LABORATORY EXPERIMENTS ON HYDROFRACTURE AND THE PERMEABILITY OF HOT GRANITE

J. Byerlee, D. Lockner, R. Summers
U.S. Geological Survey
Menlo Park, CA 94025

It has been proposed that an artificial geothermal reservoir could be created by injecting water under high pressure through a hole drilled into a hot dry batholith. By drilling a second hole to intersect the plane created by hydraulic fracture, a fluid circulation system could be created by pumping cold water into one hole and extracting hot water or steam through the other hole. We have carried out a number of laboratory experiments to investigate various aspects of this project.

It is usually assumed that during hydraulic fracture a single tension fracture is formed with its plane parallel to the direction of maximum principal stress. In laboratory experiments we have found that at high injection rates this is correct, but if the rock is under shear stress and the fluid is injected slowly enough, shear fractures are formed with their planes oriented about 30° to the direction of maximum principal stress. This occurs not only in sandstone, but also in very low permeability rocks such as oil shale and Westerly Granite. The efficiency of an artificial geothermal reservoir depends in part on the surface area of the hot rock with which the circulating fluid comes in contact. Our laboratory results suggest that it may be possible, in regions of high tectonic stress, to increase the fracture surface area simply by varying the fluid injection rate and thus to create not only a tension fracture but shear fractures as well.

A major problem in creating a fluid circulation system is knowing exactly where to drill the second hole to intersect the fractures. We found that the spacial distribution of the fracture planes can be determined accurately by determining the location of the acoustic emission events that occur during fracture. This technique should be applicable in large-scale field projects as well. It should also be possible to calculate the three-dimensional distribution of the fracture planes from the change in magnetic field at the earth's surface caused by the injection of material of high magnetic susceptibility into the fracture.

Once the circulating system is formed, how does the permeability of the system change with time? We have measured the permeability of granite under confining pressure and differential stress at temperatures to 400°C. In all cases the initial permeability at elevated temperature was found to be higher than the permeability at room temperature. This was probably caused by thermal cracking that could be detected by monitoring the acoustic emission from the rock during the experiments. The high initial permeability, however, did not persist and in nearly all cases decreased significantly during the first half day of water flow through the rock. Dissolution of the minerals was concentrated near the inlet where the pressure was highest, and precipitation occurred throughout the sample owing to oversaturation as the pressure dropped. This precipitation almost certainly caused the reduction of permeability. In many cases, particularly at the highest temperatures, measurable flow of water through the sample ceased after a few days, even in samples that contained a pre-existing fracture plane. If the same phenomenon occurs in a large-scale field project, then our results suggest that the system would tend to clog unless preventive steps were taken.

REFERENCES

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