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Supplement of

An Open-Access Stress Magnitude Database for Germany

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An Open-Access Stress Magnitude Database for Germany

Data-driven geomechanics for the best possible repository

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SpannEnD Spannungsmodell Endlagerung Deutschland
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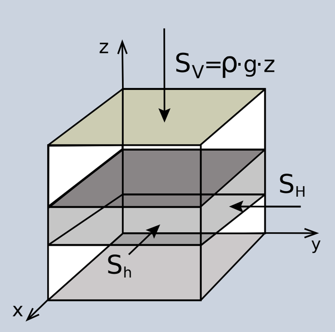
Betreut vom PTKA Projektträger Karlsruhe, Karlsruher Institut für Technologie

1 The impact of rock stresses on deep geological repositories

The crustal stress field plays a major role in the characterization of a deep geological repository for nuclear waste. It influences factors such as

- the excavation zone in the vicinity of the underground structures,
- the hydraulic permeability of the host rock,
- the self-sealing capacity,
- the occurrence of earthquakes and
- reactivation of faults as migration paths for fluids and radionuclides.

With the World Stress Map (WSM), a database of stress orientations already exists, but for stability estimation, magnitude ratios are crucial (Figs 1&2). Within the SpannEnD project, a comprehensive stress magnitude database was built and published for the first time (Morawietz & Reiter, 2020).



$$S = \begin{pmatrix} S_h & 0 & 0 \\ 0 & S_H & 0 \\ 0 & 0 & S_V \end{pmatrix}$$

Fig. 1: 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.

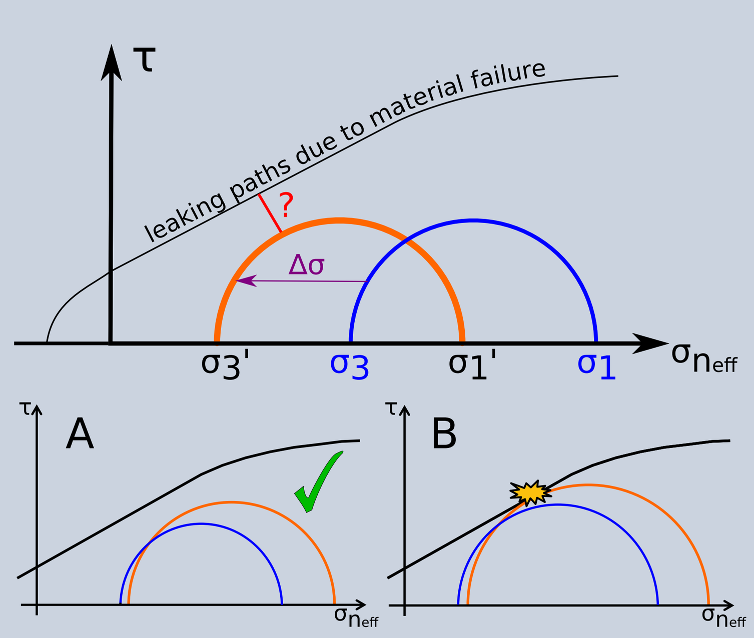
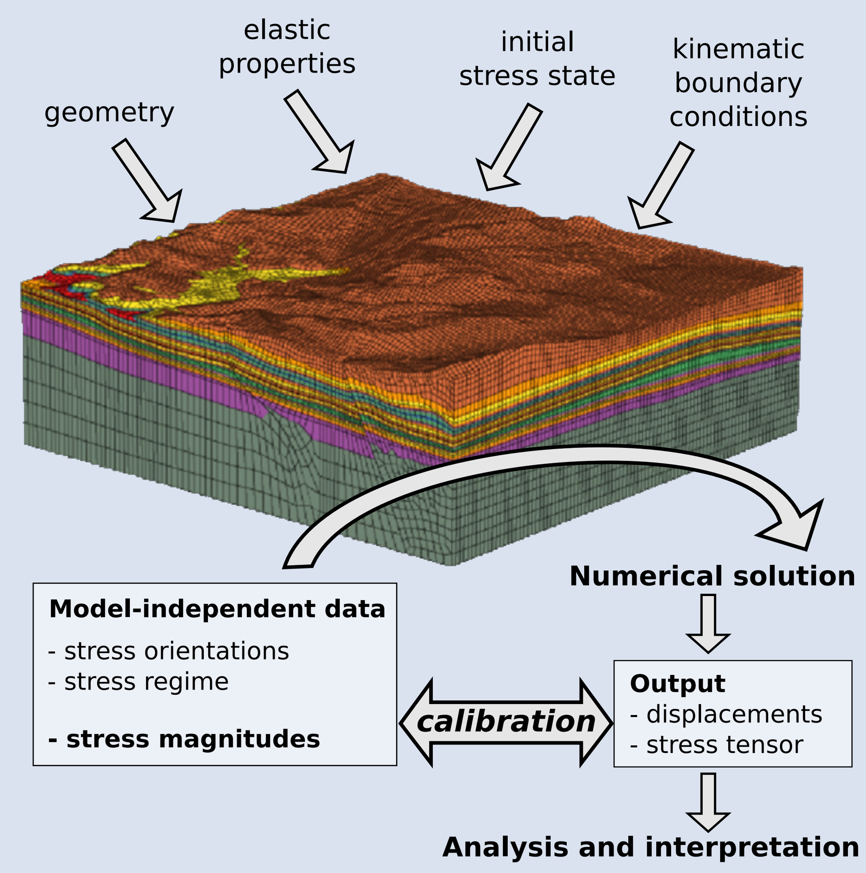


