

Northern German Unconventional Reservoirs in Upper Permian (Ca²) Microbial Slope and Basin Dolomitized Mudstones: Assessment of Oil to Source-Rock Correlations within a Sequence Stratigraphic Framework*

Ursula Hammes¹, Hans-Martin Schulz², and Achim Bechtel³

Search and Discovery Article #80393 (2014)**

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Please refer to related article by the first author and co-workers, entitled The Permian Zechstein Formation as a Potential Hybrid Unconventional Reservoir: A Sequence Stratigraphic and Sedimentological Evaluation of Organic-Rich Carbonates and Mudrocks from Shelf to Basin, Northern Germany, [Search and Discovery Article #80238 \(2012\)](#).

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Abstract

Upper Permian microbial carbonate source rocks were evaluated using sequence stratigraphic, sedimentologic and geochemical techniques to evaluate potential unconventional reservoirs in slope, basinal, and organic-rich, fine-grained and/or tight lithologies of the northern German Zechstein Z2 cycle. Carbonate microbial mudstones of the Southern Permian Basin have not been evaluated for its shale-gas/oil potential and incorporated into a sequence stratigraphic framework. Therefore, a comprehensive, basin-wide study was conducted that included sedimentology, sequence stratigraphy, and organic geochemistry. The Zechstein Formation is divided into seven 3rd-order sequences that are dominated by regressive and transgressive cycles. Sequence stratigraphic correlations from shelf to basin are crucial in establishing a framework that will allow correlation of potential productive facies in fine-grained, microbial dolomitized mudstones from slope and basin. The basal two Zechstein cycles, Z1 and Z2, contain organic-rich calcareous and dolomitized mudstones that form the transgressive third-order deposits in the basin. Tight dolomitic, microbial layers of carbonates interfingering with organic-rich mudstones are potential candidates for forming a hybrid unconventional or shale-oil reservoir. The basinal and slope succession of Z2 Zechstein sequence is dominated by dolomitized mudstones that is more organic-rich, laminated and fissile in the basin, and more massive with microbial layers on the slope. Most slope and basinal mudstones exhibit TOC contents up to 0.8%, with maturities ranging from 0.9% Ro to >2% Ro at burial depths from 2000 m to greater than 4000 m. Kerogen type was analyzed to be of Type II amorphous organic matter with increasing liptinites in less mature samples, but hydrogen index of the mudstones is up to 200 mg HC/gTOC, suggesting mixed type II/III kerogen. Biomarkers indicate in-situ source of microbial slope carbonates. Therefore, oil to source-rock correlation of microbial slope mudstones, including isotopes and biomarkers, corroborate a potential resource play in the Zechstein Z2 slope setting.

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Northern German Unconventional Reservoirs in Upper Permian (Ca2) Microbial Slope and Basin Dolomitized Mudstones: Assessment of Oil to Source-Rock Correlations within a Sequence Stratigraphic Framework

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Bechtel⁴**

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German Geologic Research Center (GFZ) Potsdam³, University of
Leoben, Austria⁴



OUTLINE

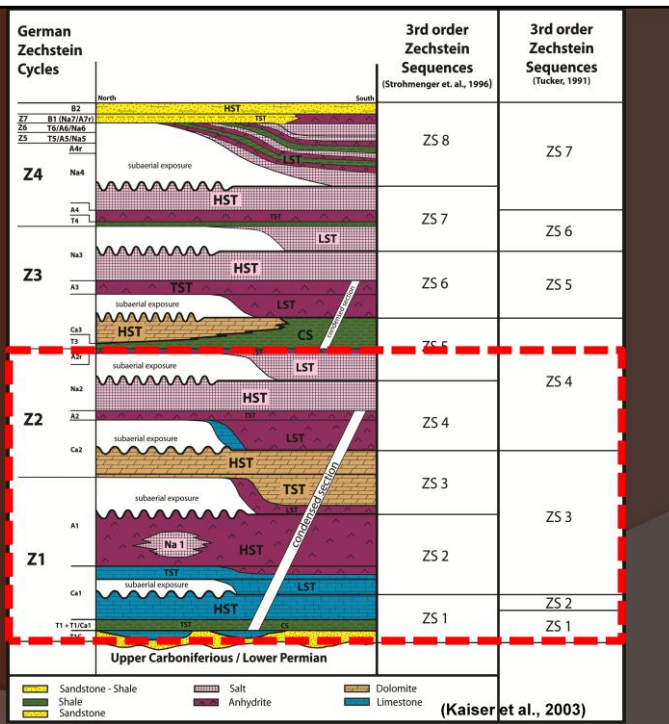
- ◉ Address problem
- ◉ Sequence stratigraphy of the Southern Permian Basin, Northern Germany
- ◉ Facies
- ◉ Geochemistry
- ◉ Conclusions

Goals

- Evaluate Zechstein Z2 mudrocks, shales, and carbonates for shale-gas/shale-oil reservoir potential.
 - TOC below 0.5%
- **ARE THESE MUDSTONES SOURCE ROCK?**
 - Microbial mudstone rock-oil source typing within a sequence stratigraphic framework.



