EGU25-19108

Investigating fault reactivation potential for the Californië geothermal field (the Netherlands) by addressing uncertainties with probabilistic modeling of structures and in situ stress.

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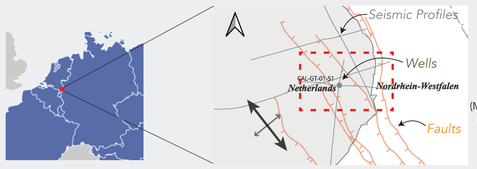
Introduction

An early challenge for geothermal exploration is investigating whether development may lead to fault reactivation or induced seismic events of societal concern. To characterize these hazards, careful considerations of structural geometries both for fault and formation horizons in the current stress state are necessary. As this understanding of the subsurface is rarely complete, we must also include measures of uncertainty. This study implements a probabilistic modeling workflow that accommodates both uncertainties in fault geometries and *in situ* stress to evaluate fault reactivation potential in the Californië geothermal field

Model Inputs

Dataset and Observations

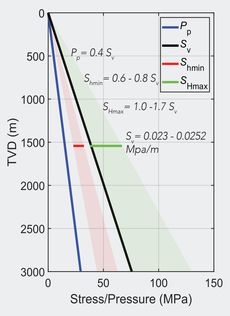


Californië geothermal system in NW Europe

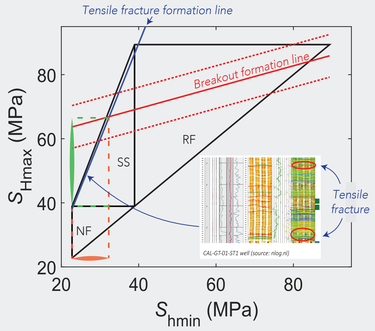
Datasets used for the structural modeling, outlined by the red box

Focal plane solution for the (M_L=1.7) 19th September 2018 event (Baisch & Vörös, 2018)

Local Stress Field Analysis



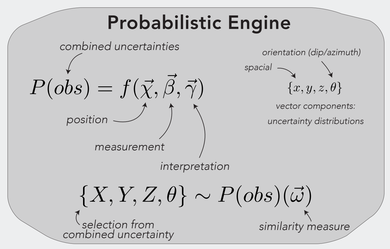
Depth dependent stress state and uncertainty ranges for the model



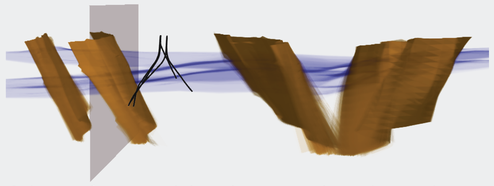
Analysis of the stress state for the Californië geothermal system is supported by observations of drilling induced tensile fractures and no apparent borehole breakouts suggest strike-slip faulting stress regime

Methodology

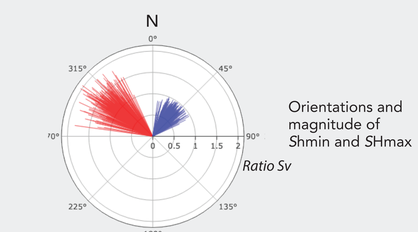
- Observations are cataloged to develop an initial 3D structural-geological model
- These initial interpretations will seed a series of probabilistic implicit 3D structural models, including uncertainties of the initial observations
- Structural models are created with new geometries and a 3D mesh is generated
- Vertical stress is calculated from formation densities and the ratio of horizontal stresses are selected from uncertainties in magnitudes and orientations described in the local stress field analysis
- Using the Finite element method, stress is projected onto the model and its structures
- Fault stability parameters: slip tendency, dilation tendency, and fracture susceptibility are computed



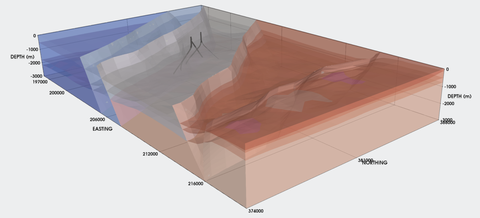
Method used to evaluate data uncertainty



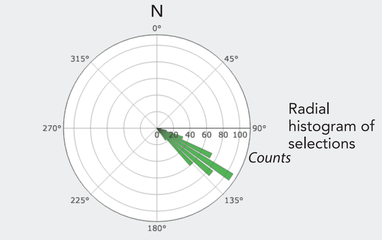
Subset of geomodel realizations plotted together to show geometric variability. Also: note the vertical plane, this represents the orientation of the projections for fracture susceptibility to the right



