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Using salt knowledge to reduce drilling risks

Marinus den Hartogh
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Content

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Introduction

- Marinus den Hartogh
- 33 years old
- Working at AkzoNobel since 2009
- Started as Geologist, now Technology Manager Brinefields

Message:
- A 3D model of the salt body helps to reduce drilling risks upfront
- To build a 3D model different well data can be combined with Zechstein salt knowledge
- Still operator should be prepared for any potential risk including drilling a stringer

Introduction

- AkzoNobel Specialty Chemical – currently still part of AkzoNobel together with Paints & Coatings
- Revenue: € 4,8 billion
- Employees: 9000
- Sites worldwide: 80+
- 5 Business Units à Industrial Chemicals à Salt

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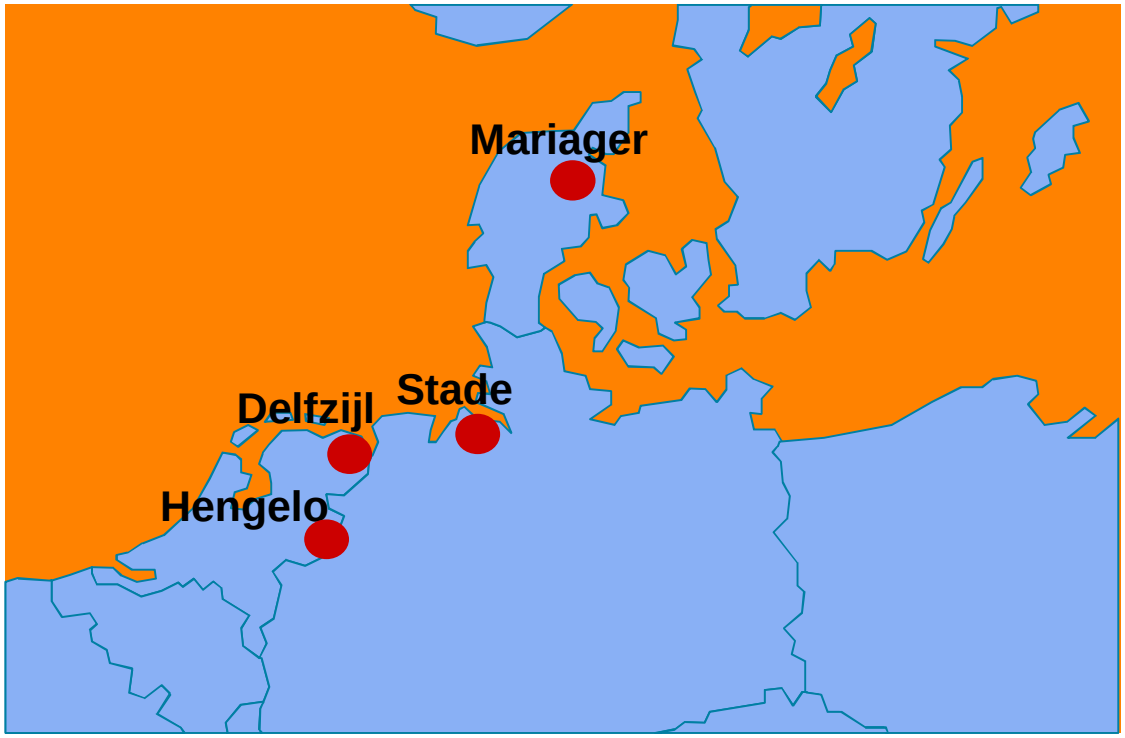
Zechstein drilling experience

Salt mining operations AkzoNobel



AkzoNobel Salt production locations:

- 2 Brinefields Delfzijl
- 1 Brinefield Mariager
- 1 brinefield Hengelo in Triassic salt
- Haaksbergen development
- Before 2003: 2 brinefields Stade