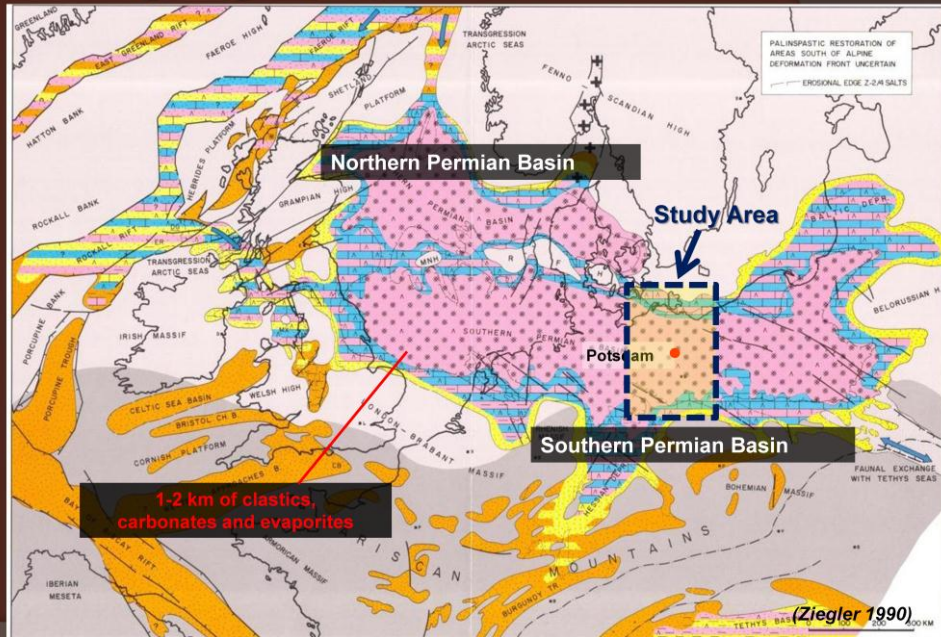
Upper Permian Zechstein Stratigraphy

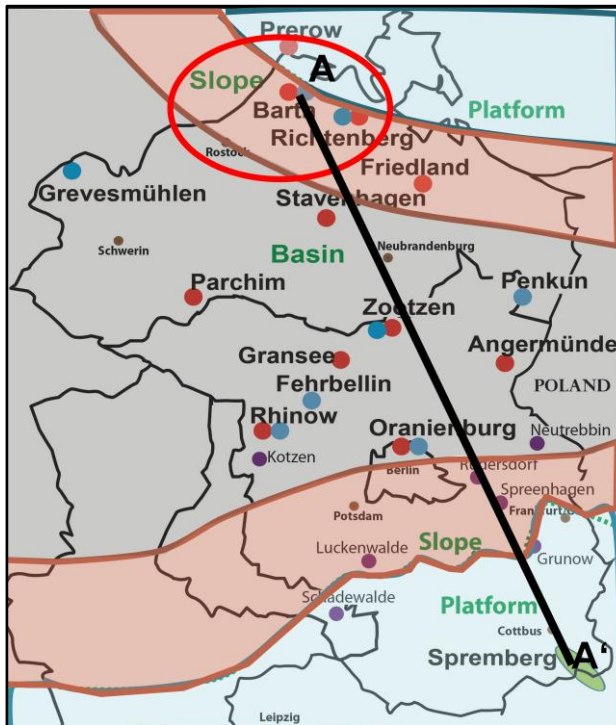




Paleogeography

Late Permian (Zechstein)





Database

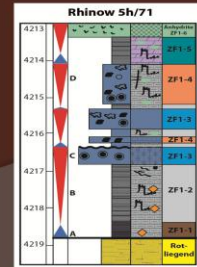
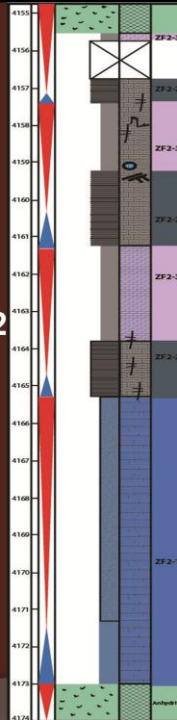
Cores and logs from German State offices in Brandenburg and Mecklenburg-Vorpommern (Research wells from Hoth et al., 1993)

