[AV]Shale Gas in the Posidonia Shale, Hils Area, Germany*

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Abstract

Shale gas is a self-sourced resource in which thermogenic or biogenic hydrocarbon gases are contained within a fine-grained, organic-rich, low-permeability matrix, occurring in free, adsorbed and dissolved states. While no commercial shale-gas enterprises are currently known outside North America, many parts of Europe contain prime targets for shale gas exploration. One of these is the Posidonia Shale (Lias ε) of northern Germany. The Posidonia Shale in the Hils Syncline is approximately 35m thick and subcrops at relatively shallow depth over a 500 sq km area. It displays a threefold stratigraphic subdivision: lower marlstone, middle calcareous shale with bivalve shells, and upper calcareous shale. It is organic-rich, and lateral variations in its maturity have been related to deep burial or the effects of the Vlotho Massif, a purported deep-seated igneous intrusion. We have analysed a total of 300 whole core pieces and core plugs from 6 research boreholes, which completely penetrated the Posidonia Shale of the Hils Syncline, covering the maturity range Rm = 0.48 - 1.45%. The two fundamental components of gas shales, namely, the origin/occurrence of in-situ gas and the nature of the rock matrix, have both been studied. Only at the highest studied maturity level (1.45% Ro) does the Posidonia Shale begin to fulfill the empirical organic geochemical criteria which label it as a gas shale candidate. The Posidonia Shale originally contained Type II kerogen of Petroleum Type Organofacies Low Wax P-N-A in all boreholes. Geochemical logging revealed that vertical heterogeneity in richness and quality is significant in single wells, in part related to depositional facies. However, maturity variability between locations is responsible for much larger shifts in TOC, S1 and S2 values. The relative amounts of the different clay mineral groups remain constant with increasing levels of thermal maturity, though porosity and pore size are reduced. Heterogeneities in bitumen, kerogen, and mineral abundances at the nanometre scale occur in overmature samples. Gas retention efficiencies for the represented maturation stages were calculated as a function of Transformation Ratio, using bulk and compositional mass balance models. Because the Posidonia Shale displays similarities to the Barnett Shale, we conclude that it represents a potentially productive gas shale in Germany.

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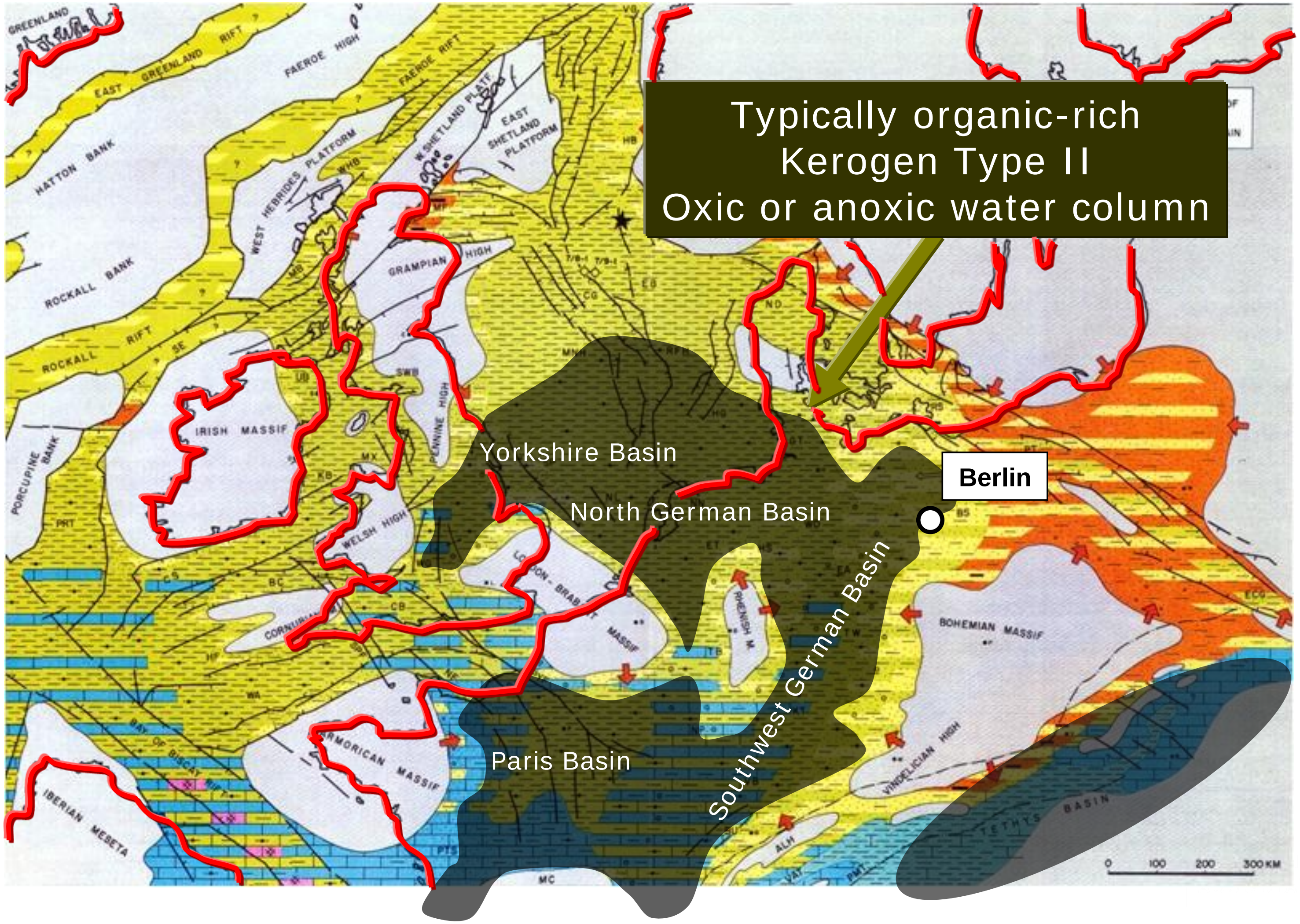
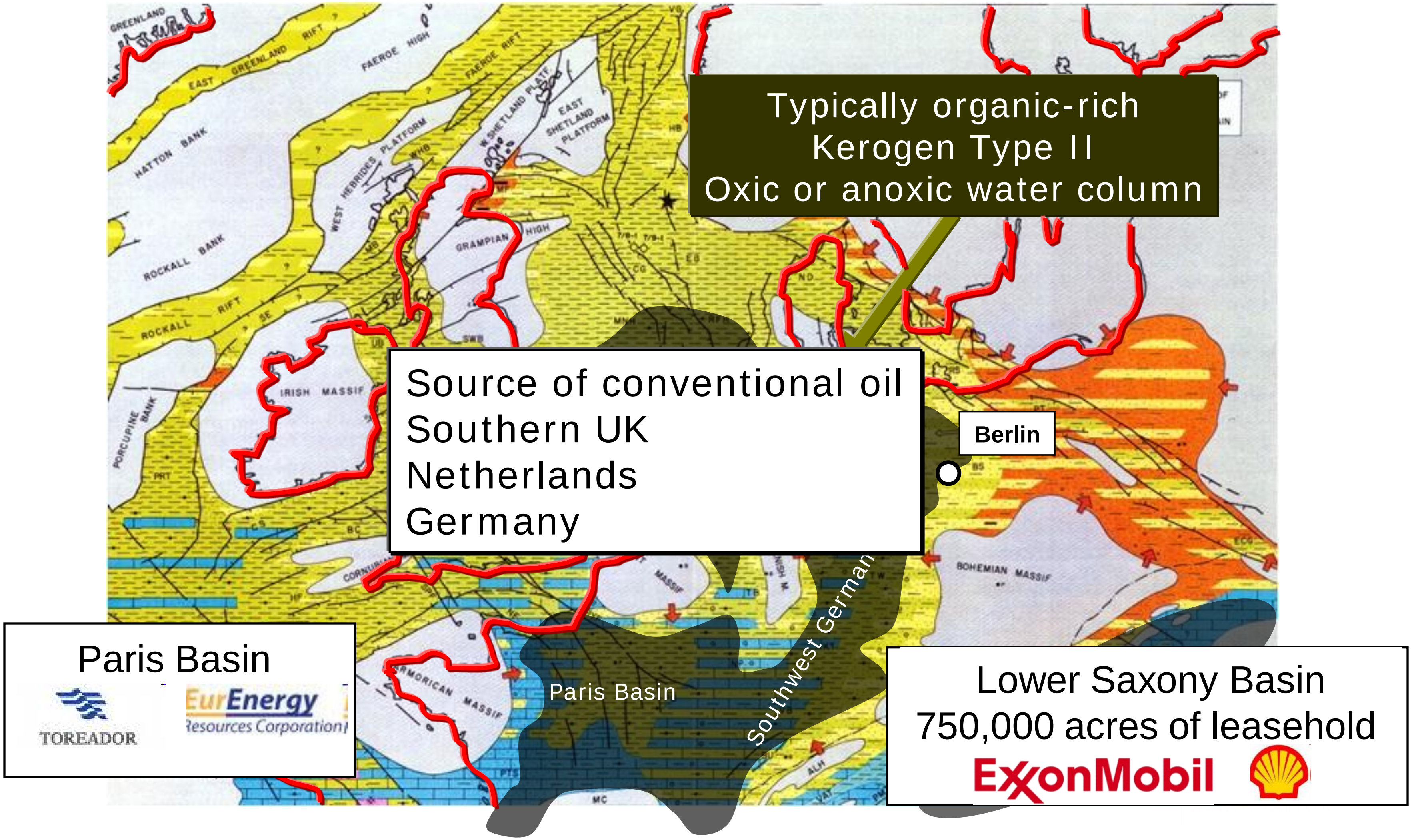
Acknowledgements

