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Mechanism of fluid-induced micro-earthquakes near Landau, Upper Rhine Graben, Germany

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Since 2006 micro-earthquakes (ML $<$ 2.8) occur in the area of Landau, a town in the Central Upper Rhine Graben, Germany. These events are related to the injection of fluids into 2,500-3,500 m deep boreholes. Within the MAGS project (www.mags-projekt.de) the seismicity was monitored with a dense network of recording stations and the seismic waveforms were analysed in details. The complex 3-D geological structure complicates the application of 1-D methods, and tests were done using 3-D seismic waveform modelling with the SOFI3D FD method. About 1,300 events were detected with cross-correlation analyses, although the signal amplitudes are quite low and the noise level in the study area is high. A part of the events was localised with an absolute (HYPOSAT) and relative (hypoDD) method. The determined hypocentres are aligned along discrete elongated structures which are interpreted as preferred rupture zones. Fault plane solutions with FOCMEC indicate normal and strike-slip shear mechanisms. The preferred strike of the faults is NNW-SSE to NNE-SSW which is similar to the regional maximum horizontal stress direction (NNW-SSE). The study of seismic shear wave anisotropy indicates a fast polarisation direction which is also in NNW-SSE direction. This azimuth-dependent anisotropy as well as the other seismological and tectonic models are consistent with fluid-filled faults oriented in NNW-SSE direction which are (re-)activated by fluid injection at depth.