

Using salt knowledge to reduce drilling risks

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AkzoNobel
SPECIALTY CHEMICALS

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Summary

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

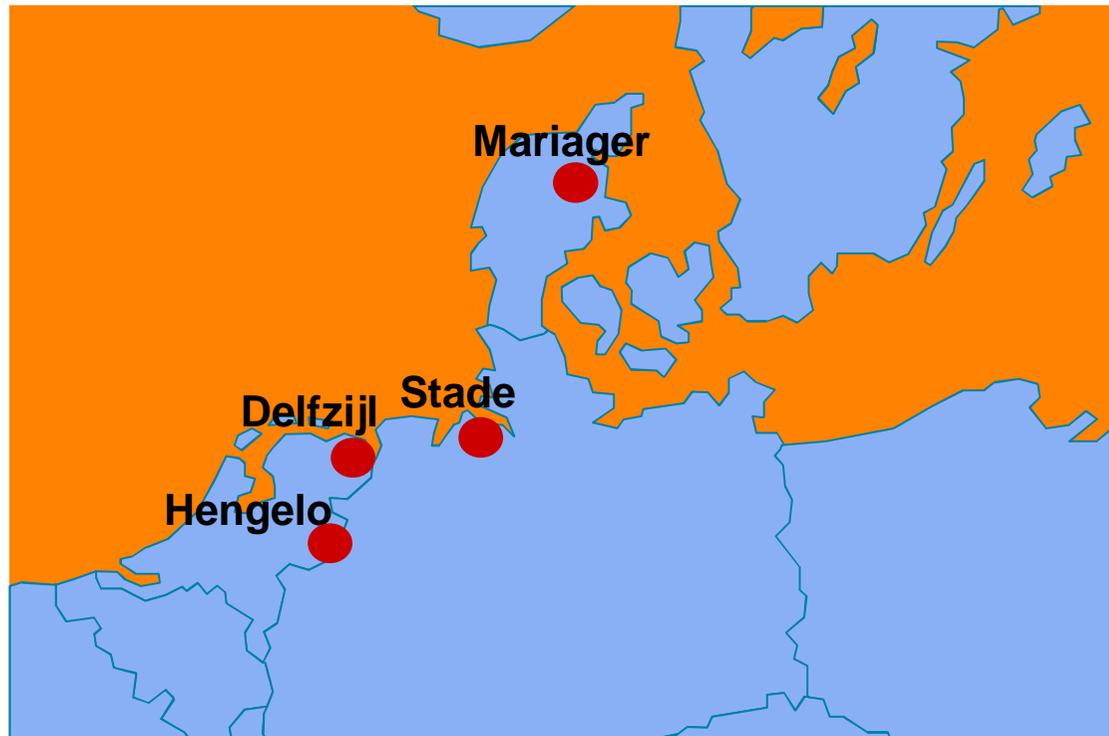
Introduction



- 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

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

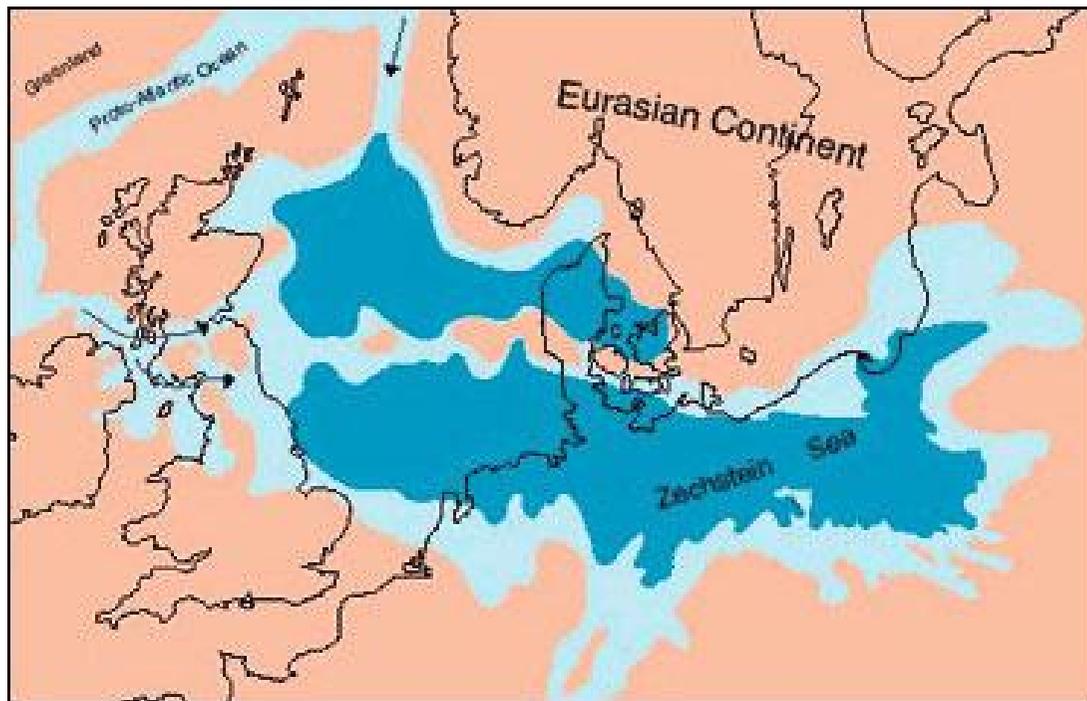
- Delfzijl:
 - Heiligerlee: 12 wells
 - Zuidwending: 9 wells à **1 kick**
 - Supervision for gas buffer Gasunie Zuidwending: 13 wells
 - Sometimes 'anhydrite floater' without any observable gas pressure
