Modelling of In-situ Stress Regime in Cap Rocks in Parts of the North German Basin

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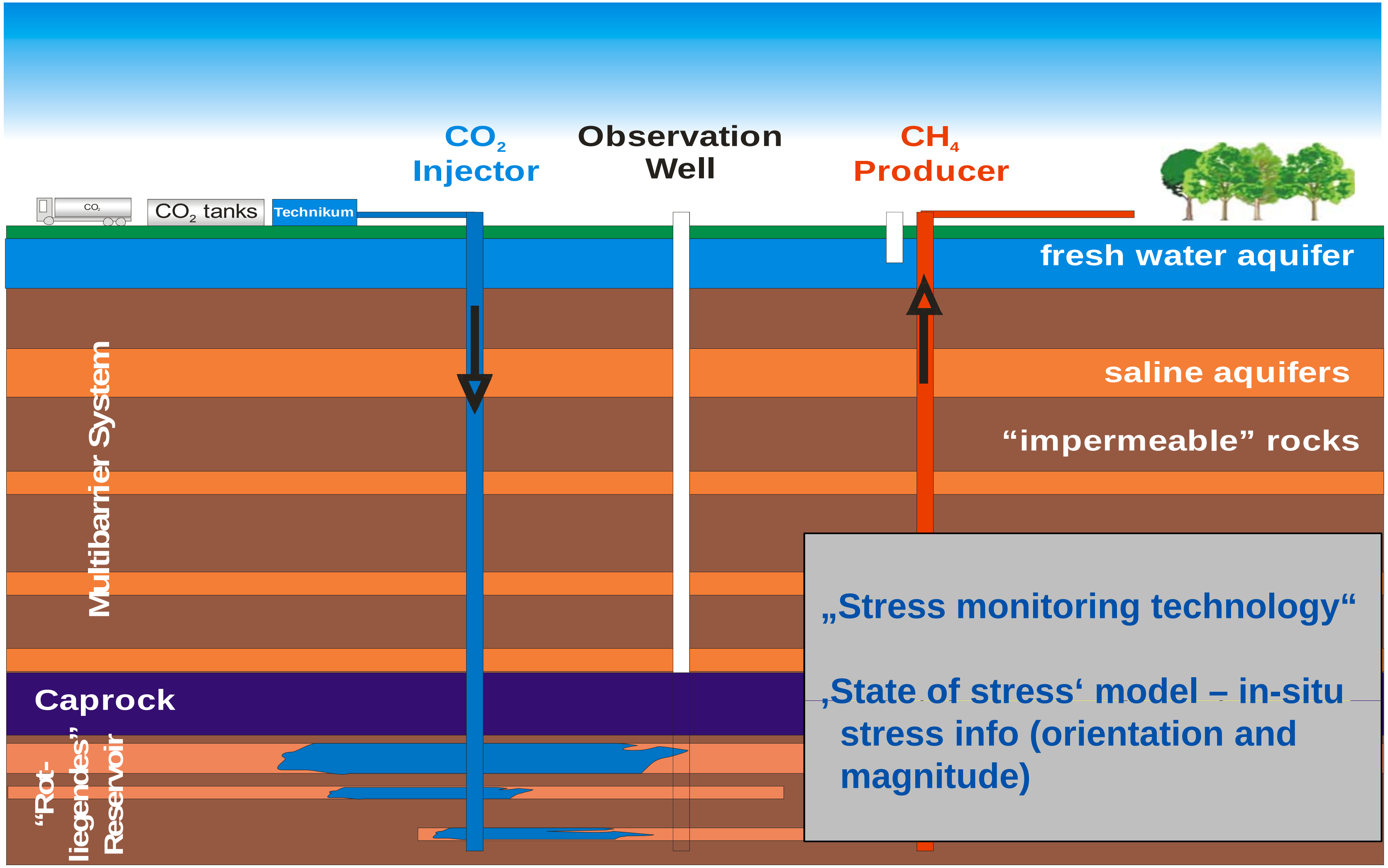
Stress Monitoring Preparation in Salinar Caprocks in Altmark Gas Field



