hot dry rock tested for geothermal energy

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In mid-December the Los Alamos Scientific Laboratory of the University of California finished drilling GT-2, a deep geothermal test hole in northern New Mexico. This hole reached a final depth of 2,929 m, where the bottom-hole temperature is 196°C. Fracturing experiments at 1,981 m were successful and large volumes of water were injected into and recovered from the hot basement rocks. The preliminary results from this experiment are encouraging for the development of a new method for extracting geothermal energy.

Although natural geothermal-energy systems have been used as energy sources since the early 1900s, they have not contributed significantly to total world-energy production largely because they are small and scarce. If geothermal energy is to become important in the future, it appears necessary to develop new means of extracting it. One such method, the dry-hot-rock, has been investigated for about 3 years by the Los Alamos Lab, under the auspices of the U.S. Atomic Energy Commission. As proposed, application of this method requires 3 basic conditions:

1. A geothermal gradient high enough to ensure adequate temperatures (higher than 200°C) within reasonable drilling depths (6 km).

2. The ability to produce, control and keep open a fracture or fractures of known geometry with enough surface area to heat the injected fluid for a reasonable length of time.

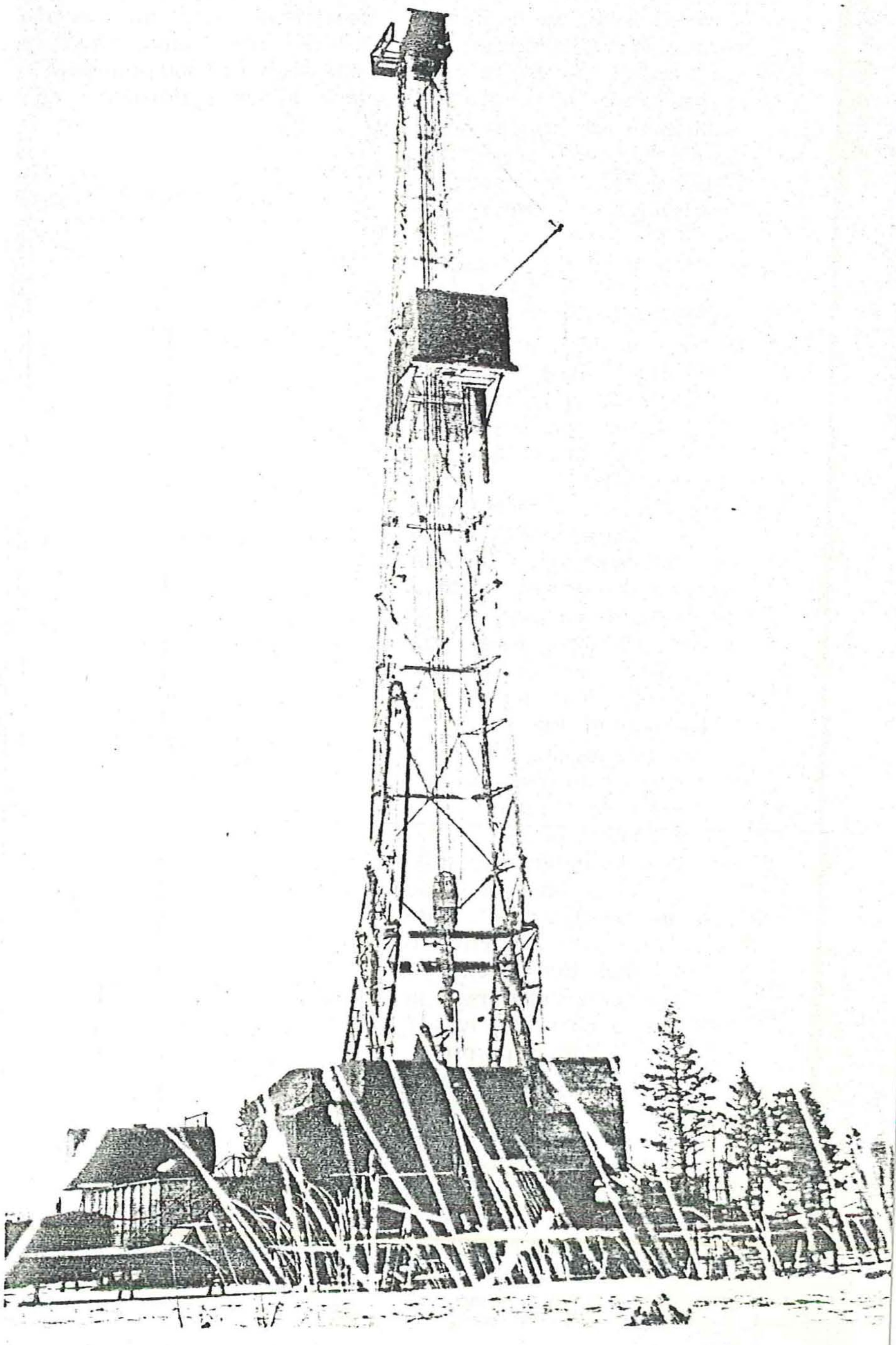
3. Essentially impermeable rock to prevent loss of the injected fluid.