Fig. 2: Mohr's stress circle without (blue) and with (orange) influence of engineering interventions such as the construction of a deep geological repository. τ ≡ shear stress, σ_{neff} ≡ effective normal stress. Δσ ≡ influence, e.g., of free surfaces and heat development. Initial stress state (blue) decides whether construction remains stable (A) or material failure occurs (B).

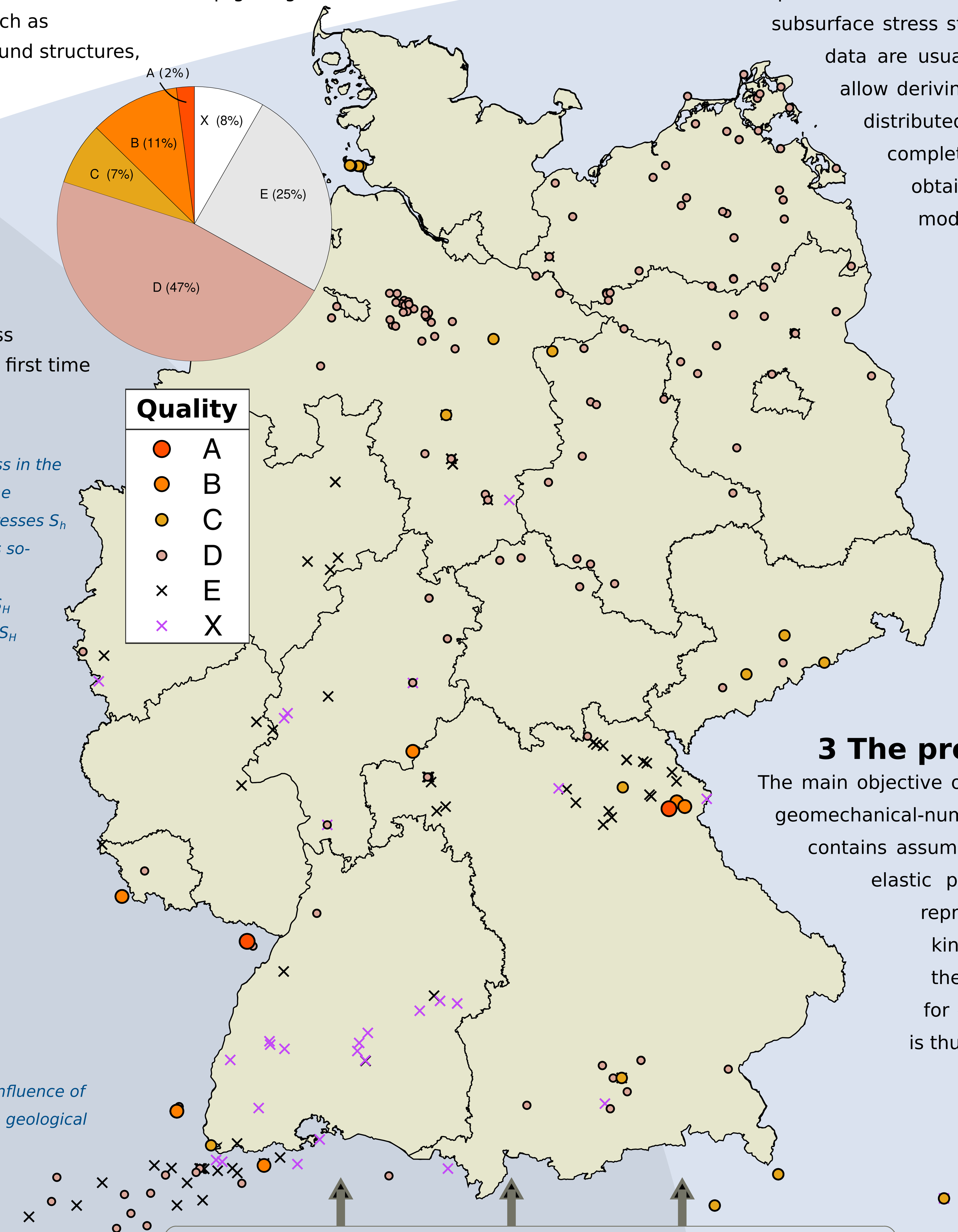
2 The role of geomechanical-numerical modeling

