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Stress state estimation – new data and variability assessment of model results

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Abstract. The upper crust of the Earth is used more and more to transport and extract raw materials and energy. It is also used for the final disposal of radioactive waste in deep geological repositories with a particularly crucial requirement for long-term safety over 1×10^6 years. An accurate knowledge of the hosting rock and surrounding formation coupled with comprehensive modelling is fundamental to demonstrate the geological site has the required properties for safe and long-term underground storage. Besides other criteria, geomechanics play an important role. Even if the determination of rock properties is already a challenge, the estimation of the contemporary stress state in the upper crust is even more challenging. To predict the stress state 3-D geomechanical–numerical models are used, but high-quality underground structure, rock properties and in situ stress data for model calibration are needed. In particular, data of maximum and minimum horizontal stress magnitudes (S_{Hmax} and S_{hmin}) are required to find suitable lateral displacement boundary conditions to produce a best-fit model.

During the recent exploration phase for a deep geological repository for radioactive waste in Switzerland, a unique dataset of stress magnitude data has been acquired from eight cored boreholes. Rock mechanical properties were constrained from geophysical logging and laboratory testing. The empirically correlated rock properties were not simply averaged, but a probability distribution was provided. The stress field was explored by conducting more than 120 micro-hydraulic fracturing (MHF) and dry sleeve re-opening (SR) tests in different stratigraphic units, to estimate the magnitudes of S_{hmin} and S_{Hmax}.

We present the results of a 3-D geomechanical–numerical model that shows the best fit with respect to the measured stress magnitudes. Considering the uncertainties of the MHF/SR tests and the ones resulting from rock property variability, the model can reproduce most of the measurements. However, we do show not only the best-fit result but also a bandwidth of individual stress components within a P_{05}–P_{95} probability range. We also show that there are still outliers for this bandwidth, but we will show that these can be explained by scaling effects.

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