

3D Geomechanical Model of the Lower Rhine Graben in the Cross-Boarder Region (BE–DE–NL)

Adam Jones¹, Michal Kruszewski¹, Moritz Ziegler^{2,4}, and Florian Amann^{1,3}

¹RWTH Aachen University, Engineering Geology and Hydrogeology, Aachen, Germany

²Technische Universität München Arcisstraße 21 Munich D-80333 Germany

³Fraunhofer Research Institution for Energy Infrastructures and Geotechnologies IEG Aureliusstraße Aachen 52062 Germany

⁴GFZ Helmholtz-Centre for Geosciences, Telegrafenberg, 14473 Potsdam, Germany



We gratefully acknowledge funding from the Federal
Ministry for Economic Affairs and Climate Action under
grant agreement no. 03EE4058A (SIEGFRIED).



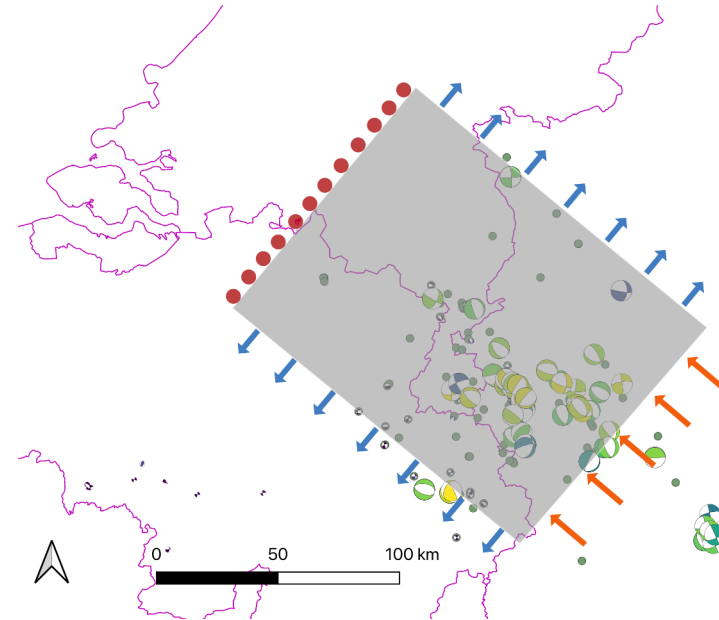
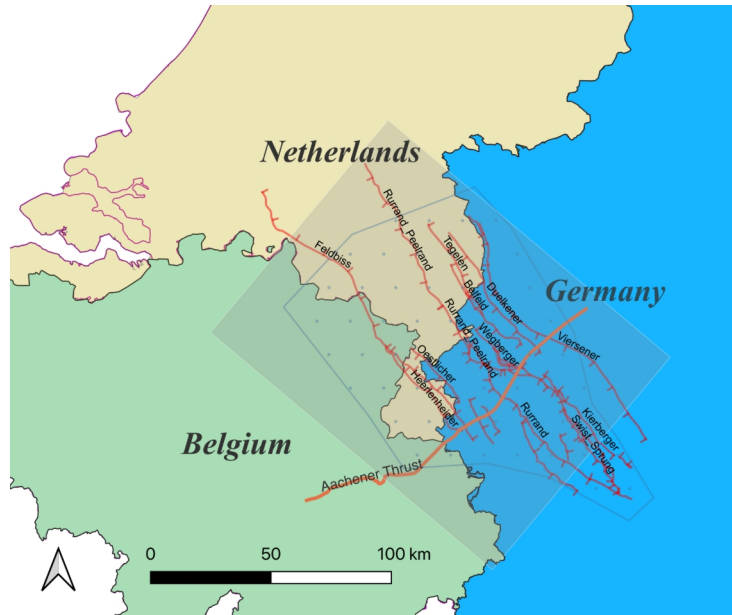
Bundesministerium
für Wirtschaft
und Klimaschutz



