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SpannEnD SPANNUNGSMODELL ENDLAGERUNG DEUTSCHLAND

Institute of Applied Geosciences
Technical Petrophysics

Slip tendency analysis of major faults in Germany

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1. Motivation

Seismicity is a crucial aspect for many underground activities such as oil and gas production, geothermal heat production, mining or the storage of nuclear waste. Since seismicity is most likely to occur on pre-existing faults it is imperative to assess their reactivation potential in order to identify regions with an elevated probability of natural seismicity or reduce the risk of induced seismicity. Critical aspects for fault reactivation are:

- Fault geometry (orientation, size, surface characteristics)
- Frictional properties (coefficient of friction, cohesion)
- Stress field
- Anthropogenic stress changes

The reactivation potential can be estimated using the so called slip tendency, the ratio between maximum resolved shear stress on the fault plane and the effective normal stress:

$$ST = \frac{\tau}{\sigma_{neff}}$$

However, only limited data is available on fault geometries and their frictional properties as well as the stress field. We present a slip tendency analysis for major faults in Germany using different fault sets and the stress tensor derived from the SpannEnD model.

2. The Stress Field: SpannEnD Model

The 3D numerical geomechanical model from the SpannEnD project (Ahlers et al. 2021) has been calibrated with stress magnitude data from the stress magnitude database (Morawietz et al. 2020) and stress orientation data from the World Stress Map (Heidbach et al. 2016) and provides a first estimate of the stress tensor in Germany and adjacent areas (extends shown in Fig. 1a, stratigraphic units shown in Fig. 1b)

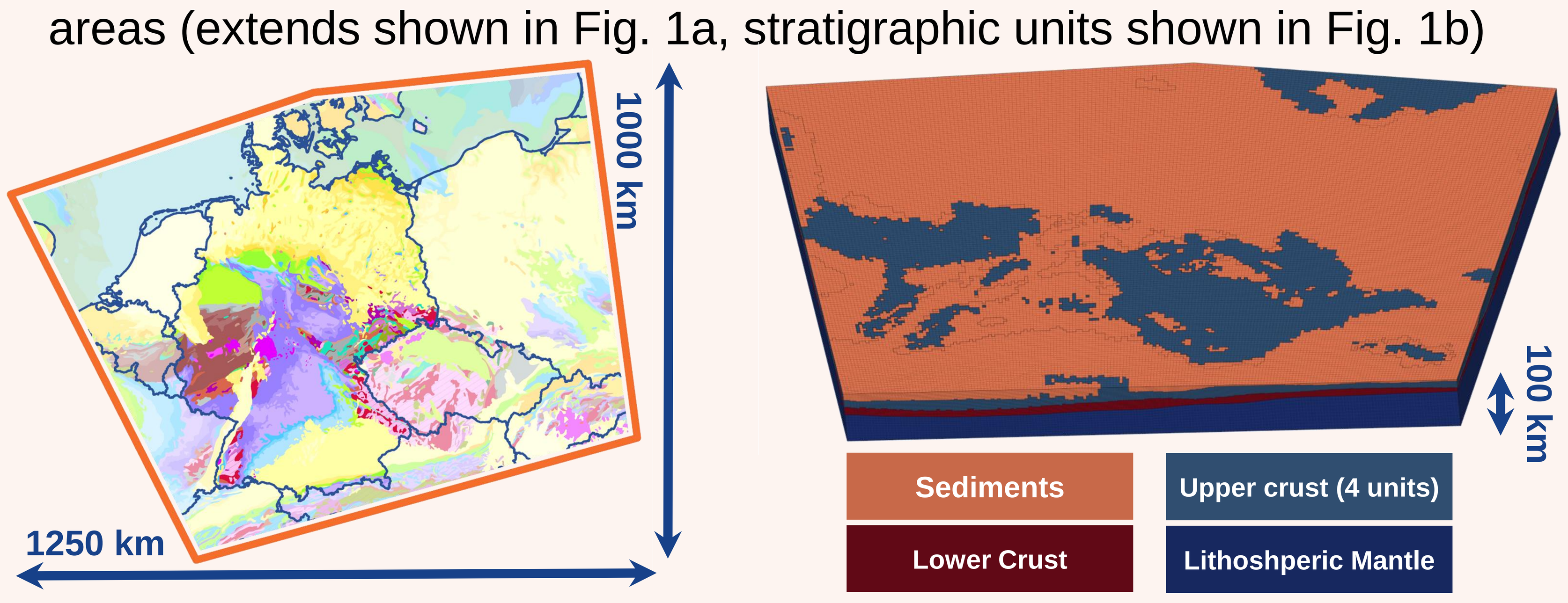

Fig.1 Left: Boundaries of the model (orange frame); Right: The discretisation of the model

3. The 3D Fault Geometries

We created three fault sets of increasingly complex 3D geometries (Fig. 2). The **vertical fault set** is based on the fault catalogue from the GeoTIS project and comprises over 900 faults. All faults have been implemented as vertical faults. The **Andersonian fault set** comprises 55 faults with Thrust faults dipping with 30°, Normal faults with 60° and Strike Slip faults with 90°. The geometries of the 23 faults of the **semi-realistic fault set** were based on geological and seismic cross sections.

