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NUMERICAL STRESS FIELD ANALYSIS FOR AN UNDERGROUND LABORATORY IN ANISOTROPIC CRYSTALLINE ROCK AS BASIS FOR HYDRAULIC STIMULATION TESTS

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Background and Motivation

The STIMTEC project includes hydraulic stimulation field tests. Numerical analysis is an important tool for planing and improving stimulation campaigns. Equally, results from field tests are crucial to validate the numerical model and to improve modeling techniques and parameters. Accompanying field tests in the Reiche Zeche mine in Freiberg, Saxony, we conduct a 3D stress field modelling to generate boundary conditions to a numercial analysis of the hydraulic stimulation tests and thereby show the mutual benefits of combining field tests and computer models.

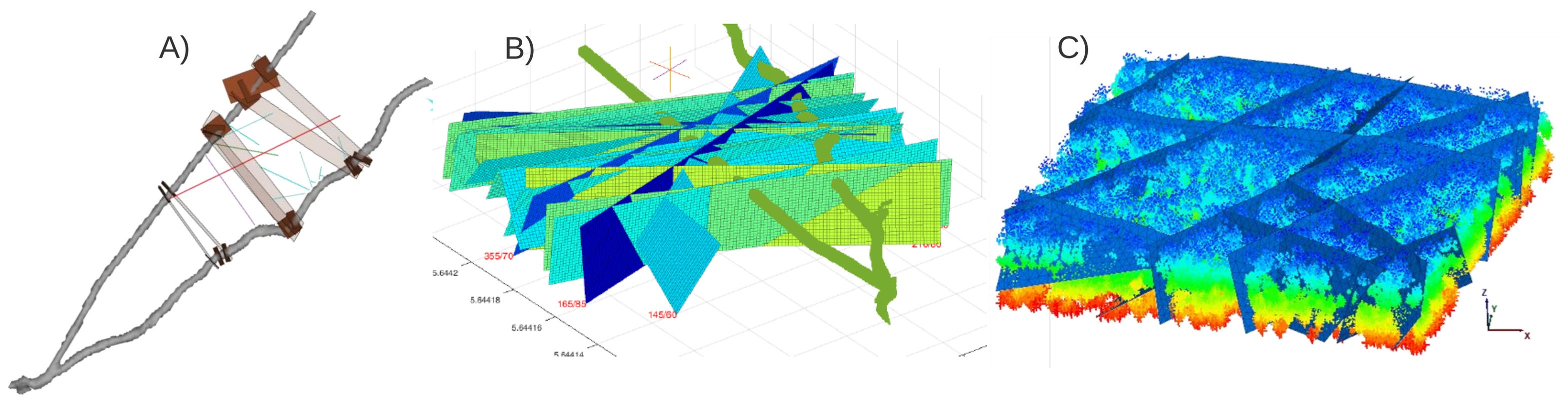


Fig.1: Different stages of the modelling process. A) 3D model representation of the test site with tunnels obtained from 3D laser scans (MABB), boreholes and mapped fault structures. B) Preceding slip tendency analysis of mapped fault structures at test site. C) Stress field model based on large 3D geomodel.

Materials and Methods

3D geological model

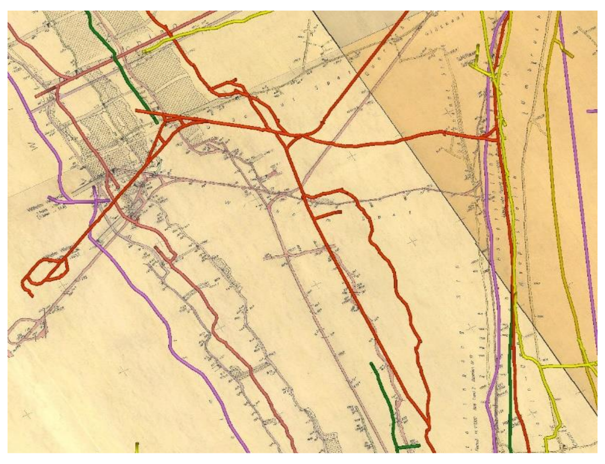


Fig.2: Original documents to 3D geomodel: Tunnel 3D data, scans of mine maps and geological maps in SKUA/GOCAD.

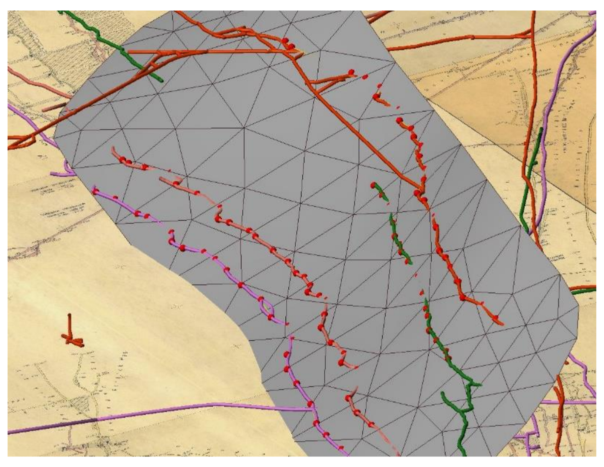


Fig.3: Fault surfaces created by discrete smooth interpolation on tunnel drifts used as constraints.

