# Applied Rock Mechanics in Salt Solution Mining

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24-11-2023

# Introduction

Els Wijermars
35 years
Beckum (Hengelo)


2007-2013: TU Delft – BSc and MSc Applied Earth Sciences
MSc Track Resource Engineering – FEMP EGEC

Geotechnical Engineer at Fugro and Witteveen + Bos

Nobian (formerly part of AkzoNobel and Nouryon)
Engineering Geologist for salt mining
Underground stability, subsidence, microseismicity and abandonment

# Topics

- Nobian salt mining operations
- Salt creep in relation to cavern abandonment
- Cavern abandonment research
- Challenges for today and the future

# Nobian salt production locations

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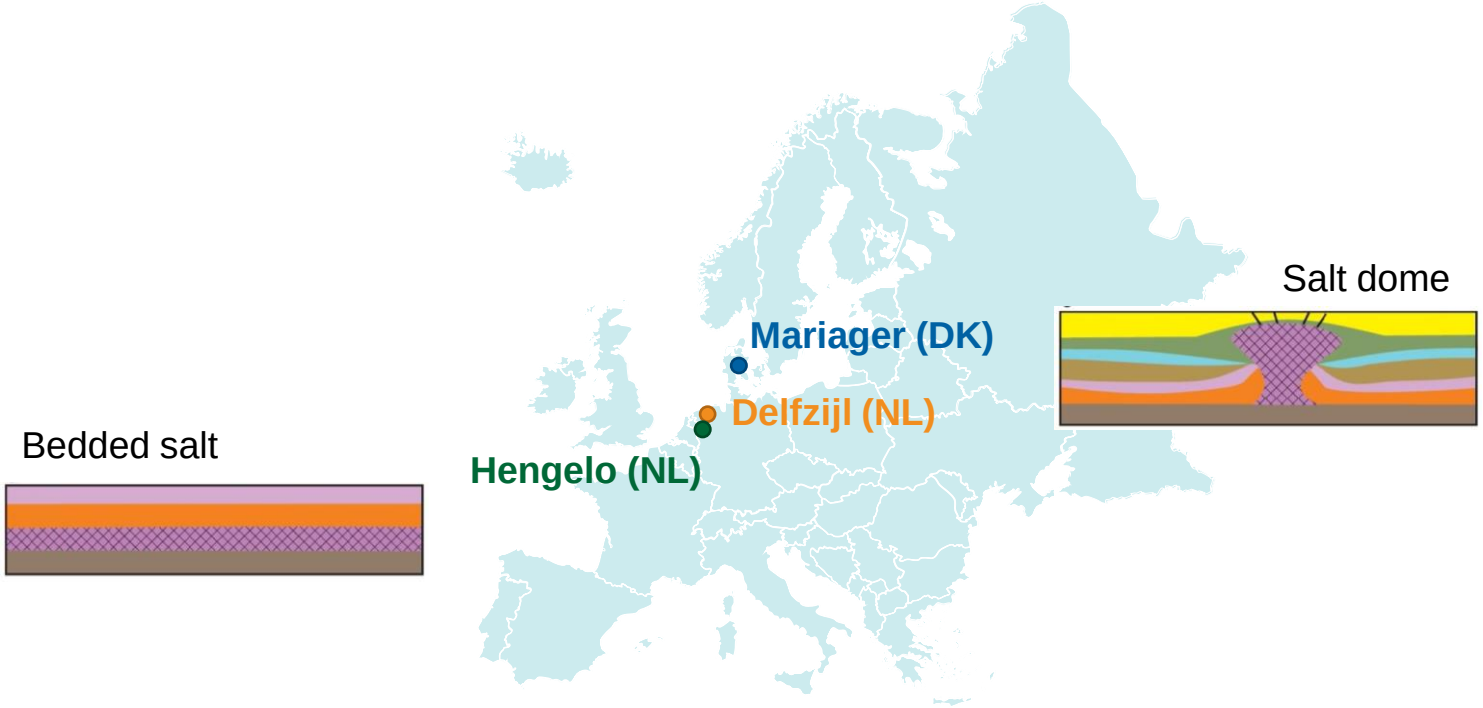
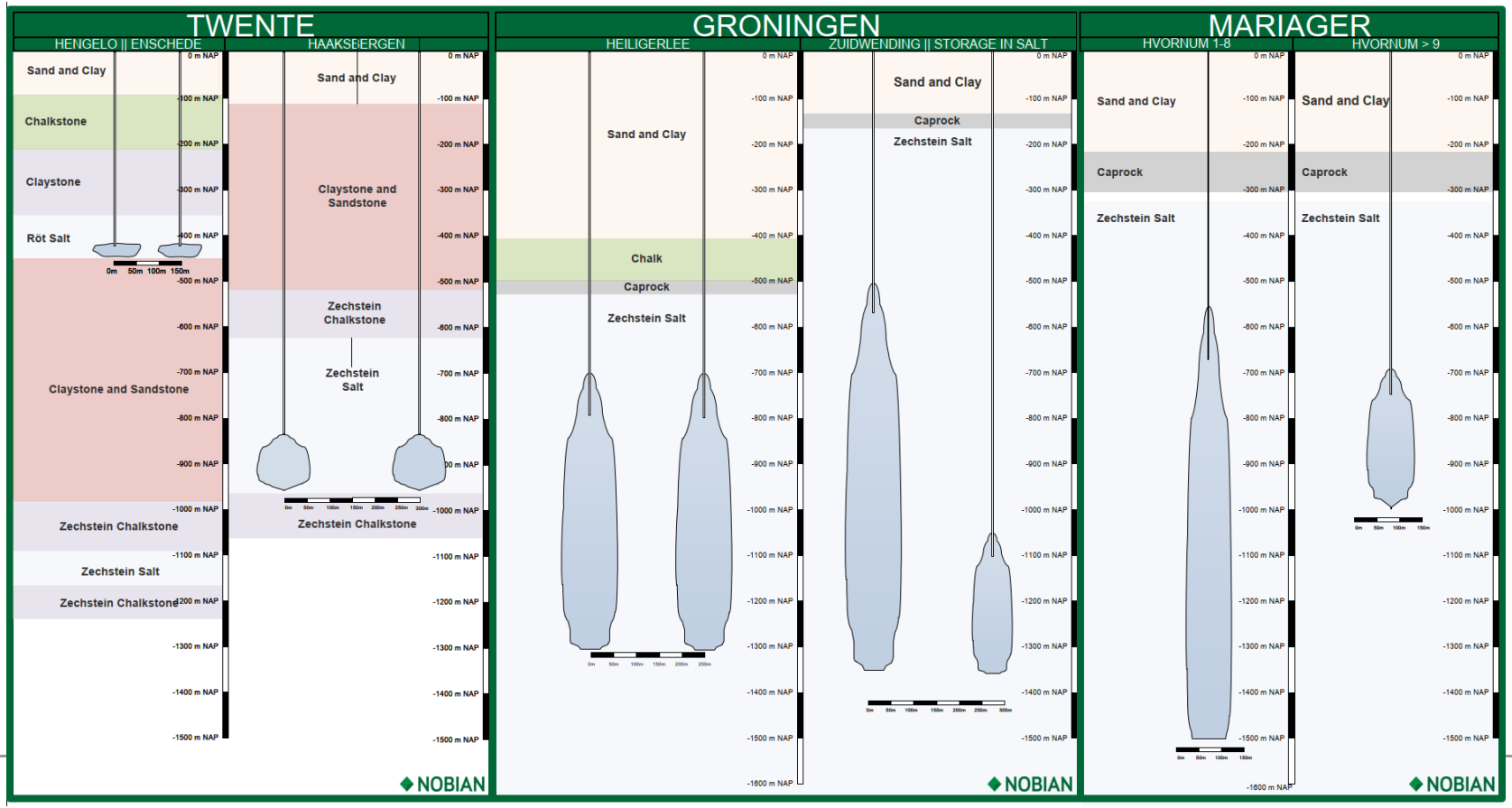
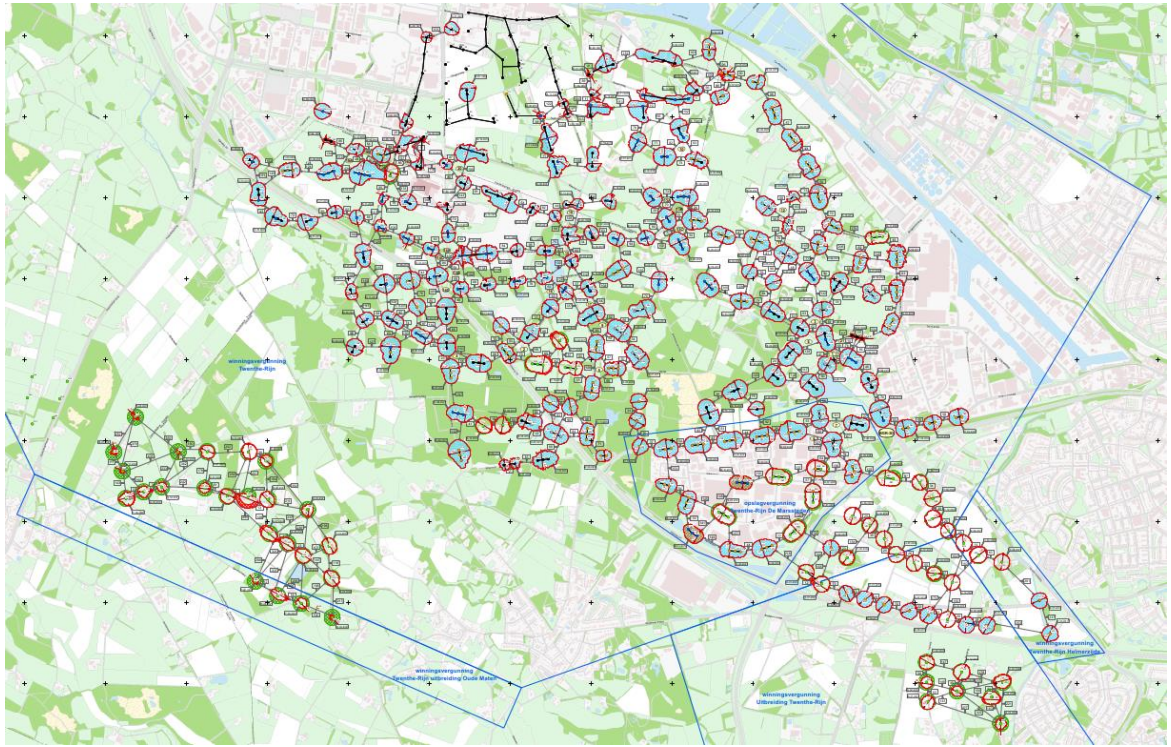