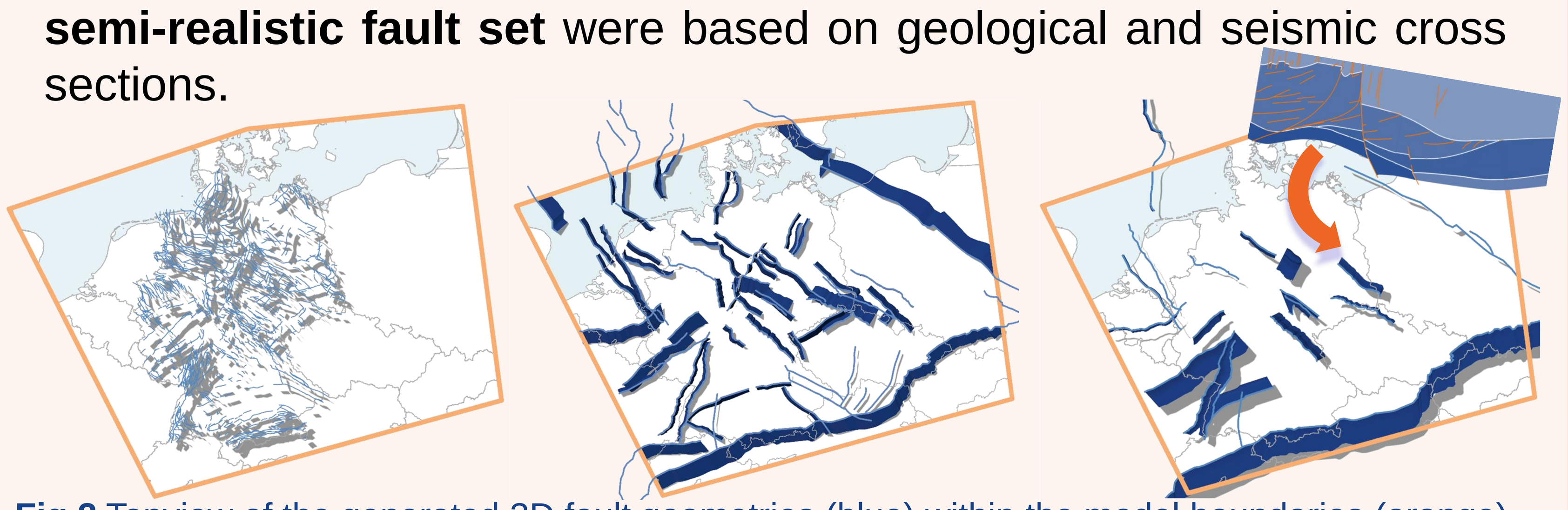

Fig.2 Topview of the generated 3D fault geometries (blue) within the model boundaries (orange). Left: Vertical fault set; Middle: Andersonian fault set; Right: Semi-realistic fault set.

4. Results

Assuming hydrostatic pore pressure, ST has been calculated and compared to seismic events with a Moment magnitude of 3.5 and greater. ST mainly ranges between 0 and 0.4 with some fault segments reaching values of 1 and higher. Faults striking in NNE and NW direction show elevated ST for all three fault sets. In general, ST is higher for the Andersonian fault set than for the vertical and semi-realistic fault set (Fig. 4).

A major influence on the fault reactivation potential is the fault geometry as generally listric normal faults (semi-realistic fault set) and thrust faults experience lower ST than normal faults with a straight geometry (Andersonian fault set) (Fig. 5).

Another major influence on the reactivation potential is the pore pressure. Overpressures as they are known for the Molasse basin can drastically increase ST (Fig. 6) by reducing the effective normal stresses.