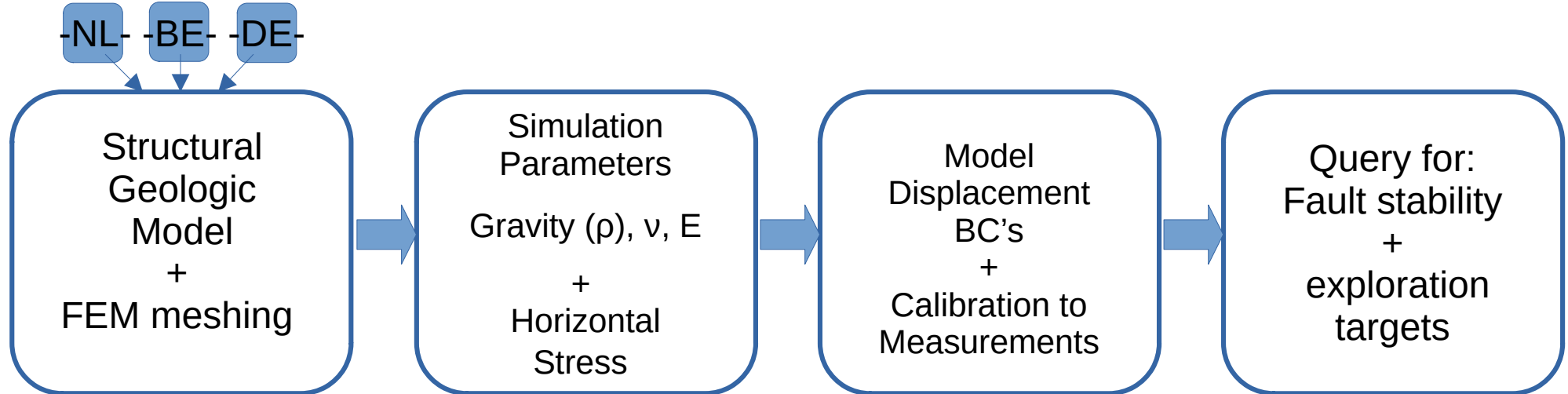
EGU26-7920

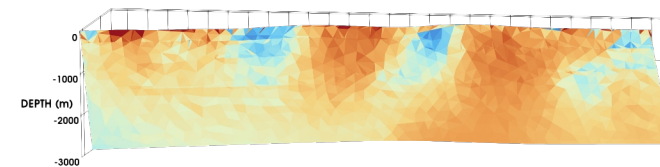
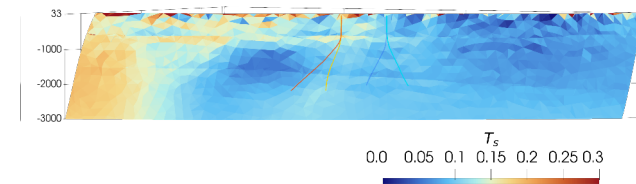
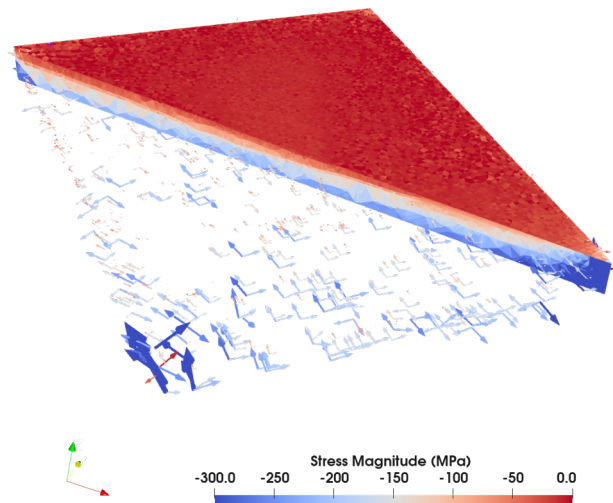
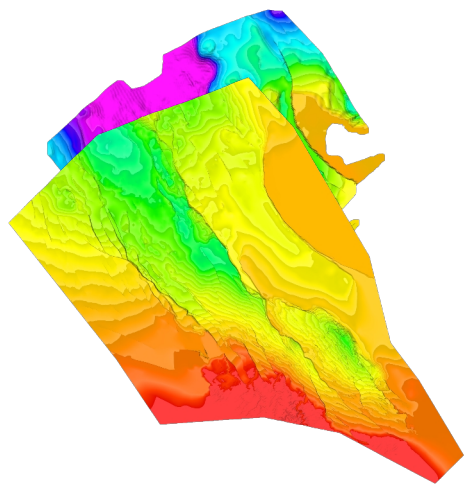
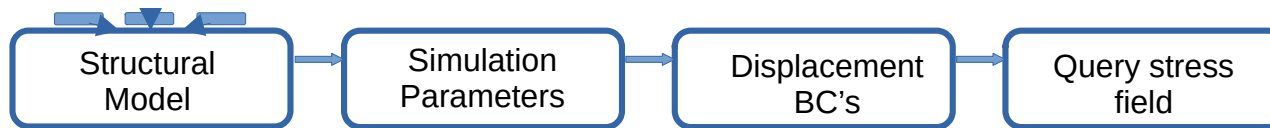


Lower Rhine Graben (LRG), a seismically active continental rift targeted for geothermal energy development



Modeling flowchart





Structural datasets

(TRI-Border Region DE-BE-NL)

- Largely compiled from legacy mining data with a few deep wells and 2D seismic lines where available.
- Arguably, three mechanically significant boundaries including the unconformities at the base of the Tertiary, the Upper Carboniferous, and the Variscan frontal thrust provide stratigraphic footing for the structural model.

