The Triassic hydrocarbon potential of the northern Dutch offshore -

The over-looked upside

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PGK presentation

The Hague, 19 September 2018

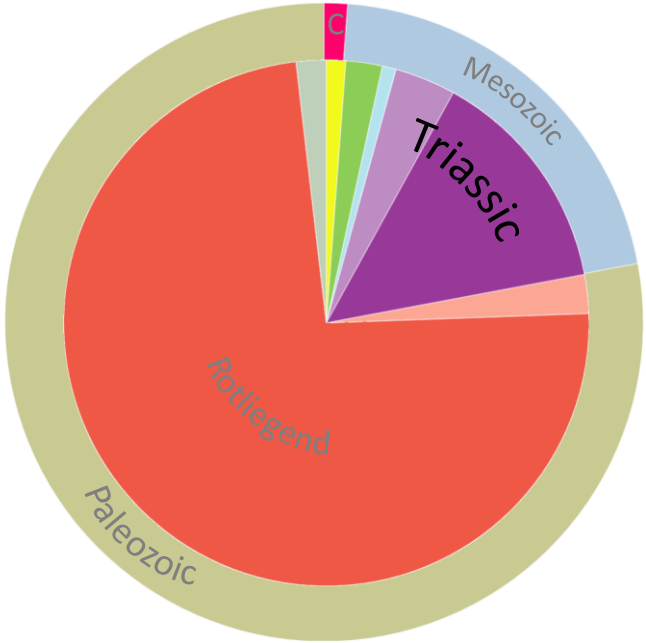
Presentation outline

- **Introduction and setting**

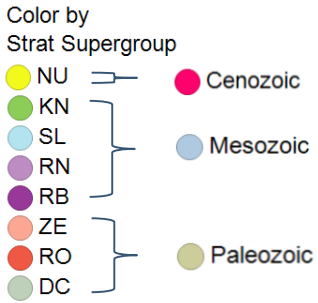
- **New and forgotten concepts**:
  - Reservoir: depositional environment and provenance
  - Source Rocks: presence
  - HC migration: Zechstein and Tertiary dykes
  - Seal: presence and overpressures

- **Conclusions**

Setting: Triassic play in the Netherlands



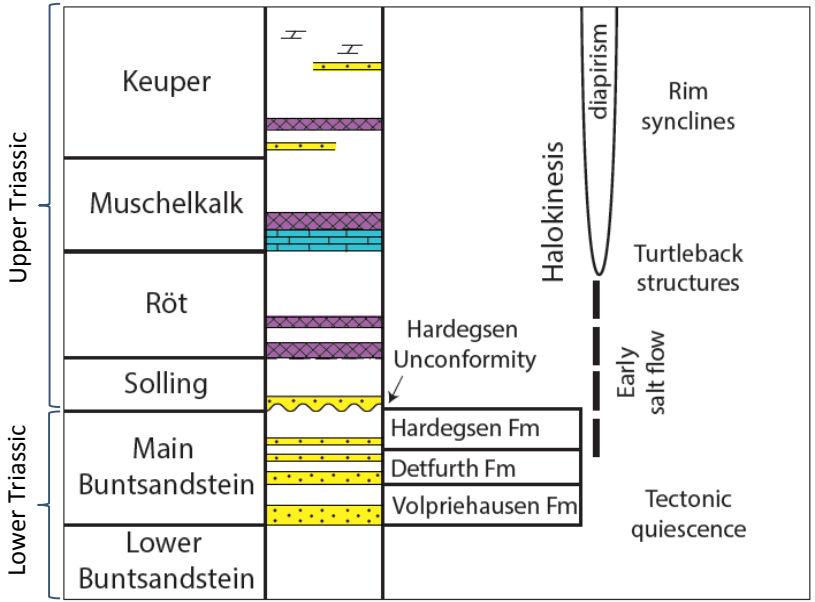
Ultimate Gas Recovery
Excluding Groningen Field



Triassic second-most prolific hydrocarbon play after the Permian Rotliegend play.

121 discovered Triassic fields in the Netherlands (115 gasfields and 6 oilfields).

Setting: Triassic play in the Netherlands



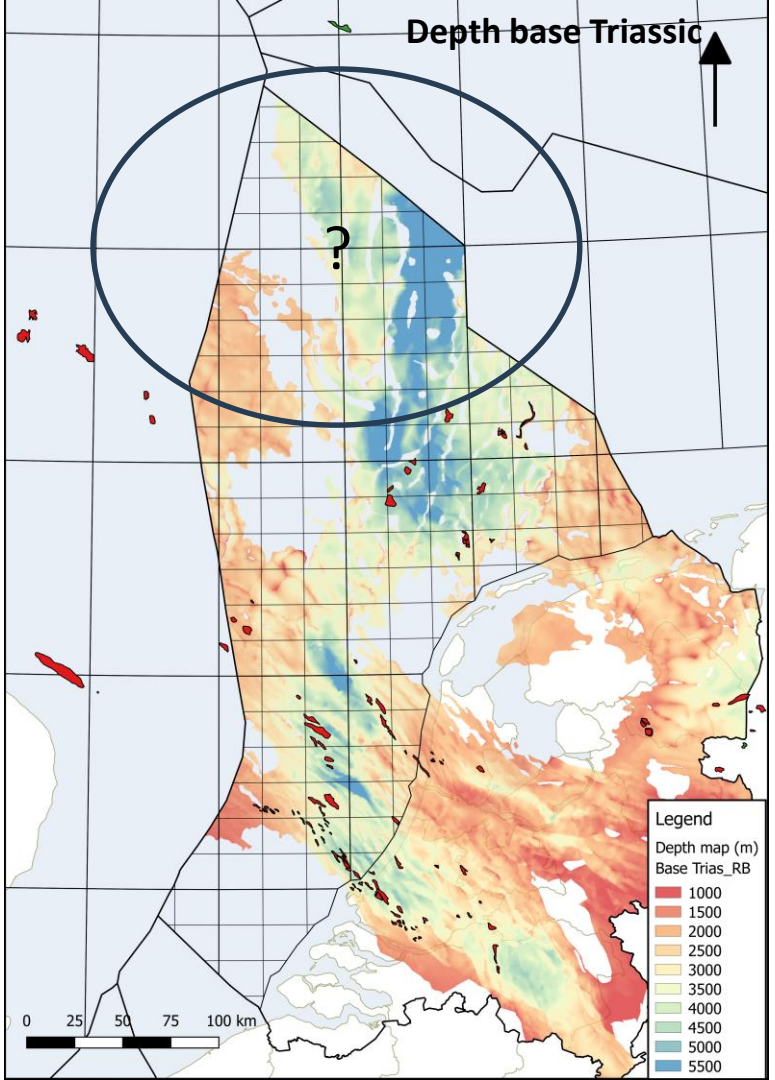
Play Element	
Source Rocks	Carboniferous coals, Toarcian shales
Reservoir	Sandstones, locally oolites, carbonates
Seal	Röt salt, anhydrite, Lower Cretaceous claystones

Setting

Established hydrocarbon play in the Southern North Sea.

Regionally widespread aeolian and fluvial sediments of the Lower Volpriehausen and Lower Detfurth Sandstones form the primary reservoir.

Currently no Triassic discoveries in northern Dutch offshore.

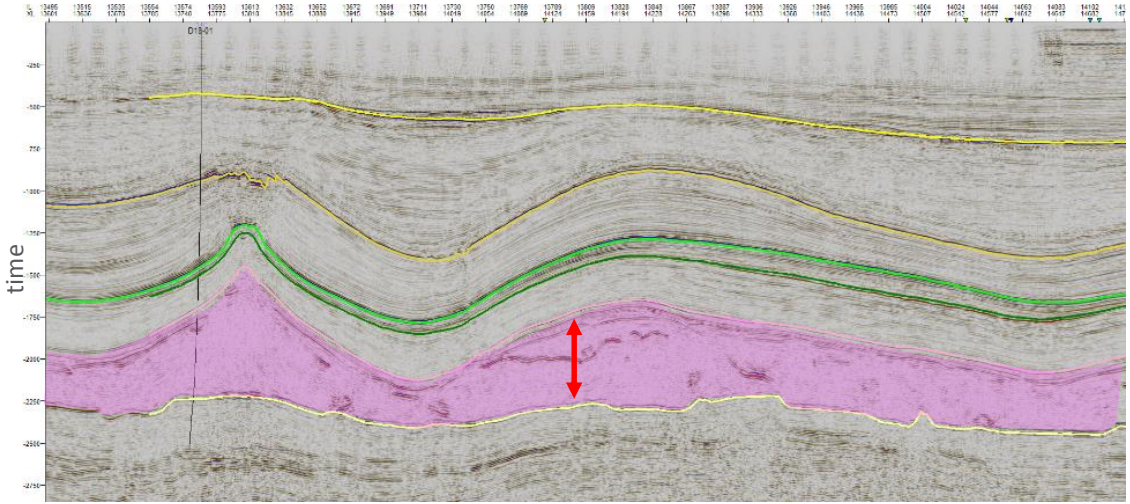


Setting

Currently no Triassic discoveries in northern Dutch offshore.

