

Worldwide Shale Resource Plays[©]



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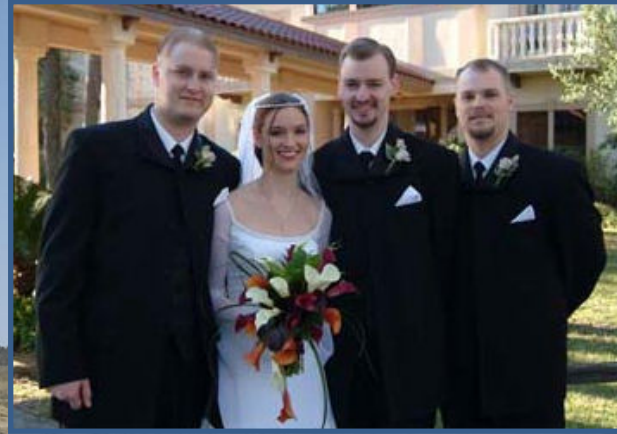
Worldwide Geochemistry, LLC



Outline

- Introduction
- North American Shale Resource Plays
 - Shale Gas
 - Shale Oil
- Worldwide Shale Resources
- Summary

The Jarvie Shale: 4 shale offspring same source(s) – therefore all the same?



Shale: it's all the same, right ?

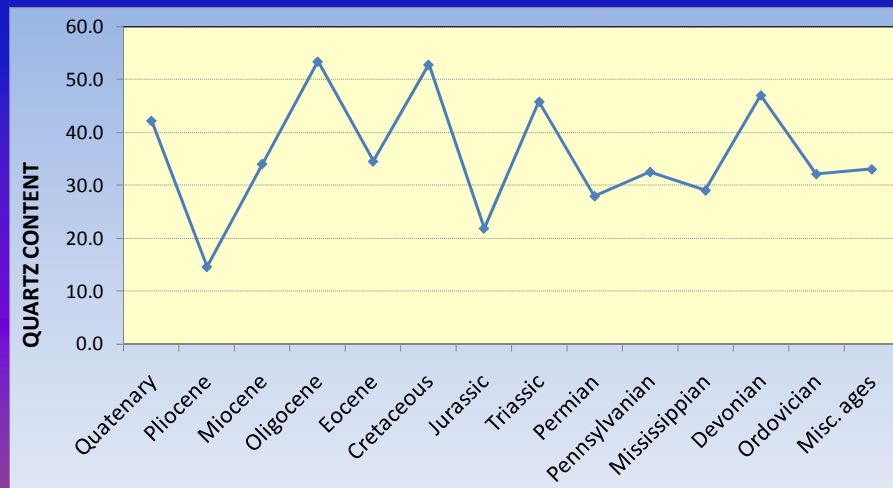
Shale Composition

Average Percent Mineral Composition

Age	Count	Clay Minerals	Quartz	Potassium Feldspar	Plagioclase Feldspar	Calcite	Dolomite	Siderite	Pyrite	Other
Quaternary	5	29.9	42.3	12.4	0.0	6.6	2.4	0.0	5.6	0.8
Pliocene	4	56.5	14.6	5.7	11.9	3.2	0.0	2.9	1.8	3.4
Miocene	9	25.3	34.1	7.8	11.7	14.6	1.2	0.0	1.9	3.4
Oligocene	4	33.7	53.5	3.0	0.0	5.5	0.0	0.0	0.0	4.3
Eocene	11	40.2	34.6	2.0	8.1	3.8	4.6	1.7	1.6	3.4
Cretaceous	9	27.4	52.9	3.6	1.6	2.9	7.9	0.1	1.6	2.0
Jurassic	10	34.7	21.9	0.6	4.4	14.6	1.6	0.4	10.9	10.9
Triassic	9	29.4	45.9	10.7	0.7	3.7	4.1	5.1	0.0	0.4
Permian	1	17.0	28.0	4.0	8.0	0.0	1.0	0.0	0.0	42.0
Pennsylvanian	7	48.9	32.6	0.5	6.2	1.4	2.1	3.4	3.5	1.4
Mississippian	3	57.2	29.1	0.4	2.9	0.0	0.0	0.6	5.1	4.7
Devonian	22	41.8	47.1	0.6	0.0	2.0	1.3	0.3	3.3	3.6
Ordovician	2	44.9	32.2	1.0	6.3	9.5	0.5	0.5	3.4	1.7
Misc. ages	29	47.8	33.1	1.0	5.5	5.2	2.3	0.8	3.1	1.2

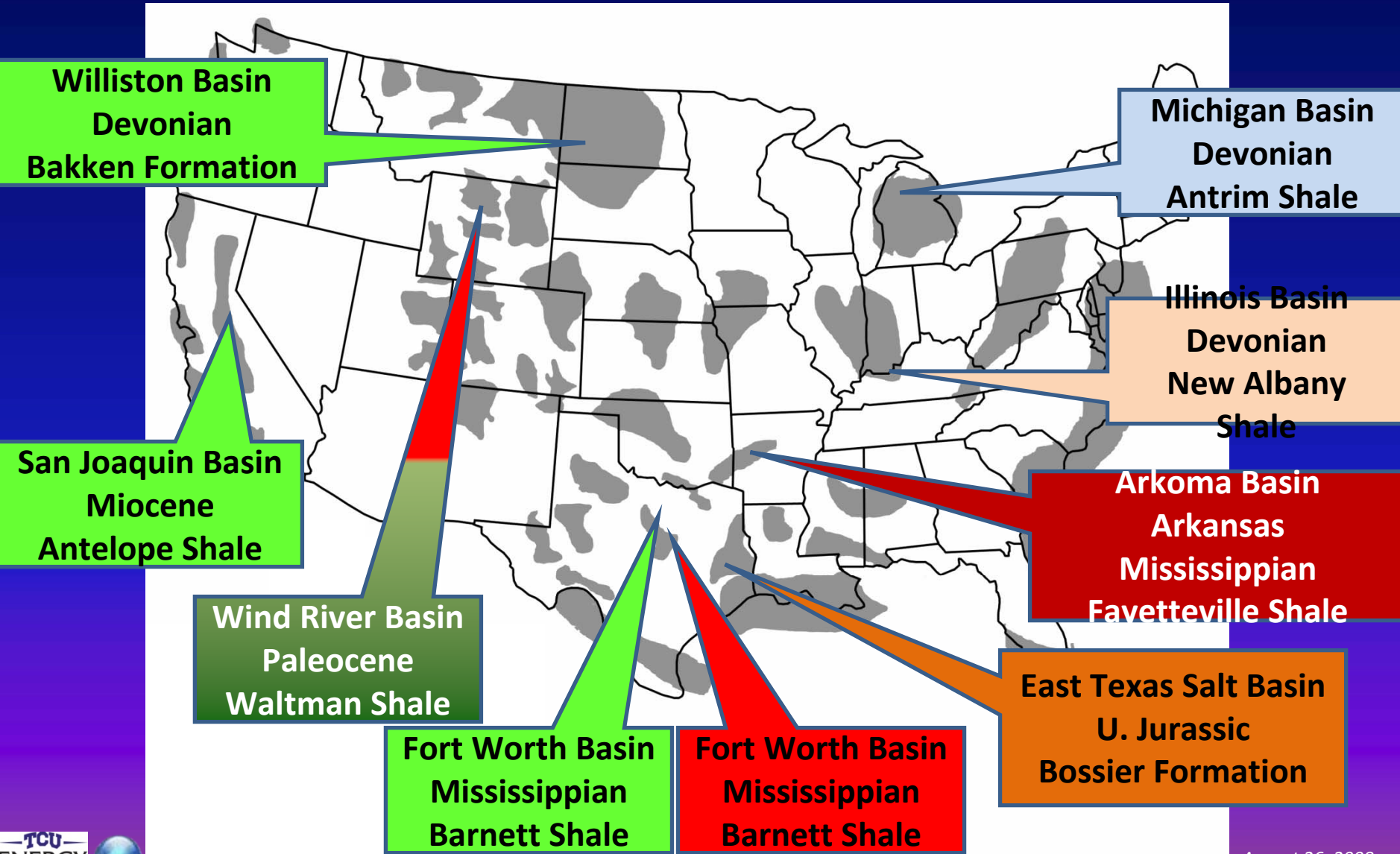
Average Clay: 38%

Average Quartz: 36%



O'Brien and Slatt, 1990

Shale Resource Basins: They're All the Same, Right ?



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Key Difference Among Shale-Gas Systems ?

