

Gas Generation and Retention in the Bakken Shale, Williston Basin*

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Abstract

The Bakken Shale is charged with high concentrations of indigenous gas at low levels of maturity ($Ro = 0.3 - 0.7\%$). A good correlation with TOC demonstrates that the gas is adsorbed to indigenous bitumen and kerogen. During the succeeding levels of early catagenesis the kerogen structure loses diaromatic components by generation and migration and/or cross-linking and condensation, and the gas is no longer retained. The origin and fate of the gas seems intrinsically linked to that of the diaromatic structural units in the organic matter which we know are inherited from green photosynthetic sulphur bacteria living in the water column under photic zone euxinia above the site of source rock deposition.

Here we employ organic geochemistry and basin modelling to evaluate the shale gas potential of the Bakken Shale and to place findings within a petroleum systems context. Compositional kinetics have been measured to predict GOR development as a function of maturity, and to establish the phase behaviour of the generated fluids. The Bakken Shale is indeed inherently more gas-prone than many marine source rocks worldwide, exhibiting a lower saturation pressure.

Carbon and hydrogen isotopes have been utilized to trace the origins and fate of the light hydrocarbons occurring in a free form, the diaromatic units and also the latter's thermal degradation products. To facilitate comparisons with known shale gas provinces, star diagrams based on TOC, Tmax, vitrinite reflectance, Transformation Ratio and light hydrocarbon concentrations have been constructed. Potential sweet spot definition will be presented.

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ExxonMobil



Take home messages

1. Shale oil and shale gas exploration and production – source rock properties of paramount importance
2. Organic matter properties help govern dysfunctionality in the case of the Bakken Shale
3. Is HI of 300 mg/gTOC critical? Change in adsorptive properties related to disappearance of certain aromatic units from the kerogen.
4. Bakken is a low GOR system overall - variability in field GOR is complex: generation kinetics and phase behavior are important.

The Bakken Shale

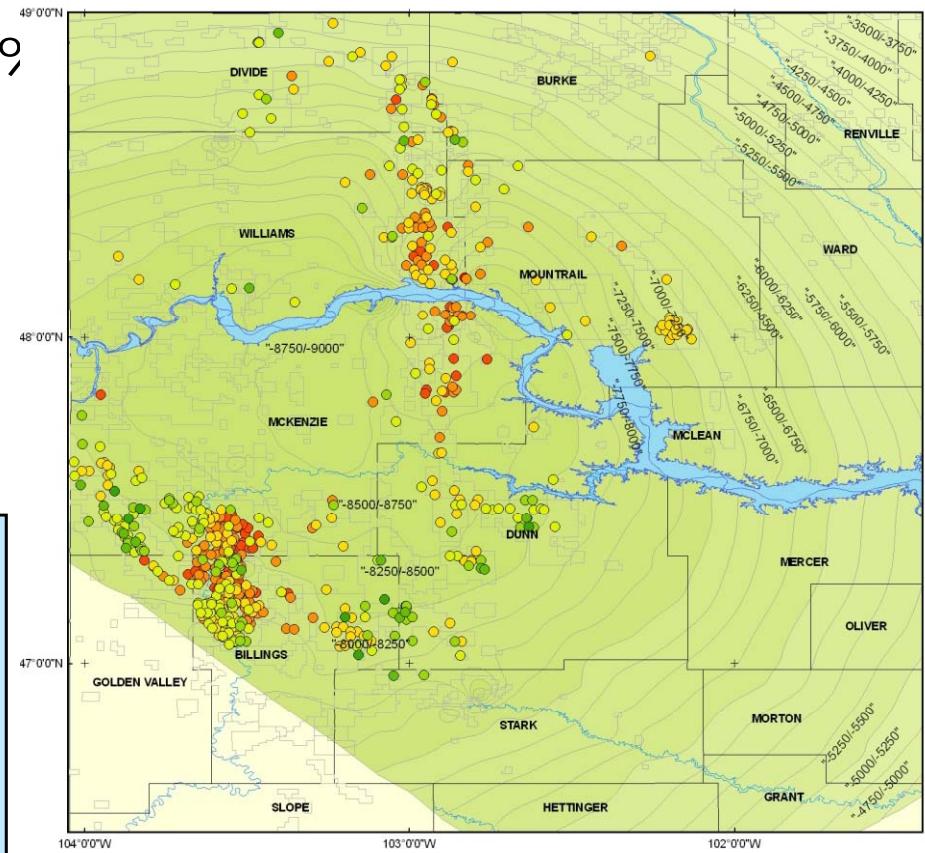
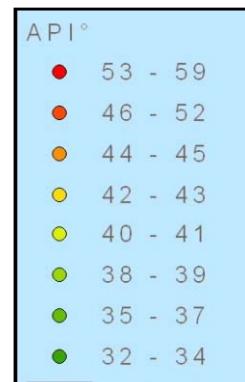
➤ Paleozoic Source Rock

- Uniform facies Type II (basin centre)
- Broad maturity range 0.3 – 1.6 %
- TOC 6-20%
- Overpressured where mature



➤ In-Situ Petroleum

- Paraffinic composition
- High API gravity
- High in gasoline
- Low in sulphur



Selected References

WILLIAMS (1974)

Correlation of Madison oils with Bakken source

MEISSNER (1978)

Regional overpressuring of Bakken in-source reservoir

PRICE (1984)

Comprehensive Organic Geochemical Characterisation of Bakken
Significance of Gas for Migration Behaviour of Bakken Petroleum

JARVIE & ELSINGER (1996)

Oil systems

MUSCIO ET AL. (1994)

Early gas generation

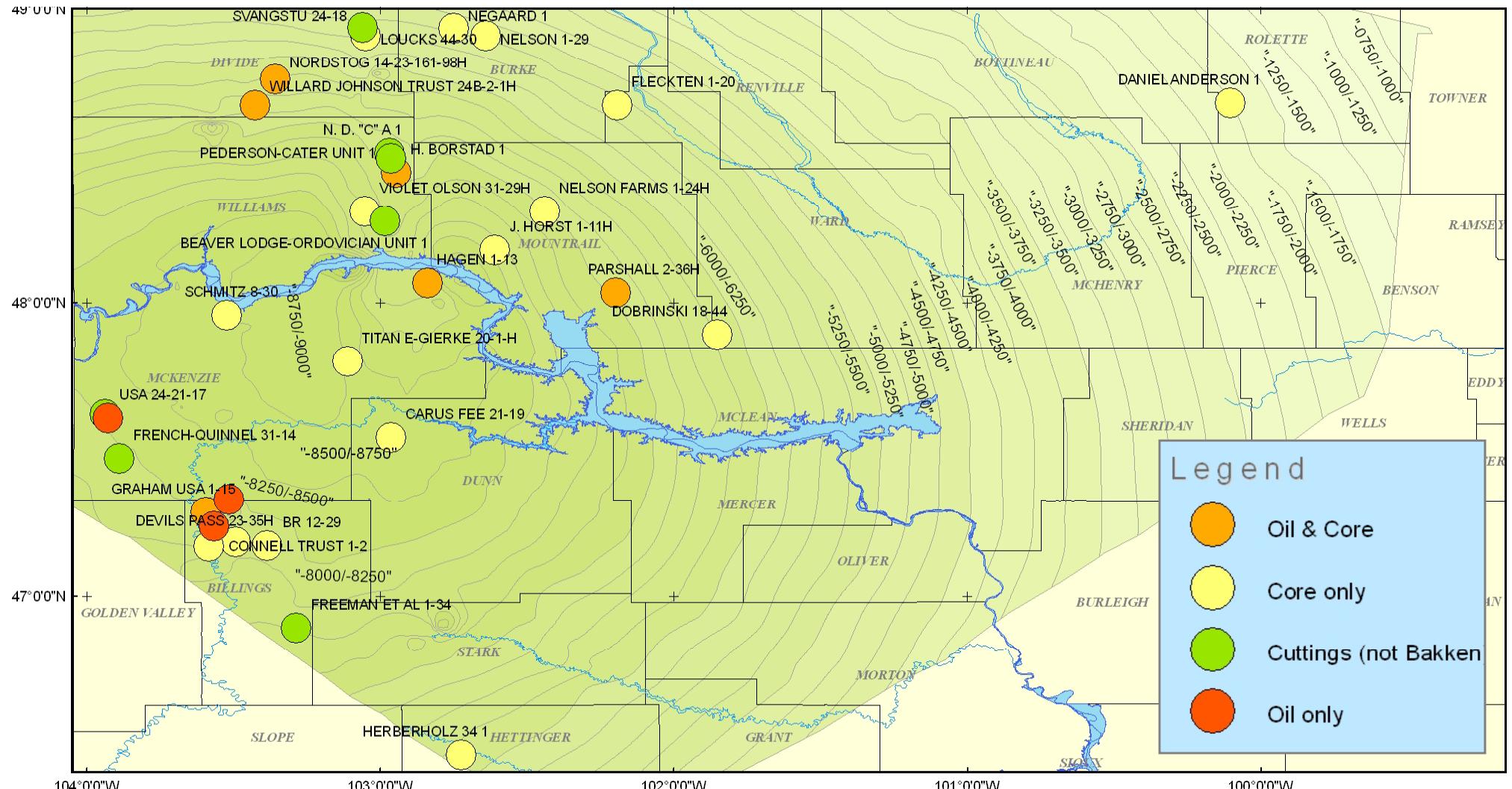
MUSCIO AND HORSFIELD (1996)