General perception:

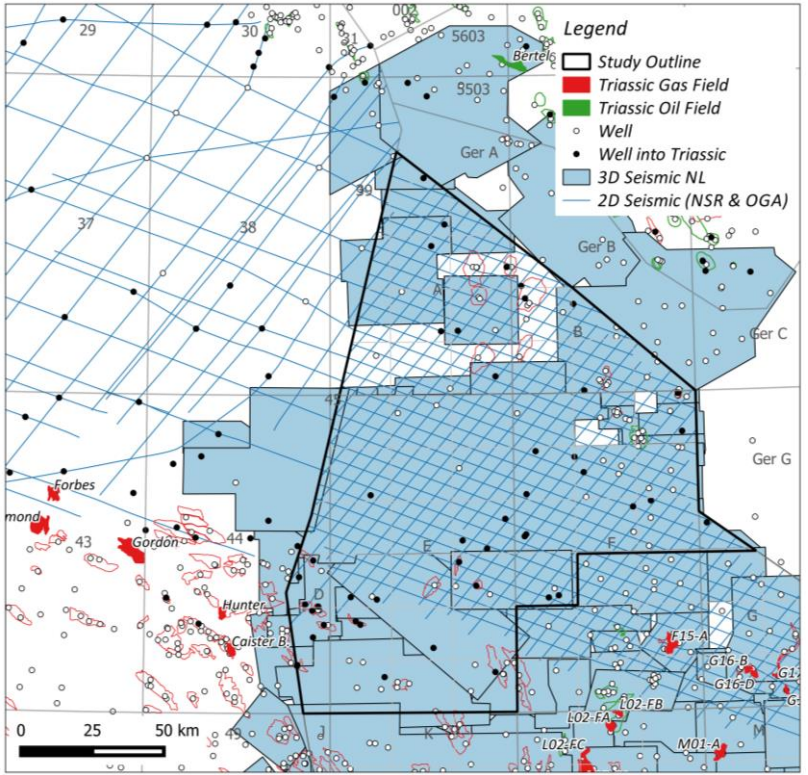
- Thinning/shaling out of sst packages towards north
- Thick ZE prevents HC migration
- Limited HC source rocks present



Only 20 wells have been drilled in the study area (17000 km^2) targeting Triassic reservoir rocks (11 of these wells invalid tests).

Data availability

- Regional geology of 5 countries area: indications for local sediment provenance (DK)
- Data available at time of study: seismic surveys (DEF, NSR lines), UK OGA lines and wells
- Quality of seismic data is variable



Triassic play element

Reservoir presence

Source rock

HC migration

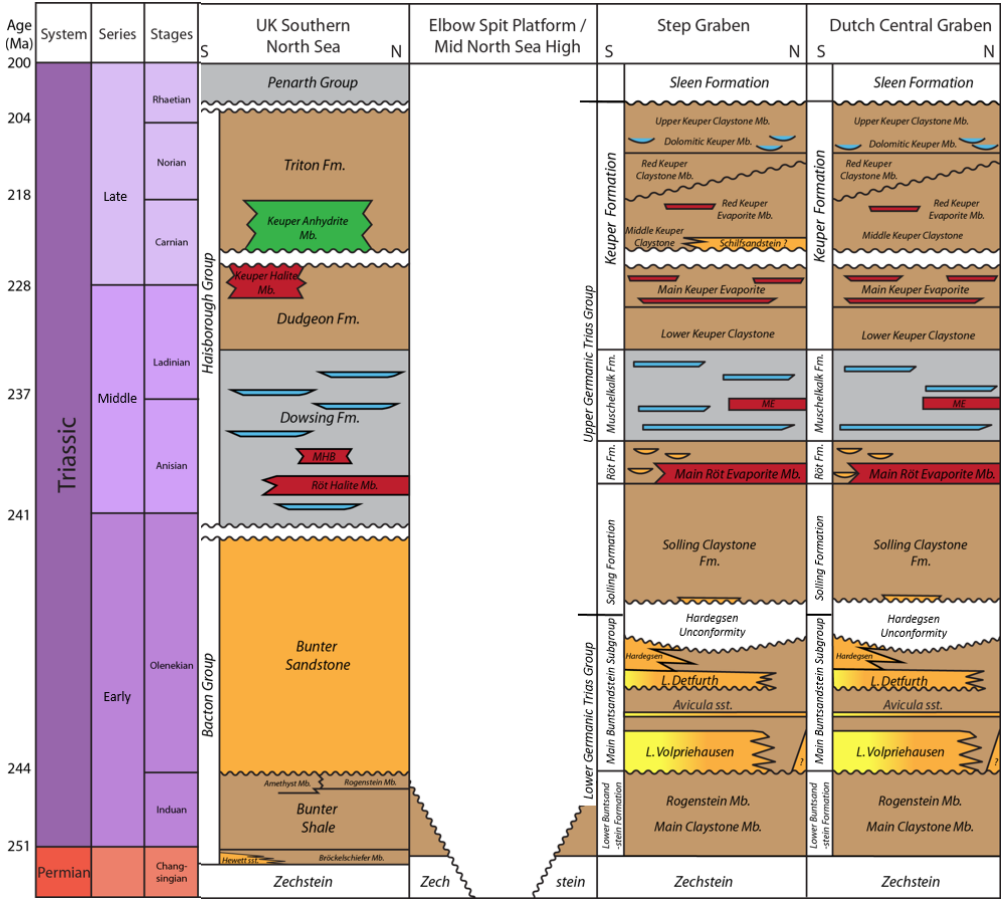
Seal

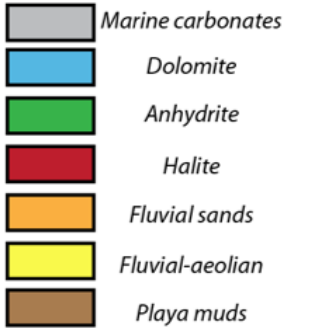
Reservoir presence

General perception: Thinning/shaling out of sst packages towards the North

EBN: Potential for local depocentres in northern Dutch offshore

Stratigraphic subdivision of the Triassic





ME = Middle Muschelkalk Marl and Muschelkalk Evaporite Member

MHB = Muschelkalk Halite Mb.

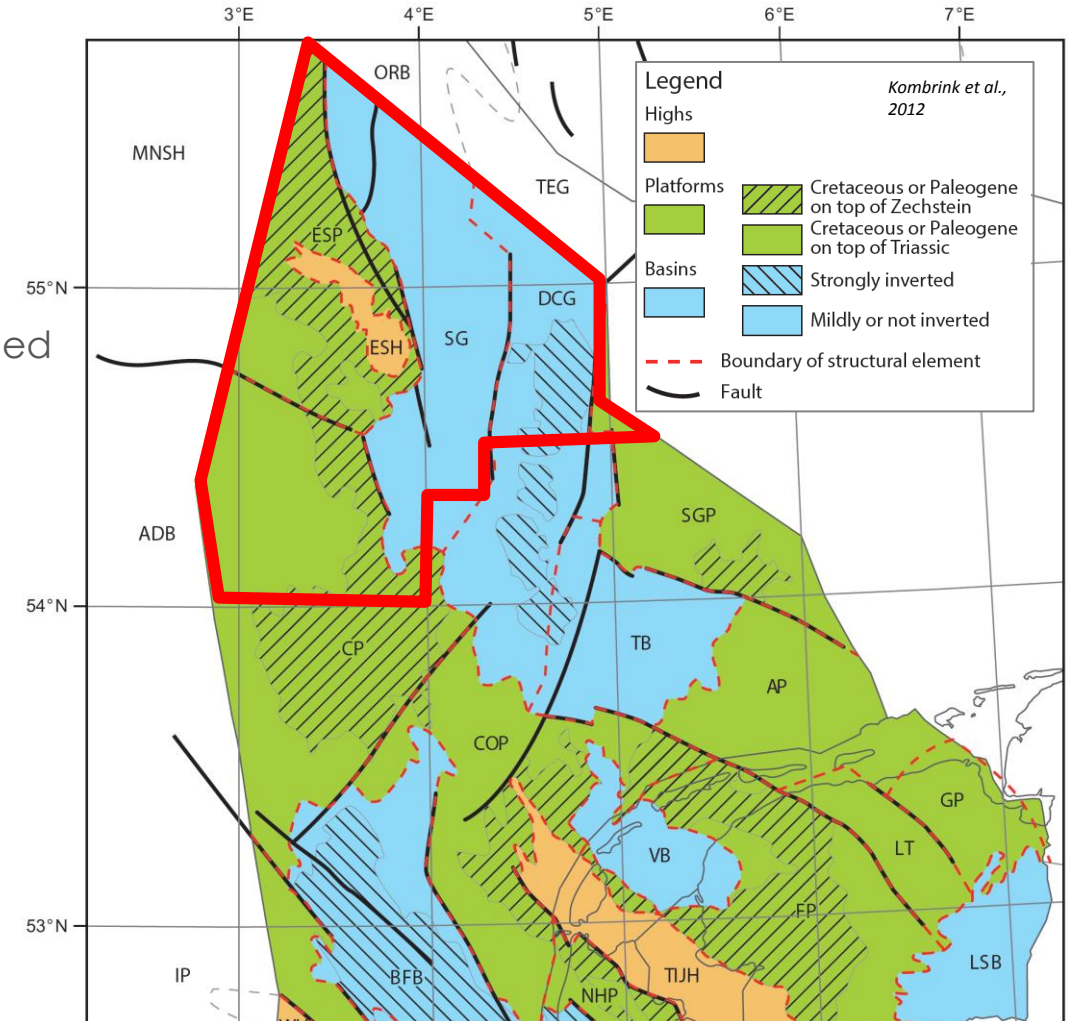
Main Buntsandstein Subgroup (MBU)