Zechstein drilling experience

- Delfzijl:
  - Heiligerlee: 12 wells
  - Zuidwending: 9 wells à **1 kick**
  - Supervision for gas buffer Gasunie Zuidwending: 13 wells
  - Sometimes ‘anhydrite floater’ without any observable gas pressure
- Mariager:
  - 7 wells
- Hengelo:
  - 1 well in Haaksbergen
- Stade:
  - 10 wells (7 in brinefield Stade, 3 in brinefield Hollenbeck à **1 kick**

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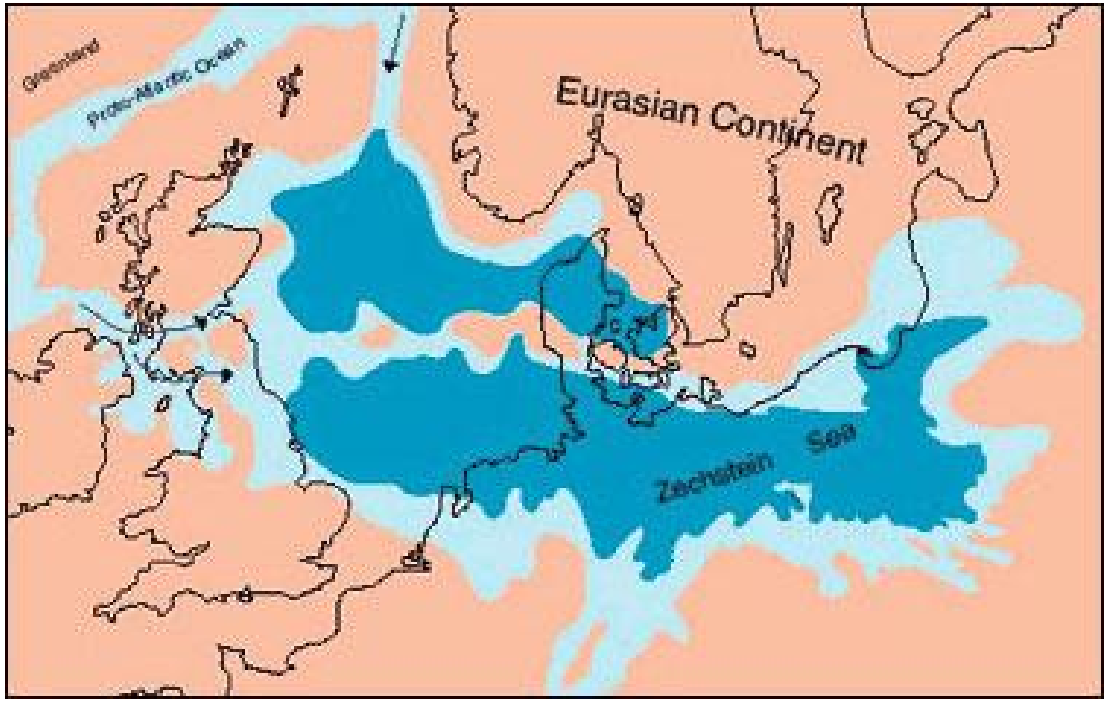
Zechstein stratigraphy

Zechstein salt - knowledge build-up

- Research bij DEEP Underground Engineering – an engineering firm providing services to the salt industry (2012-2013)
  à Based on results new drillings for gas buffer Zuidwending