Unusual maturation characteristics

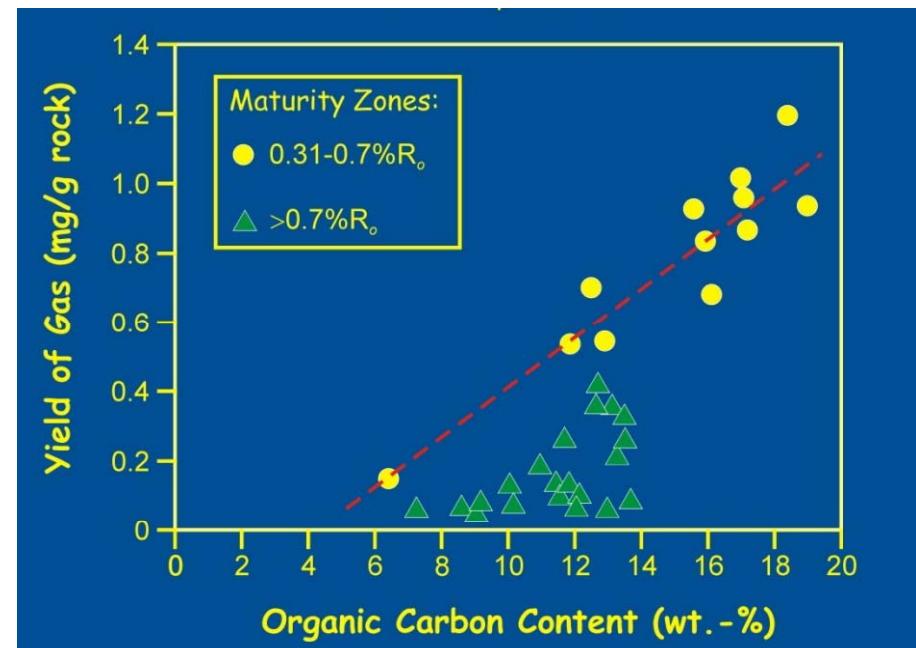
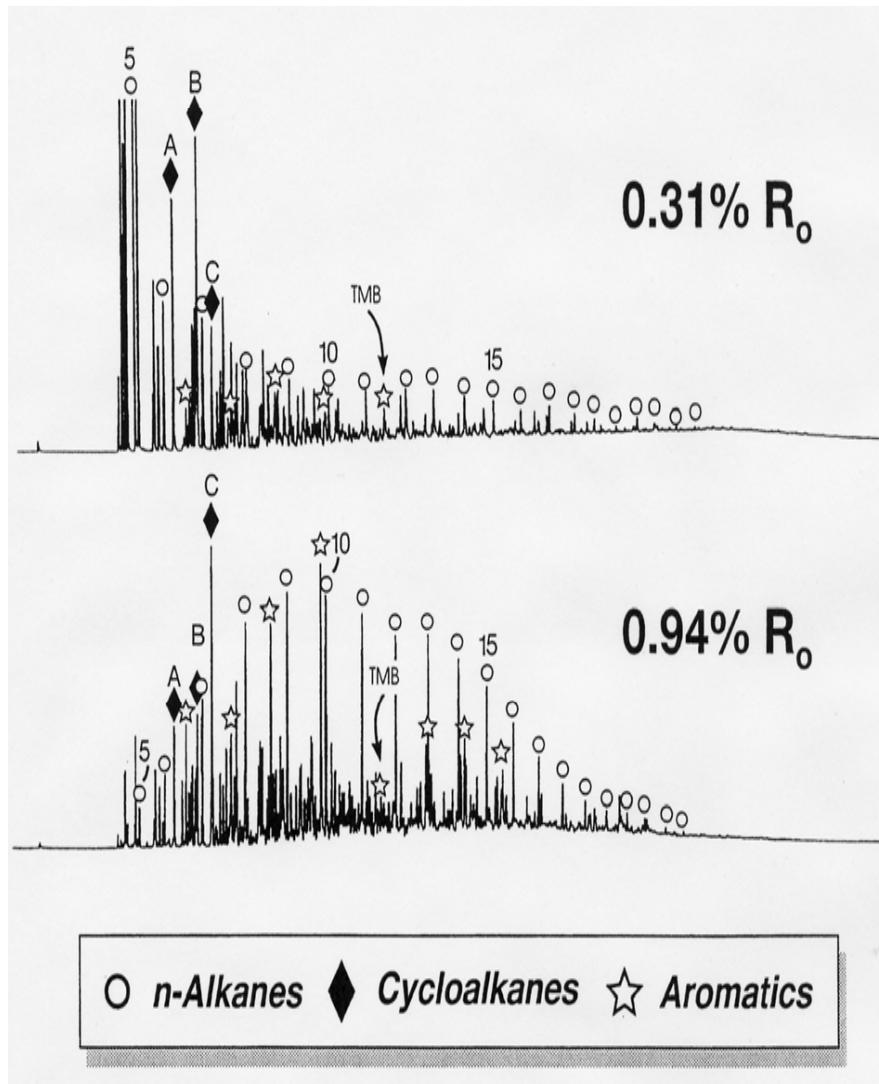
Today's Presentation

- Physical and chemical changes that take place during maturation
 - Adsorptive properties
 - GOR
 - Saturation pressure
 - Part 1: natural maturation series
 - Part 2: simulated maturation series
- 
- Bulk petroleum characteristics

