Geomechanical-numerical Models without Stress Magnitude Data

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Knowledge of the undisturbed stress state in the subsurface is of key interest for successful and sustainable subsurface resource extraction and storage management. However, stress data is usually sparse, subject to large uncertainties, and acquisition of new data is expensive. 3-D geomechanical-numerical models can provide a remedy by providing the full stress tensor throughout a volume of interest. However, information on horizontal stress magnitudes which is essential for the model calibration is usually missing.

Here we present an approach that allows a model calibration on indirect stress information instead of (or in addition to) stress magnitude data. Initially, the full range of reasonable stress states are defined. These stress states are assessed for plausibility by comparison with the indirect information that provide upper and lower bounds of the horizontal stress magnitudes. This indirect information are Formation Integrity Tests (FITs), borehole breakouts (BOs), and drilling induced tensile fractures (DITFs). A successful FIT can be used as a lower boundary for the least principal stress component. Modelled stress states that predict a least principal stress magnitude higher than an FIT pressure is expected to be unreliable. BOs occur when the maximum circumferential stress around a borehole wall exceeds the compressive strength of the rock. A model that shows an agreement between the observed BOs and modelled stress state assuming a corresponding rock strength is expected to be reliable. DITFs occur if the minimum circumferential stress around a borehole wall is smaller than the tensile strength of the rock. A modelled stress states reliability is assessed analogously to the BOs. Further indirect observations can be seismicity or available estimates on the differential stress.

The information obtained through comparison of different possible stress states with the indirect information is used to assign weights to the initially defined reasonable stress states. This way, reliable modelled stress states can be identified as those with a high probability while unreliable ones are rejected. Eventually, a bandwidth of likely stress states is provided that allows an educated evaluation of the 3-D stress state with quantified probabilities using Bayes statistics. We present the validation of our approach using a generic model and results from a case study of the Bavarian Molasse.

See also: Ziegler, M., & Heidbach, O. (2023). https://doi.org/10.1029/2022JB024855

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