tributions to the study of microparticles in polar ice cores. Not only has the BPRC group been responsible for most of the advances in that field over the last quarter-century (*1*), but the Thompsons have pointed out more than once in the last decade the dramatic contrast in microparticle deposition rates on the polar ice sheets between Wisconsin and Holocene times (*2*) that was discussed in the article.

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Hot Dry Rock: More Promise Than Problem?

In "Hot dry rock: Problems, promises" (Research News, 27 Nov., p. 1226), Richard A. Kerr portrays the Los Alamos hot dry rock (HDR) program as one that has set its goals too high, has not met these goals, and is recovering from "nearly disastrous damage to their system." As Kerr states, "all went reasonably smoothly" from 1974 until 1979, as Los Alamos completed the world's first HDR system at a depth of 2.75 kilometers (km) in granite rock and successfully operated it for 3 years (*1*). While we sympathize with the British motive for wanting to continue research more conveniently in low temperature rock at shallow depths, efficient and easily usable geothermal energy requires temperatures higher than 200°C. Hence, it was decided that the American program would address the formidable problems of creating and operating fracture systems in deeper, hotter, and more highly compressed rock. Since 1982, we have worked at depths and temperatures of at least 3.6 km and 240°C.

True, we encountered problems with drilling and fracturing the hotter rock. As Kerr states, after reviewing difficulties with our first new well, EE-2 (energy extraction hole 2), a panel of drilling experts provided guidance for the next well; but, of course, their advice could not be applied to the already completed EE-2. Nevertheless, EE-2 served us well for 3 years, until it was damaged during a 1983 hydraulic fracturing experiment as a consequence of a piping flange failure. The well was repaired temporarily and was used for three more years. Although this is hardly "disastrous damage," the well was limited in production rate, which accounts, in part, for our inability to achieve the goal—35 megawatts of thermal power—during preliminary reservoir testing in 1986. From September through November of 1987, the well was permanently repaired by drilling out its side, in an operation called "sidetracking." Then the bottom was redrilled for 1 km about 25 meters away from the old well, bypassing its damaged zone. This drilling was trouble-free and, although conducted in the deepest and hottest zones, was accomplished at rates 2½ times faster than in the case of the original drilling. When combined with recent successful drilling in the other well, EE-3, this indicates that the problems of the late 1970s and early 1980s are behind us.

Fracturing of deep hot rock also has proved to be a major obstacle to HDR development. However, the problem is yielding to research. In early years, the mapping of hydraulic fractures with the locations of induced microearthquakes was in its infancy—so much so that we placed more confidence in our theoretical predictions of fracture patterns than in the mapping and drilled accordingly. Consequently, when tectonic stresses and natural joint patterns unexpectedly changed with depth, the predrilled wells could not be linked with fractures. Thanks to efforts at Los Alamos and in the British HDR program, seismic fracture mapping has been remarkably improved, and fractures can be located with a precision of 20 meters (*2*). HDR reservoirs are now created by drilling the injection well completely and the production well partially, and then by fracturing the injection well and mapping the fractures with seismometers at the bottom of the partial well and nearby shallow wells. The partial well is then finished by drilling through the fractures. This technique worked superbly during two recent redrilling campaigns at Los Alamos and during the most recent drilling in England.

In summary, thanks to improvements in drilling and fracturing, HDR development is poised to take great strides. A partnership of the Bechtel Corporation and Intermountain Geothermal (a subsidiary of Chevron) is exploring the feasibility of developing an HDR reservoir at Roosevelt Hot Springs in Utah. In the meantime, we continue technical collaboration with our Japanese colleagues, who are developing a reservoir at Hijiori, and with the British, whose next endeavor is to create a reservoir at a depth of 4.5 km.

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Satellite Map

I could hardly agree more with the comments (News & Comment, 4 Dec., p. 1346) of Representative George Brown (D–CA) on the need for complete freedom of access to information (less truly classified material). However, the remark that "a map sold to tourists by the National Air and Space Museum giving the name, orbit, and launch date of all the satellites in space, information that is considered 'higher than top secret' " needs clarification. Indeed, there is such a graphic display chart, "The Satellite Sky," on sale at the Air and Space Museum; but it is not even remotely classified. Nor, in fact, have any of the data on the graph been abstracted from any limited access documents. I should know; I am the author of that graph. All of the information displayed is readily available in the open literature, and most of it comes from *Pravda*, *Izvestia*, or *Krasnaya Zvezda*. It seems the Soviet Union, pleased with its successes in space, quite freely makes available the orbital parameters and launch date of its Earth-orbiting spacecraft. Determining the launch base is not a complicated exercise in spherical geometry. On the other hand the Pentagon chooses not to make this information available to the public for many months after any given launching, as though that procedure would hide their spacecraft from any country that decided it wanted that knowledge. Brown is correct, of course, when he states that our country's efforts to control access to information is far overdone and is a practice that should be halted.

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