Seismology and Enhanced Geothermal Systems

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Recent technical advances increase the potential utility of seismological methods for monitoring physical processes in geothermal systems, and in Enhanced Geothermal Systems (EGS) experiments in particular, although many challenges remain.

Differential methods for locating microearthquake hypocenters relative to one another can delineate the shapes of failure zones with a resolution of a few tens of meters, and the resulting images of failure zones can greatly increase the uniqueness of interpreting source mechanisms in terms of physical processes. This kind of combined interpretation has, for example, demonstrated the occurrence of tensile failure in both natural and exploited geothermal systems. Differential methods are poor for determining absolute locations, however. Approaches that combine absolute and differential arrival times can improve this situation, but using calibration data from timed explosions provides the greatest absolute accuracy.

The extension of microearthquake source mechanism studies beyond "fault-plane solutions" to the more general moment-tensor representation has produced evidence of volumetric seismic processes such as tensile failure. Expected processes such as unsteady fluid flow require a further extension to include net forces in source mechanisms, and we have recently extended source-mechanism inversion methods to include forces.

Three-dimensional models of seismic wave speeds provided by tomographic methods can significantly improve the accuracy achievable by all the above methods. In addition, tomography has direct applications, because geothermal exploitation, and probably natural processes, can cause the wave speeds to vary with time. Recent extensions of tomographic methods increase the objectiveness with which temporal changes can be detected. A shortcoming of local-earthquake tomographic methods is their restriction to the shallow, relatively cool region above the maximum earthquake depth. Rays from regional earthquakes that pass through the deeper portions of geothermal reservoirs and their heat sources may provide data that can extend resolution to greater depths.

We will illustrate the application of seismological methods using data from natural and exploited geothermal systems, and from EGS experiments currently in progress.