Madison Group Source Rocks, Williston Basin, USA*

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Abstract

Madison Group reservoirs have yielded hundreds of millions of barrels of oil since production began in the 1950s. Historically, these oils were thought to be sourced by the Bakken Shale. However, oil fingerprint including light hydrocarbons and biomarker data clearly show these oils not to be related to Bakken Shale source rocks except in special cases in US fields. However, mixing of Madison and Bakken Shale sourced oils in Canadian Williston Basin reservoirs is quite common as a result of lateral migration and trapping of both Madison and Bakken Shale sourced oils. Finally, there can also be differences in stratigraphic nomenclature particularly the Tilston Member of the Mission Canyon formation. The evidence for Madison Group source rocks starts with an inversion of produced oil chemistry that demonstrates the difference from Bakken Shale produced oils and rock extracts in all geochemical properties from bulk analysis (e.g., sulfur contents), light hydrocarbons, pristane/phytane ratios, and traditional extended biomarker data. Review of the depositional setting of various Madison Group intervals demonstrate the occurrence of hypersaline, evaporitic, and highly sulfidic settings. The presence of microbialites further amplifies available biomass for source rock development, although these may be part of the source story as well. The primary source rock for Madison Group reservoirs has been largely focused on the Lodgepole Formation, which has been documented as a source rock in both Canada and the USA. However, additional source rock intervals are found throughout the Madison Group from the Ratcliffe Member of the Charles Formation to various members of the Mission Canyon Formation. Identification of prospective Madison Group source rocks was initiated with a review of available cores as this is a conventionally produced carbonate reservoir. High TOC and hydrogen indices have been now recorded in various members of the Madison Group including the Lodgepole, Mission Canyon (at least three separate source intervals, and the Ratcliffe Member of the Charles Formation. Of 38 samples with greater than 1% TOC from 16 wells in North Dakota, restored TOC values range from 3-5 wt.%. Hydrogen indices range from about 300 to over 600 mg HC/g TOC. In order to confirm these rock units as effective source rocks, correlation to produced oils was accomplished verifying the Madison Group source potential.

Selected References

Hendricks, M.L., 1988, Shallowing-Upward Cyclic Carbonate Reservoirs in the Lower Ratcliffe Interval (Mississippian), Williams and McKenzie Counties, North Dakota, *in* S.M. Goolsby and M.W. Longman, (eds.), Occurrence and Petrophysical Properties of Carbonate Reservoirs in the Rocky Mountain Region: Rocky Mountain Association of Geologists, p. 371-380.

Peterson, J.A., 1996, Williston Basin Province (031), *in* D.L. Gautier, G.L. Dolton, K.I. Takahashi, and K.L. Varnes (eds.), 1995 National Assessment of United States Oil and Gas Resources – Results, Methodology, and Supporting Data: U.S. Geological Survey Digital Data Series DDS-30, Release 2, 1996.

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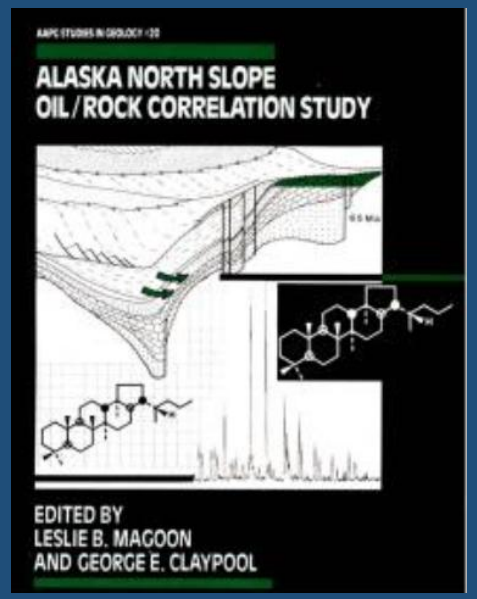
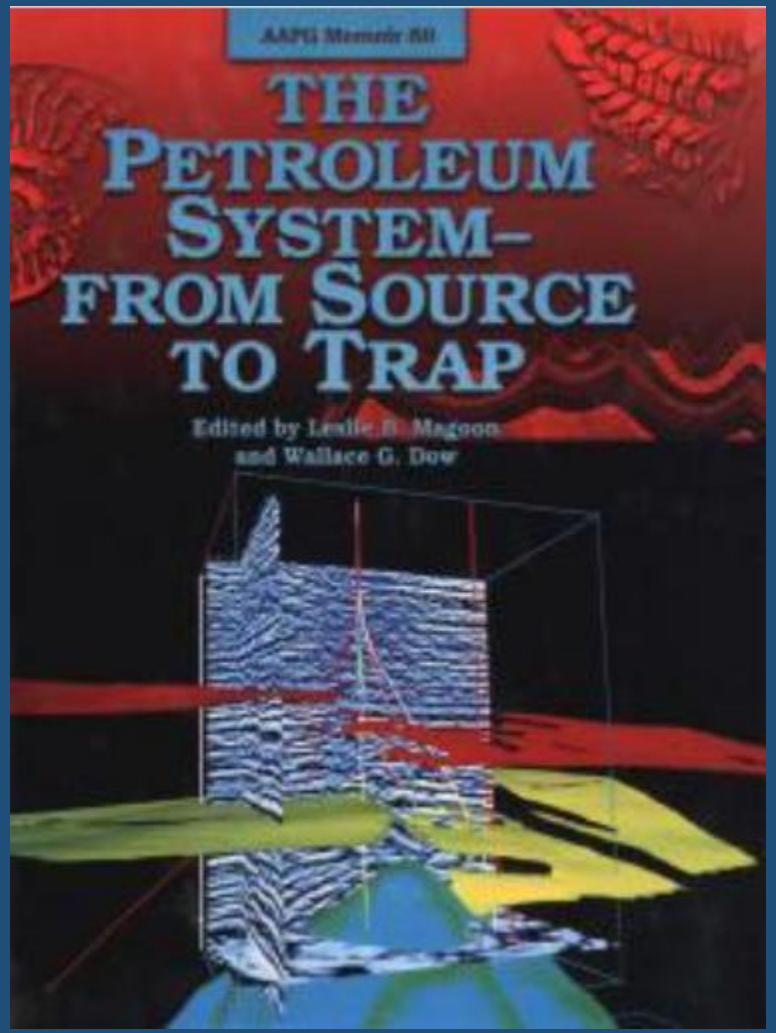
Honoring 50 years of Les Magoon



