[AV]Carbon and Hydrogen Isotope Systematics in Gases from Horizontal Bakken Shale Wells*

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Abstract

We report here composition and isotope data from horizontal Bakken shale wells in North Dakota that penetrated different sections of different maturities and found that ethane carbon isotopes in oil-dissolved gases are excellent predictors of maturity of the organic matter of the source rock kerogens, thus opening opportunities for assessing migration of oils and gases.

The 8 wells of this study are in two maturity domains, based on Bakken Shale Rock-Eval hydrogen indices. The less mature domain around Squaw Gap and Bicentennial ("SGB) has high hydrogen indices (HI~450 to 530mg/g), whereas the more mature domain around Pierre Creek, Buckhorn, and Elkhorn Ranch ("PCBE) has lower hydrogen indices (HI≈170 t o 270mg/g). Gases from the less mature SGB wells(GOR~350 to 390) has high %C2+ concentrations (27 to 48%), whereas gases in the more mature PCBE area have higher GOR's (~560 to 720) and lower %C2+ (~30%). In the less mature wells at Squaw Gap (HI~535), the produced gas has ethane carbon values δ^{13}C2 of -38 ‰, in contrast to δ^{13}C2 of -34.2‰ at the more mature Elkhorn Ranch well 44-25H . Similarly, other isotopic properties, such as the differences δ^{13}C2-3 and δ^{13}CiC4-nC4 as well as isotopic differences between gas components and oil, tend to decrease with maturity. Ethane δ^{13}C values are an excellent proxy for all maturity-related properties of gases and associated oils as well as rock properties such as HI. In particular, hydrogen isotope values in ethane and propane are excellent predictors of the onset of kerogen conversion. Therefore, our gas isotope-HI relationship can be useful in various ways in exploration and production of Bakken Shale plays: The comparison of HI in Lower and Upper Bakken Shale along the trace of a horizontal well with those calculated from the gas isotopes in the oils will allow: a determination of the indigenous nature of the oils (no significant migration) or, if a discrepancy is found, an estimate of the migration distance, using existing HI distribution maps published by the North Dakota Geological Survey. A lower maturity determined from gas isotopes compared to oil biomarker maturity could indicate fracture zones from which gases from the locally less mature Bakken Shale bleed into the oil that is derived from more mature Bakken source rocks.

Reference

Nordeng, S.H., 2009, Salts as candidaates for air storage in the Williston Basin: North Dakota Geological Survey, GI-78, CD-Rom.

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Abstract ID: 985364

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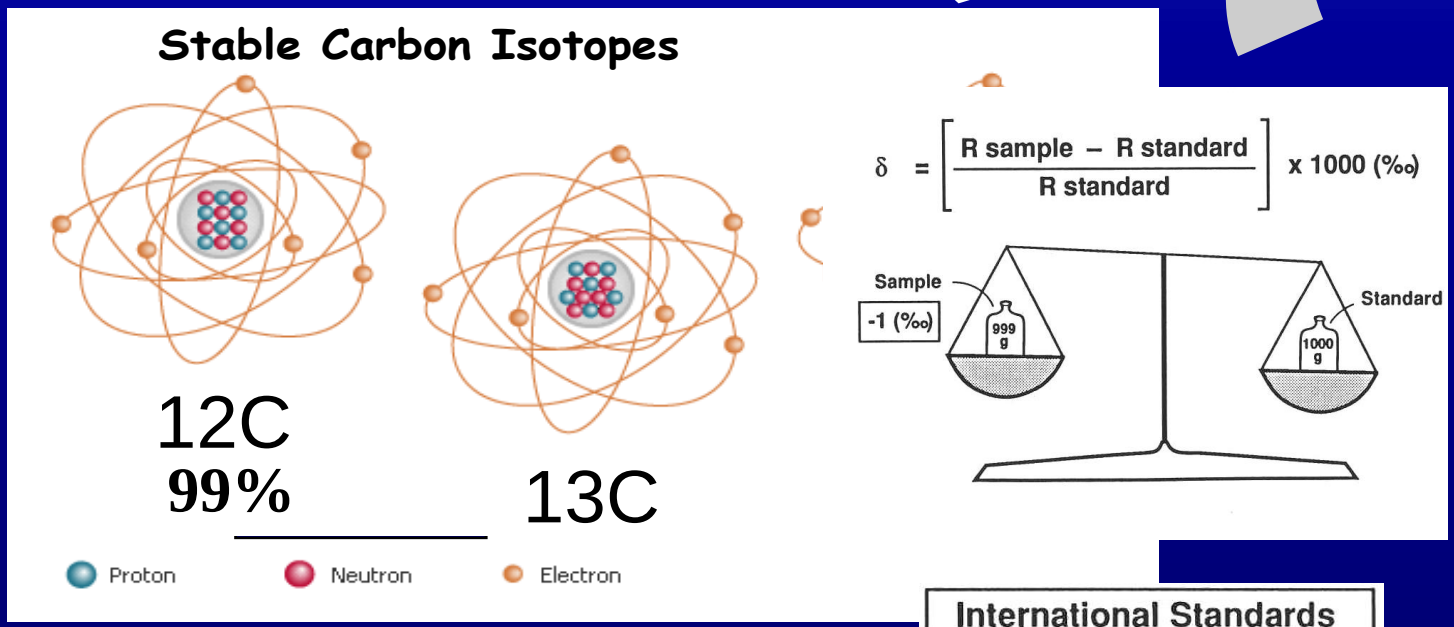
We Turn Data into Solutions

Outline

- A Few Isotope Fundamentals
- The Bakken Shale Petroleum System
- Why Gas Isotopes in Oils?
- Bakken Gas Systematics
  - Relationship to Kerogen Transformation
  - Gas-Oil Relationship
- Applications
  - Prediction of Migrated Oil
  - Prediction of Fracture Gas

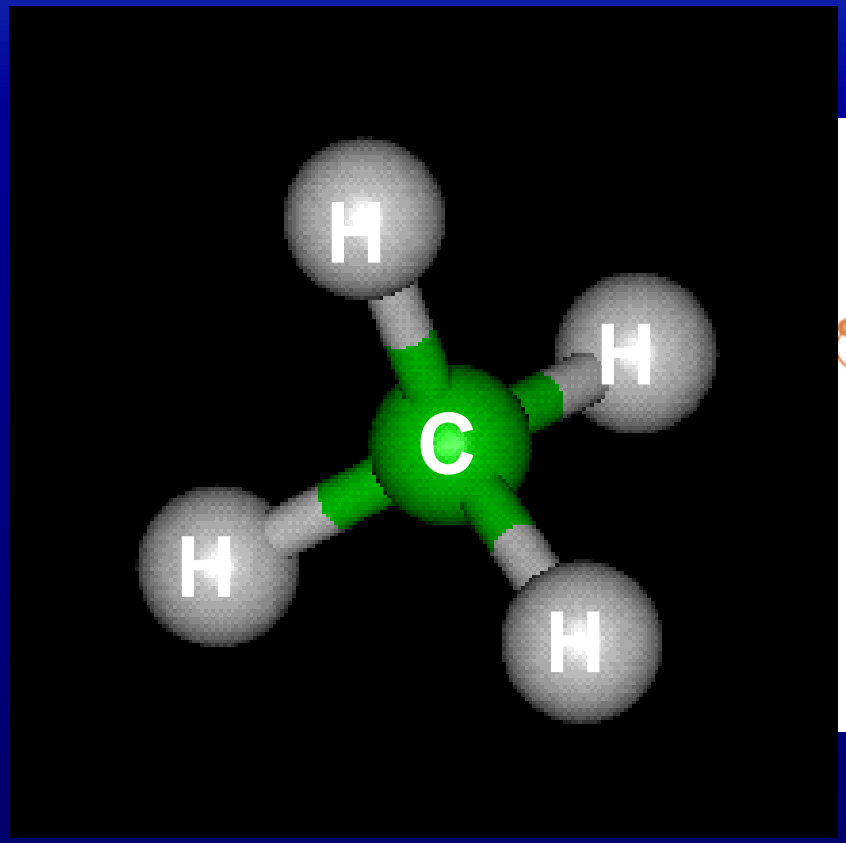
Stable Carbon Isotopes



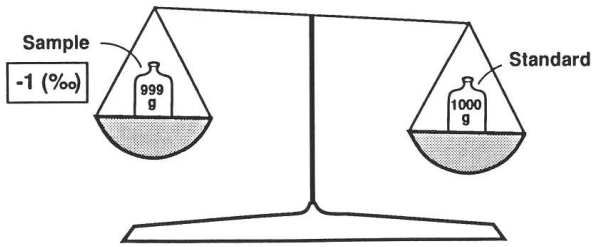
International Standards
Carbon:
PDB Belemite Carbonate
$^{13}C/^{12}C = 11237 \ 10^{-6}$

Carbon $\delta^{13}C$ (‰)	(PDB) ppm ^{13}C
+10	11,222
0	11,112
-10	11,002
-20	10,893
-30	10,783
-40	10,673
-50	10,563
-60	10,453
-70	10,343
-80	10,232

Stable Hydrogen Isotopes



$$\delta = \left[\frac{\text{R sample} - \text{R standard}}{\text{R standard}} \right] \times 1000\ (‰)$$

