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No data instead of big data – a novel approach to stress modelling

Moritz O. Ziegler[1], **Oliver Heidbach**[1,2], **and Mojtaba Rajabi**[3]

[1]GFZ German Research Centre for Geosciences, Telegrafenberg, 14473 Potsdam, Germany
[2]Institute for Applied Geosciences, Technical University Berlin, Ernst-Reuter Platz 1, 10587 Berlin, Germany
[3]School of Earth and Environmental Sciences, University of Queensland, Saint Lucia, QLD 4067, Australia

Correspondence: Moritz O. Ziegler (mziegler@gfz-potsdam.de)

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Abstract. Knowledge of the undisturbed stress state in the subsurface is of key interest for the safety assessment of deep geological repositories. However, stress magnitude data are usually sparse, the available data are subject to large uncertainties, and the acquisition of new data is expensive. This highlights the importance of 3D geomechanical-numerical models that provide the full stress tensor throughout a volume of interest. Nevertheless, such a model needs some stress magnitude data for calibration. However, what happens if there are no such data available?

We present a novel approach that enables a model to be calibrated on indirect observations instead of (or in addition to) stress magnitude data. First, the range of stress states that are theoretically possible are defined. These stress states are then assessed for plausibility by comparison with indirect observations or manifestations of the stress state. Amongst indirect data suitable for the approach are formation integrity tests, borehole breakouts, drilling-induced tensile fractures, and other indirect data:

- Formation integrity tests (FITs) are commonly executed during drilling. A successful FIT does not provide a stress magnitude estimate, but it can be used as a lower bound for the least principal stress component. Modelled stress states that predict a least principal stress magnitude higher than an FIT pressure at a corresponding location and depth are expected to be unreliable.
- Borehole breakouts occur if the maximum circumferential stress around a borehole wall exceeds the compressive strength of the rock. Areas with observed breakouts can be compared to the modelled circumferential stress state at the corresponding location and depth in conjunction with an assumption regarding the rock strength. A stress state that shows an agreement between the observations and model results is expected to be reliable.
- Drilling-induced tensile fractures occur if the minimum circumferential stress around a borehole wall is smaller than the tensile strength of the rock. A modelled stress state's reliability is assessed analogously to the borehole breakouts.
- Further indirect data may be observations of seismicity (stress state reaches a critical state) or available estimates on the differential stress.

All of this indirect information available on a volume of interest is assessed individually in order to single out reliable stress states. Finally, a combination of different types of indirect data allows one to significantly narrow down the range of possible stress states. Instead of pinpointing an uncertain single best-fit stress state, a range of likely stress states can be provided with a high level of certainty. In addition, characteristics of the lithology are reflected in the additional data and help to improve the model.

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