- Mariager:
 - 7 wells
- Hengelo:
 - 1 well in Haaksbergen
- Stade:
 - 10 wells (7 in brinefield Stade,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

Zechstein stratigraphy

Zechstein salt - knowledge build-up

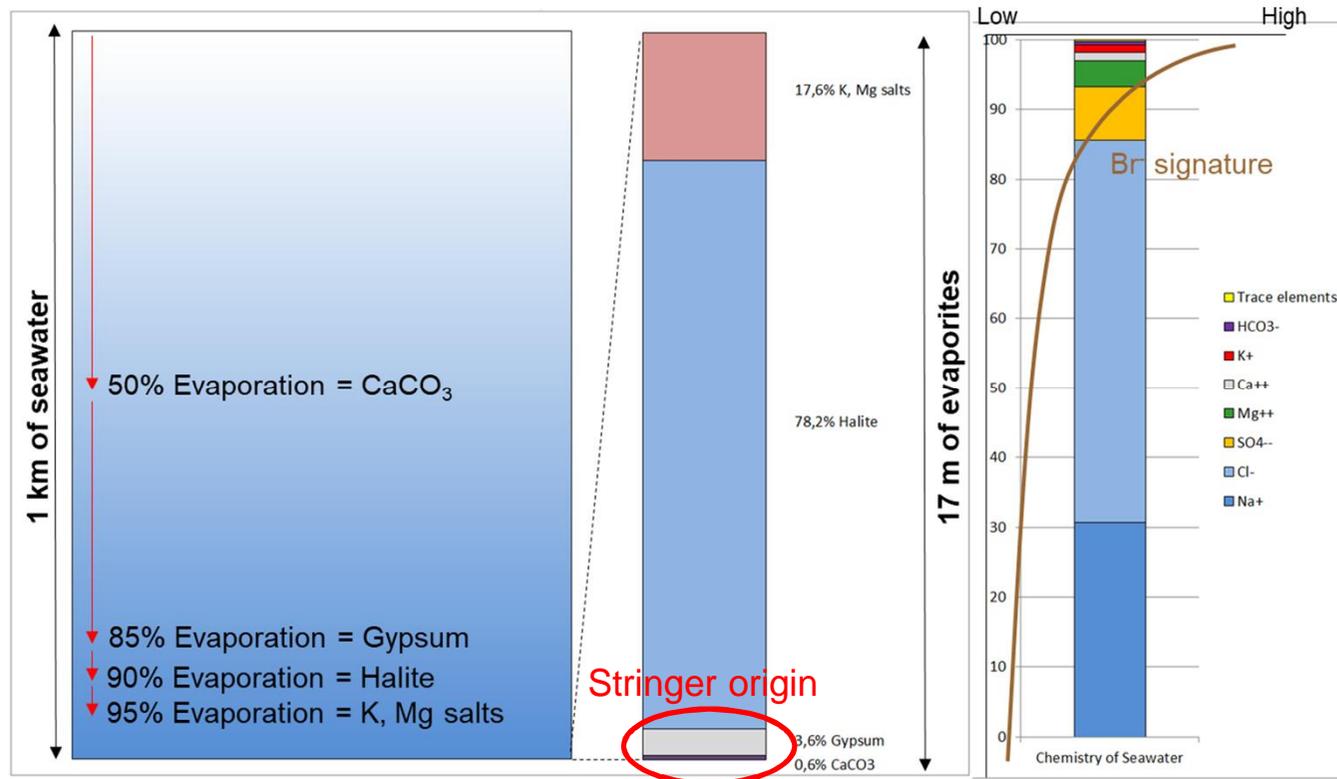
- Research bij DEEP Underground Engineering – an engineering firm providing services to the salt industry (2012-2013)
 - à Based on results new drillings for gas buffer Zuidwending
- Further study by geologist Roderick van der Kroef – University of Utrecht (2013)
 - à Based on data from existing AkzoNobel 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



