusing on the hydrologic regime in the basalt, in particular on the possible pathways by which radionuclides could be transported from the repository site to the Columbia River. Rockwell believes that the discharge point is quite distant and that it would take 40,000 years or longer for radionuclides to reach the river, an estimate which if accepted would satisfy regulatory criteria by a wide margin.

But the USGS has not yet reviewed Rockwell's data or its data-collection methods, and remains to be convinced. "We feel that the groundwater flow system could be discharging all along the

Waste Bill Approved

Finally reaching agreement in the waning days of the 97th Congress, the House and Senate on 20 December passed legislation that is intended to bring a federal-state accommodation on radioactive waste disposal.

The main barrier to final passage was lifted when Senator James McClure (R–Idaho), chairman of the Energy and Natural Resources Committee, yielded to the threat of a filibuster on an issue deemed of critical importance by potential repository host states. Their position was that, if a repository site selected for licensing application by the Department of Energy (DOE) and the President should be unacceptable to the host state, its "veto" of the site should stand unless overridden by both houses of Congress.

Although there was substantial congressional support for this position, the bills first passed by the House and Senate had not gone that far, each body having chosen instead to give the host states a veto that would stand only if sustained by at least one house of Congress. But Senator William Proxmire, whose home state of Wisconsin contains granite formations that are of interest to DOE, was able to take advantage of the lateness of the hour by threatening to filibuster unless the state position was accepted.

McClure, as Senate manager of the legislation, chose to give in to Proxmire rather than see the legislation die, just as a previous radwaste bill had died in 1980 at the close of the 96th Congress. This broke the impasse, with the Senate agreeing by voice vote to the bill with the more liberal state veto provision. Final passage in the House was by a vote of 256 to 32.

The concession made to the potential host states should give them strong leverage in their dealings with DOE, whom some of the states (particularly Utah) have accused of failing to give them complete and timely information and of attempting to push the site selection process too rapidly.

But environmental lobbyists, citing what they perceive as important defects remaining in this long and complex piece of legislation, would have preferred to see the measure die. They found especially objectionable some procedural shortcuts on environmental review and a provision calling for DOE to present to Congress within 2½ years a site-specific proposal for a Monitored Retrievable Storage (MRS) facility for spent fuel or high-level waste. They see in the MRS the possibility that the goal of permanent disposal of radwaste might be abandoned. But nuclear industry lobbyists and DOE strongly favored passage of the legislation despite the major concession to states' rights. DOE has felt hamstrung for lack of the kind of statutorily defined federal-state "consultation and cooperation" mechanism that the legislation provides.—**L.J.C.**

river." John B. Robertson of the USGS told *Science*. To resolve this issue, a special review group has been established, with Rockwell, the Battelle Pacific Northwest Laboratories, and the USGS all participating, and with the Lawrence Berkeley Laboratory serving as referee.

But a variety of other questions also has been raised. For instance, fractures found in core samples suggest that the basalt is under high horizontal compressive stress. Besides complicating the design and construction of the repository, the stress might induce fractures and create new pathways for radionuclides to escape.

Now there is even a question whether the very large, 20-foot-diameter shaft needed for a repository could be constructed deep into the basalt. "At the moment, a big issue is can they in fact sink a shaft," say Harry Smedes, a respected field geologist formerly with the USGS who is now an adviser to the NWTS program leaders. "Knowing that the upper third of the formation has a lot of water-bearing beds in it, they feel that you have to drill an enormous borehole rather than use the conventional drill-and-blast, dig-it-out method where you've got men down in the hole. It's really pushing the state of the art. It depends on what drilling company you talk to as to how optimistic or pessimistic an answer you get."

The Nevada tuff. The investigation of Nevada tuff—a rock formed not from the extrusion of lava flows but from the welding together of pumice, ash, and other material hurled out of volcanoes in explosive eruptions—is going on at Yucca Mountain, in an area that takes in the southwest corner of the Nevada Test Site and extends over onto other federally owned land. This location seems to have considerable potential as an area for disposal of radioactive waste. For one thing, the test site, which covers 1350 square miles, is already contaminated from three decades of nuclear weapons testing and presumably will be kept under tight institutional control for a long time to come. For another, some 1600 to 2000 feet of the tuff lies above the water table and this "unsaturated zone" may constitute an excellent geologic medium for radwaste disposal.

But some major technical issues have arisen in the Yucca Mountain investigation and remain unresolved. For instance, a potential earthquake problem came to light as the result of tests conducted only last spring. The tuff was found to be under high tensional tectonic stress—stress that tends to separate the rocks—and this makes existing faults in the area susceptible to movement in the event of a sizable earthquake in the larger region, which is seismically active.