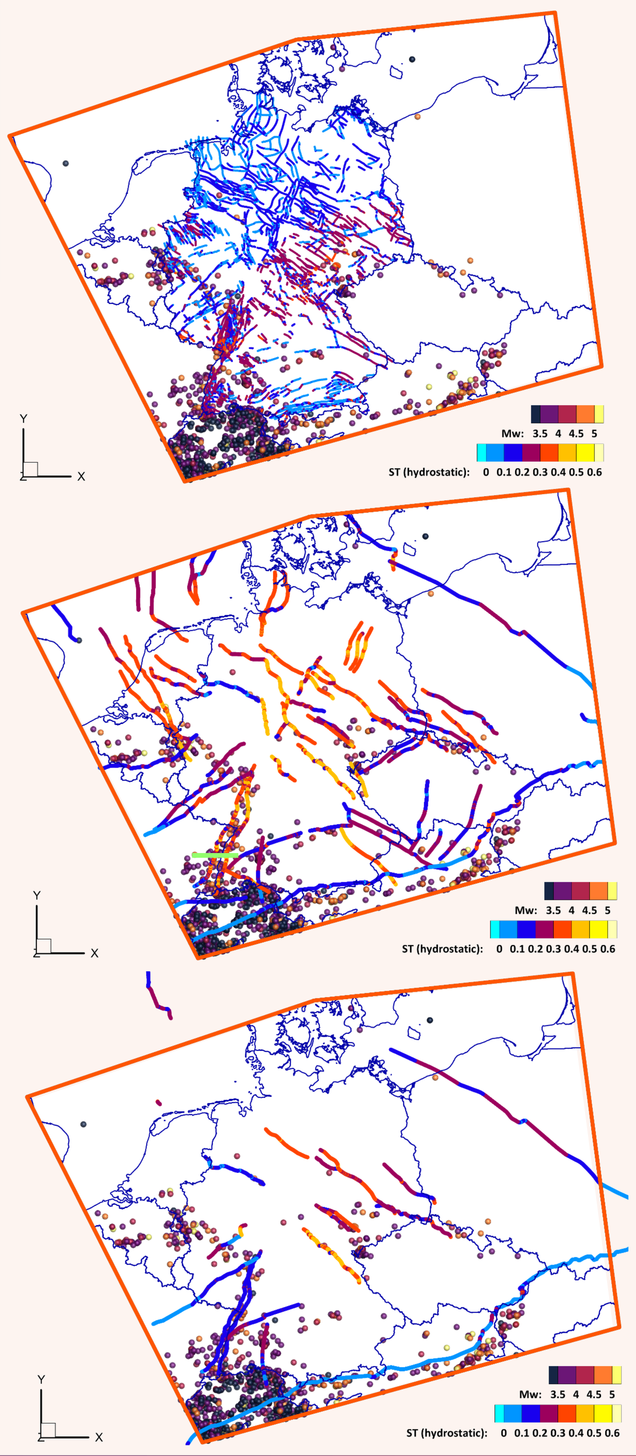

Fig. 3 ST for a hydrostatic pore pressure in a depth of 8 km. Seismic events with a moment magnitude Mw of 3.5 and greater are plotted alongside.
Top: vertical fault set.
Middle: Andersonian fault set
Bottom: Semi-realistic fault set

The green lines in the middle and bottom figures indicate the location of Fig. 5

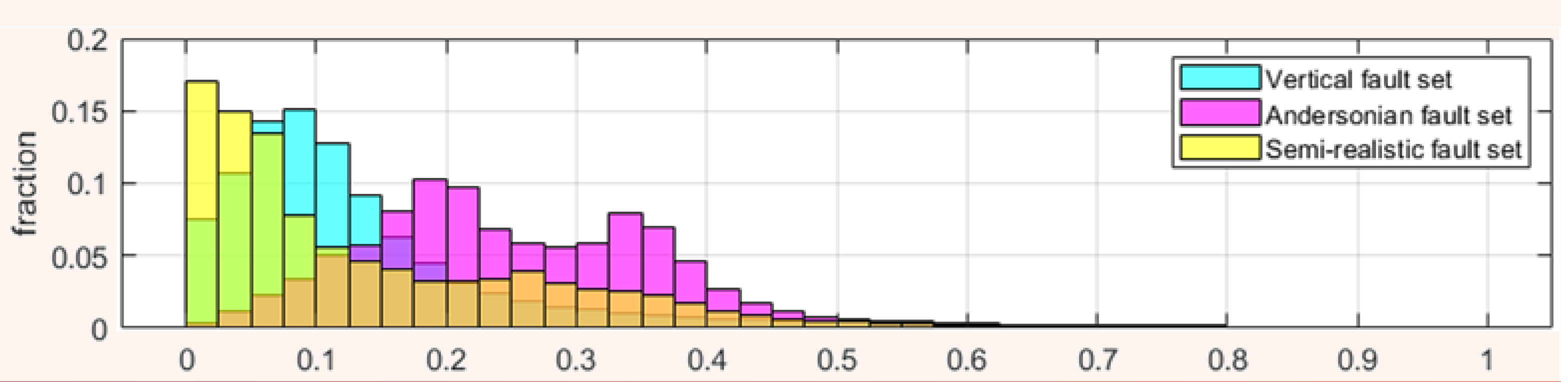

Fig. 4 ST histogram for the vertical fault set, the Andersonian fault set and the semi-realistic fault set