Orientations and magnitude of Shmin and SHmax

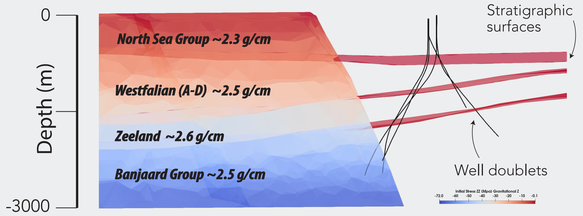


3D meshed volume from structural model realizations



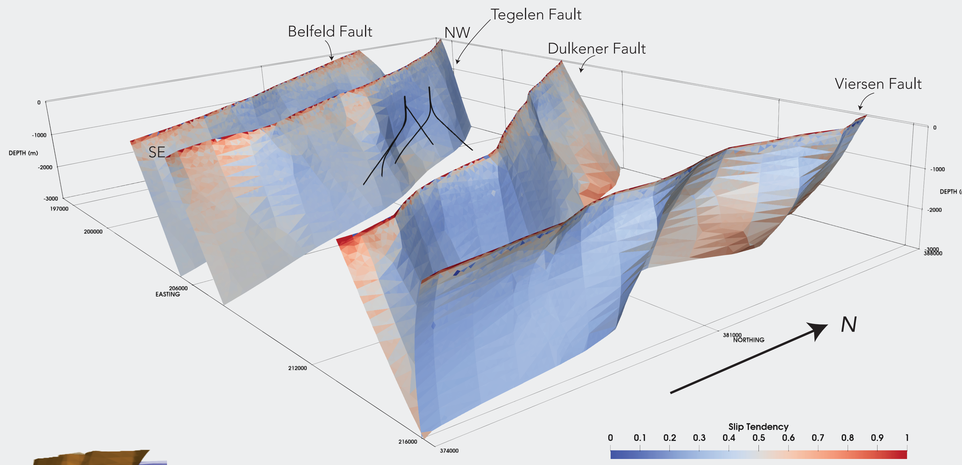
Radial histogram of selections

Subset of input horizontal stresses

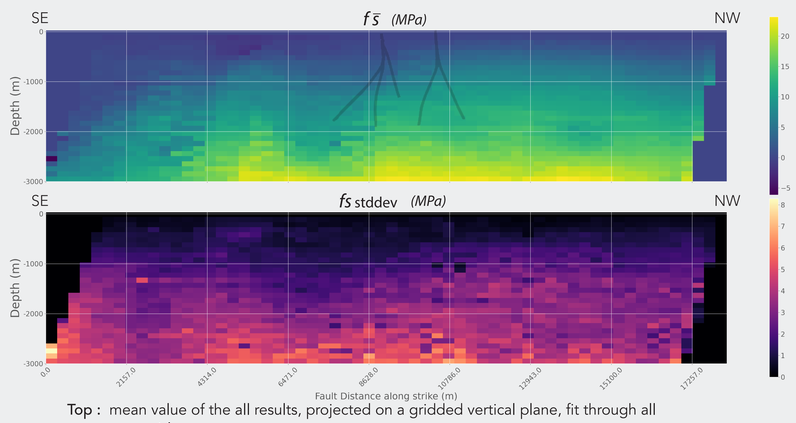


Inital stress zz condition is computed from integrating gravitational force from formation densities

Results

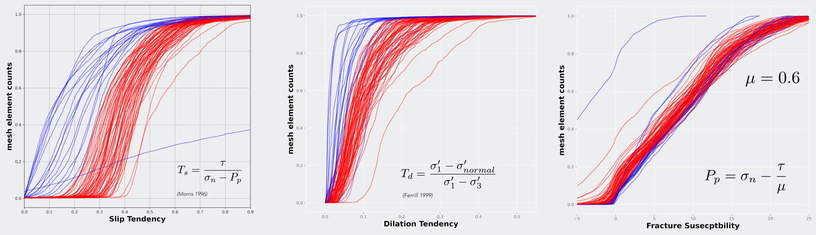


Combined Fracture Susceptibility, from all simulations, Projected on a vertical surface (only Tegelen fault)



Top : mean value of the all results, projected on a gridded vertical plane, fit through all geometries.
Bottom : Standard deviation of the set of projections on an equivalent plane as the the top fig

CDF plots of fault stability results from simulations n=100



Blue = Normal Faulting Stress Regime
Red = Strike-slip Faulting Stress Regime

References:
David A. Ferrill, James Winterle, Gordon Wittmeyer, Darrell Sims,Shannon Colton, Amit Armstrong, Stressed Rock Strains Groundwater at Yucca Mountain, GSA TODAY Vol. 9, No. 5 May 1999
A Morris, DA Ferrill, DB Henderson, Slip-tendency analysis and fault reactivation, Geology 24 (3), 275-278
Vörös R and Baisch S. Induced seismicity and seismic risk management – a showcase from the Californië geothermal field (the Netherlands). Netherlands Journal of Geosciences, Volume 101, e15. https://doi.org/ 10.1017/njg.2022.12

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