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Microseismicity Observed at a Non-Pressure-Stimulated Geothermal Plant

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The North Alpine Foreland Basin in south-eastern Germany provides remarkably favorable conditions for the exploitation of geothermal energy resources. Scarce background seismicity leads to low seismic hazard and the existence of a natural aquifer obviates the need for high-pressure hydraulic stimulation. This hydrothermal usage was previously assumed to be unproblematic with regard to induced seismicity and most of the currently operating hydrothermal geothermal plants supply thermal baths or district heating with relatively low flow rates and temperature drops. However, in February of 2008 two regionally recorded, shallow magnitude $M_l > 2$ earthquakes occurred at a geothermal power plant which is located in the municipality of Unterhaching south of Munich. One of the main differences of this specific plant is their combined heat and electric power production which is accompanied with much higher flow rates and thus larger volumes of circulated water. These events showed that induced seismicity can not be ruled out even in this fortunate setting and emphasized the need for a detailed analysis of the case, especially considering that in 2012/13 a series of larger plants for power generation are about to go into production. We present results from two years of data acquired with a local five station seismic network. Overall, more than 100 events with magnitudes mostly below 1 could be detected with a magnitude of completeness of around 0 and the largest observed magnitude at 2.1. Absolute locations are calculated in a 3D velocity model constructed from a high-quality 3D seismic survey and a simple two-layer v_p/v_s model. As a result, the epicenters cluster tightly within 500 m around the open-hole part of the injection well. The hypocentral depths are computed to be 1500 m below the well bottom but are less well constrained due to uncertainties in the shear wave velocity model and the spatial distribution of the network. Several indications point towards a necessary modification of the v_p/v_s model resulting in shallower hypocentral depth estimates. Relative locations computed applying a nested 'Master-Event' scheme show an alignment of earthquake locations along a strike that is in good agreement with estimates of focal mechanisms and the main fault system penetrated by the well. Preliminary results from the analysis of correlations with operational data reveal a possible connection with sudden changes in the injection parameters. The analysis furthermore suggests that in this case pore pressure changes might be subordinate to thermal stresses. One aspect that is suspected to also have a major influence on the observed seismicity is the favorable orientation of the pierced fault system in the present day stress field. The presented results show that even non-pressure stimulated geothermal plants operated hydrothermally at low injection pressures and with very good hydraulic parameters are able to generate induced seismicity under certain still to be investigated conditions and have led to a rethinking of the demand for seismic monitoring at upcoming geothermal facilities in this area.