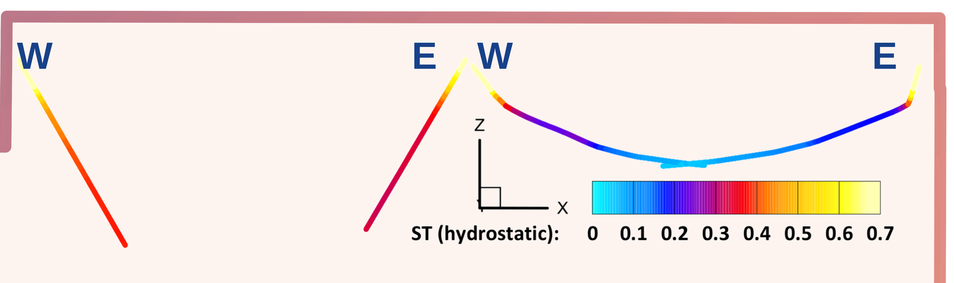

Fig. 5 Cross section through the Upper Rhine Graben (URG) boundary faults illustrating the impact of fault geometry on the reactivation potential (left: Andersonian fault set; Right: Semi-realistic fault set) displaying ST for hydrostatic pore pressure

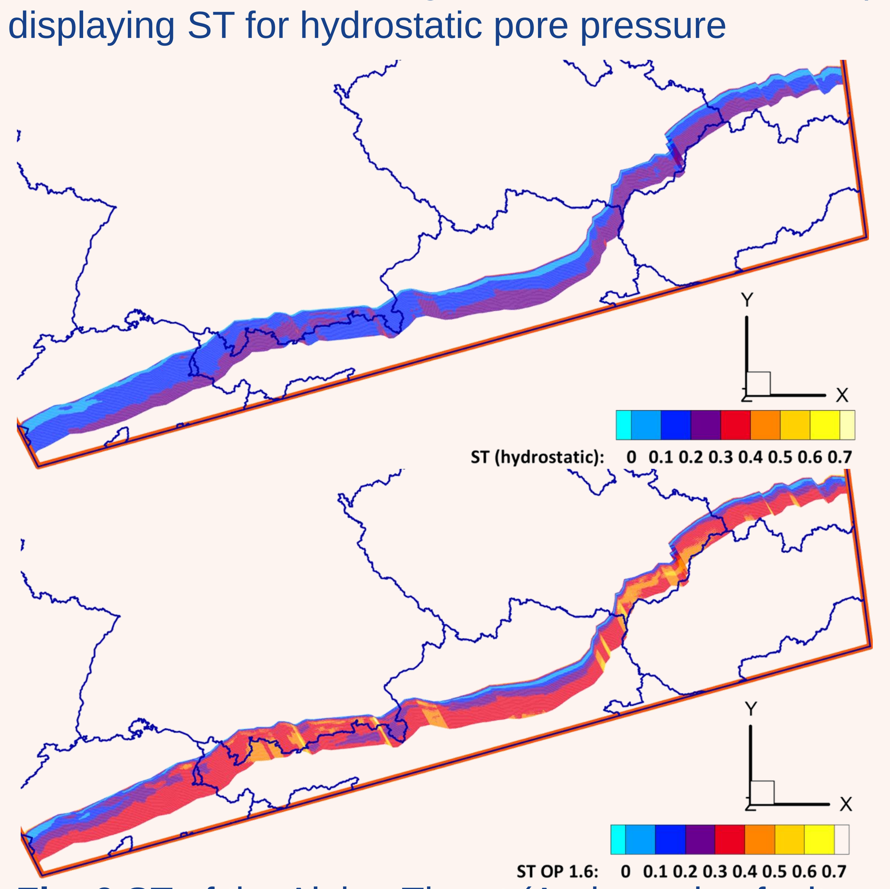

Fig. 6 ST of the Alpine Thrust (Andersonian fault set). Top: With hydrostatic pore pressure; Bottom: Pore Pressure gradient of 16 MPa/km

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