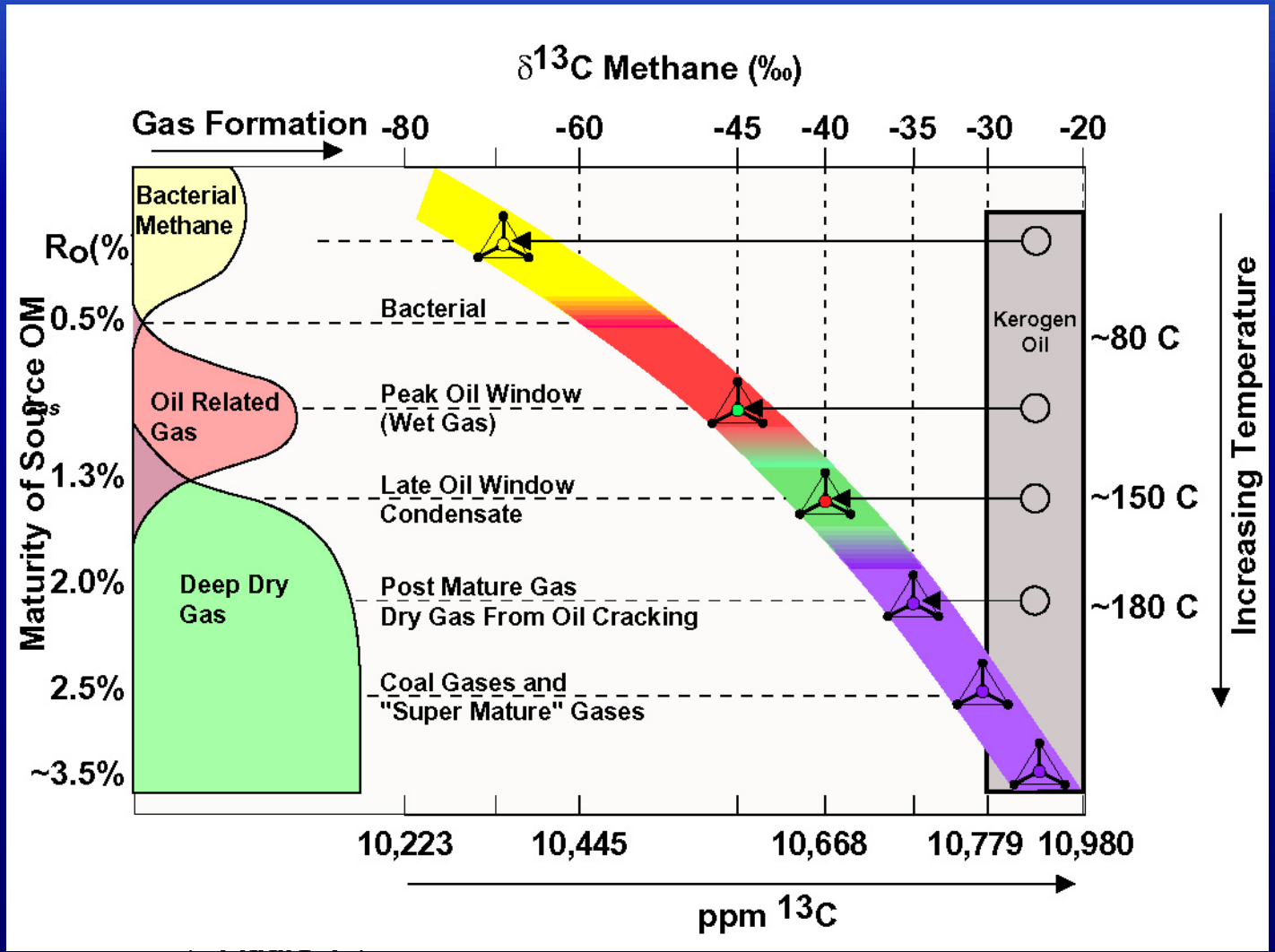


International Standards

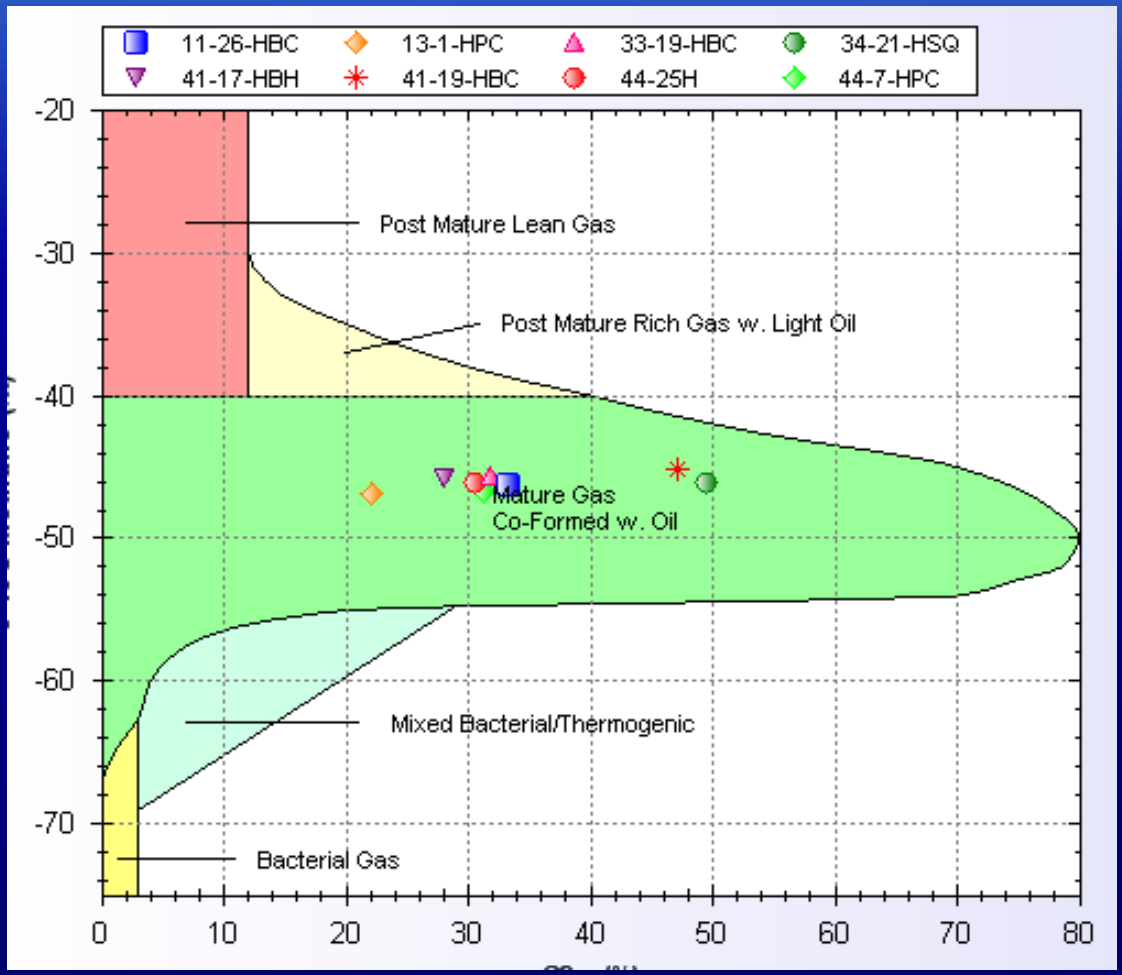
SMOW

Carbon Isotopes in Gases

are driven by temperature
as are processes of oil and gas formation



Bakken Gases Are Classic Oil-Associated Gases

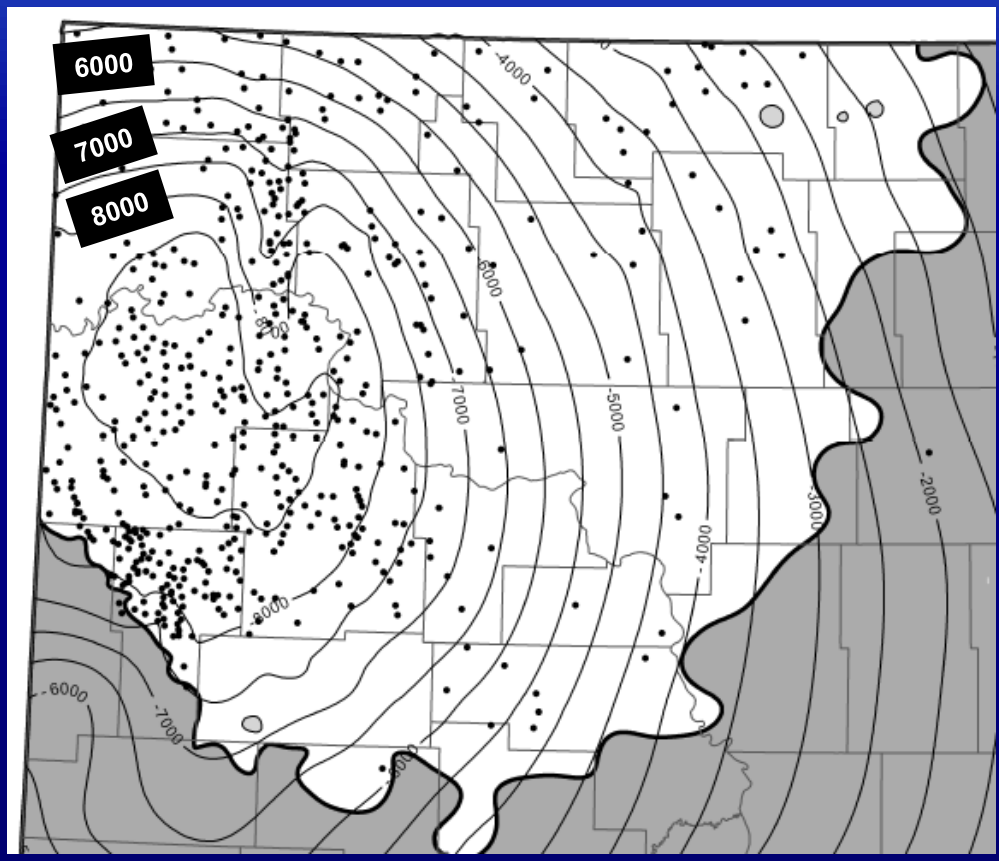


δ^{13}C-Methane (‰)

