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Deriving the triggering potential in the Lower Rhine Embayment using background seismicity near Weisweiler, Germany

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The Earth's crust is permeated with faults and fractures due to its long tectonic history. Faults and fractures not only act as zones of weakness but can increase permeability and act as conduits to circulate fluids in the underground, making them ideally suited for geothermal energy production. However, human-induced changes to *in-situ* pressure fields have a documented history of leading to fault (re-)activation in the form of earthquakes (seismic slip) or aseismic slip that does not generate measurable ground motion.

This study aims to quantify the current background earthquake activity, the spatiotemporal relationship to the seismotectonic setting, and the remote earthquake-earthquake triggering propensity in the Lower Rhine Embayment (LRE) in western North-Rhine Westphalia. The study area is targeted for extensive exploration activities focused on geothermal energy production. While regional mean slip rates do not exceed 0.1 mm/yr, paleo-seismic studies suggest that the normal faulting system has hosted a series of ~14 earthquakes of $M_w > 5.0$ since the 14th century, including the 1992 M_w 5.3 Roermond earthquake. Therefore, estimating background seismicity rates independent of anthropogenic stress perturbation is one important element in developing strategies to minimize the probability of felt earthquakes caused by industrial activity.

We evaluate waveform data from a temporary deployment of 48 seismic stations operating between July 2021 and May 2022 in a radius of roughly 10 km around a future exploration well drilling site in Weisweiler. We implement a machine learning-based earthquake detection algorithm, *SeisBench*, to detect earthquakes and denoise the continuous seismic waveforms (*DeepDenoiser*), estimate P- and S-phase arrivals (*PhaseNet* and *Generalised Phase Detection; GPD*), and associate earthquake phases using a Bayesian Gaussian mixture model (*GaMMA*). We locate 81 local earthquakes to complement the 14 recorded in the Earthquake Observatory Bensberg (BNS) catalog for a total of 95 seismic events recorded between July 2021 and December 2021 with magnitudes ranging from $0 < M_L < 1.3$. In addition, we use the continuous BNS catalog to evaluate the dynamic triggering potential in the LRE starting in 1990. We select 20 teleseismic mainshocks with M > 6 (1990 – 2015) and M > 7 (2016 – present), as well as the 1992 Roermond M_w 5.3 due to the high amplitude shaking it caused within the study area. Preliminary remote dynamic

triggering results suggest that the passing surface waves of the July 2021 M 8.2 Chignik, Alaska earthquake may have triggered a seismic sequence of about 16 locatable earthquakes. The migrating aftershock sequence of the Roermond earthquake also suggests the mainshock caused limited dynamic triggering within the study area, which lies outside of the classical aftershock zone of ~2-3 fault lengths.