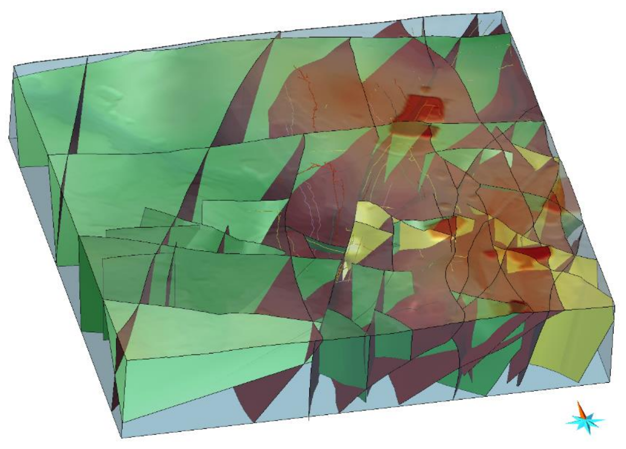


Fig.4: Large scale 3D model covers 2.5 x 2.5 x 0.5 km and contains topography, tunnels and 45 fault structures.

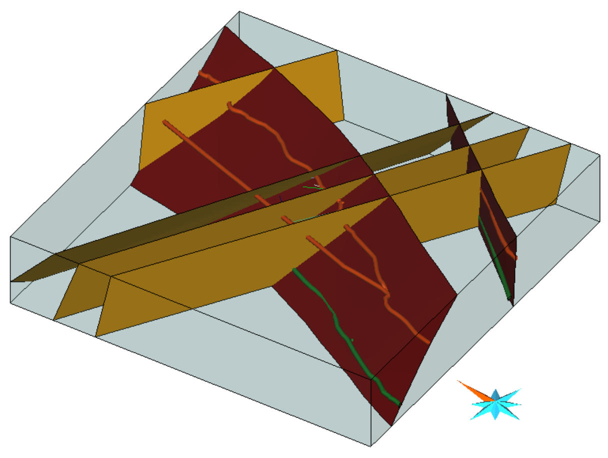
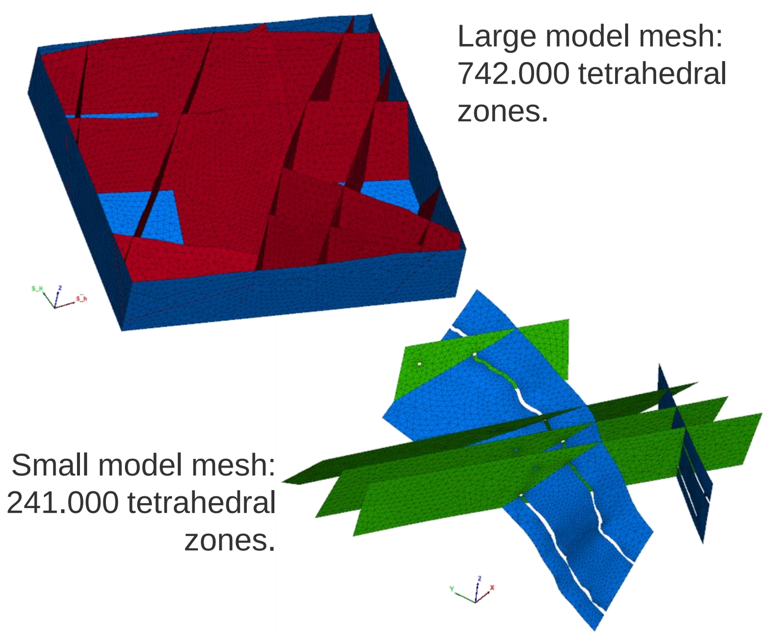


Fig.5: Small scale integrated model. Includes tunnel drifts, boreholes and locally mapped fault structures (yellow). 250 x 250 x 50 m.

