Seismological Software for Geothermal Monitoring

Gillian R. Foulger & Bruce R. Julian
Durham University, Durham, United Kingdom

Seismology provides powerful tools for monitoring conditions and processes in geothermal reservoirs. With support from Award # DE-FG36-08GO18187 by the Department of Energy we have, over the last four years, enhanced seismological methods in several ways to make them more useful for geothermal investigations, and applied the new methods to datasets:

Relative hypocenter locations – Microearthquake hypocenters measured relative to one another can give high-resolution three-dimensional images of failure zones, but relative-location methods are insensitive to absolute locations. Such locations are usually not useful for such purposes as guiding drilling. We developed a hybrid hypocenter-location algorithm that uses both absolute and relative arrival times and greatly increases sensitivity to absolute location.

Source mechanisms – Standard models of earthquake source mechanisms such as moment tensors include only force systems that lack net forces and torques. Some processes that might occur in geothermal systems, such as unsteady fluid flow, would theoretically involve net forces. We extended source-mechanism inversion methods to be able to estimate net forces.

Seismic tomography – Three-dimensional seismic-wave speed structure can delineate geothermal reservoirs, and temporal changes in wave speeds can be used to monitor changes in pore-fluid pressure within them. Local microearthquakes in geothermal areas, however, are shallow, and cannot be used to determine structure at great depth. We extended seismic tomography methods by using also arrival times from distant (regional and teleseismic) events. In cases where suitable seismicity exists, this extension will enable us to measure wave speeds, and their temporal changes, beneath the local earthquakes and within the deep parts of reservoirs and the heat sources under them.

In our talk we will present examples of the use of the new methods on synthetic seismic data and some real datasets.

In order to disseminate our results, and knowledge of microseismic monitoring, we ran a training course immediately prior to the Geothermal Resources Council Annual Meeting at Reno, in September 2012. We also established the website *www.microearthquakes.org*, where material is posted in support of the geothermal microearthquake community. Software based on our recent work, as well as related scientific articles and tutorial material are also available there.