1984



1995

Pimienta-Tamabra(!)—A Giant Supercharged Petroleum System in the Southern Gulf of Mexico, Onshore and Offshore Mexico

2001

Acknowledgements

- James A. Peterson
- Dick Inden
- Julie Lefever and Stephan Nordeng
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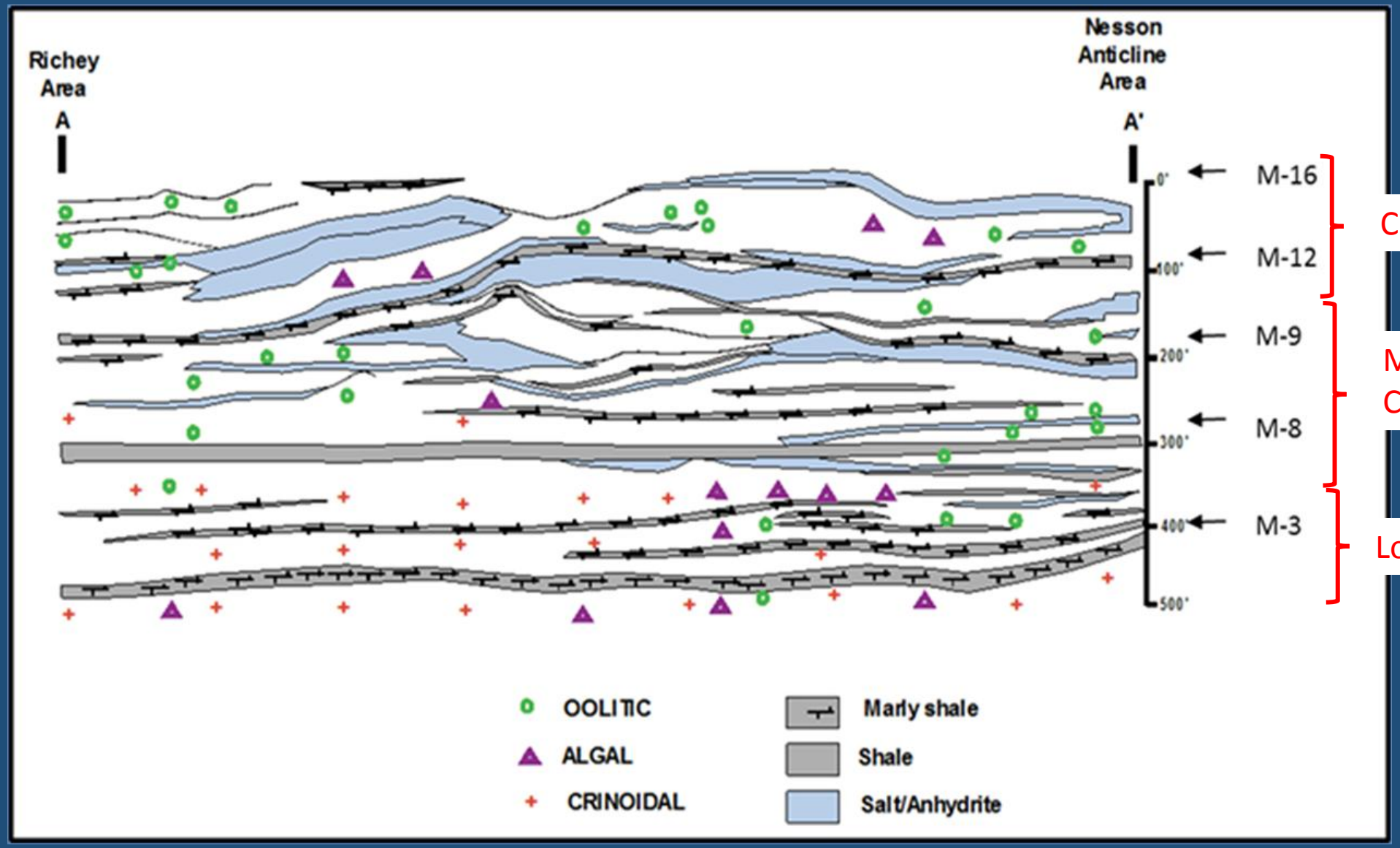
- Albert Maende, Wildcat Technologies
- Brian Jarvie, Geomark Research (Leco TOC, CC, and HAWK)
- Don Rocher et al., Geomark Research (GCMSMS)
- Paul Walker, Weatherford Labs (SARA, GCMS)