Numerical stress field model



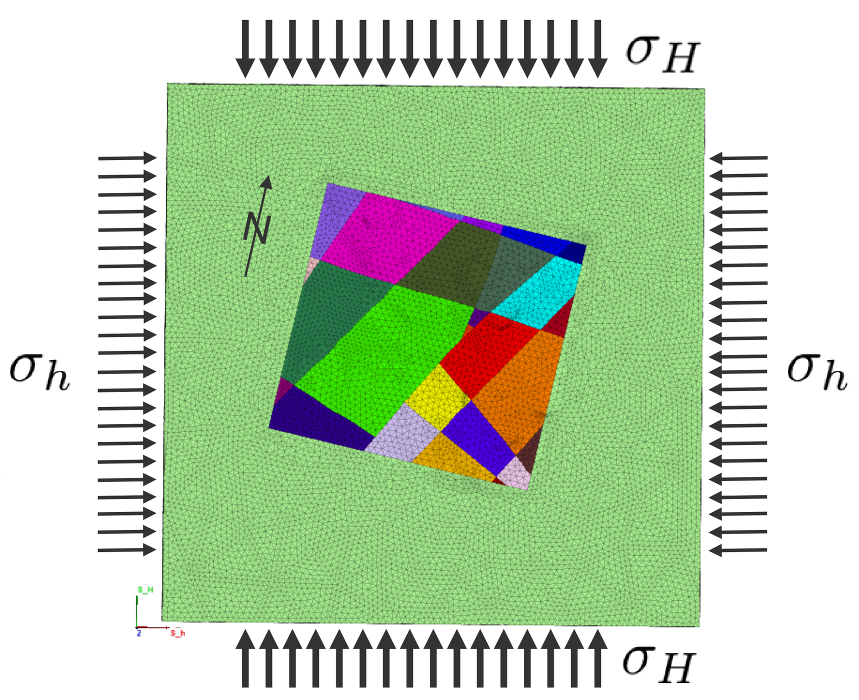


Fig.6: Discontinuities in meshes for numerical modeling performed with DEM code 3DEC by ITASCA. Large mesh extended with auxiliary blocks parallel to regional principal stress directions. Meshes generated in RHINO with GRIDDLE plug-in.

Fig.7: Top view of large numerical model with total extent 5 x 5 km. Model parameters from core tests. Stress boundary conditions. Bottom fixed in z-direction. Initial stress ratio 0.7 : 1. Large model results used as boundary stress to smaller integrated model.

Results and Interpretation

- Preceding slip tendency analysis shows low probability of reactivation of faults (Fig. 1B)
- Stress field model results fit measurements from hydraulic testing in injection well during field test campaign (RUB) in orientation and magnitude
- Local stress field is anisotropic with stress ratio of 1.3 : 1 : 0.8 and describes Strike Slip Regime
- We assume the locally mapped faults to either be discontinuous or to be healed

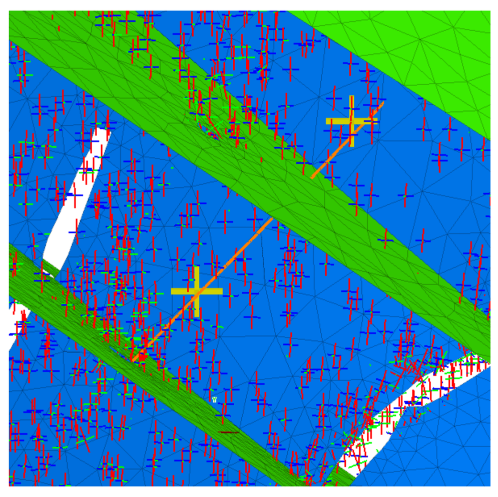


Fig.8: Top view of small model stress field. Up is direction of σ_H. Orange is injection well path, yellow are markers of frac intervalls and corresponding histogram position for stress magnitude inside model. Stress tensors show direction of maximum compressive stress (red) is parallel to σ_H. Direction of intermediate stress matches vertical stress. For calculation we fixed the locally mapped faults (green) as they would perturb calculated stress directions and magnitudes.

Outlook and Recommendations

- The generated local stress field is used as boundary condition for numerical simulation of the hydraulic fracturing process
- For each fracking interval we can choose the corresponding stress tensor and involve it into the analysis
- Hydraulic fracture evolution will be simulated according to chosen constitutive models, parameters and stress field
- Mode of failure (tensile, shear or mixed-mode) will be monitored during the simualtion
- Reliable stress field modeling demands also reliable and sufficient in-situ stress field measurements.

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M. C. Neves, L. T. Paiva, and J. Luis. “Software for slip-tendency analysis in 3D: A plugin for Coulomb”. In: Computers & Geosciences 35.12 (2009), pp. 2345–2352. ISSN: 00983004.
Software used: 3DEC, GRIDDLE by ITASCA, RHINO 5, SKUA/GOCAD by Paradigm, Matlab
Fig.1: Author, A) MABB, GFZ, SKUA/GOCAD. B) GFZ, MATLAB. C) ITASCA
Fig.2, Fig.3, Fig.4, Fig.5: Author, LfLUG, SKUA/GOCAD
Fig.6, Fig.7, Fig.8: Author, ITASCA

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