KFA-Jülich

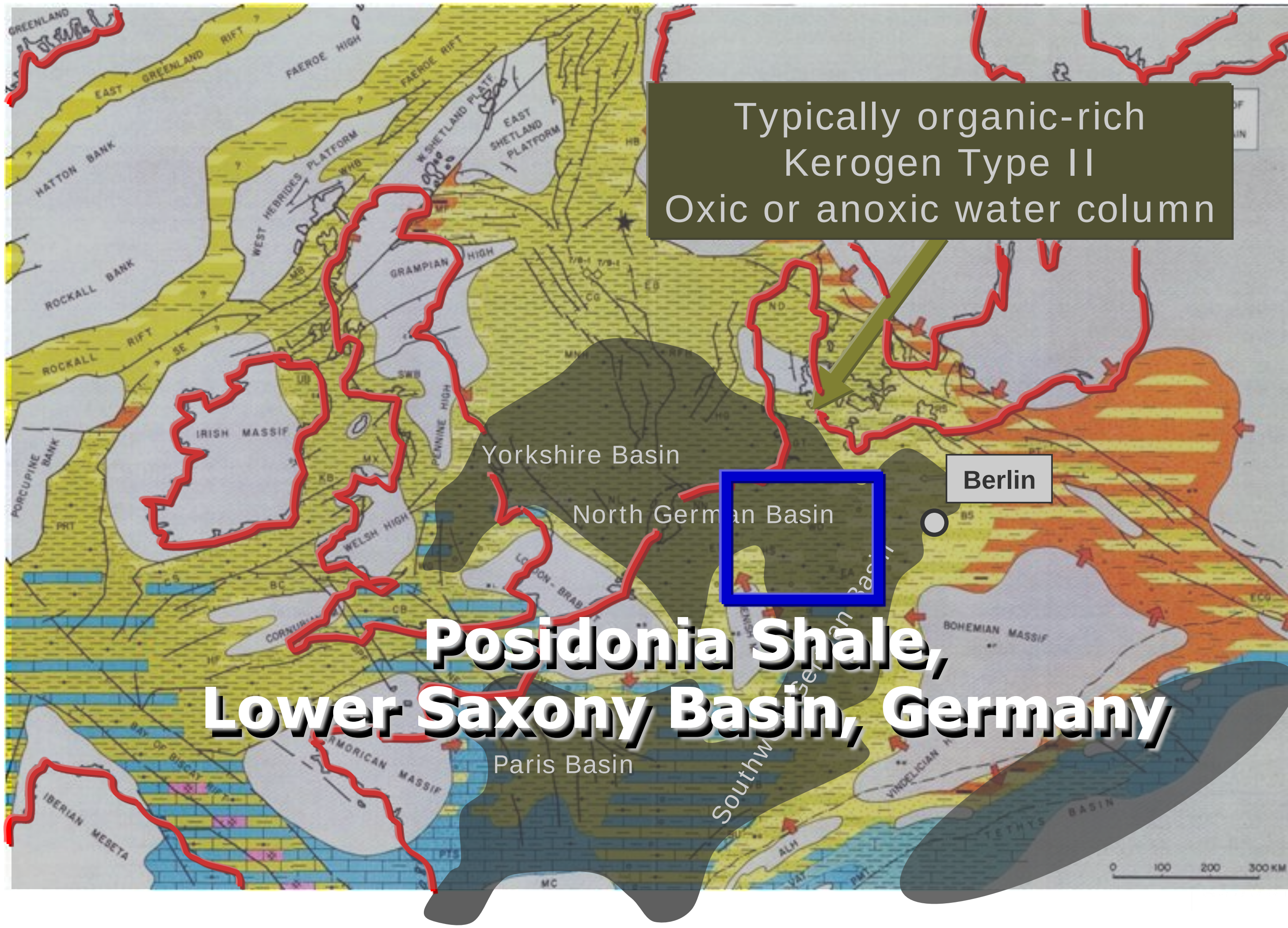
Lower Jurassic (Toarcian)



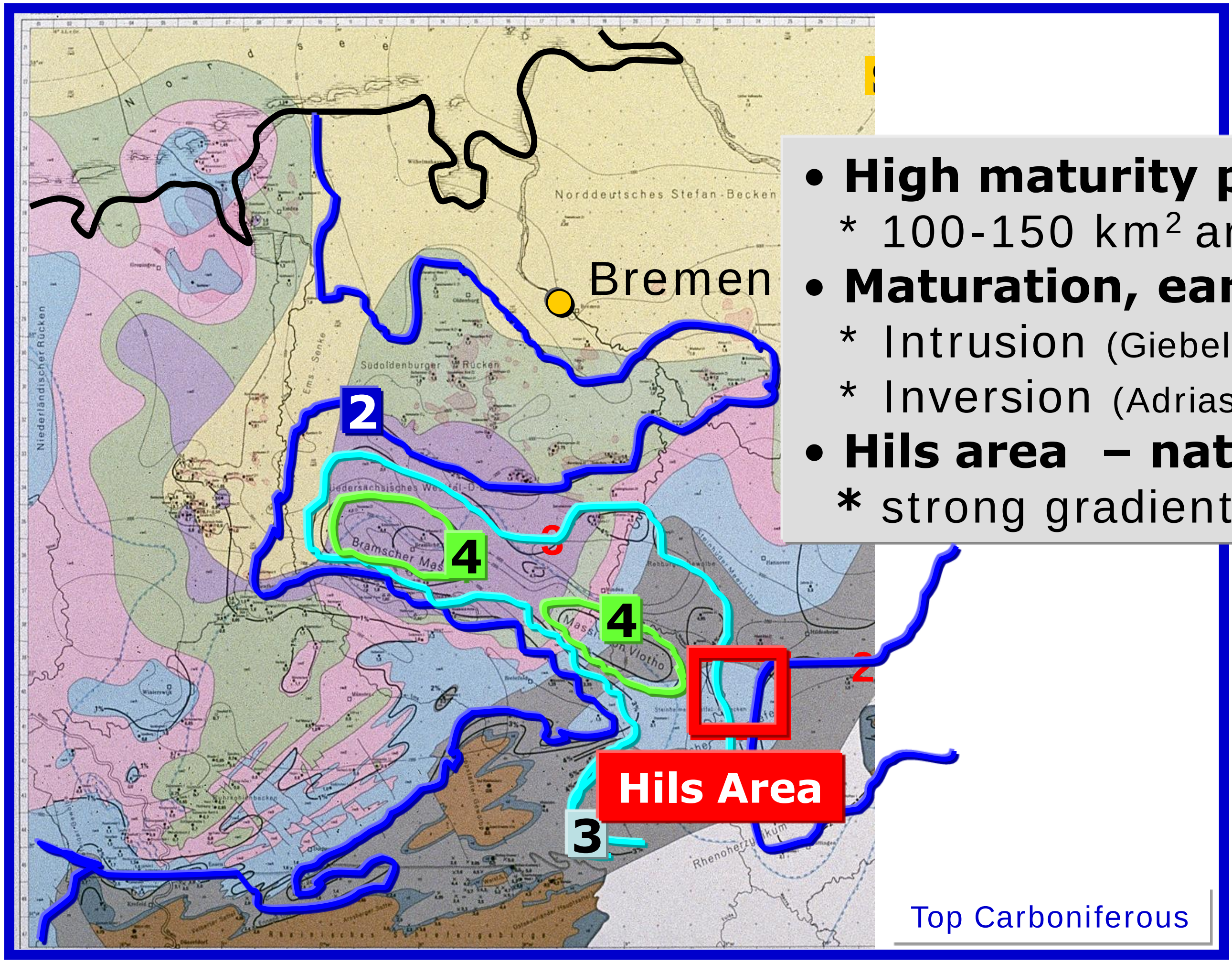
Lower Jurassic (Toarcian)



Lower Jurassic (Toarcian)

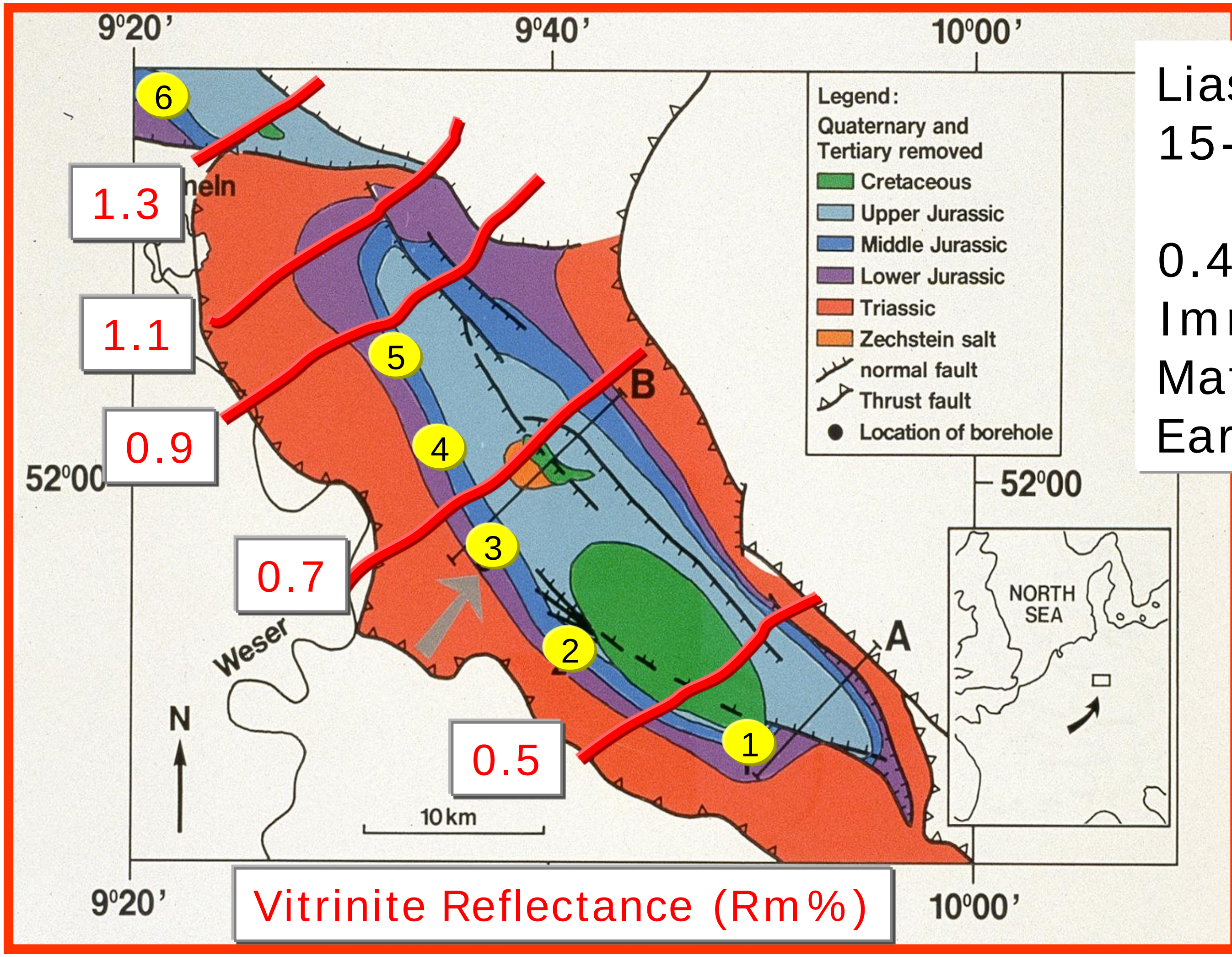


Vitrinite Reflectance Trends



- **High maturity present**
  * 100-150 km^2 areas
- **Maturation, early Cretaceous**
  * Intrusion (Giebeler-Degro, 1986)
  * Inversion (Adriasola Munňoz et al. 2007)
- **Hils area – natural lab**
  * strong gradient