Content

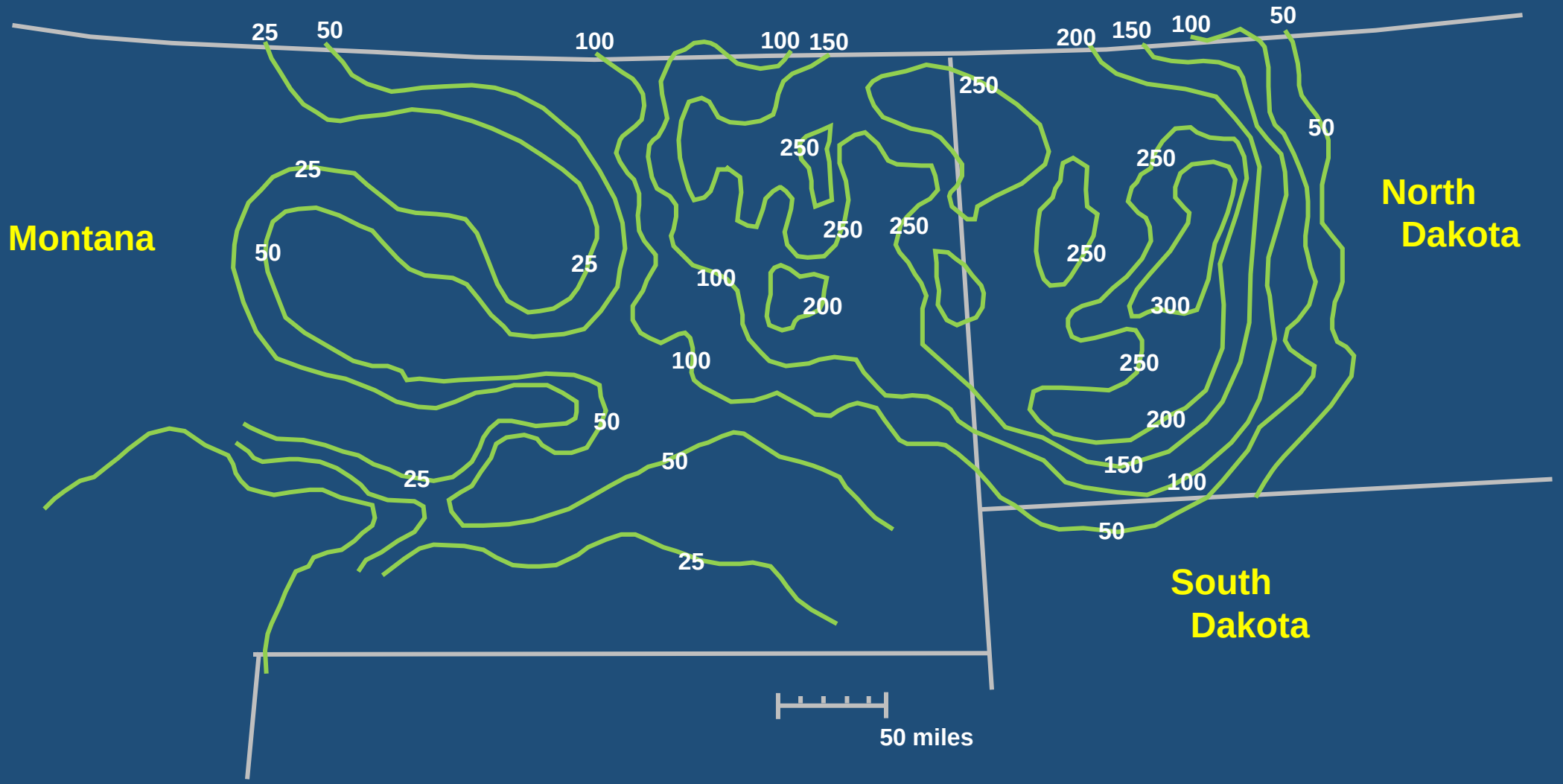
- Background
- Results: Madison Group Source Rocks
  - Basic data (TOC, Rock-Eval)
  - Volumetric estimates
  - Gas chromatographic fingerprinting
  - Biomarker assessment
- Synopsis

Diagrammatic Illustration of Madison Group



Peterson, 1996

“Net thickness of marine dark shale and shaly carbonate interbeds of Madison Group”