IP, GIP, EUR

Governed by:

- Organic richness, kerogen type, and thermal maturity
(how much gas could be generated and when?)
- Expulsion / Retention
- Presence of open fractures
- Mechanical properties of rock
- Response to current stimulation techniques



Thermogenic vs. Biogenic Gas

- Thermogenic
 - wet gas (except at very high thermal maturity)
 - -35 to -50 (delta $^{13/12}\text{C}$ per mil) → heavy
- Biogenic
 - dry gas (98%+ methane)
 - -55 to -85 (delta $^{13/12}\text{C}$ per mil) → light)

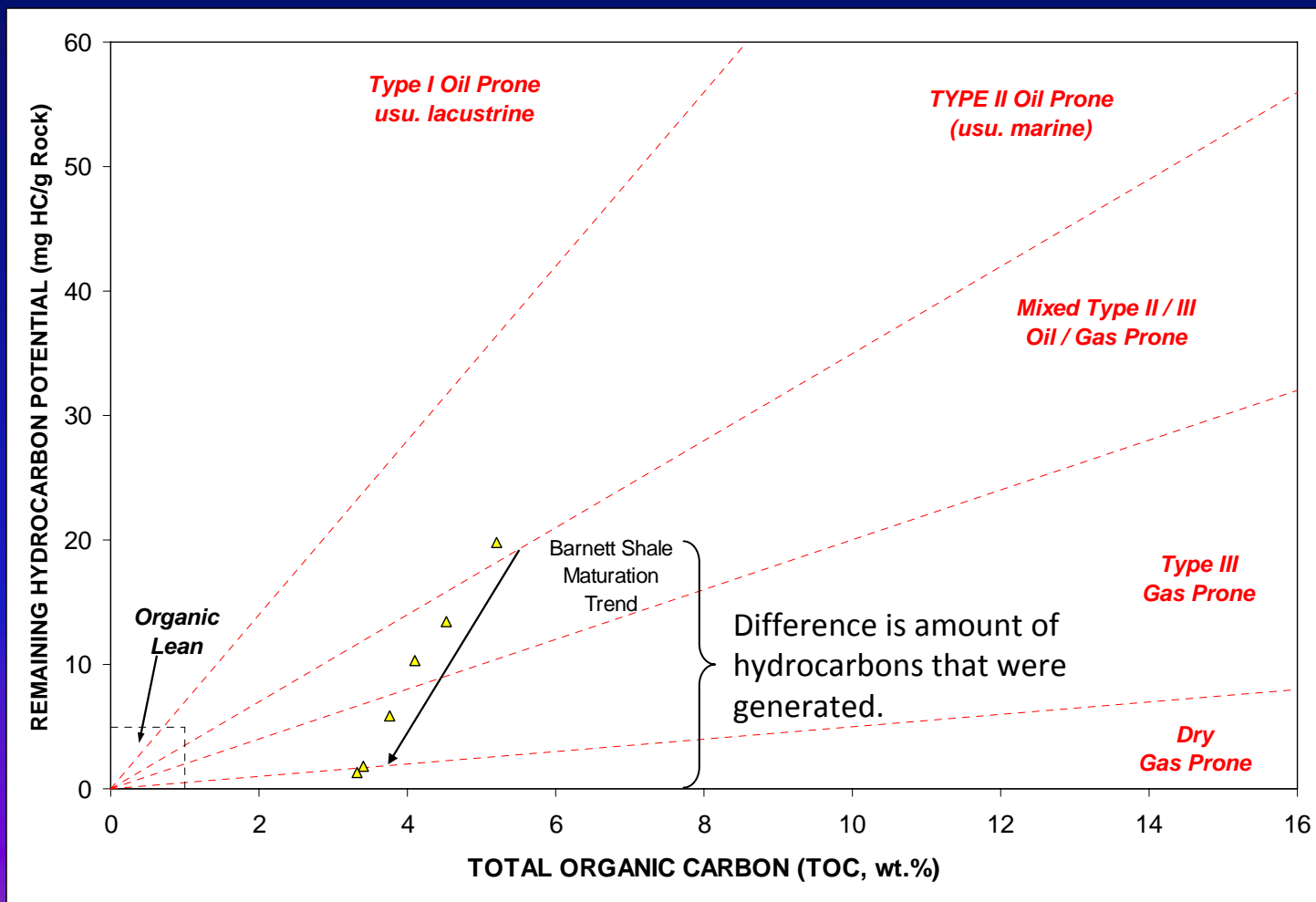


Thermogenic Shale-Gas System Types

1. Organic-rich, indigenous thermogenic gas shales
 - 1) Early to oil window mature (0.50-1.0%VRo)
 - 2) Gas window mature (1.0% - 2.0%VRo)
 - 3) Dry gas window mature (2.0% - 3.0% VRo)
 - 4) Post-gas window mature (> 3.0% VRo)
2. Intra-formational
 - 1) Shale-Shale (organic rich throughout)
 - 2) Shale-conventional reservoir lithologies, but tight
3. Inter-formational gas systems (gas migrated into shale)
4. Combination tight shale-classical reservoir systems