Adjusted from: van der Kooij, 2016

Structural setting

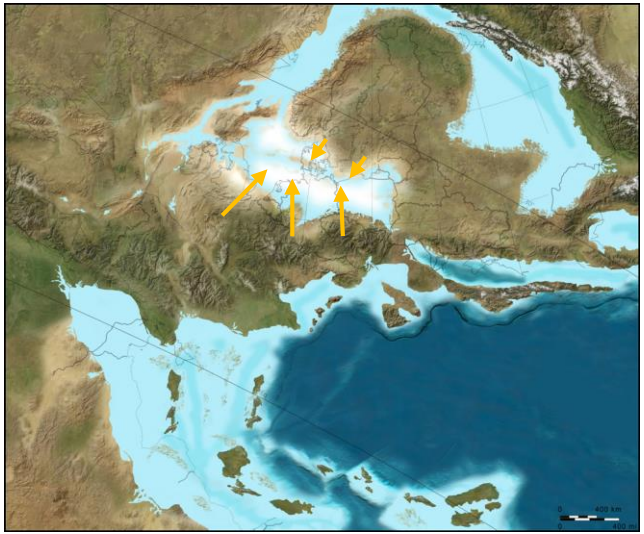
Elbow Spit Platform
Elbow Spit High
Cleaver Bank Platform
} Triassic (partly) eroded

Step Graben
Dutch Central Graben
} Triassic present



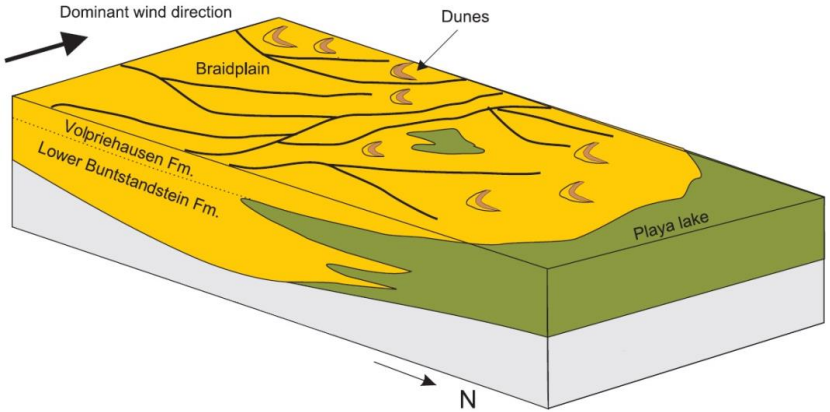
Kombrink et al., 2012

Early Triassic paleogeography – hot arid plains



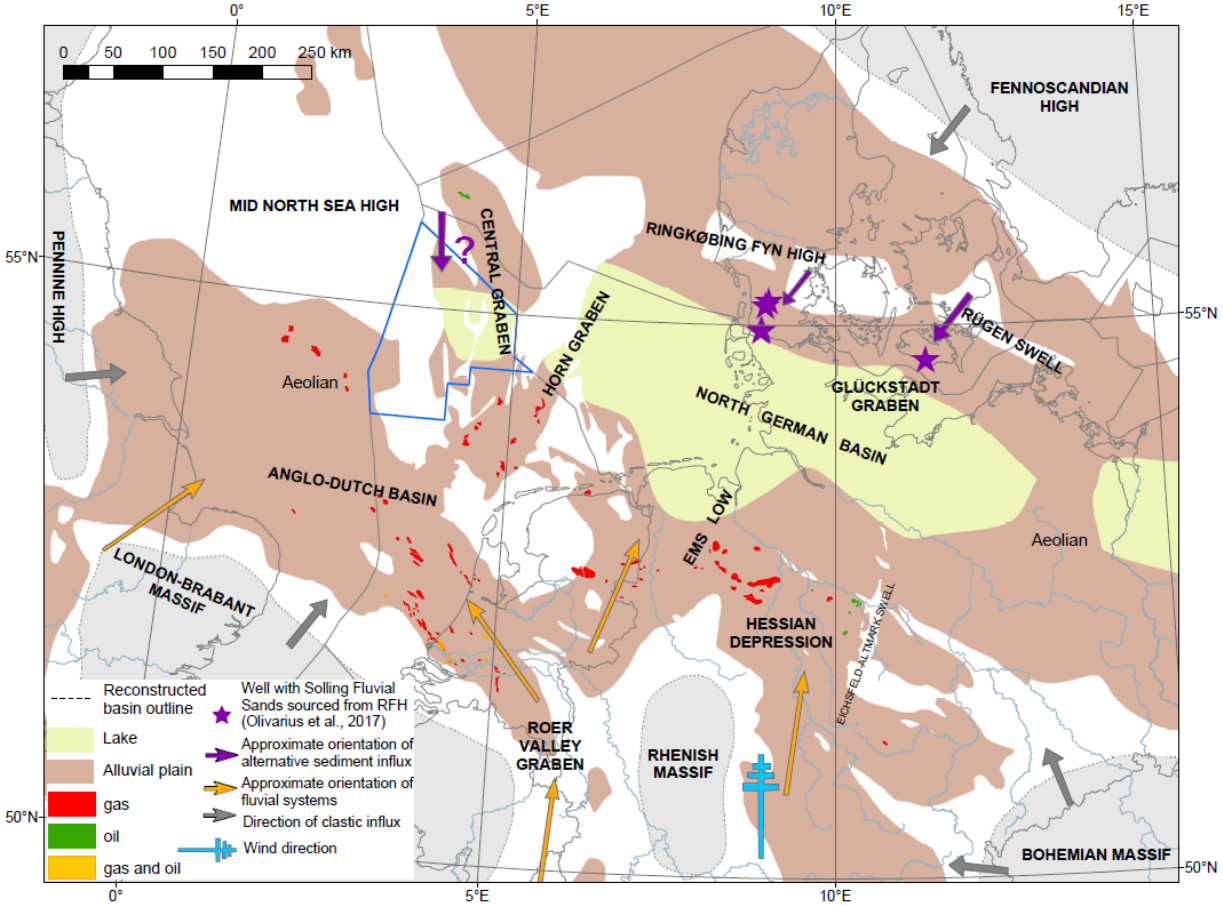
Early Triassic paleogeographic reconstruction

Lake Eyre, Central Australia



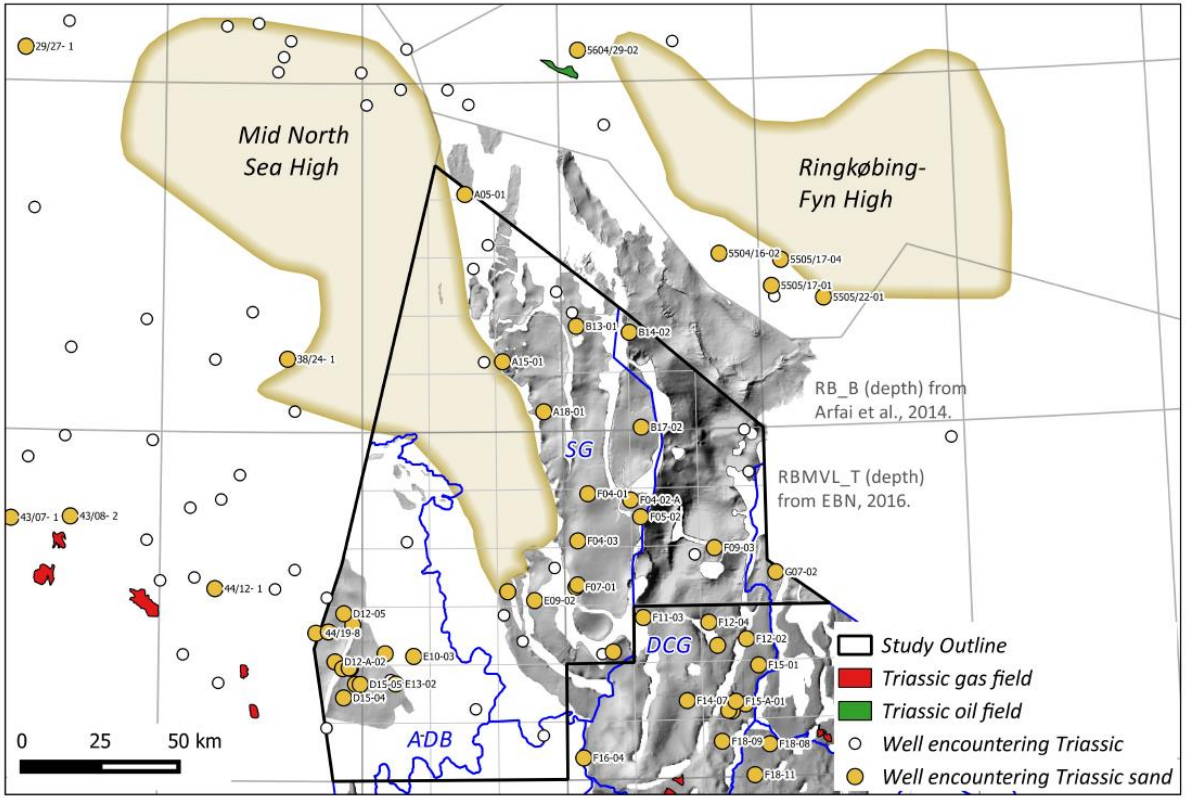
Wong et al. (eds), 2007
Zwan and Spaak, 1992
http://www.cpgeosystems.com/250_P_Trias_EurMap_sm.jpg

Reservoir – local provenance?