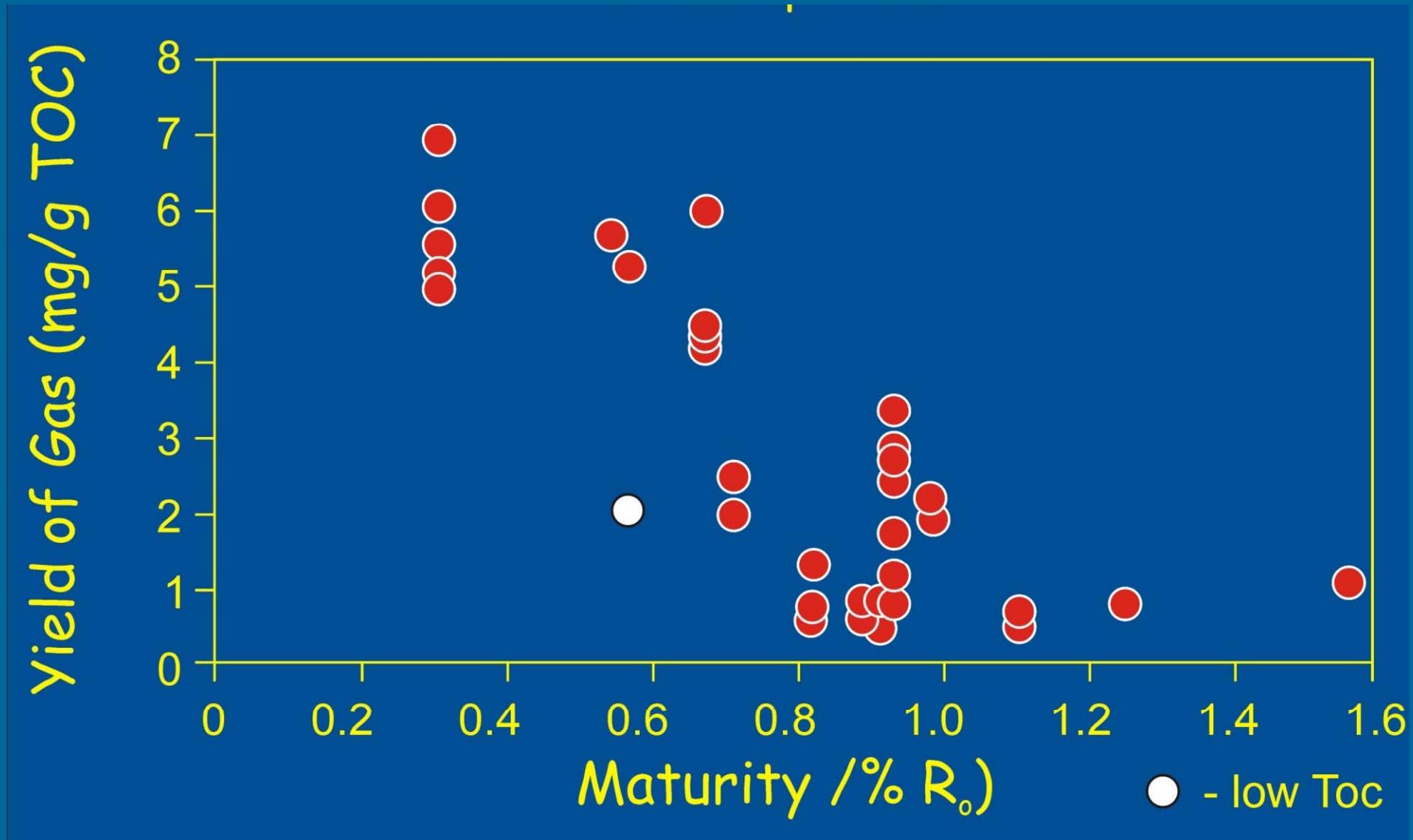
Samples



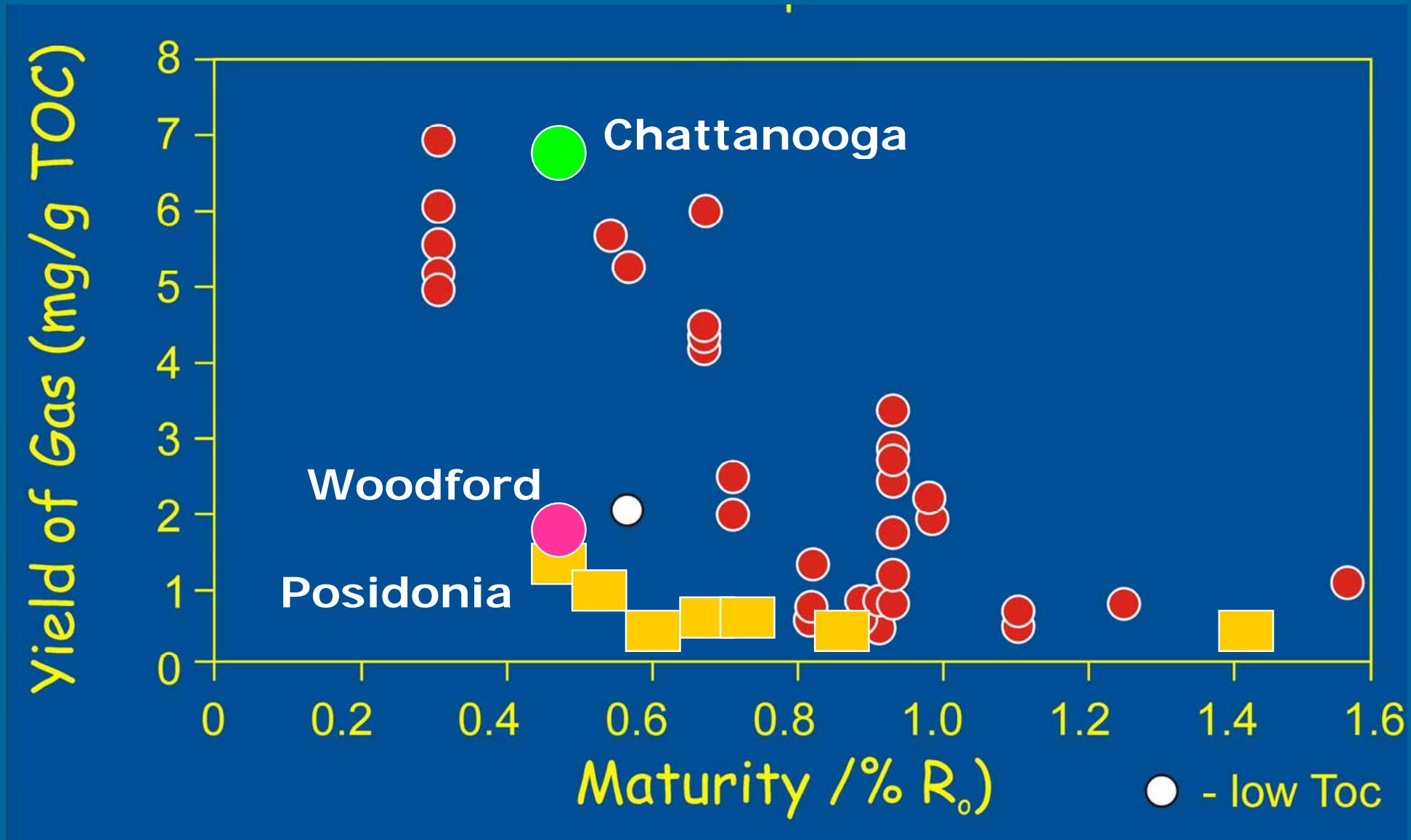
Early Gas in the Bakken Shale



Gas Yield as a function of maturity

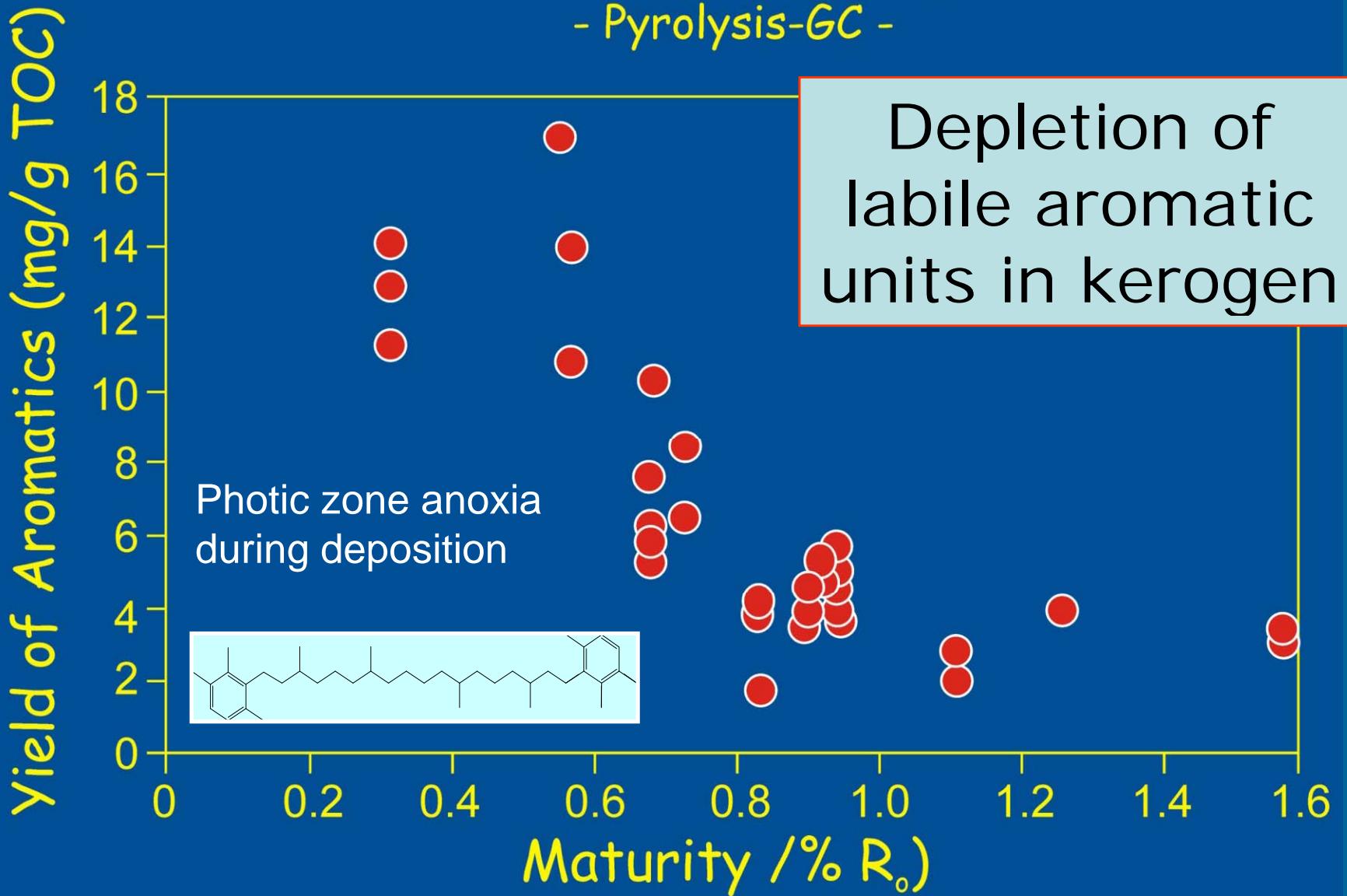


Gas Yield as a function of maturity



