European Deep Drilling Leaves Americans Behind

Ambitious American plans to compete in the race to inner Earth have fallen prey to budget cuts and shifting motivations

AMERICA IS RIDDLED WITH more than 2 million holes. Ten thousand new ones are drilled each year, all in search of oil and minerals. Academic researchers want just a few more, but done their way. Compared to the $6 billion for a Superconducting Super Collider, the cost would be nominal. All the same, plans for world-class scientific drilling of the continents have foundered on Gramm-Rudman budget cuts, infighting in the earth sciences, and unrealistic cost projections.

Meanwhile, foreign drilling programs are churning ahead. After a 5-year shutdown for retooling, Soviet drillers this month are renewing their 20-year drilling effort in their world-record hole. They have already penetrated 12 kilometers into the crystalline rock of the far northern Kola Peninsula, and they are aiming to go several kilometers more. In West Germany, researchers have been guaranteed the quarter-billion dollars they need to drill a 10-kilometer hole in Bavaria, starting next August. But back in the United States, the deepest scientific hole drilled so far, sunk next to the San Andreas in Cajon Pass, reached a mere 3.5 kilometers in 1988 before cost overruns and budget cuts indefinitely suspended it short of its relatively modest 5-kilometer goal.

Los Alamos National Laboratory

Deepest of its kind. *This diamond drill rig is sinking a hole in the Valles Caldera that is the deepest (1762 meters) and hottest (295°C) continuously cored U.S. hole.*

Why the great drilling gap? The answer lies in how many different ways drillers can sell a deep hole in the crust. When Soviet scientists and engineers took up deep drilling two decades ago, they sold the idea on scientific, economic, and technological grounds. As a result, they have set the standard for big-time drilling ever since they started the Kola hole in 1970. By 1975, they had replaced a standard oil drilling rig with new technology capable of ultradeep drilling and reached a depth of more than 7 kilometers. In the process, they certainly fulfilled any promises needed to launch the project. They totally revised theories of the structure of the crust there and discovered unsuspected copper and nickel ore of economic grade beneath an adjacent mining district.

These accomplishments determined the direction of Soviet scientific drilling to this day. To the Soviets, deep holes are not simply tools for testing geological theory. They expect more. One additional payoff is improved drilling technology. Another is insight into the deepest strata beneath known mineral resources. The route from technology development and deep exploration to practical applications is a short one—after all, the Ministry of Geology, which runs scientific drilling, also operates the Soviet oil, gas, and mining industries. And there is always the unspoken allure of the Sputnik effect—the glory of having the deepest hole in the world.

Mark Zoback of Stanford University, who headed the abbreviated Cajon Pass drilling effort, sums up the Soviet effort this way: "It's probably not worth the money scientifically, but the Soviets did not justify it solely as the testing of scientific hypotheses. They decided to explore the crust, develop technology, and do some science. When you take it all together, maybe it's worth it."

The Soviets must believe so. After making 7 kilometers of headway in 5 years at Kola, they struggled for 9 years to pierce the next 5 kilometers before getting stuck at 12 kilometers. Costs for this drilling reportedly ran to more than $100 million, but they were not about to quit. They are now ready to drill again after 5 years of straightening and lining the hole and upgrading equipment. The target depth: still 15 kilometers.

