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Slip tendency analysis of 3D faults in Germany

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For many underground operations such as geothermal energy exploitation, mining, oil and gas production or the storage of high-level radioactive waste, active tectonic or induced seismicity is of concern. Seismicity usually occurs on pre-existing faults that are reactivated under adequate stress conditions. Thus, an assessment of the reactivation potential of faults can aid in the identification of areas particularly prone to the occurrence of seismic events or such areas where adequate geotechnical measures have to be taken to avoid anthropogenic fault reactivation. A tool for the assessment of the fault reactivation potential is the so called slip tendency, which is the ratio between the maximum resolved shear stress on the fault plane and the normal stress. Such an analysis requires information about the stress field acting on the fault plane and information about the fault geometry, fault orientation and frictional properties. Information about these parameters can be very limited, since 3D fault geometries are often only extrapolated from geological surface data. Furthermore, stress data is usually sparse, only available pointwise and unevenly spatially distributed. Geomechanical-numerical modelling can be used to derive a spatially comprehensive description of all six independent components of the stress tensor from the available stress data.

For Germany, an estimate of the stress tensor is provided by the geomechanical-numerical model by Ahlers et al. (2022). Furthermore, fault geometries as part of geological models of the German federal states are available for large parts of Germany. We use both the stress data derived from the geomechanical-numerical model and the fault geometry data from the federal state models to calculate slip tendencies for more than 10.000 faults and fault segments. The resulting slip tendency is generally the highest in the northern Upper Rhine Graben area where it routinely reaches values of 0.7 and more. In the Alpine and Alpine Foreland region the slip tendency is generally the lowest with values only very rarely exceeding 0.3. In North Germany slip tendency values range mainly between 0.3 and 0.6 but with both higher and lower values being fairly common. In general, faults striking in NNE-SSW direction and NW-SE direction display the overall highest slip tendencies whereas faults striking in ENE-WSW direction show very low slip tendencies. With increasing depth slip tendencies generally decrease strongly. However, there are still major areas in Germany where either no fault geometries or only insufficient fault geometries

are available. Furthermore, pore pressure has a major influence on the slip tendency. For our calculations, we assume hydrostatic pore pressure. While overpressured pore fluid is documented for example for the Molasse Basin in South Germany, no spatially comprehensive pore pressure data set is currently available for the whole of Germany.