In most regions these requirements are met only in holes drilled into Precambrian basement crystalline rocks.

According to this method, once a suitable area has been selected, largely on the basis of heat-flow measurements and detailed geologic mapping, a deep hole is drilled into the hot, dry impermeable rock. Hydraulic fracturing is then used to generate one or more fractures, which serve as heat-exchange surfaces. A nearby shallower hole is drilled directionally to intersect the fracture and establish subsurface circulation. Cold water injected down the deeper hole is heated by the exposed hot rock surfaces, rises and returns to the surface as a pressurized liquid via the shallower hole. After surface energy extraction, the pressurized water can be returned down the deeper well, producing essentially a closed system. Make-up water may be added as necessary to replenish loss by leakage.

The drilling of GT-2, the second of the Los Alamos Lab's deep test holes, began in February 1974. The drilling

This Calvert-Western rig drilled in the Jemez Mountains of New Mexico.



site is in Sandoval County, New Mexico on the western flank of the Valles Caldera. There the heat flow has been measured at between 4 and 5 heat-flow units (10^{-6} calories/cm^2/second). The site is about 32 km west of Los Alamos, near New Mexico Highway 126.

The Valles Caldera is a late-Cenozoic collapse feature with a diameter of 19 to 24 km. Surface rocks at the site are part of the Bandelier Tuff, which was ejected from the caldera 1.1 to 1.4 million years ago. Beneath the Bandelier in descending order are the Cenozoic Paliza Canyon Formation and Abiquiu Tuff (Cenozoic), Abo Formation (Permian), Madera Limestone and Sandia Formation (Pennsylvanian), and Precambrian basement rocks. Precambrian rocks were intersected at a depth of 730 m. Petrographic analysis of samples from cores recovered during the drilling of GT-2 indicates that the Precambrian rocks are predominantly monzogranitic and biotite granodioritic gneiss, with lesser amounts of hornblende-biotite schist and pegmatites.

While drilling GT-2, we made 26 coring runs using both a conventional Christensen diamond bit and a modified deep-sea drilling core bit. Core was recovered from 24 of these attempts with recoveries ranging from less than 10% to 100% and a total recovery of about 35 m of core. Petrographic, physical property, chemical, and isotopic studies have been started on these cores and the results will be reported later.

During drilling, a complete geophysical-logging program was followed, including caliper log; induction, self-potential and resistivity electrical logs; density (scattered gamma) log; three-dimensional sonic-velocity log; gamma log (natural gamma activity); dipmeter survey; neutron-activation log; and temperature log.

Results of these logging operations are being examined to determine the elastic properties of the rocks, their density, temperature, porosity, lithologic character, induration, the strike and dip of bedding planes and fractures and the existence of water movement. The elastic properties of the rocks and their density and porosity are also being determined independently as a check on logging results and for calibration purposes.

In addition to the logs mentioned above, a Birdwell seisviewer and the U.S. Geological Survey borehole televiewer (fine-grained sonic-type logs) have been used to locate fractures in the rock penetrated. These results are presently being compared with fracture data obtained from the cores and from other logging methods.

