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Geothermal induced seismicity: What links source mechanics and event magnitudes to faulting regime and injection rates?

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Improving estimates of seismic hazard associated to reservoir stimulation requires advanced understanding of the physical processes governing induced seismicity, which can be better achieved by carefully processing large datasets. To this end, we investigate source-type processes (shear/tensile/compaction) and rupture geometries with respect to the local stress field using seismicity from The Geysers (TG) and Salton Sea geothermal reservoirs, California. Analysis of 869 well-constrained full moment tensors (MW 0.8-3.5) at TG reveals significant non-double-couple (NDC) components (>25%) for ∼65% of the events and remarkably diversity in the faulting mechanisms. Volumetric deformation is clearly governed by injection rates with larger NDC components observed near injection wells and during high injection periods. The overall volumetric deformation from the moment tensors increases with time, possibly reflecting a reservoir pore pressure increase after several years of fluid injection with no significant production nearby. The obtained source mechanisms and fault orientations are magnitude-dependent and vary significantly between faulting regimes. Normal faulting events (MW < 2) reveal substantial NDC components indicating dilatancy, and they occur on varying fault orientations. In contrast, strike-slip events dominantly reveal a double-couple source, larger magnitudes (MW > 2) and mostly occur on optimally oriented faults with respect to the local stress field. NDC components indicating closure of cracks and pore spaces in the source region are found for reverse faulting events with MW > 2.5. Our findings from TG are generally consistent with preliminary source-type results from a reduced subset of well-recorded seismicity at the Salton Sea geothermal reservoir. Combined results imply that source processes and magnitudes of geothermal-induced seismicity are strongly affected by and systematically related to the hydraulic operations and the local stress state.