PROJECT SUMMARY

Applicant: The University of North Carolina at Chapel Hill
Principal Investigator: Dr. José A. Rial, Wave Propagation Laboratory.

Real-time Fracture Monitoring in Engineered Geothermal Systems with Seismic Waves

This is a three-year project to develop a monitoring system designed to provide real-time images of subsurface fracture distribution and fluid migration for the exploration, development and exploitation of geothermal reservoirs. Because it is based on the measurement and processing of natural and induced micro-earthquakes, the proposed system is specially suited for engineered geothermal systems (EGS), where it will help reduce production costs by providing engineers with critical information on the progress and effects of reservoir stimulation (injection, hydrofracturing) in real time, and with accuracy and scope not obtainable by any other indirect or remote-sensing technology. The monitoring software will be based on the integration of novel data processing techniques, recently developed by our research group with DOE funding that include methods of interpreting shear-wave splitting (SWS) measurements, seismic clustering and seismic wave attenuation. Special efforts will be dedicated to the important task of detecting crack size (from micro-cracks to faults) by exploiting newly developed theories on frequency-dependence of shear-wave splitting. Attention will also focus on the analyses of multiple SWS along single seismic rays, which reveals changes in the distribution and extent of crack systems at depth.

The project deals specifically with the development of the software, but our vision of the final product is clear: a portable seismic array of 20-25 three-component geophones deployed around the EGS site telemeters to a computerized portable station where software detects and locates the seismicity induced by the EGS operation. As data streams into the array, the software processes the seismic waves, and images of crack geometry, crack intensity and affected volume of rock begin to emerge. Around the field, wireless laptop computers receive and display the expanding cloud of seismic events, followed by images of crack geometry and fracture intensity that grow clearer as newer data arrives and the inversion of SWS measurements stabilizes. The laptop computers contain data from previously detected crack systems at the site, so before-and-after-injection comparisons of crack directions can be done on the spot. As data accumulate, tomographic slices of the affected rock volume become available, so that changes in crack orientation, fluid motion, and rock temperature within the real-time image can be identified and mapped.

Important benefits of the proposed study to the DOE EGS program:

- Real-time estimates of the volumetric extent and size of fracture systems, their geometry, size, continuity and intensity around the stimulating borehole, between boreholes and throughout the field.
- Detection of directions along which fluid migration takes place in the subsurface. Detection of anomalously high temperature zones where high enthalpy, supercritical steam may exist.
- Recommendations as to the location of additional injection/production wells to maximize cost-effectiveness of production help increase efficiency of the fieldwork and thus decrease exploration costs.
- A system for remote seismic fracture detection as envisioned here will help maximize cost effectiveness in the exploitation of environmentally clean geothermal resources for the benefit of the general public, and thus it could easily become an important public relations vehicle for the Department of Energy's Geothermal Program.