- Zechstein Z1 cores sampled and described
- Zechstein Z2 cores sampled and described
- Zechstein Z2 data from Hartwig and Schulz (2010)

Basin Stratigraphy

Zechstein cycle Z2

Zechstein cycle Z1



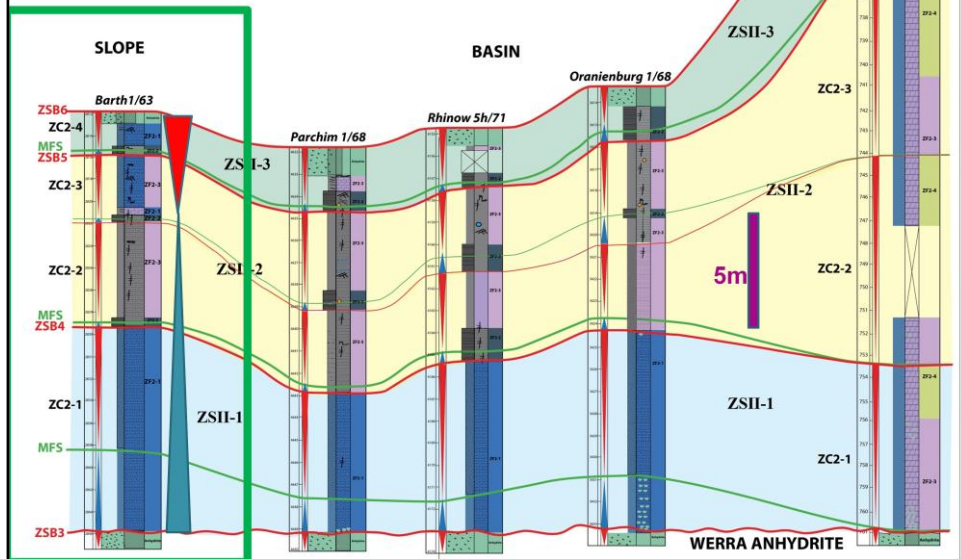
N

~400 km

PLATFORM

S

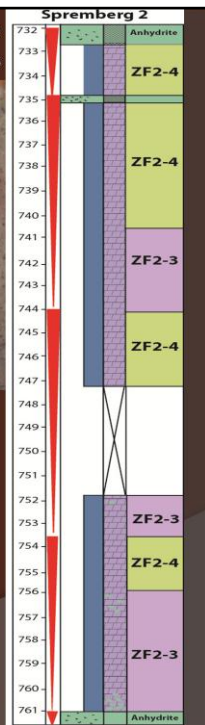
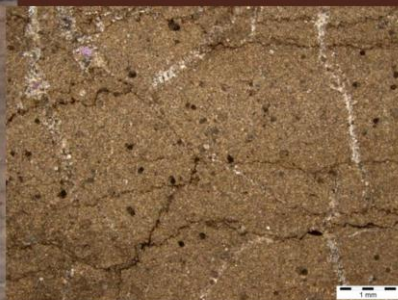
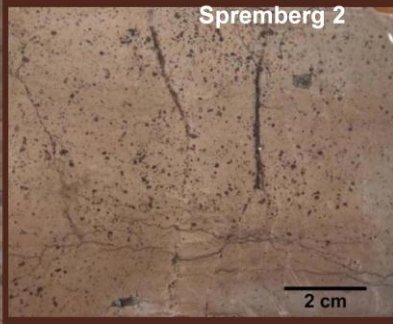
Shelf to Shelf Correlation



Z2 Platform Facies



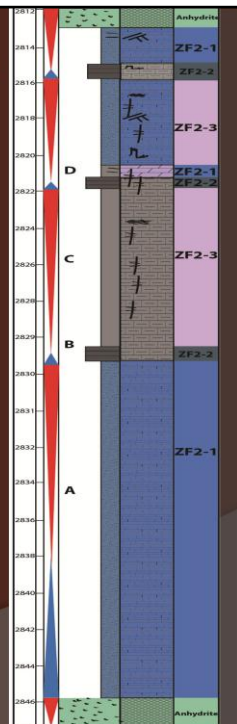
Z2 platform cycle stacking patterns Spremberg 2