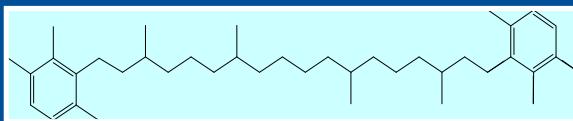
Kerogen Structure

- Pyrolysis-GC -



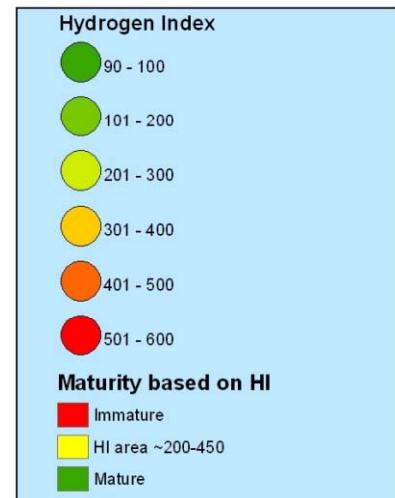
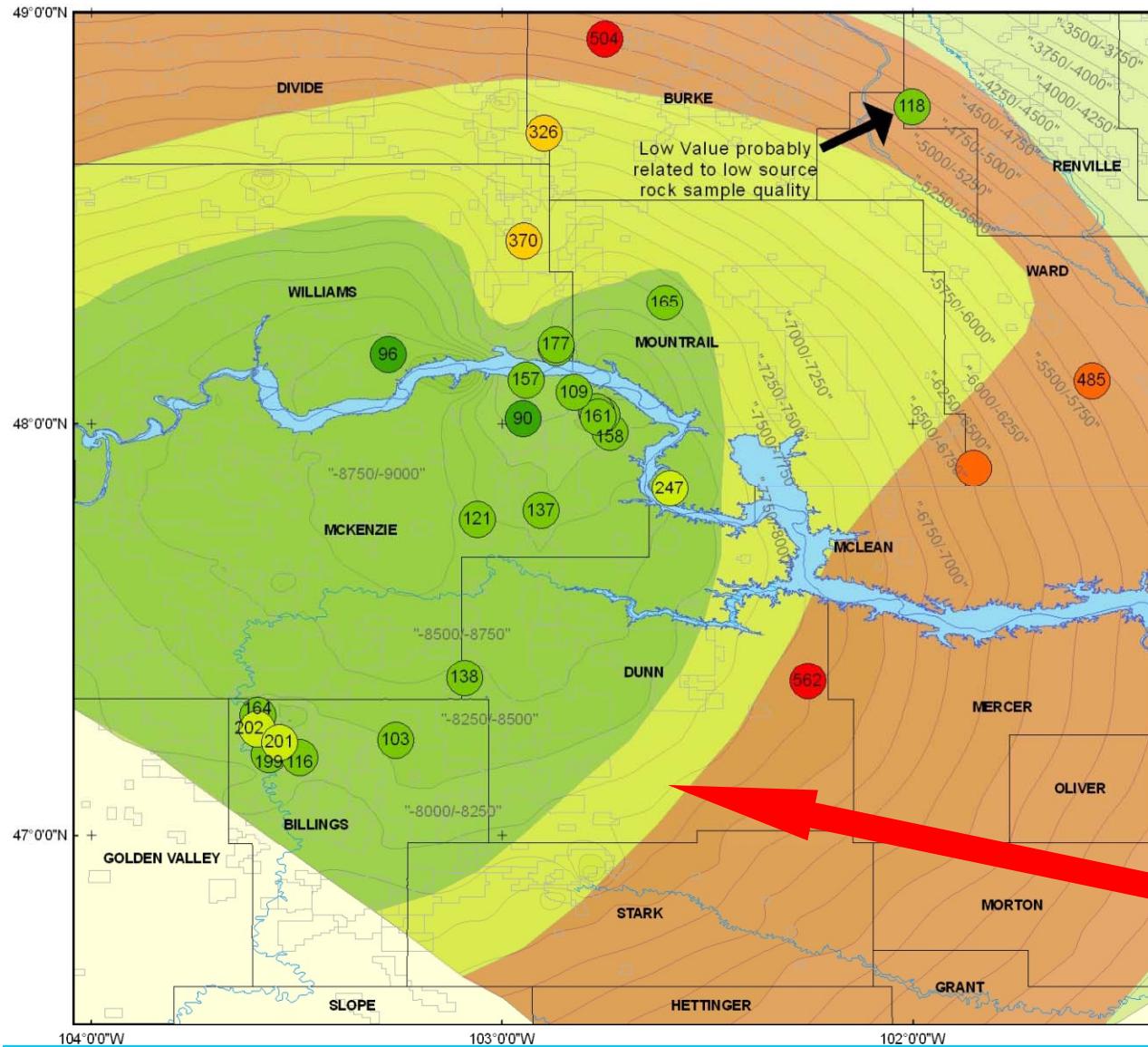
Depletion of
labile aromatic
units in kerogen

