abstract of paper given at European Seismological Commission ESC 2008, 31st General Assembly, Crete, Greece, 7 - 12 September, 2008.

Seismic Monitoring of Hydraulic Stimulation Tests at the Coso Geothermal Field, California, Using Microearthquake Locations and Moment Tensors

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We studied high-resolution relative locations and full moment tensors of microearthquakes occurring before, during and following hydraulic stimulation experiments in two wells at the Coso Geothermal Field, California, with the objective of mapping new fractures, determining the mode and sense of failure, and characterizing the stress cycle associated with injection. New software developed for this work uses improved and corrected algorithms to combine waveform cross-correlation measurements of arrival times with relative relocation methods, and to assess confidence regions for moment tensors derived using linear-programming methods. We show the first results from applying these new techniques to data from the US Navy's permanent network of three-component digital borehole seismometers and from 14 portable three-component digital instruments installed at the surface for a several-month interval spanning injection experiments in well 34A-9 in 2004 and well 34-9RD2 in 2005. In the experiment in well 34A-9, the co-injection earthquakes were more numerous, smaller, more explosive and had more horizontal motion, compared with the background earthquakes. Injection affected the source orientations in the activated volume for at least two months after injection ceased. In the experiment in well 34-9RD2, the injection produced spatially coherent seismicity different from the scattered ongoing background activity. The relocated hypocenters reveal a well-defined planar structure, 700 m long, 600 m high in the depth range 0.8 to 1.4 km below sea level, striking N 20 degrees E and dipping 75 degrees to the WNW. The moment tensors show that it corresponds to a mode I (opening) crack. Perturbations to the seismicity rate and source orientations near the bottom of the well persisted for at least two months following the injection.