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Reservoir Changes Derived from Seismic Observations at The Geysers Geothermal Field, CA, USA

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Induced seismicity associated with the exploitation of geothermal fields is used as a tool to characterize and delineate changes associated with injection and production of fluids from the reservoir. At the same time public concern of felt seismicity has led to objections against the operation of geothermal reservoirs in close proximity to population centers. Production at the EGS sites in Basel (Switzerland) was stopped after renewed seismicity caused concern and objection from the public in the city. Operations in other geothermal reservoirs had to be scaled back or interrupted due to an unexpected increase in seismicity (Soultz-sous-forêt, France, Berlín, El Salvador). As a consequence of these concerns and in order to optimize the use of induced seismicity for reservoir engineering purposes, it becomes imperative to understand the relationship between seismic events and stress changes in the reservoir.

We will address seismicity trends at The Geysers Geothermal Reservoir, CA USA, to understand the role of historical seismicity associated with past injection of water and/or production of steam. Our analysis makes use of a comprehensive database of earthquakes and associated phase arrivals from 2004 to 2011. A high-precision sub-set of the earthquake data was selected to analyze temporal changes in seismic velocities and Vp/Vs-ratio throughout the whole reservoir. We find relatively low Vp/Vs values in 2004 suggestive of a vapor dominated reservoir. With passing time, however, the observed temporal increase in Vp/Vs, coupled with a decrease in P- and S-wave velocities suggests the presence of fluid-filled fractured rock. Considering the start of a continuous water injection project in 2004, it can be concluded that the fluid saturation of the reservoir has successfully recovered. Preliminary results of 3-D velocity inversions of seismic data appear to corroborate earlier findings that the lowest Vp/Vs estimates are observed in the center of the reservoir. Vertical depth-sections indicate that these low values are co-located with production zones and production related seismicity. In contrast, the highest Vp/Vs estimates are co-located with injection zones and their associated seismicity.