November 21st, 2024
9th Dutch Exploration Day

Return to the Zechstein Play

Unlocking its potential for wider energy applications

Aart-Peter van den Berg van Saparoea

GEODE Zechstein 2024

November 21st, 2024
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Contributors:

TNO:

- ❑ Renaud Bouroullec
- ❑ Stefan Peeters
- ❑ Jurgen Foeken
- ❑ Serge van Gessel

EBN:

- ❑ Marloes Kortekaas
- ❑ Aart-Peter van den Berg van Saparoea
- ❑ Esmée Boter
- ❑ Sibren Dieters
- ❑ Edward Wiarda
- ❑ Harald de Haan
- ❑ Liza de Groot
- ❑ Silke van Klaveren
- ❑ Daan den Hartog Jager

QA/QC panel:

- ❑ Jo Garland (Cambridge Carbonates)
- ❑ Bastiaan Jaarsma (EBN)
- ❑ Heijn van Gent (SodM)
- ❑ Allard van der Molen (Nobian)

Content

- Introduction to the GEODE platform
- Zechstein play
- Zechstein CO_2 storage potential
- Zechstein hydrogen storage potential
- ZEZ2C exploration potential

GEODE in a nutshell

November 21st, 2024
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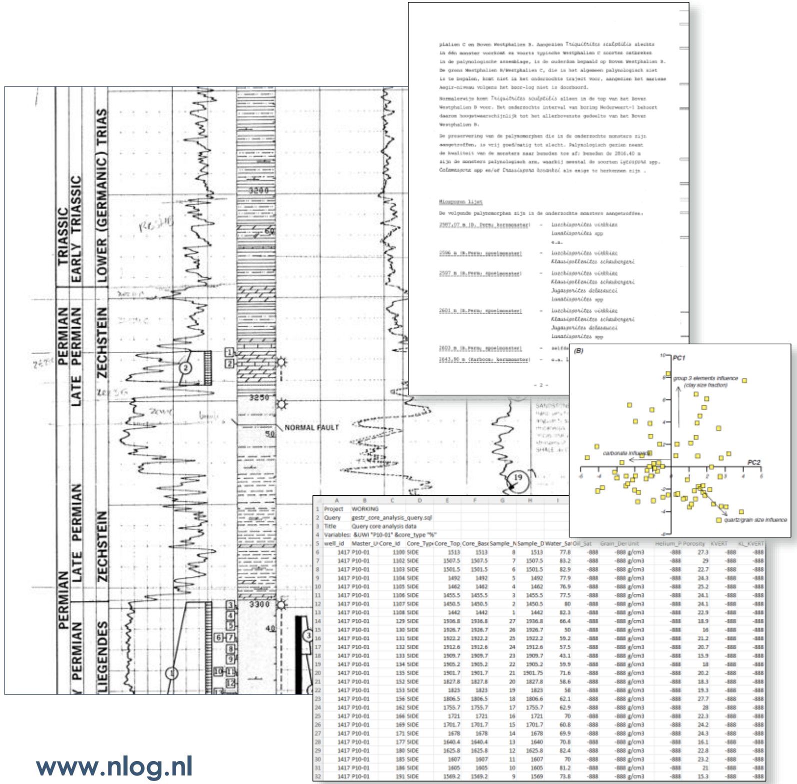
- Joint project of EBN and TNO to create an atlas of subsurface resources in the Netherlands.
- Easily accessible web-based GIS environment where **play-based exploration data and knowledge** is presented for:
  - the main **hydrocarbon** plays in NL
  - saline aquifer **CO_2 Storage** in the Dutch offshore
  - **H_2 storage** in Zechstein salt in NL
- Results of this project are made available to the public free of charge.
- Online since November 2021, yearly updates and added plays evaluations.

www.geodeatlas.nl

GEODE

From data to accessible knowledge

> 500 integrated datasets and interpretations



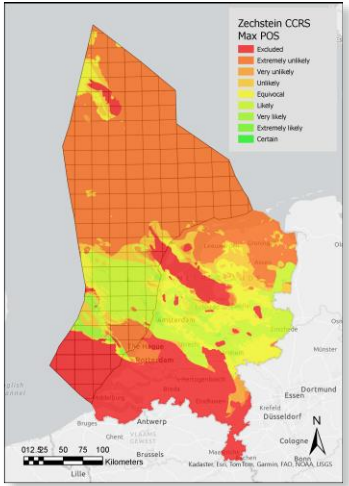
Reservoir screening information
> 280 datasets/maps

