

Monitoring reservoir response to earthquakes and fluid extraction, Salton Sea geothermal field, California

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Continuous monitoring of in situ reservoir responses to stress transients provides insights into the evolution of geothermal reservoirs. By exploiting the stress dependence of seismic velocity changes, we investigate the temporal evolution of the reservoir stress state of the Salton Sea geothermal field (SSGF), California. We find that the SSGF experienced a number of sudden velocity reductions (~ 0.035 to 0.25%) that are most likely caused by openings of fractures due to dynamic stress transients from local and regional earthquakes. Depths of velocity changes are estimated to be about 0.5 to 1.5 km, similar to the depths of the injection and production wells. We derive an empirical in situ stress sensitivity of seismic velocity changes by relating velocity changes to dynamic stresses. We also observe systematic velocity reductions (0.04 to 0.05%) during earthquake swarms in mid-November 2009 and late-December 2010. On the basis of volumetric static and dynamic stress changes, the expected velocity reductions from the largest earthquakes with magnitude ranging from 3 to 4 in these swarms are less than 0.02% , which suggests that these earthquakes are likely not responsible for the velocity changes observed during the swarms. Instead, we argue that velocity reductions may have been induced by poroelastic opening of fractures due to aseismic deformation. We also observe a long-term velocity increase ($\sim 0.04\%$ /year) that is most likely due to poroelastic contraction caused by the geothermal production. Our observations demonstrate that seismic interferometry provides insights into in situ reservoir response to stress changes.