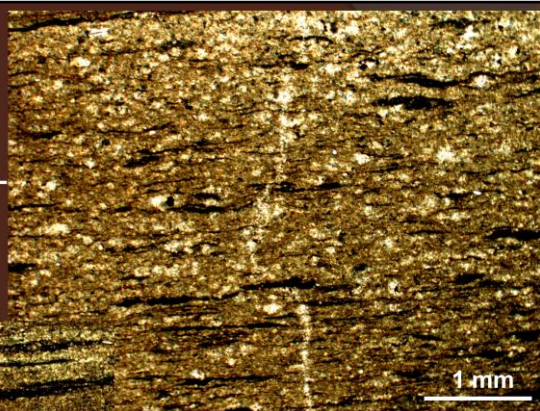
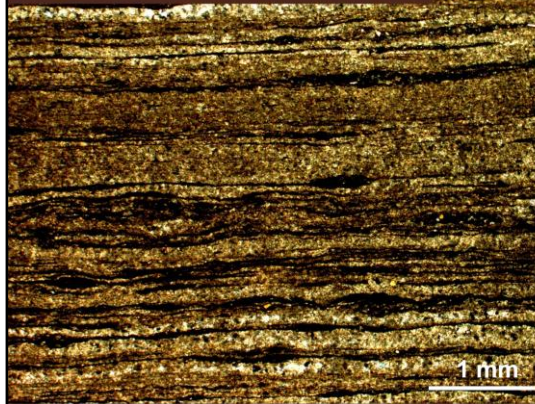
Z2 Slope Facies



Z2 slope cycle stacking patterns Barth 1-63



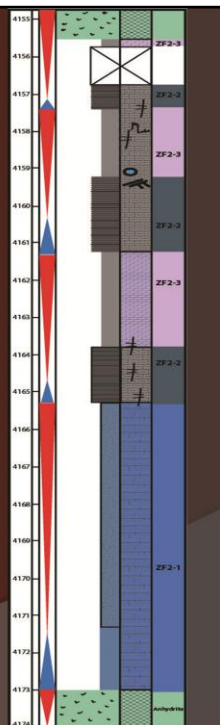
Microbial
anhydrite/dolomi-
tized mudstones



Z2 Basin Facies



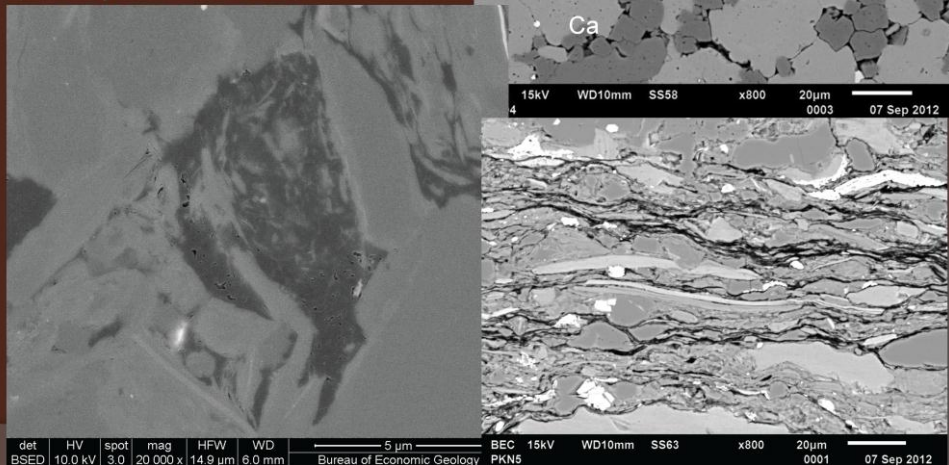
Z2 basin cycle
stacking patterns
Rhinow 5h/71



Petrography

Z2 Carbonates– dominated by intercrystalline porosity

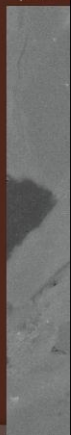
Ar-ion milled BSEM images
(taken by Rob Reed, BEG)



