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Geomechanical modelling to minimize the risk of induced seismicity during underground gas storage operations in a depleted gas field in the Netherlands

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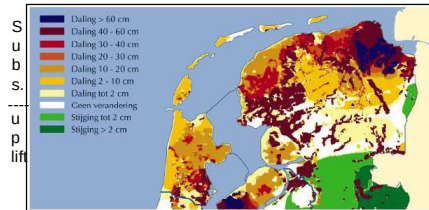
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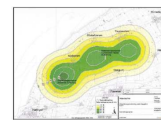
2

Background on ground surface movement in the north of NL

Subsidence due to natural causes until 2050



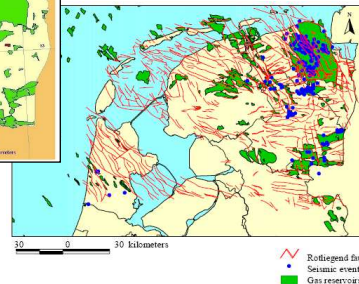
Subsidence due
to salt extraction



Subsidence due
to gas extraction

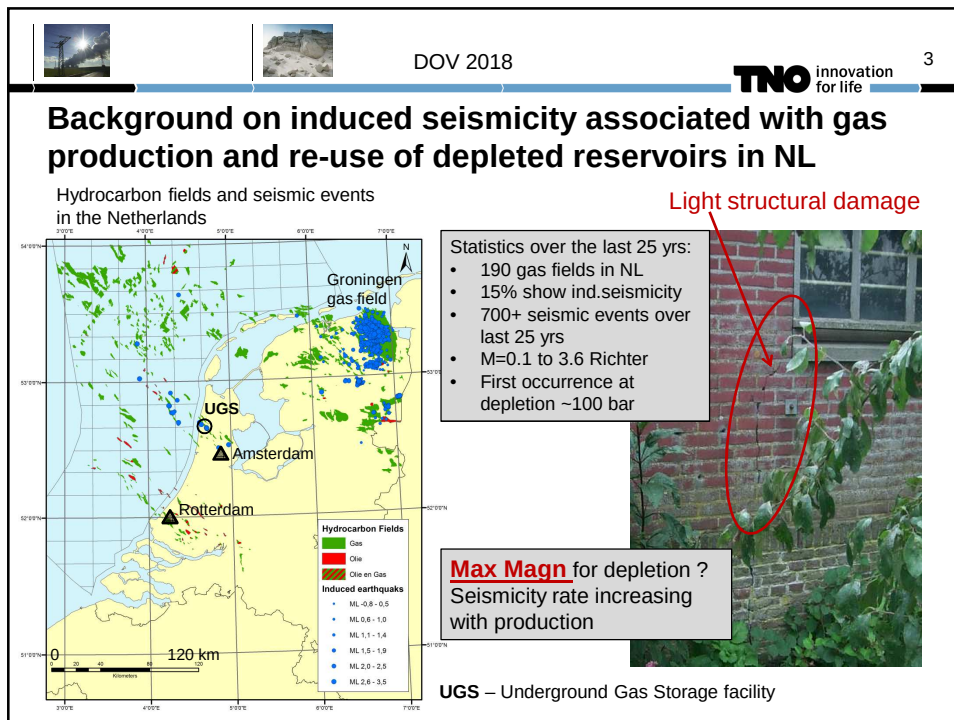


Seismic events
related to gas extraction



Location map








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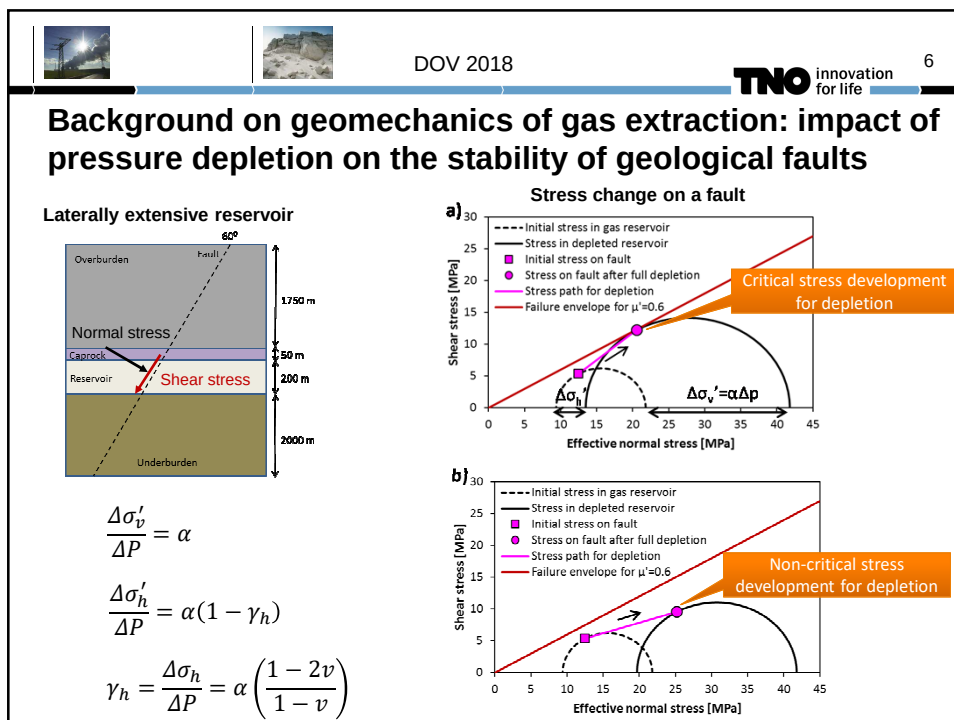
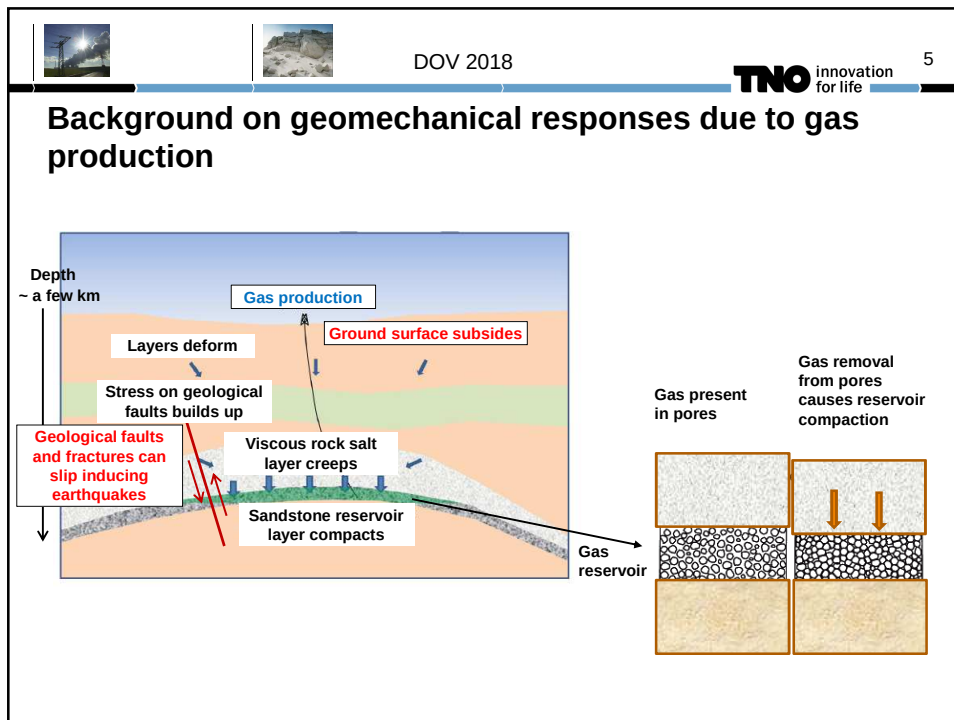
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Study scope and objective

- › Scope: **Induced seismicity** associated with the use of a depleted gas field for underground storage of natural gas (UGS).
- › Aim: Investigate the geomechanical effects of reservoir re-pressurization and UGS operations on **the stability of major faults** in the field under study.

Layout

1. Background on the geomechanics of gas production/injection
2. Background on the UGS project
3. Modeling approach
4. Model set-up
5. Results
6. Conclusions





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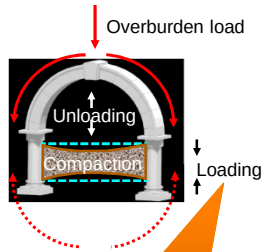
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Background on geomechanics of gas extraction: production-induced stresses and differential compaction

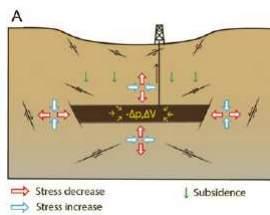
Laterally non-extensive and faulted reservoirs

