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Spectra of stress: Variability in lithologies represented in geomechanical models

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Knowledge of the current undisturbed stress state is a key issue of subsurface applications. Amongst others, the stability of caverns and boreholes depend on the stress magnitudes. For the prediction of the stress in a rock volume 3D geomechanical-numerical models are used. Technically the task is to estimate the equilibrium of forces between gravity and the elastic response due to lateral displacement boundary conditions that result in a best-fit with respect to pointwise stress magnitude data. For sensitivity studies of the effect of variable boundary conditions, the rock properties (Young's modulus, Poisson ratio, density) are assigned to the corresponding lithologies that are implemented in the model volume. However, mainly the Young's modulus has a high variability within each lithological unit.

We demonstrate an approach where obtained information on the rock property distribution is included in a geomechanical model to provide several possible stress states. From these individual cases the range of stress states that are likely to be expected are estimated. This results in a bandwidth for the components of the stress tensor. For each component, a median stress magnitude is provided as well as a 1σ and 2σ range. This allows a more comprehensive estimate of the stress state which, in turn, allows to include uncertainties on stress magnitudes in the design of underground structures due to being more informed. Even though, a safety margin will always have to be included, well known and quantified uncertainties may lead to a reduction of said margin. In turn, this improves economic feasibility. The required safety margins can be adapted to the prevailing stress state for each individual unit if potentially unstable zones are identified well in advance.

We demonstrate the applicability of the approach on the site of a planned deep geological repository. The Swiss National Cooperative for the Disposal of Radioactive Waste (NAGRA) provides an unprecedented amount and quality of both stress magnitude and rock property data

records for this site. For each unit a cumulative density function of the rock properties is available which allows a robust assessment of the variability. Eventually, we are able to provide a bandwidth of the expected stress magnitudes throughout the model volume. A comparison with the measured bandwidths of stress magnitude data records along borehole trajectories shows a very good agreement between the modelled bandwidth and the range of obtained stress magnitudes.