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## Deep geothermal-induced seismicity: controlling factors and hazard mitigation measures

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As many industrial activities impacting the underground, deep geothermal projects can be associated with the occurrence of induced seismic events. This seismicity is sometimes a direct consequence of stimulation operations needed to enhance the permeability of geothermal reservoirs, but, in other cases, it can also occur in different phases of geothermal projects, as during wells shut-in, after injection operations, or during the production phase, which generally implies lower flow rates and injection pressures. The intensity of this seismicity, in terms of magnitudes of seismic events, can be extremely variable, from microseismic events ( $M < 2$ ), not felt at the surface, to large earthquakes ( $M > 5$ ) that pose a serious risk to neighboring populations and may lead to the abandon of geothermal projects. In this context, it is of paramount importance to: i) better characterize and understand the interactions between natural and anthropogenic factors which may lead to geothermal-induced seismicity and ii) evaluate currently applied approaches to handle and minimize associated risks.

The objective of this work is to establish a state of the art about deep geothermal-induced seismicity, by describing factors that have a bearing on the generation of seismic events, as well as by discussing existing means to handle their occurrence. Based on a worldwide review of geothermal projects, we created a large database describing each selected case study in terms of geological properties and tectonic setting, operational parameters and type of geothermal systems, as well as spatio-temporal characteristics of the observed induced seismicity. Collected data are analyzed in order to better understand possible cause-effect relationships between induced seismicity and geothermal operations with the aim of identifying the most important preexisting and anthropogenic factors, as well as their interactions, which may have a key role on the occurrence of seismic activity.