C2+(%)

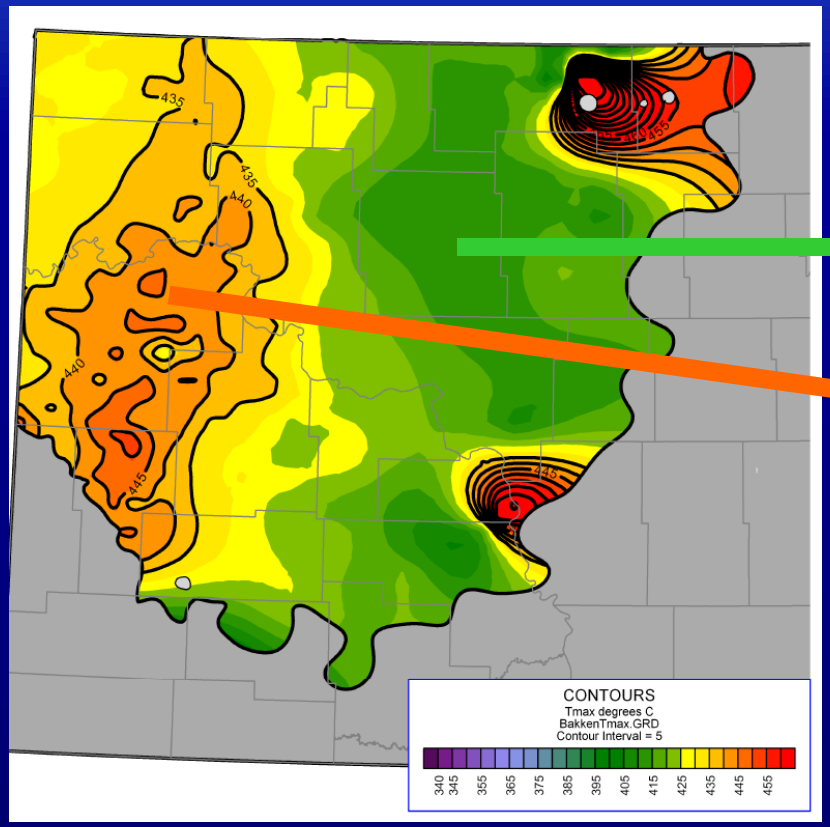
Bakken Shale Petroleum System
One Uniform Source With Simple Subsidence History

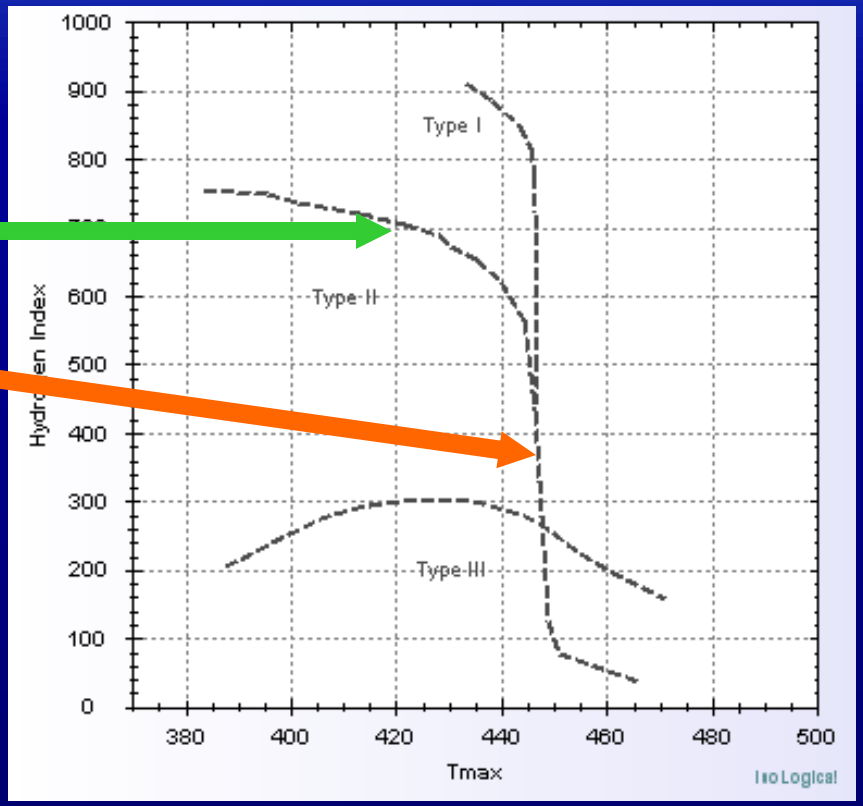
Mississippian	Lodgepole Formation	*"False Bakken"*
		Pelmatozoan limestone
	Bakken Formation	*upper*
		middle
Devonian		*lower*
		"Sanish"
	Three Forks Formation	



Conversion of Kerogen to Oil Lowers the Hydrogen Index

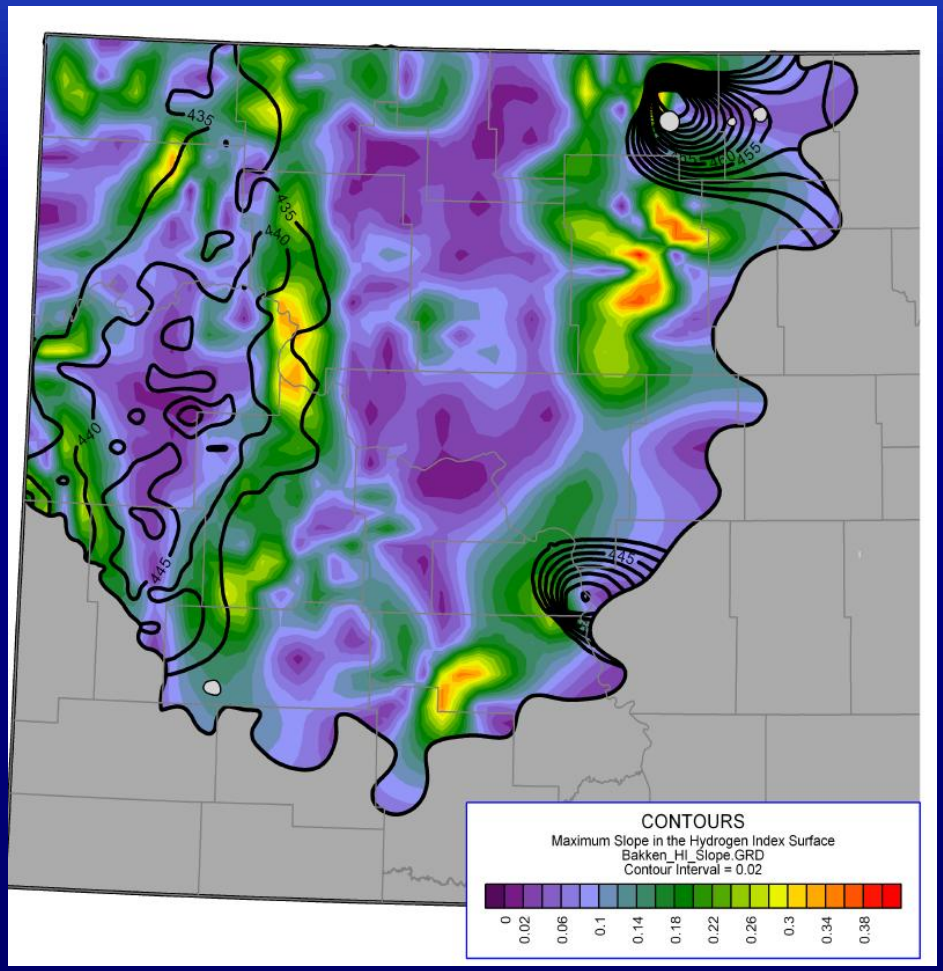
Tmax



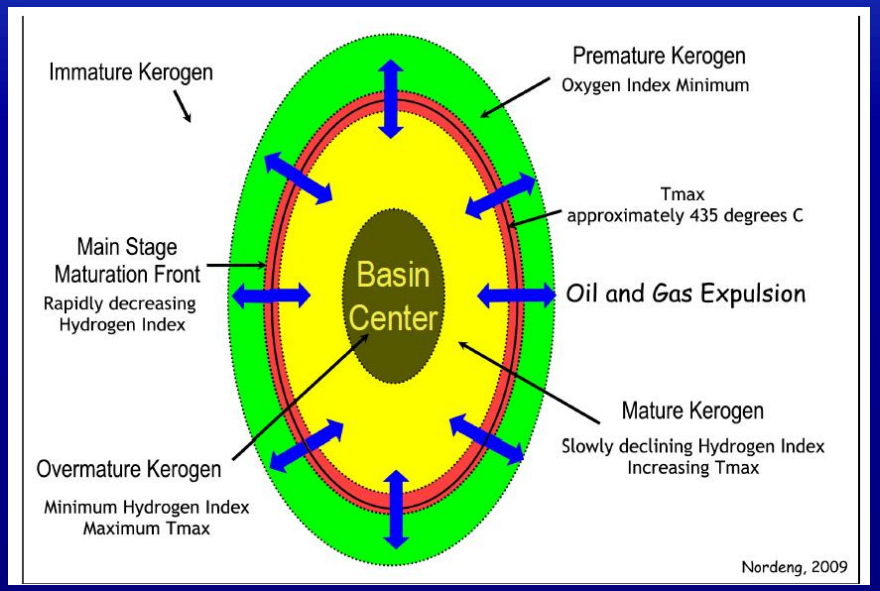


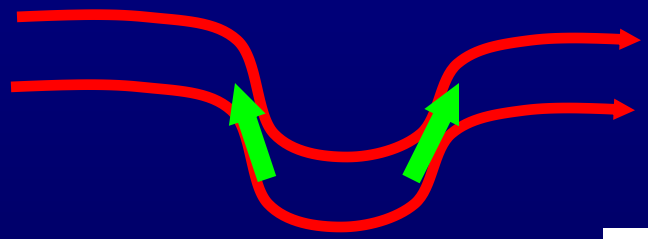
Oil Formation and Migration Model: Oil Formation at Highest Gradient of HI