Adjusted from Southern Permian Basin Atlas

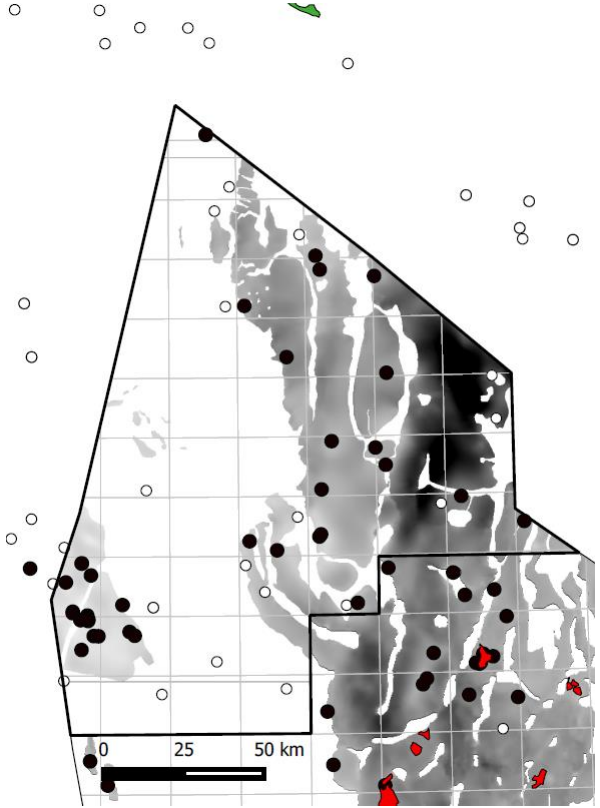
Northern Early Triassic sands: local provenance?



Top Lower Volpriehausen Sst Member depth map in study area.

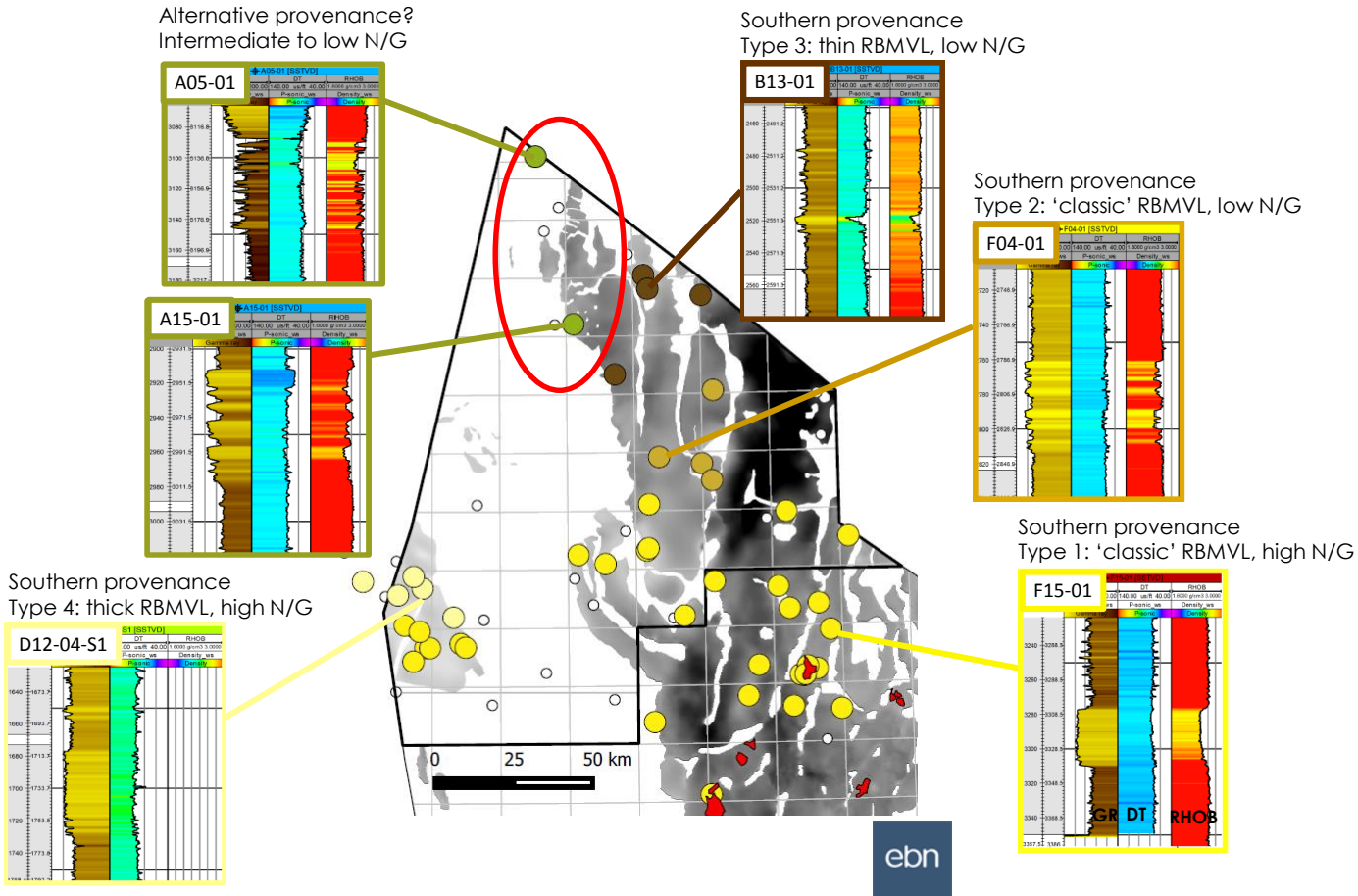
Structural elements in blue (SG: Step Graben, DCG: Dutch Central Graben, ADB: Anglo-Dutch Basin) (Kombrink et al., 2012).

Study of Lower Volpriehausen sst logs



Typical well log response of Lower Volpriehausen sst.

Local reservoir provenance?

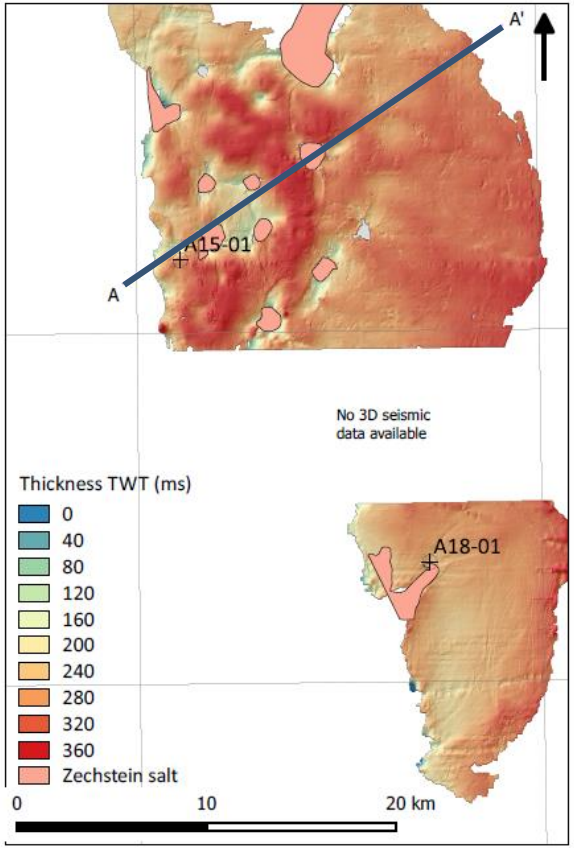


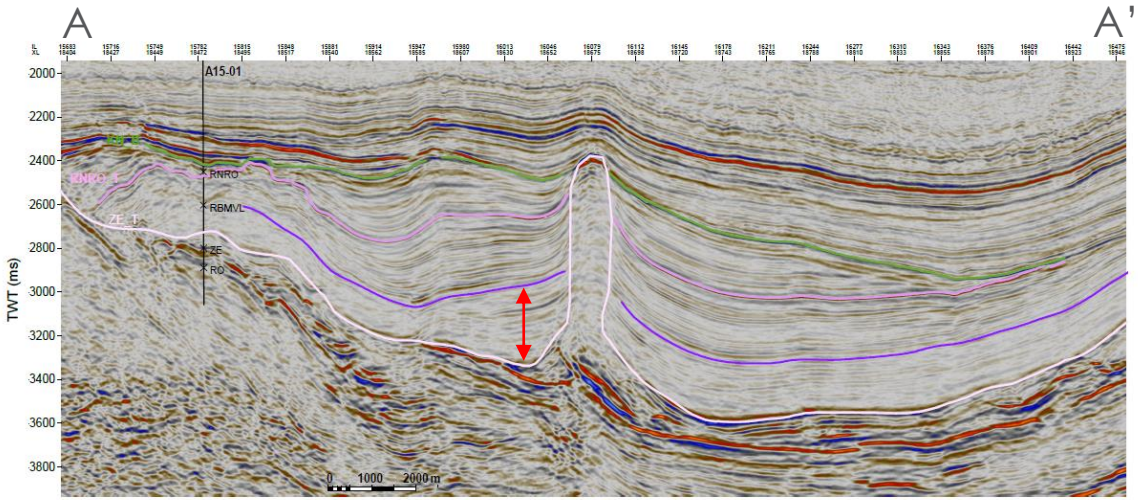
MBU reservoir rocks are present in most of the study area