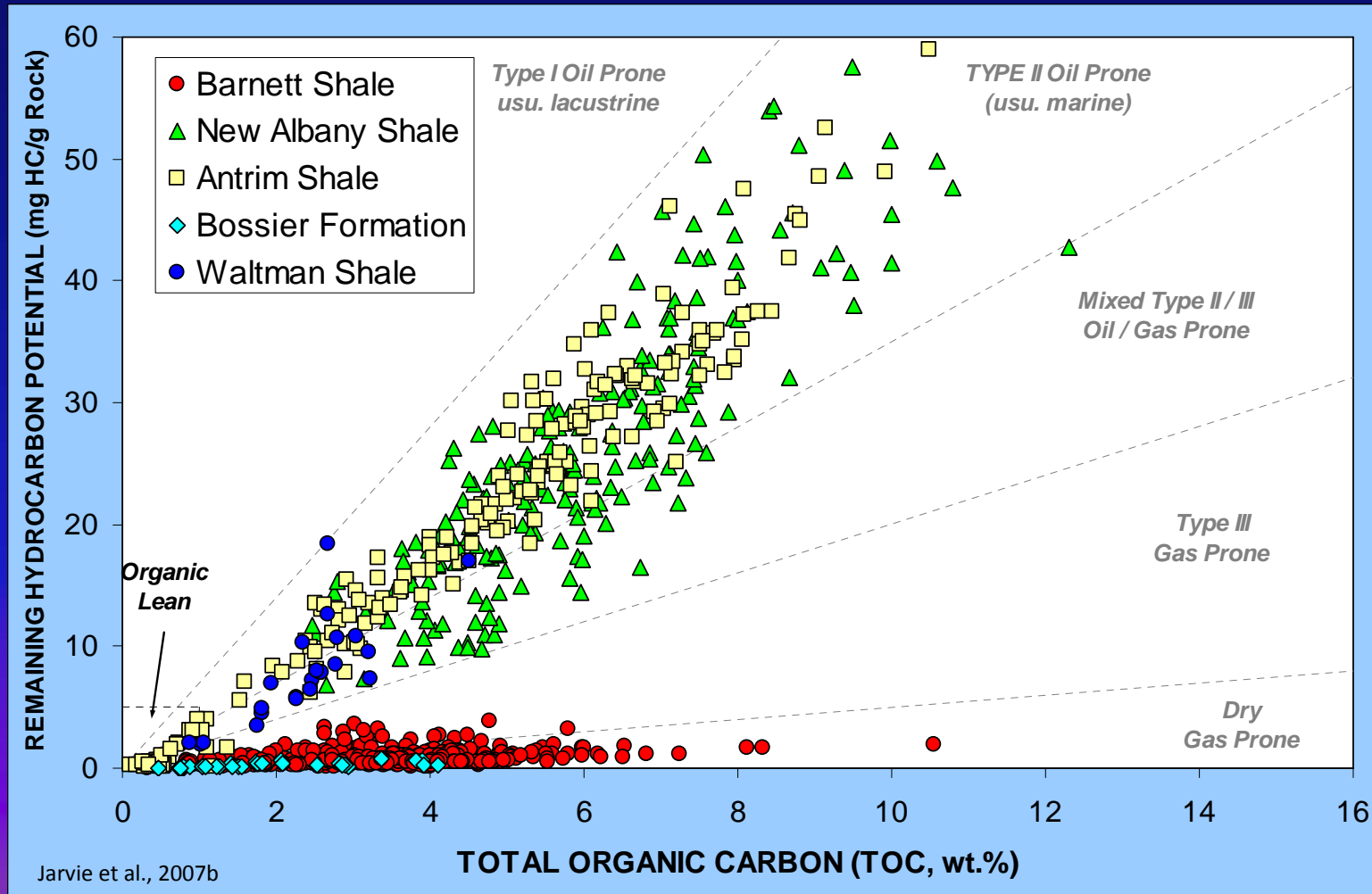
TOC Loss with Maturation



Jarvie and Lundell, 1991

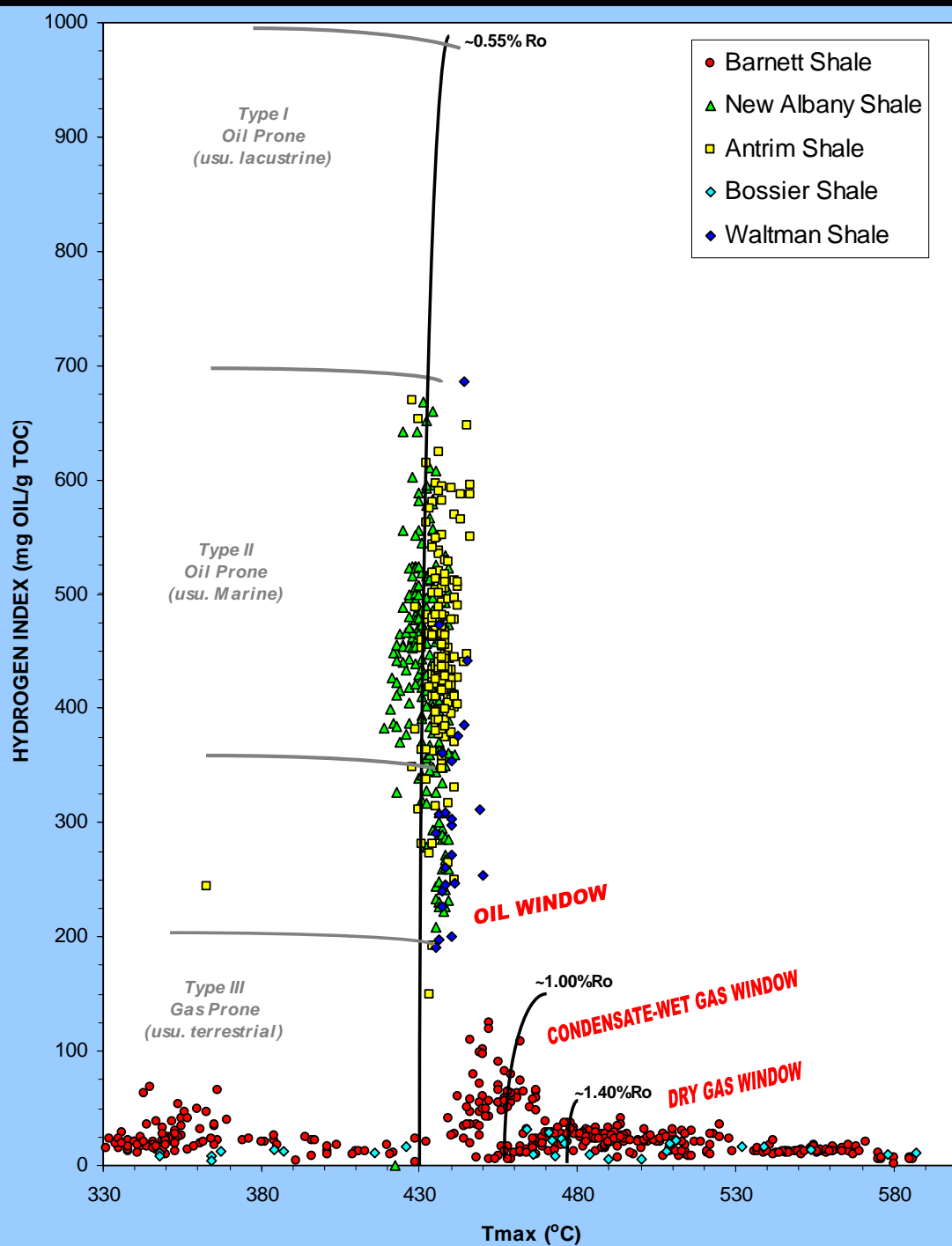


Comparison of Thermogenic Shale Sub-Types



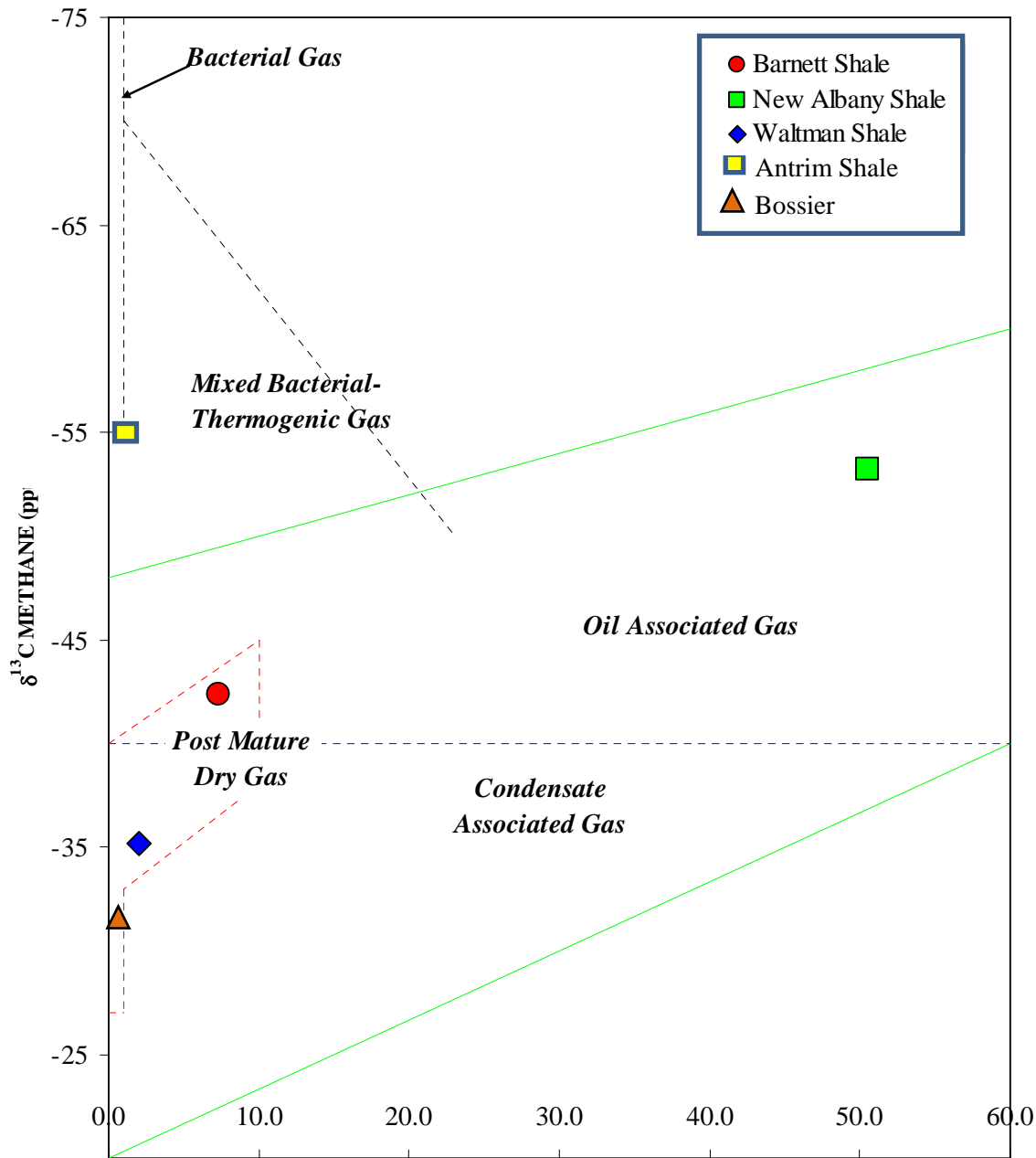
Modified Espitalie Kerogen Type and Maturity Plot

Jarvie et al., 2007b



Inferred Gas Type and Thermal Maturity from Methane Carbon Isotope and C2-C4 volumetric yields

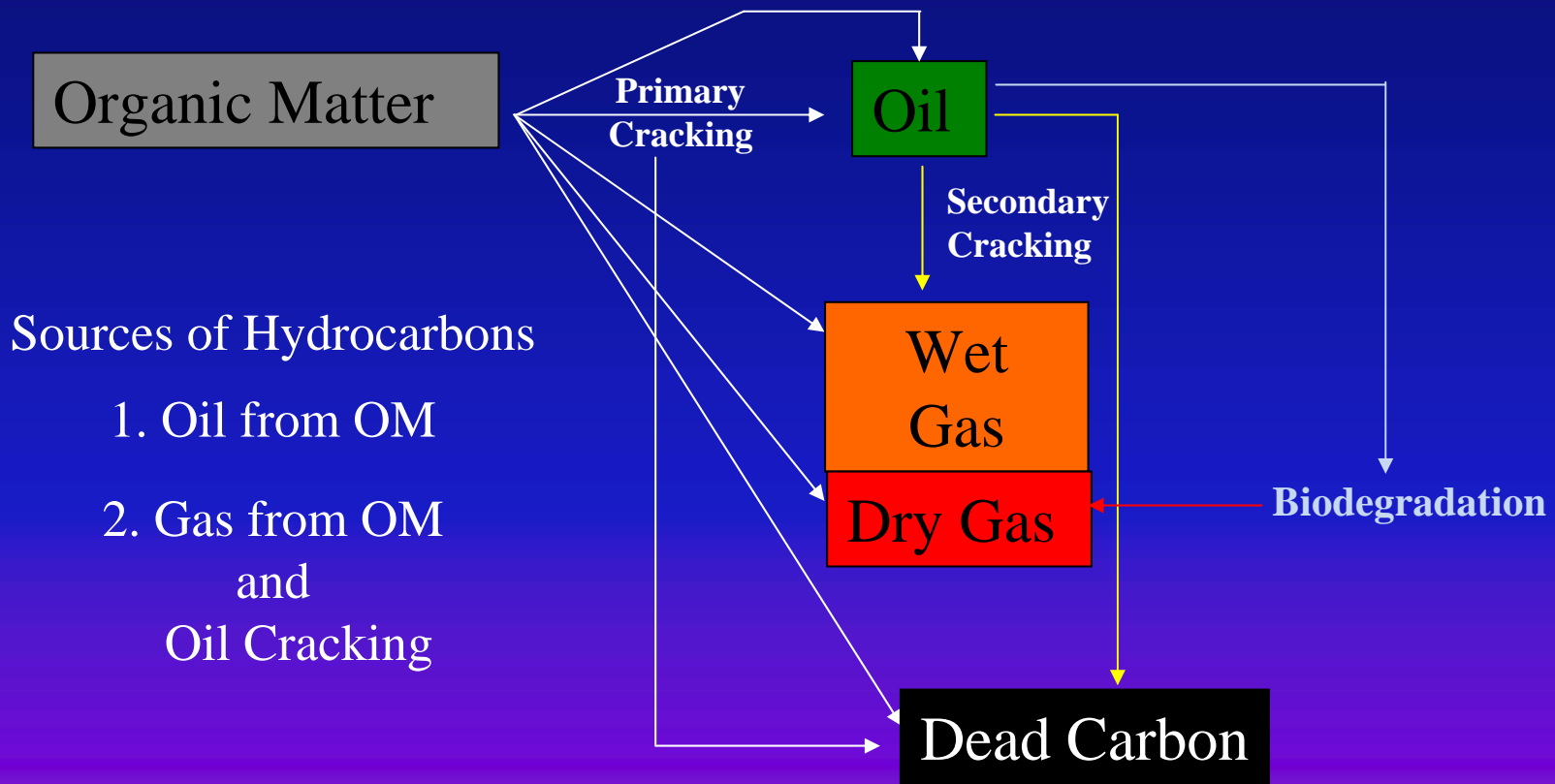
ETHANE, PROPANE, and BUTANES (vol.%)