Seal assessment information
> 120 datasets/maps

Fault information
> 20 datasets/maps

Country wide **basin model**
> 80 datasets/maps

Zechstein CCRS map



Risk/chance maps
> 150 maps

Zechstein play

2024 update

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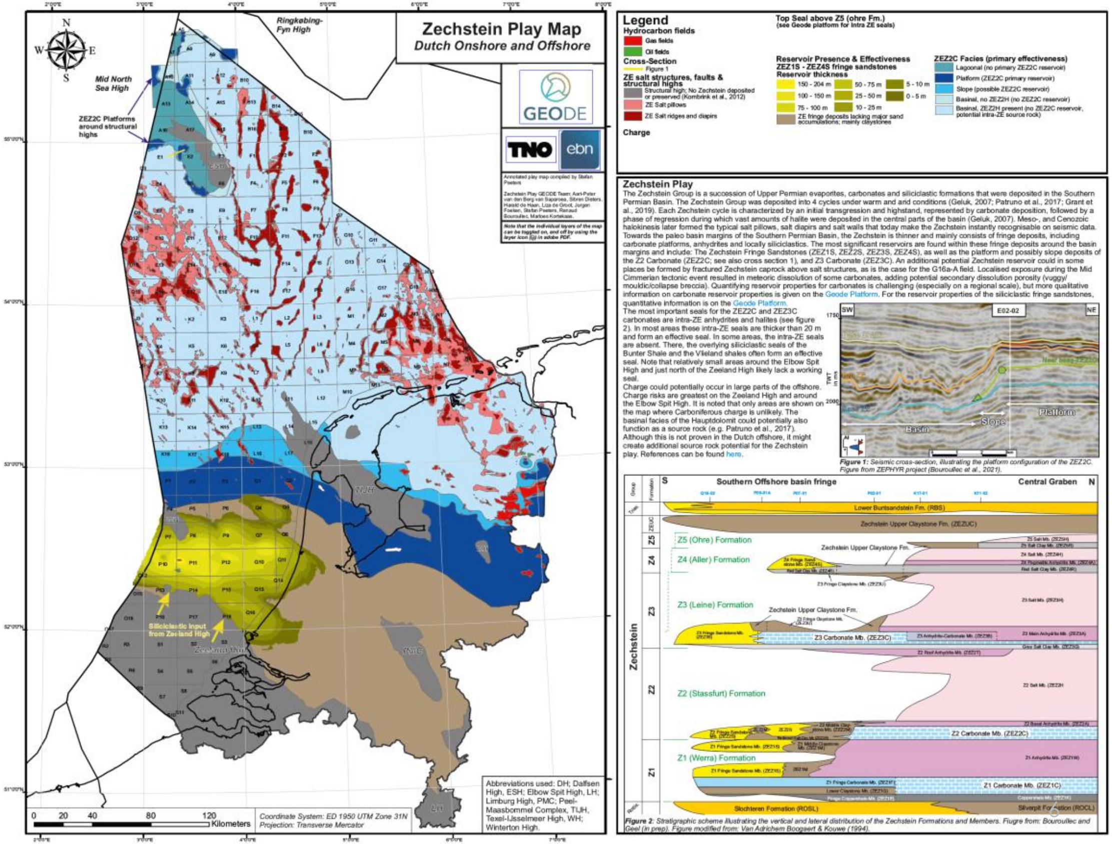
Sub-plays:

- **Zechstein Fringe Sandstones**
- **Zechstein 2 carbonates**
- **Zechstein 3 carbonates**
- **Evaporites**

New maps:

- **Reservoir quality**
- **CO_2-storage**
- **H_2-storage**
- **Onshore**

[Zechstein annotated play map](#)



CO_2 Storage in Saline Aquifers

Zechstein Fringe Sandstones

Assumption: closed aquifer

Deliverables:

- **Capacity Density (Mt/km^2)**
- **Permeability * Thickness (kh as proxy for injectivity)**

Input:

- **Pore Space Height (Thickness * Porosity)**
- **Pressure Space**
- **Compressibility of the system (Rock + Water)**
- **Density CO_2**

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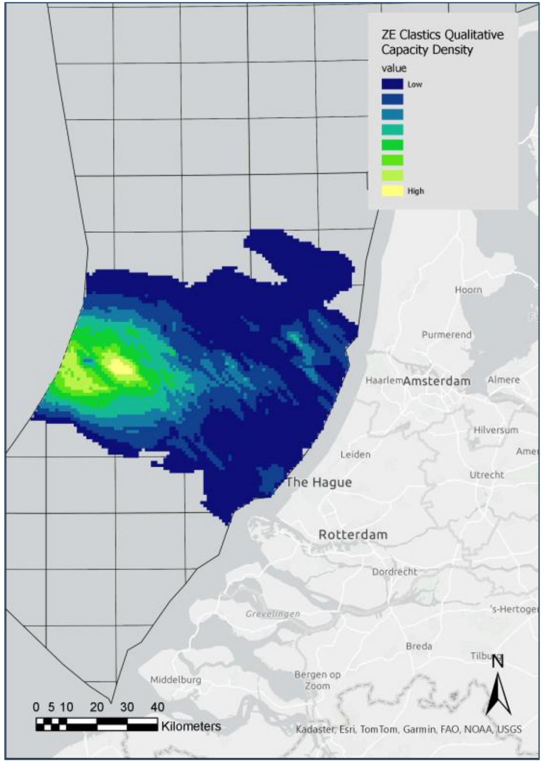
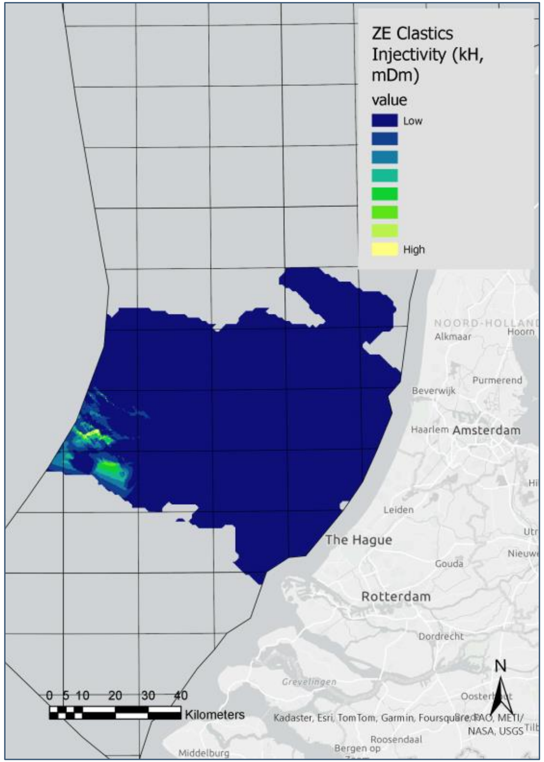
Qualitative Capacity Density



Injectivity



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CO_2 Storage in Saline Aquifers