Stratigraphy and Key Boreholes



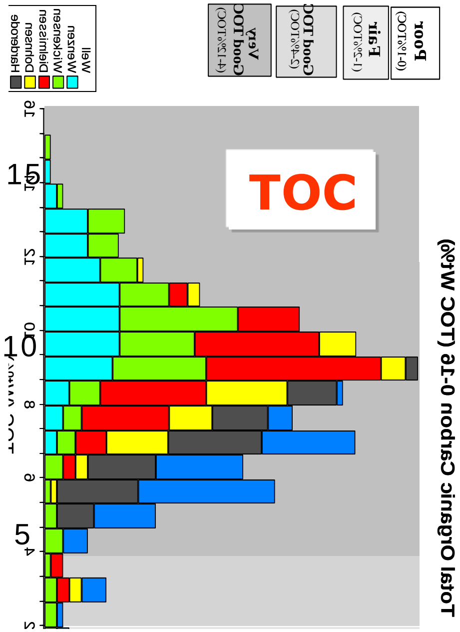
Lias epsilon
15-40m thick

0.48 – 1.45% Rm
Immature
Mature
Early overmature

Talk Outline

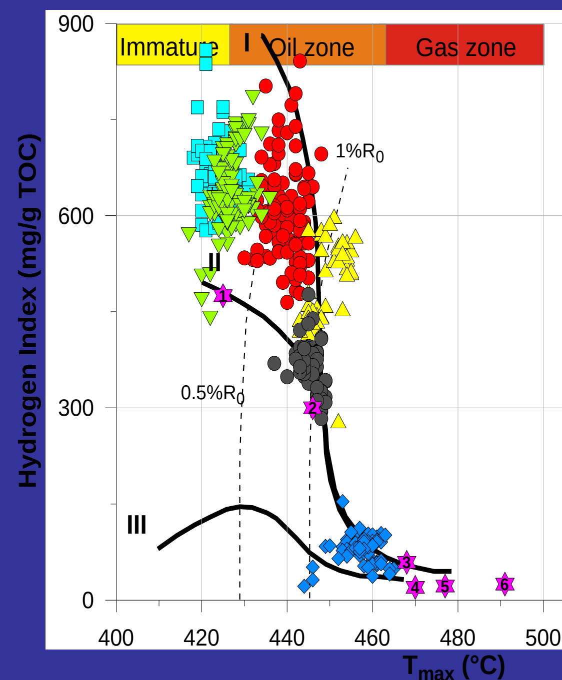
- Quick-View Posidonia Shale – a European gas shale candidate
- Gas-in-place mass balance and MSSV calculation for R_m >1.45%
- Chemical versus physical control of GOR for R_m = 0.52 - 1.45%
- Conclusions