Maximum Slope of Hydrogen Index

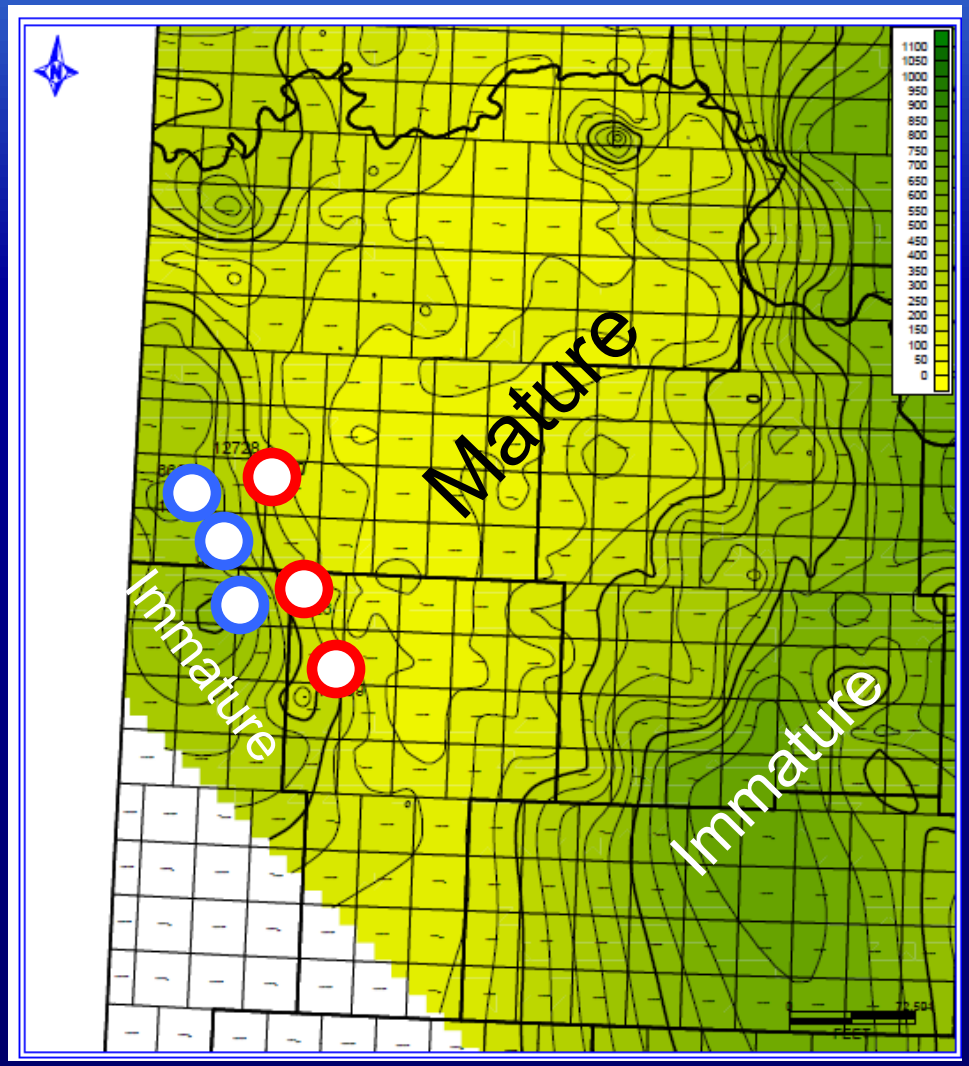


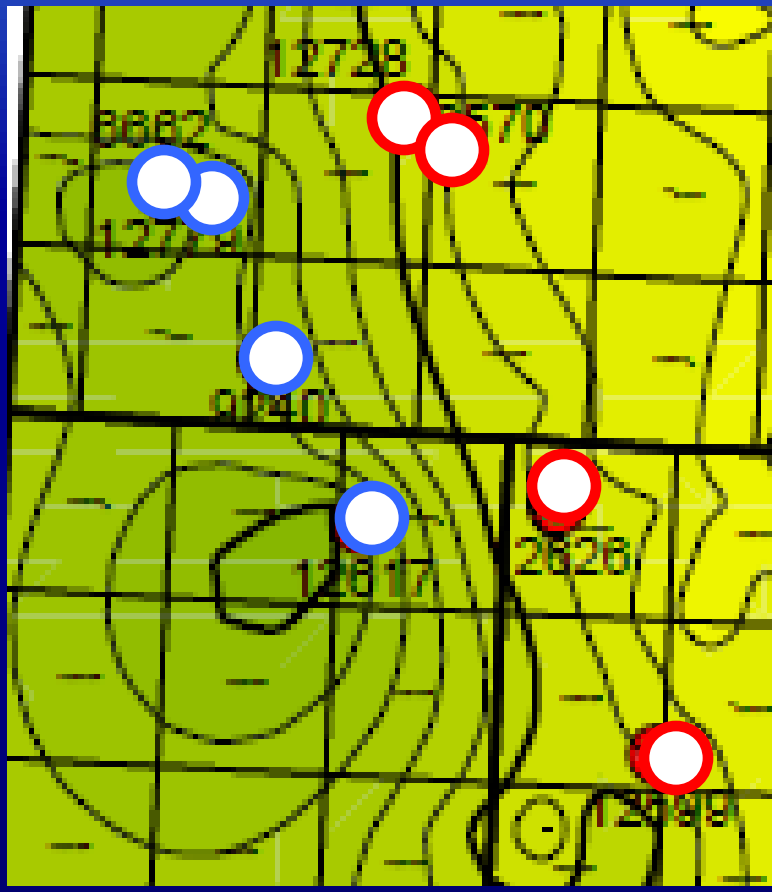
Migration Model



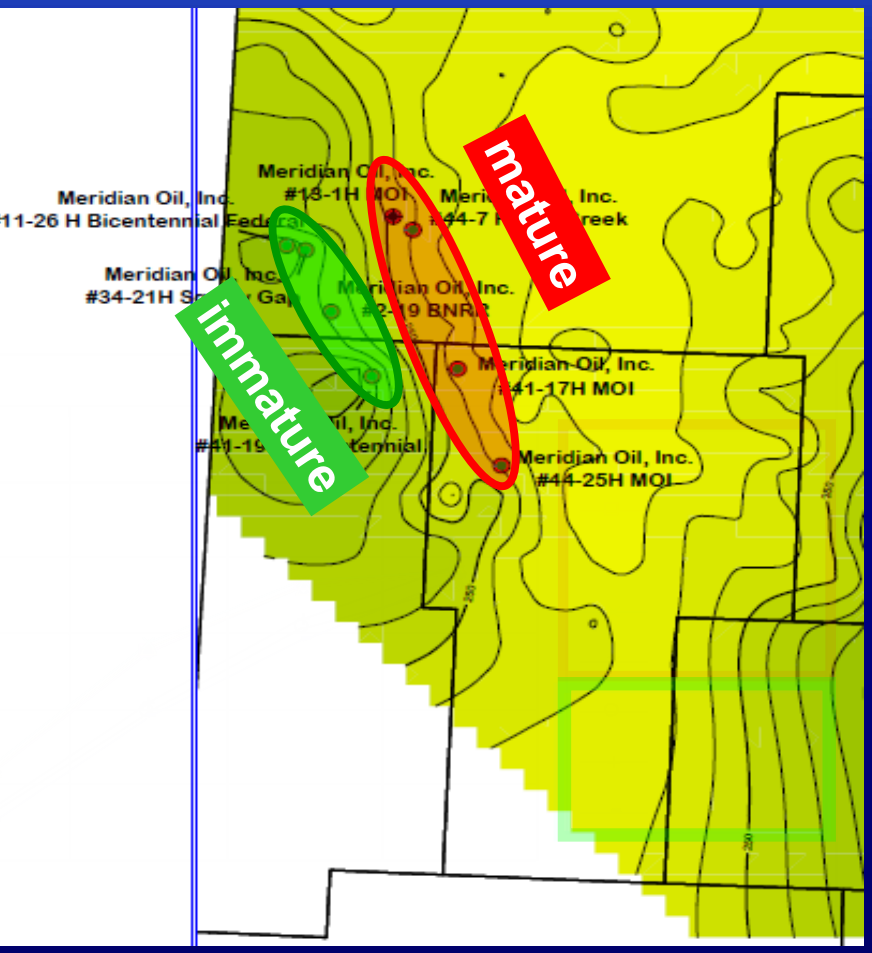


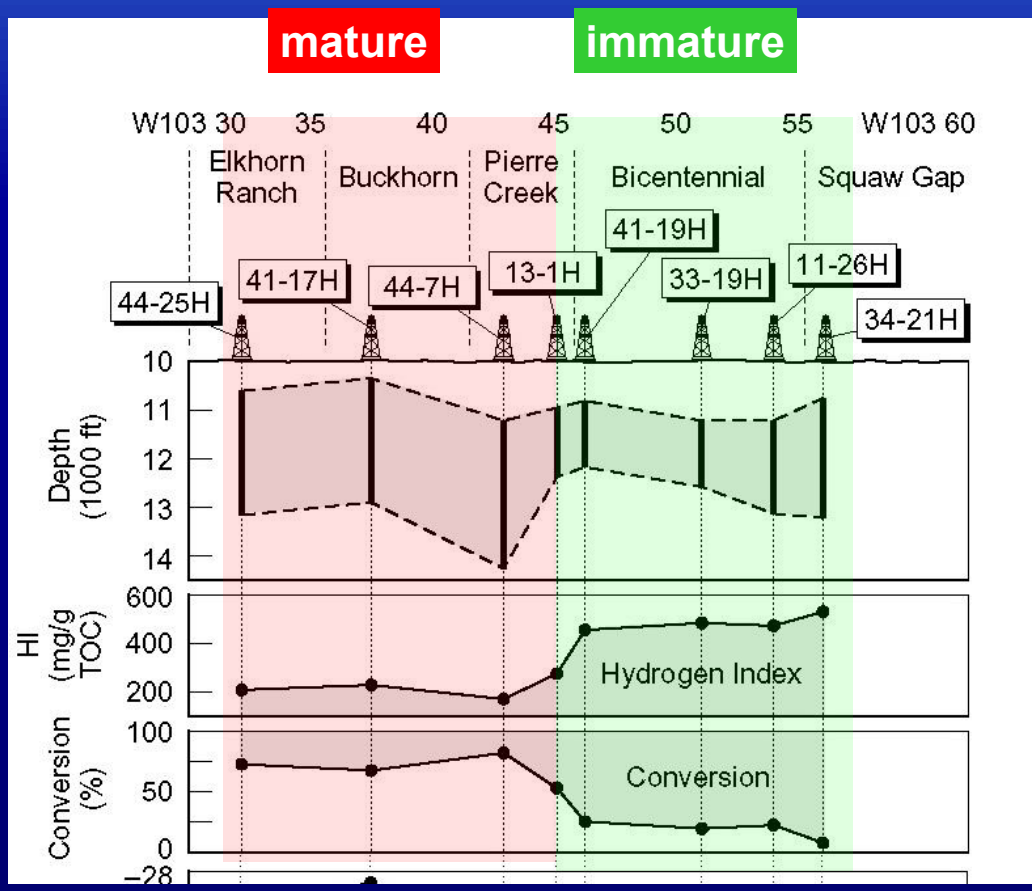
Study Wells are at the HI Hingeline





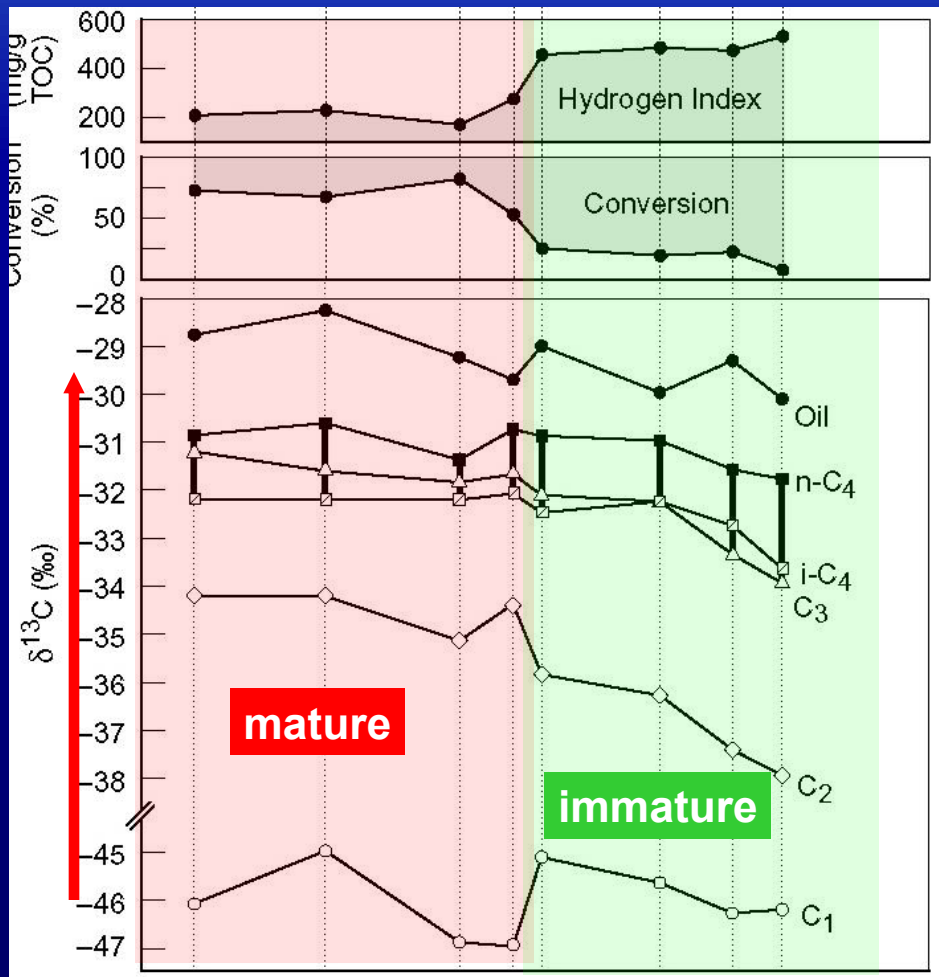
Gases From Deeper, The Kitchen ……and from the Cooler Hills