Peterson, 1996

Hunt-1 NPRR
Dawson Co., MT

30-40 ft of gamma ray spikes

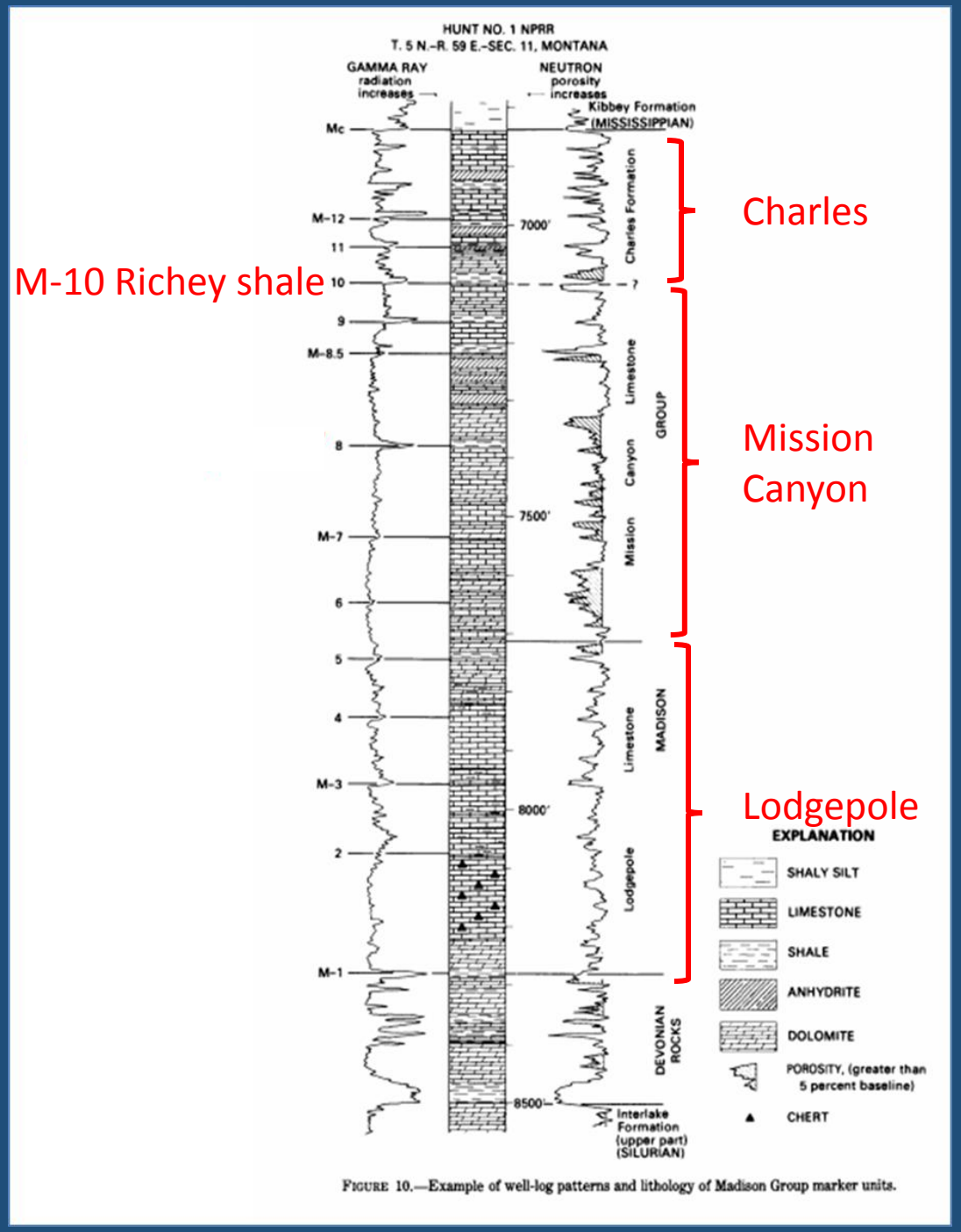
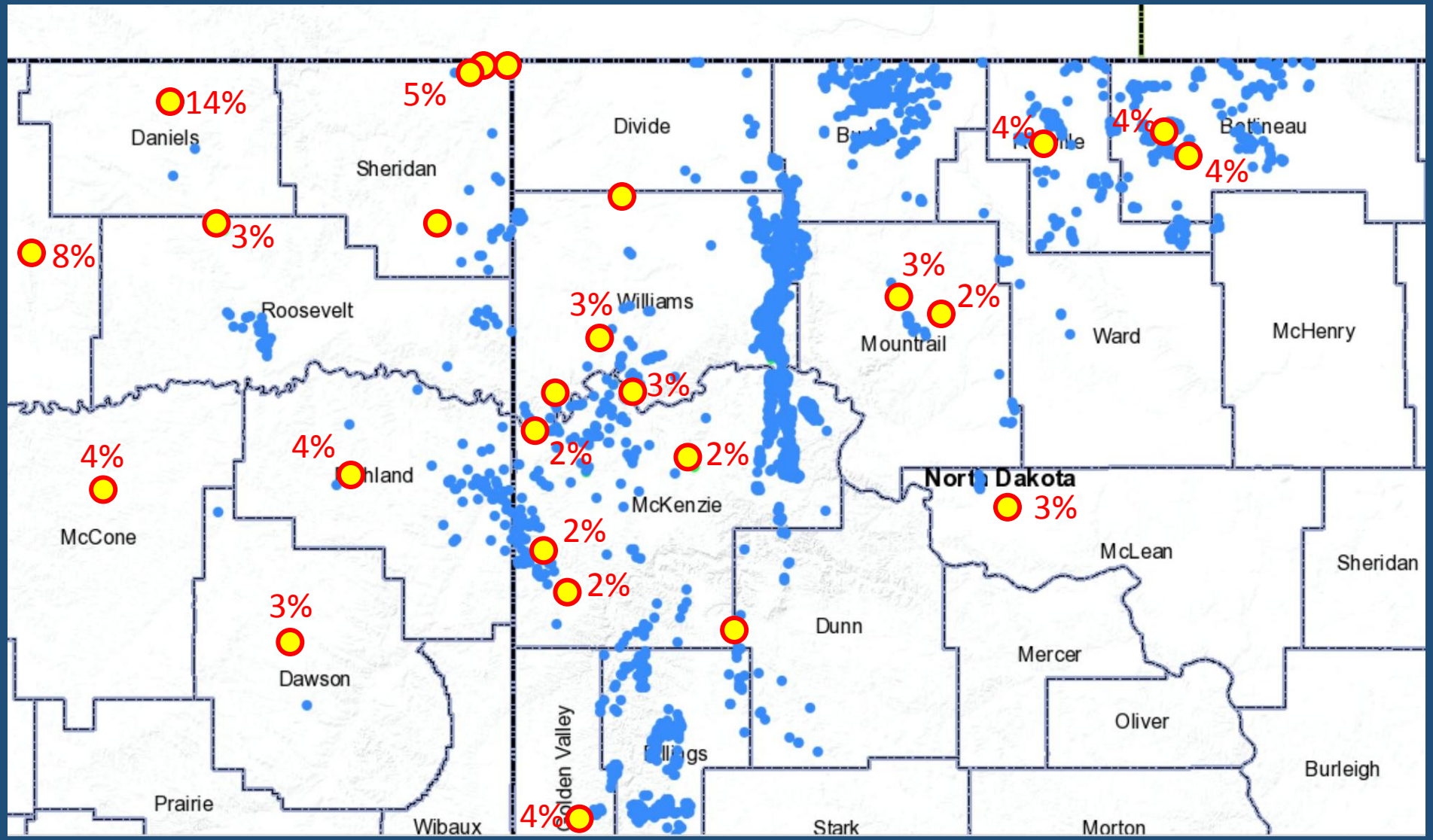


