GFZ Helmholtz Centre POTSDAM

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World Stress Map Beyond Orientations

The First Quality Ranking Scheme for Stress Magnitude Data

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SpannEnD SPANNUNGSMODELL ENDLAGERUNG DEUTSCHLAND

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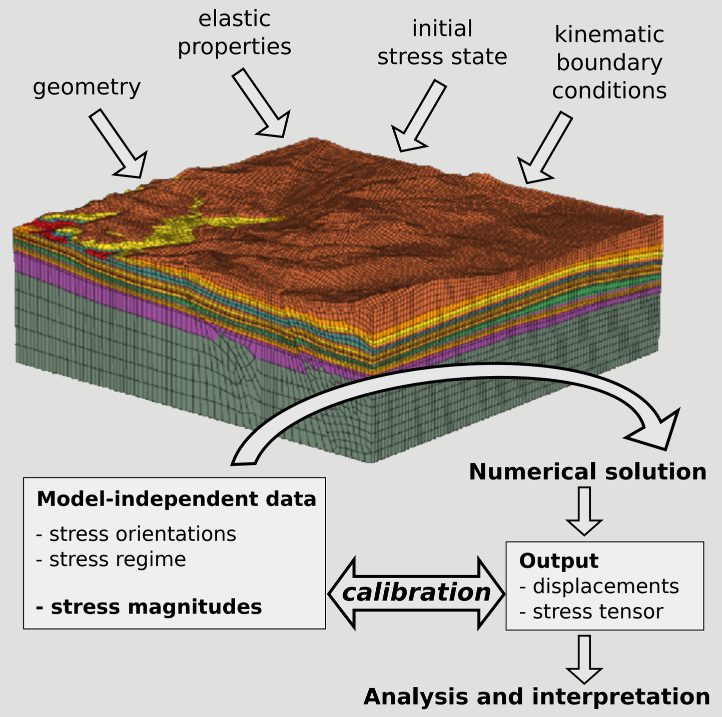
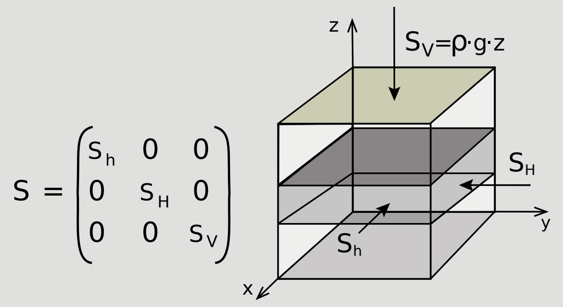
Motivation

Knowledge of the in situ stress magnitudes and orientations is important for subsurface stability issues. The World Stress Map (WSM) is an established open-access compilation of stress orientations. However, since the difference between the minimum and maximum principal stress magnitude is of central importance to assess the subsurface stability, stress magnitude data are also essential. They are needed to calibrate 3D geomechanical-numerical models, which use available point-wise and partial stress information to estimate a continuous and complete description of the 3D stress state.



