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How to estimate the 3D stress state for a deep geological repository

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Abstract. When stresses yield a critical value, rock breaks or pre-existing faults are reactivated, generating pathways for fluid migration. Thus, the contemporary undisturbed stress state is a key parameter for assessing the stability of deep geological repositories and for quantifying whether stress changes induced by sub-surface constructions and storage of heat-generating waste lead to a critical state. The prediction of the contemporary 3D stress state is achieved with geomechanical–numerical models that are based on the static geological models. These are based on 3D seismic imaging and borehole data and describe the 3D structure and distribution of rock properties. Furthermore, pointwise measurements of the stress state are needed to fit the model to these data. The workshop is divided into three parts. Each part will have a short introduction to the specific topic, followed by dedicated hands-on exercise in small groups and discussions of the exercise outcome and its implications.

1. *How do we formally describe the stress field?* Here you will learn that the stress field is different from other physical field quantities such as temperature or displacement. The latter can be described with a scalar or a vector at a point. In contrast, the stress state at a point is described with the so-called Cauchy stress tensor that has nine components. We will give a quick tour through this concept, starting from very basic physics, and explain why the tensor is needed. In particular, you will learn in the exercises that stress cannot be measured directly with most methods but that strain is observed, from which stress is inferred.
2. *How do we actually measure stress?* We present a range of methods that determine individual components of the stress state. In the exercise you will analyse borehole image logs to identify borehole breakouts and drilling-induced tensile fractures at the borehole wall. These are used to derive the orientation of the minimum and maximum horizontal stresses. Furthermore, we will present methods for the estimation of stress magnitudes. These are essential data for the calibration of a 3D geomechanical model. We will give a brief overview of different methods and in the exercise on the analysis of mini-hydraulic fracture tests as well as on the sleeve-fracturing and sleeve re-opening methods.
3. *From a viewpoint to a 3D description.* If rock properties in the sub-surface were homogenous and isotropic and were to follow a simple linear behaviour between stress and strain, we could estimate the stress state analytically. However, this is not the case, and we will discuss three questions.
   a. How many pointwise stress data are needed to efficiently constrain a 3D model?
   b. How do I know whether a data point taken from less than a cubic metre is a good representation of a large rock volume, i.e. a whole lithological layer?
   c. How can we quantify the uncertainties of the model stress state, and what is the typical range?

You will use a case study in northern Switzerland to explore these questions.