FIGURE 10.—Example of well-log patterns and lithology of Madison Group marker units.

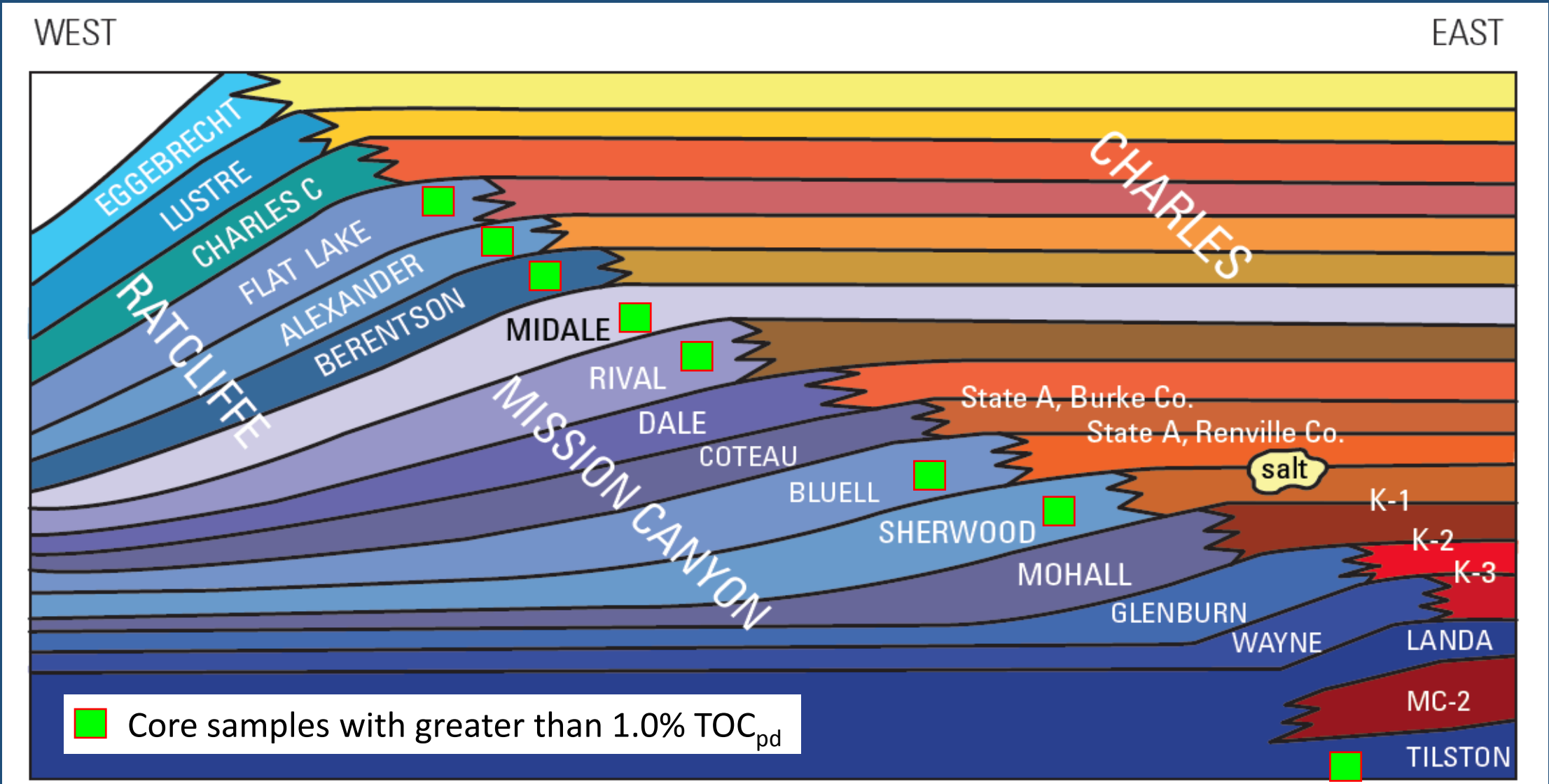
Peterson, 1996

Madison Production with location