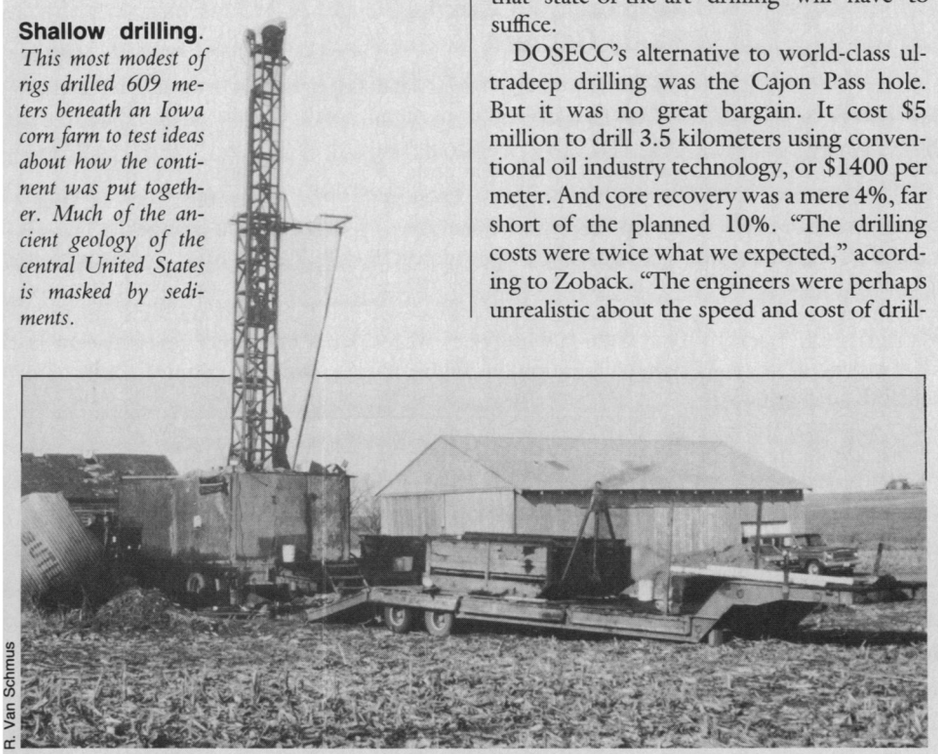
And that is by no means their only ambitious project. Seven other Soviet scientific holes are being drilled, the deepest of which is the Saatly hole in the oil region near the Caspian Sea. At 8.3 kilometers and still going, the Saatly hole is another example of Soviet doggedness. It is still under way after 12 years, although the going is so tough the drilling team has progressed only 300 meters during the past 7 years.

West German researchers have no intention of taking a decade or two to drill their 10-kilometer ultradeep hole. They have their money—all anyone thinks they will ever need—and they are well along in what has to be the Mercedes Benz of drilling programs. They could buy a top-of-the-line program because all $250 million for the KTB project, as it is called, is new money—none of it had to come out of another scientist's pockets. As Heinrich Rischmuller of the KTB project in Hannover tells it, the German Minister of Research and Technology was looking for a project—it could have been anything from a new telescope or a high-energy particle collider to a deep hole—that would not be exorbitantly expensive but would still appeal to the public. If it enhanced West German prestige, all the better. With no chance of losing any of the funding they already had, German geoscientists presented a united front in their successful bid for an ultradeep hole. As a fringe benefit, they will have new technology to sell abroad as well.

So far, things are going well for the Germans. They completed their development and testing phase during the drilling of a 3.5-kilometer pilot from late 1987 to early 1989. Taking a cue from the Soviets, they never tried the existing oil drilling technology. Instead, the Germans merged oil drilling equipment designs with those from the mining industry and added their own modifications. Standard oil drilling rigs penetrate soft sedimentary rock quickly, but in hard crystalline rock they leave a ragged-shaped hole and return only chips of rock for analysis. The high-speed, diamond-tipped drilling bits of mining rigs cut a smooth hole and reliably return sample cores the entire length of the hole. But mining rigs have had depth limits of 5 kilometers or less and had produced holes too narrow for the array of instruments scientists must lower into them.

All this technological innovation costs money, lots of it. Drilling costs alone for the 10-kilometer hole, excluding the cost of doing the science, are estimated at $110 million, or $11,000 per meter. That is at least several times the amount most people had had in mind for ultradeep holes.

U.S. researchers, alas, have had few of the advantages enjoyed by their German and Soviet colleagues. In the end, using deep drilling to find mineral deposits, develop technology, or boost national prestige did not sell. The Americans have had to fall back on selling solely the science of deep drilling, and even the earth science community has not been all that receptive. Not that the drilling community did not try. The origins of current drilling efforts can be traced to a meeting in 1974 at Ghost Ranch, New Mexico. Taking a cue from the can-do American oil industry, participants at the Ghost Ranch conference placed their faith in conventional oil drilling technology, estimating that a 9-kilometer hole could be drilled in crystalline rock for only $1000 per meter in 1975 dollars.



