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Seismicity and deformation in the Coso Geothermal field from 2000 to 2012

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Induced micro-seismicity in geothermal reservoirs, in particular in enhanced geothermal systems (EGS), is an intended byproduct of injection and production, as it often indicates the generation of permeability pathways on either pre-existing or newly generated faults and fractures. The hazard of inducing an earthquake large enough to cause damage to surface structures, however, is not easily avoided and has led to termination of geothermal projects. To explore the physical processes leading to damaging earthquakes, we investigate the evolution of seismicity and the factors controlling the migration, moment release rate, and structure within the seismicity in the Coso Geothermal Field (CGF).

The CGF has been in production since the 1980s and includes both naturally occurring geothermal resources and portions of the reservoir that are EGS projects. We report on seismicity in the CGF that has been relocated with high precision double-difference relocation and simultaneous velocity inversion to understand the reservoir compartmentalization, in particular, where boundaries to flow exist both vertically and horizontally. We also calculate moment magnitudes (Mw) from the initial displacement pulse of the seismograms to relate moment directly to the deformation. We find that two distinct compartments form the CGF, which are divided by an aseismic gap that also shows a relatively low Vp/Vs ratio. Further, we find that events with Mw> 3.5 tend to map onto larger fault structures that are imaged by the relocated seismicity.

We relate the temporal and spatial migration of moment release rate to the injection and production records in the reservoir by employing a thermo-poro-elastic finite element model in which the compartment boundaries are defined by the seismicity. We find that pore pressure effects alone are not responsible for the migration of seismicity and that poro-elastic and thermo-elastic strain changes can account for more of the observed moment release rate than pore pressure alone. These initial results indicate that coupled models of fluid flow, heat flow and solid deformation improve our understanding of the physical mechanisms that control induced seismicity in geothermal reservoirs and possibly other settings as well.