Geophysical Research Abstracts
Vol. 16, EGU2014-16766, 2014
EGU General Assembly 2014

Analysis of induced seismicity in geothermal reservoirs - an overview

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In this overview we report results of analyzing induced seismicity in geothermal reservoirs in various tectonic settings in particular within the framework of the European GEISER project. In the exploration phase of a geothermal field, the seismic network, subsurface fault mapping and in situ stress are of primary interest. The image of the seismic cloud observed is dependent on the design of the installed network, the velocity model used and the applied location technique. In the stimulation phase, the attention is turned to reservoir hydraulics (i.e. fluid pressure, injection volume) and their relation to larger magnitude seismic events, their source characteristics and occurrence in space and time. Source mechanisms indicate a change in isotropic components of the full waveform moment tensor for events close to the injection well (tensile cracks) as compared later stages (shear cracks) further away from the injection well. Tensile events with >15% isotropic components coincide with high Gutenberg-Richter b-values and low Brune stress drops. We identified in situ stress as the most critical parameter for reservoir development and reservoir life-time estimates after the presence of heat. This is because near-well stresses can change from one to another stimulation, and multiple stimulated wells (in crystalline rock only) follow the field Kaiser effect, where little or no seismicity is produced until the previous maximum stress level is exceeded. We recommend to obtain a 3D velocity model of Vp and Vs down to reservoir depth prior to exploitation, apply real-time seismicity and frequency analyses of local 4D tomography for Vp/Vs ratios, and locate seismicity in real-time so that field operators are in a position to adjust the rate and volume of the fluid injected if seismic events start to occur far away from the boundary of the seismicity cloud.