of Madison Group source rocks having > 2% TOC_{pd}



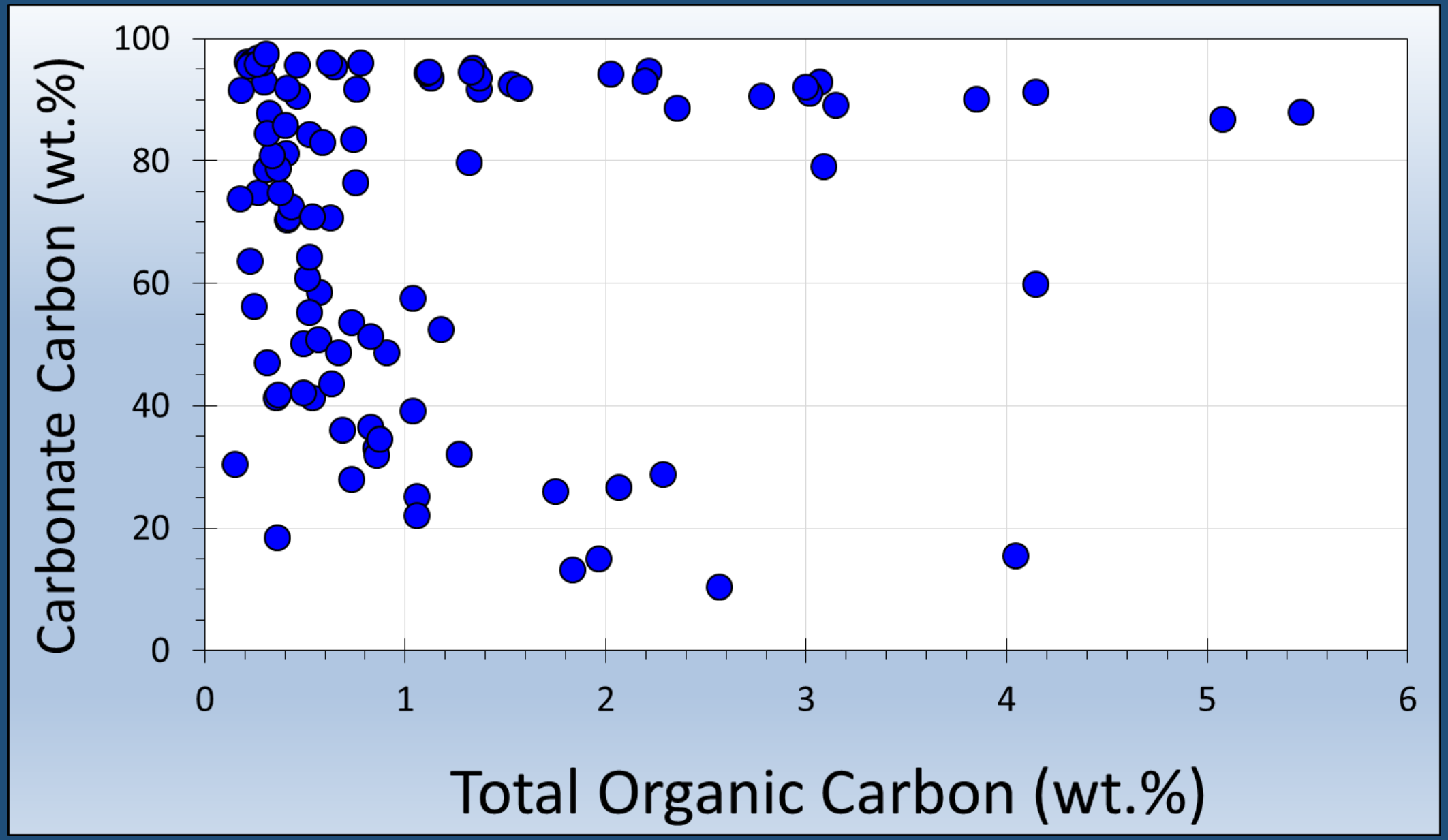
Madison Group Organic-Rich Intervals

(excl. Lodgepole and False Bakken)

