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Monitoring Geothermal Processes with Microearthquake Mechanisms

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The full (moment-tensor) focal mechanisms of microearthquakes at geothermal areas are valuable for diagnosing processes such as shear faulting and tensile cracking, whether these processes occur naturally, as a by-product of energy-extraction, or result from attempts to enhance permeability and geothermal production. Linear-programming provides a robust method for inverting seismic-wave polarity and amplitude-ratio data to determine moment tensors of geothermal microearthquakes in the relevant magnitude range, and this method has by now been successfully applied to many geothermal areas.

We extended the linear programming method to compute confidence regions for moment tensors. This involves adding an inequality constraint to keep the misfit function below a specified limit chosen on the basis of a priori estimates of measurement error. The method then moves the solution in six-dimensional moment-tensor space in various specified directions as far as the constraint allows. In this way, within the declared constraints, an envelope enclosing all solutions that fit the data is obtained.

Inverting amplitude ratios for moment tensors using data from several geothermal areas in Iceland, Indonesia, and California shows that mechanisms often, but not always, lie systematically along a trend between the double-couple and the dipole points on the source-type plot (Hudson et al., Source type plot for inversion of the moment tensor, J. Geophys. Res., 94(B1), 765-774, 1989). Confidence regions computed by our new method are often elongated in the double-couple to dipole direction. This observation suggests that part of the observed systematic trend may be an artifact of measurement error. Further work is required to determine whether all of the trend can be attributed to error, and also to understand why natural earthquakes are distributed in source-type space the way they are.