Abundance and thickness of Lower Volpriehausen Sst. decrease from south to north.

Fluvial sands with local/alternative provenance may have developed as reservoir in the northwestern area.

Early Triassic thickening: depocenter at A15-01





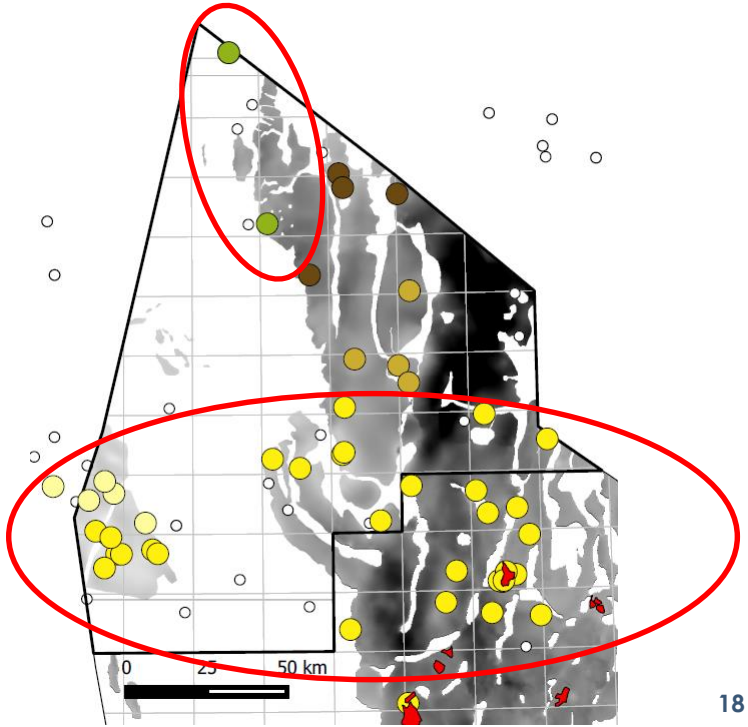
van der Kooij, MSc-thesis 2016

Reservoir presence

General perception: Thinning/shaling out of sst packages towards north

EBN:

- Potential for local depocentres and local provenance in Step Graben area
- ‘Classical’ southern provenance present in southern part of study area



Triassic play element

Reservoir presence

Source rock

HC migration

Seal

Source rocks

General perception: Limited HC source rocks present in northern Dutch offshore

EBN: Recent studies show potential presence and maturity of several source rock intervals in the northern Dutch offshore.

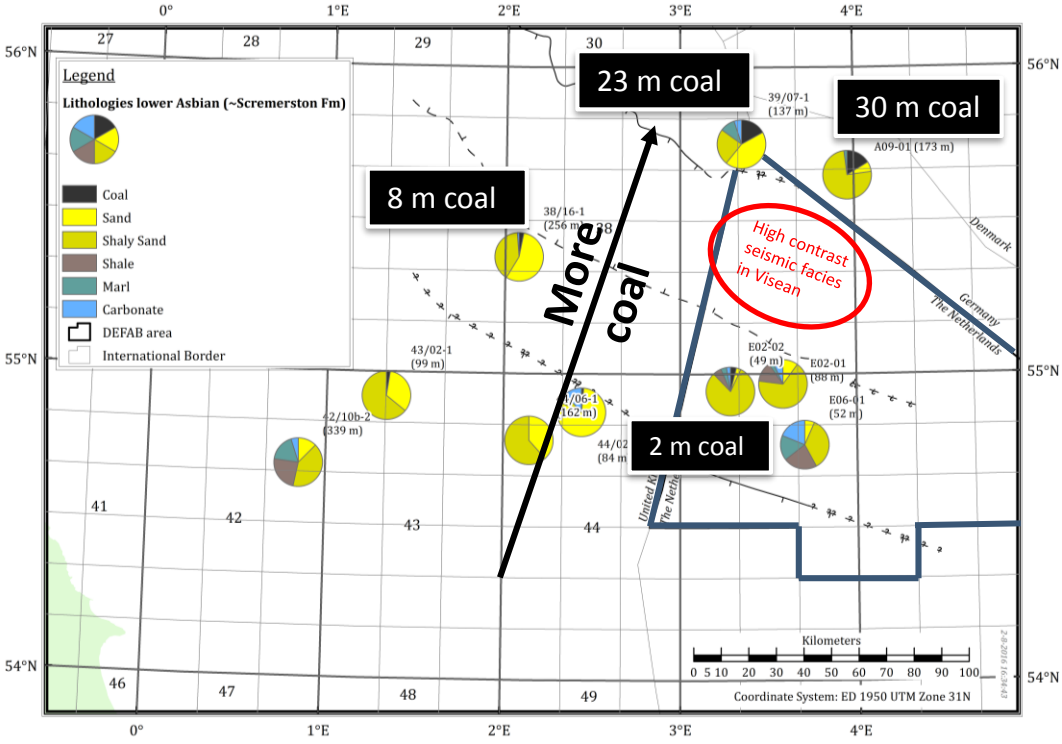
Source rocks in the study area

Coals

- N-ward increase in coal content in **Scremerston Fm**.
- Yoredale Fm and Namurian (**Epen Fm**) also contain coal; up to 7.5 m encountered in wells.

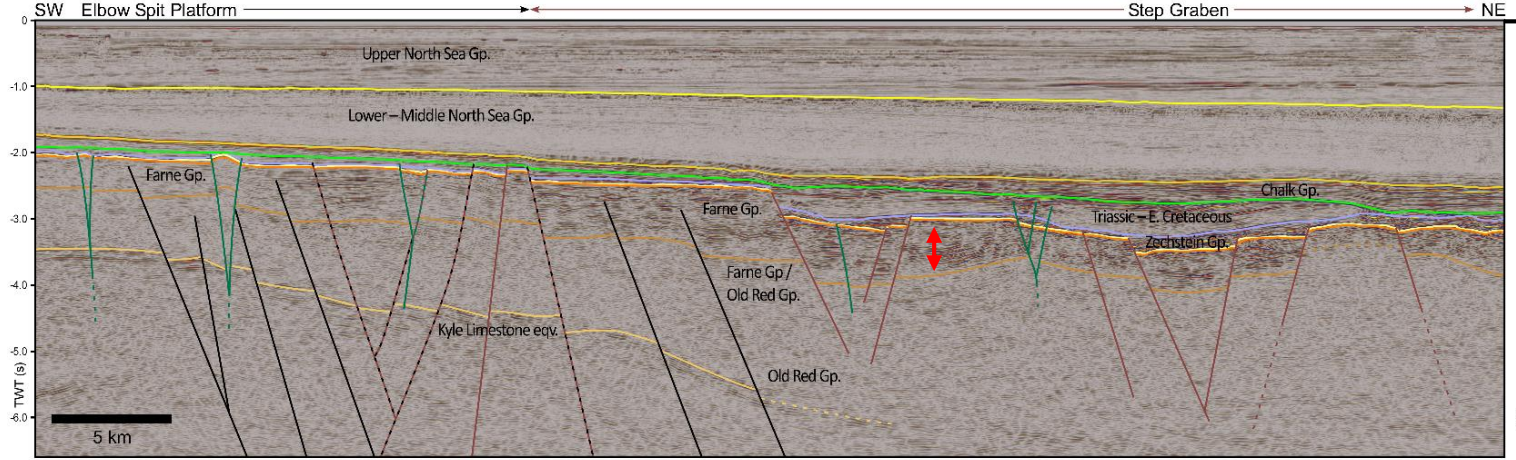
Potential additional source rocks

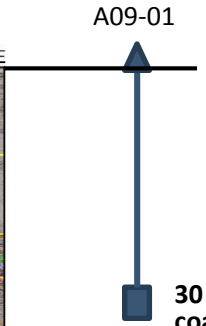
- Lateral charge from **Westphalian**
- Namurian marine shales; potential in the S
- Bituminous limestones Yoredale
- Lateral migration from downthrown proven Posidonia Shale, Zechstein.