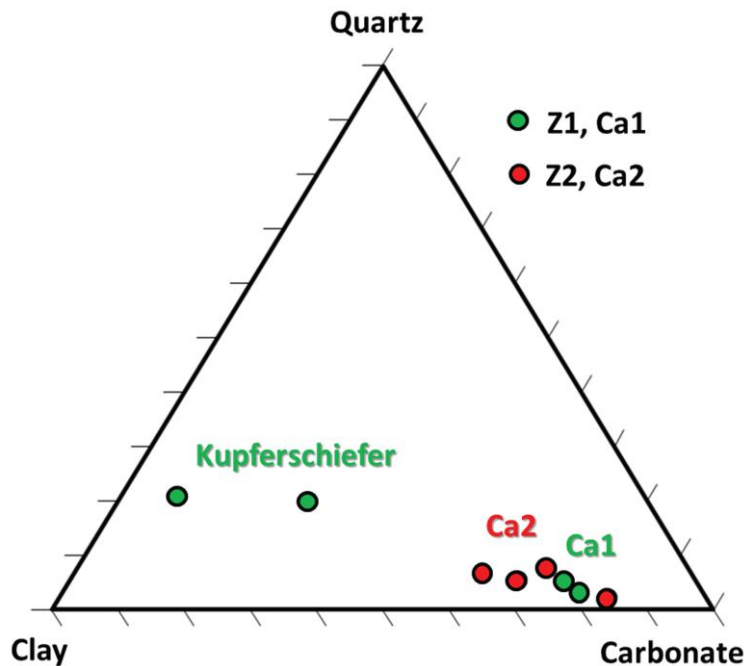
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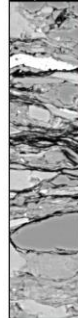
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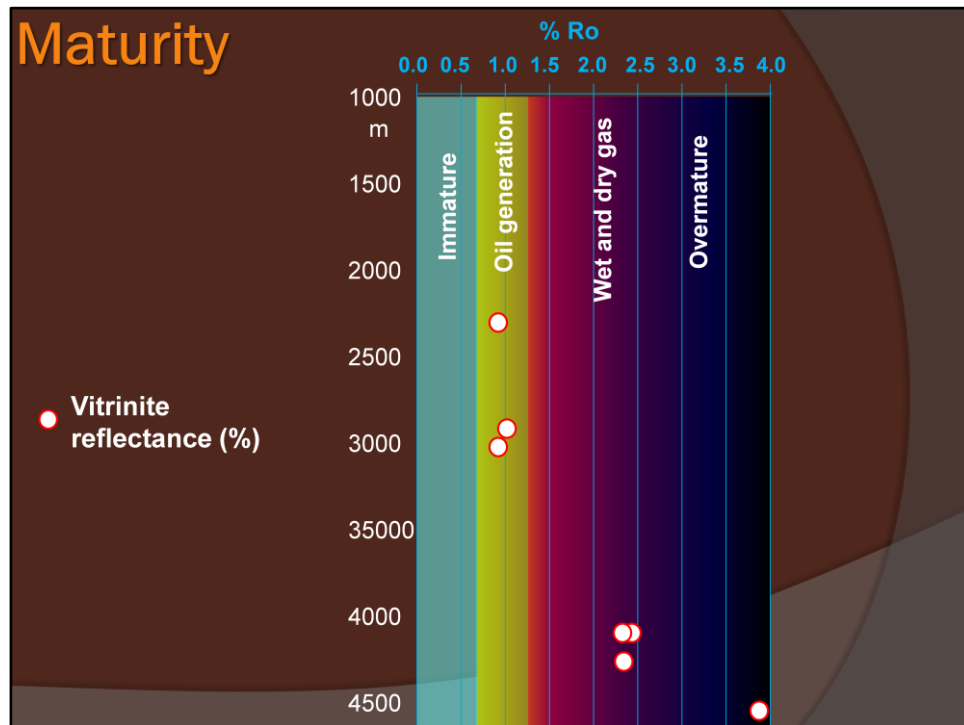
7 Sep 2012



