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Fluid-injection induced seismicity in the Cooper Basin (Australia): spatial, temporal, and energy characteristics

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Induced seismicity has been recognized as a concern in subsurface industrial operation, and particularly at fluid-injection sites in major oil and gas exploitation plays, where hydraulic stimulations are conducted to increase rock permeability. Induced seismicity occurs also in Enhanced Geothermal Systems (EGS), where hydraulic fracturing is used to accelerate heat extraction from the rock. If that seismicity can be controlled, EGS may represent a valid alternative to produce energy with a low-carbon impact.

The government of South Australia has tested the potential of geothermal energy in the Cooper Basin (South Australia), with a long-term fluid-injection experiment that has been conducted in several of its EGS geothermal fields. The stimulation was accompanied by sporadic sequences of induced earthquakes which occurred within a time interval between 2003 and 2012. Until the project was stopped in 2015, more than 50,000 locatable events occurred, with magnitudes ranging between -2.0 and 3.7.

As part of the FracRisk consortium (wwww.fracrisk.eu), we have analyzed the induced earthquakes, from data (in particular event catalogs) that were kindly provided by the Energy Resources and Division of the Government of South Australia. Catalogs include information about hypocentral location and magnitude of the detected events.

We inspect potential links between the location of consecutive events in time and magnitude, which suggests that aftershocks can occur even for low-energy events. In some cases they show an Omori-type behavior. We further study the seismic efficiency as a function of treatment parameters, namely the ratio between measured vs. theoretical seismic moment, and we propose this as a way to distinguish “triggered" from “induced" events. The seismic response of the Cooper Basin reservoir varies accordingly to the time of the stage, reflecting a different behavior in the amount of tectonic stress release. Finally, we focus on the main controlling factors of fluid-flow propagation, and the geometry of the created fractures, observed in the triggering front and the backfront of the seismicity. This enables us to infer the fracture development.

The results are consistent with a model in which the induced seismicity in the Cooper Basin is mainly controlled by faulting area rather than the maximum injected volume. Pore-pressure diffusion effects alone are not enough to control the observed induced seismicity. Clearly, this has much bearing on fracturing mechanisms around pre-existing tectonic faults and the geometry of fluid-flow propagation in the subsurface.