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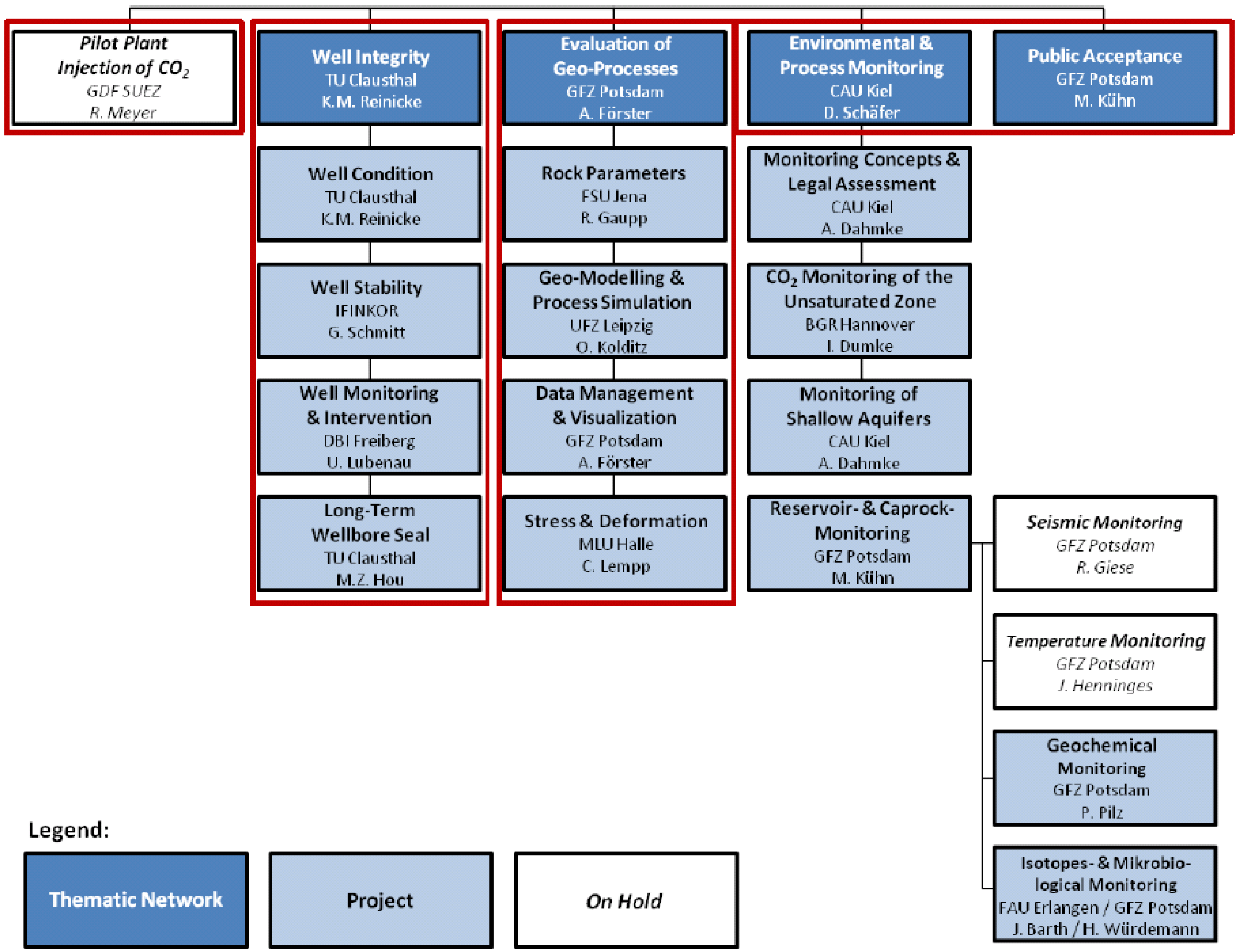
Project structured in five Thematic Networks



Evaluation of stress and deformation

Knowledge concerning the state of stress in the suprasalt formations in the North German Basin:

a) Stresses in suprasalt formations are decoupled by the Zechstein-salt formations from the subsalt stress conditions.

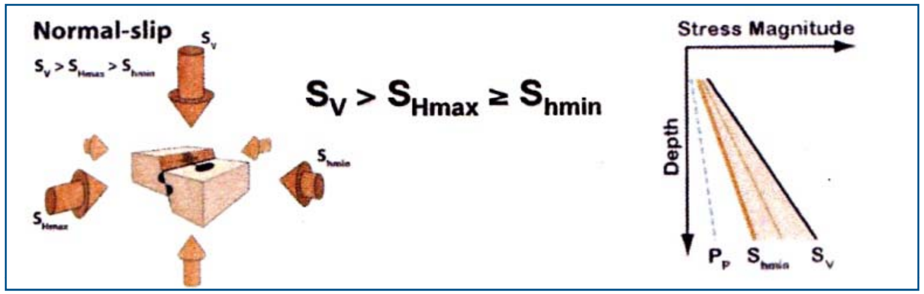
b) Stress directions: S_H is scattering around E-W with variations of + /- 40° in the suprasalt sequences.

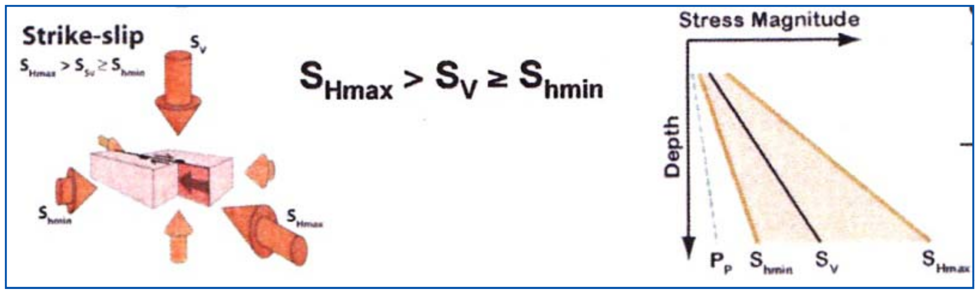
c) Stress gradients: $S_H \approx S_V$ = around 25 MPa/km,
S_h < 25 MPa/km (in subsalt), but > 14 to 16 MPa/km (in suprasalt formations)

State of stress in the sealing suprasalt caprock of the Altmark

Evaluation of available drilling- and borehole-data from GDF SUEZ result in a cautiously generalized state of stress model for the suprasalt of the Altmark:

- Stress directions of S_H resp. S_h do not apparently deviate form the E-W resp. N-S trend.
- Stress gradients represent ANDERSONs either normal slip or strike slip situation.