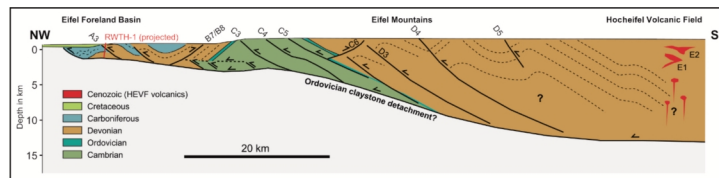
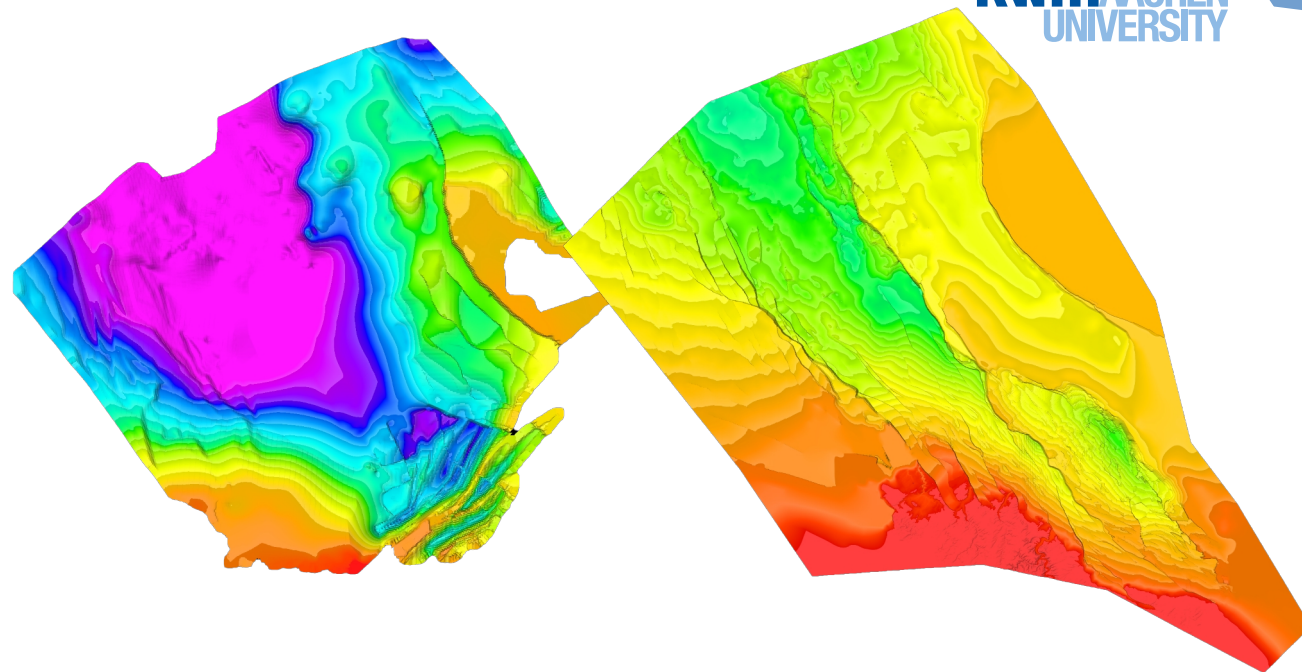