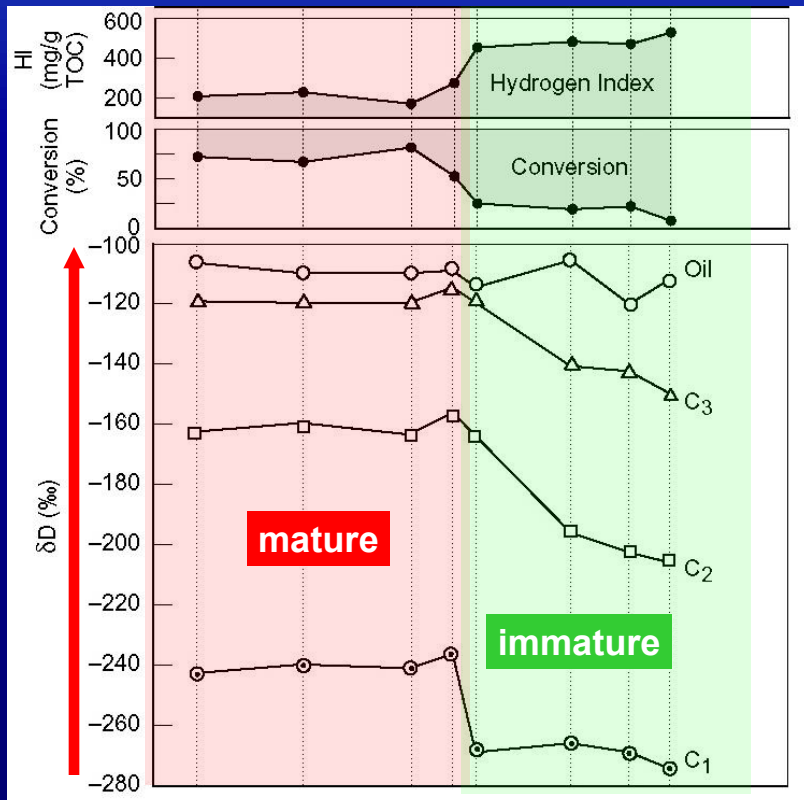


Gas Isotopes Monitor
The Conversion of Kerogen to Oil

Carbon Isotopes



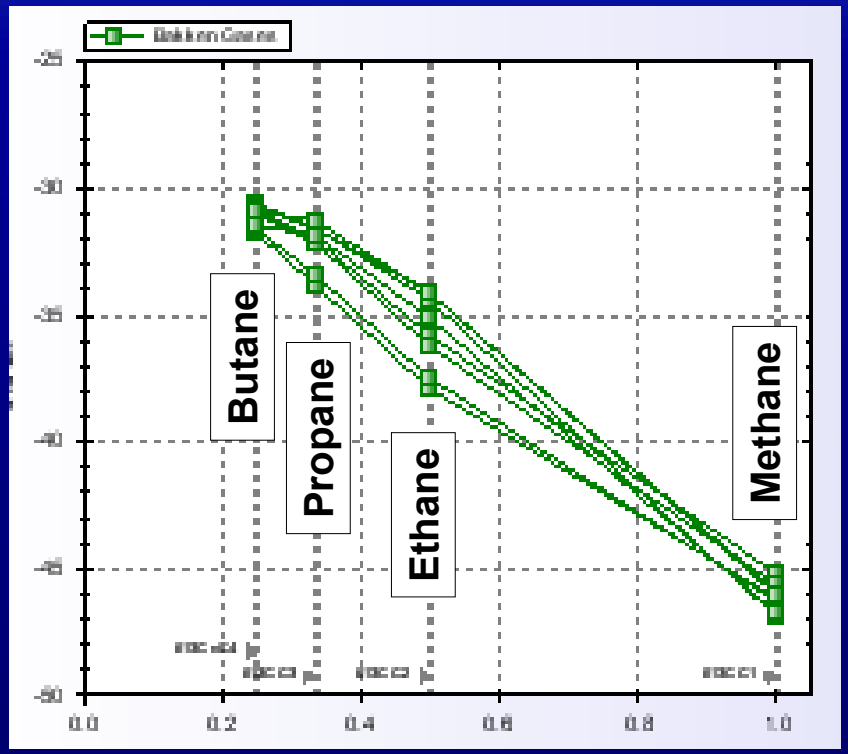
Hydrogen Isotopes



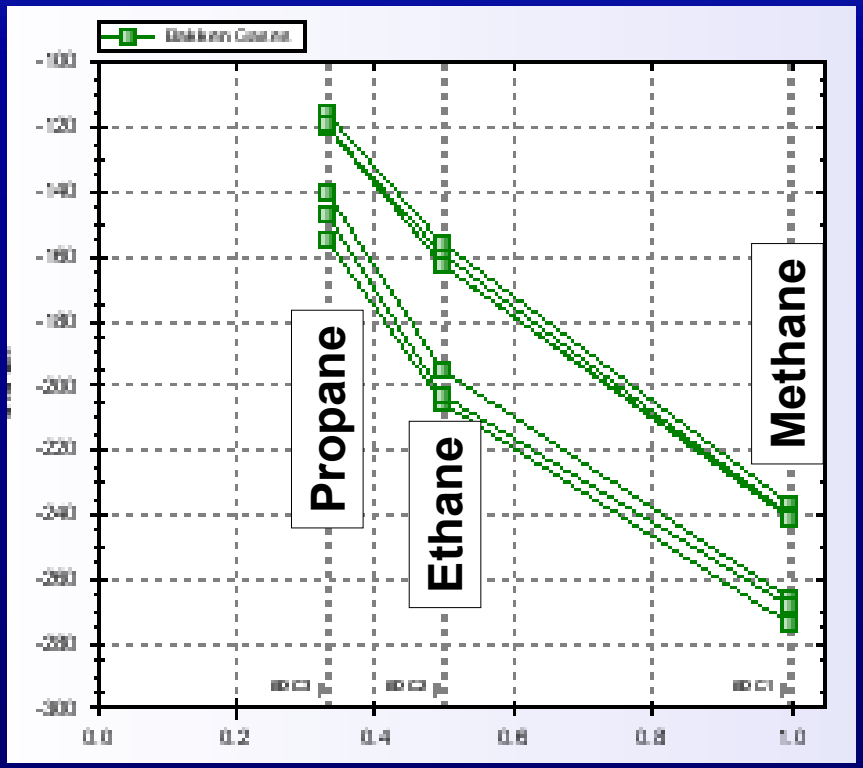
Carbon and Hydrogen Isotopes

Follow The Same Rules of Kinetic Cracking From Precursor Organic Matter

Carbon Istopes



Hydrogen Isotopes



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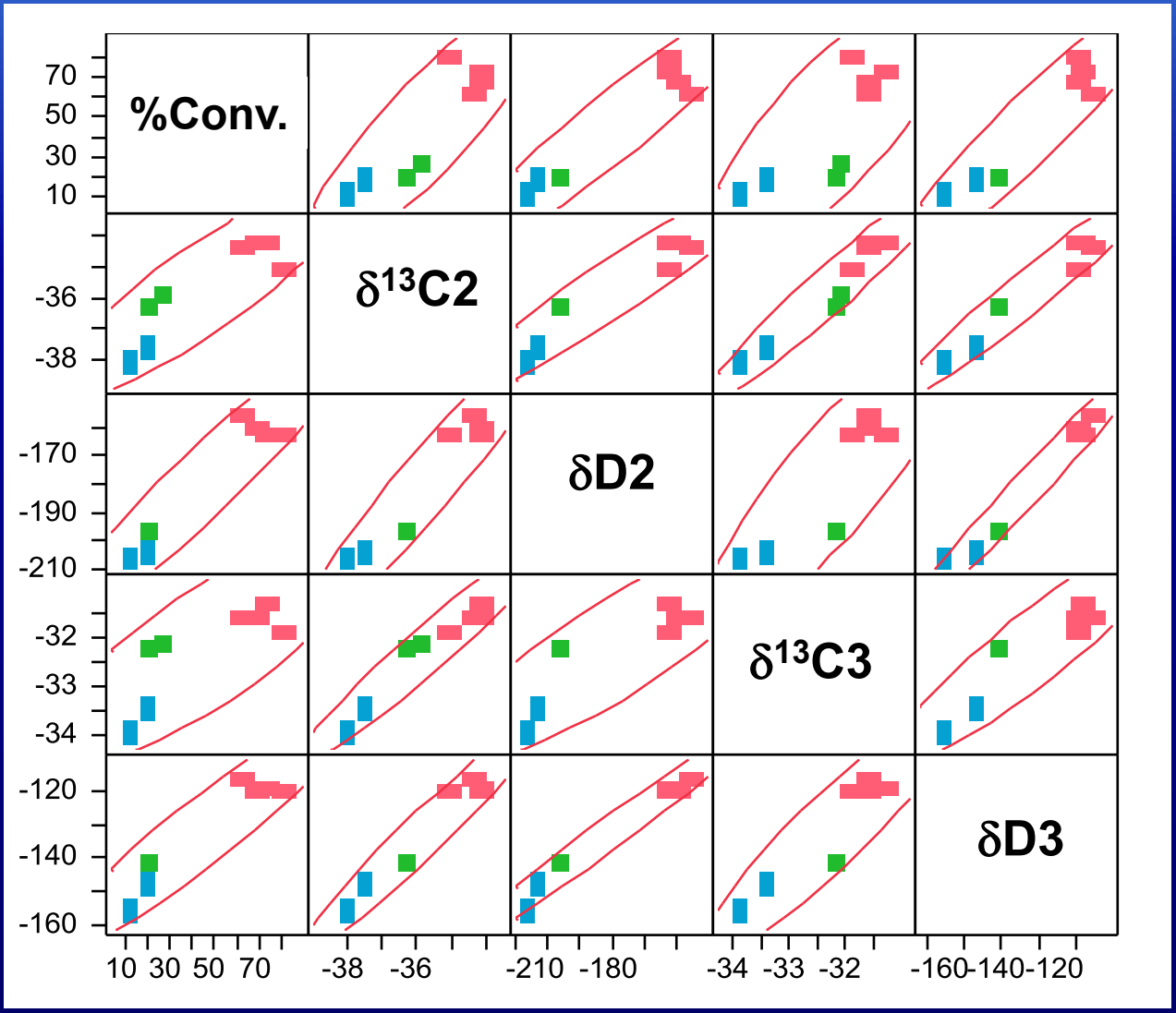
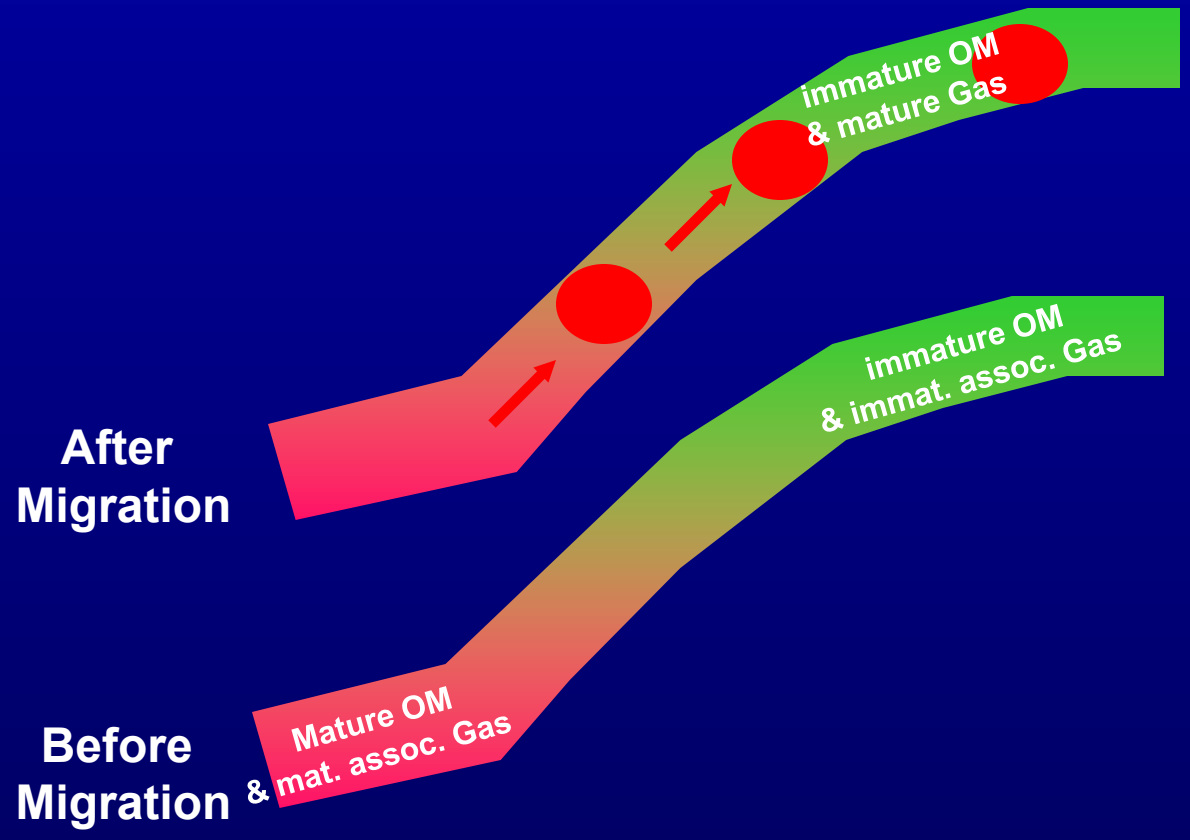
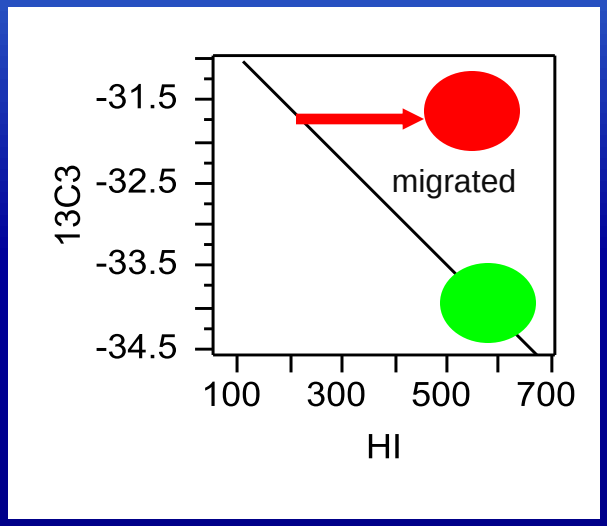
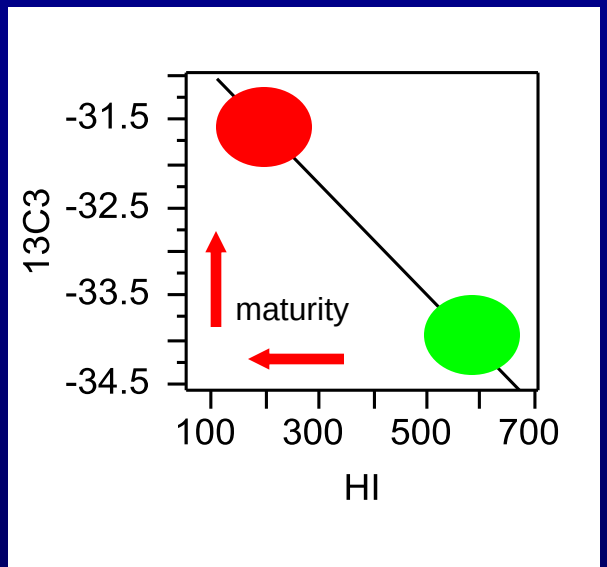