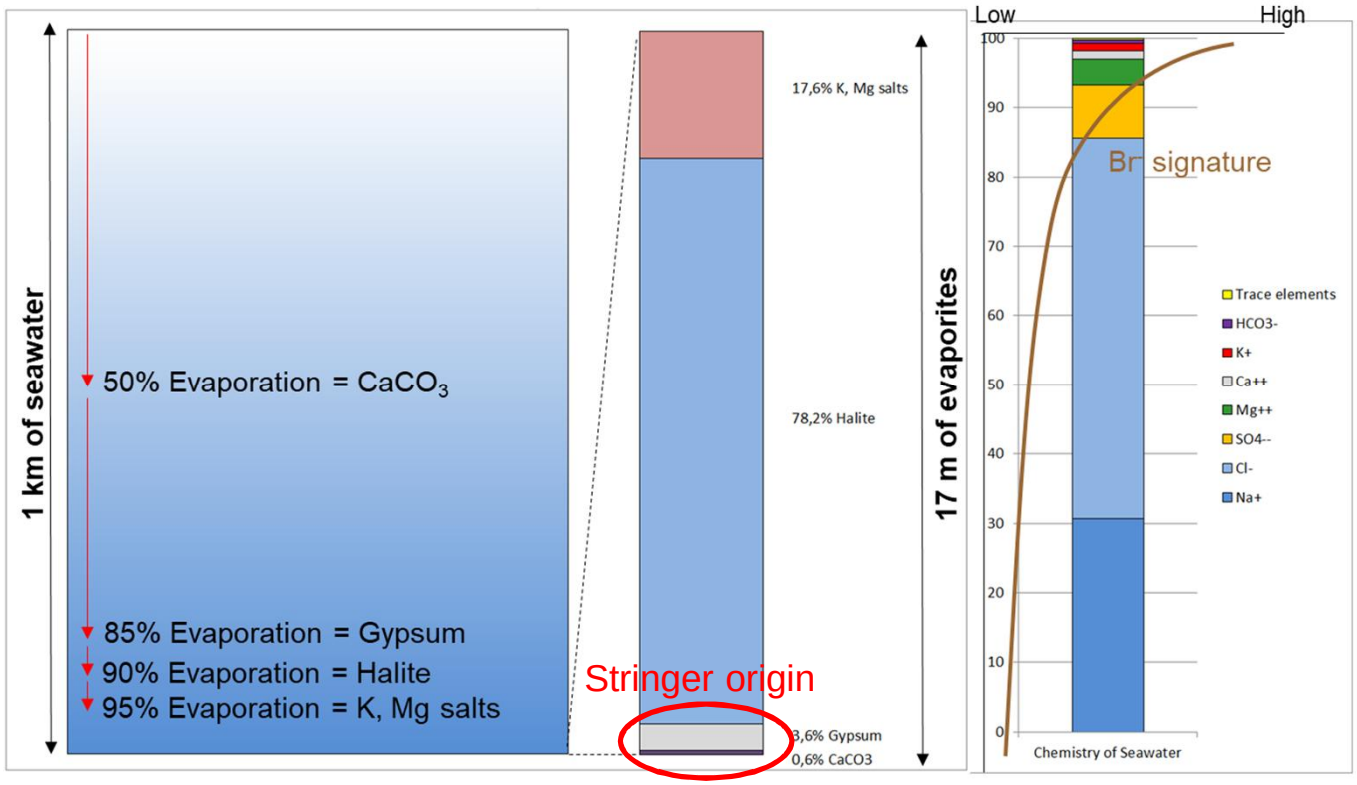
- Further study by geologist Roderick van der Kroef – University of Utrecht (2013)
  à Based on data from existing AkzoNobel wells and brine production data

