PROCEEDINGS, Thirty-Sixth Workshop on Geothermal Reservoir Engineering
Stanford University, Stanford, California, January 31 - February 2, 2011
SGP-TR-191

Mapping Deep Structure in Geothermal Areas using Local and Regional Microearthquake Data

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Tomographic study of volcanic and geothermal areas has always been limited by the absence of local microearthquakes at depth, a result of the same high temperatures that make these areas interesting and important. Seismic ray coverage is limited to the volume above the deepest earthquakes, and this circumstance excludes study of the deeper parts of geothermal reservoirs and their heat sources. An additional problem is that some geothermal areas, particularly ones not under exploitation, are only weakly seismogenic and provide few data useful for tomographic inversion.

These limitations can be overcome by using seismic-wave arrival times from regional earthquakes (ones at distances of a few tens to hundreds of kilometers) in addition to those from any local events available (those within the volume being studied). Waves from regional events penetrate to mid-crustal to upper-mantle depths and propagate upward through the region under study.

A difficulty arises with using regional data, however, because of unknown travel-time variations that may have been introduced by propagation over long distances between the earthquakes and the local region of study. This difficulty is similar to that imposed by ignorance of the hypocentral locations of local earthquakes, and can be solved by a similar mathematical approach: solving simultaneously for parameters describing the geometry of the incoming wave front and for the local three-dimensional structure. In fact, regional earthquakes offer advantages over local events because they require the addition of fewer extra unknowns (3 per event vs. 4) and because it can be presumed that incoming wave directions from earthquakes near one another will be similar. Offsetting these advantages are the requirement that regional seismic activity must exist and the fact that regional seismic waves often are relatively weak. We are currently developing new software based on this new approach that uses local and regional earthquake data to determine three-dimensional structure and its variation with time.