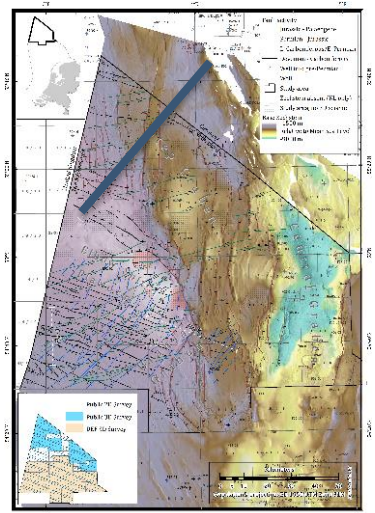


from Ter Borgh et al., 2018

Coals in Lower Carboniferous north of the Elbow Spit Platform







- Lower Carboniferous is present north of the Elbow Spit Platform.
- Has a high contrast seismic facies.

Ter Borgh et al., 2018

Source rocks

General perception: Limited HC source rocks present in northern Dutch offshore

EBN: Recent studies show potential presence and maturity of several source rock intervals in the northern Dutch offshore.

Triassic play element

Reservoir presence

Source rock

HC migration

Seal

HC migration

General perception: Thick Zechstein prevents HC migration

EBN: two possible migration pathways:

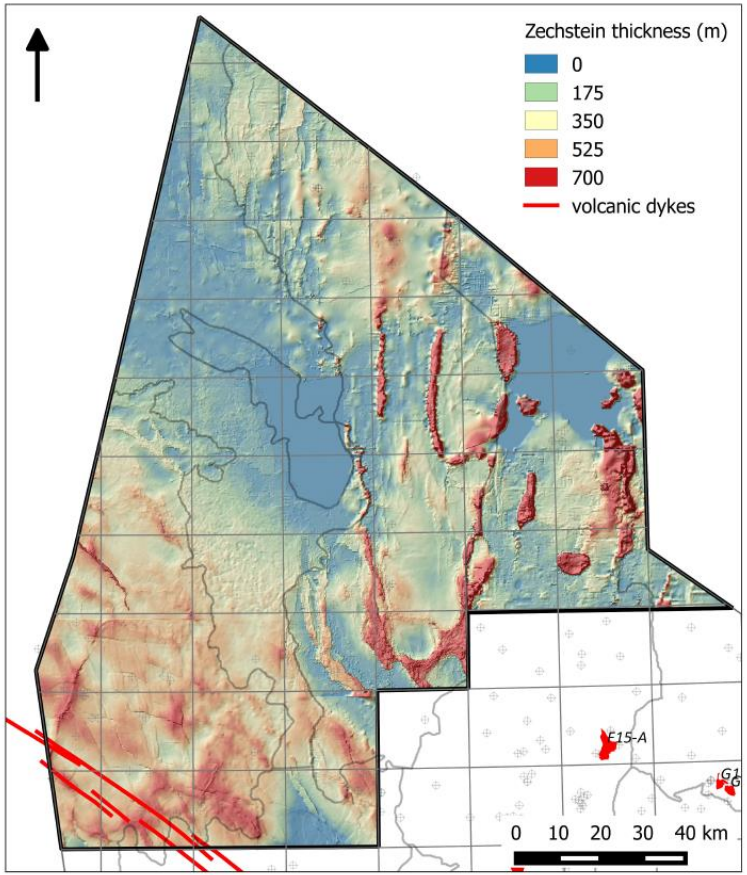
- ‘Classical’ vertical migration through Zechstein windows or along major faults
- Tertiary dykes present in NL

HC migration through Zechstein windows

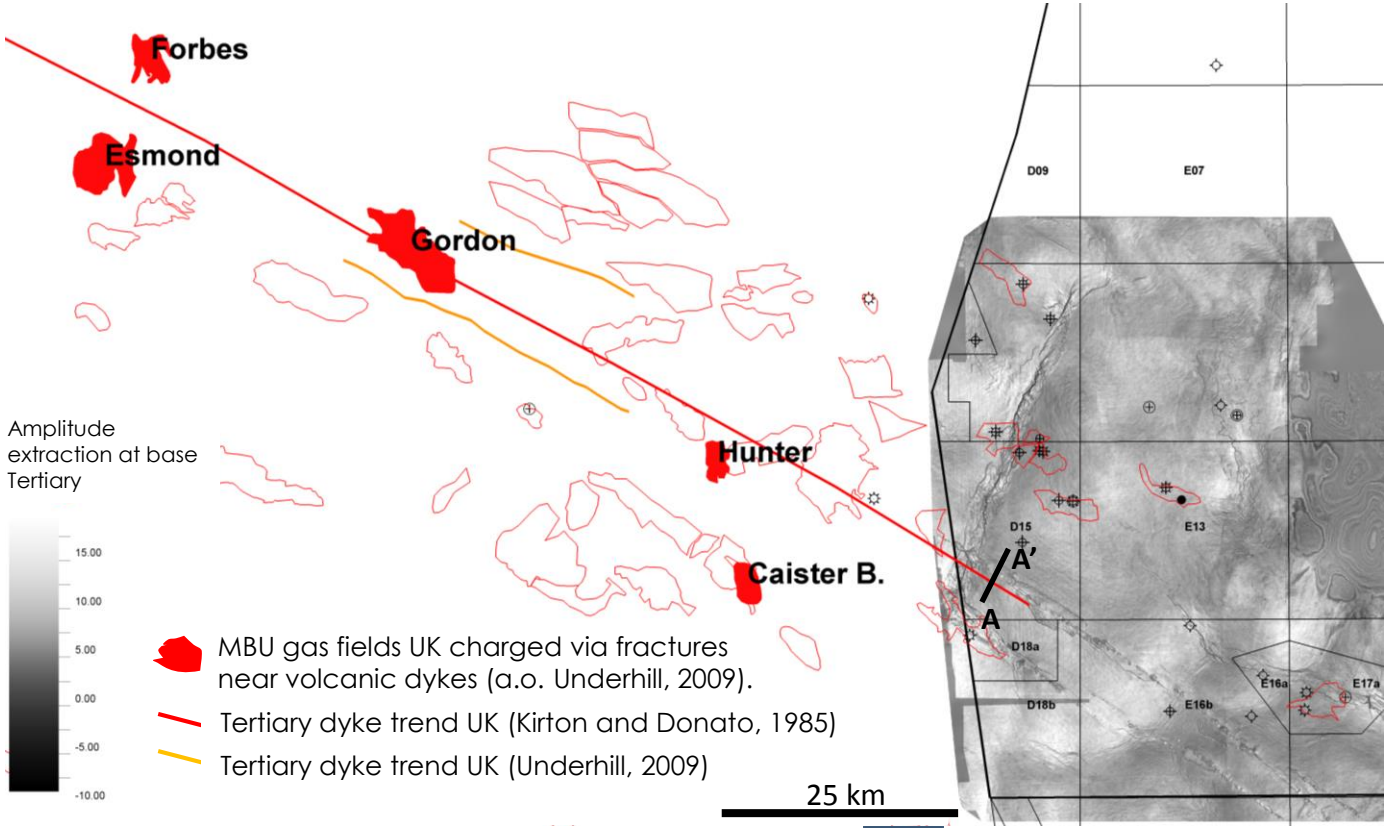
Three charge mechanisms:

- Salt windows (Zechstein thickness)
- Faults
- Volcanic dykes

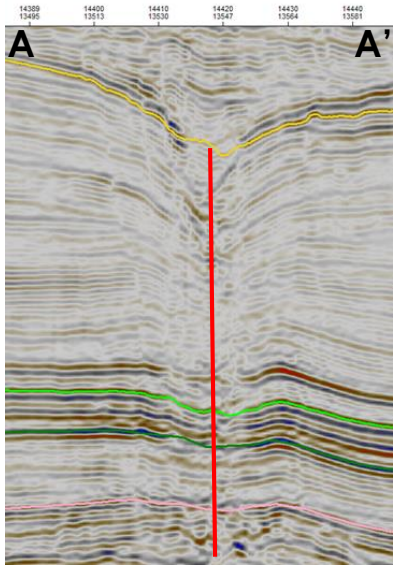
Analysis per lead is required



HC migration via Tertiary dykes

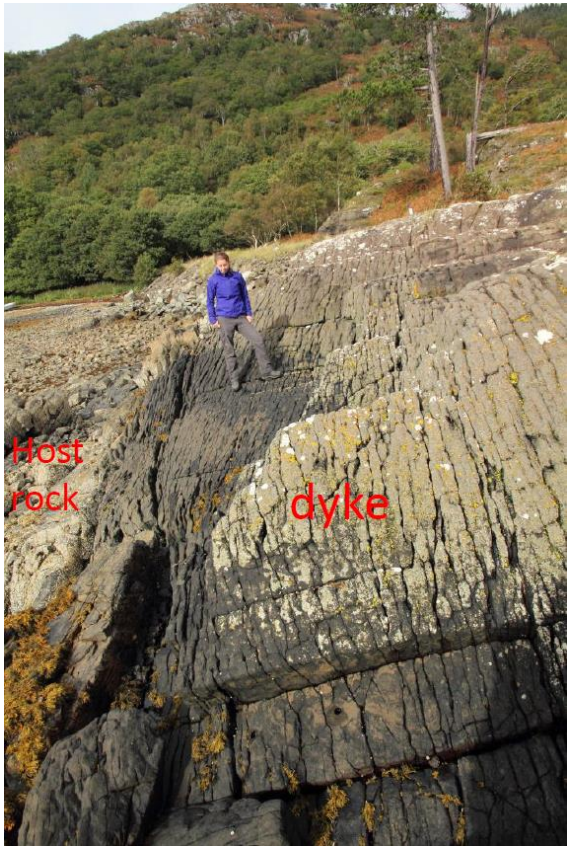


- Thick ZE: charge bypassed ZE via volcanic dykes
- Significant lateral HC migration



