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Frequency Magnitude Distribution of induced microseismicity - Lessons learned from the mining environment

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Often a pronounced microseismic activity is observed due to induced stress changes in the wake of operations in the near-surface underground, as e.g. the mining of minerals, the backfilling of old mining cavities or the extraction and injection of fluids. A statistical evaluation of the Frequency Magnitude Distribution (FMD) of this activity can help to characterize the underground and its seismogenic behavior. Thus, the parameters of the Gutenberg Richter relation (GRR) describing the observed FMDs are often used to estimate the seismic hazard caused by human interference. However, induced microseismicity is highly variable both in space and time with respect to its rate and its FMDs. Thus, a simple application of concepts developed for tectonic regimes is not straightforward.
Results from microseismic and microacoustic datasets spanning several orders of magnitudes are presented. They indicate that a reasonable interpretation of the observed FMDs is only possible with an understanding of the underlying fracture processes. FMD analyses of microacustic data indicate e.g. a clear correlation between observed b-values and structural units in an abandoned mining complex during backfilling. Furthermore, the b-values are sensitive to changes of the acting stress regime with high b-values during times of tensional stress components and lower values during periods of purely compressional stresses.
Different event clusters of microseismic activity induced during coal mining and found by waveform similarity analysis exhibit highly distinct FMDs. The cluster analysis, a precise relocation of the events and a study of their FMDs allow a distinction between small magnitude events concentrated around the mined out coal seam and stronger activity with a non-GRR at some distance from this seam in presumably more competent layers.
These results indicate that a correct interpretation of the observed FMDs in the context of induced seismicity often depends on additional information like the precise knowledge of the underground structure, a complementary stress modeling, precise relocation of the events or a waveform cluster analysis. Furthermore, results are often highly dependent on the spatial and temporal resolution of the analysis when stress fields quickly change in time and space and when adjacent structural units exhibit highly variable fracture characteristics.