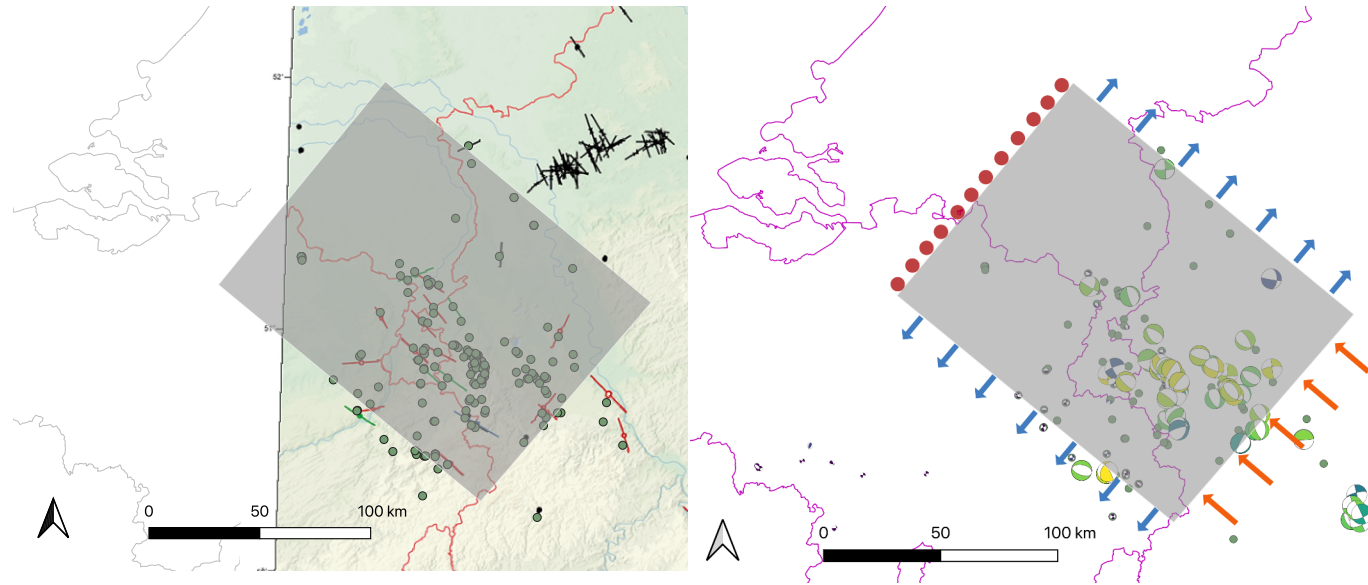
Fig. 8. Schematic geological cross section along BELCORP-DEKORP line 1A integrating the subsurface-reflection interpretation from this study (Figs. 4, 6) with outcrop stratigraphy, surface dip (Nordrhein-Westfalen Geologisches Landesamt, 1992) and projected borehole information of well RWTH-1 (Trautwein-Bruns et al., 2010; Trautwein-Bruns et al., 2011). 2D fault restoration and unfolding above an Ordovician claystone detachment will remain below the 22 km shortening predicted by wedge-scale balancing (Fig. 7).

D. Eickhoff et al.

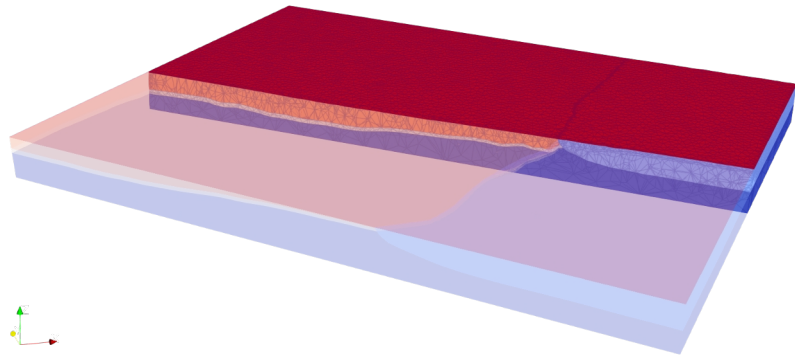
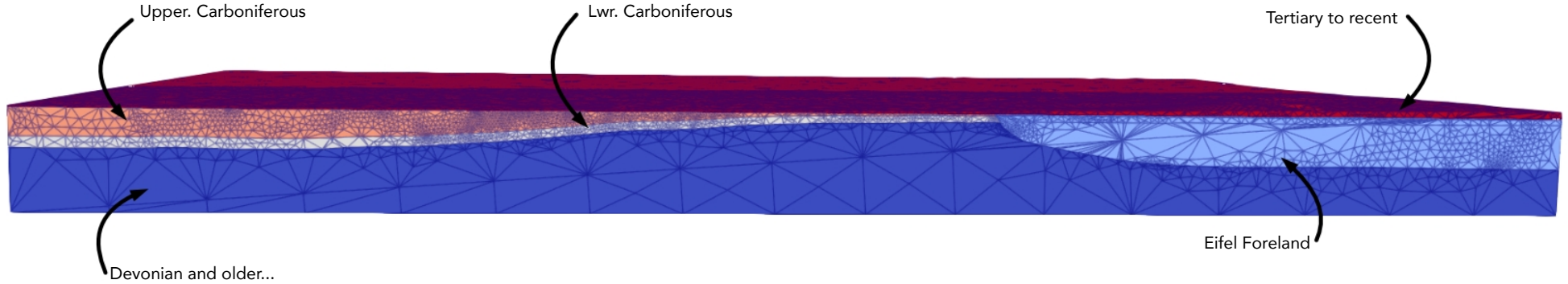