# Nobian cavern fields - comparison

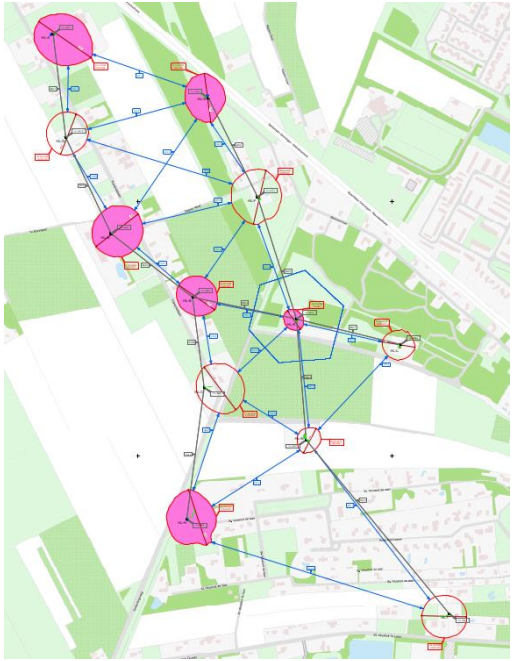


# Nobian cavern fields - Hengelo

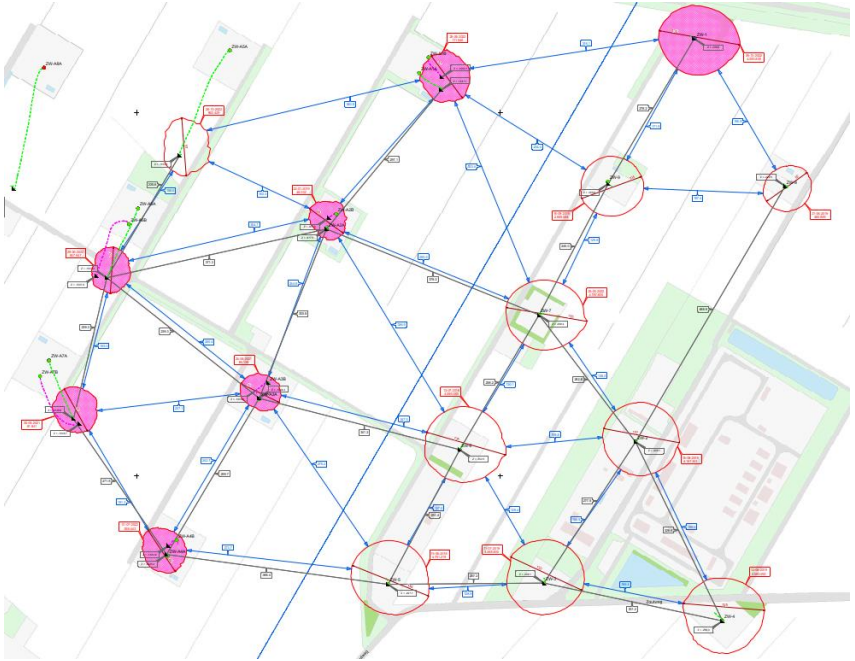


# Nobian brine fields - Delfzijl

Heiligerlee



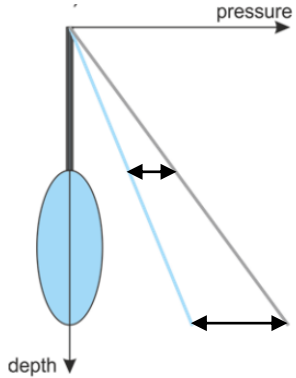
Zuidwending



# Salt creep in relation to cavern abandonment


Creep behaviour from lab tests

+




cavern data

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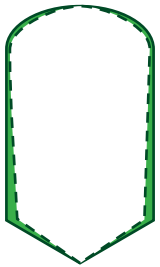

cavern convergence

# Salt creep in relation to cavern abandonment

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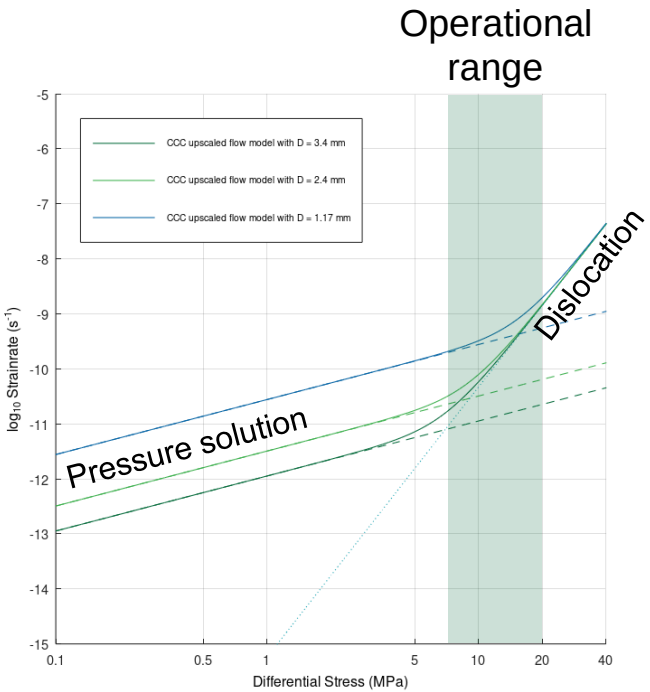
Salt Creep Mechanisms