Why Gas Isotopes in Oil?

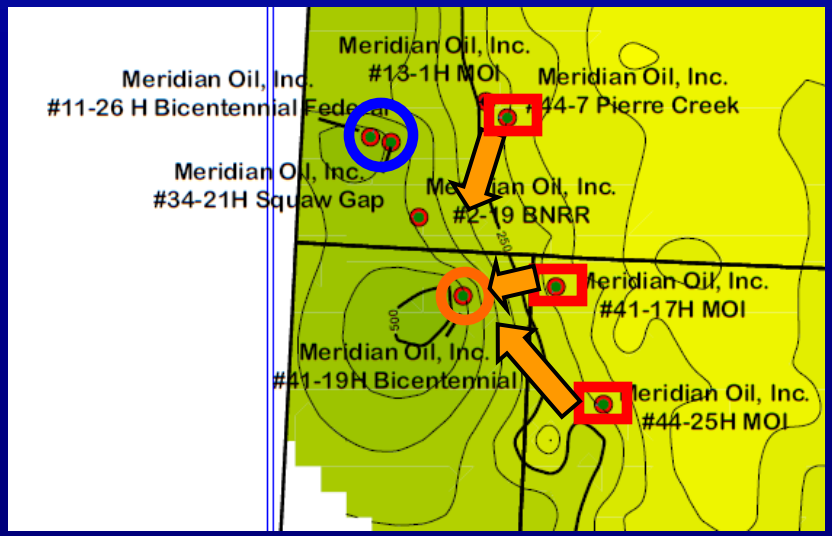
Associated Gases in Oils Are Coeval to Oil Generation and Migrate with Oil