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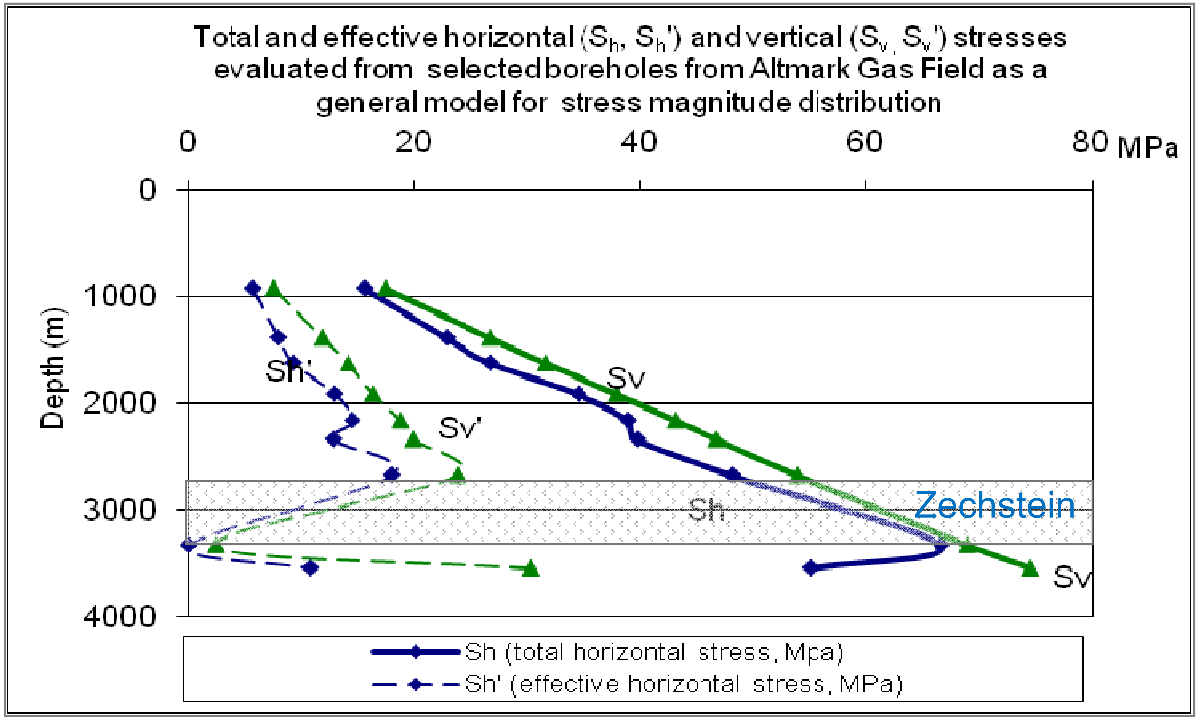
Stress gradients in the Altmark



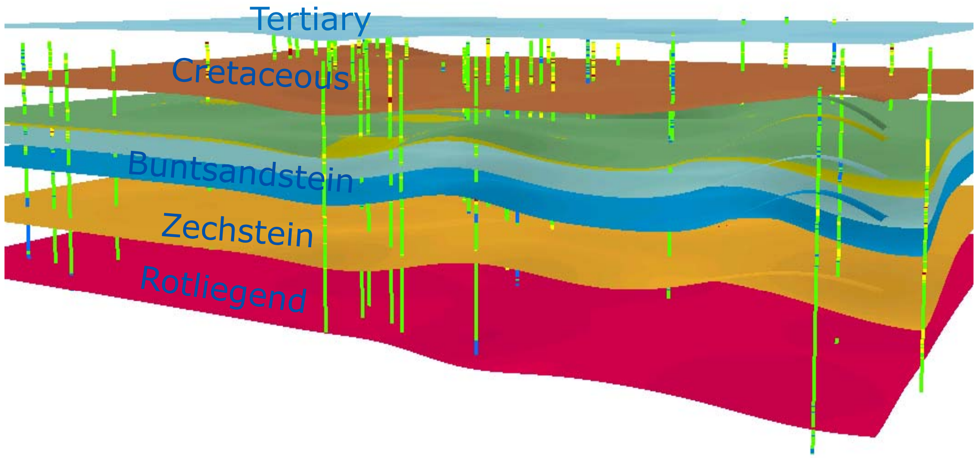
S_V – S_h stress difference vs. depth diagram displays variations of stress gradients with differences of 9% to 15% of S_V resp. S_H being effective as S_h in the Suprasalinar

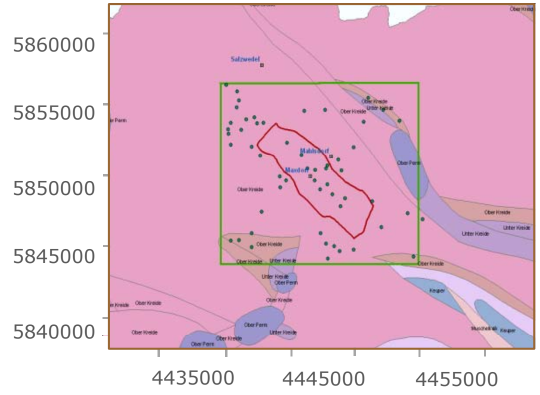
Stress vs. depth diagram

Strategy to evaluate stress anisotropy of 0.85 to 0.91 * $S_H = S_h$ in Altmark

- The used strategy for this attempt is the systematic anylysis of borehole breakout distributions related to the different formations in all available boreholes.
- The basic assumption is a correlation between stress anisotropy and elongation or ovalization of an originally circular borehole.
- Despite a lack of any information about the orientation of the breakouts the elliptic character of the borehole may be a scale of the stress anisotropy.

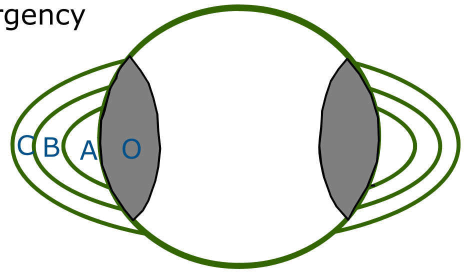
Stress anisotropy information from borehole breakouts



