PARAMETRIC EXPLORATION FOR HOT DRY ROCK

Tsvi Meidav
Trans-Pacific Geothermal, Inc.

Panaceas will elude the Hot Dry Rock explorationist as they have the hydrothermal reservoir hunter. No single technique can determine the petrophysical and temperature regime of rocks at depth. Principles and limitations of individual techniques define the uncertainty associated with each. Joint- or multiple-parameters may narrow down uncertainties.

Heat flow techniques increase in reliability with the increase in spatial data distribution and depth of holes. Spatially distributed data permits the separation of effects due to shallow convective regime from deeper heat sources, convective or conductive. Structural geology, stratigraphy and hydrogeological data may provide useful constraints to heat flow models.

Electrical resistivity methods can determine the gross three-dimensional distribution of the conductivity of the rock volume. That conductivity value can be affected by, or be the composite effect of temperature, porosity, saturation, presence of metallic minerals, salinity of the saturating fluid and geometrical effects.

Seismic techniques permit the 3-D determination of compressional and shear wave velocities, their ratio and their distinct attenuation rates. Compressional wave velocity is affected by the rock mineralogy, porosity, pore fluid, compressive modules, and temperature. Shear wave velocity is affected by the same parameters as compressional waves, but in a different way than compressional waves. Hence, changes in the ratio of P/S wave velocity (or Poisson's Ratio) can serve as important indicators of changes in rock temperature, pore fluid state and degree of saturation, and pore geometry.

Gravity and magnetics provide valuable structural and generalized stratigraphic distribution of rock masses that are important in the determination of gross geometrical character of the geological regime at a specific site. The drastic change in density at the melting point provides ways of determining the approximate geometry of the molten rock mass, and thus provides at least one temperature-depth plane information. The Curie point, at which rocks lose their magnetism due to temperature (about 578°C), permits the mapping of another temperature plane. Neither the gravity method nor the iso-Curie technique can guarantee unique interpretations. However, the gravity method is less subject to the ambiguities that shroud magnetics, inasmuch as magnetic susceptibility effects, remanent magnetization effects, hydrothermal oxidation of magnetics can all drastically affect the magnetic field in a way that may not be easily distinguishable from the Curie effect.

Regional geological studies provide initial conceptual models on the nature and distribution of various rock types. The reasonableness of assumptions regarding the occurrence of a suitable heat source, rock environment of the desired permeability characteristics may be adjusted based upon such preliminary studies, especially when supported by age dating, mapping and analysis of the geochemistry of water and gases of local springs.

Success of the technology of geothermal (hydrothermal or Hot Dry Rock) resides in the synergism of multi-technique approach to the definition of in-site geothermal and petrophysical properties. The nonunique relationships between any one geophysical technique and the desired temperature or petrophysical state of the rock would foredoom any attempt in prognostication. Inchoate success in reducing temperature, porosity and other desired information may come about through joint- or multi-parameter interpretation of different physical rock properties. These include joint gravity and magnetic data, electrical resistivity and seismic data, compressional and shear wave velocity data, seismic wave attenuation, as related to shear and compressional wave velocity data, and other data set permutations. Even when data sets are limited for a given area, the stratigraphic changes in one single variable may provide an important insight to significant changes in the pore volume character (or some other character). This was the case for the "bright spot" technique in seismic reflection or oil, where the slight change in acoustic impedance due to saturation with oil or gas, as distinct from water, made it possible to detect the petroleum deposit directly, in some cases.

An underutilized body of data, often already in the files of the exploration company, may include the following:

(1) Interval velocities and their areal distribution. These are calculable in every case where coherent reflectors occur and sufficiently large cable spreads have been employed in taking the data.
(2) Poisson's Ratio areal distribution.
(3) Changes in Poisson's Ratio and attenuation as related to porosity and pore fluid characteristics.
(4) Reinterpretation of electrical resistivity data, by using seismic stratigraphy to provide modeling constraints.
(5) Isolation of preferred fracture patterns in rocks from data on electrical and seismic wave anisotropies.

Joint multi-technique interpretations, associated with a more quantitative assessment of the causes of relative magnitude changes in each of the parameters, offer the promise of a greater success rate in predicting the petrothermal or hydrothermal state of the rocks. A few examples to demonstrate this statement, culled from various case histories, will be shown to demonstrate the proposed concepts.

☆U.S. GOVERNMENT PRINTING OFFICE: 1983-0-676-026/15