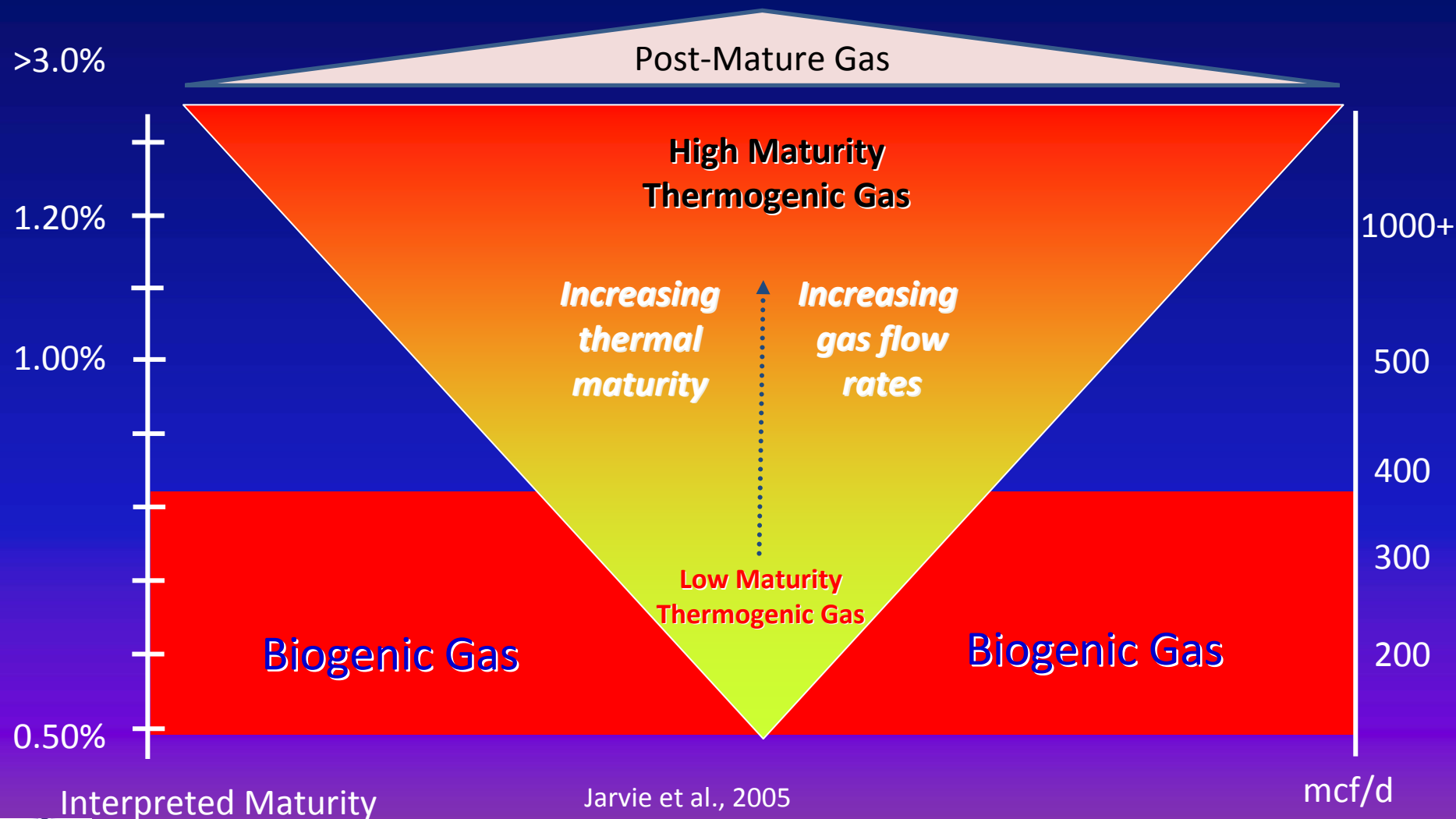
Jarvie et al., 2007b



Schematic of Thermogenic Oil and Gas Generation



Expected Gas Flow Rates by gas system type



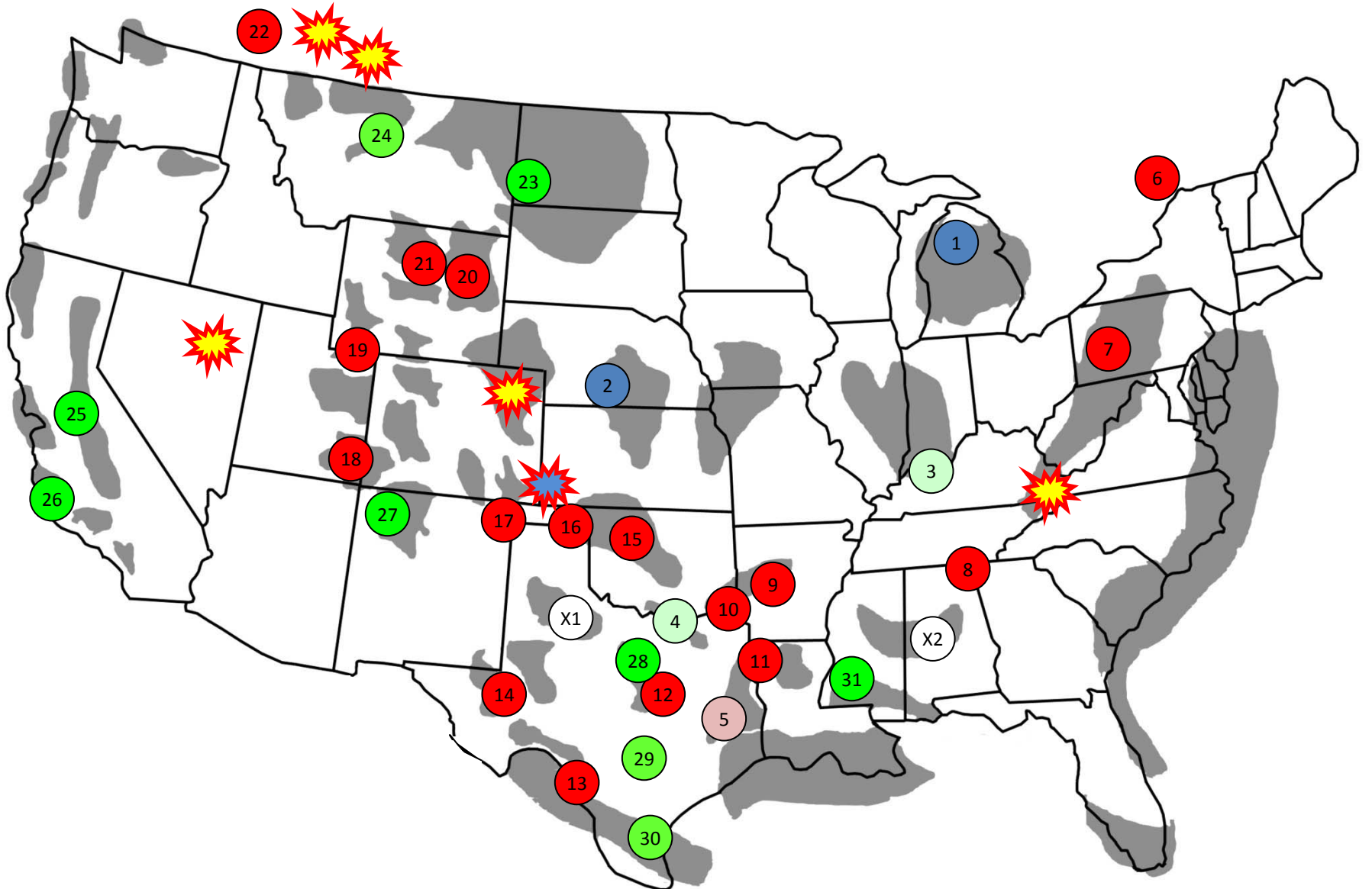
Interpreted Maturity

Jarvie et al., 2005

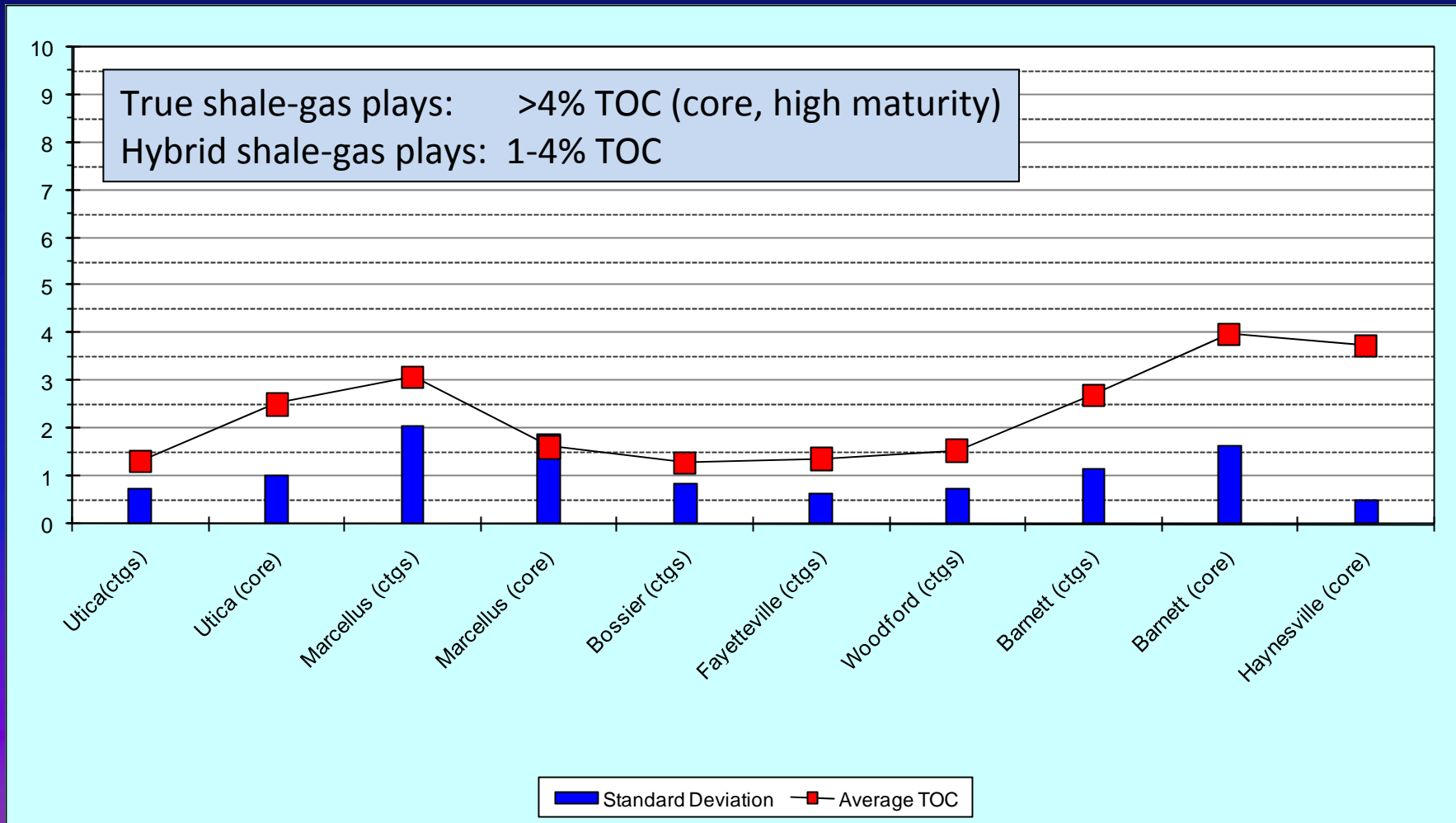
