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The Re-evaluation of the 2004 Rotenburg MW 4.4 Earthquake

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The MW 4.4 Rotenburg earthquake of 20 October 2004 is the strongest seismic event instrumentally recorded in the intraplate region of northern Germany. Due to its magnitude and location in the vicinity of the Söhlingen natural gas field, the Rotenburg earthquake is a key event for the assessment of the seismicity and seismic hazard of northern Germany. Until now, it is not clear if the Rotenburg earthquake is an induced, triggered or a pure tectonic event. Published hypocenter locations from various institutions differ considerably. One main reason is that not all existing data have been used in previous studies.

We managed to increase our waveform database for this earthquake significantly by including all relevant data, which have not been used in the previous studies. On this basis, 76 P- and S-phases were picked at seismograms of 62 stations. The greatest azimuthal gap between two stations was significantly reduced from 83° to 38°, which resulted in a more reliable epicenter localization.

The new enlarged set of phases served as input for the 3-D relocalization with NonLinLoc in combination with the advanced CRUST1.0 P-wave-velocity model. To reduce uncertainties, we used different inversion approaches. Furthermore, the first arrivals were selected by different analysts to identify and quantify subjective errors. In addition, a Jackknife approach was conducted to estimate a more realistic confidence area.

Based on the new data, the epicenter of the Rotenburg mainshock is relocated in the center of the Söhlingen hydrocarbon field, in a depth significantly below the reservoir. The horizontal uncertainties are in a range of ±(1 - 2)km. Due to the lack of near seismic stations and the absence of an accurate S-wave-velocity model, the hypocenter is less well-constrained, ranges in depths between 8 and 18 km and is strongly influenced by the vp/vs-ratio. Focal depth uncertainties are in the range of ±(1 - 3)km.

A pre-existing 3-D geological model (Uta, 2017) was updated to identify faults that are the potential source for the Rotenburg event. The fault pattern was improved by interpreted seismics (Gast and Gundlach, 2006) to show a more realistic incidence angle and extension to deeper layers. Linking the relocated hypocenter with faults in the Söhlingen area, the boundary fault at the western margin of the Söhlingen natural gas field is a potential seismogenic fault of the Rotenburg mainshock.

The second major part of this project deals with a macroseismic reevaluation. Previous studies (Leydecker et al., 2006, Dahm et al., 2007) only used a subset of the 1100 questionnaires. The macroseismic dataset has now been enlarged by 200 paper questionnaire reports which were not considered before. We harmonized the dataset of the digital and digitized questionnaire reports. On our enlarged data basis we apply the “Did you feel it?”-algorithm (Wald et al., 2011) to calculate macroseismic intensities for each single questionnaire. The intensities are used to estimate a macroseismic epicenter and focal depth.

Finally, results of the instrumental evaluation in combination with the improved geological 3-D model were linked with the macroseismic estimation.