Containment

- **Top Seal Quality**
- **Faults**
- **Legacy wells**
- **Overpressure**
- **Hydrocarbon shows**

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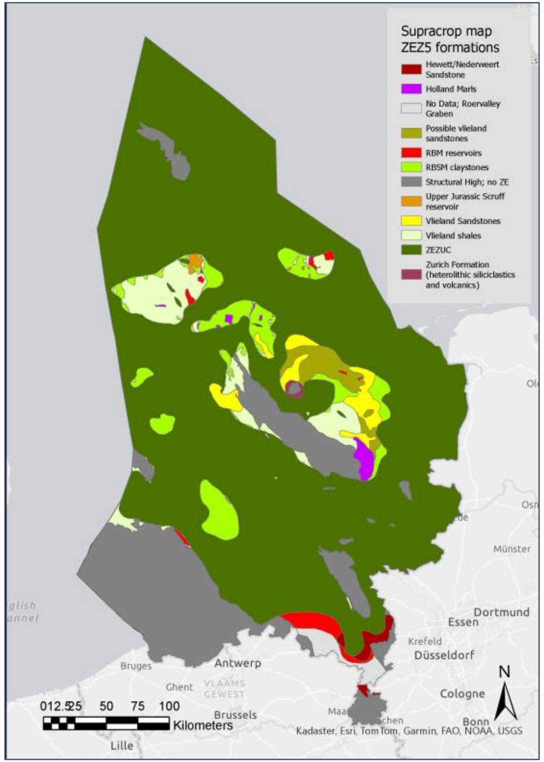
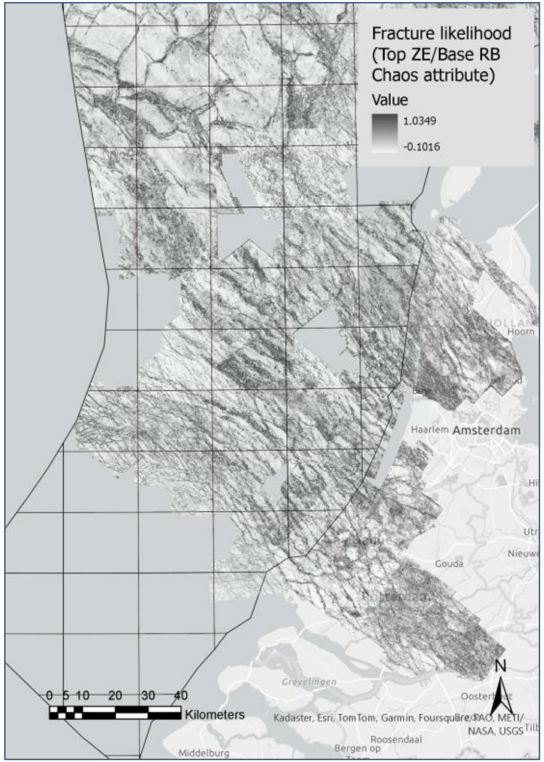
Zechstein supracrop map



Fracture likelihood (chaos attribute)



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Underground H_2 Storage in Salt Diapirs

Salt must be present:

- below 1000 m TVDSS for sufficient storage capacity (max pressure)
- above 1500 m TVDSS to prevent cavern convergence (due to salt creep)

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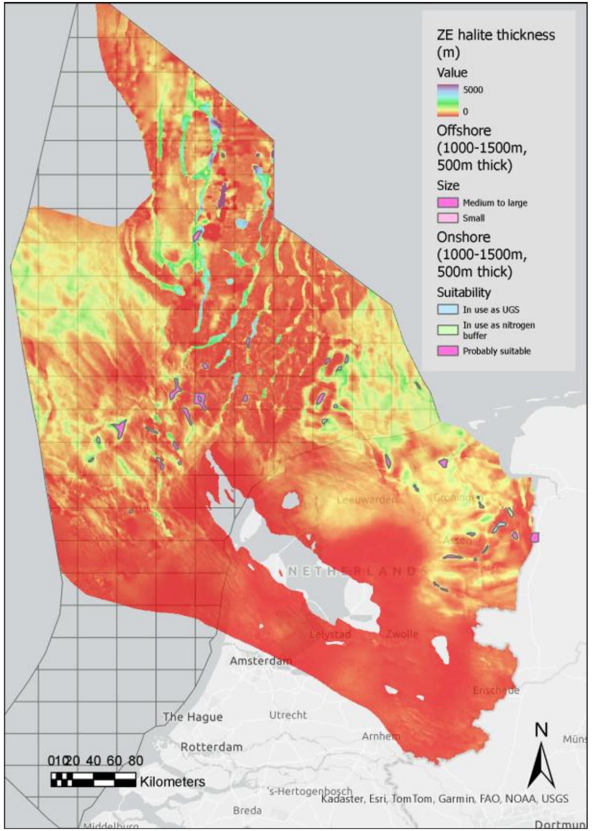
Zechstein halite thickness



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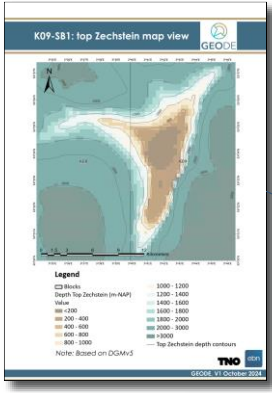
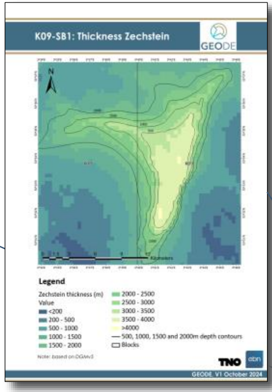
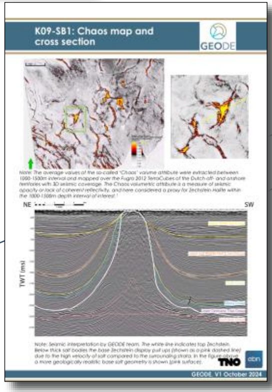
Underground H_2 Storage in Salt Diapirs