Calibration datasets

- HF + HTPF (jacking, mini-fracs), borehole failures (DITF, BO)
- Focal mechanism and expanded catalogue (RUB, Fraunhofer IEG)



Mesh blocks (inclusive)



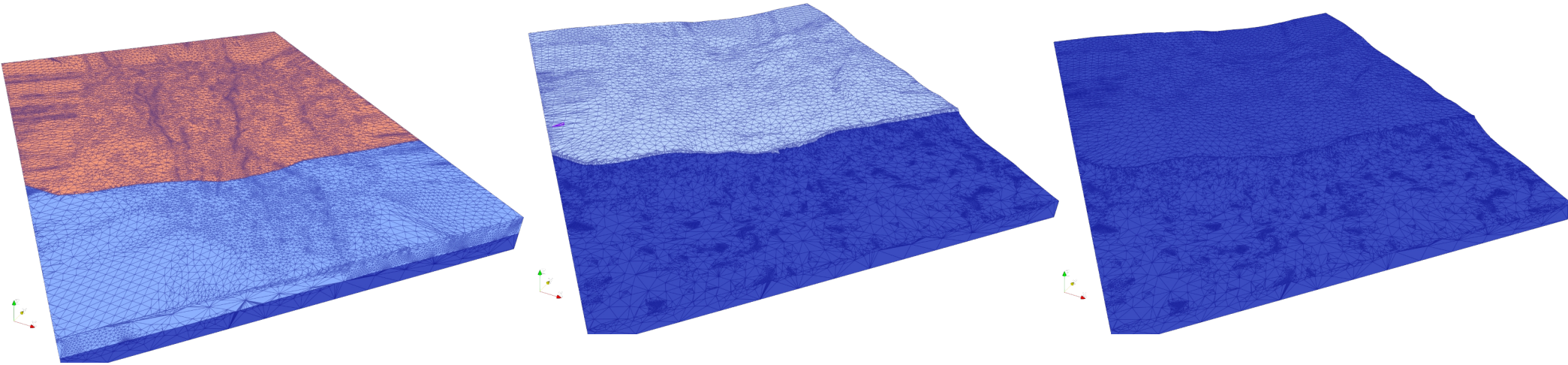
- Fully tetrahedral FEM mesh.
- Differentiable by the 5 significant lithological structures
- Faults are not mesh inclusive but rather queried from the model results

Mesh blocks (reduced)