From a technical standpoint this finding has not been considered particularly alarming; many mines have survived earthquakes, and, it is felt, a properly engineered Yucca Mountain repository could withstand such an event. Nonetheless, according to William W. Dudley, the USGS coordinator for the welded tuff investigation, the discovery that the probability of earthquake activity at the site is greater than was once believed, though perhaps not greater than 1 in 10,000 for any one year, created a stir among the project managers because of the regulatory and political problems that might be provoked.

DOE has reason enough to take such problems seriously, because, by some indicators, the Nevada political environment for radwaste disposal has changed from warmly receptive to coldly hostile. As recently as 1978 a radwaste repository was viewed by Nevada political leaders as a possible economic boon. But during the last few years both Governor Robert List, a Republican, and the Democratic candidate who beat him in November, Attorney General Richard Bryan, have led a crusade to shut down a commercial low-level waste facility at Beatty, not far from the Nevada Test Site.

Why this change in the political climate? In an interview in early 1981, Governor List said, "It goes back to the atmospheric testing of the 1950's. The AEC misled the public. People don't trust the authorities. They are cynical. We have families who remember, survivors who litigate in the courts, high public awareness."

Salt beds and salt domes. A fundamental concern on the part of officials in the salt states—particularly Utah, Texas, and Mississippi—is that DOE has not stuck to what was to have been a sequential, step-by-step approach to site screening and selection. Instead, to keep from having to abandon its plan to select a salt site for an exploratory shaft this coming May, DOE has chosen to go to a dual-track approach. Construction of the exploratory shaft will proceed while at the same time the collection of hydrologic data continues—data on which originally the site's selection for full "characterization" was to have in part been based.

For either bedded or dome salt the cost of constructing an exploratory shaft and doing the necessary in situ tests is expected to run somewhere between $30 million and $50 million. Thus, by going to this phase without adequate hydrologic data, DOE is gambling that the site will not be disqualified on the basis of information that comes in from test wells located around the site—information which could be gathered *before* the costly shaft is built if more time were allowed.

William Fisher, director of the Texas Bureau of Economic Geology, observes that something else besides money is being put at risk—DOE and the waste program's credibility. "I personally would prefer that they not take that risk," he says. According to Fisher, DOE has so little hydrologic data for the Palo Duro Basin, where a specific site remains to be pinpointed, that geohydrology cannot be used as a screening tool. Yet in and around the areas of interest there is, he says, some evidence within the formation of "interior dissolution."

In March 1981 the USGS advised DOE by letter that the chances for predicting subsurface geologic and hydrologic conditions were "significantly better in bedded salt than in dome salt." The basic reason for this, as indicated in the USGS letter, is that, while bedded salt formations can vary, they are in general characterized by a relatively simple "layer cake" geology of salt interbedded with other kinds of material and overlain by rocks from the erosion of surrounding highland areas.

Salt domes, on the other hand, are far more complex. They were formed when deep layers of bedded salt, being relatively light and buoyant, pushed up through weak places in the overlying rock, rising thousands of feet until they approached the earth's surface, where characteristically the dissolving action of groundwater on the salt and the consolidation of less soluble materials has formed a caprock.

"A good way to visualize it," says Smedes, "is to take a bunch of colored cloths or old rags and let each color represent a different rock type and have them stacked up like a layer cake, and then draw this entire mass up through a hole you've made by thumb and forefin-

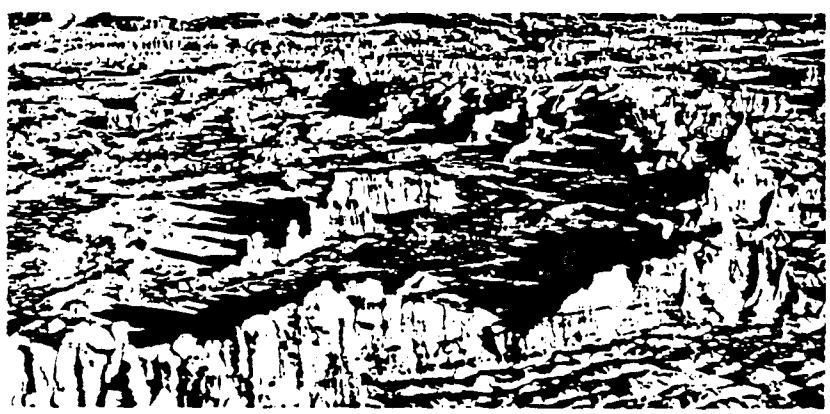
William J. Broad, who has been a News and Comment reporter since 1978, is leaving *Science*. He is joining the science staff of the *New York Times*.

ger. You'll notice there are very complex vertically oriented folds, highly convoluted. Then if you snip part of that off and make a horizontal section, you'll see how complicated these crenulations are, largely vertically oriented but really like a marble cake. To the extent that these different rock types have desirable and undesirable hydrologic or mechanical properties, you can see the difficulty, the near impossibility, of trying to predict or determine ahead of time what the configuration is."

