Causal processes of the temporal and spatial variations in the Gutenberg-Richter parameters

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OBJECTIVE

Testing the hypothesis that the fault spatial distribution and geometry together with operational parameters are the cause of the spatiotemporal variations in the Gutenberg-Richter parameters in the Groningen gas field

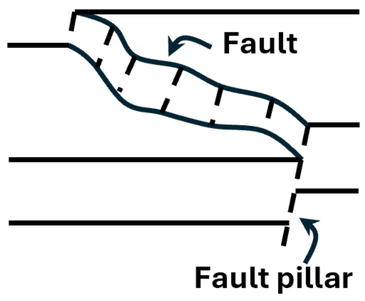
METHOD

Incorporate uncertainty in fault properties through Monte Carlo assessment

data

Fault database:
- 1047 faults,
- 35770 fault pillars

For each pillar:
- Strike
- Dip
- Offset
- Reservoir thickness



Fault properties
- Friction coefficient
- Slip weakening parameters

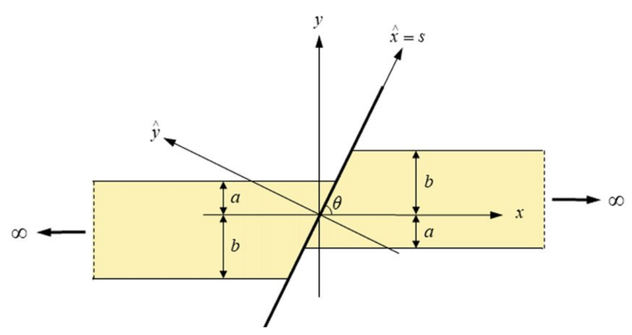
Reservoir properties
- Young's modulus
- Initial pressure
- Reservoir depth

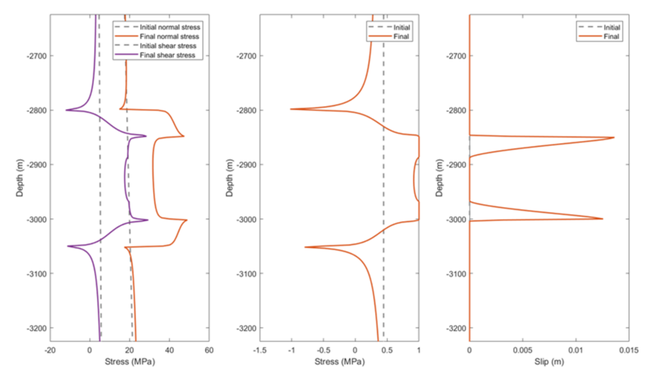
analysis

Panther [1]

Analytical model for stress changes and aseismic fault slip on an offset fault due to reservoir pressure changes [2, 3].

For each fault pillar compute
- Depletion (dP) required for seismic nucleation
- Amount of aseismic slip at nucleation

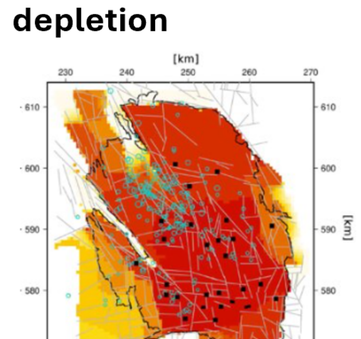




Look-up table of nucleation pressures & slip lengths for all fault pillars

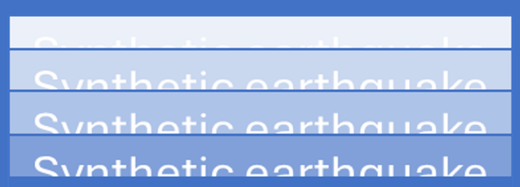
Pillar #	dP_activation	Slip length
1	150	10
2	153	9
3	150	9
4	155	8
5	155	9
6	175	10
7	200	10
8	200	10
9	175	8
10	200	10
11	200	10

Groningen reservoir depletion

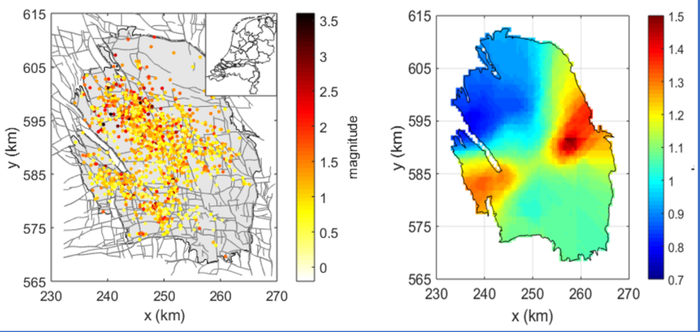


results

Ensemble of synthetic catalogues



Groningen earthquake catalogue:
Spatiotemporal variations in event locations and *b*-value [4]



References

[1] TNO, Physics-based semi-ANalytical Tool for Human-induced Earthquake Rupture (PANTHER), [2] Jansen, J. D., Singhal, P. & Vossepoel, F. C., Insights From Closed-Form Expressions for Injection- and Production-Induced Stresses in Displaced Faults. J. Geophys. Res. Solid Earth 124, 7193–7212 (2019). [3] Jansen, J.-D. & Meulenbroek, B., Induced aseismic slip and the onset of seismicity in displaced faults. Neth. J. Geosci. 101, e13 (2022). [4] Muntendam-Bos, A. G. & Grobbe, N., Data-driven spatiotemporal assessment of the event-size distribution of the Groningen extraction-induced seismicity catalogue. Sci. Rep. 12, 10119 (2022).