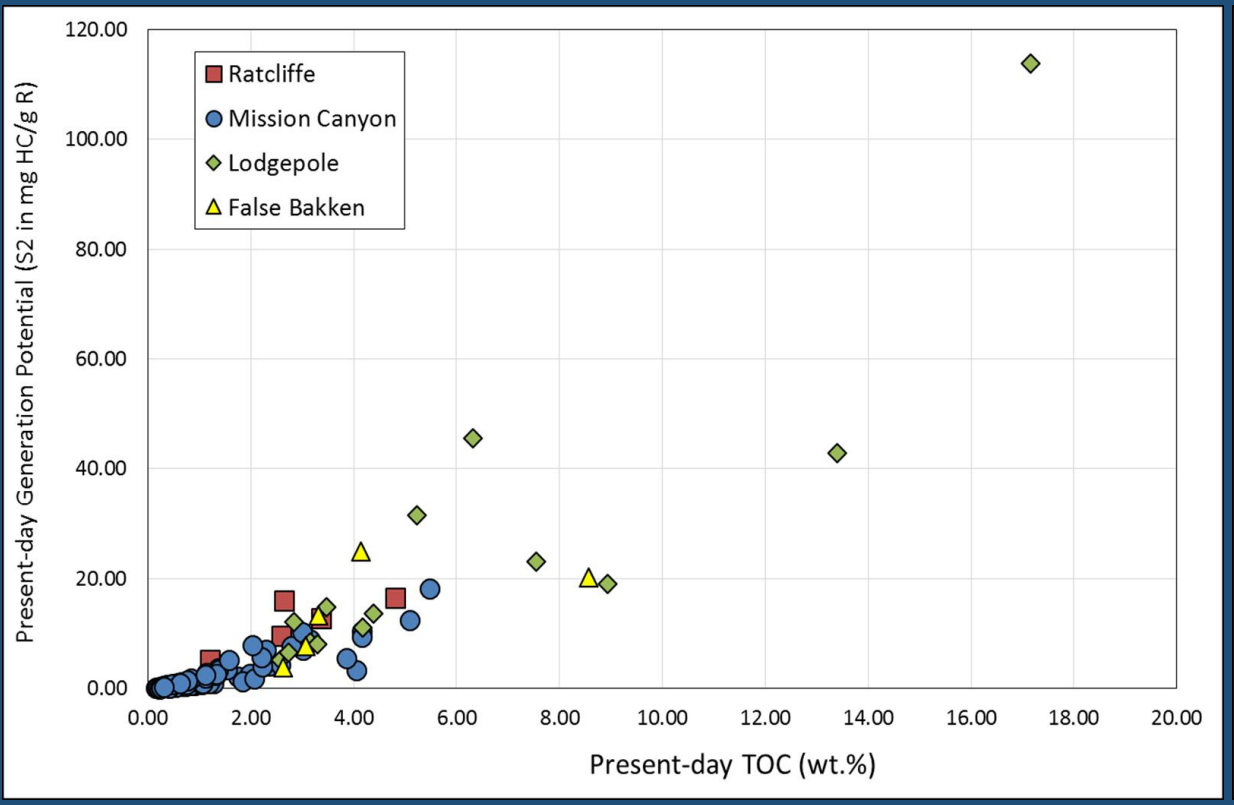


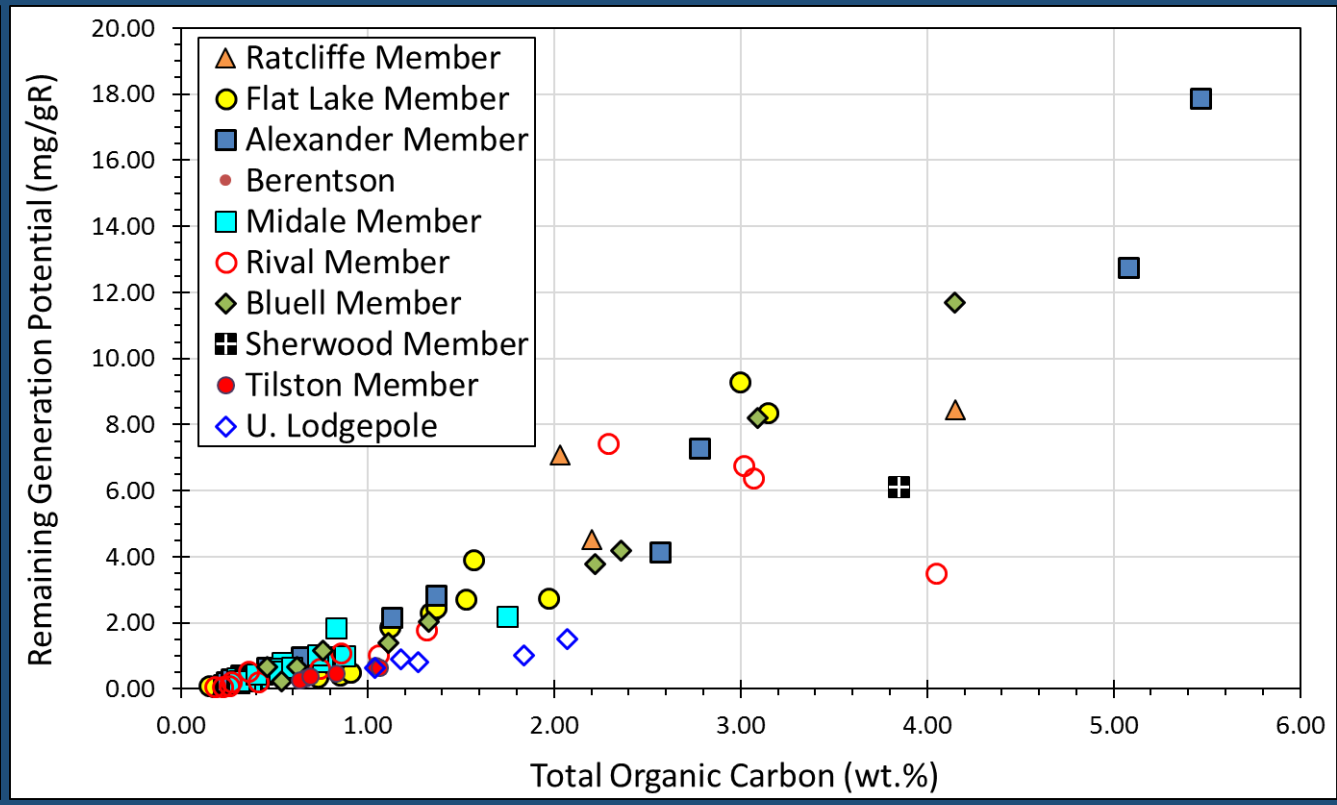