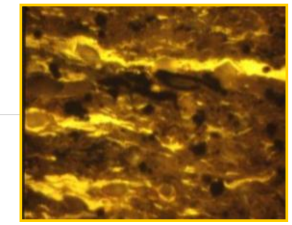
Quick-View 1 Basic OM characteristics

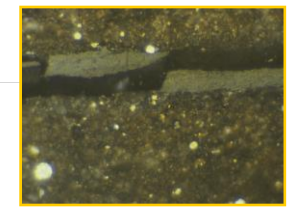


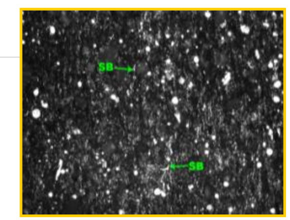
Rm = 0.48%

HI



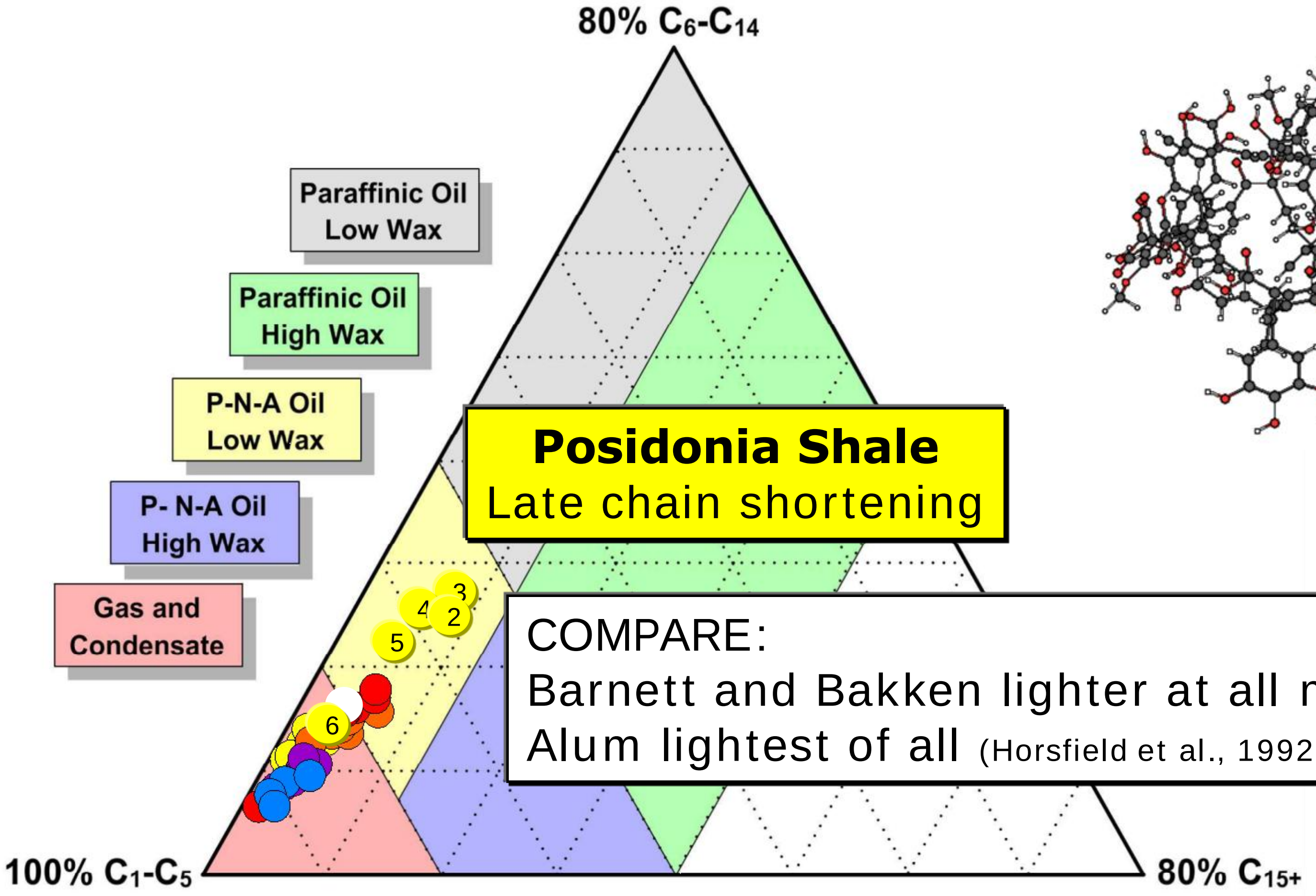


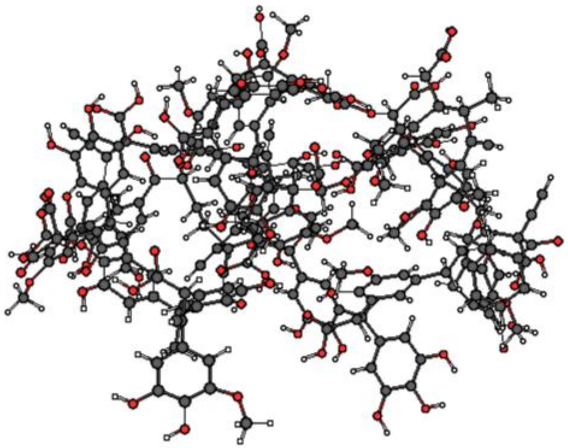




Rm = 1.45%

Quick-View 2 Chain lengths in kerogen

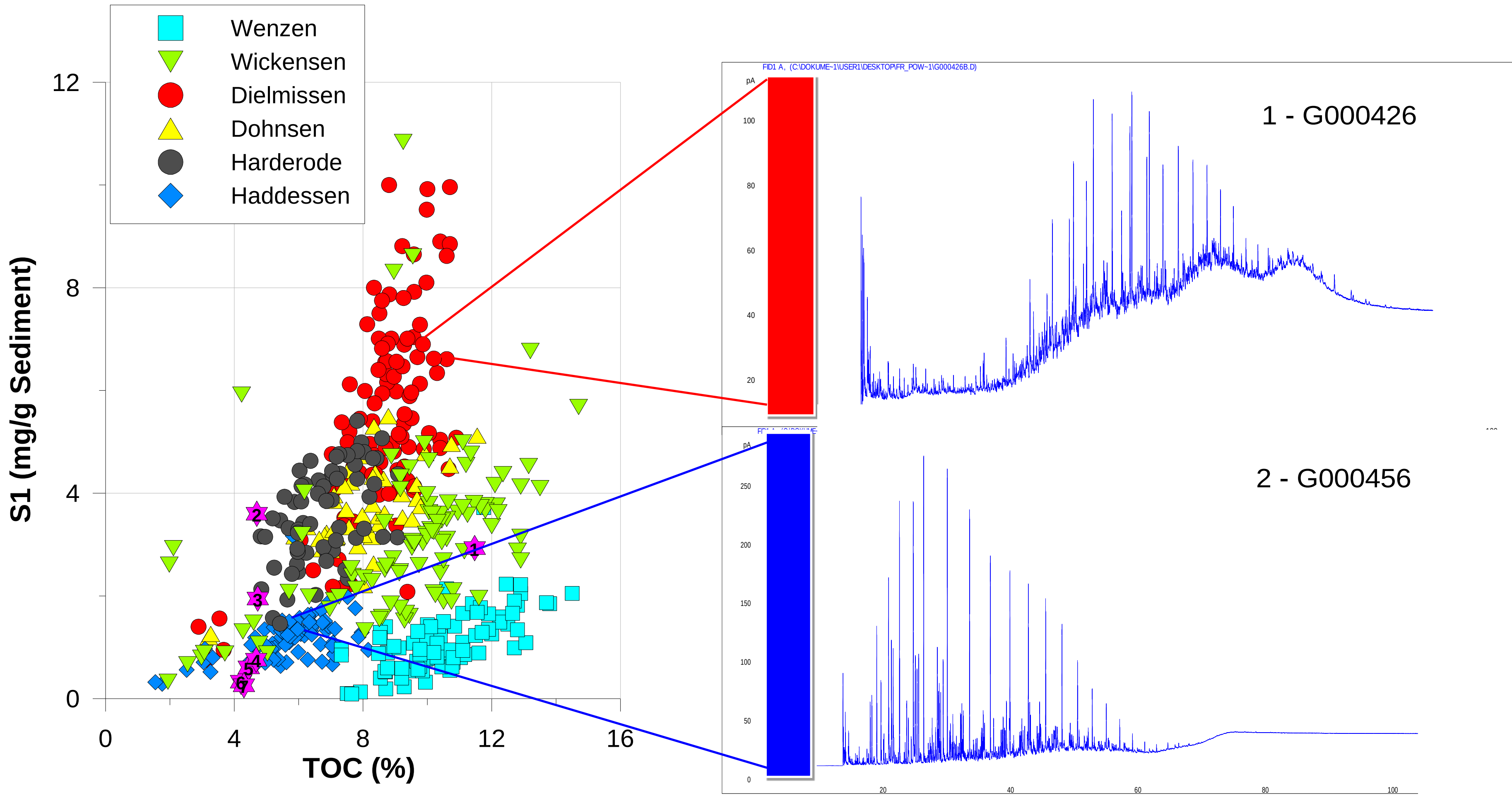




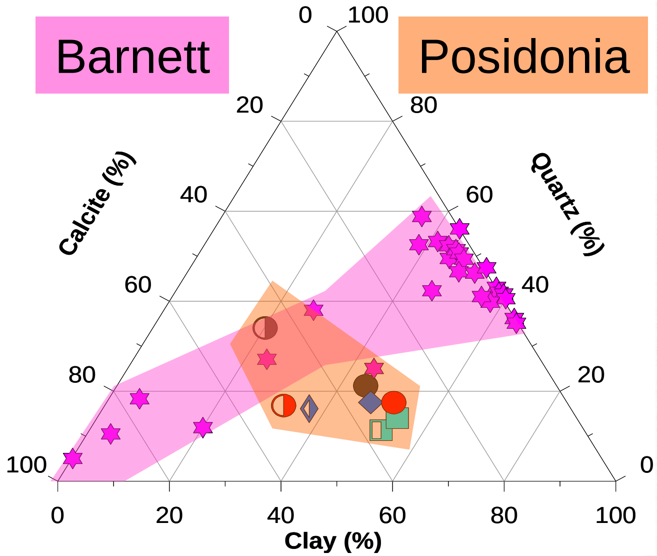
Posidonia Shale
Late chain shortening

COMPARE:
Barnett and Bakken lighter at all maturities
Alum lightest of all (Horsfield et al., 1992; Muscio et al., 1994)