mcf/d



North American Shale Resource Plays



Comparison of TOC Values Cuttings vs. Core, Various Shales

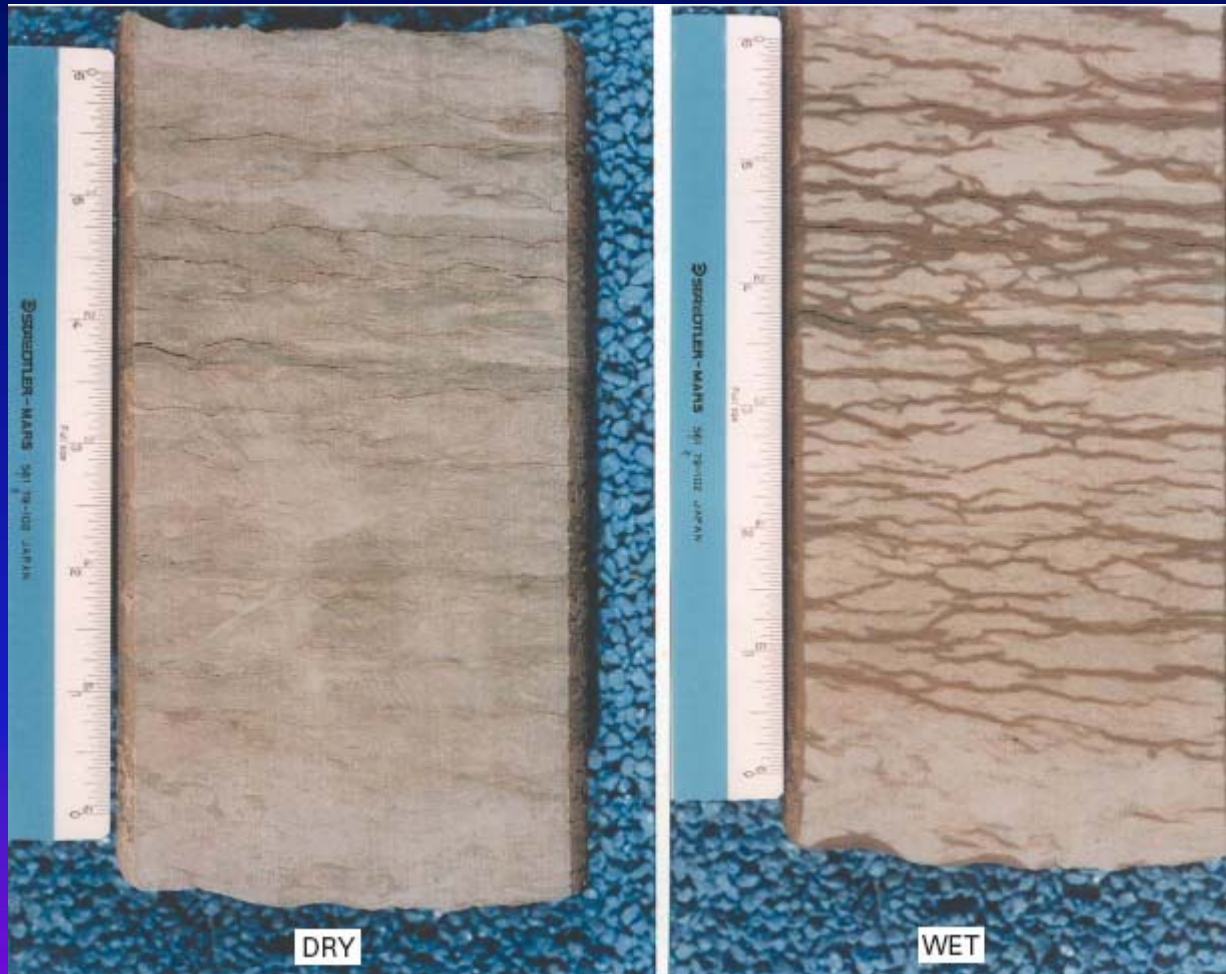


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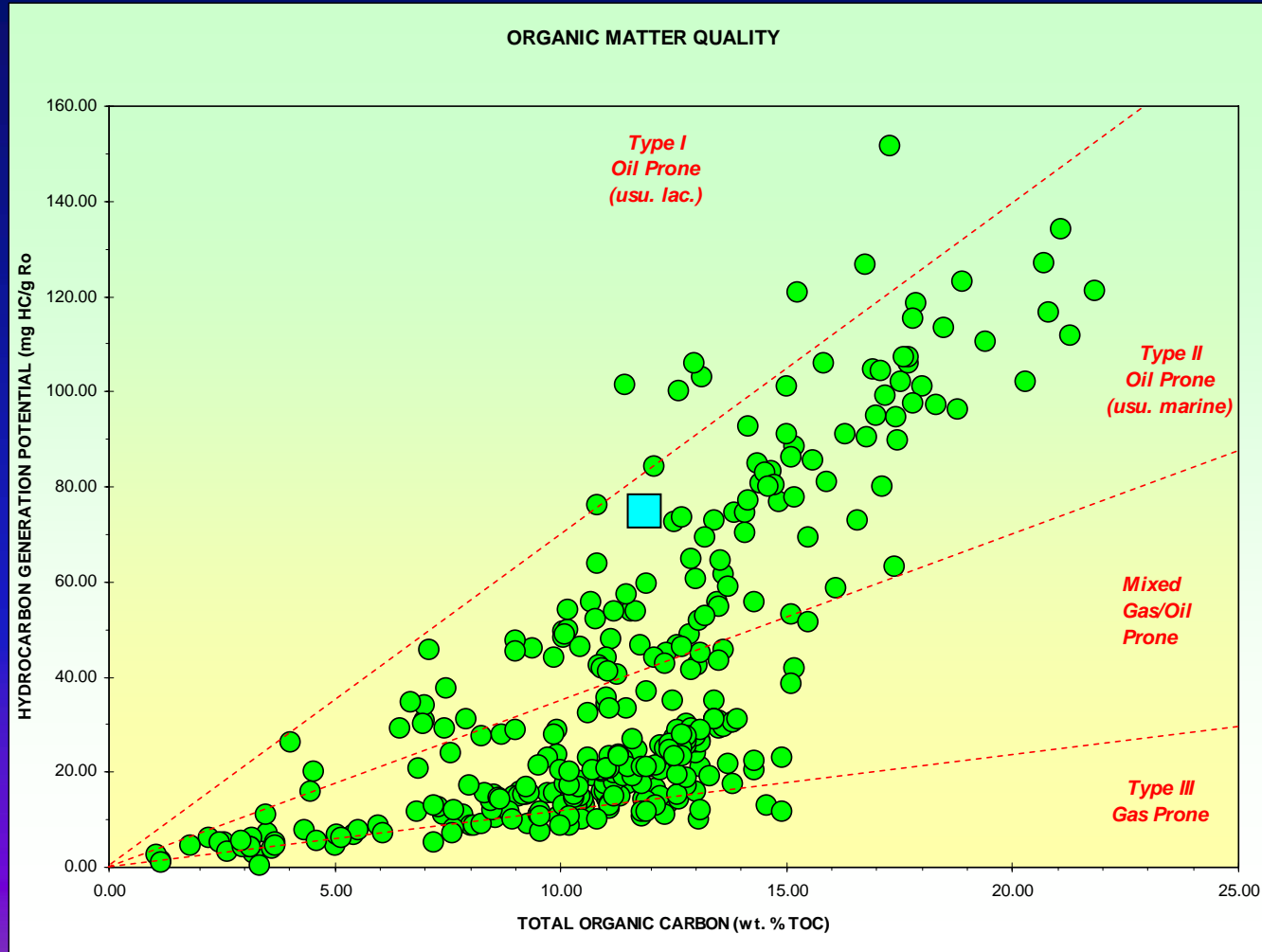
Fractures in Bakken Shale