Bottom Tertiary

Lwr Carboniferous

Devonian



Vertical stress calibration

This study

Ute Trautwein-Bruns et al. 2010

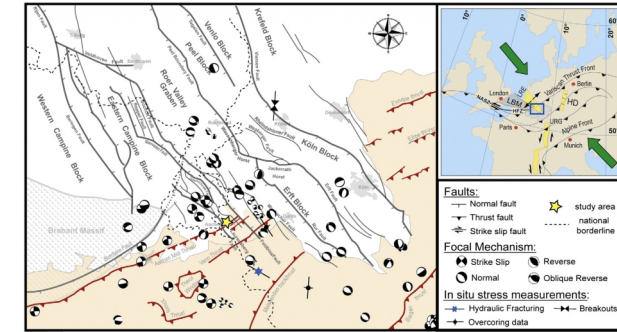
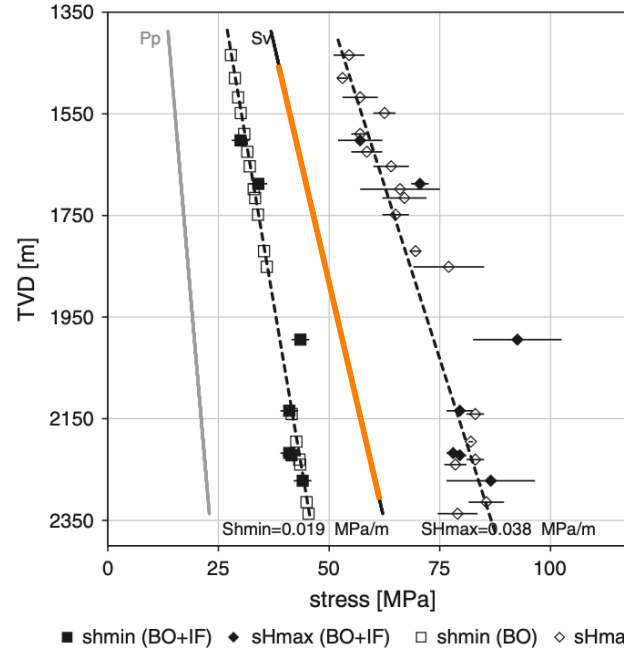
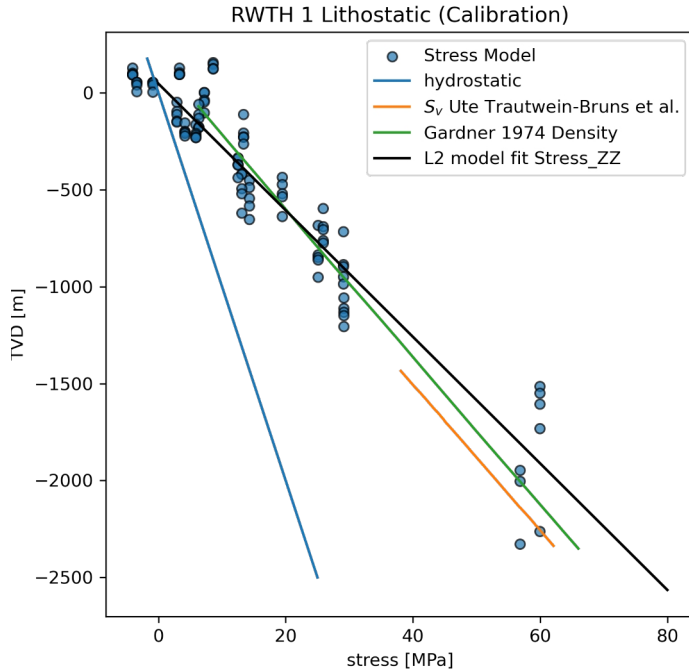
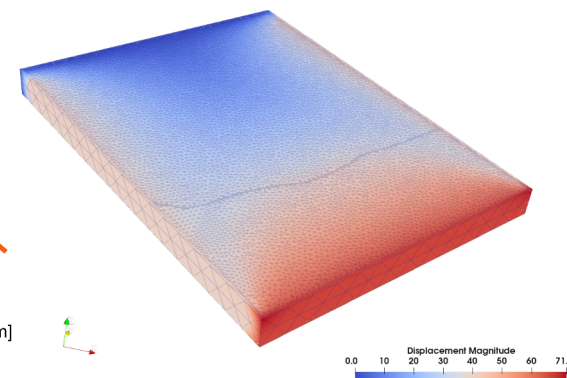
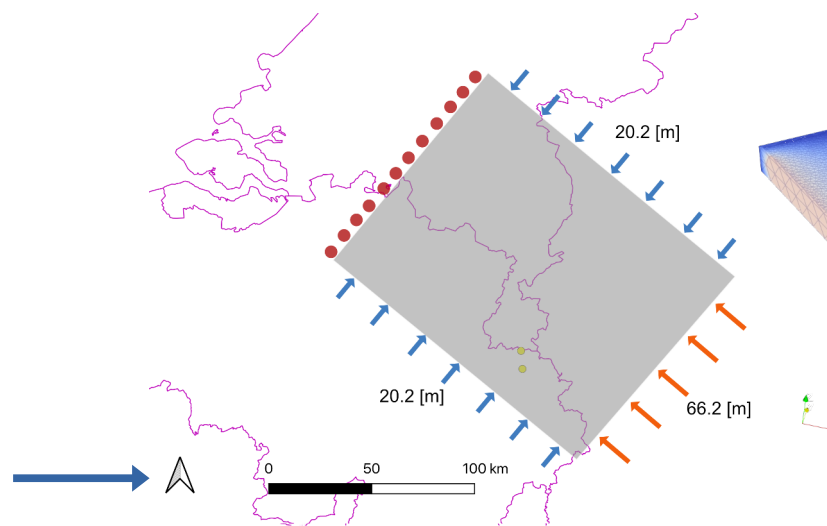
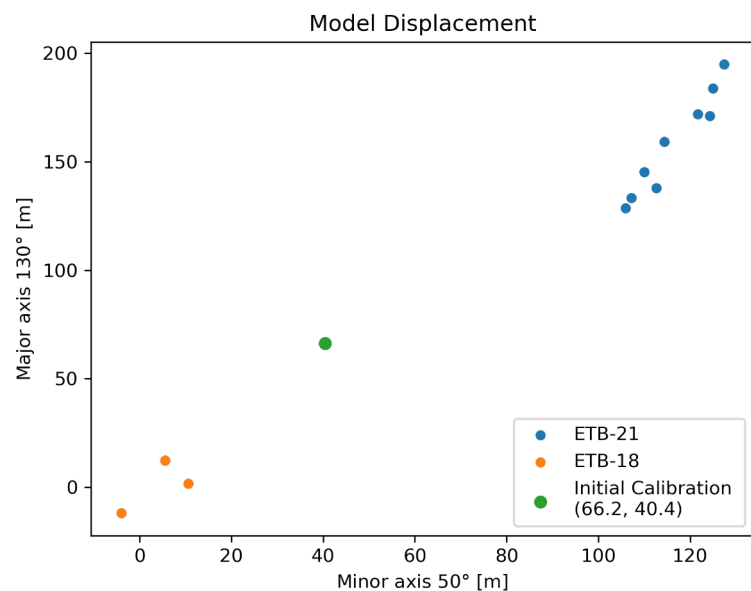