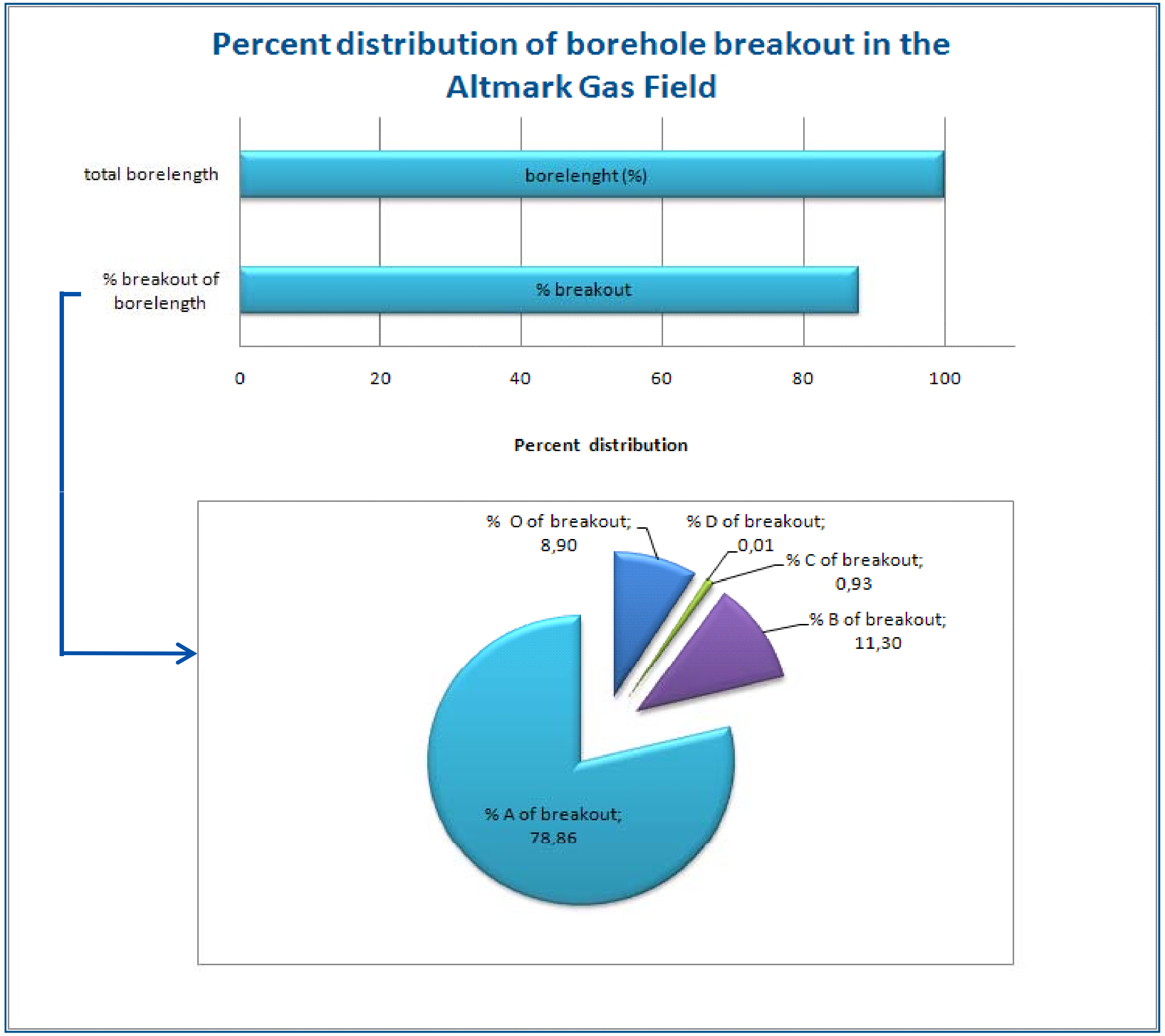


Borehole breakout categories

- A 0 – 100 mm
- B 100 – 300 mm
- C 300 – 500 mm
- D > 500 mm
- Borehole convergency



Stress anisotropy information from borehole breakouts:

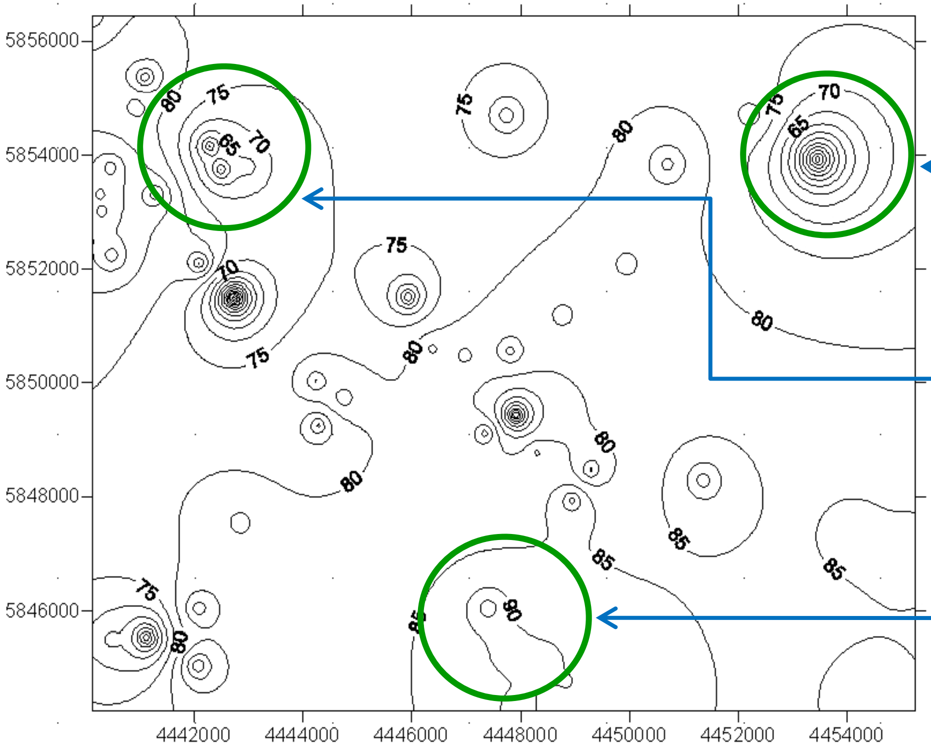


Proceeding at the Stress Anisotropy Analysis

- Category A breakouts of up to 100 mm are related to the borehole lengths within a distinct geological formation (f.e. Bunter).
- The propotion of A-brekouts is evaluated for each formation and displayed as a map containing lines of equal levels of breakout density.
- An important aspect of this analysis is the fact, that the brittle or ductile behaviour of the rocks are not decisive for the breakout formation – not deformability but stress anisotropy is responsible for the breakouts