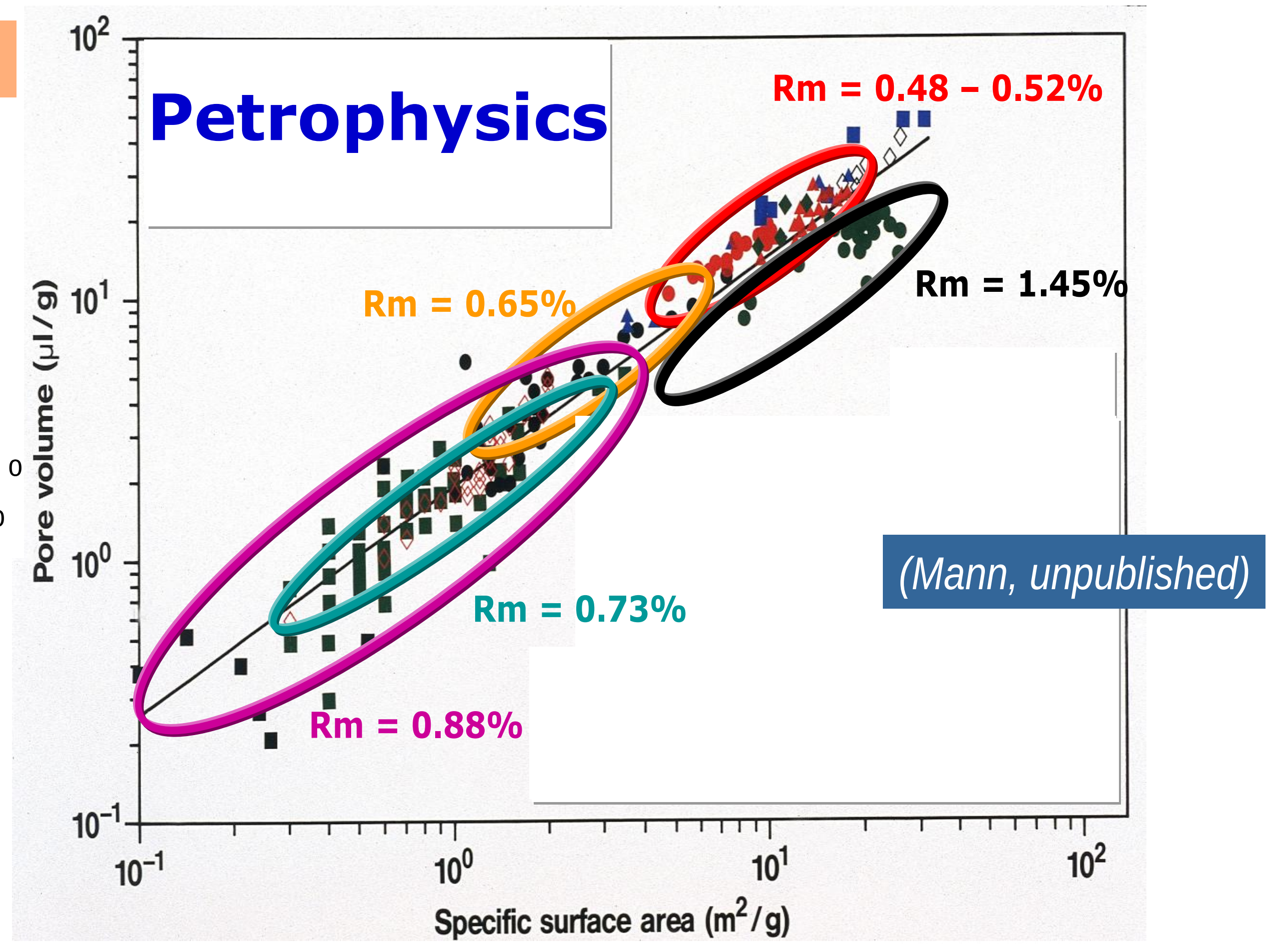
Quick-View 3 Free hydrocarbons



Quick-View 4 Rock properties



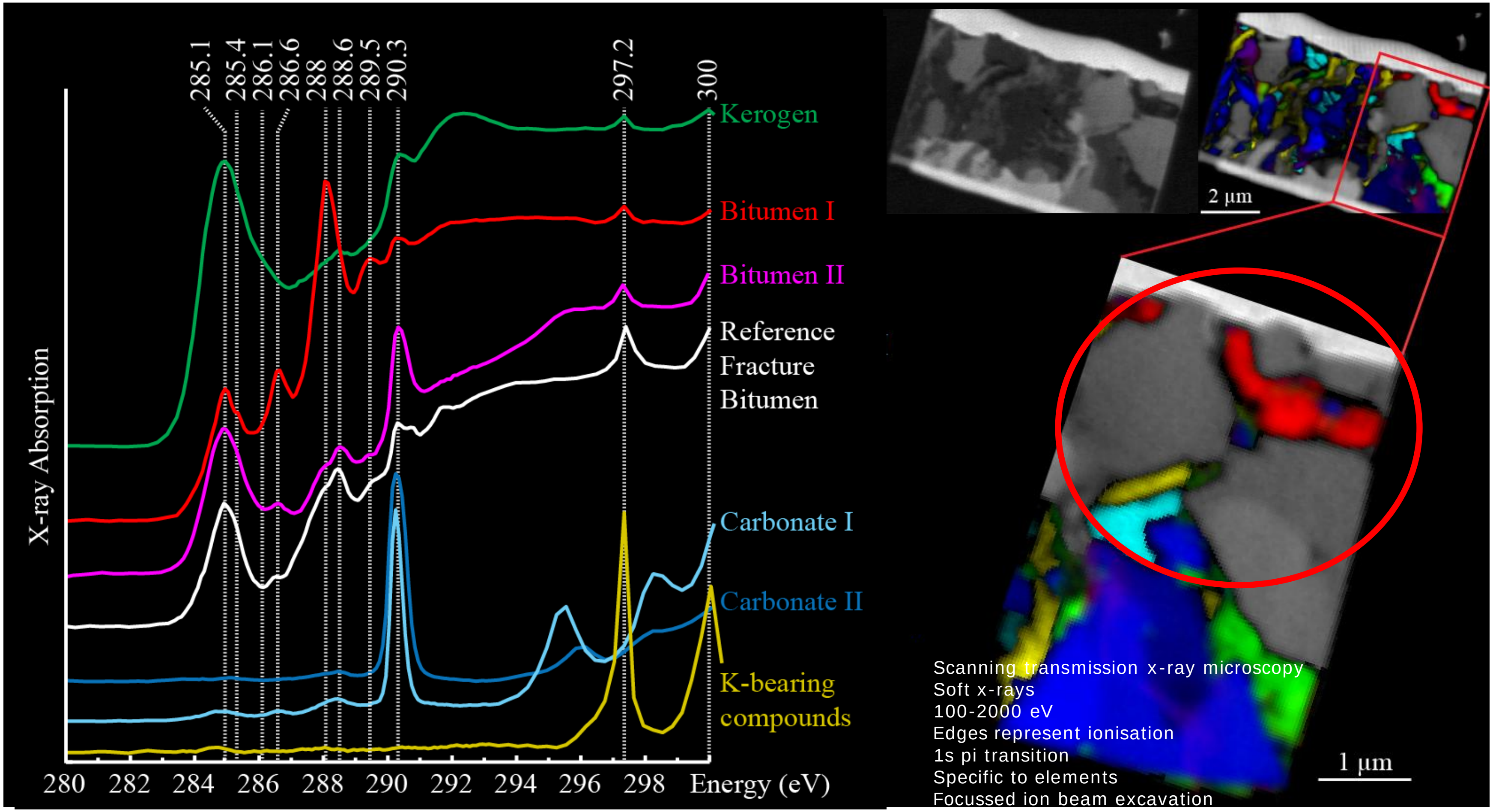
Mineralogy



Quick-View 5 sub-micron level

Bernard et al., 2010

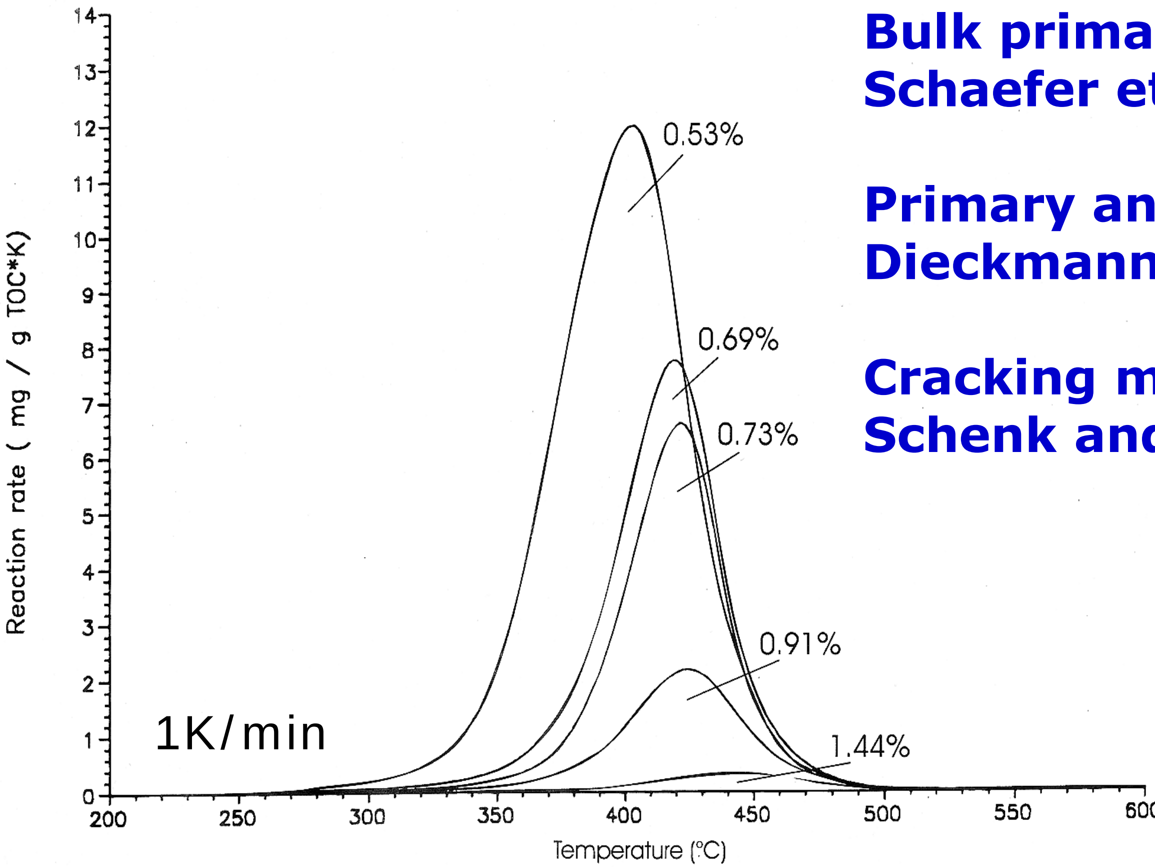
Haddessen Well : STXM characterisation at the C K-edge



Quick-View 6 Cracking Models

Posidonia Shale
YES

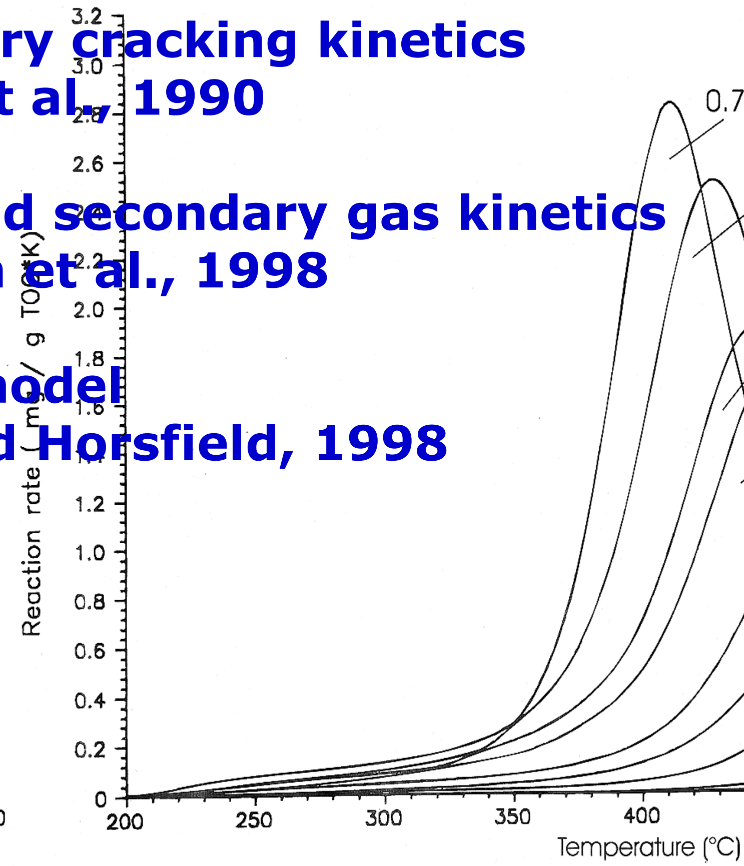
Carboniferous
NO



Bulk primary cracking kinetics
Schaefer et al., 1990

Primary and secondary gas kinetics
Dieckmann et al., 1998

Cracking model
Schenk and Horsfield, 1998



Mass balance models

Regional Carbon Inventory

Merewether and Claypool,1980	Powder River Basin
Jones, 1980	Various incl Green River Formation
Rullkötter et al., 1988	Lower Saxony Basin
Lewan et al. 1995	Illinois Basin
Reed et al., 2010	Marcellus Shale

Expulsion Effects at SR Edges

Leythaeuser et al., 1980 -1986	Numerous
Mackenzie et al., 1987	Kimmeridge

Generation and Migration SR Models

Larter, 1985	Kimmeridge/Draupne, UK and Norway
Pelet, 1985	Toarcian, Paris Basin
Cooles et al., 1986	Worldwide BP
Muscio et al., 1994	Bakken Shale application
Jarvie et al., 2007	Barnett Shale application

Exploration Equation

Gas-in-place

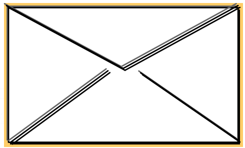
Mass = original OM x conversion x retention efficiency x GOR

Rm range 0.48 – 1.45%

Mass balance calculation **supplemented by** **MSSV pyrolysis**

Rm range > 1.45%

MSSV pyrolysis

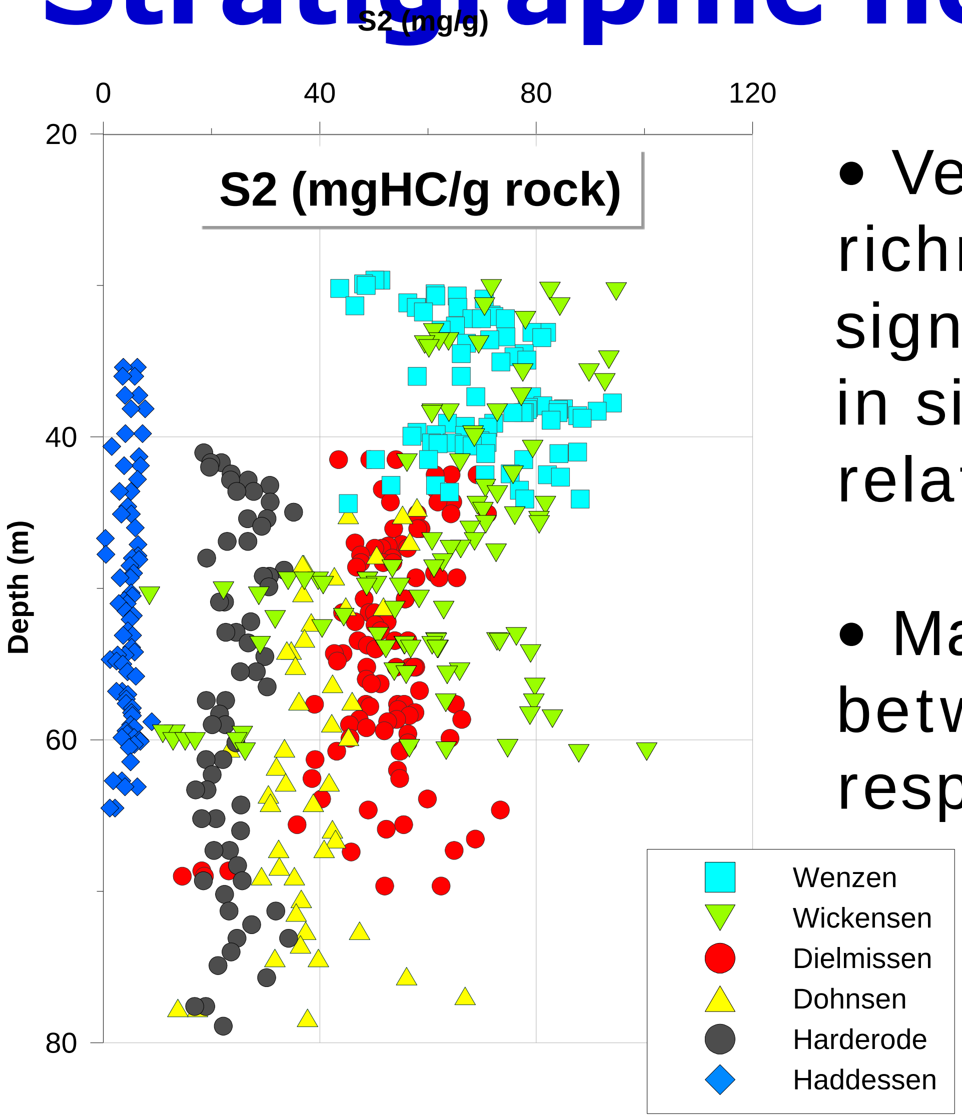


Input Data

476 samples from 6 wells

POSIDONIA STATISTICS		TOC %	S1 mg/g rock	S2 mg/g rock	HI mg/g TOC	PI	Tmax °C
mean of 101 samples	Wickensen	9.66	3.45	61.59	637	0.05	427
mean of 82 samples	Wenzen	10.55	1.12	69.80	662	0.02	424
mean of 48 samples	Dohnsen	8.00	3.64	39.25	491	0.08	449
mean of 104 samples	Dielmissen	9.05	5.96	53.77	594	0.10	439
mean of 64 samples	Harderode	6.79	3.59	24.50	361	0.13	446
mean of 77 samples	Haddessen	5.76	1.19	4.62	80	0.21	458

