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Thermo-Hydro-Mechanical modelling of a reinjection operation in the North Alpine Foreland Basin

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FUNDAMENTALS

Geothermal operations alter subsurface pore fluid pressure, modifying effective stress and potentially destabilising rock masses — a key mechanism behind induced seismicity.

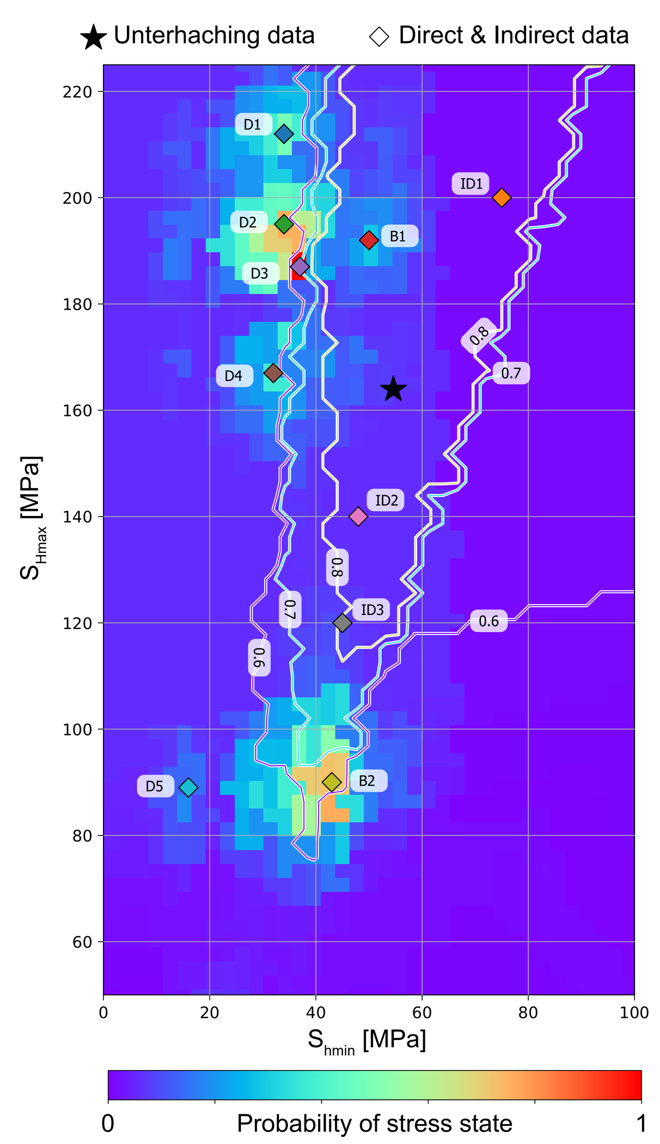
Induced seismicity has been recorded almost from the start of operation at the Unterhaching geothermal plant (North Alpine Foreland Basin).

A 3D thermo-hydro-mechanical model was developed for the reinjection well, incorporating realistic lithology, pore fluid overpressures, and varying fault hydraulic properties.

Uncertainties in the initial stress field are screened against observed microseismic activity to retain physically consistent scenarios and discard implausible ones.

INITIAL STRESS STATE

Possible stress states at a depth of 4000 m at Unterhaching from direct (colour code) and indirect data (isolines).