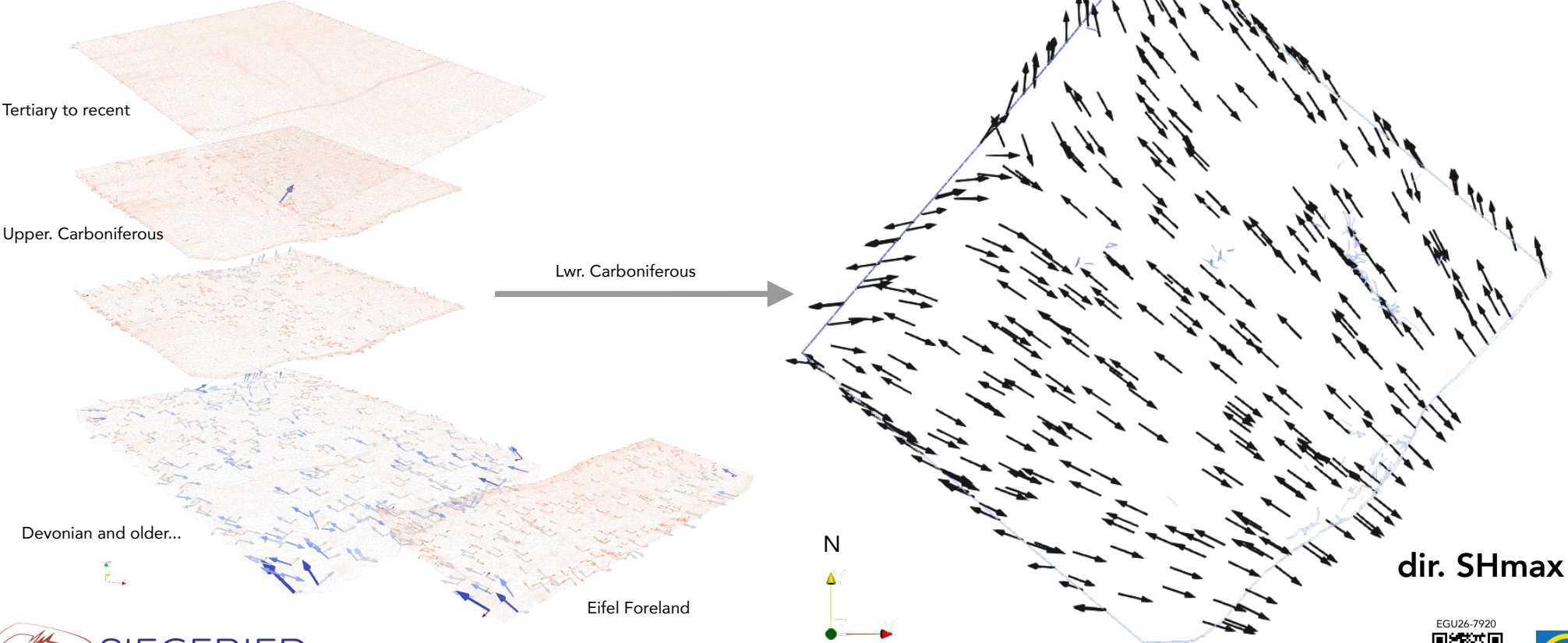
Fig. 1. Seismotectonic position of the Aachen borehole (left map, after Geluk et al., 1994; Walter, 2007 and Vos et al., 1993) showing the NW-SE trending normal faults of the Lower Rhine Embayment and the NE-SW trending thrusts of the Variscan Mountains. The earthquake focal mechanisms (compiled after Camelbeeck et al., 2007; Hinz, 2003, and Dost and Haak, 2007) are indicating the recent seismic activity of the region. The information about in situ stress measurements are taken from the World Stress Map database (Heidreich et al., 2008). The tectonic overview map (upper right map, modified from http://commons.wikimedia.org/wiki/File:Hercynian_structures_Europe_EN.svg, retrieved on 06.10.2009) presents the main structural features and the general direction of motion (after Fritsch and Meschede, 2007 and Verniers et al., 2001). LURG = Upper Rhine Graben, HD = Hessian Depression, LIM = London Brabant Massif, NASE = North Aachen Shear Zone.