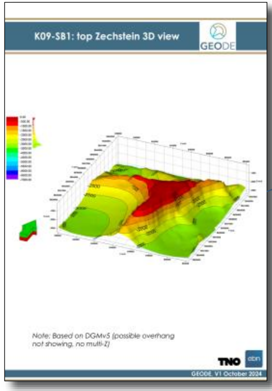
- **Screening based on geomechanical constraints; salt present between 1000 and 1500 m TVDSS**

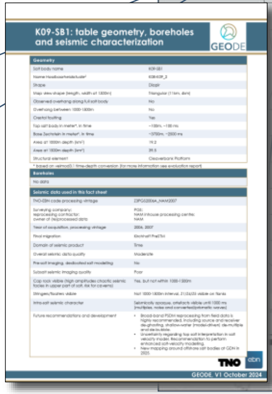
- **Fact sheets for largest suitable salt bodies**



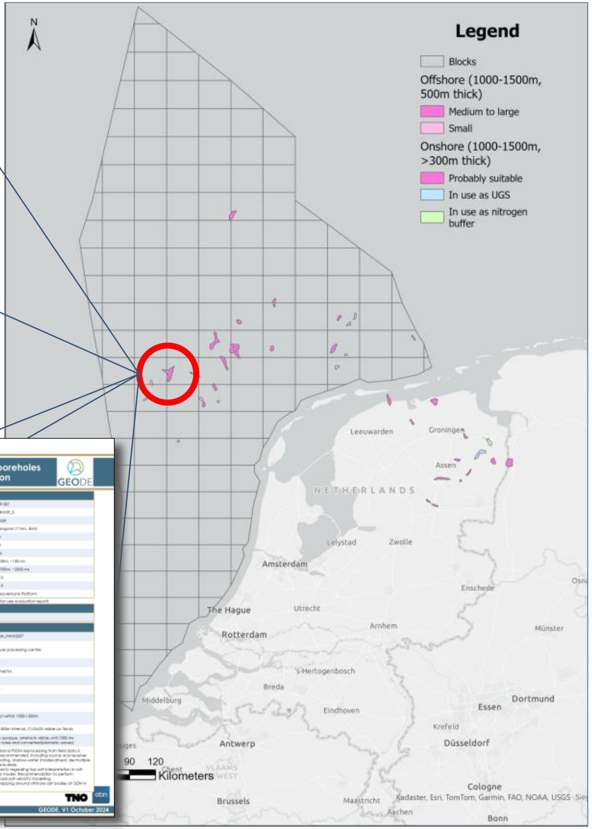








Suitable salt bodies



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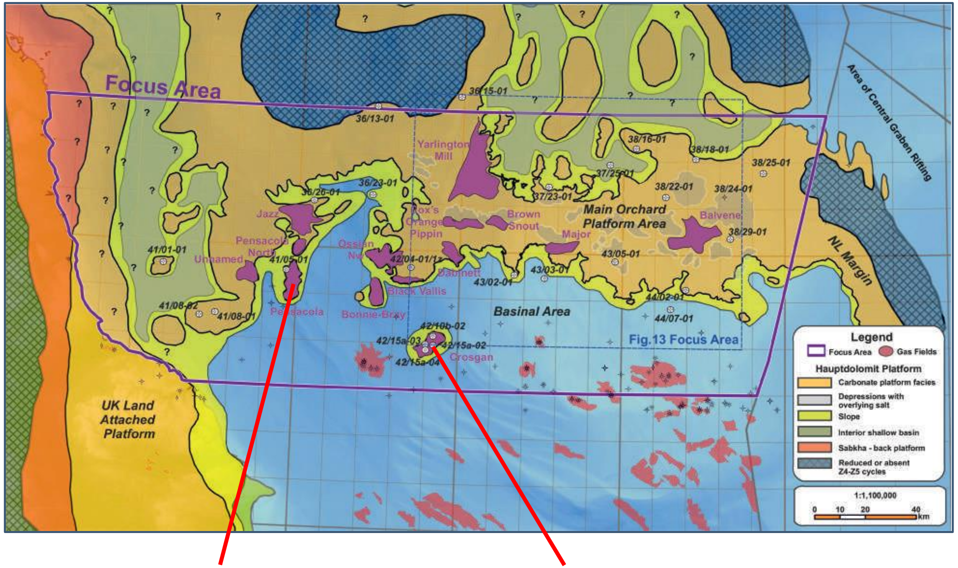
Exploration for Natural Gas

ZEZ2C sub-play

- Zechstein 2 carbonate play in the UK
- Carbonate platforms along the Mid North Sea High
- Recent exploration successes