Evaluations of stress and deformation

Regional breakout intensity distribution in different geological formations. Example: Breakout intensity in Muschelkalk, Category A



Lithological characteristics

ca. 70% ductile
30% brittle

ca. 30 - 35% ductile
60 - 65% brittle

ca. 20% ductile
80% brittle

→ Breakout intensities are independent of rock deformability differences

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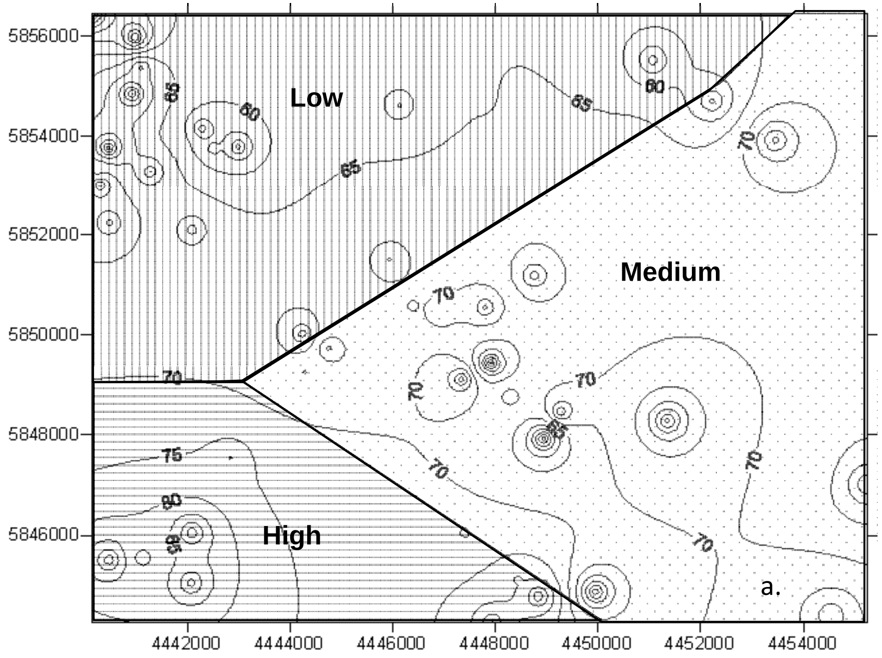
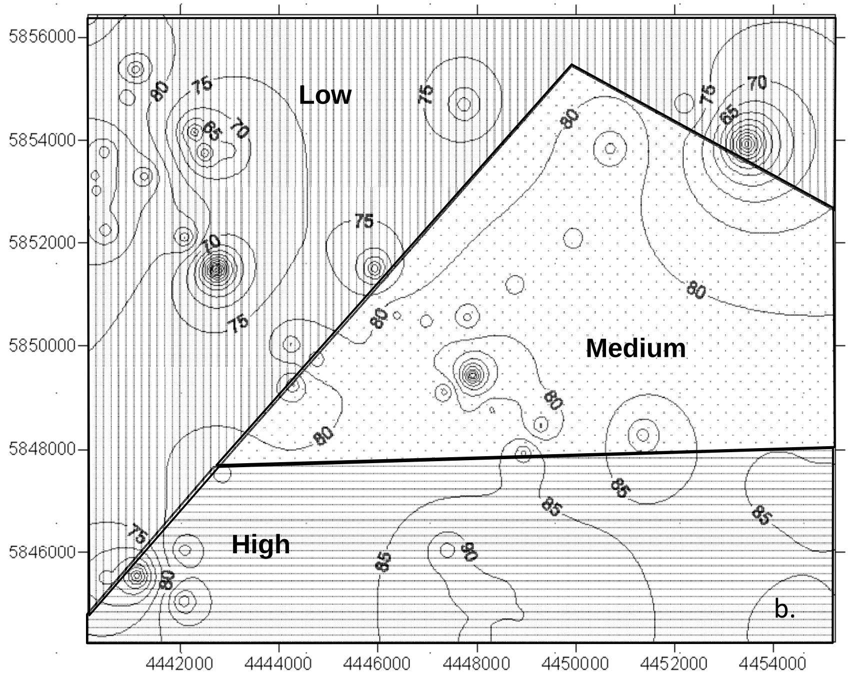
Breakout intensity distribution in different geological formations