Stress transfer around a depleting reservoir

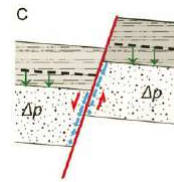


Unloading of the overburden
above the reservoir and
loading of the side-seal

Possible faulting mechanisms nearby a depleting reservoir



Differential compaction across a fault



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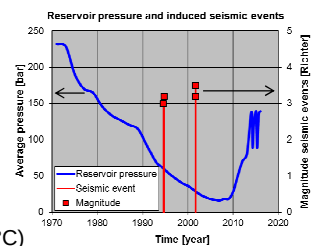
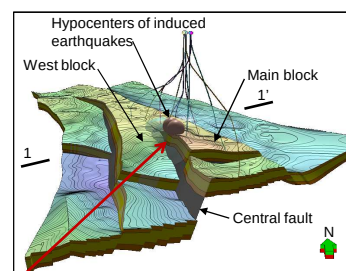
Background on the UGS project

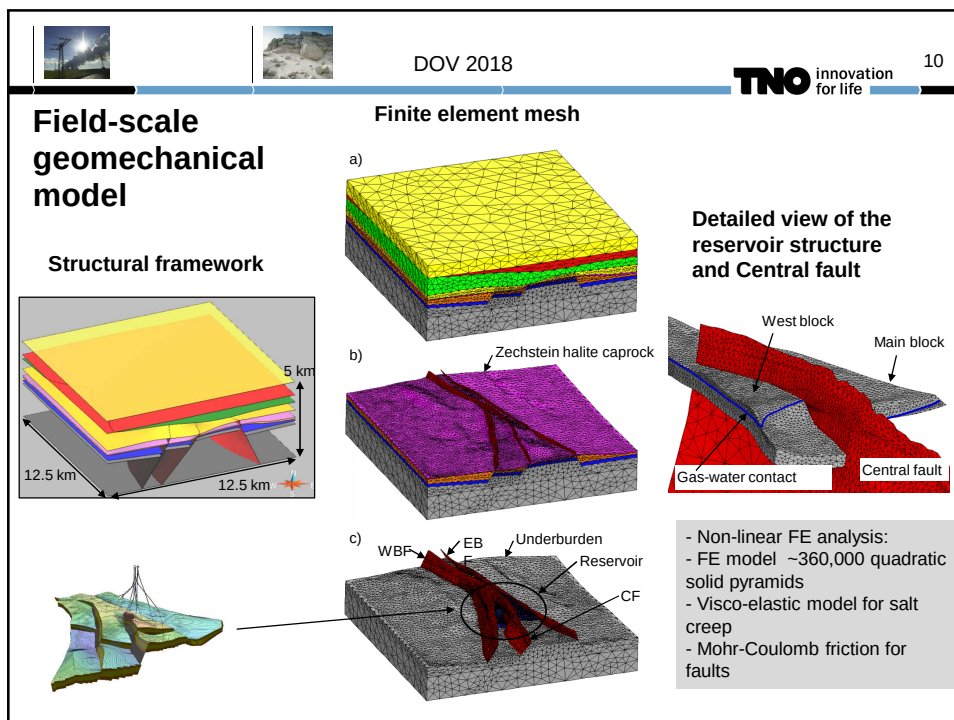
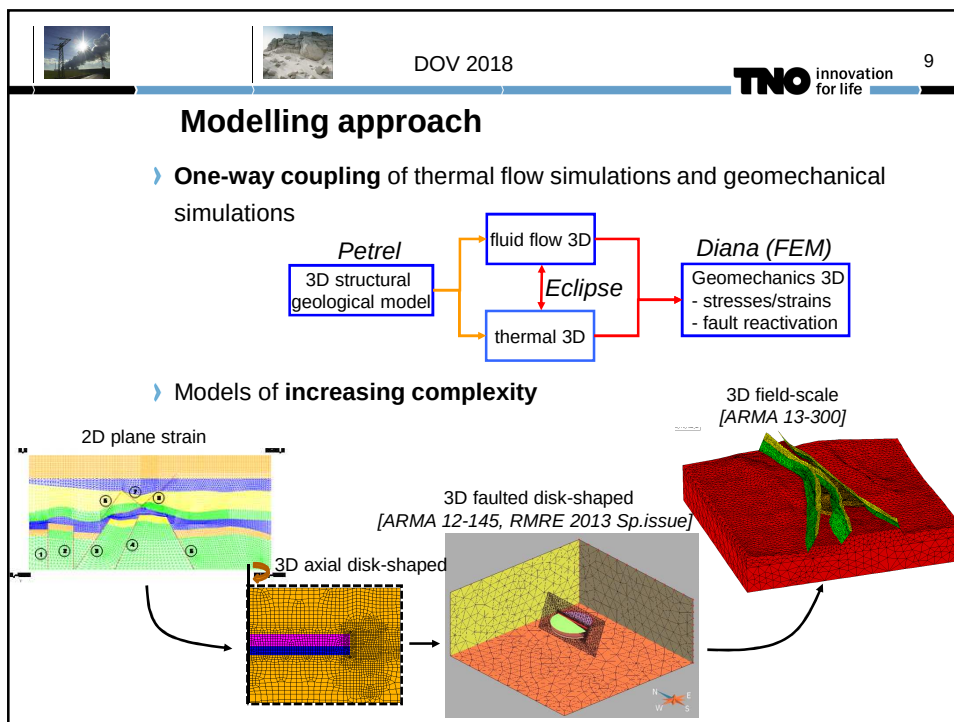
Field characteristics:

- › Original volume: 16.8 bcm at 230 bar
- › Gas production 1970-2007; p from 230 to 15 bar
- › **4 induced events:**
 - 1994: $M=3.0$ & 3.2 ; Intensity V ($\Delta P \sim 150$ bar)
 - 2001: $M=3.5$ & 3.2 ; Intensity VI
- › **The hypocenters of the recorded seismic events are located on, or close to, the Central fault**
- › Induced seismic events are caused by fault reactivation

UGS project:

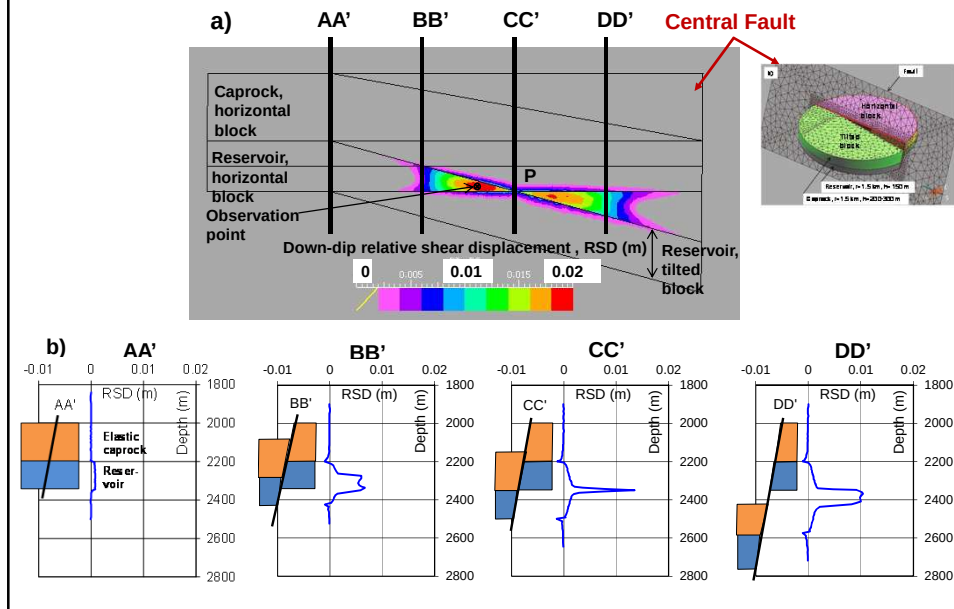
- › Cushion gas injection 4 bcm; 80 bar in 4 years
- › Working gas 4-9 bcm; 80 – 130 bar during 50 years
- › Injection of cold gas (24°C / 64°C) into the hot reservoir (86°C)





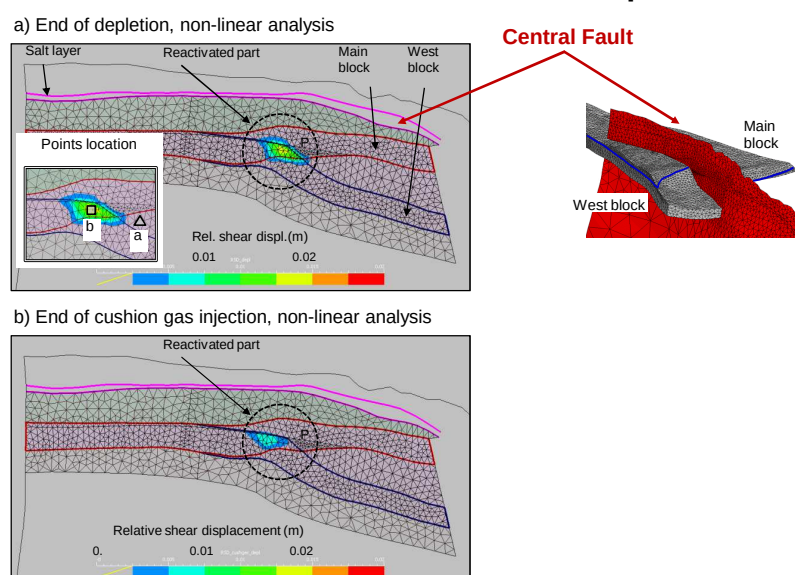
Disk-shaped model results: Relative shear displacement