R. Van Schmus

Shallow drilling. *This most modest of rigs drilled 609 meters beneath an Iowa corn farm to test ideas about how the continent was put together. Much of the ancient geology of the central United States is masked by sediments.*

The same faith in a relatively simple technological solution to deep drilling still prevailed in 1984 when three federal agencies signed an interagency accord on continental scientific drilling. In the accord, the U.S. Geological Survey, the National Science Foundation, and the Department of Energy agreed to coordinate their drilling efforts. At the same time, a university consortium called Deep Observation and Sampling of the Earth's Continental Crust (DOSECC) was formed to operate a drilling program for NSF. Egged on by a Reagan White House looking to beat the Russians, DOSECC chose as its first priority an ultradeep 10-kilometer hole in the southern Appalachians (*Science*, 29 June 1984, p. 1418).

The cost of joining the "ultradeep club" with the southern Appalachian hole looked to be $2000 to $3000 per meter—one-quarter what the Germans would decide is a reasonable figure—but in the end even that kind of money could not be raised. The departure of drilling advocate Ralph DeVries from the White House Office of Science and Technology Policy eliminated what nationalist motivations there were for going that deep. His departure also marked the last time that the funding of technology development had much appeal, according to Robert Andrews of DOSECC. The tone of reviews of NSF proposals suggest to him that state-of-the-art drilling will have to suffice.

DOSECC's alternative to world-class ultradeep drilling was the Cajon Pass hole. But it was no great bargain. It cost $5 million to drill 3.5 kilometers using conventional oil industry technology, or $1400 per meter. And core recovery was a mere 4%, far short of the planned 10%. "The drilling costs were twice what we expected," according to Zoback. "The engineers were perhaps unrealistic about the speed and cost of drilling. I wish it were cheaper and deeper, but we have a lot to learn." The learning process involved how to deal with sections of hole that opened to three times the diameter of the drill bit, rubble falling into the hole, and drill pipe that jammed.

As if mechanical problems were not enough, the Cajon Pass hole suffered budgetary woes as well. Funded year by year starting in late 1986, the hole got a go-ahead for fiscal year 1988 when NSF's Continental Lithosphere program was slated for about a 100% increase. Everybody from Congress to the White House was behind the increase—until the October stock crash and Gramm-Rudman budget restrictions prompted Congress to scrub it. That stopped Cajon Pass in its tracks.

Even some earth scientists were not sorry to see it abandoned. Deep drilling, even at a cost of a few million NSF dollars per year, is big science for geologists, who usually work alone with students or in small, temporary groups. Their field equipment can consist of a map, a rock hammer, a tent, and a jeep. And there is a widespread feeling among geologists that such work had been shortchanged even before the advent of deep drilling. "The message is that the earth science community is not ready to support deeper drilling," says Andrews, "as long as funding is insufficient for small geological proposals."

After 5 years of steadily declining ambitions, the U.S. scientific drilling community is settling on an approach that could be palatable all around: shallow rather than deep drilling, at least for the time being.

Shallow drilling is nothing new in the United States (*Science*, 4 August, p. 468). The Department of Energy, which has its own drilling group, has drilled four holes of less than 1 kilometer each into the just-cooled volcanoes of the Inyo volcanic chain in California. Drilling problems were minimal, and the recovered cores fundamentally altered the way the Inyo drillers, at least, view the behavior of erupting magma, all for less than $400 per meter. Three DOE shallow holes into the Valles Caldera of New Mexico punctured a geothermal system actively depositing minerals. The drilling cost was $600 per meter. And DOSECC's 609-meter hole near Quimby, Iowa, confirmed a couple of hypotheses about how the continent was put together, at the bargain basement cost of $83 per meter.

Shallow drilling is clearly doable, but the hard part of creating a continuous, reliable program will be to coordinate projects spread around a variety of government agencies. "There has been coordination [under the three-agency accord] and it works," says Andrews. "Now they're trying to build something formal." According to participants in the ongoing negotiations, the coordination would be tightened to the point that a true national drilling program would emerge with the three agencies laying out a multiyear plan of jointly evaluated holes. Until now, it has been every agency for itself, the one with drilling money at times inviting the others to join in the science. The catch is DOE's relatively narrow mission to investigate scientifically the heat energy of the crust. If the agency does not see a fair share of the holes targeting thermal targets, it will not be able to participate.

Whether any dependable scientific drilling program emerges, outside of DOE's, remains to be seen. Most observers are guardedly optimistic, but, given that, as one scientist puts it, "Murphy was a driller"; they are ready for the worst.

■ RICHARD A. KERR