In the comparative evaluation of potential repository sites, the estimation of the subsurface stress state is essential. However, the available point stress data are usually incomplete, since most stress indicators do not allow deriving the full 3D stress tensor. In addition, the data are distributed spatially unevenly. Therefore, a continuous and complete description of the 3D stress state can only be obtained by estimating a 3D geomechanical numerical model calibrated with available stress data.



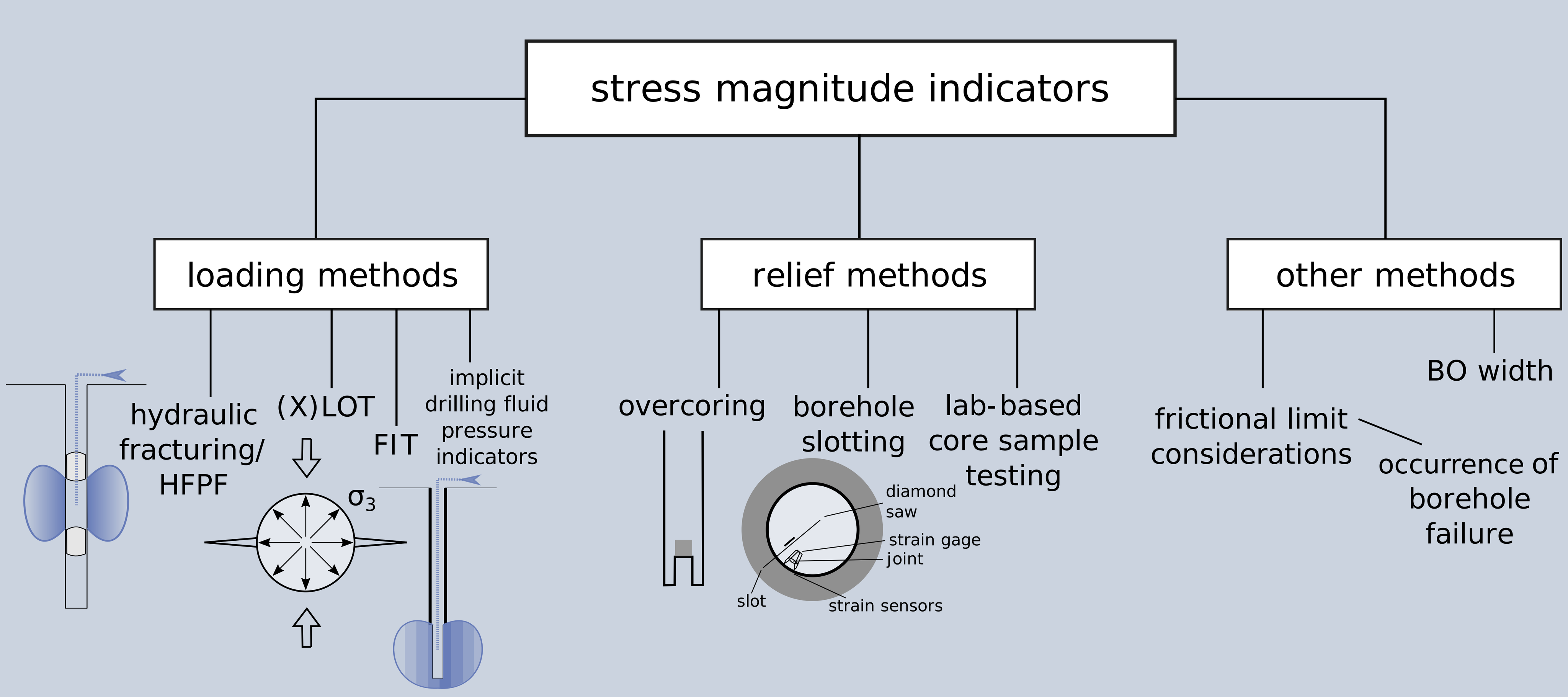
3 The project

The main objective of the SpannEnD project is the development of a 3D geomechanical-numerical model for the whole of Germany. This model contains assumptions about the geological structure as well as the elastic properties of the modelled lithologies. In order to reproduce the stress state as realistically as possible, the kinematic boundary conditions are adjusted to provide the best possible approximation of the data points used for calibration. The compiled stress magnitude database is thus the prerequisite for a meaningful model calibration.