Photic zone anoxia
during deposition



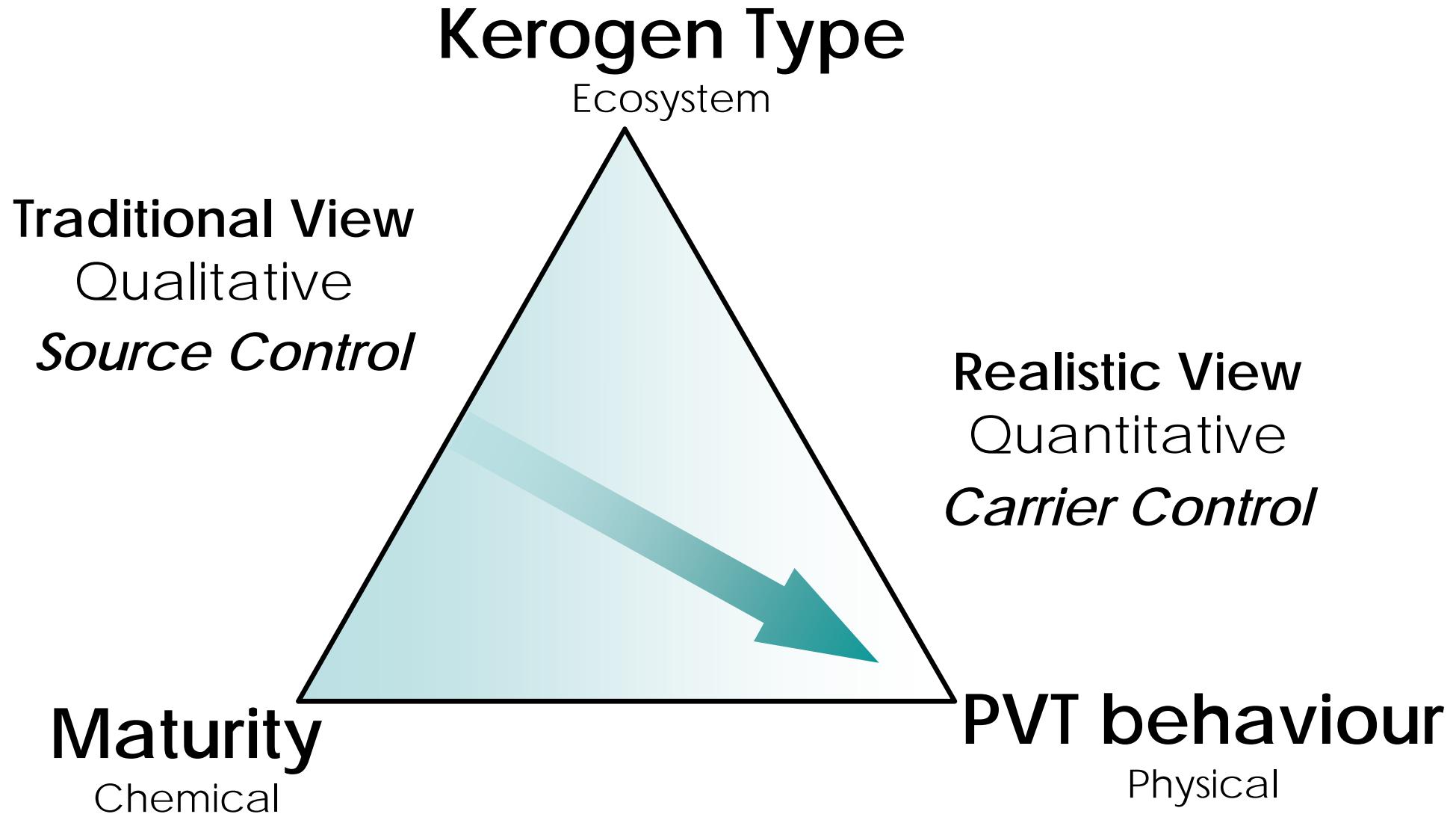
Hydrogen Index Zonation

(approximate)



Zone of lowered
adsorption
capacity
due to structural

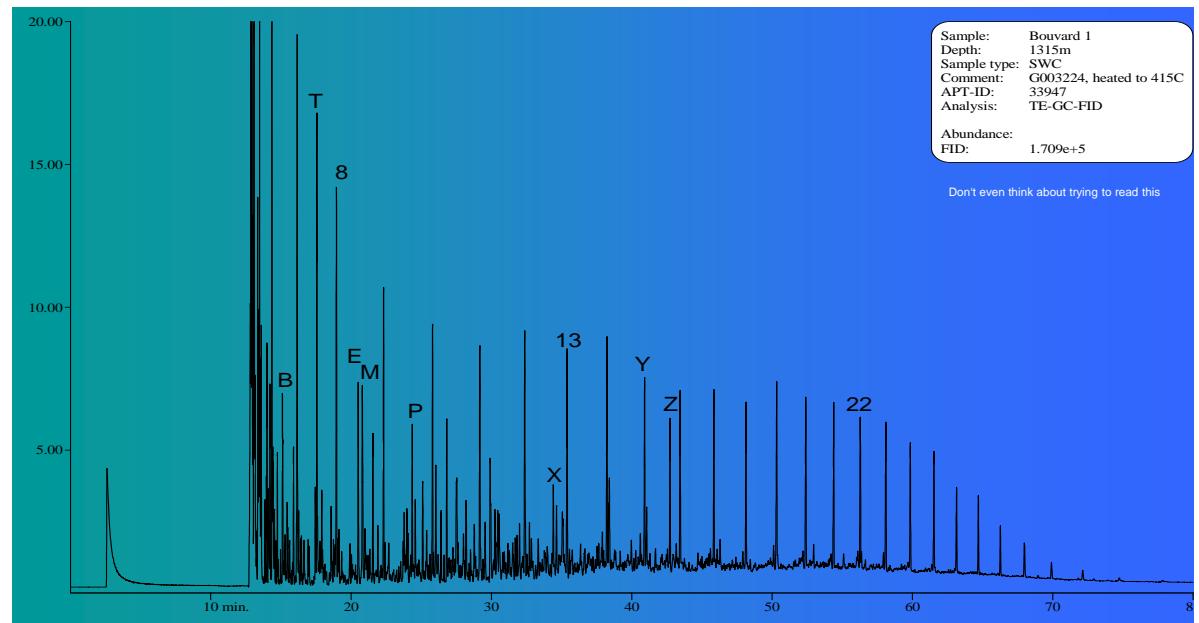
Petroleum Quality in Reservoirs



Simulated Maturation using MSSV pyrolysis (Horsfield et al., 1989)

