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Observation and Characteristics of Injection-induced Repeating Earthquake Sequences at Basel

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We detect and analyse repeating earthquake sequences in the Basel 1 microseismic data set. Using a combination of waveform similarity and estimates of source radius we identify 144 repeating earthquake sequences with a total of 422 events.
Their spatial and temporal characteristics differ greatly from the trend of the entire microseismic distribution. Repeating events are an ubiquitous feature at small distances from the injection source (<250-300m) and during the stimulation phase (when wellhead pressure increases monotonically), but are clearly under-represented after shut-in and at larger distances. The observations indicate that the repeating events compose a subset of the microseismic data which is more sensitive to pore pressure changes than the total induced seismicity at Basel, which is at larger distances not only affected by pore pressure variations, but presumably also by stress transfer from the larger (Mw>2.0) events. This suggests that the mapping of injection-induced repeating earthquakes in time and space may help to evaluate the relative contribution of different triggering mechanisms (pore pressure versus stress transfer).
Furthermore, this study shows that a significant percentage of the fractures stimulated in the Basel reservoir ruptured repeatedly: More than 15 percent of all located events are repeaters.
We anticipate that the occurrence of repeating events is a common feature in injection induced microseismic data sets, and that it is useful to incorporate repeating events in future statistical analyses of microseismic data, which so far generally assume that each potential source in the stimulated reservoir can only fail one-time.