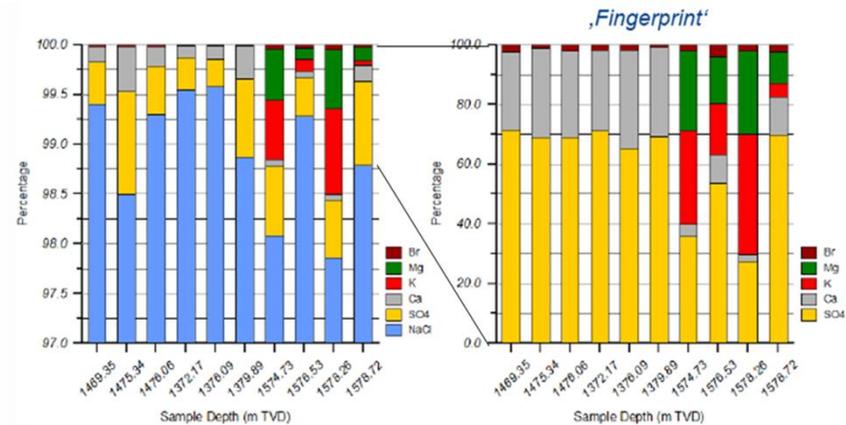
Zechstein stratigraphy - deposition

- 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

AGE	GROUP/CYCLE		OFFSHORE FORMATIONS	ONSHORE EQUIVALENTS	
LATE PERMIAN	BACTON GROUP		BUNTER SHALE FM.	SHERWOOD SANDSTONE GROUP	
	Z5/6	ESKDALE GROUP	BROCKELSCHIEFER FM.	ROXBY FORMATION	
			ZECHSTEIN LETTEN FM.		
			GRENZANHYDRIT FM.		LITTLEBECK FM.
			UNTERER OHRE FM.		SLEIGHTS FM.
			ALLER HALIT FM.		SNEATON FM.
			LEGMATTANHYDRIT FM.		UPGANG - SHERBERN FM.
	Z4	STAINTON-DALE GROUP	ROTER SALZTON FM.	CARNALLITIC MARL FM.	
			LEINE HALIT FM.	BOULBY HALITE FM.	
			LYOPTANHYDRIT FM.	BILLINGHAM FM.	
			PLATTENDOLOMIT FM.	BROTHERTON FM.	
	Z3	TEESIDE GROUP	GRAUER SALZTON FM.	FORDON EVAPORITE FM. AND SEAHAM RESIDUE	
			DECKANHYDRIT FM.		
			STASSFURT HALIT FM.		
			BASAL ANHYDRIT FM.		
	Z2	AISLABY GROUP	HAUPTDOLOMIT FM.	KIRKHAM ABBEY FM.	
			WERRAANHYDRIT FM.	HARTLEPOOL or HAYTON ANHYDRITE FM.	
ZECHSTEIN KALK FM.			CADEBY FM.		
Z1	DON GROUP	KUPPERSCHIEFER FM.	MARL SLATE FM.		
		LEMANSANDSTONE FORMATION	YELLOW SANDS		
MID-LATE PERMIAN	ROTLIEGEND GROUP		LEMANSANDSTONE FORMATION	YELLOW SANDS	