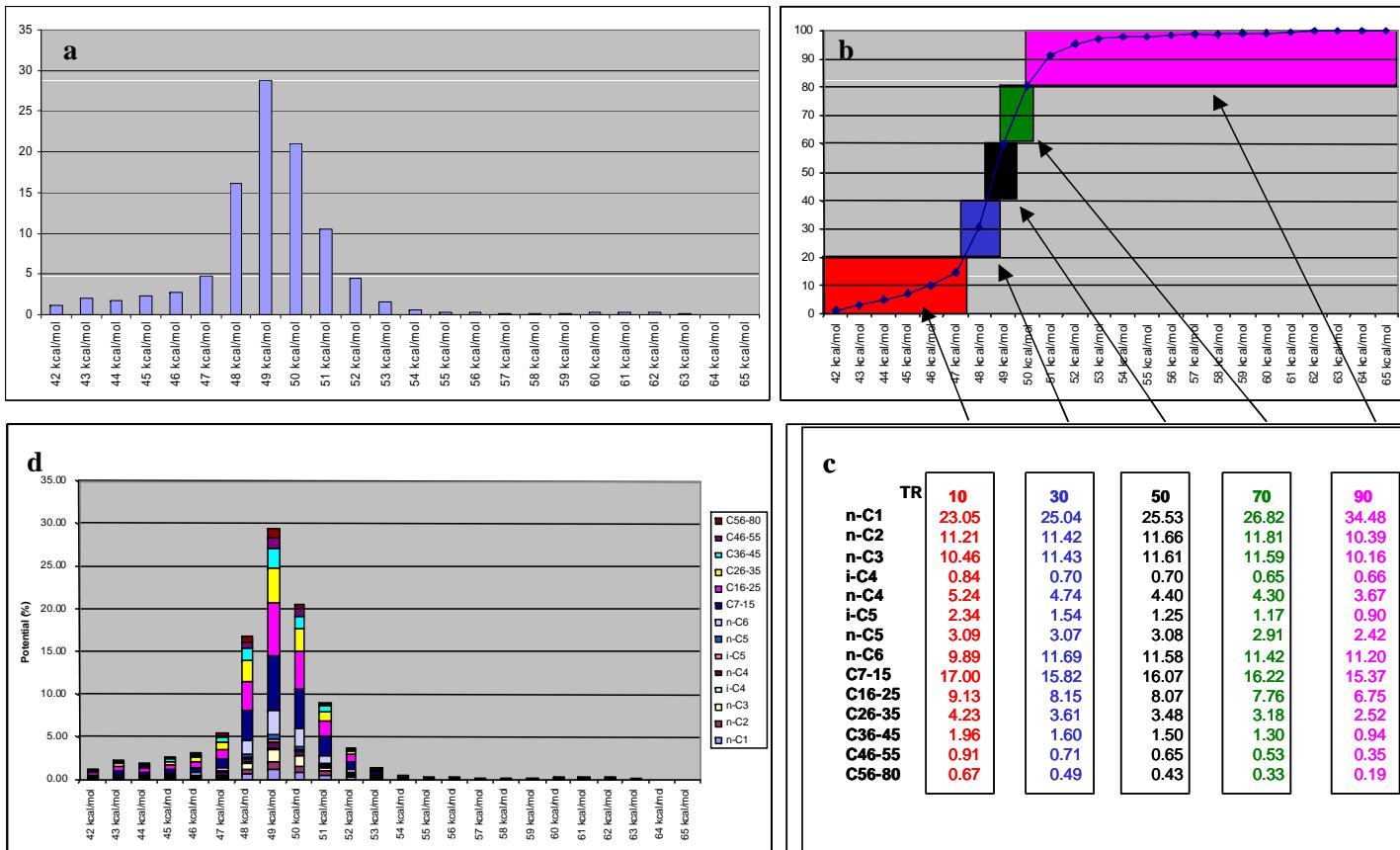


- Distillation fractions
- Compound classes
- Individual compounds



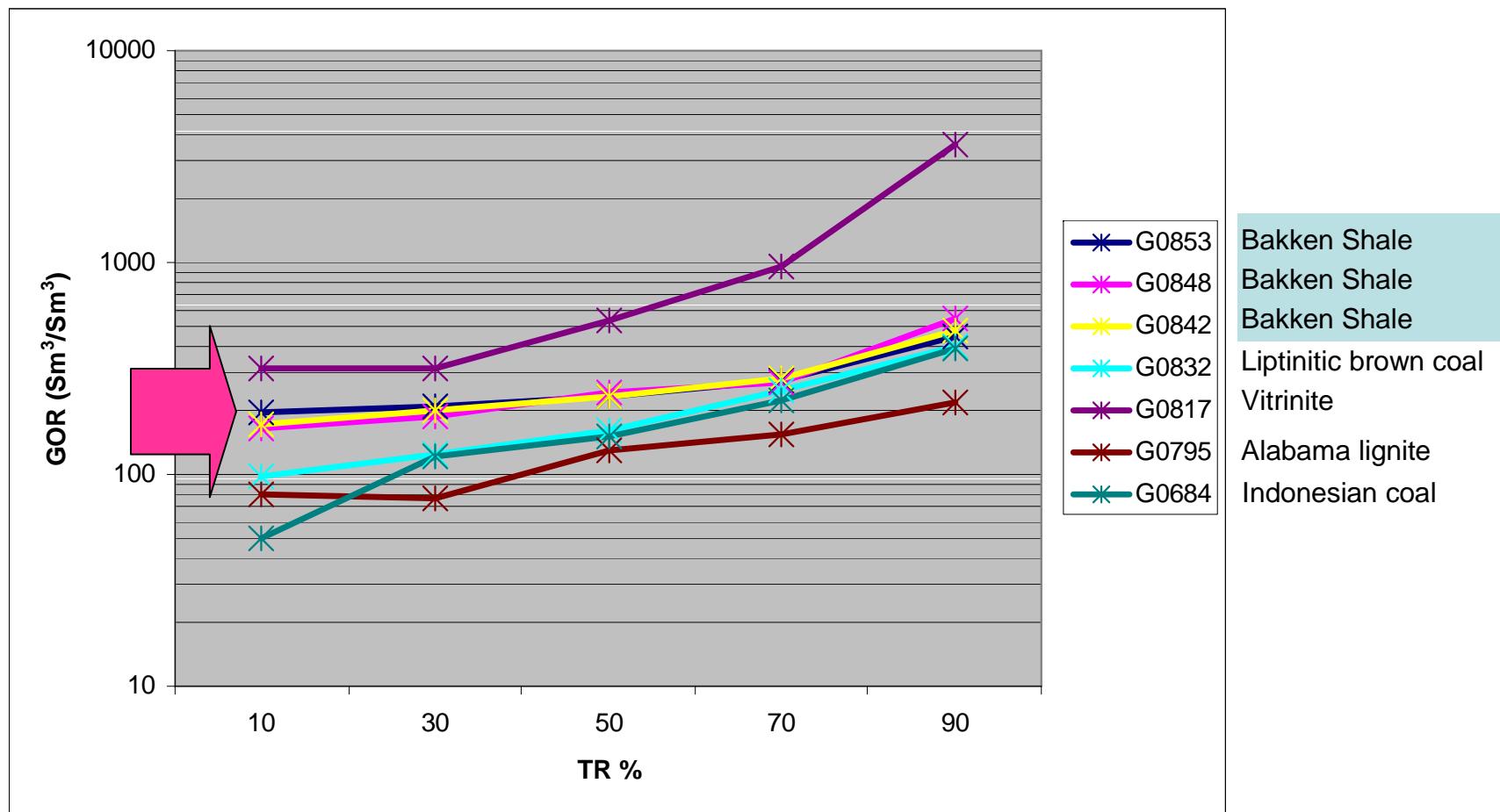
Compositional Kinetic Model

Gases – Individual components, tuning
 Liquids – Boiling ranges, molecular weight and density