Pensacola
8.4 BCM
recoverable

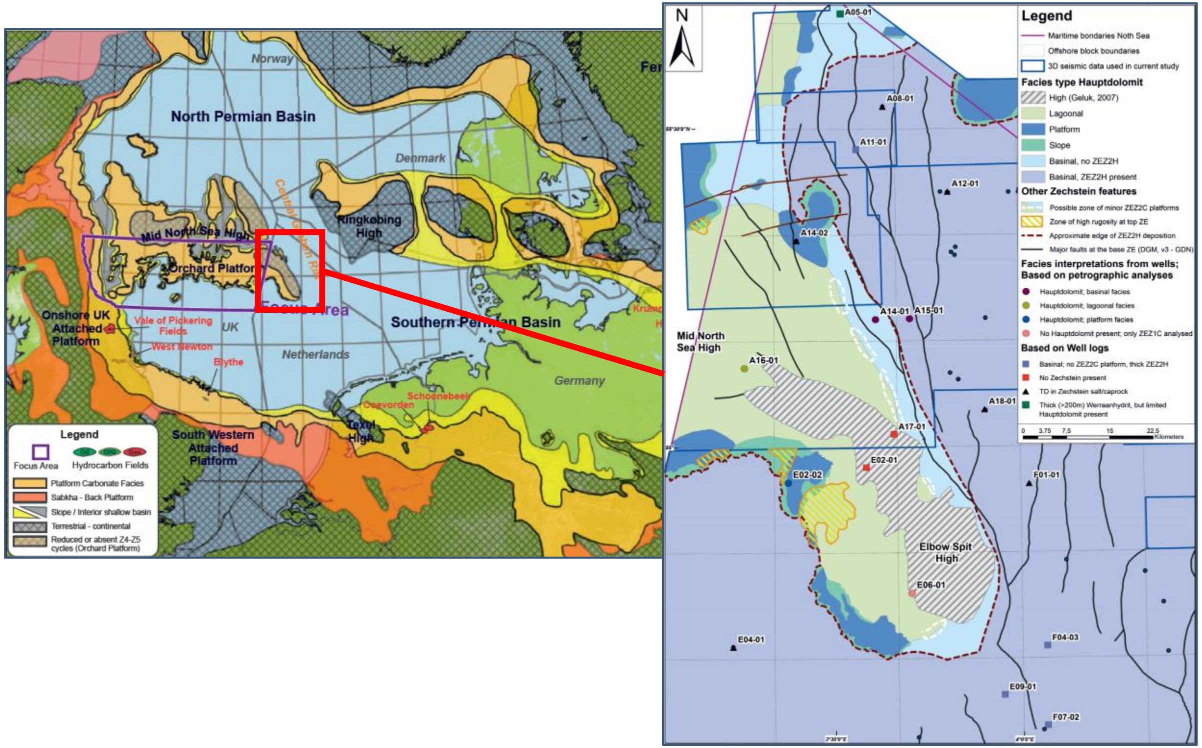
Crosgan

2023 Browing Stamp - Zechstein Z2 Hauptdolomite in UK Mid North Sea High

Exploration for Natural Gas

ZEZ2C sub-play

- **Play extends into northern Dutch offshore around the Elbow Spit High**
- **Area mapped in detail in TNO ZEPHYR study**



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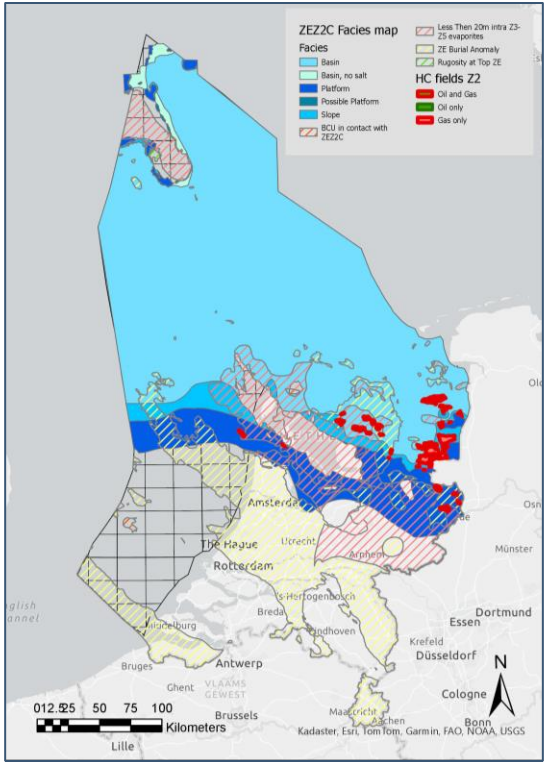
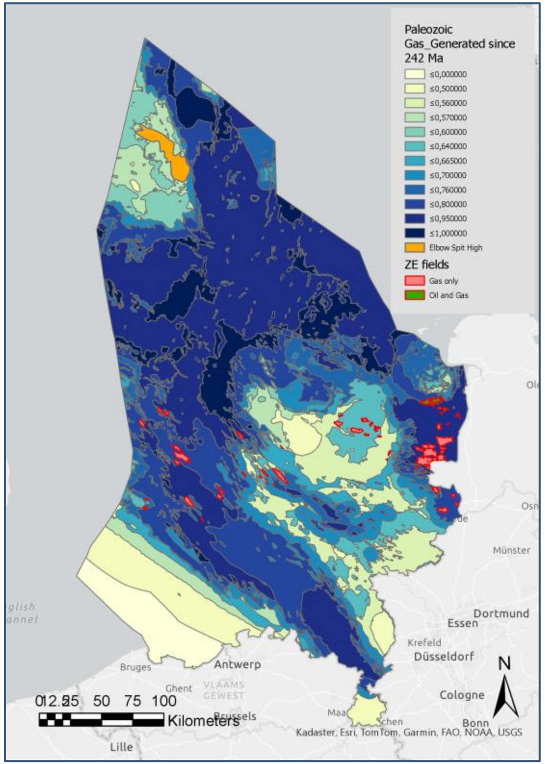
2021 Peeters et al - ZEZ2C around the Elbow Spit High