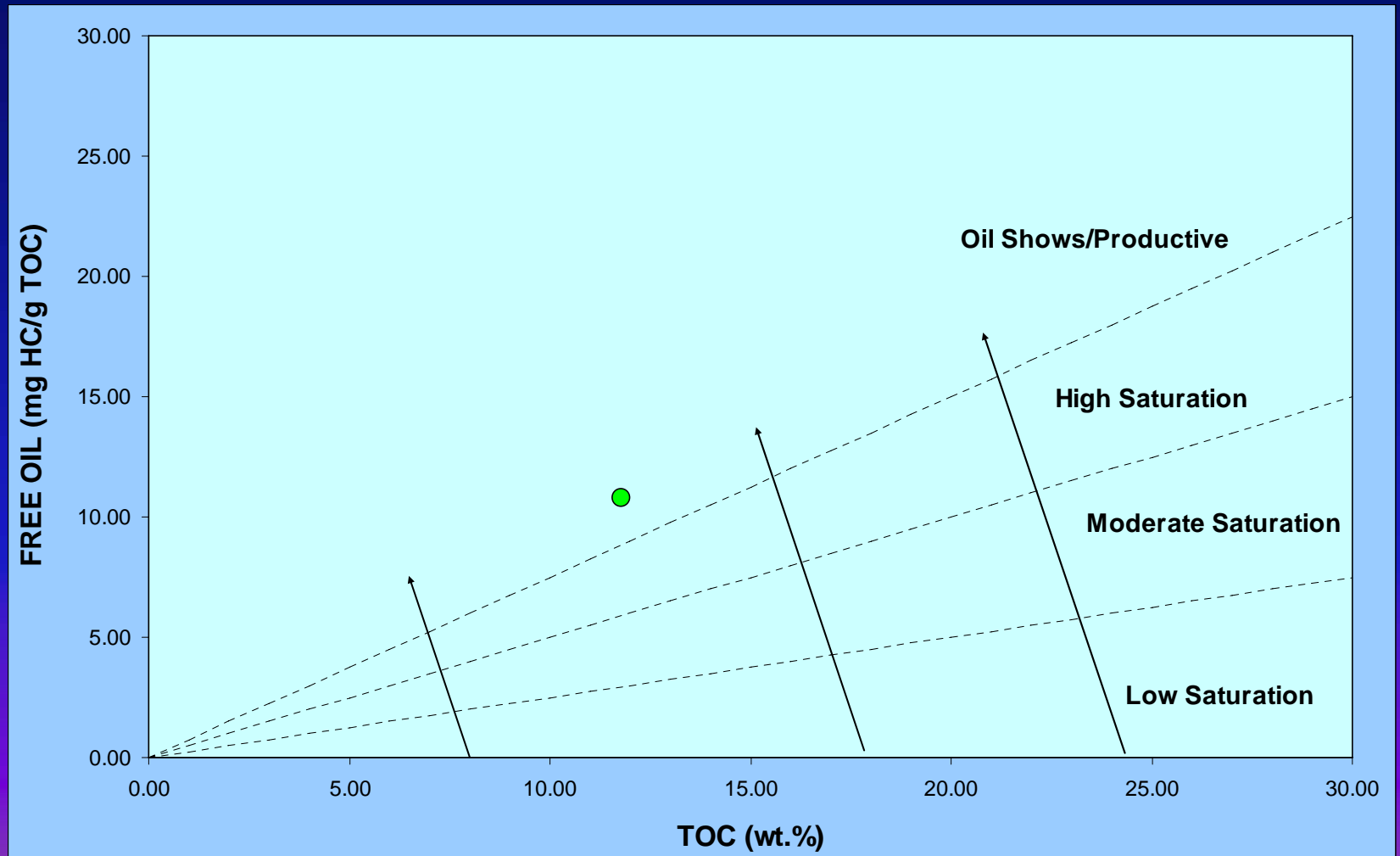
Pitman et al., 2001

Bakken Shale Database

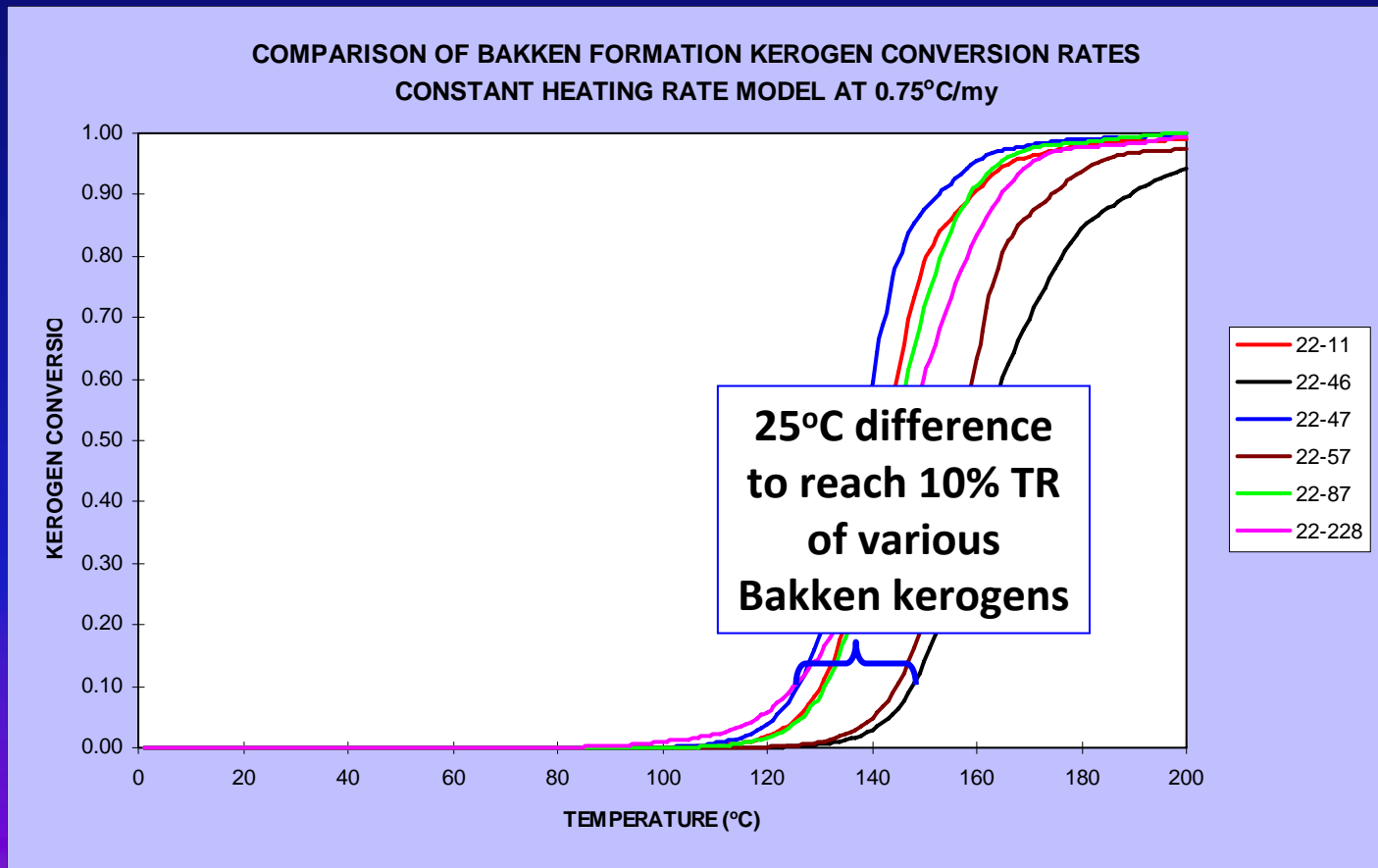
Williston Basin, USA



Residual Oil Saturation from geochemical analyses



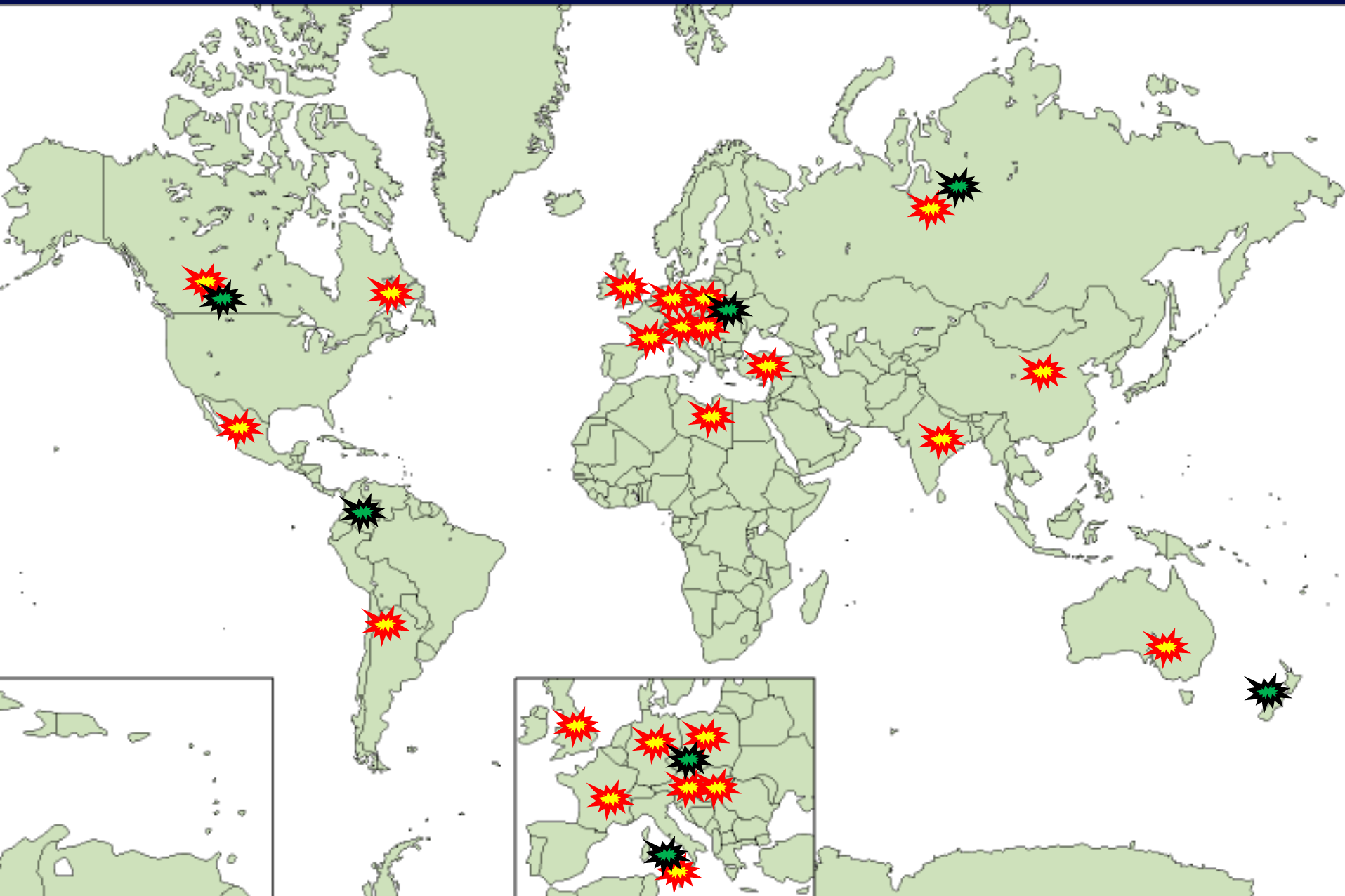