Zechstein stratigraphy - chemistry

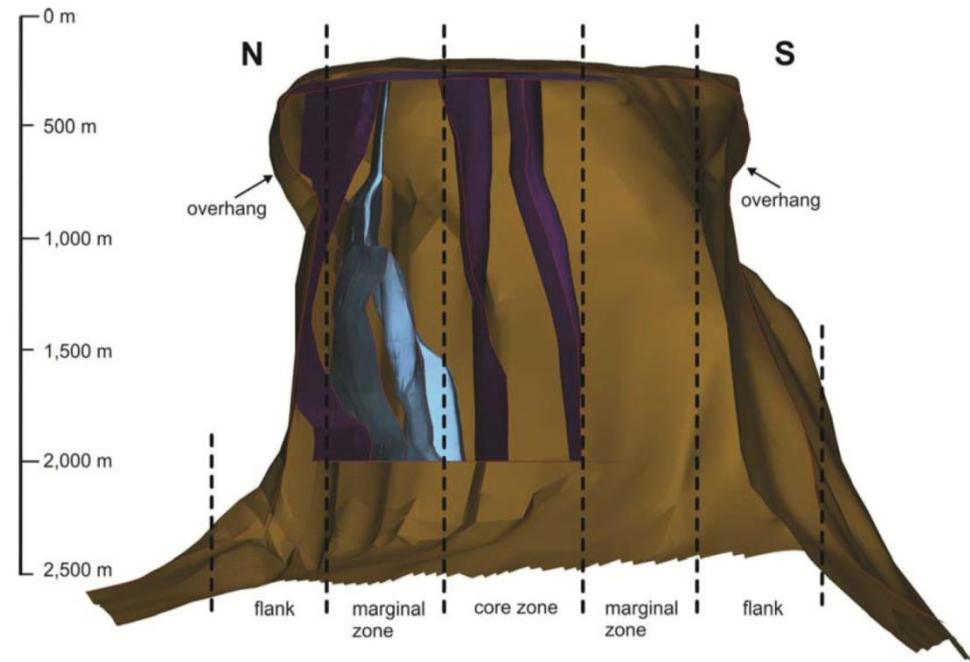
- Within salt rock in a dome: >97% salt, à the other 0.5 - 3% non-NaCl ions
- The chemical composition of the non-NaCl ions is determined by the stratigraphy
- This applies both for core-/cutting material and brine composition
- Example: lower Z3 and upper Z3 in one well



Modeling and drilling preparation

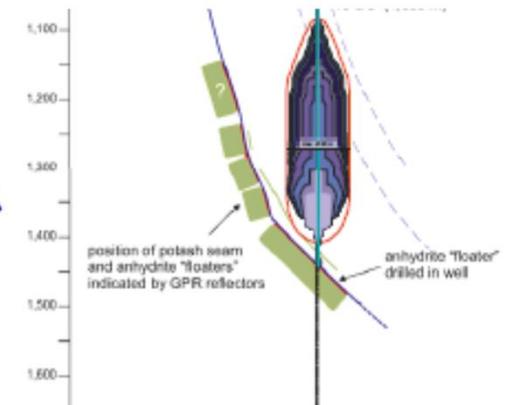
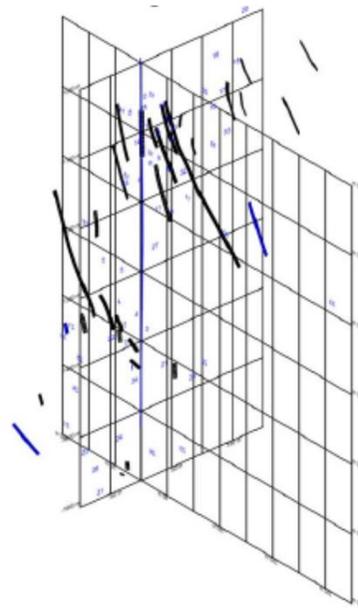
Modeling – 3D model

- 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 up to 5000 psi at wellhead



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

Thank you for your attention

Questions?