Geophysical Research Abstracts
Vol. 13, EGU2011-3308, 2011
EGU General Assembly 2011

Magnitudes of induced earthquakes versus geometric parameters of stimulated volumes

Serge Shapiro, Oliver Krüger, Carsten Dinske, and Cornelius Langenbruch
Freie Universitaet Berlin, Fachrichtung Geophysik, Berlin, Germany (shapiro@geophysik.fu-berlin.de)

Pore fluids in rocks and pore-pressure relaxation can trigger aftershocks of earthquakes. Sometimes fluid injections into geothermal boreholes are able to induce significant (felt at the surface) or even potentially damaging seismic events. For instance, this was the case by several stimulation injections at such Enhanced Geothermal Systems like the ones at Basel, in Cooper Basin, at The Geysers field and at Soultz. Often it has bin claimed that the probability of such events is enhanced just before or shortly after the end of injections. Comparing temporal seismicity rates of statistically well represented small-magnitude events to the seismicity rate of large-magnitude events we found that the last ones are systematically underrepresented. With increasing injection time the seismicity rate of such events tends to the theoretical limit well established for numerous fluid-induced small-magnitude earthquakes. We compared statistics of induced events to those of randomly distributed thin flat discs modelling rupture surfaces in a finite stimulated volume. We found that the factor limiting the seismicity rate of large-magnitude events is the minimal principal axis of the stimulated volume. It controls the order of a largest possible magnitude. This conclusion is in a well agreement with real data on induced seismicity at geothermal and hydrocarbon reservoirs. Because usually the minimal axis increases with time, it leads to a relative enhancement of the large-magnitude probability at the end of injection operations or shortly after it. We analyze an impact of the geometry of a stimulated volume on the Gutenberg-Richter-type frequency-magnitude distribution of induced earthquakes. Results of our numerical modelling show very close similarity with real data. This geometrical control of the magnitude frequencies indicates that a necessary condition of a large-scale earthquake is a stress-state perturbation on a large part of its potential rupture plane. This also explains why hydraulic fracturing of hydrocarbon reservoirs induces seismicity of magnitudes significantly lower than stimulations of geothermal reservoirs. The minimal principal axis of the stimulated volume is usually one-two orders of magnitude smaller in the former case than in the latter one. Monitoring of a spatial growth of seismicity in real time can thus help to reduce a risk of damaging events during rock stimulations by keeping the minimal principal axis of the stimulated volume restricted.