Variation in Bakken Shale Organofacies: Rates of Decomposition (kinetics)



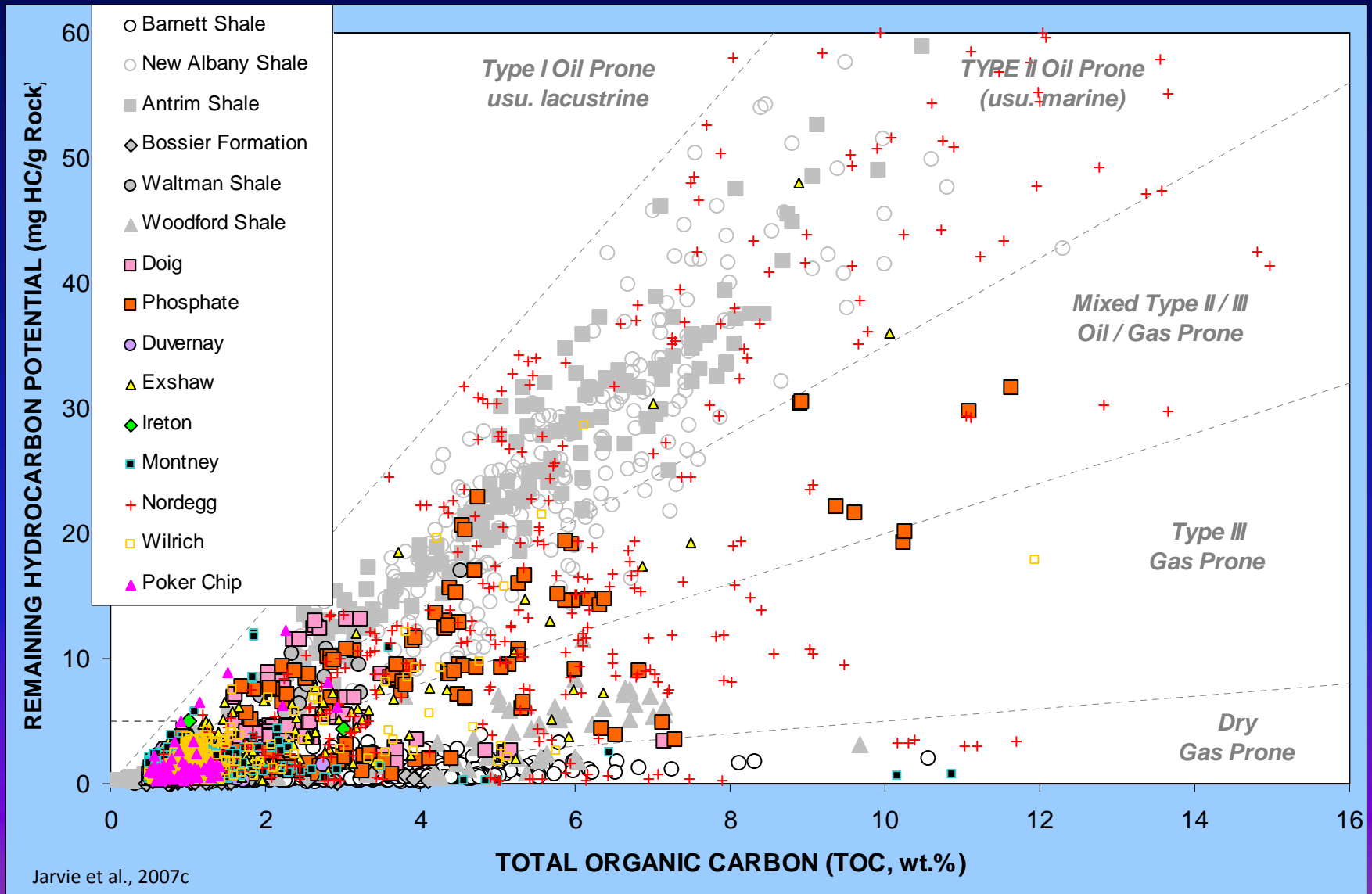
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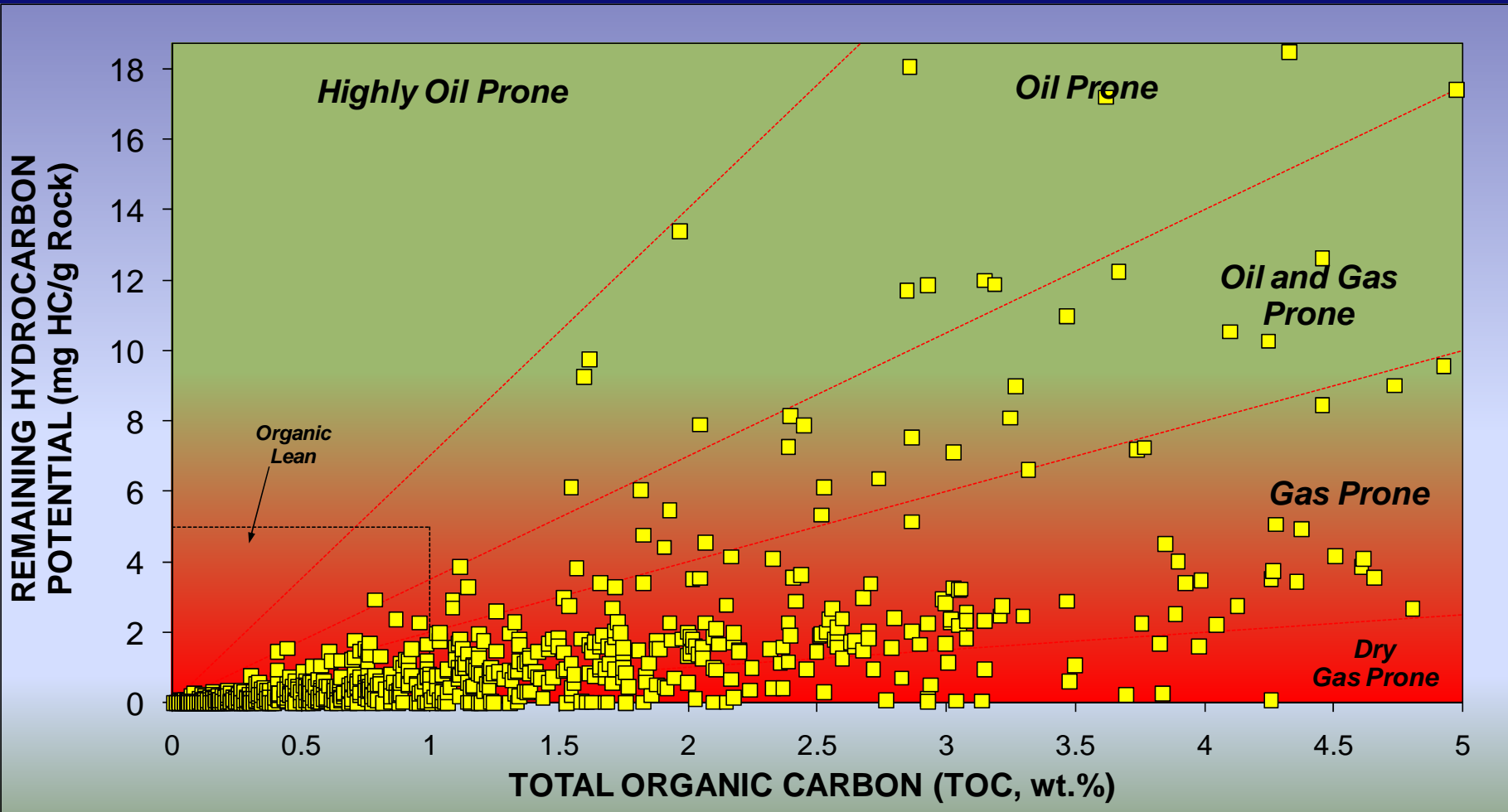
Global Potential Shale Resource Plays