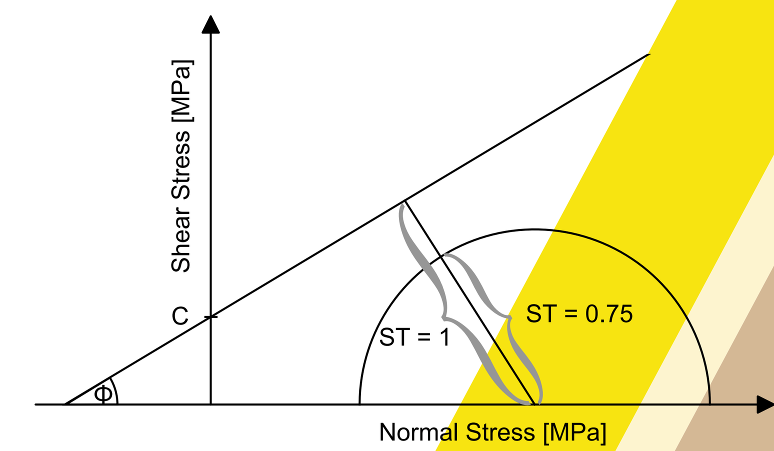


RESULTS - SLIP TENDENCY

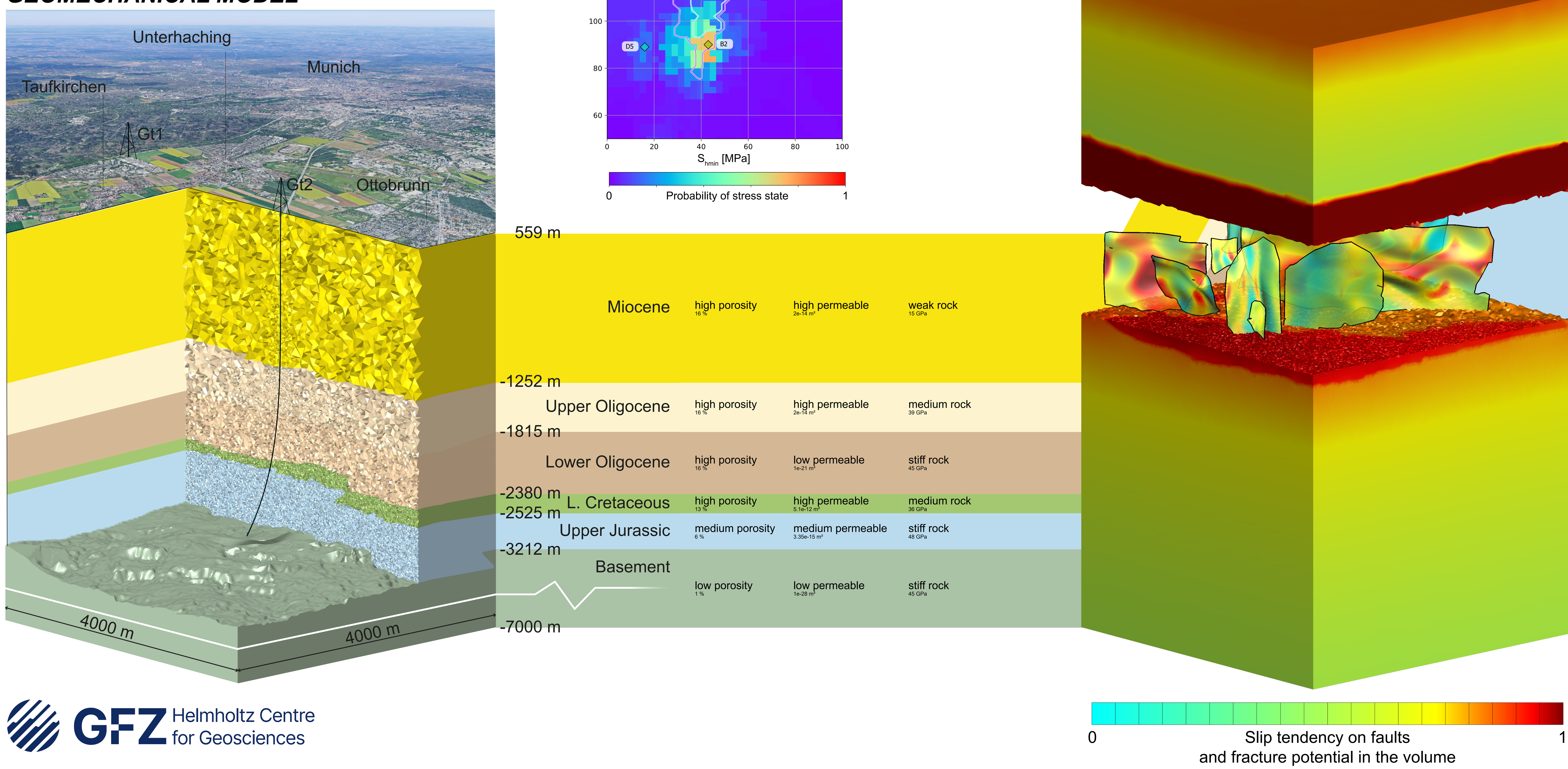
Failure occurs if the shear stress τ exceeds the normal stress σ_n. Cohesion C delays failure and coefficient of friction μ = tan(Φ) defines the slope. Slip tendency is used to assess whether a fault fails or not.