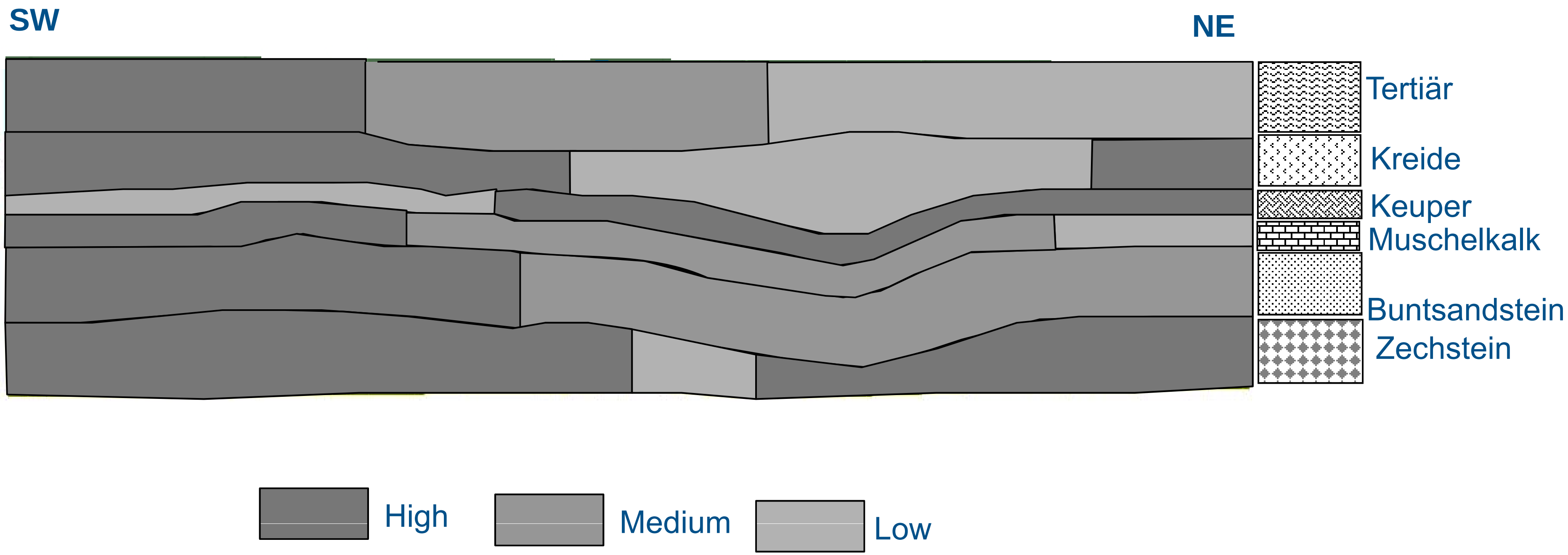


Example: Breakout intensity
In Buntsandstein, Category A

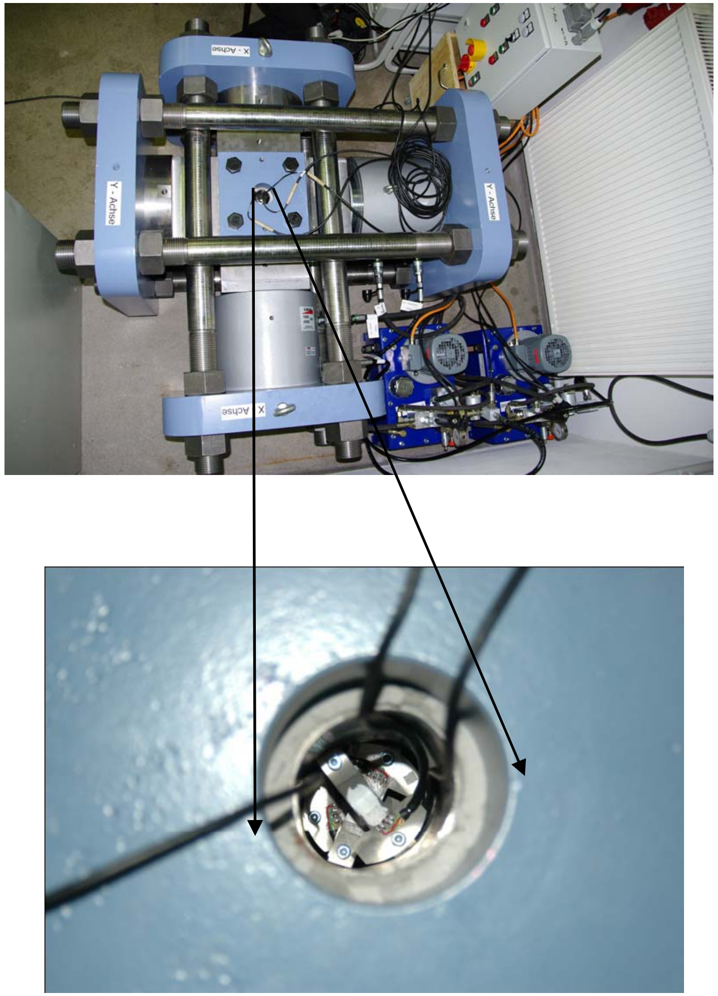


Example: Breakout intensity
in Muschelkalk, Category A

Breakout intensity distribution = stress anisotropy distribution in different geological formations

