The impact of viscoelastic caprock on fault reactivation and fault rupture in producing gas fields

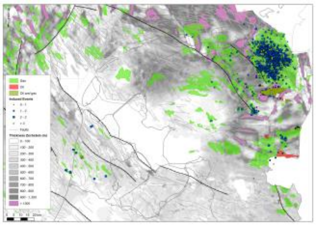
TNO innovation for life

Brecht Wassing, Loes Buijze and Bogdan Orlic

brecht.wassing@tno.nl, TNO, Utrecht, The Netherlands

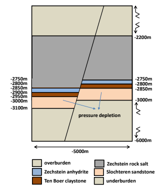
Introduction

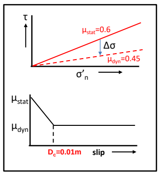
In several dozen of the gas fields in The Netherlands seismicity has been recorded during production. Understanding the underlying processes of induced seismicity in the gas fields is crucial for the assessment and mitigation of seismic hazard. We use a 2D geomechanical model (FLAC3D) to analyze the relation between pore pressure changes in the reservoir rocks, associated fault stress changes and fault rupture. As in many Rotliegend gas fields in The Netherlands caprocks consist of Zechstein rock salts, we specifically focus on the impact of these viscoelastic caprocks on the timing of fault reactivation and fault rupture characteristics.



Gas fields and induced seismicity in The Netherlands.

Modelling approach



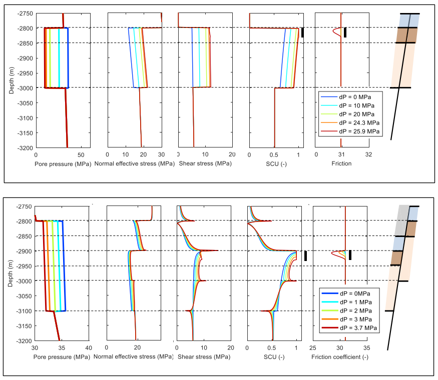


Geomechanical model in finite difference software of FLAC3D, including slip weakening fault.

- FLAC3D Quasi-static model: Onset of fault reactivation and nucleation of the seismic event during the depletion phase
- FLAC3D Dynamic model: Seismic rupture phase
- Fault: interface elements with slip weakening friction coefficient
- Scenario: 0 m and 100 m fault offset
- Scenario: without and with viscoelasticity in the rock salt (effective Newtonian viscosity of 10^{17} Pa s)

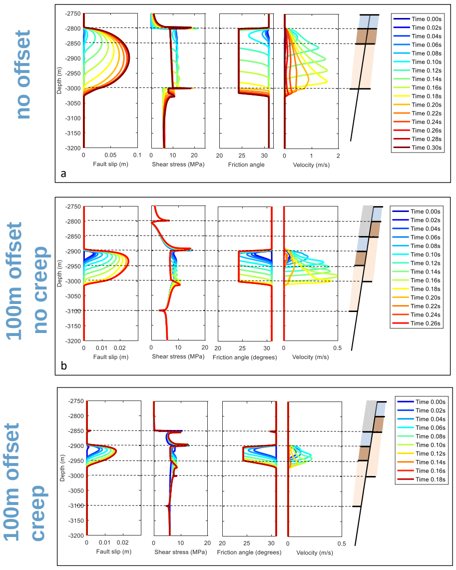
Modelling results

Static pore pressure depletion

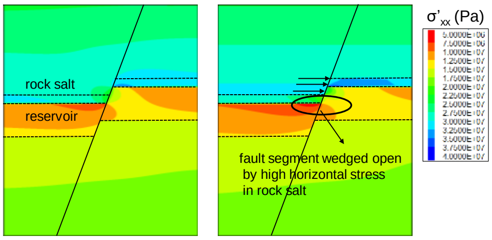


Evolution of fault stress and fault shear capacity utilization (SCU) during ongoing depletion. Fault reactivation occurs at SCU=1. A minimum slip length is needed (black bar) for nucleation of a rupture event. Fault offset promotes early fault reactivation and nucleartion of seismicity. In case of 100m offset rupture starts at 3.7MPa depletion; in case of no fault offset rupture starts at 25.9MPa.

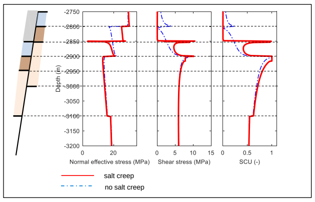
Dynamic fault rupture



Evolution of dynamic fault rupture in time: fault slip, shear stress, fault rction and slip velocities. Viscoelastic behaviour of salt promotes rupture at early stages of depletion, small slip displacements, slip velocities, stress drops, and rupture lengths.



Contourplot of initial horizontal effective stresses in FLAC3D model without (left) and with (right) salt creep accounted for. Models show lower effective horizontal stresses in the reservoir below the Zechstein layers if salt creep is accounted for – resulting in lower normal effective stresses on the fault segments below the Zechstein salt (see also figure on the right ⟶).



Comparison of initial stresses in model with and without salt creep.

Conclusions

- Fault offset promotes early fault reactivation and nucleation of seismicity during early depletion stage due to effects of differential compaction and stress arching
- Viscoelasticity of rock salt further promotes early reactivation, due to the transfer of shear stress from rock salt to lower rocks and fault segments and high horizontal stresses in the salt which 'wedge open' the lower fault segments.
- Early fault reactivation & rupture are characterized by lower stress drops, smaller rupture lengths, slip displacements and slip velocities & shorter event duration.

References

Itasca. 2013. FLAC3D Fast Lagrangian Analysis of Continua in 3 Dimensions. User's guide. Itasca Consulting Group.

Acknowledgements

This work is part of a project that received funding by the *European Union's Horizon 2020 research and innovation programme* under grant agreement number 640715 and number 691728. The content of this poster reflects only the authors' view. The *Innovation and Networks Executive Agency (INEA)* is not responsible for any use that may be made of the information it contains.