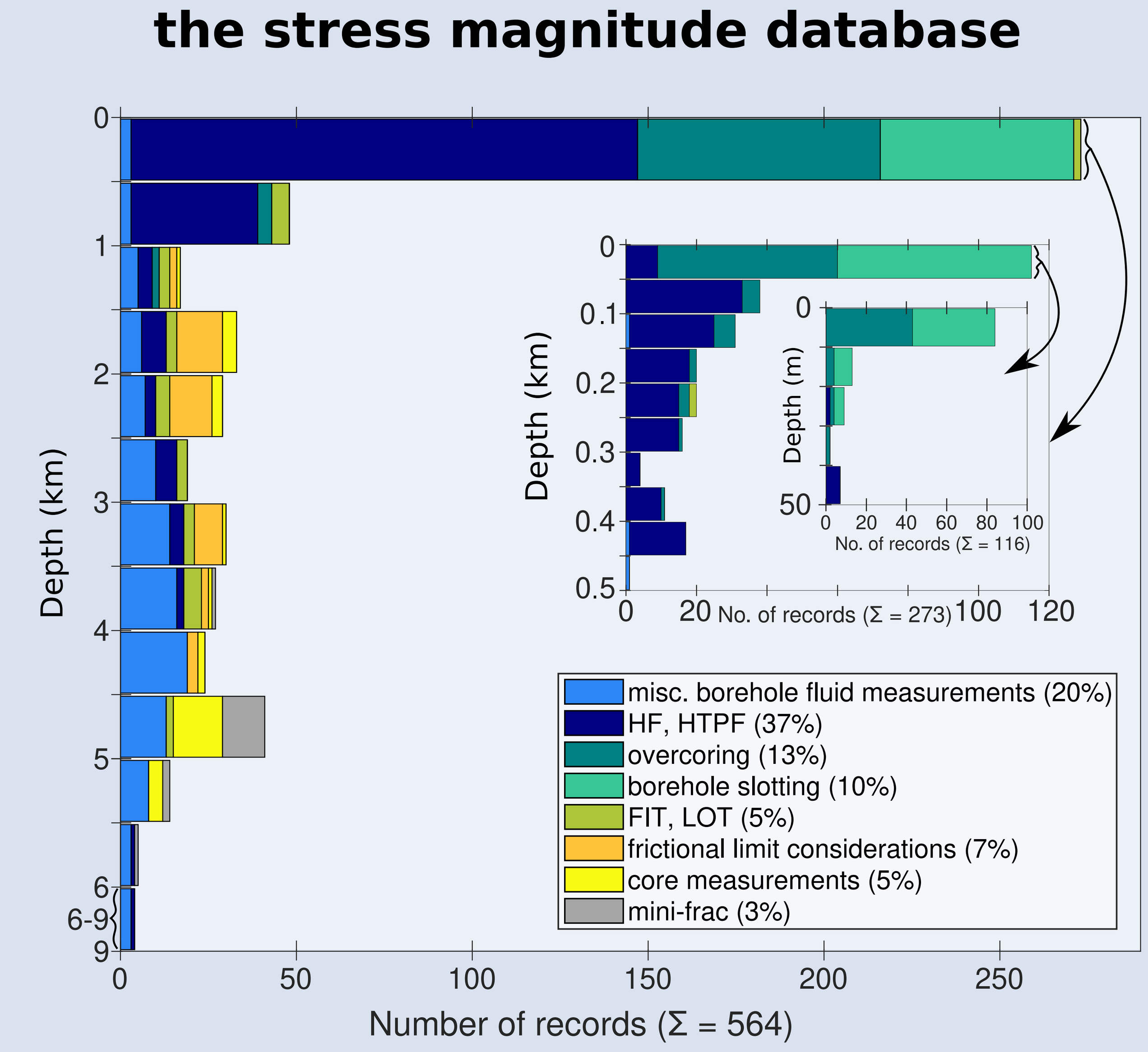
6 Lateral distribution and quality of data in the stress magnitude database

4 Where the data come from



As mechanical stress cannot be measured directly, components of the reduced stress tensor are derived from measurements of other quantities that are physically linked to stress. This results in a number of methods for the quantification of stress magnitudes. Abbreviations: HTPF – hydraulic testing of pre-existing fractures, (X)LOT – (extended) leak-off test, FIT – formation integrity test, BO – borehole breakout. The schematic illustration of the borehole slotter is based on a drawing by Prof. Fecker & Partner.

5 Depth distribution of the data in the stress magnitude database



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