Stratigraphic heterogeneity



- Vertical heterogeneity in richness and quality is significant on a metre scale in single wells, in part related to shale facies

- Maturity variability between locations is responsible for larger shifts

Extent of Generation

Petroleum Generation Index

$$PGI = \frac{\text{Petroleum Generated} + \text{Initial petroleum}}{\text{Total Petroleum Potential}}$$

$$PGI = \frac{(S2o - S2m) + S1o}{S2o + S1o}$$

Extent of Expulsion

Petroleum Expulsion Efficiency

$$PEE = \frac{\text{Petroleum Expelled}}{\text{Petroleum Generated} + \text{Initial Petroleum}}$$

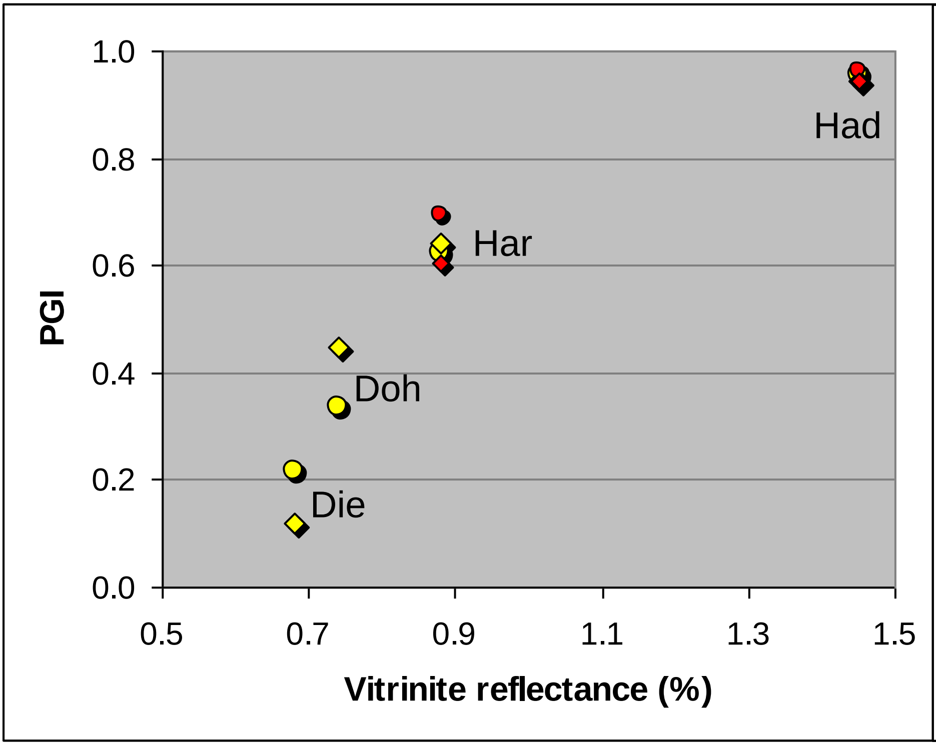
$$PEE = \frac{(S2o + S1o) - (S2m - S1m)}{(S2o - S2m) + S1o}$$

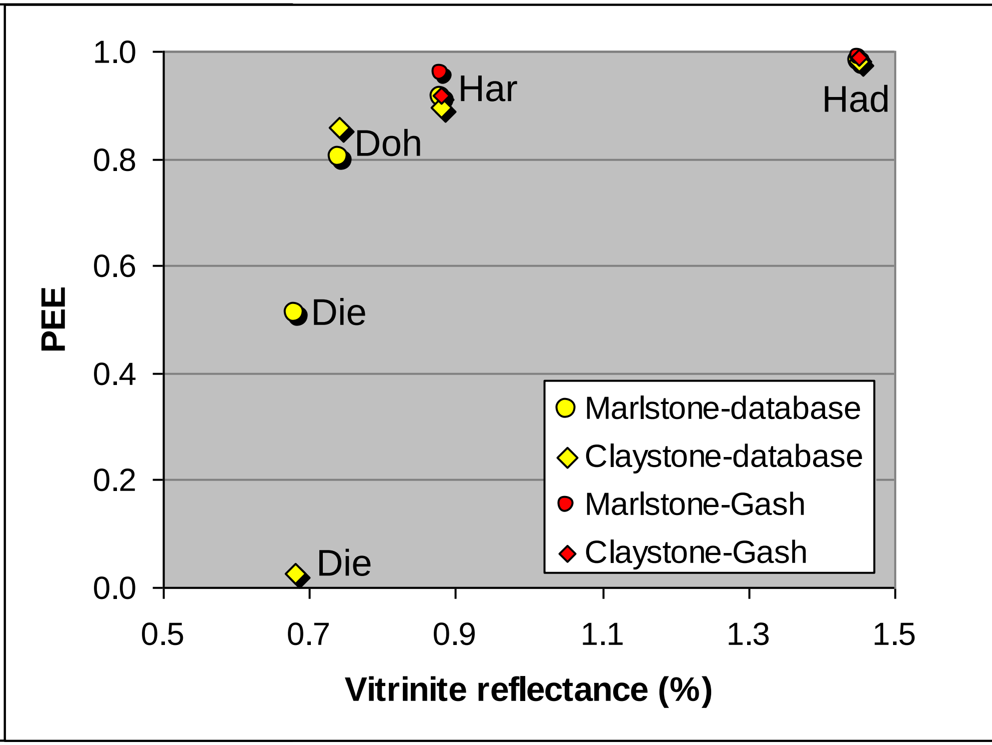
Assess gas loss from S1m using MSSV pyrolysis

Pyrolyse immature sample to the TR that was calculated from the mass balance

$$PGI = \frac{(S2o - S2m) + S1o}{S2o + S1o}$$

Degree of generation and expulsion





High conversion

Efficient expulsion

Exploration Equation

Gas-in-place

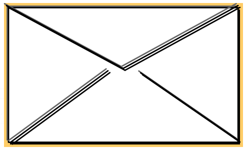
Mass = original OM x conversion x retention efficiency x GOR

Rm range 0.48 – 1.45%

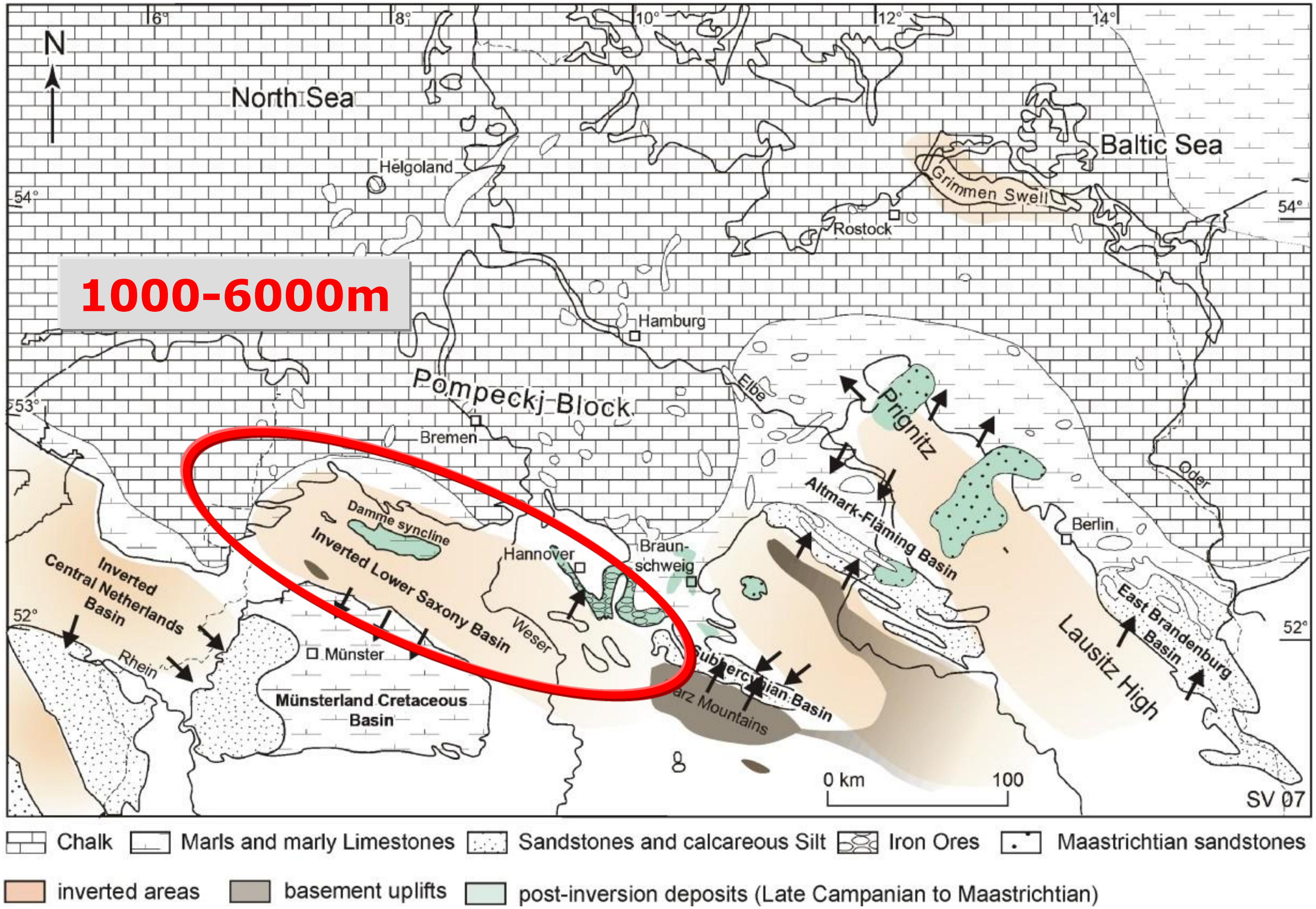
40m thick, 150 sq km
Gas yield = 5.0 * 10^6 metric tons or 0.25 Tcf at 1.45%