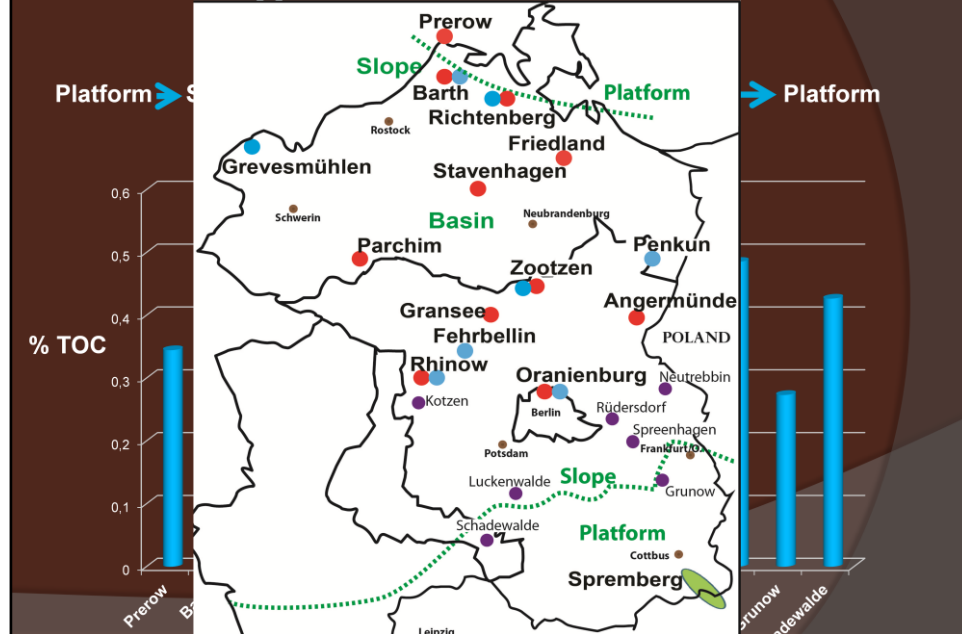
Sep 2012

Oil and Source Rock Characterization

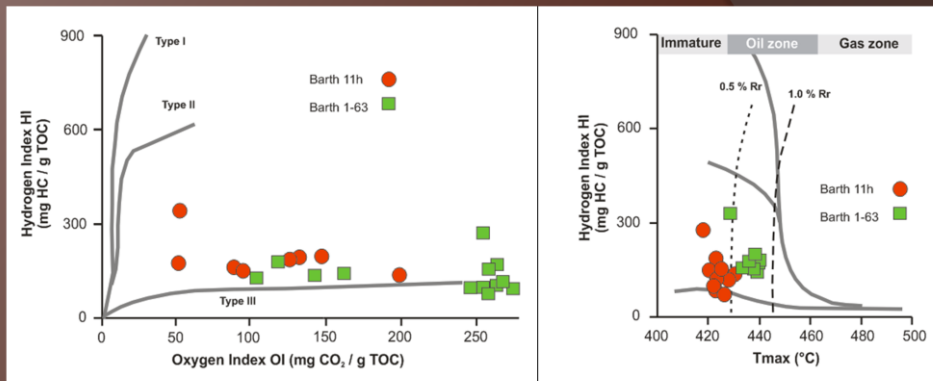
Maturity



Average TOC Shelf to Basin Z2



Rock-Eval Analysis cuttings and whole core



Measured data

BARTH 11h

Rr (%): 0.5 – 0.9

λ_{max} (nm): 560 – 610

$\delta^{13}C_{org}$ (‰): -23.9 to -25.2

BARTH 1-63

Rr (%): 0.5 – 0.9

λ_{max} (nm): 560 – 610

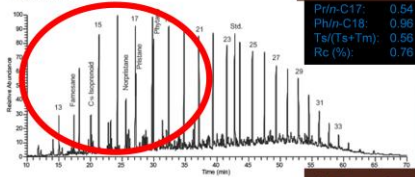
$\delta^{13}C_{org}$ (‰): -24.3 to -26.0

Presenter's notes: Overall organic composition; red is cuttings; green is core samples; mix type II/III. Barth 1-63 more mature than 1h; that is why it has higher OI; green already expelled oil but some green and all red still has higher hydrocarbon generation potential.

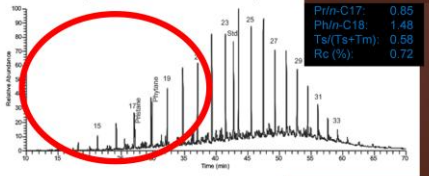
Tmz vs. HI shows again mixture of type II and III. Measured vitritinite reflectance showed similar maturity as did spectral fluorescence measurements to confirm early maturity. C13 shows high marine content.

Saturated Hydrocarbons

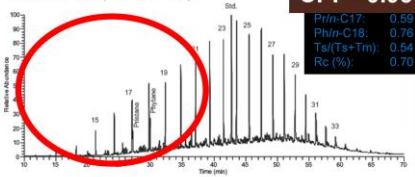
Barth 11 Oil



Barth 11 (2955, 3555, 3795 m)

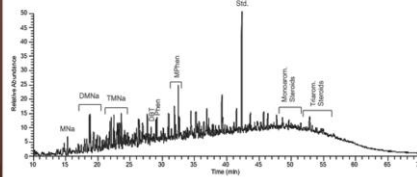


Barth 1-63 (-3, -7, -10)