We made 9 successful temperature measurements in deeper parts of the hole. These measurements, made at the bottom of the hole before coring or drilling the next interval, indicate an undisturbed rock bottom-hole temperature of 196°C and a geothermal gradient increasing with depth from 50°C/km to 60°C/km.

Because hydraulic fracturing is a critical part of our project, the fracturing experiments made at 1,981 m will be repeated at the bottom of the hole. In our earlier uphole experiments two fractures were created in an open part of the hole extending from 1,981 to 2,042 m. This rock fractured under a pressure of about 2,000 pounds per square inch above hydrostatic and about 36,000 gallons of water were injected into the resulting fractures. A third fracture was made at a depth of 1,951 m by perforating the steel liner over a 10-ft interval. This fracture required a pressure of about 2,500 pounds per square inch above hydrostatic and about 3,000 gallons of water were injected. We obtained almost complete recovery of the injected water, indicating that the rock at this depth was indeed impermeable.

Environmental concern dictated that the hydraulic fracturing be carefully monitored for seismic signals. Seismic arrays surrounding the site were established by two LASL research groups. In addition, sensitive tiltmeters were set up around the hole. No significant seismic signals or surface tilt were recorded by these instruments.

LASL's future plans for this site include final fracturing experiments in GT-2 and the drilling of a second hole to complete the system. Core studies will continue and will be expanded because of the unique nature of this hole.

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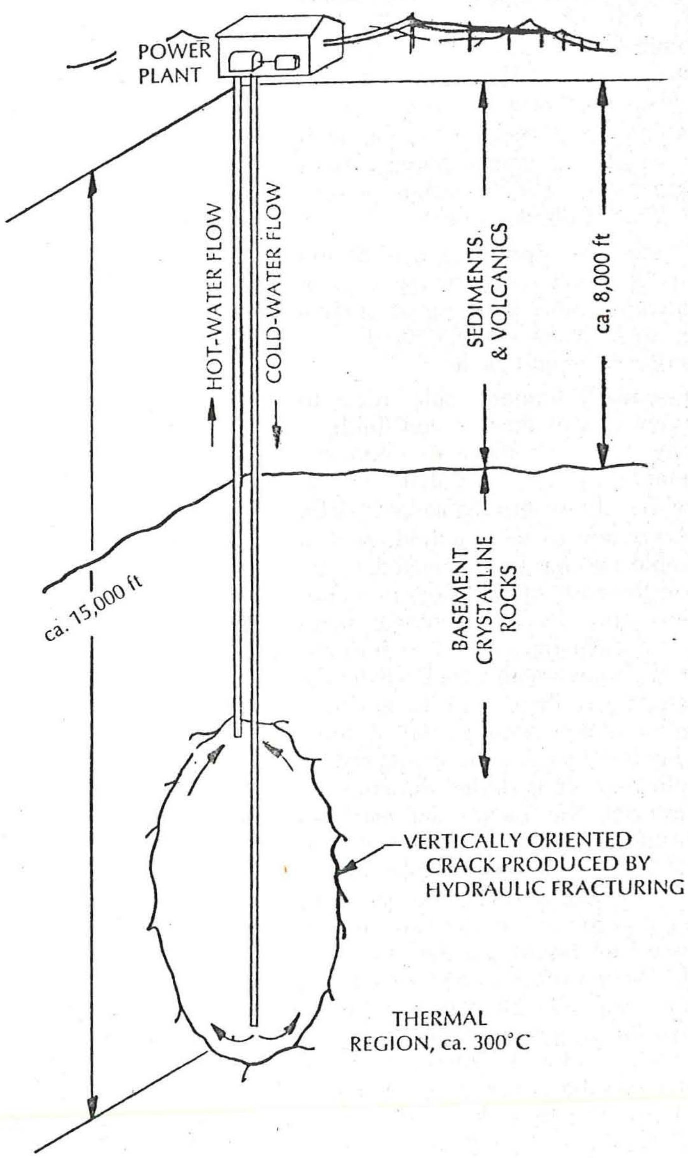

How the Los Alamos Lab proposes to extract geothermal energy.