Rm range > 1.45%

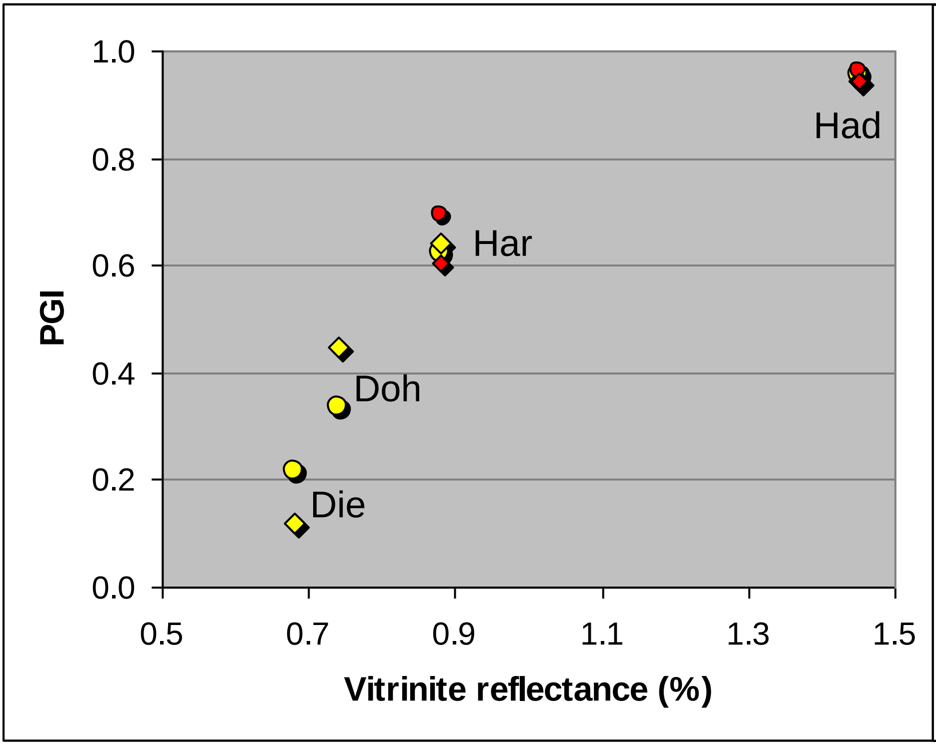
40m thick, 150 sq km
Maximum gas yield of 2.5 Tcf
50 bcf per sq mile