Fig. 13. In situ stress magnitudes observed from borehole failure analysis. Solid black lines mark the hydrostatic pore pressure (Pp), the vertical stress (Sv) and the derived trend of minimum horizontal stress ($Sh_{min} = 0.019 \cdot TVD$) and maximum horizontal stress ($SH_{max} = 0.038 \cdot TVD$).

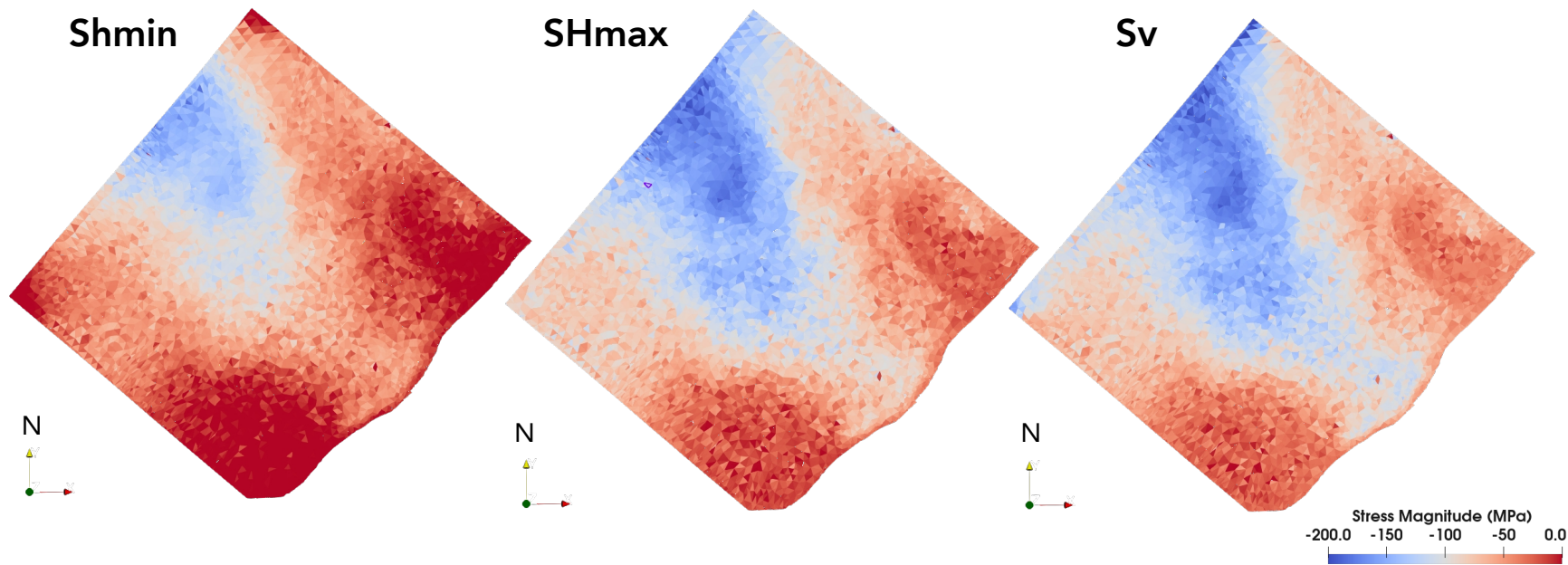
Boundary Conditions (major/minor displacements)



Horizontal principal stresses



Magnitude Principal stresses for Lower Carboniferous



Reference:

Trautwein-Bruns, Ute, Katja C. Schulze, Stephan Becker, Peter A. Kukla, and Janos L. Urai. "In Situ Stress Variations at the Variscan Deformation Front — Results from the Deep Aachen Geothermal Well." *Tectonophysics* 493, nos. 1–2 (2010): 196–211. <https://doi.org/10.1016/j.tecto.2010.08.003>.

D. Eickhoff, S. Back, K. Reicherter, and J. R. R. Ritter, "Seismic reprocessing of BELCORP-DEKORP 1A reveals deep fault reflections of the Paleozoic Eifel Fold and Thrust Belt in Germany," *Tectonophysics*, vol. 903, p. 230702, May 2025, doi: [10.1016/j.tecto.2025.230702](https://doi.org/10.1016/j.tecto.2025.230702).