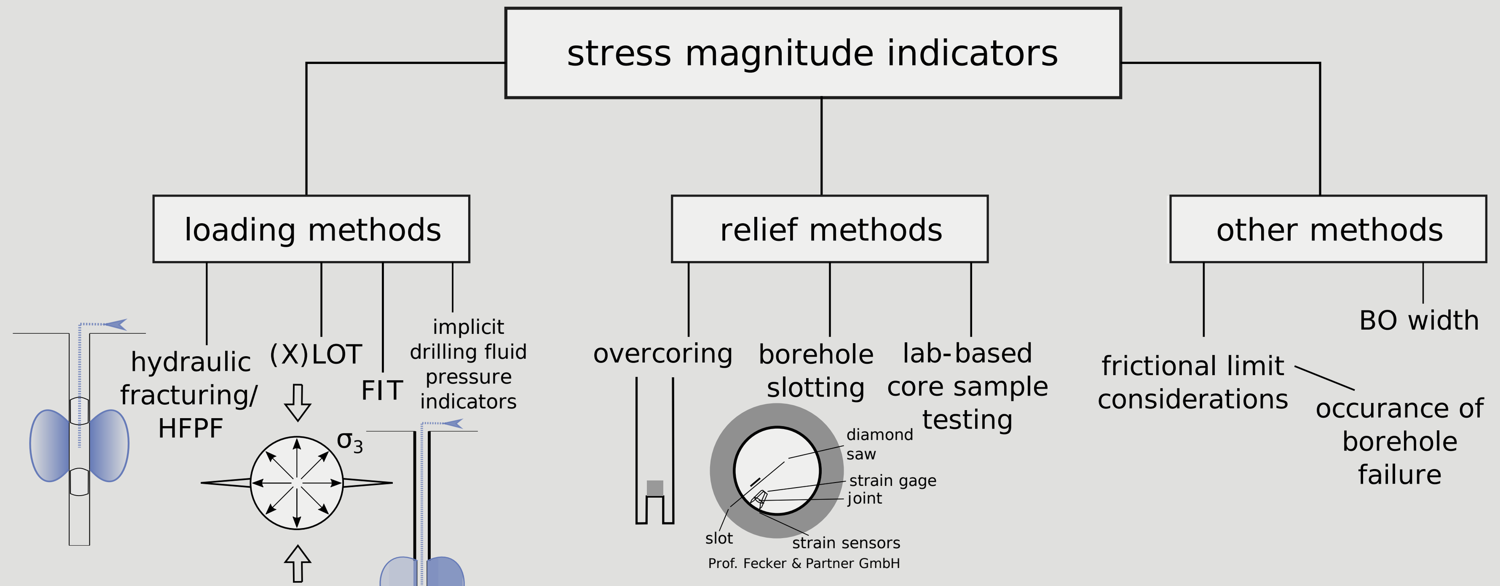
What's behind the stress tensor



Assuming that the vertical stress in the Earth's crust S_V is a principal stress, the minimum and maximum horizontal stresses S_h and S_H are also principal stresses. This so-called reduced stress tensor is fully determined by four components: the S_H orientation and the magnitudes of S_V, S_H, and S_h.

Where the data come from

As stress cannot be measured directly, components of the reduced stress tensor can be inferred from measurements of other quantities that are physically linked to stress. This results in a number of methods for quantifying stress magnitudes:



Result 1: An open-access stress magnitude database for Germany

We compiled a comprehensive and open-access stress magnitude database for Germany and adjacent regions, consisting of 568 data records. On the right side of this poster, the composition of this database is shown in multiple aspects:

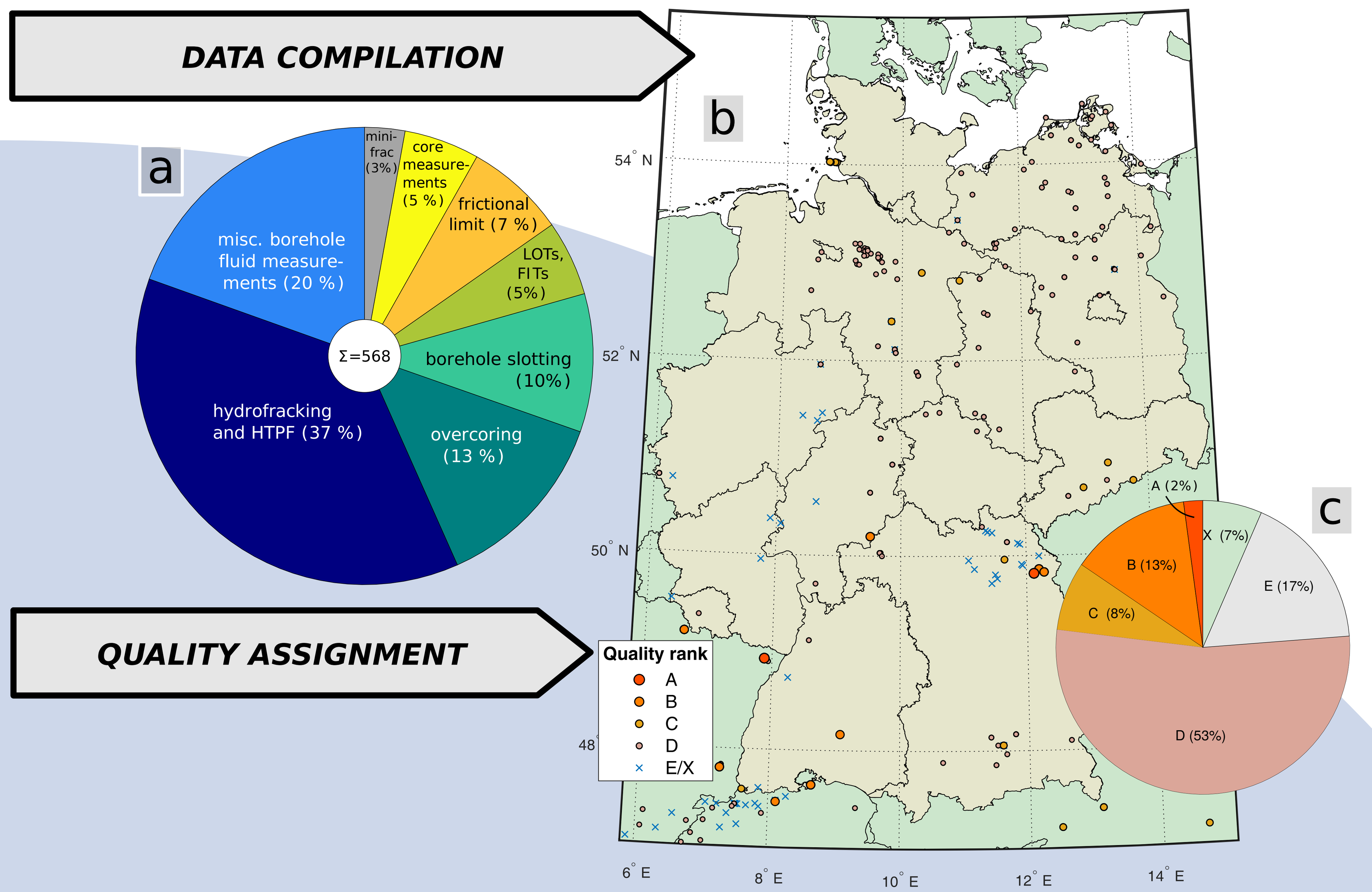
a) overall proportions of indicators,
b) spatial distribution of the data records as a map view,
c) overall proportions of the assigned qualities,
d) depth distribution of the assigned qualities,
e) depth distribution of the stress magnitude indicators.

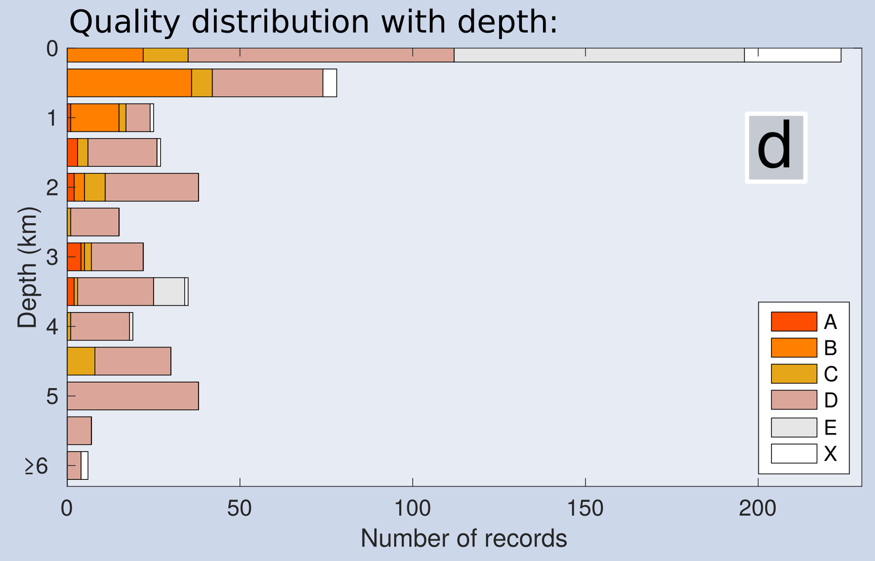
Result 2: A quality ranking scheme for stress magnitude data