HC migration via Tertiary dykes

- Thick Zechstein: charge bypassed Zechstein via volcanic dykes
- Significant lateral HC migration
- The analogue fields charged via Tertiary dykes are underfilled



Photo's from M. ter Borgh

HC migration

General perception: Thick Zechstein prevents HC migration

EBN: two possible migration pathways:

- Tertiary dykes are present in NL
- ‘Classical’ vertical migration through Zechstein windows and along major faults

Triassic play element

Reservoir presence

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HC migration

Seal

Seal and overpressure

General perception:

- Upper Germanic Triassic rocks are proven seal
- Overpressure has caused seal breach

EBN:

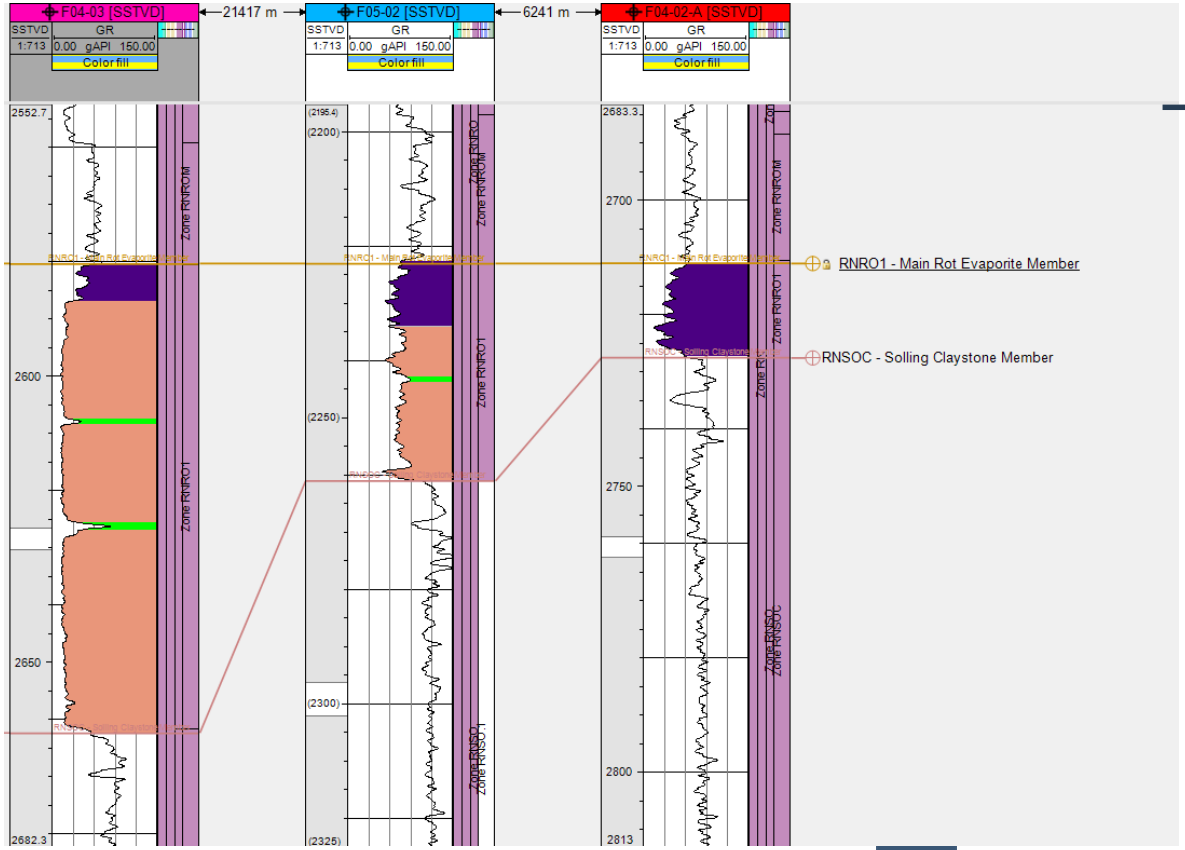
- Main Röt evaporites present in large part of the study area
- Overpressure may restrict column height but may offer an opportunity:
  - Significantly higher reservoir pressures – so more GIIP
  - Arrest of compaction and therefore better porosity – and more GIIP

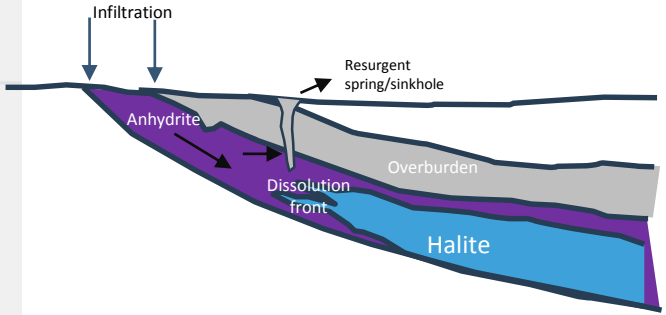
Seal

Seal dependent on trap type:

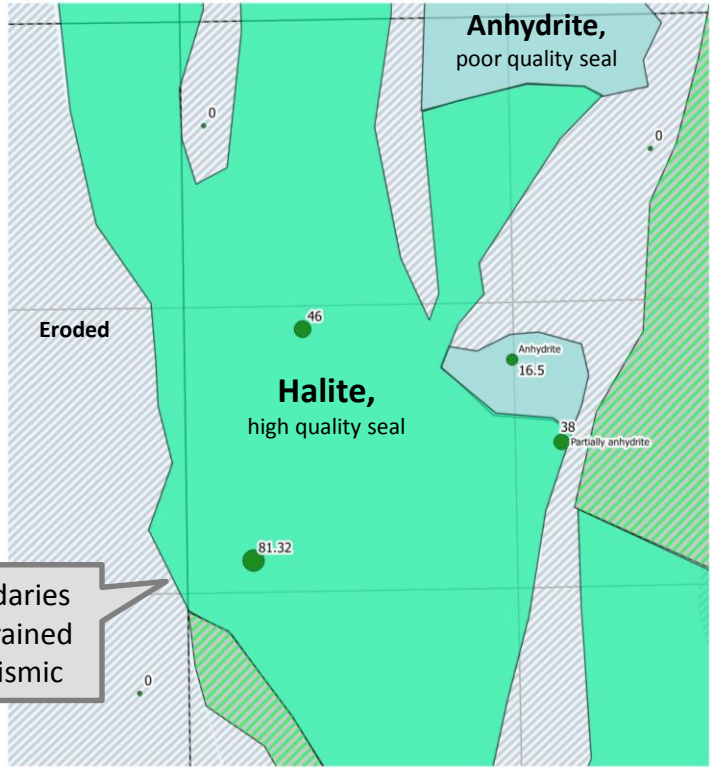
3WDC	4WDC	Unconformity trap	Fault seal
ZE side/top seal			
Upper Germanic Triassic	Upper Germanic Triassic		
		Sealing overburden (Jurassic, Cretaceous or Paleogene strata)	
			Fault Seal

Seal – Main Röt Evaporite (RNRO1)



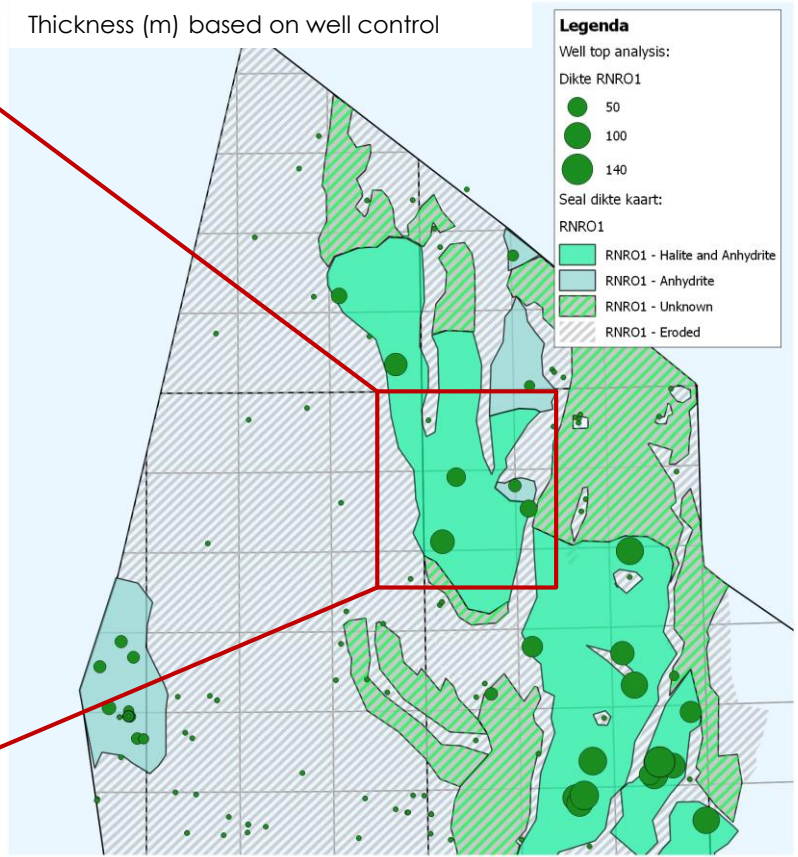


Seal – Main Röt Evaporite (RNRO1)