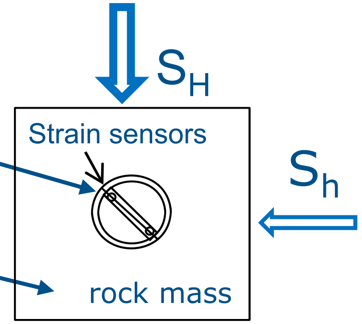


Hard-Inclusion (H-I) test device



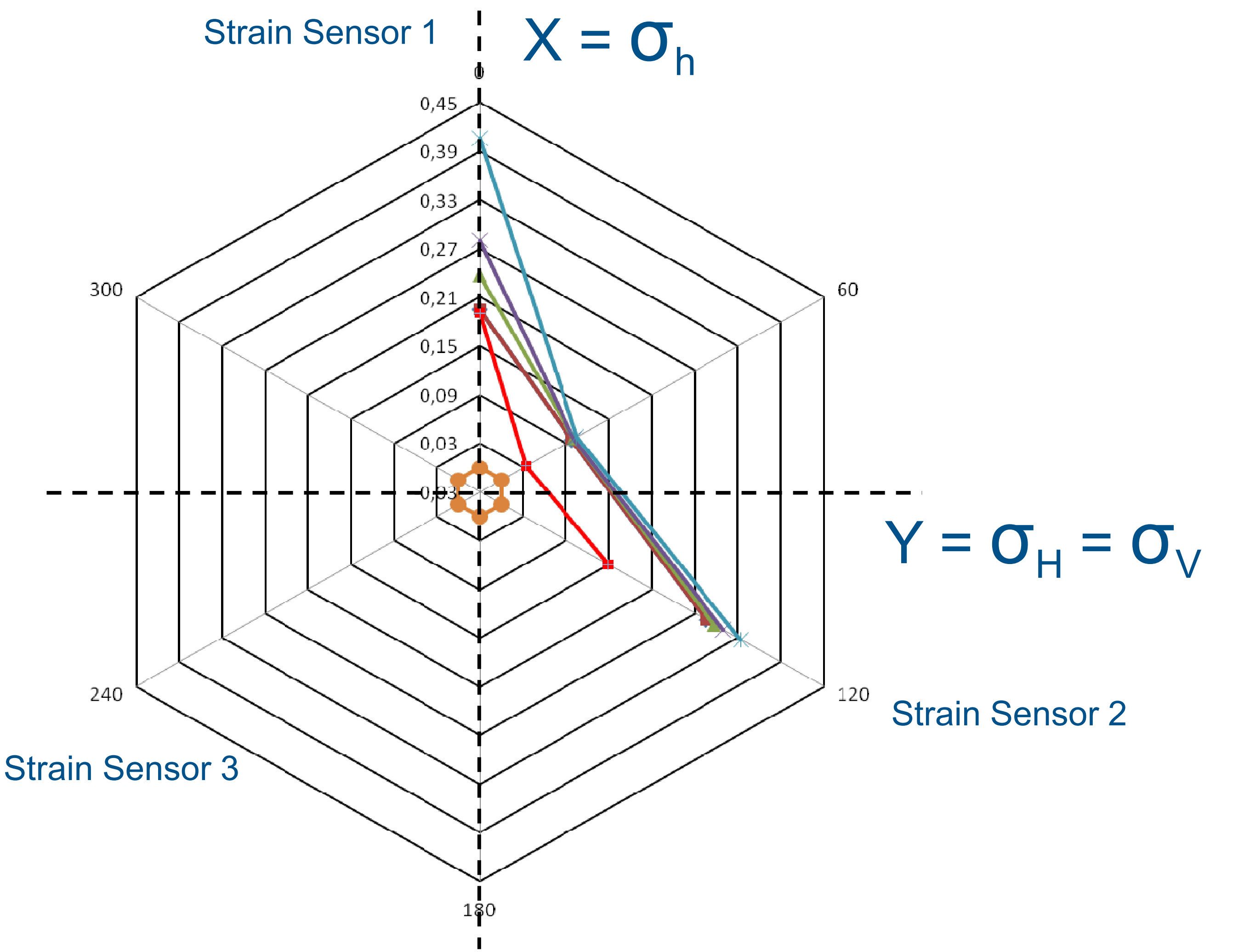
Steel tube with strain sensors of H-I test device

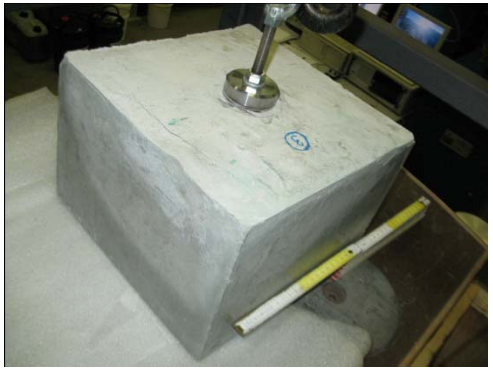
Rock mass of different caprock quality.