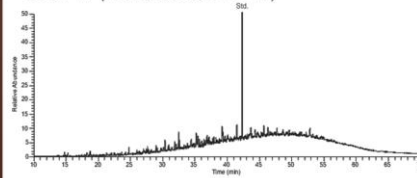


Aromatic Hydrocarbons

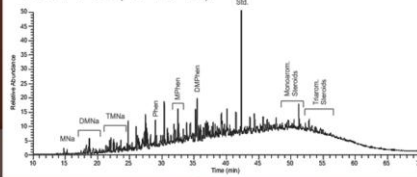
Barth 11 Oil



Barth 11 (2955, 3555, 3795 m)



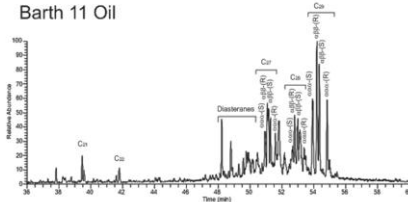
Barth 1-63 (-3, -7, -10)



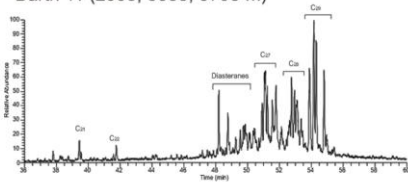
Presenter's notes: Similar biomarker patterns in both wells and oil. Rocks released hydrocarbon compounds that can be seen in the oil (carbon preference index, CPI). CPI odd numbered n-alkanes divided by even chains – the closer to 1, the more mature. If immature, then CPI is lower than 1. Comparison shows oil coming from these rocks.

Steranes (m/z = 217)

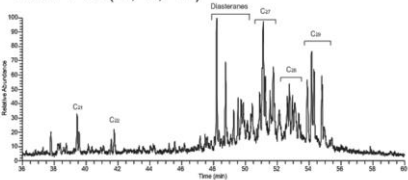
Barth 11 Oil



Barth 11 (2955, 3555, 3795 m)

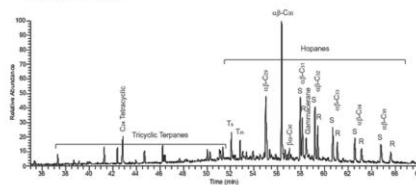


Barth 1-63 (-3, -7, -10)

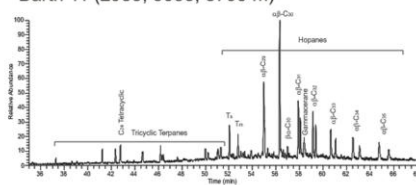


Terpanes (m/z = 191)

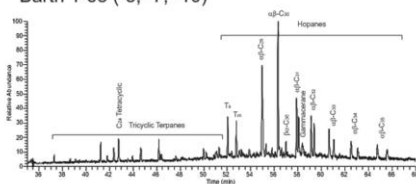
Barth 11 Oil



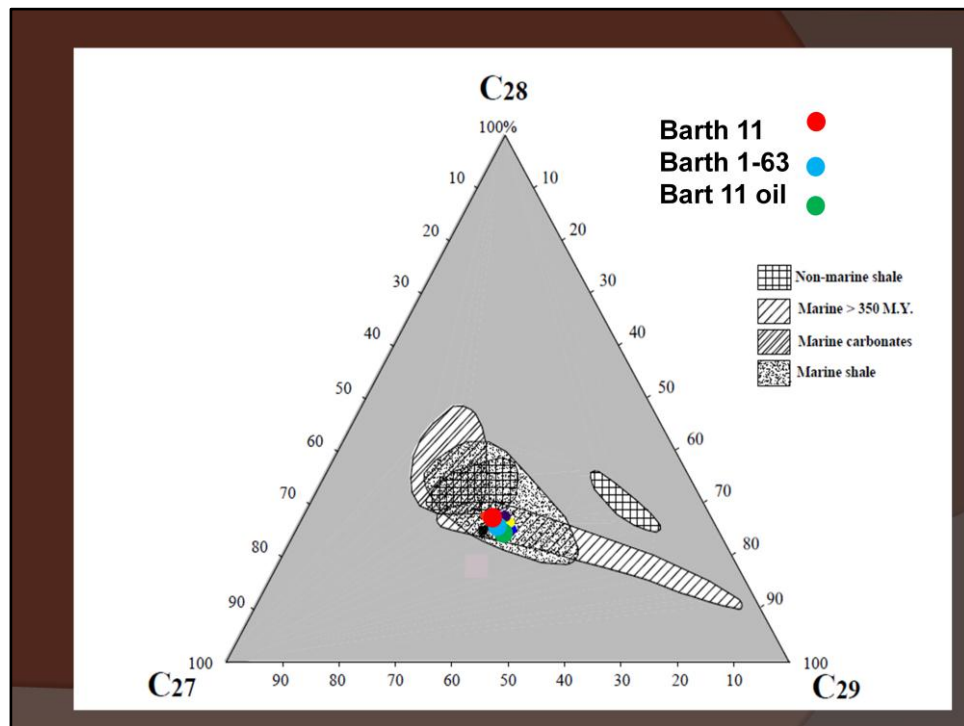
Barth 11 (2955, 3555, 3795 m)