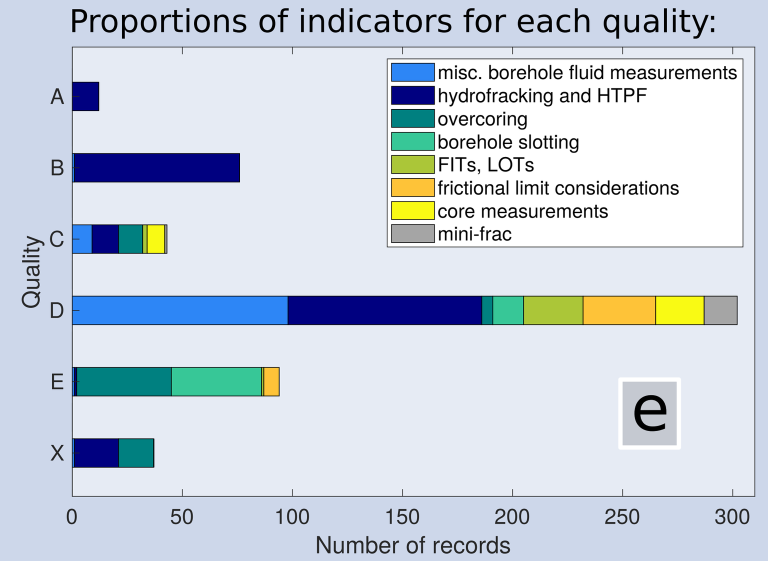
Based on the German data compilation, we developed a quality ranking scheme for stress magnitude data for the first time. In contrast to the established WSM quality ranking for S_H orientation data records, estimates of stress magnitudes cannot be averaged over large rock volumes or depth ranges. Instead, each point-wise information has to be considered separately. Thus, we developed a different approach for the quality ranking scheme of S_h magnitude data records which incorporates both the type of stress magnitude indicator and the degree of information that is available:

indicator \ quality	A	B	C	D	E
HF/HTPF	information on successive injection cycles, access to all interim values and pressure curves desirable, SD given where possible, technical details about the measurement process, analytical approach given, unperforated borehole	main pressure values given, analytical approach given, unperforated borehole	no measurement information, sporadic pressure values, focus only on resulting stress values	stress magnitudes but no pressure values, irreplicable evaluation of measurement data	depth <10m, no depth information available
XLOT, mini-frac	3 or more cycles with consistent FCP, access to pressure curves desirable, unperforated borehole, pre-exploitation tests	information on successive injection cycles, all interim values given, access to pressure curves desirable, SD given where possible, technical details about the measurement process, unperforated borehole	stress information only from the first injection cycle, main pressure values given	stress magnitudes but no pressure values, irreplicable evaluation of measurement data	depth <10m, no depth information available
LOT	-	-	pressure curve and/or picked pressure values available	irreplicable evaluation of measurement data	depth <10m, no depth information available
relief methods in situ (OC/BS) or in lab (WVA etc.)	≥11 consistent measurements with depth ≥300m, fully transparent technical and analytical approach considering temperature	≥8 consistent measurements with depth ≥100m, fully transparent technical and analytical approach considering temperature	fully transparent technical and analytical approach	only resulting stress values given	depth <10m, no depth information available
unspecifed or implicit drilling fluid pressure indicators	-	-	some kind of test description	no test description, but only stress values	depth <10m, no depth information available
FIT	-	-	-	narrowing the value range of σ_3 (lower bounds)	depth <10m, no depth information available
frictional limit considerations	-	-	-	supplemented by empirical data (e.g. material coefficients from rock sample in laboratory), combined with other indicators (e.g. borehole failure)	based on no or very little empirical data, no depth information available

If no indicator is designated or no specific stress information is quantified in the data reference, the data record is also assessed as E-quality. If the referenced data source is currently not available, the quality of the data records is set to X. Abbreviations: HF – hydraulic fracturing, HTPF – hydraulic testing of pre-existing fractures, XLOT – extended leak-off test, LOT – leak-off test, OC – overcoring, BS – borehole slotting, WVA – wave velocity anisotropy, FIT – formation integrity test, SD – standard deviation, FCP – fracture closure pressure. (Version dated december 2019.)







Summary and outlook

The presented qualitity ranking scheme was published along with the German stress magnitude database. Both are available via an open-access repository (see QR-code). The ranking shall be subject for expert discussions and will be expanded by additionial indicators when applied on further data. The German pilot study is intended to be a template for a global implementation within the framework of the WSM project (www.world-stress-map.org). Further countries and regions that we will explore are Australia, Scandinavia and India. We invite you to contribute to this project in your area or country of interest and to join the WSM team as an official collaborator.

short URL to review version of the database: bit.ly/39dYBf3

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