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Key aspects governing induced seismicity

Loes Buijze (1,2), Brecht Wassing (1), and Peter Fokker (1)
(1) TNO/Geological Survey of the Netherlands (loes.buijze@tno.nl), (2) Utrecht University, The Netherlands

In the past decades numerous examples of earthquakes induced by human-induced changes in subsurface fluid pressures have been reported. This poses a major threat to the future development of some of these operations and calls for an understanding and quantification of the seismicity generated. From geomechanical considerations and insights from laboratory experiments the factors controlling induced seismicity may be grouped into 4 categories; the magnitude of the stress disturbance, the pre-existing stress conditions, the reservoir/fault rock properties and the local geometry. We investigated whether the (relative) contributions of these factors and their influence on magnitudes generated could be recognized by looking at the entire dataset of reported cases of induced seismicity as a whole, and what this might imply for future developments.
An extensive database has been built out of over a 160 known cases of induced seismicity worldwide, incorporating the relevant geological, seismological and fluid-related parameters. The cases studied include hydrocarbon depletion and secondary recovery, waste water injection, (enhanced) geothermal systems and hydraulic fracturing with observed magnitudes ranging from less than -1.5 to 7. The parameters taken into account were based on the theoretical background of the mechanisms of induced seismicity and include the injection/depletion-related parameters, (spatial) characteristics of seismicity, lithological properties and the local stress situation. Correlations between the seismic response and the geological/geomechanical characteristics of the various sites were investigated.
The injected/depleted volumes and the scale of the activities are major controlling factors on the maximum magnitudes generated. Spatial signatures of seismicity such as the depth and lateral spread of the seismicity were observed to be distinct for different activities, which is useful when considering future operations. Where available the local stress situation is considered, as well as the influence of the natural seismicity. Finally, we related induced seismicity to several reservoir and fault rock properties, including fault rock stability as is observed from the laboratory.
The combination of activities of different natures and associated seismicity occurring through distinct mechanisms in this dataset is very useful for a better understanding of the factors governing induced seismicity and the operation-specific seismic expressions.