Zechstein salt - background



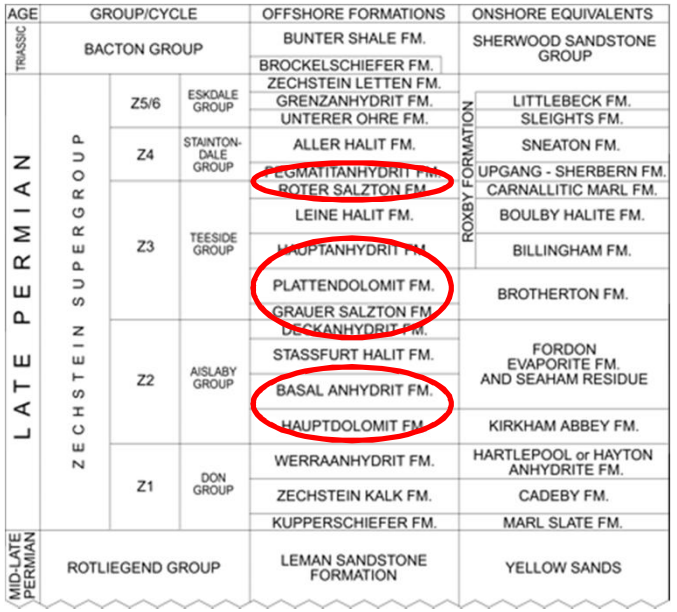
- Zechstein evaporites formed about 255 Ma BP
- Source: Zechstein sea, Southern Permian Basin
- **Evaporation and crystallization analogue to salt production**

Zechstein stratigraphy - evaporation



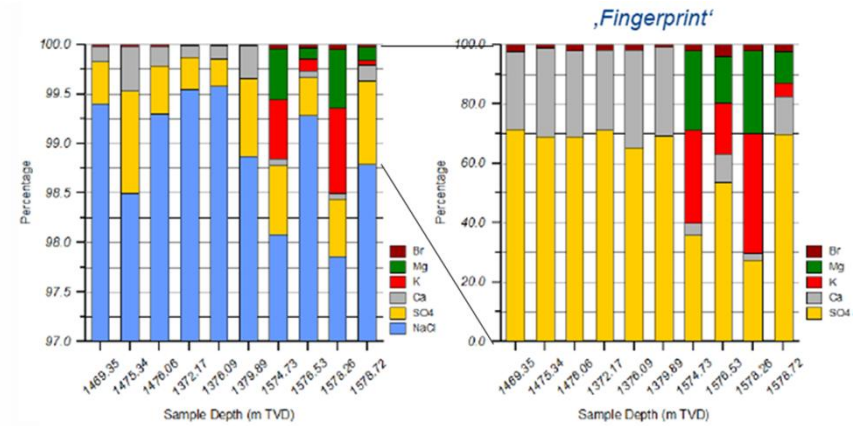
Zechstein stratigraphy - deposition

- Zechstein deposited in cycles driven by climate and tectonics
- About 6 main cycles, with subcycles.
  à Each cycle has a different seawater chemistry
- Seawater chemistry determines evaporite composition
  à detailed stratigraphy based on evaporite composition



Zechstein stratigraphy - chemistry

- Within salt rock in a dome: >97% salt,
  à the other 0.5 - 3% non-NaCl ions
- The chemical composition of the non-NaCl ions is determined by the stratigraphy
- This applies both for core-/cutting material and brine composition
- Example: lower Z3 and upper Z3 in one well



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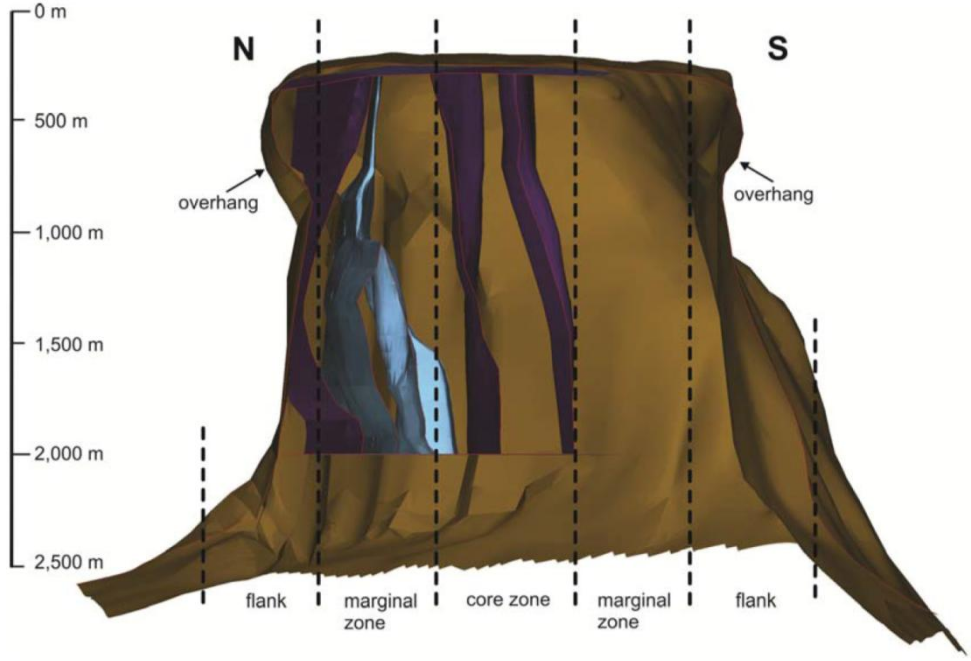
Modeling and drilling preparation