Barth 1-63 (-3, -7, -10)

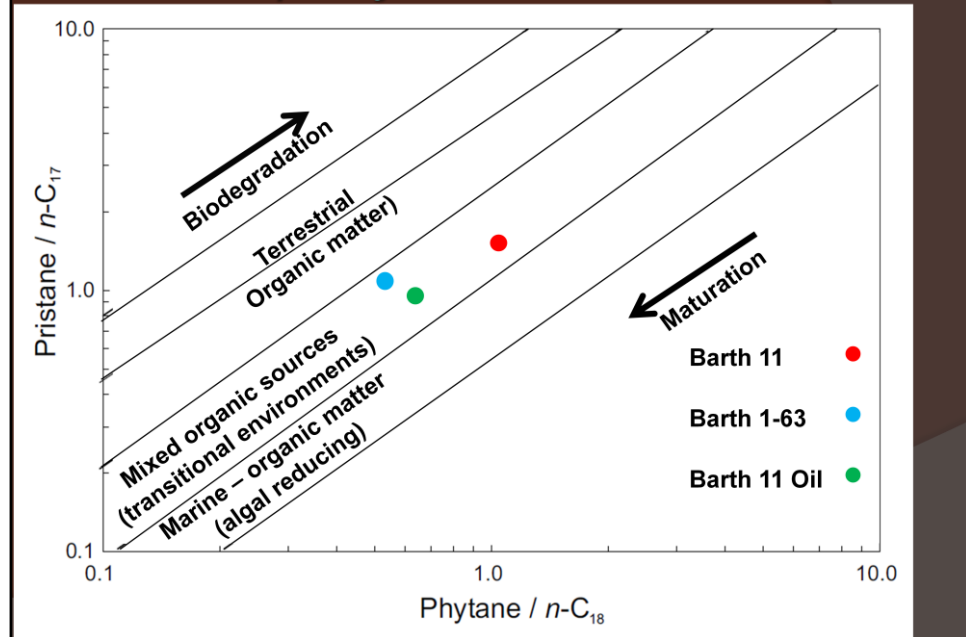


Presenter's notes: Similarity of patterns. Oil is coming from these rocks.



Presenter's notes: Plot shows general classification and samples in marine shale realm.

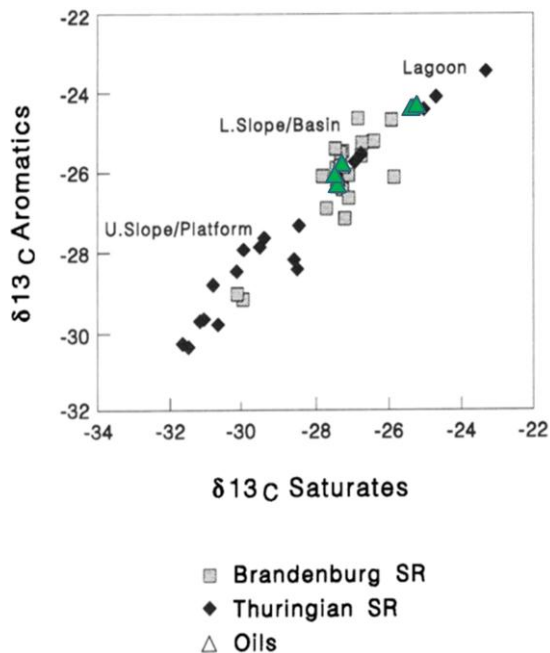
Pristane/Phytane Ratios



Presenter's notes: Biomarkers from phytol chain attached to chlorophyl.

Z2 Source Rock/ Oil correlation using biomarkers

(from Karnin et al.,
1996)



Conclusions

- Sequence stratigraphic correlations from platform to basin identifies organic-rich intervals.
- Bituminous, laminated, calcareous mudstones and mudrocks are present in the Zechstein Z2 basin residing in oil to overmature window.
- Although Z2 mudrocks have very low TOC, oil-rock biomarker study proves sourcing from microbial mudstones.
- Microbial organic-rich mudstones in slope setting present horizontal drilling opportunities.

Z2 Unconventional Reservoir Model

PROXIMAL

DISTAL