Exploration for Natural Gas ZEZ2C sub-play

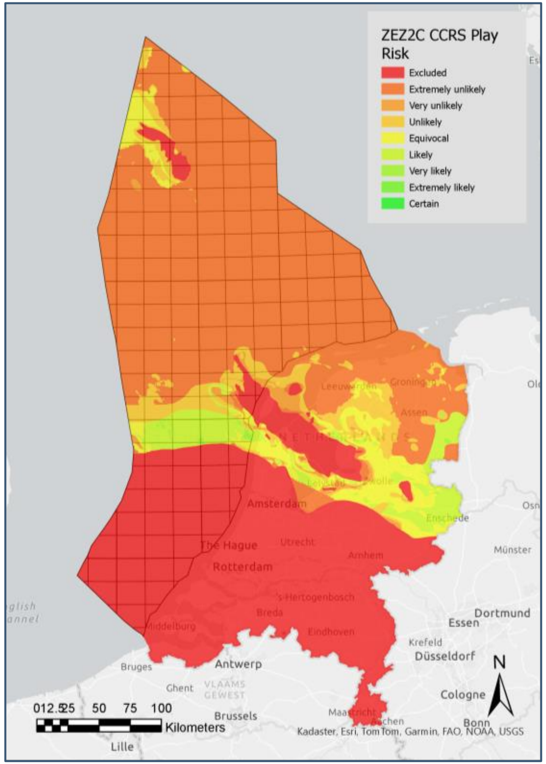
ZEZ2C facies map



Paleozoic gas generated since 242 Ma



ZEZ2C CCRS map



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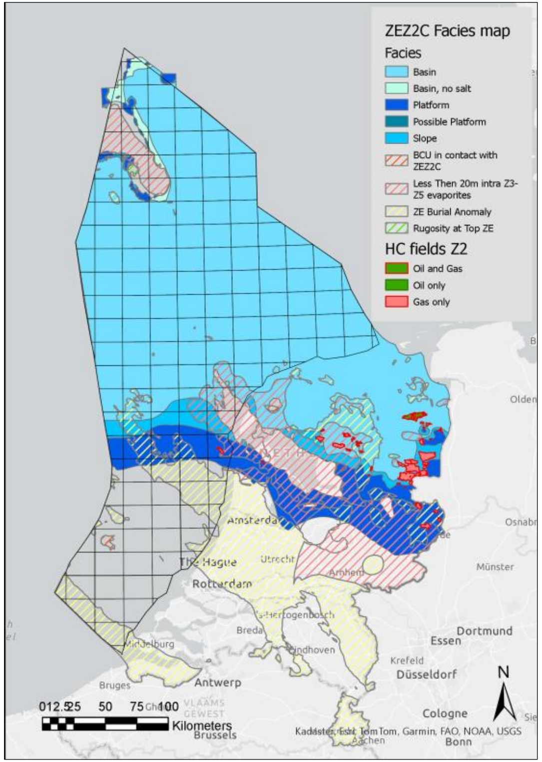
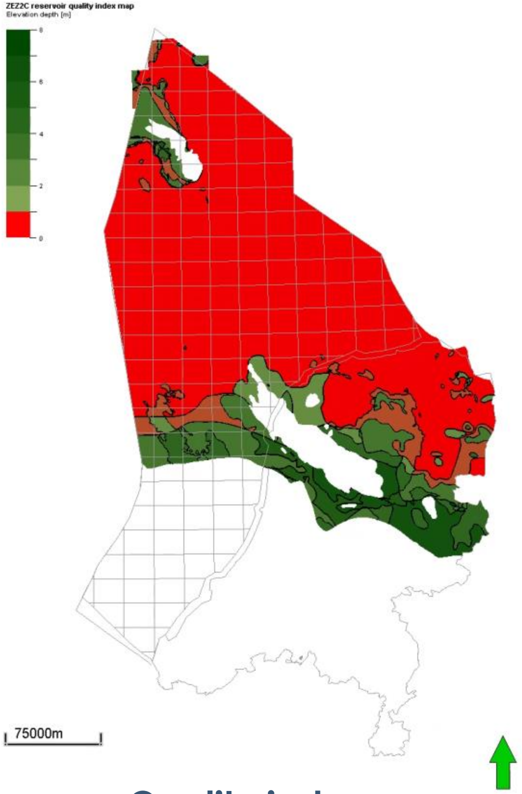
Zechstein carbonates