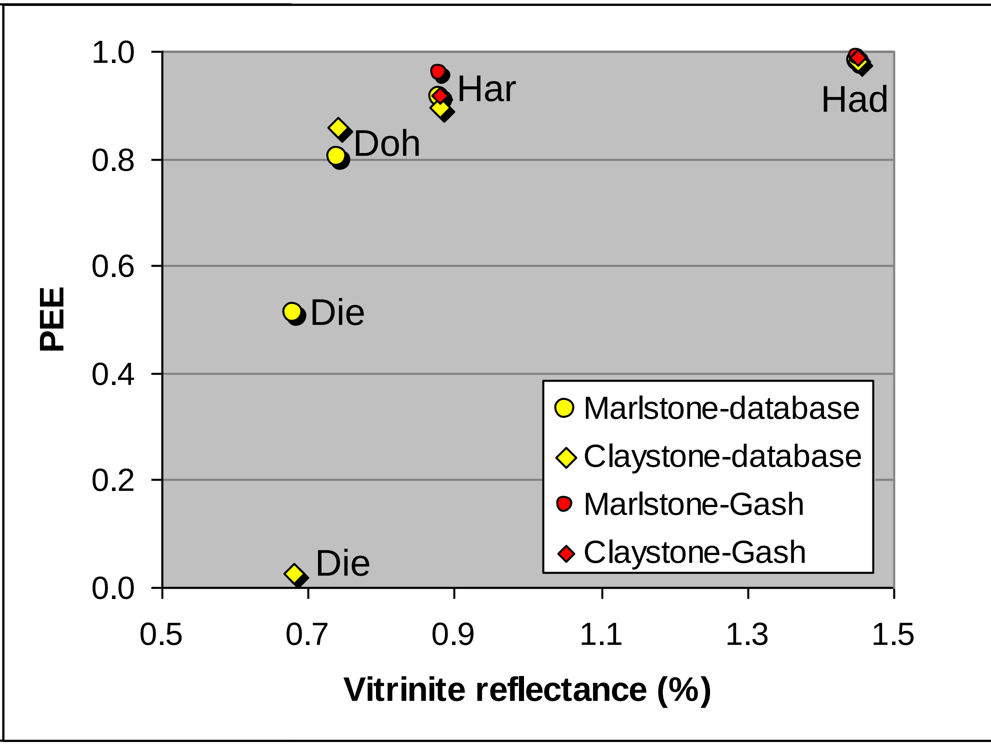


Inversion and GOR



Phase behaviour
of cumulative and instantaneous fluids

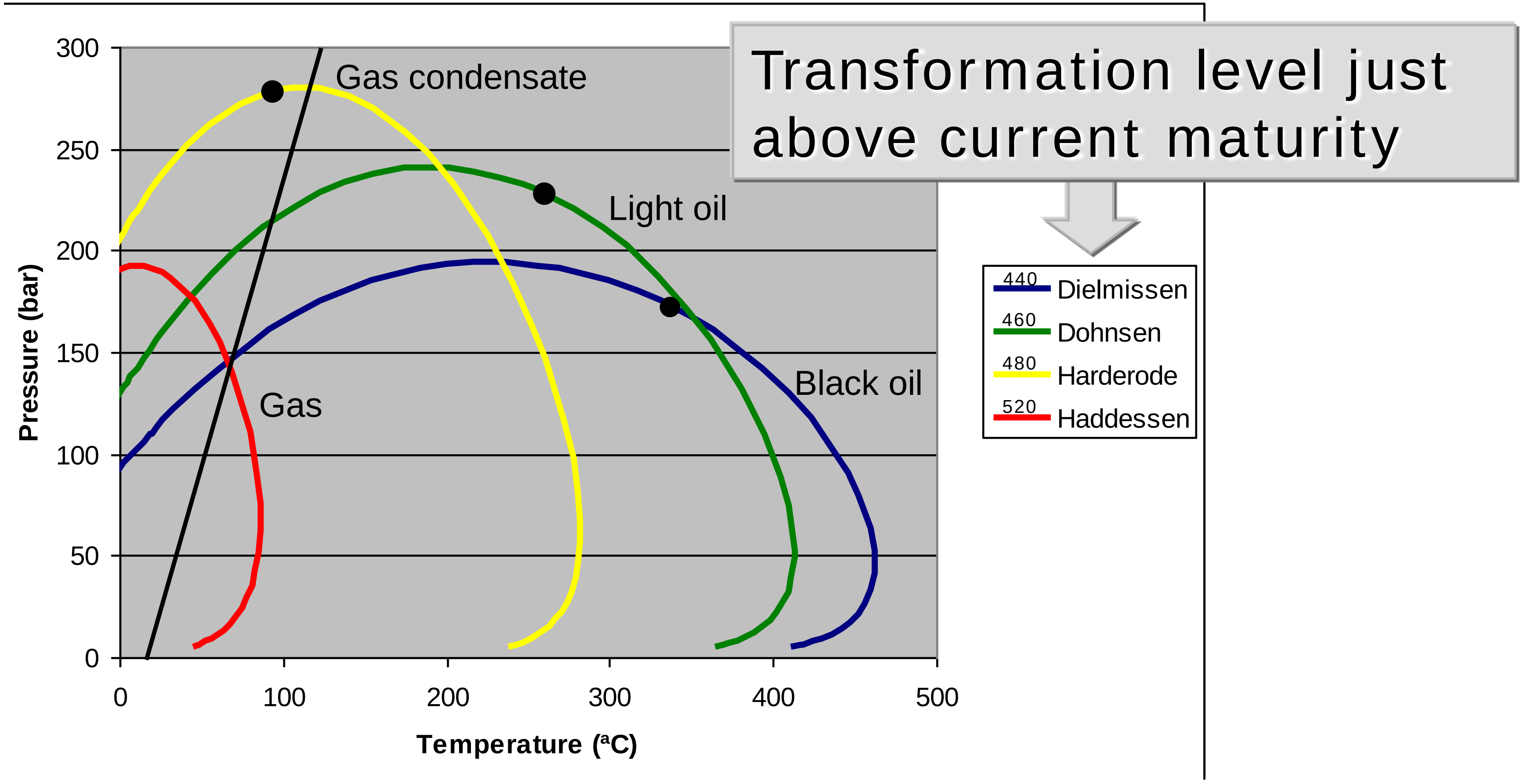




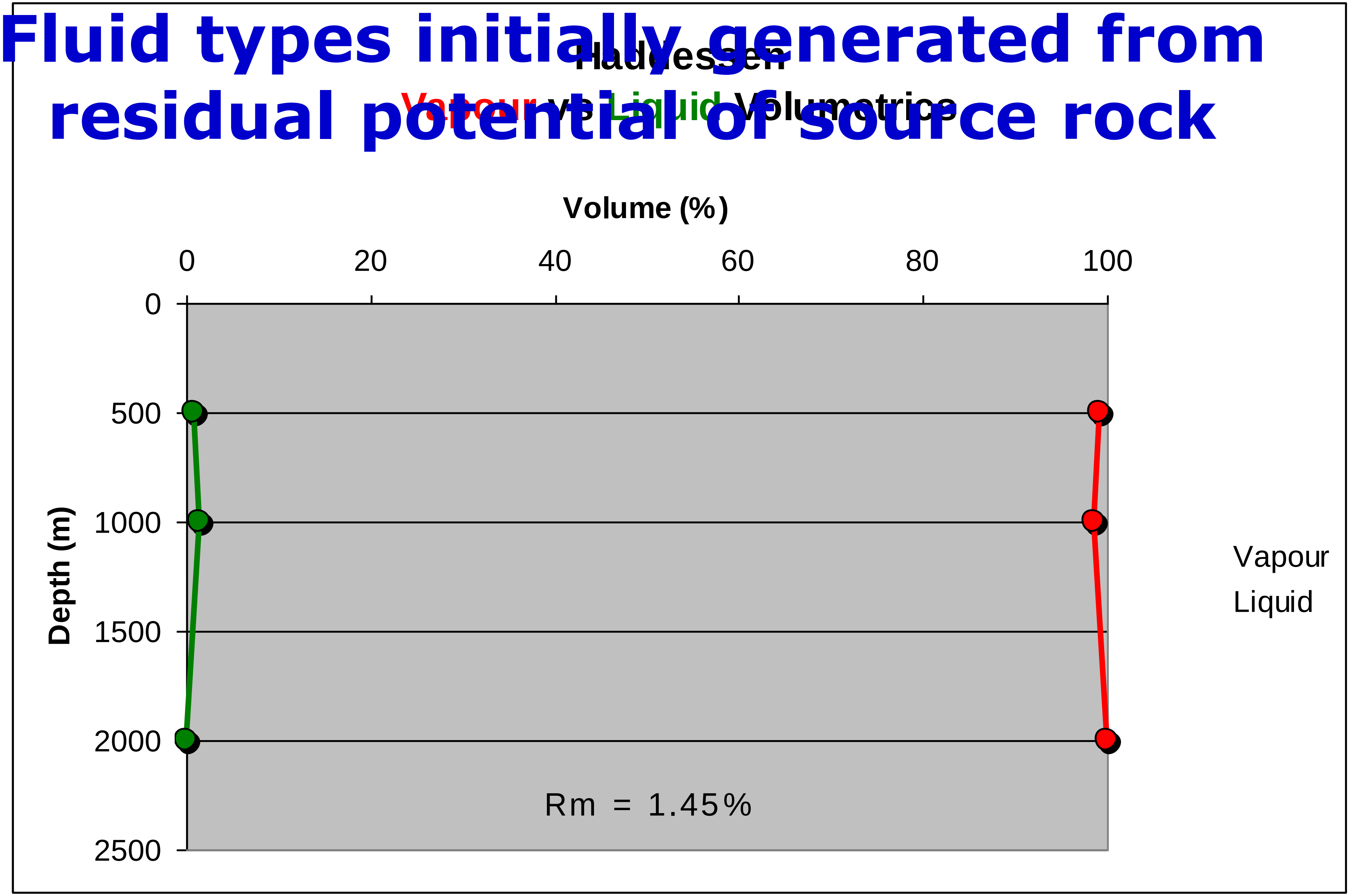
High conversion

Efficient expulsion

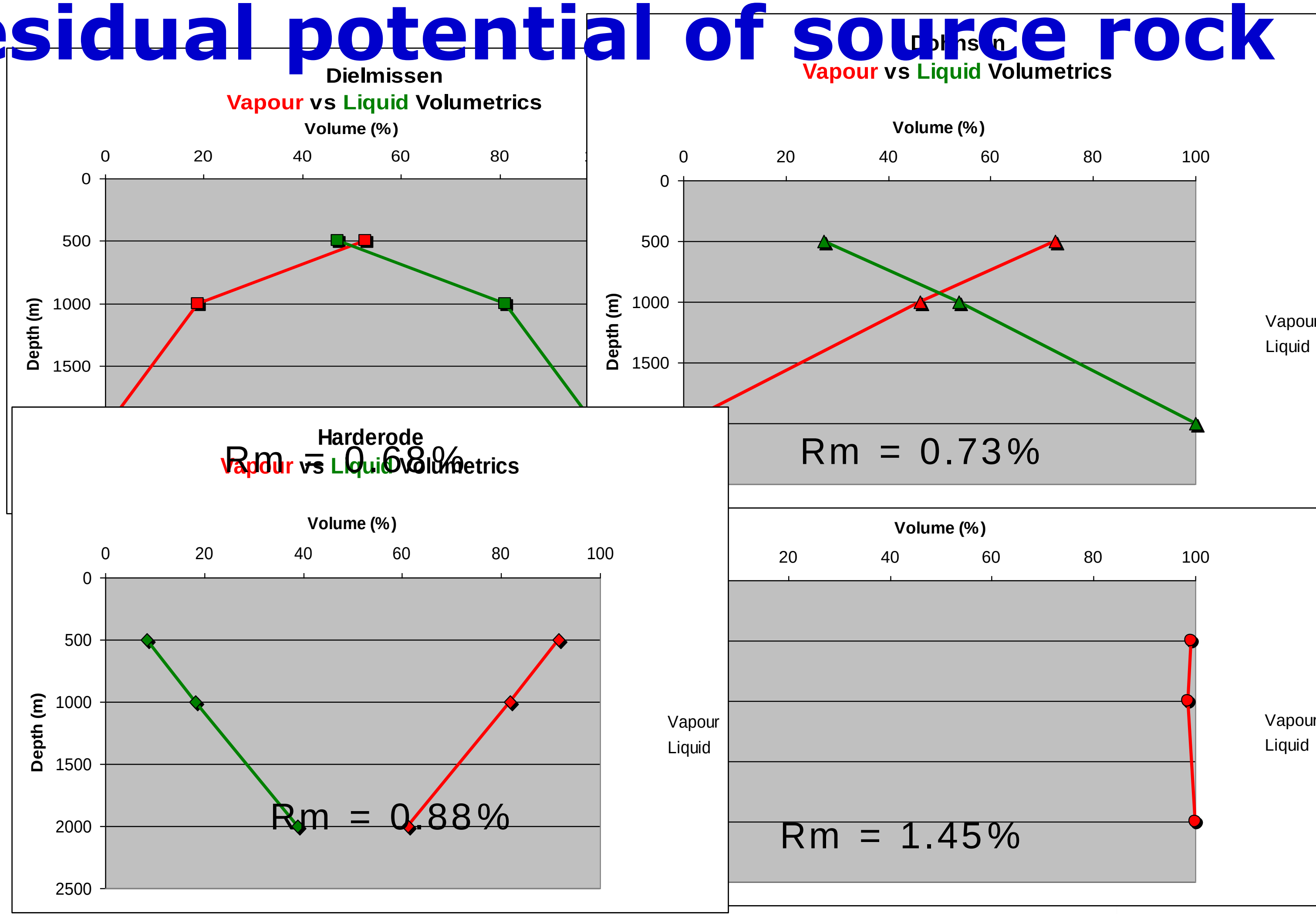
Instantaneous compositions



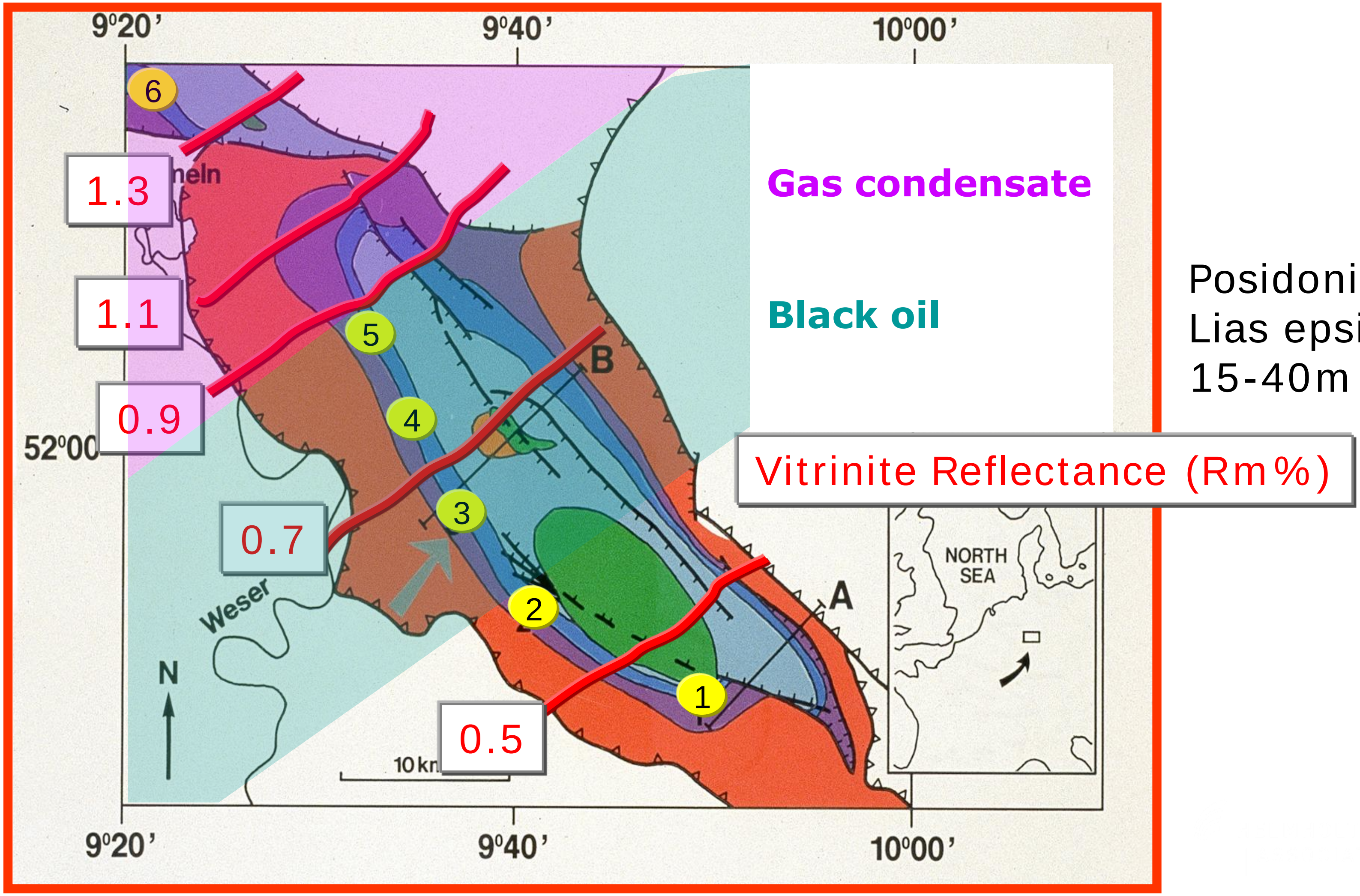
Fluid types initially generated from residual potential of source rock



Fluid types initially generated from residual potential of source rock



Influence of phase behaviour



Posidonia Shale
Lias epsilon
15-40m thick

Conclusions

- Posidonia Shale is an efficient expeller of liquid hydrocarbons
- At Rm >1.45% the Posidonia Shale fulfills empirical shale gas criteria
- Upscaling: 2.5 Tcf for 40m thickness over 150 sq km in LSB
- PVT plays key role in GOR control of potential shale oil plays

Gas Shales in Europe

GASH
Gas Shales in Europe

Reservoir scale, regional scale, black shale database

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brgm Géosciences pour une Terre durable · BGS · NGU Norges geologiske undersøkelse · Geological Survey of Belgium · Ministerio de Educación y Ciencia, Instituto Geológico y Minero de España · Państwowy Instytut Geologiczny · SGU Sveriges geologiska undersökning Geological Survey of Sweden