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Remote triggering and numerical simulations of passing seismic waves at the Larderello-Travale Geothermal Field, Italy

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Seismic waves generated by large magnitude earthquakes can affect geological systems located thousands of kilometers far from the epicenter. The Larderello-Travale geothermal field is one of the most studied high-enthalpy geothermal systems worldwide shown to be sensitive to incoming seismic energy. In this study we detected local seismic activity at the Larderello-Travale field, coinciding with the passage of Rayleigh waves released by the 2011 M9.0 Tohoku earthquake. The earthquakes of local magnitudes 1.6 and 1.7 occurred at 6 km and 8 km depth, respectively. We suggest that these earthquakes were dynamically triggered by transient Rayleigh waves which induced a maximum vertical displacement of approximately 7.5 mm at the hydrothermal field (for waves with period of 200 s). We estimate a dynamic stress of about 8 kPa for a measured peak ground velocity of 0.8 mm/s and propose that this additional stress in a clock-advance process triggered the local earthquakes which may have eventually occurred naturally at a later time. Previous studies also report increased seismic activity at the Larderello-Travale geothermal field after regional earthquakes.

We conducted numerical simulations of P-, S-, Love and Rayleigh waves propagating through a detailed model of the Larderello-Travale geothermal field based on the known velocity structure. This enables us to identify potential regions where seismic energy may accumulate due to local structure. Results indicate that maximum displacements focus differently when considering body or surface waves. We identify a region located at 3-5 km depth (k-horizon) that may correspond to the brittle-ductile boundary where almost no seismic energy is focused.