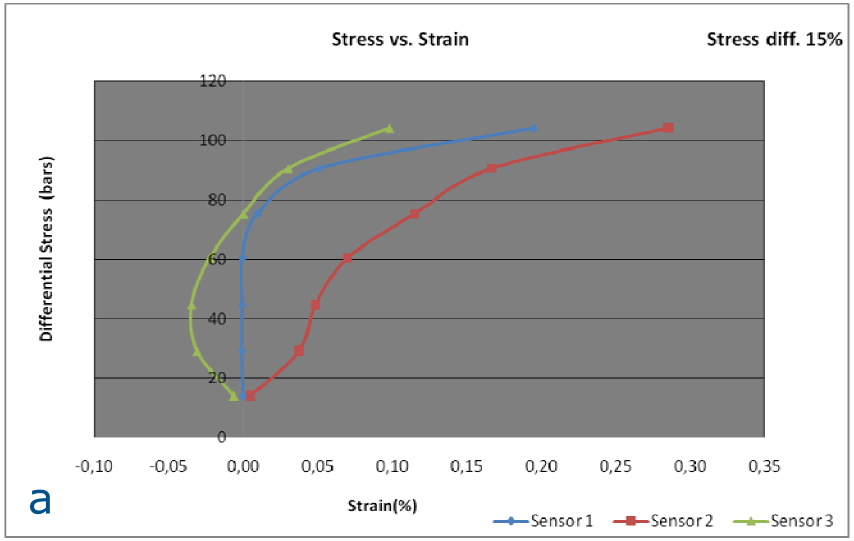
Example rock mass

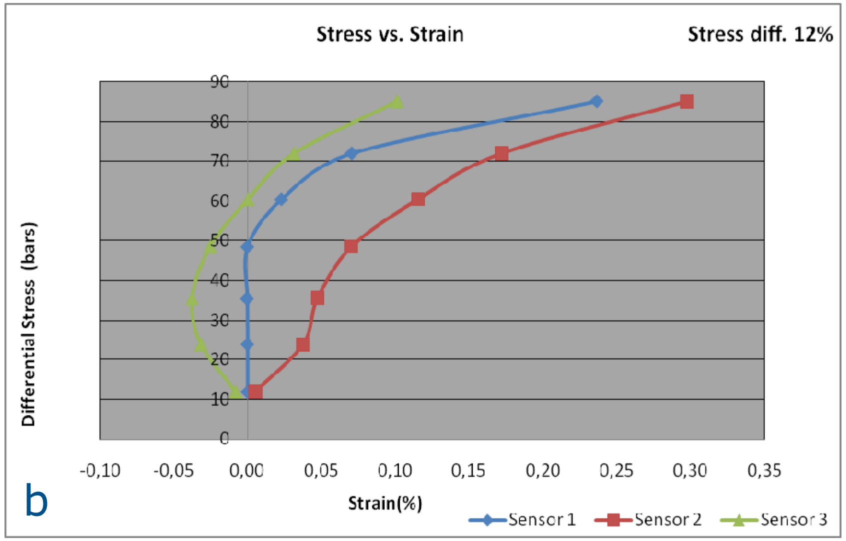
Example: Sandstone as Testmaterial

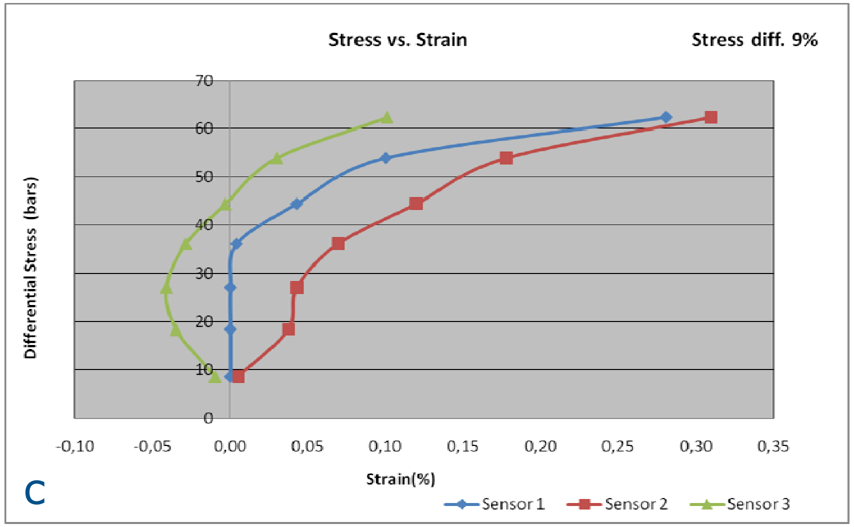




Example: Sandstone as Testmaterial

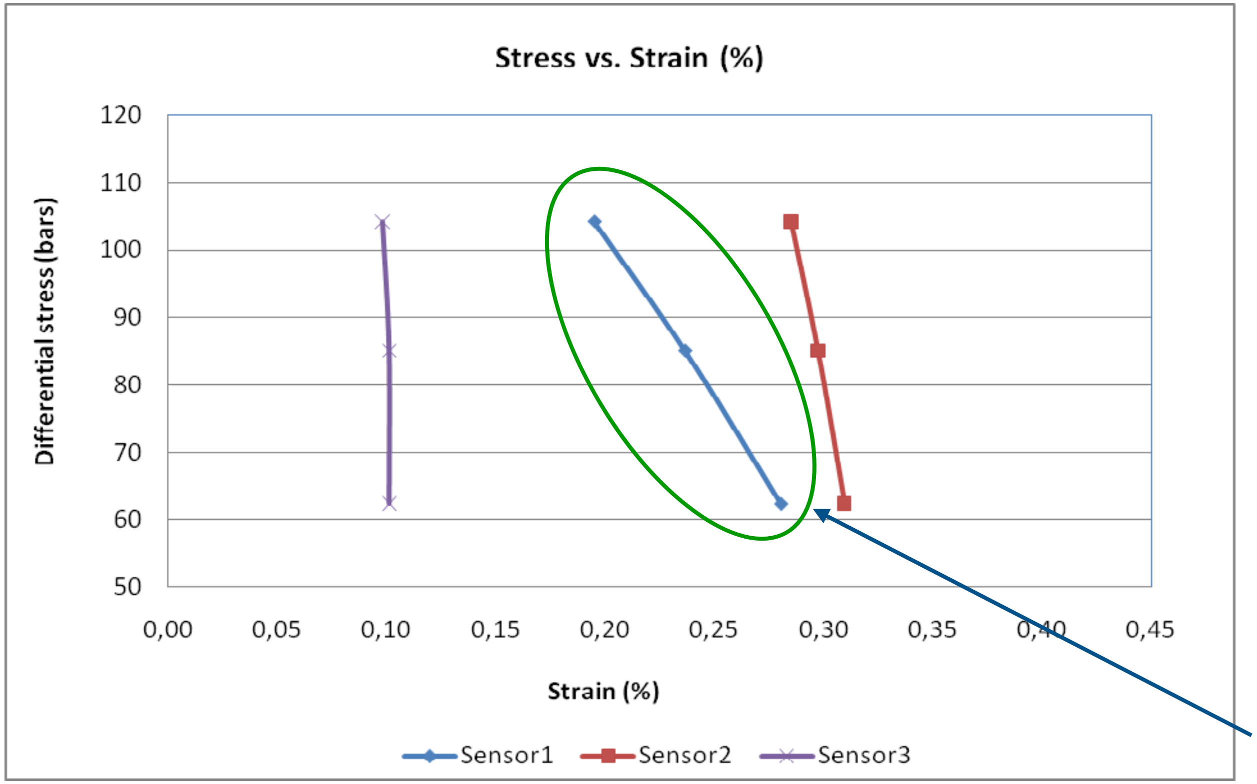






Differential stress vs. strain diagram of the three sensors for the S_H-S_h Differences of 15%(a), 12%(b) and 9%(c)

Example: Sandstone as Testmaterial



Deformation differences are higher along the orientation of S_h

Conclusion:

- A distinct stress anisotropy with S_h = up to 0.85 S_v can be observed in the caprocks in Altmark. A stress anisotropy distribution model is developed

- Laboratory experiments are under investigation using the H-I test device in order to evaluate the effect of defined stress differences on borehole liners in distinct rock types.

- The lab tests may optimize the hard inclusion tool as an in-situ stress monitoring device.

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