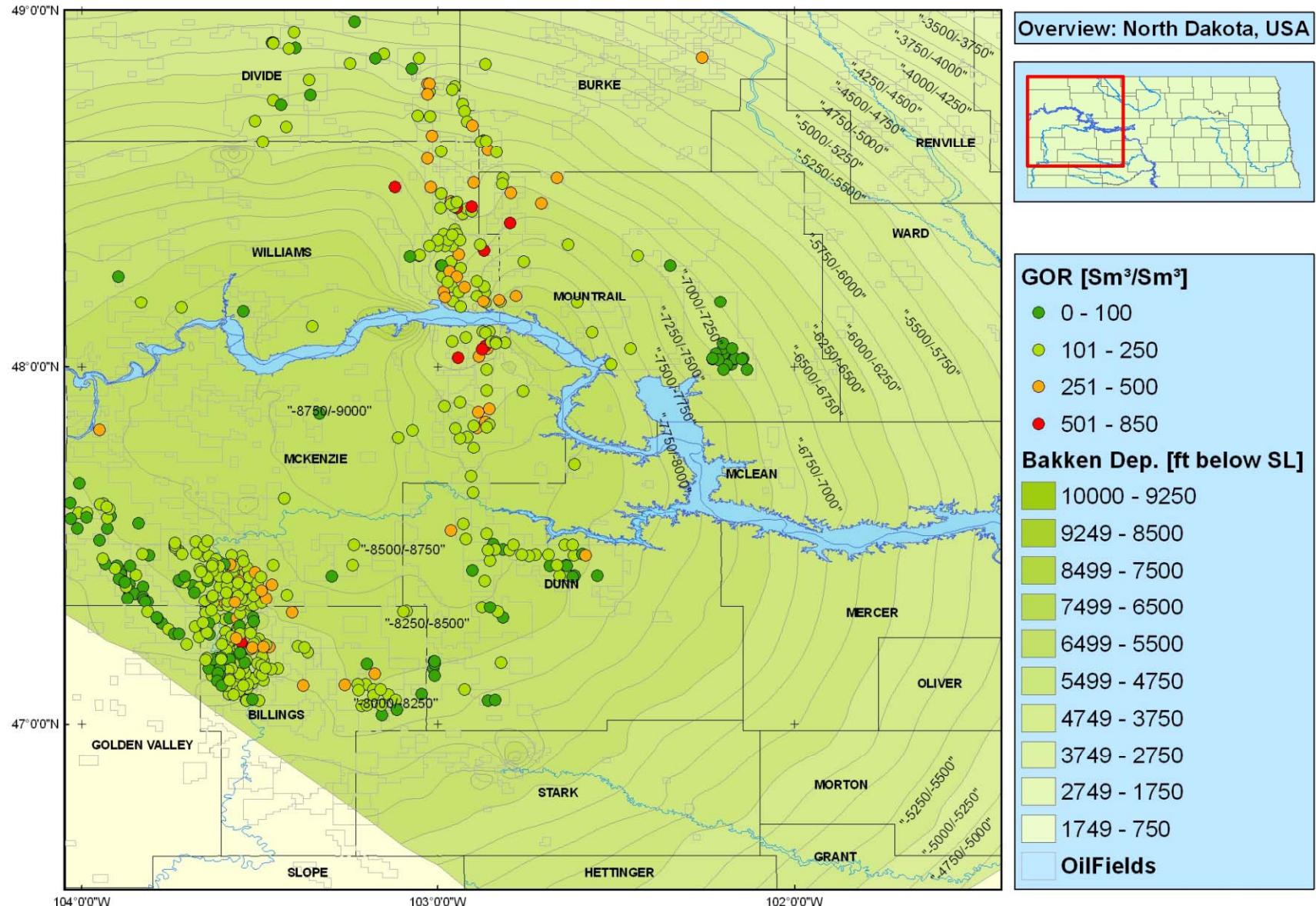
Cumulative GOR versus maturity

Range: 200 – 600 m³/m³
 800 – 2400 scf/bbl



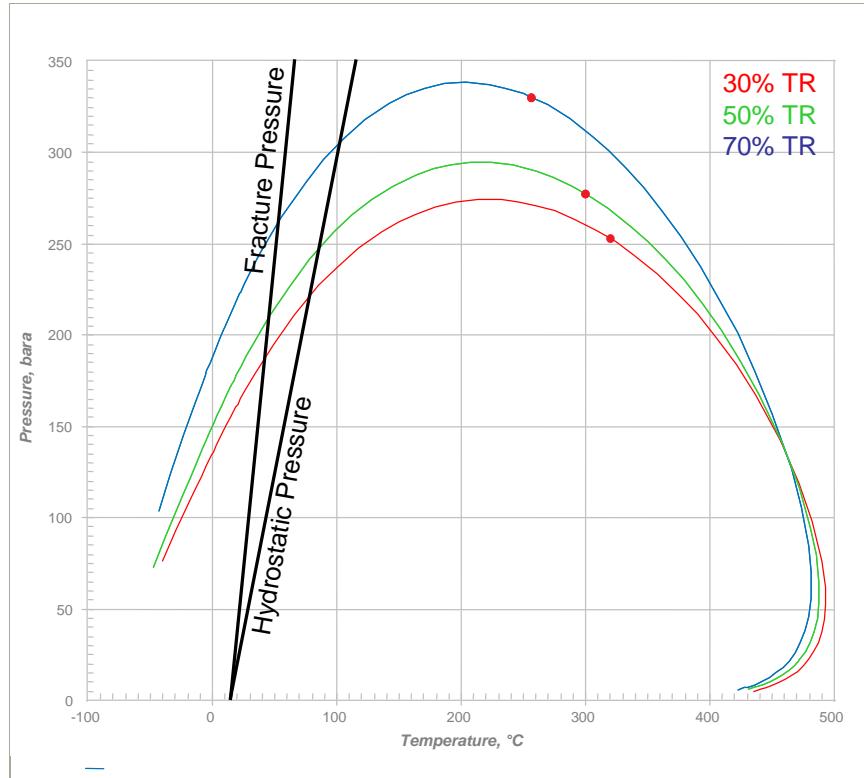
	0.01	0.1	1	10	kg/kg
Scf/bbl	50	500	5000	50000	
	10	100	1000	10000	Sm ³ /m ³