Complex as dome salt may be, all salt, as a generic rock type, presents complications because of the brine that it contains. The brine, as has been known since the 1960's, tends to migrate toward the facility is to be built, from the north end of the site to the south end. Major brine pockets, incidentally, seem to be associated more with bedded salt than dome salt.

While salt beds are in general simpler than salt domes, DOE's investigation of the bedded salt of the Paradox Basin in Utah has not followed a happy or predictable course. Test boreholes have been drilled at four locations in the basin, and, unluckily, the best of them from a geologic standpoint has seemed to be a site in Davis Canyon within less than a mile of Canyonlands National Park.

Moreover, according to Robert J. Dingman, a consultant to the Utah state geologist, the most likely path for any



Canyonlands National Park

A promising bedded salt site is less than a mile from the park. Collection of hydrologic data may require drilling in the park itself.

a heat source and, unless excessive temperatures are avoided, waste canisters could become immersed in a hot, highly corrosive bath.

For the most part the brine exists as microscopic "inclusions" in the salt. But it can also occur in large pockets, sometimes under pressure sufficient to blow out a well or create havoc in a mine. Twice now over the 8 years that DOE's Waste Isolation Pilot Plant (WIPP) project for military transuranic waste has been in progress near Carlsbad, New Mexico, drilling rigs have hit brine pockets.

The last time was November a year ago when DOE, acting at the insistence of state officials, sought to determine the nature of an anomaly that had been detected in a seismic survey near the north end of the proposed repository. Although not a show stopper, the discovery of this brine pocket, together with indications of some other irregularities or anomalies present at depth, led DOE to agree recently to a state recommendation to shift the repository's location, if radionuclide transport by groundwater is toward the park and the Colorado River. Collection of the relevant hydrologic data will require borehole drilling inside the park itself, Dingman believes. This requirement, if confirmed (DOE disputes Dingman's finding), could ignite further controversy about the exploration for radwaste disposal sites on the edge of a national park.

Last July, Utah's Governor Scott Matheson, disturbed at a DOE decision that the selection of a salt site for an exploratory shaft shall not be subject to a full environmental impact review, ordered state agencies to withhold all assistance from DOE, for example, denying permits for the transport of overweight drilling rigs on state roads. The effect has been to put the Paradox Basin investigation under a virtual moratorium.

Numerous scientific groups, in the United States and abroad, have concluded that the concept of the deep mined geologic repository for the disposal of radioactive waste is feasible. But the American experience to date in four rock types—basalt, tuff, and bedded and dome salt—shows that carrying out this concept is no simple, straightforward engineering task. A USGS official, testifying before a congressional committee last June, cautioned: "How successfully and quickly [the major geologic issues] can be resolved remains uncertain, in our opinion. Answers to many of the questions require innovative experimental procedures of large geometric dimension and long time periods."

Another authority, Paul A. Witherspoon, until recently head of earth sciences at the Lawrence Berkeley Laboratory and a leading expert on granite as a disposal medium, has proposed to DOE and the NRC, thus far unsuccessfully, that for every rock type and every candidate site a large-scale, 5- to 10-year experiment costing up to $39 million should be conducted to simulate the effect of heat from waste canisters on the rock mass.

According to Witherspoon, the experiment would serve mainly to influence repository design and the spacing of the waste packages but it might in some cases reveal a site to be unsafe and unacceptable. "I've heard a lot of program managers say, 'If we find a problem, we'll engineer around it.' That, in my opinion, is a very naive approach," Witherspoon told *Science*.

Despite all such cautionary advice from the experts, the cliché that "radioactive waste disposal is a political but not a technical problem" continues to be heard. It reflects a misapprehension of the realities of geologic disposal which is obviously quite widely held in Congress as well as in nuclear industry circles.

In 1970 the geologic disposal program suffered a political setback from which it has never fully recovered when the Atomic Energy Commission (AEC), acting precipitiously, announced that the nation's first repository would be built in a salt mine at Lyons, Kansas. The proposal soon had to be withdrawn, for the site was shown to be ill-chosen and possibly unsafe. DOE is not likely to make, or to be allowed to make, mistakes as obvious as those the AEC made at Lyons. But unless the technical realities of geologic disposal are respected for what they are, with NWTS schedules adjusted as needed to fit those realities, further political embarrassments could well lie ahead.—LUTHER J. CARTER

A contributing writer to Science, *Carter is doing a study for Resources for the Future of the nuclear waste problem as a world dilemma.*