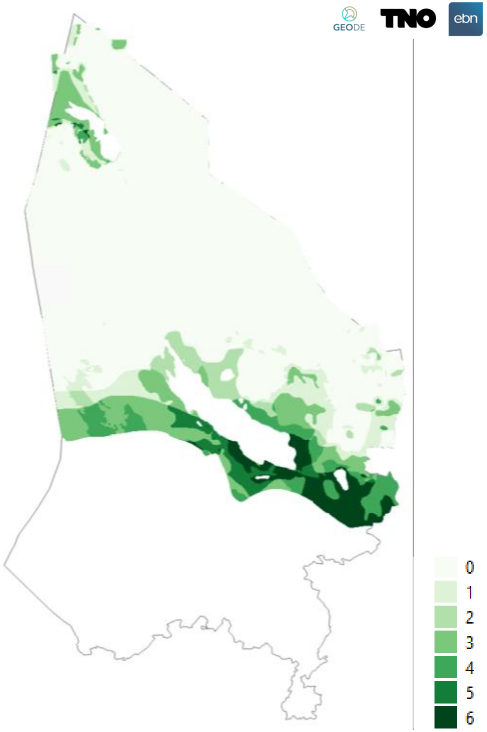
Reservoir-quality index map



Facies map



Quality index map



CRS input map

CO_2 Storage in Saline Aquifers

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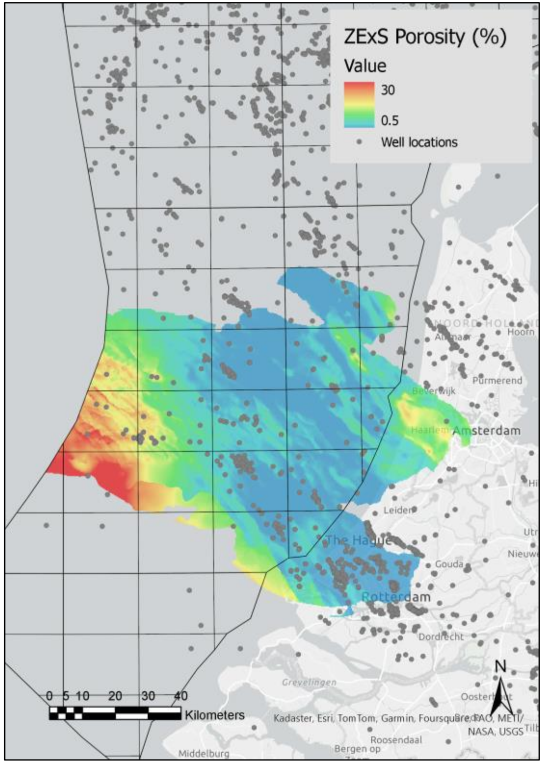
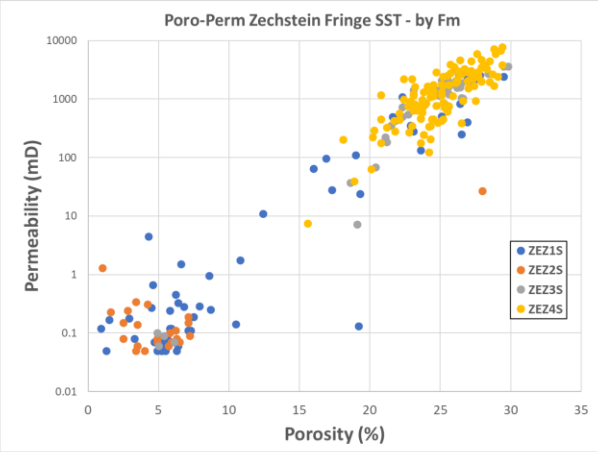
Zechstein Fringe Sandstones

- **Sparse well data**
- **Deep burial in basin center**
- **ThermoGIS workflow**





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How to calculate Capacity Density?

$Q = A \,.\, D \,.\, \Phi.\, \rho CO_2 \,.\, E_{st}$

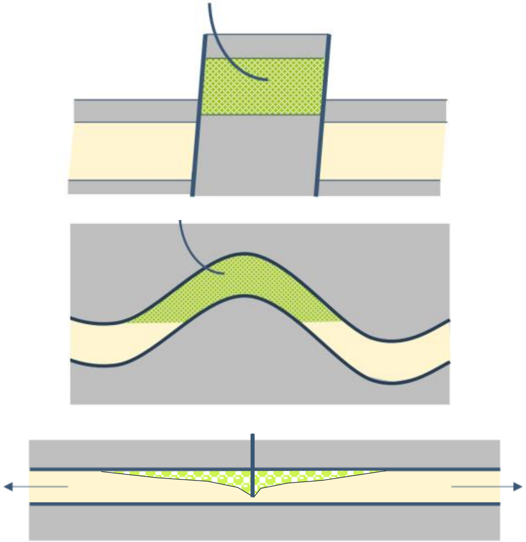
A= Area aquifer, D=thickness of good reservoir rocks, Φ=porosity, ρCO_2 density of CO_2, E_{st} = storage efficiency (<1)

(*best practice for the storage of CO_2 in saline aquifers SACS and CO2STORE projects 2007*)

- Is the aquifer Open, Semi-Closed or Closed
- **Closed** aquifer: Pressure constrained
- **Open** aquifer: Pressure can dissipate. Pore volume constrained

- **Closed aquifer**:
- $Q = A \,.\, D \,.\, \Phi.\, (Cr+Cw).\, \Delta P.\, \rho CO_2$

- **Regional** versus **local** storage efficiency
  Calculating local storage efficiency requires *dynamic modelling*



Storage Volume Calculation Closed Aquifer

$Q = A \,.\, D \,.\, \Phi.\, (Cr+Cw).\, \Delta P.\, \rho CO_2$

Q= Storage Capacity

A: Area from GEODE maps

D: Thickness from Geode maps

Φ: Porosity from Geode maps

Cr: Rock Compressibility

constant = 9.1E-5 (1/bar)

Cw: Water Compressibility

constant = 3.2E-5 (1/bar)

ΔP: Pressure Space

constant = 0.035 bar/m

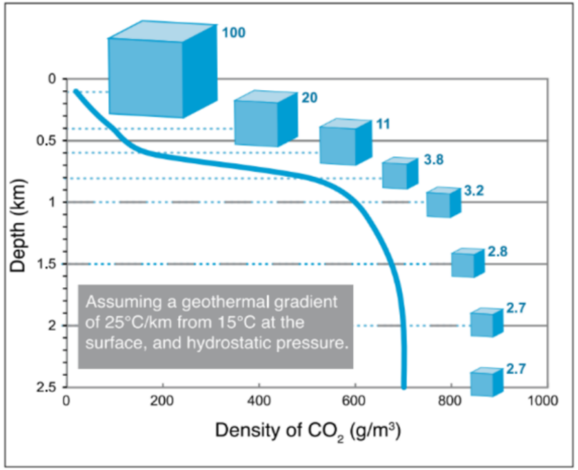
ρCO_2 :Density CO_2

constant = 700 kg/m3

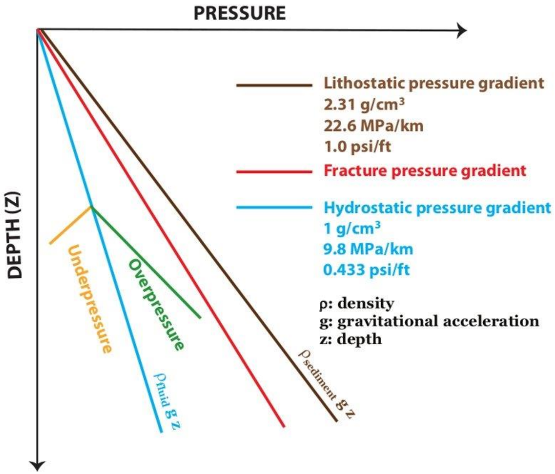
Storage Efficiency Factor

GEODE (E_{st}) = (Cr+Cw). ΔP

Depth (m)	Efficiency Factor	E_{st} (%)
1000	0.004	0.43
1500	0.006	0.65
2000	0.009	0.86
2500	0.011	1.08
3000	0.013	1.29
3500	0.015	1.51
4000	0.017	1.72

