

Reservoir monitoring by a 4-D geoelectrics

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Advanced geoelectrical techniques for imaging fluid flow behaviors have been developed by Geophysical Laboratory of Kyushu University. The method, fluid flow tomography (FFT), has been applied to monitor fluid flow behaviors during massive production through boreholes and injection of separated hotwater into the formation. Fluid flow distribution in potential fractures could be continuously traced and visualized as a function of time on the survey site. Potential fractures can be evaluated by 3-D inversion of Self-Potential data based on a potential theory. The FFT method has been applied to determine the location of fractures in geothermal fields.

A charged current electrode is connected to the conductor casing pipe of an injection or a production well. The earthing electrode is fixed at an infinite distance away from the charged borehole. The base potential electrode is also fixed at a few km away from the borehole and on the side opposite the current line to minimize electromagnetic coupling effects. Multiple potential electrodes are used for the present FFT survey. An electric current of 1-10 amps and a frequency of 0.1 Hz are introduced into the earth by FFT transmitter. The resulting voltages are measured with a sampling rate of 1,800 runs per second by a digital recording system controlled by a personal computer on the site. The charged potentials are converted to apparent resistivities multiplying by a geometric factor of the mise-a-la-masse method and SP which may be produced due to streaming potentials in reservoirs. Then these data are digitally measured and stored in a personal computer on the site.

During the course of drilling of an exploratory borehole in a virgin geothermal field, high quantities of hydrogen gas were blowing out from the borehole. Therefore, two sidetracks were drilled to avoid the harmful gas zones. However, they were unsuccessful. Finally, the FFT method was conducted to locate potential fractures and to determine the casing program of the borehole. In the field survey, SP distribution on the ground surface were measured before injection, during injection and after injection of water. Strike and dip of major fracture were determined by 3-D inversion of time-sliced SP data. The estimated fracture plane coincided with the results of directional drilling of the borehole.

A multichannel geoelectrical system and various computer programs for data acquisition, data processing and inversion analysis have been developed by Geophysical Laboratory of Kyushu University. The FFT method has been applied to direct imaging of potential fractures in a reservoir. The fluid flow behavior in the reservoir can be monitored with a function of time and visualized by the 4-D geoelectrical field survey.