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Field-scale model results: Relative shear displacement

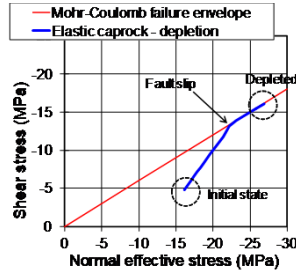
12





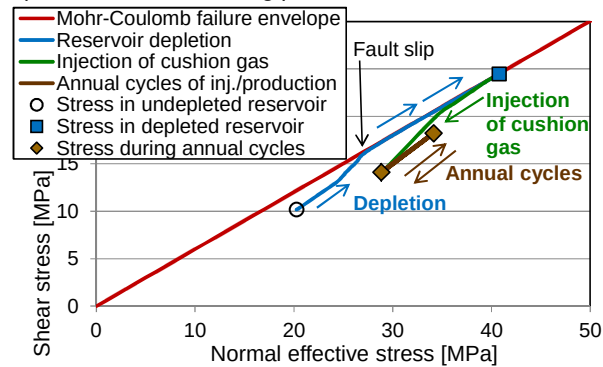
Field scale model results: Stress paths on the Central fault

Disk-shaped model results



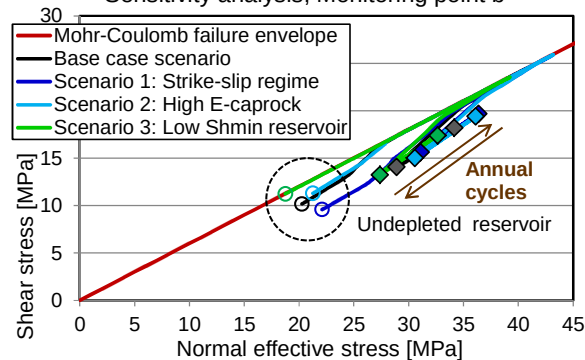
Field-scale model results

b) Base case, Monitoring point b



Field-scale model results: Sensitivity analysis Stress paths for observation point b on Central Fault

Sensitivity analysis, Monitoring point b





Conclusions

Depletion phase

- › Model predictions of the area on the Central fault that was critically stressed during gas production agree well with the seismological data / interpretations.

Cushion gas injection phase

- › Additional fault slip could be expected during cushion gas injection.
- › The area affected by fault reactivation is smaller (than during gas production) and does not overlap with the area critically stressed during production.

Annual cycles of injection and production

- › The stress changes on the Central fault associated with annual cycles of gas injection and production are clearly in the elastic region. The Central fault is not critically stressed anymore.
- › Continuous monitoring of induced seismicity is strongly recommended.



Underground gas storage site in operation since 2015

Gasprom Contracted 1.9 Bcm in Bergermeer UGS

Gasopslag Bergermeer officieel geopend

1 april 2015

Gasopslag, Nieuws

Den Haag, 31 maart 2015 – Maria van der Hoeven, directeur van het Internationaal Energie Agentschap, stelt morgen samen met TAQA Energy B.V. en haar partner EBN B.V. Gasopslag Bergermeer officieel in gebruik. Daarmee is de

Dutch UGS Bergermeer put into full commercial operation



Underground gas storage Bergermeer in the Netherlands was put into full commercial operation on April 1st.

The storage has a capacity of 4.1 bcm that makes it the largest gas storage in Europe with third-party access rights, Gazprom Export said in a statement.

Gazprom Group participated directly in the implementation of this project providing the necessary volume of 'cushion gas' and contracting 1.9 bcm of storage capacity, according to the statement.





Thank you for your attention !

Netherlands Journal of Geosciences, Special Issue, December 2017
Induced Seismicity in the Groningen Gas Field, the Netherlands



<https://www.cambridge.org/core/journals/netherlands-journal-of-geosciences/latest-issue>