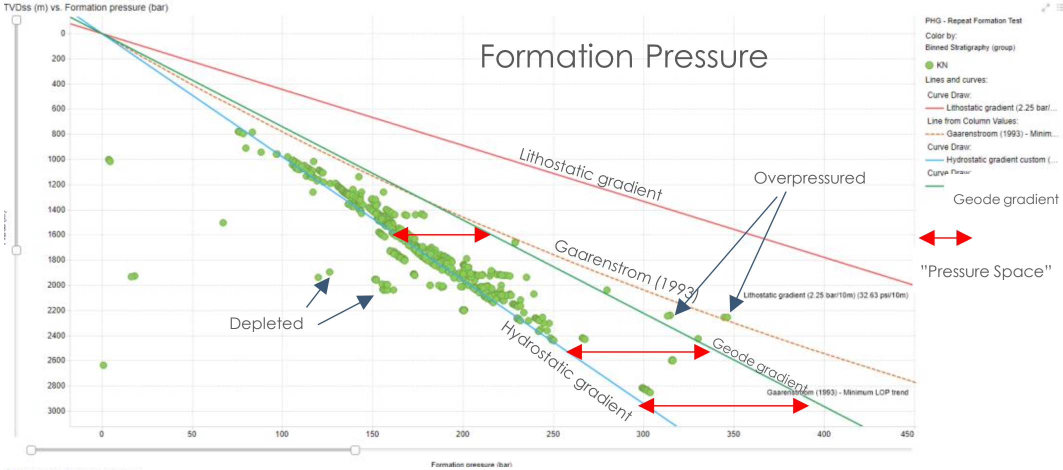


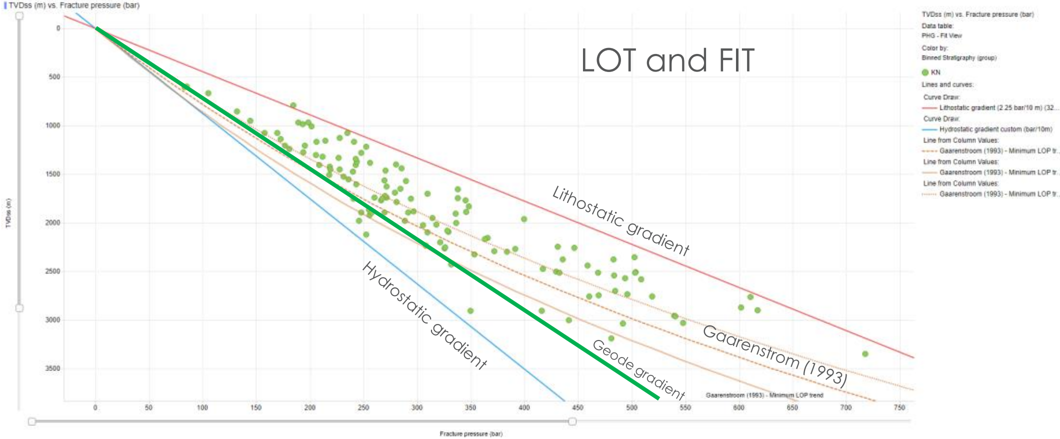
Depth vs density for CO_2. At depths greater than 800 m,
).

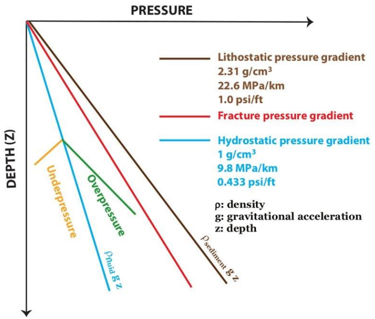


“Pressure Space” from SNS pressure database (NLOG)

- CO2 storage will increase the formation pressure
- Stay below pressures that may cause leakage or seismicity
- Indication of fracture gradient from Leak-Off tests (LOT) and Formation Integrity Tests (FIT)
- Geode Pressure Space between hydrostatic and 1.035 bar/10m
- Overpressure reduces Pressure







CO_2 Storage in Saline Aquifers

Deliverables

1. Capacity Density Zechstein Fringe Sandstones
2. Kh Zechstein Fringe sandstones (as proxy for injectivity)
3. Capacity Density x Kh Fringe Sandstone (sweet spots for CCS)
4. Hydrocarbon shows
5. Overpressure maps
6. Faults, legacy wells, Seal quality

Underground Hydrogen Storage in Salt Diapirs

Deliverables

1. Depth (Top and Base Salt map)
2. Thickness
3. Salt structure shapes
4. Temperature
5. Pressure
6. Stress field
7. Faults
8. Salt heterogeneity
9. Factsheets per salt body

Exploration for Natural Gas

Key deliverables

- Thickness
- **Porosity/permeability Fringe Sandstones**
- **Reservoir quality maps ZE2 & ZE3 Carbonates**
- GDE maps
- Post-drill Well Analysis
- **CRS and CCRS maps**

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