Boundaries constrained by seismic

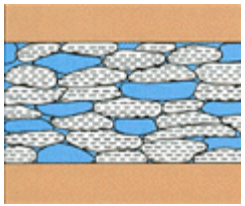
Thickness (m) based on well control



*Isochores are taken as thickness

Overpressure – what is it?

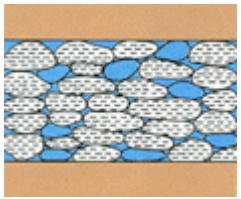
Normal Pressure



Weight of the sedimentary overburden (lithostatic pressure, or vertical stress) is carried by grains at their contacts.

- Pore pressure at a certain depth is related to the height (and salinity) of the overlying water column.

Overpressure

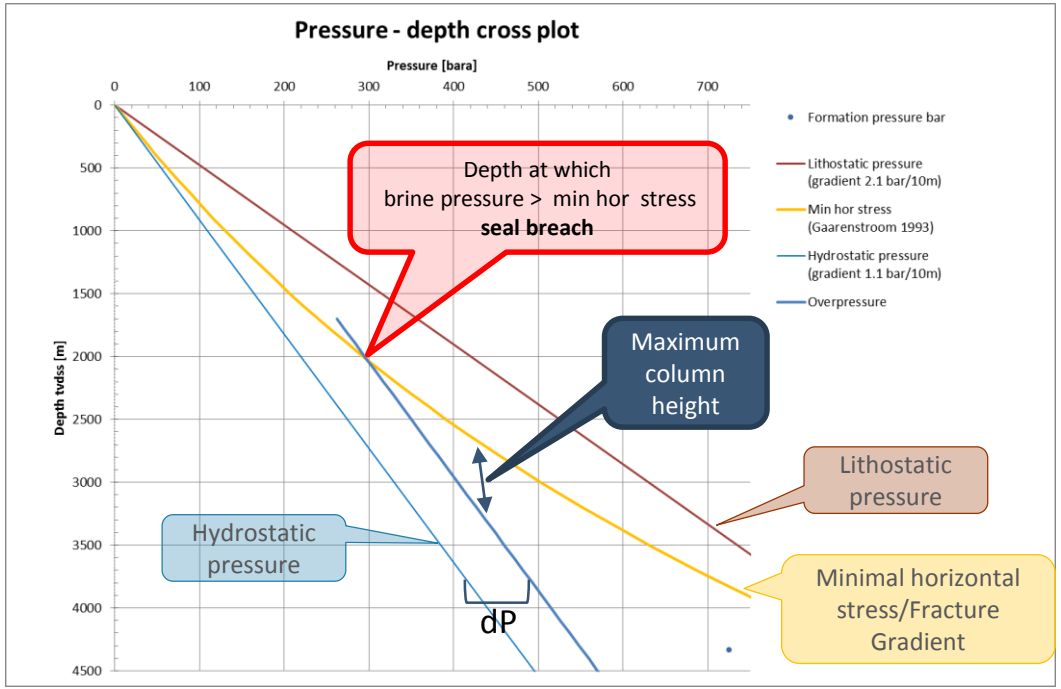


Overpressure is the fluid pressure in excess of hydrostatic pressure.

Overpressure can occur when burial of fluid filled sediments is so rapid that pore fluids cannot escape.

- Porefill will carry part of the weight of sedimentary overburden
- Pressure of the pore fluids increases .
- Compaction is arrested.

Overpressure



Increasing over-pressure:

- If pore pressure > minimum horizontal stress rock will start to fail (break)
- formation water escapes and allowing the pore pressure to stabilise at equilibrium depth & pressure (depth of fluid retention) and acting like a valve.

THREAT:

- escape of gas and limitation of gas column height resulting in smaller/zero GIIP

OPPORTUNITY:

- compaction arrested causing higher porosity,
- higher pore pressure,
- both resulting in higher GIIP

Seal and overpressure

General perception:

- Upper Germanic Triassic rocks are proven seal
- Overpressure has caused seal breach

EBN:

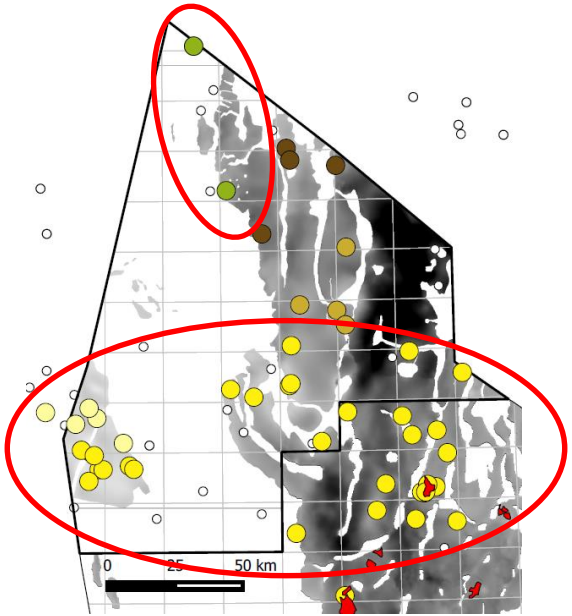
- Main Röt evaporites present in large part of the study area
- Overpressure may restrict column height but may offer an opportunity:
  - Significantly higher reservoir pressures – so more GIIP
  - Arrest of compaction and therefore better porosity – and more GIIP

Triassic play elements
Concluding Remarks

Conclusions

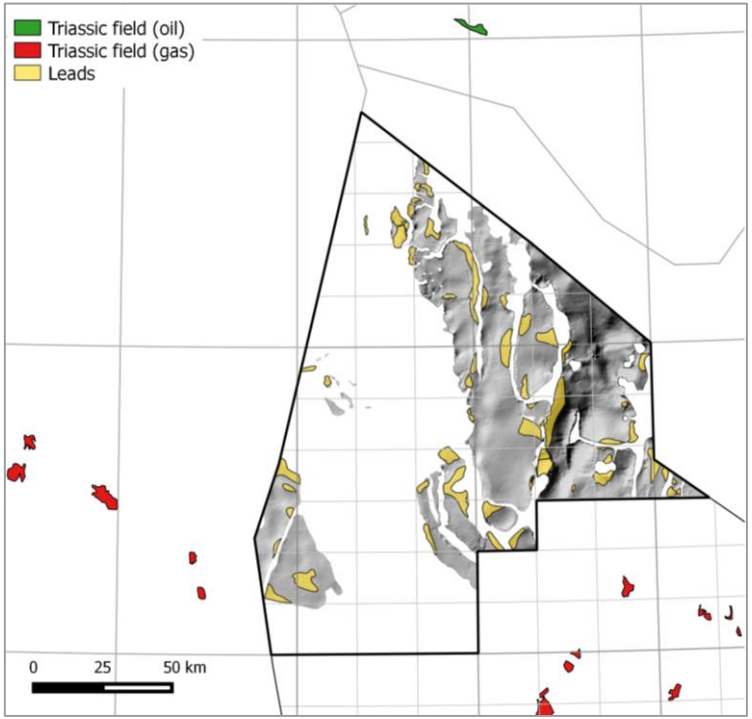
Critical review of all currently available data provide new insights in Triassic play elements for northern Dutch offshore:

- Local depocentres present in NW Step Graben, possible local provenance
- Southerly sourced Volpriehausen sst well developed in southern part of study area
- Recent (EBN) studies show alternative source rock intervals presence and maturity
- HC migration possible via Zechstein windows, major faults or via Tertiary dykes
- Overpressures may offer an opportunity (larger GIIP)



Further work

- Establish risk maps at play element and prospect level: Seal, Charge, Reservoir
- Establish lead portfolio with risked volume ranges
- Prioritise further follow up for lead/prospect maturation
- Publish prospect portfolio at ebn.nl



EBN, 2016

Thank you for your attention

More information? Contact us:
exploration@ebn.nl

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Fugro and Spectrum ASA, for giving permission to show data from the DEF survey
EBN Colleagues, students Utrecht University: Cas van der Kooij, Aike Vonk and Gioia Bezemer

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