Pressure solution (PS) and Dislocation creep (DC)

$$\dot{\varepsilon} = \dot{\varepsilon}_{ps} + \dot{\varepsilon}_{dc} = \underbrace{\frac{A_{ps}}{TD^3} e^{\left[\frac{Q_{ps}}{RT}\right]} \sigma^{n_{ps}}}_{\text{Pressure solution creep}} + \underbrace{A_{dc} e^{\left[\frac{Q_{dc}}{RT}\right]} \sigma^{n_{dc}}}_{\text{Dislocation creep}}$$



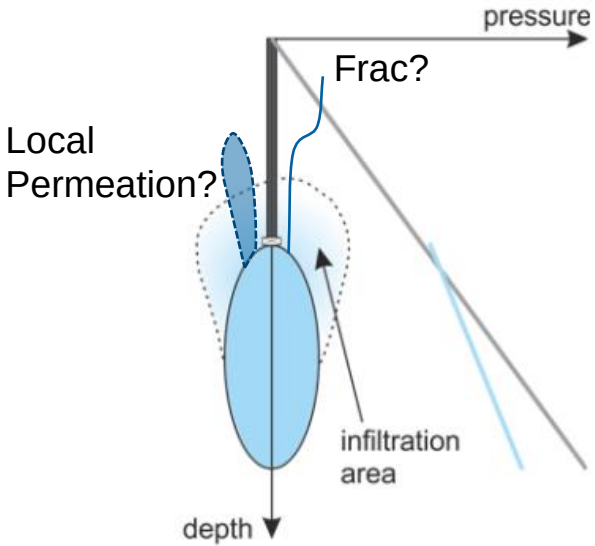

Low differential stresses after abandonment (hard shut-in)

→ Pressure solution creep becomes more important

→ In historic cavern field design this was not taken into account

→ Pressure build-up and subsidence can be faster than expected

# Cavern abandonment research




- Multi-scale research project to improve unstanding of the processes by the **Cavern Closure Consortium** (MaP, Brouard Consulting, smartTectonics, *Geostructures*)
  - Micro-scale
  - Cavern scale
  - Salt formation scale
- Investigation of possible consequences
  - Effect of leakage of brine
  - Long-term subsidence

# Cavern abandonment research

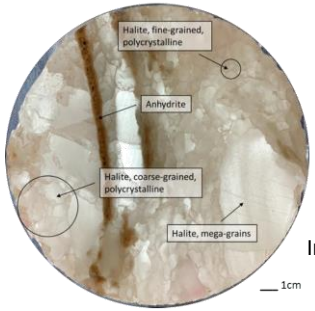



Image: MaP

## Micro-scale

- Subdivision of salt into lithological classes based on halite grain size and impurity content
- Deformation tests in lab (IfG Leipzig, Germany)
- Deformation tests in mine (Altaussee mine, Austria)
- Permeation tests in lab (IfG Leipzig, Germany)
- Study micro-structure before and after tests
  → Recrystallisation results in smaller grain size around cavern
  → Faster pressure solution creep in abandonment phase
- Numerical or synthetic creep tests