ST > 1: Failure
ST < 1: Stable

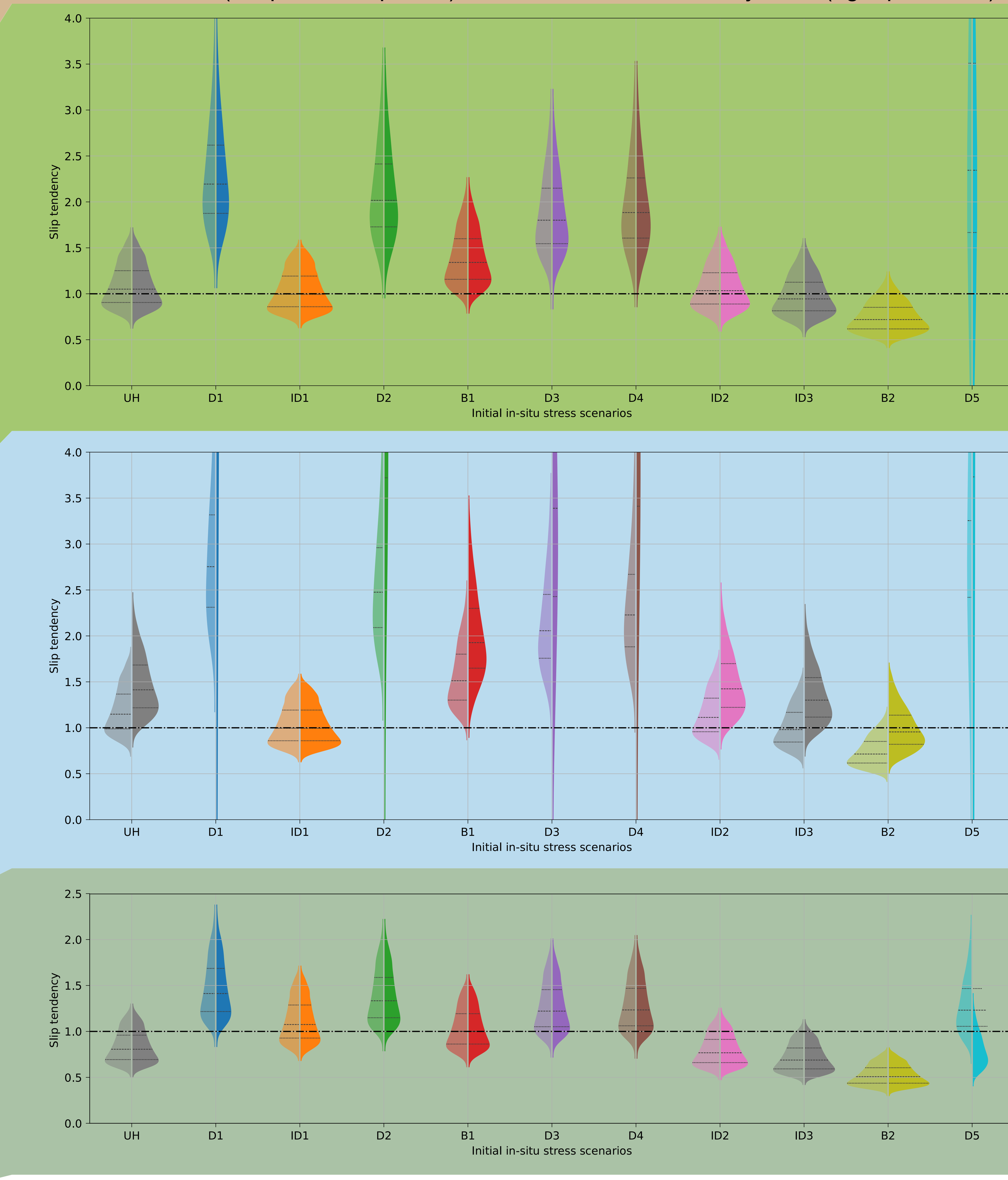
$$ST = \frac{\frac{\tau_{\max} - C}{\sigma_n}}{\mu}$$



GEOMECHANICAL MODEL



Slip tendency in three units and eleven initial stress states. Violin plots consist of the most optimal orientations, a cohesion between 0 MPa and 10 MPa, and a friction between 0.5 and 0.9. Before (left part, transparent) and after four months of injection (right part, bold).



CONCLUSION

1. Stress state and fault properties most strongly control rock stability.
2. Recorded induced seismicity only possible with certain parameter sets.
3. Model-observation screening sharpens stress state predictions for future operations.

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