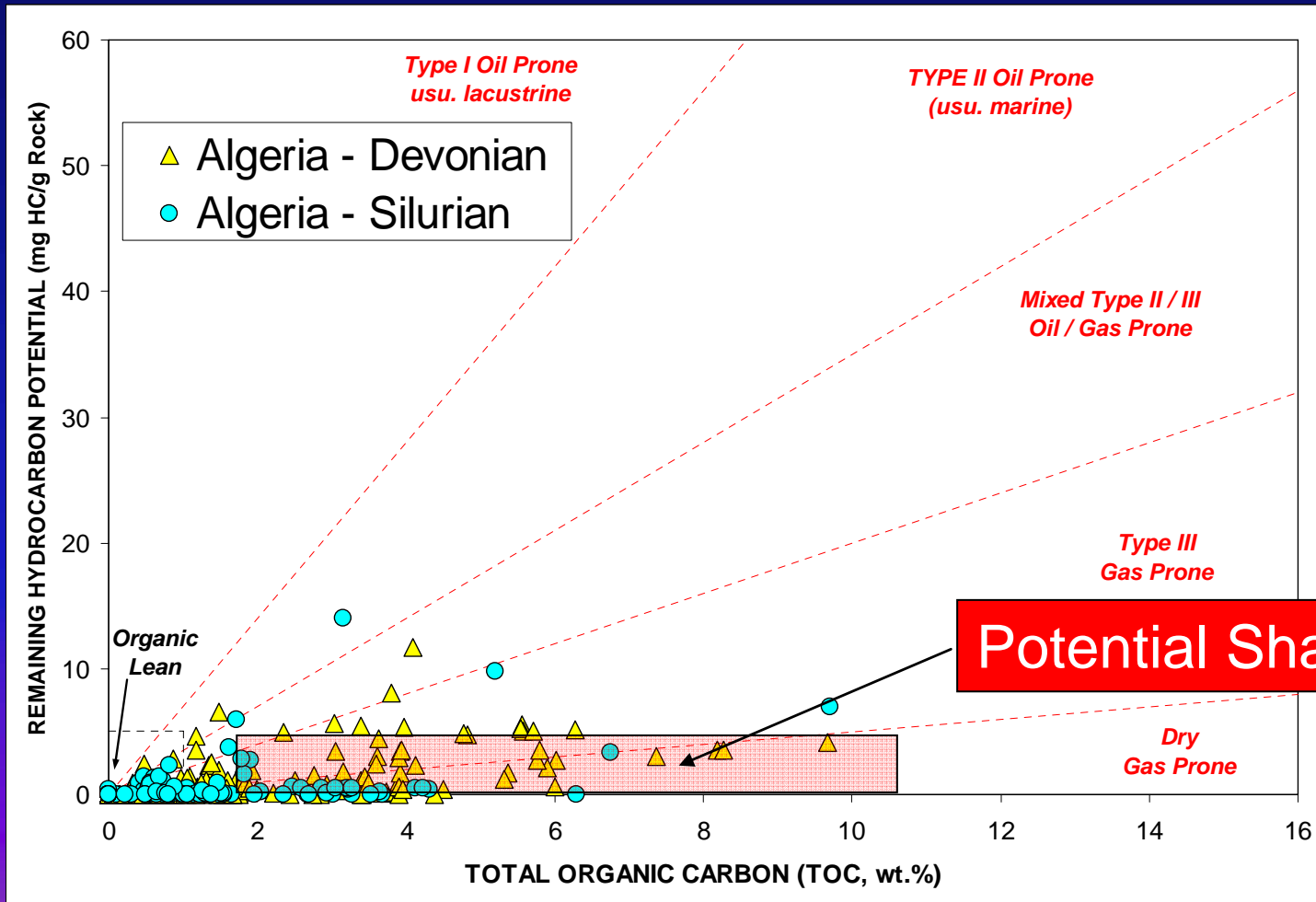
Western Canada Basin Source Rocks



Devonian Shale Poland



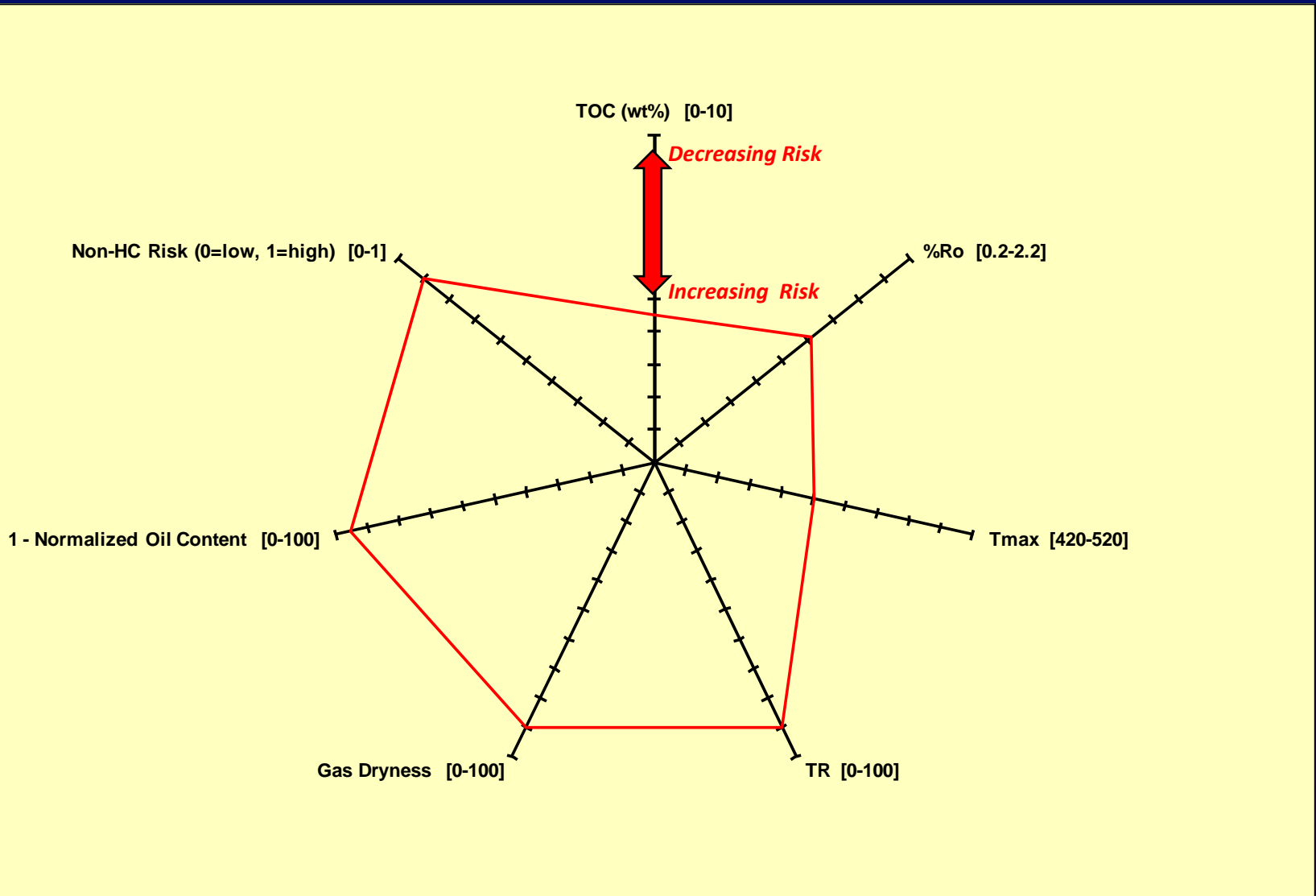
Devonian and Silurian Source Rocks in Algeria



Jarvie et al., 2005



Geochemical Shale-Gas Risk Assessment



Summary

- There are differences in and among shale resource plays
- Shale-gas and shale-oil systems have multiple system types and EURs reflect these differences
- Worldwide development of shale resource plays will expand in 2008/2009 especially in Europe and Asia

Thank you !

Peace be with you...

Shalom...

Salam alakum

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