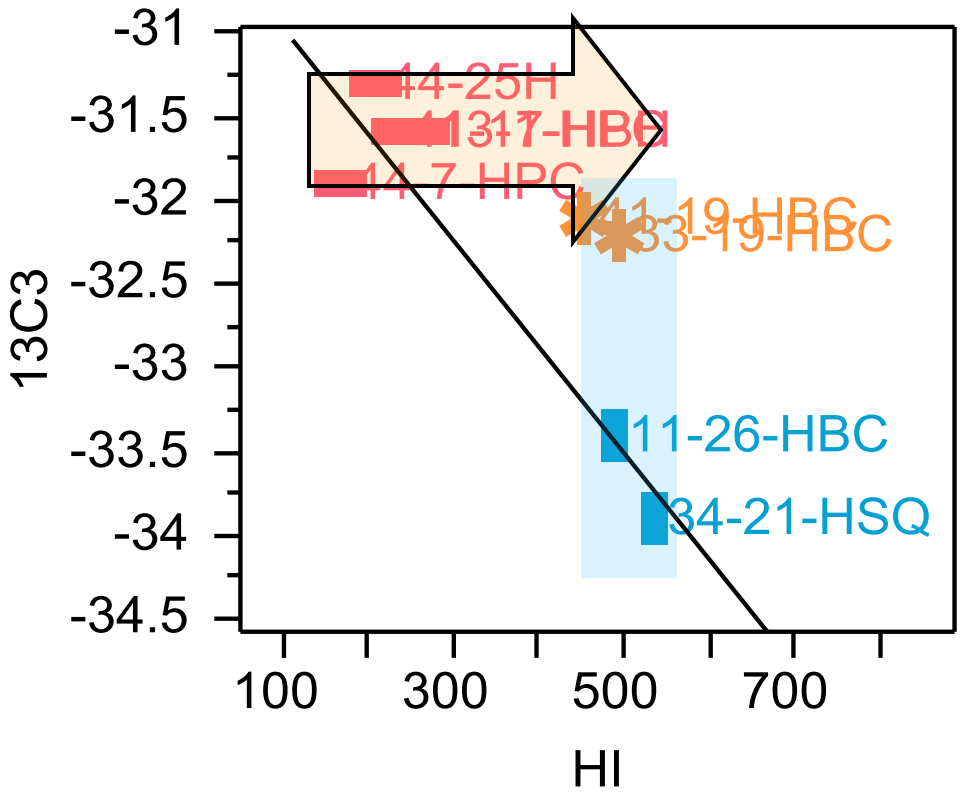




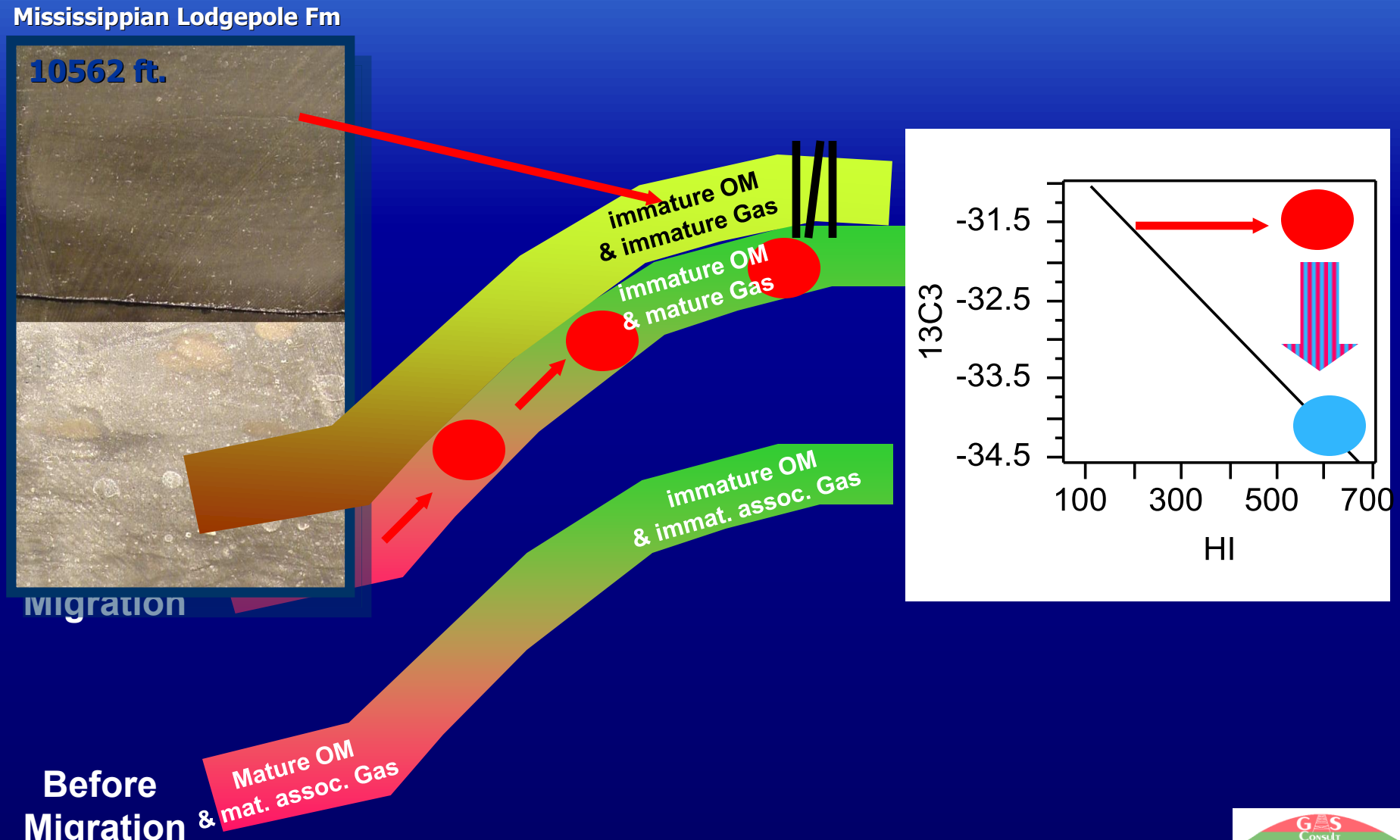


Gases Migrate From Mature To Immature Sections

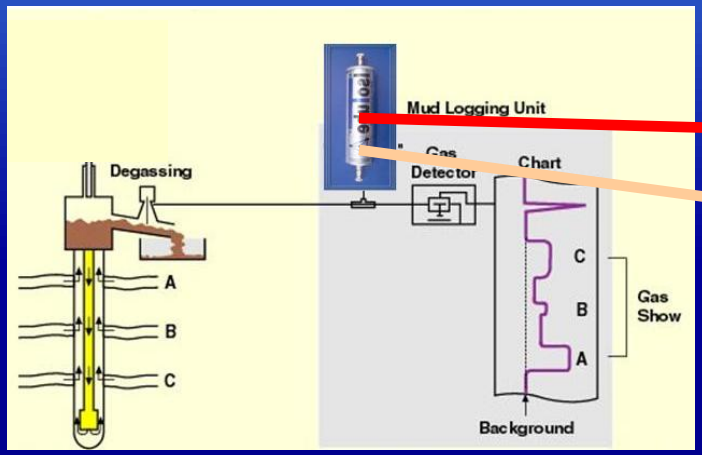


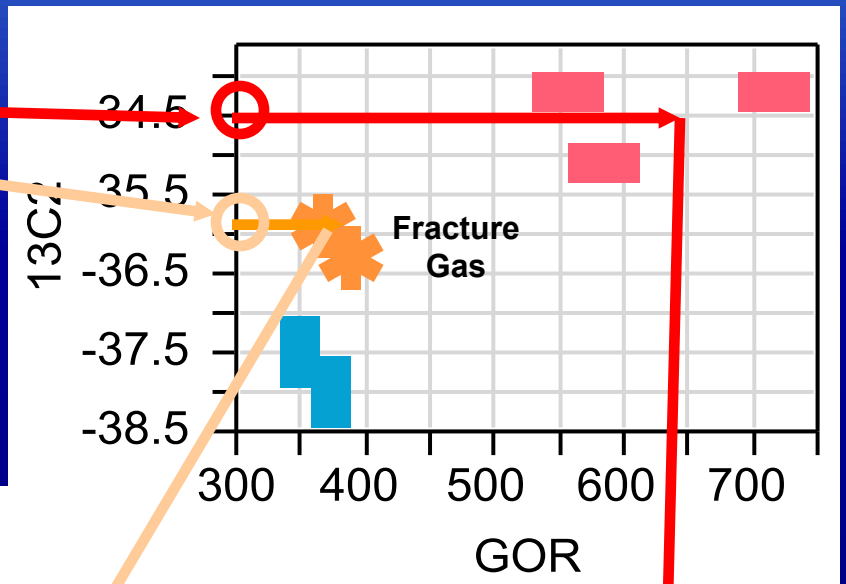


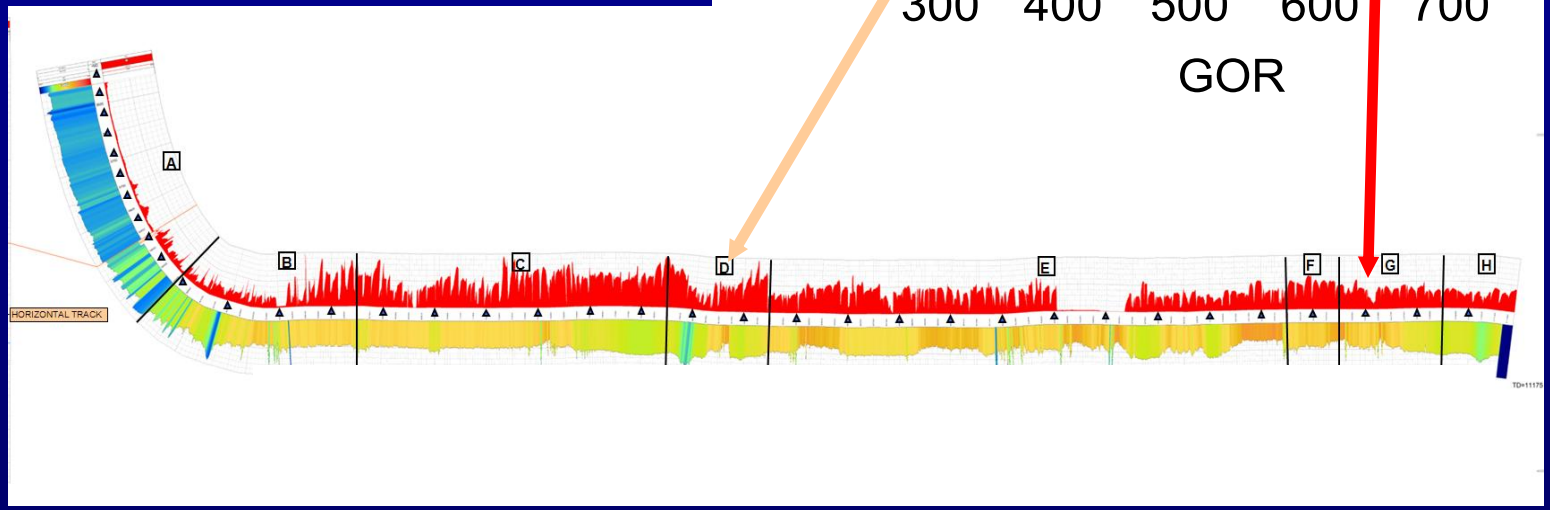
Fracture Gas From Top Seal



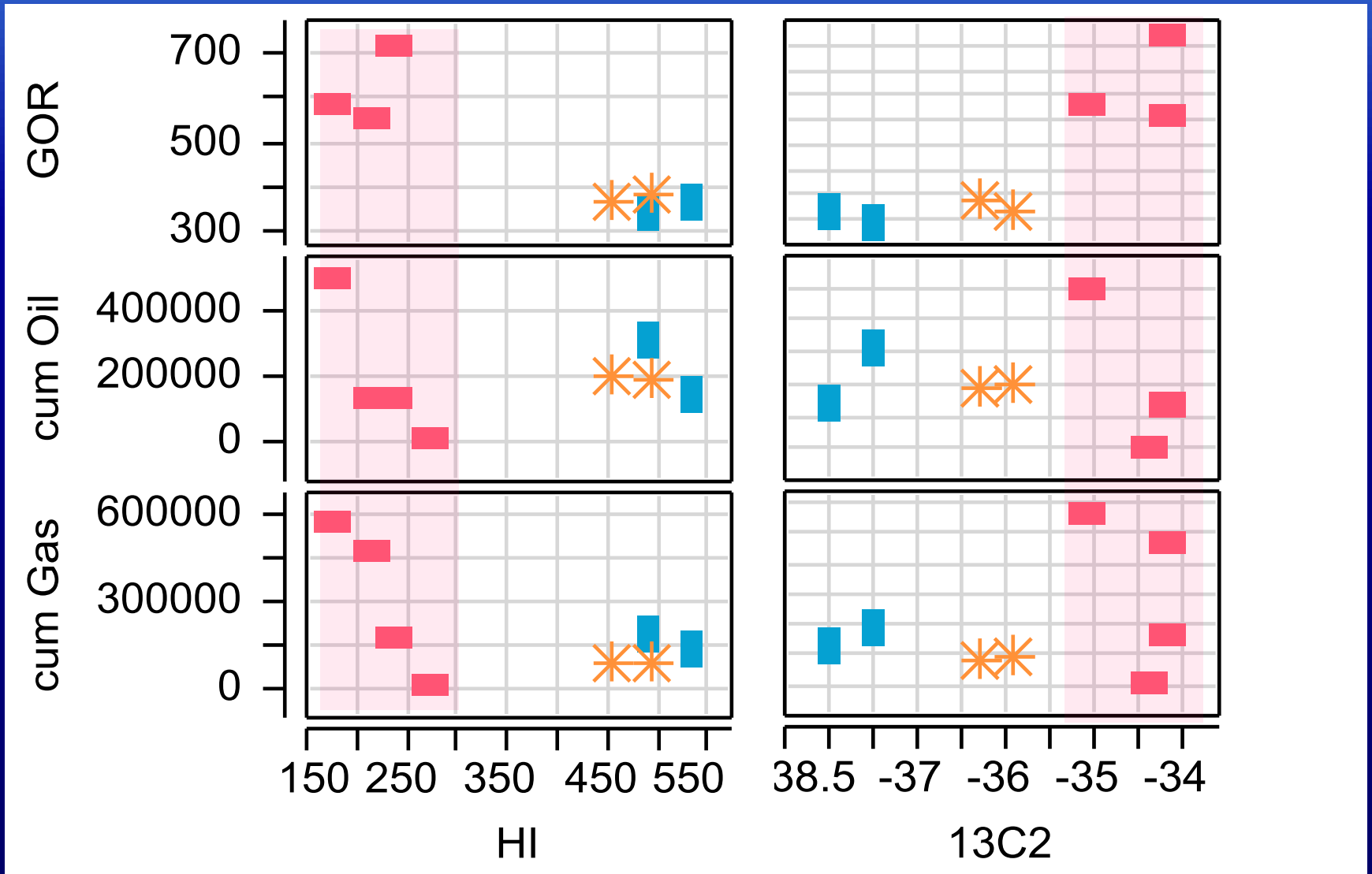
Why Gas Analyses in Oils?







Proxies from Gas Isotopes?



Conclusions

- Gas isotopes in oil associated gases in the Bakken reflect the conversion of kerogen to oil; i.e. maturity
- Migrated oils can be recognized by mature gases in immature environments
- Fractures can possibly be identified by immature gas signatures in mature settings
- Proxies for oil and gas production: high maturity gas signatures are indicative of high gas and oil production