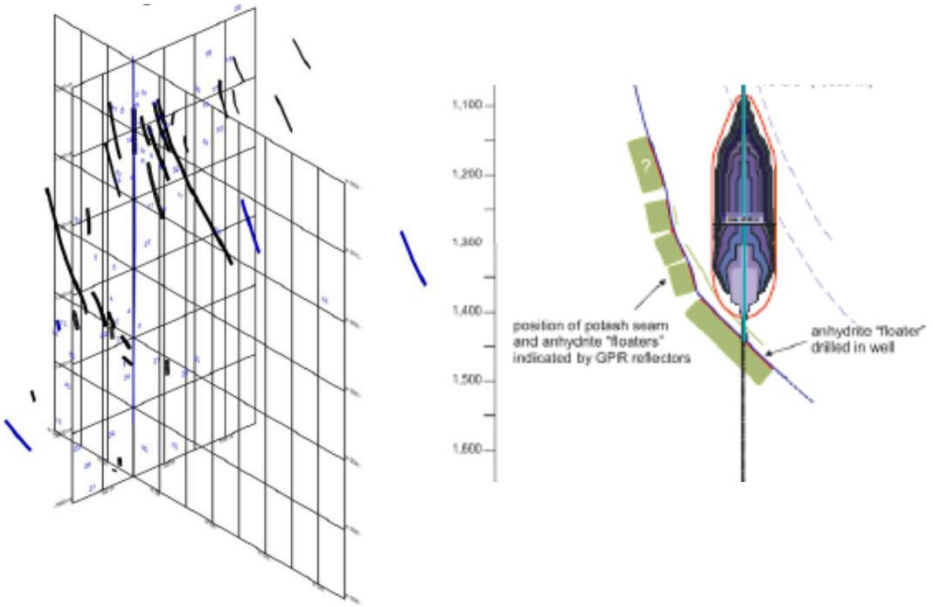
Modeling – 3D model

- 3D model made for Zuidwending, next step: Heiligerlee
- Stratigraphic knowledge of Zechstein salt
- Vertical Seismic Profile
  à reflectors indicate differences in seismic wave velocity
- Ground Penetrating Radar
  à reflectors indicate potassium and anhydrite
- Seismic Data



Drilling preparation

- Check on 3D model
- Check on GPR log interpretations from neighboring wells
- In case of strong indications for stringers
  à adapt well trajectory if possible
- **Always be prepared!**
  à in our case well control measures op to 5000 psi at wellhead



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Summary

Summary

- AkzoNobel Salt has drilled >50 wells in different Zechstein salt bodies
- Sometimes (anhydrite) floaters/stringers have been hit, resulting in a kick in two cases
- Stratigraphical knowledge of Zechstein salt bodies in combination with well logging and 3D modeling is helpful to reduce drilling risks upfront
- Still operators should always be well prepared in case of hitting a pressurized stringer

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Thank you for your attention

Questions?