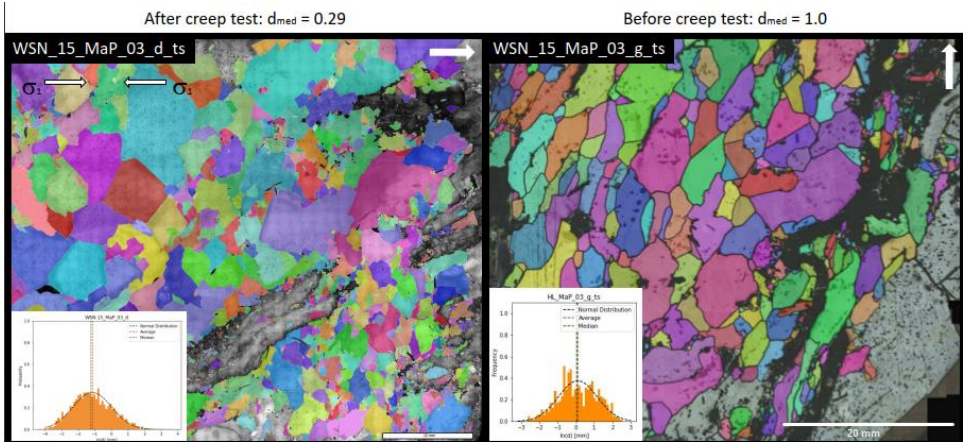



Image: MaP

# Cavern abandonment research

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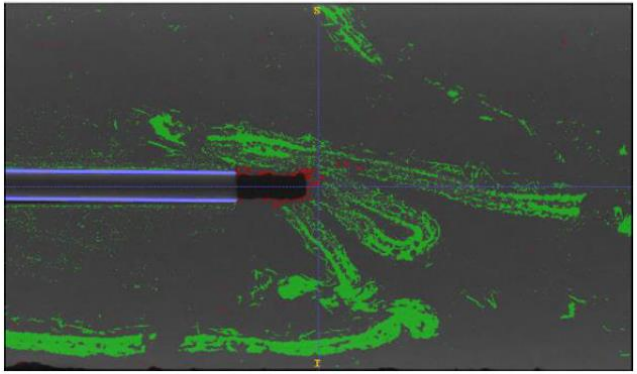

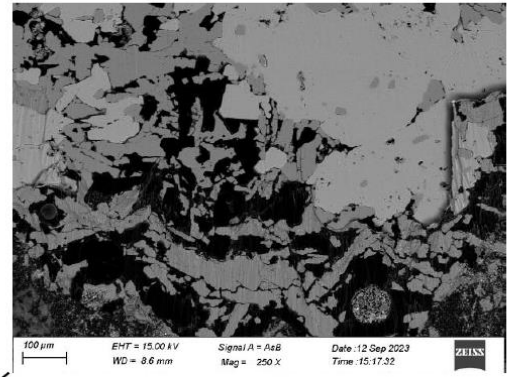



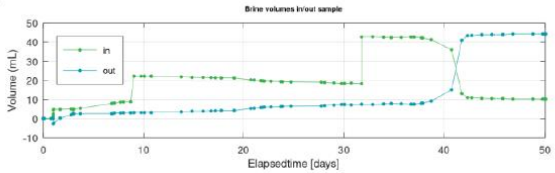


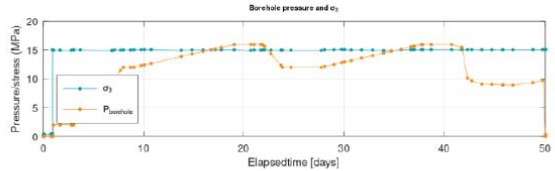

# Cavern abandonment research

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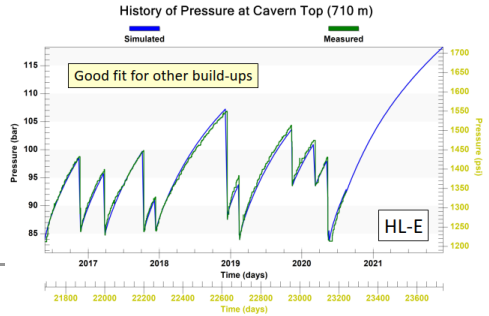
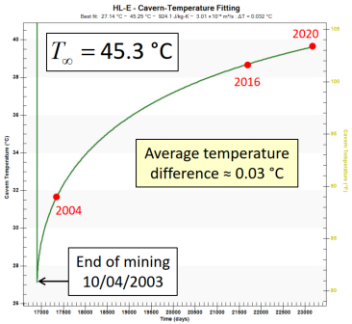
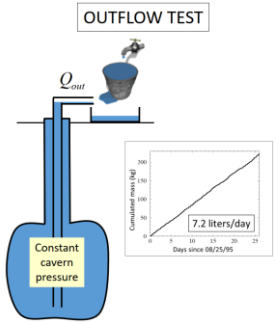
## Cavern scale

