SpannEnD project: 3-D stress modelling in the upper crust of Germany

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Geomechaniccal stability of deep geological repositories is affected by endogenous and exogenous processes and by geotechnical operations. Stability prediction requires estimates of future stress changes and the current stress state. However, data records on the current stress state are incomplete, sparse and spatially unevenly distributed. Therefore, geomechanical models are essential to predict the 3D stress tensor. The most important data for the model are the elastic rock properties and rock density as well as stress data for the model calibration. The aim is to find the optimal initial and boundary conditions that result in a best-fit with respect to available stress data within the model volume.

We compiled the first open access database for stress magnitude data for Germany and adjacent areas (Morawietz et al., 2020) as an extension of the existing stress orientation database (world-stress-map.org). It contains 568 data records, but only 15 % have reliable quality, which means that on average only one stress magnitude data record is available for an area of 100 × 100 km^2. Thus, the key task of the project SpannEnD (Spannungsmodell Endlagerung Deutschland) was to develop a 3-D model that covers Germany to provide first-order 3-D stress tensor predictions for regional and local scales.

Based on existing compilations of the crustal structure in and around Germany, data were merged into one structural model and populated with elastic rock properties. While the first model consists of four mechanical units and 1.3 million finite elements (Ahlers et al., 2021), the subsequent model consists of 12 units and 11.1 million finite elements.

The results of the best-fit model with respect to the stress data reveals that there are regional differences when calculating the fracture potential, i.e. the distance to failure of intact rock as well as different values of slip tendency, which provides a measure of the reactivation potential of pre-existing faults. The observed variability of the modelled stress field can be used as a first-order assessment. In addition, the model can be used to derive initial and boundary conditions for models on a regional scale. Furthermore, that makes it investigate the influence of the large-scale crustal structure on the overall stress pattern.

The modelling workflow is designed in such a way that new data and higher finite element resolution can be implemented if required. This will improve the reliability of the large scale model prediction and the initial and boundary conditions for high-resolution regional models for selected areas during the site selection process.

References

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