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A stress field model for the Unterhaching geothermal plant: Challenges and solutions in local model calibration

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The stress field of Earth's upper crust is crucial for geodynamic processes and of key importance in planning and managing the utilization of the subsurface, such as geothermal energy extraction, stimulation of enhanced geothermal systems, or safety assessment of deep geological repositories. The contemporary 3-D stress state also provides the basis to assess the impact of induced stress changes which can lead to the reactivation of pre-existing faults, the generation of new fractures, or subsidence due to long-term depletion.

However, information on the stress state of Earth's crust is sparse and often not available for the areas of interest. So far, the stress tensor orientations and stress regimes have been systematically compiled and provided by the World Stress Map (WSM) project in a public-domain database. Yet, the acquisition of stress tensor orientations is not necessarily accompanied by the determination of the stress magnitudes, which, however, are required when investigating questions related to stability and hazard mitigation strategies of georeservoirs. To estimate the 3-D stress state, geomechanical-numerical modelling is applied. For the calibration of such models, stress magnitude data are essential. A major challenge is to bridge the scale gap between the widely scattered data that is required for model calibration and the high-resolution small-scale geological model in the target area. Ziegler et al. (2016) presented a multistage approach to resolve this challenge. For this, two successively calibrated models are created – one large-scale model with coarse resolution but available stress magnitude data for calibration, and one local model with fine resolution, e.g., based on a 3-D seismic survey of the target area, but without any stress data. Synthetic data obtained through the large-scale model is used to calibrate the small-scale local model.

First, we validated the multistage approach by means of generic models to rigorously quantify the associated introduced uncertainties. For this purpose, we implemented a highly simplified model lithology with only vertical stratification and no lateral changes. In a second step, we applied the multistage approach in a real-world setting and demonstrated the applicability on a local model of Unterhaching, south of Munich/Germany, where a geothermal district heating plant is located. Here, a local high-resolution model based on a 3-D seismic survey (Budach et al., 2018) has been successfully calibrated on a regional-scale stress model of the Bavarian Molasse Basin. The results of the local-scale model agree with the large-scale model. At the same time, stress change due to rock property variability, only resolved in the local-scale model, is shown.