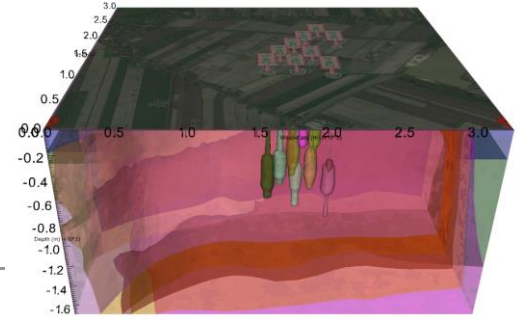
- Upscaling of deformation and permeation behaviour observed in micro-scale
- Reconstruction of creep behaviour based on cavern data in stand-still mode
- Reconstruction and forecast of temperature development
- Cavern scale tests (limited pressure operation window)
- Tests on new wells (XLOT)
- Implementing different deformation and permeation behaviour in 2D and 3D geomechanical models to compare different abandonment scenarios and perform sensitivity analysis

Images: Brouard Consulting



# Cavern abandonment research

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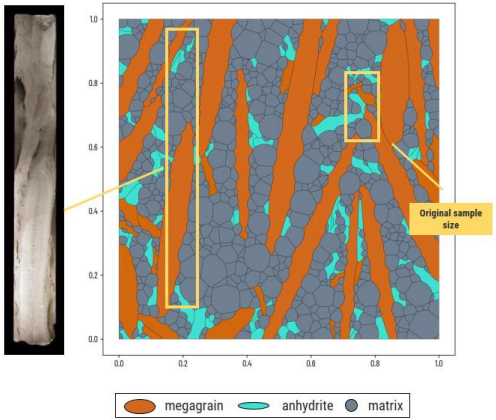
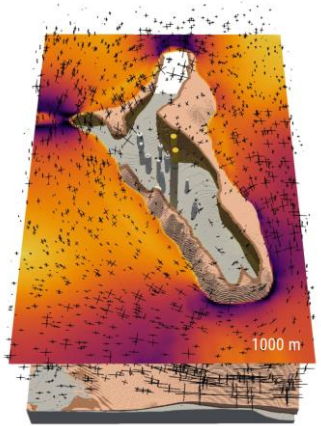
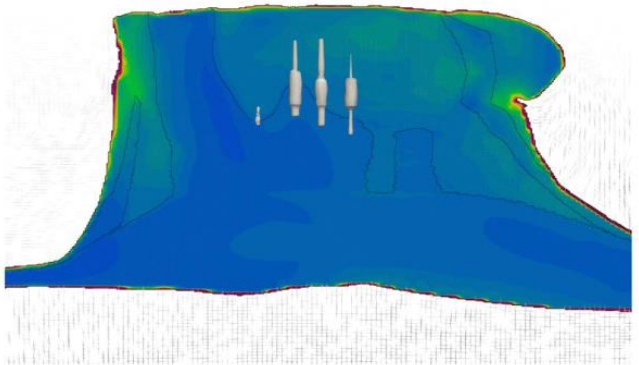
## Salt formation scale

- Upscaling of deformation and permeation behaviour from lab and cavern scale to field scale
- Reconstruction of salt dome formation to determine salt viscosity limitations
- 3D model with caverns and internal salt structure and different rheology

Images: smartTectonics



# Challenges for today and the future

- Safe abandonment of existing large caverns
- Consider complete life cycle of cavern field in design stage of new developments
- Public opinion on (salt) mining
- Develop caverns for (energy) storage of new media ($H_2$, compressed air)

# Thank you

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