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Investigating the possible effects of salt in the fault zones on rates of seismicity – insights from analogue and numerical modeling

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The presence of salt in dilatant normal faults may have a strong influence on fault mechanics and related seismicity. However, we lack a detailed understanding of these processes. This study is based on the geological setting of the Groningen area. During tectonic faulting in the Groningen area, rock salt may have flown downwards into dilatant faults, which thus may contain lenses of rock salt at present. Because of its viscous properties, the presence of salt lenses in a fault may introduce a strain-rate dependency to the faulting and affect the distribution of magnitudes of seismic events.

We present a "proof of concept" showing that the above processes can be investigated using a combination of analogue and numerical modeling. Full scaling and discussion of the importance of these processes to induced seismicity in Groningen require further, more detailed study.

The analogue experiments are based on a simplified stratigraphy of the Groningen area, where it is generally thought that most of the Rotliegend faulting has taken place in the Jurassic, after deposition of the Zechstein. This is interpreted to mean that at the time of faulting the sulphates were brittle anhydrite. If these layers were sufficiently brittle to fault in a dilatant fashion, rock salt could flow downwards into the dilatant fractures. To test this hypothesis, we use sandbox experiments where we combine cohesive powder as analog for brittle anhydrites and carbonates with viscous salt analogs to explore the developing fault geometry and the resulting distribution of salt in the faults.

In the numerical models we investigate the stick-slip behavior of fault zones containing ductile material using the Discrete Element Method (DEM). Results show that the DEM approach is in principle suitable for the modeling of the seismicity of faults containing salt: the stick-slip motion of the fault becomes dependent on shear loading rate with a modification of the frequency magnitude distribution of the generated seismic events.

Based on the results of our models we conclude that if the rocks underlying the salt layer did form dilatant faults in the past, the overlying rock salt could have flown into the open fractures, resulting in the presence of salt lenses inside the fault zones at present. The distribution of salt in the fault zone is controlled by the failure mode of the underlying rocks, the fault geometry, the rate of faulting and the rheology of the overlying salt. The results from the DEM models show that the presence of salt can make the fault behavior dependent on the shear loading rate, resulting in a complex interplay between stick-slip dynamics of fault and visco-elastic behavior of salt.