GOR of Bakken Tested Fluids

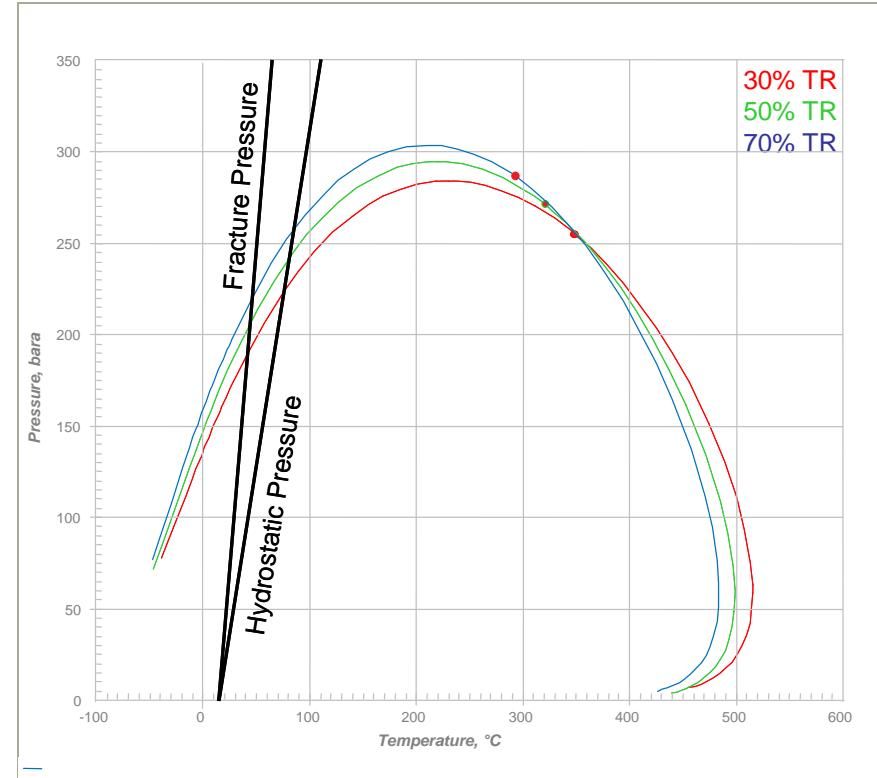


Predicted Phase Envelopes

2 Bakken samples at 3 stages of maturation



Bakken Fm. G000852

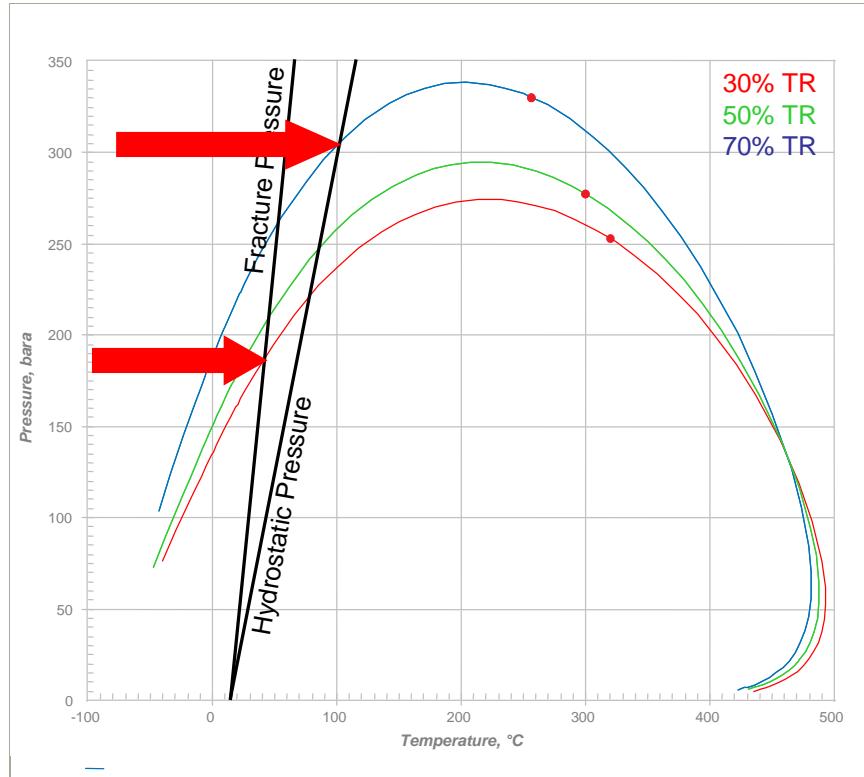


Bakken Fm. G000842

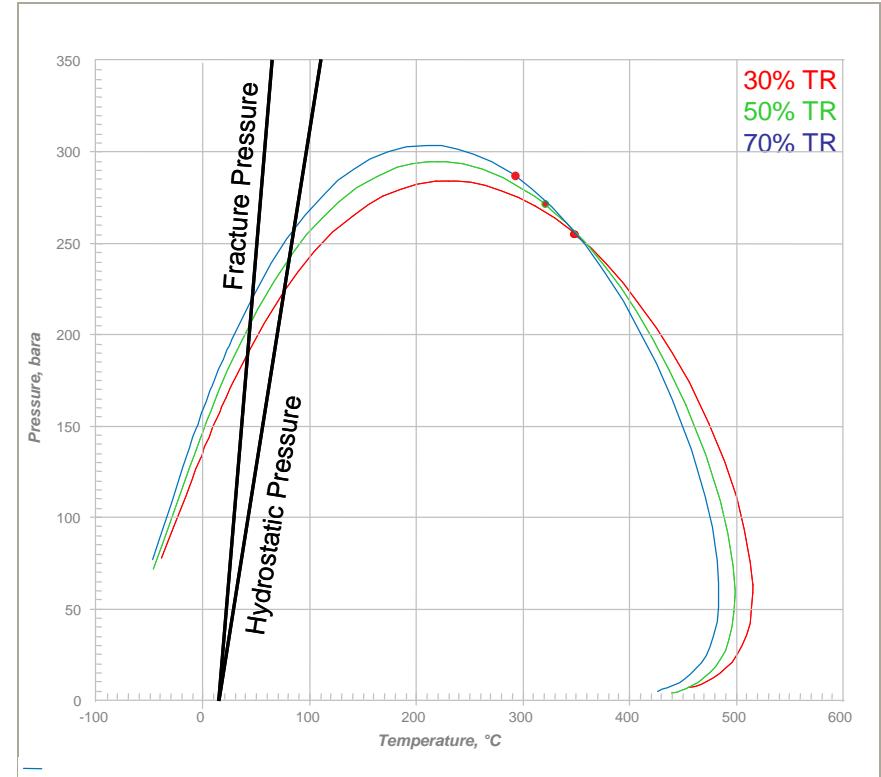
Philipp Kuhn (unpublished)

Predicted Phase Envelopes

2 Bakken samples at 3 stages of maturation



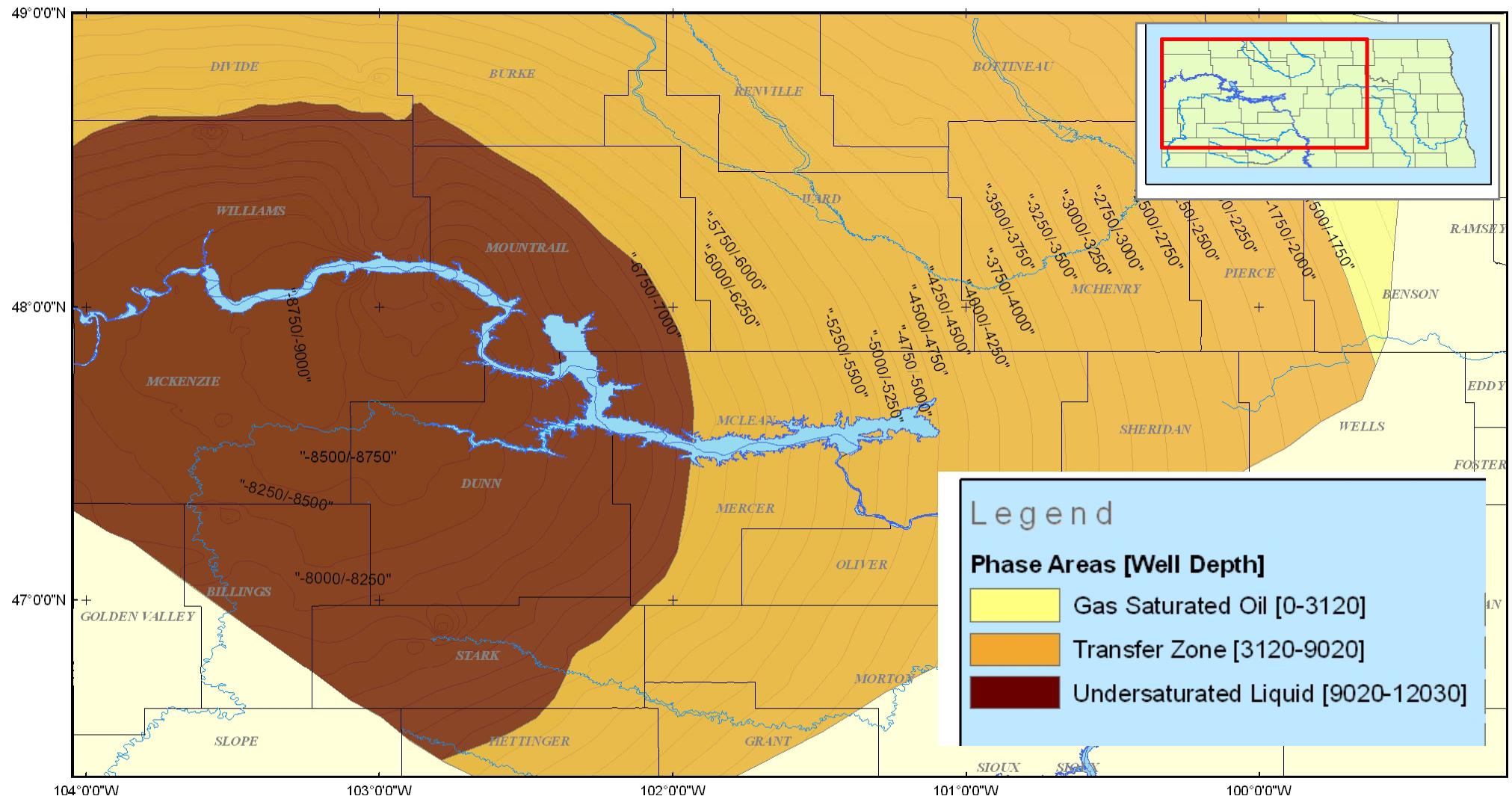
Bakken Fm. G000852



Bakken Fm. G000842

Philipp Kuhn (unpublished)

Predicted Phase Distribution



Conclusions

1. Shale oil and shale gas exploration and production – source rock properties of paramount importance
2. Organic matter properties help govern dysfunctionality in the case of the Bakken Shale
3. Is HI of 300 mg/gTOC critical? Change in adsorptive properties related to disappearance of certain aromatic units from the kerogen.
4. Bakken is a low GOR system overall - variability in field GOR is complex: generation kinetics and phase behavior are important.
5. Evolution of bulk petroleum properties within petroleum system model is the next step

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