Modified from Hendricks, 1988

Carbonate vs Organic Carbon

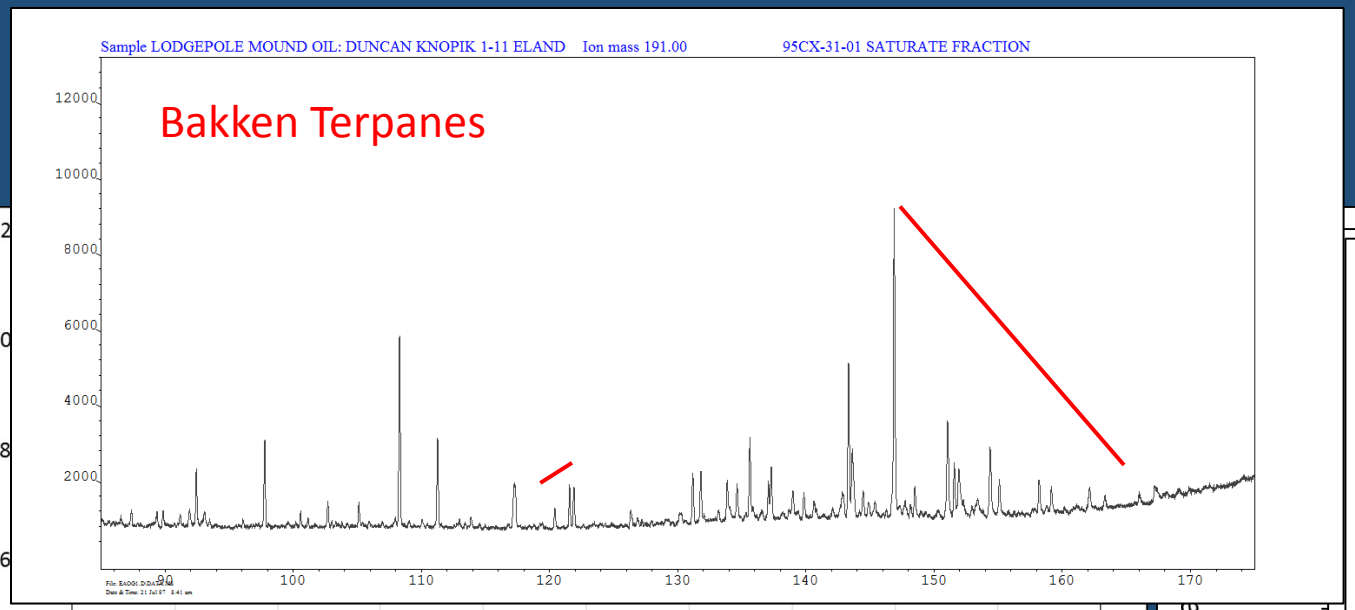


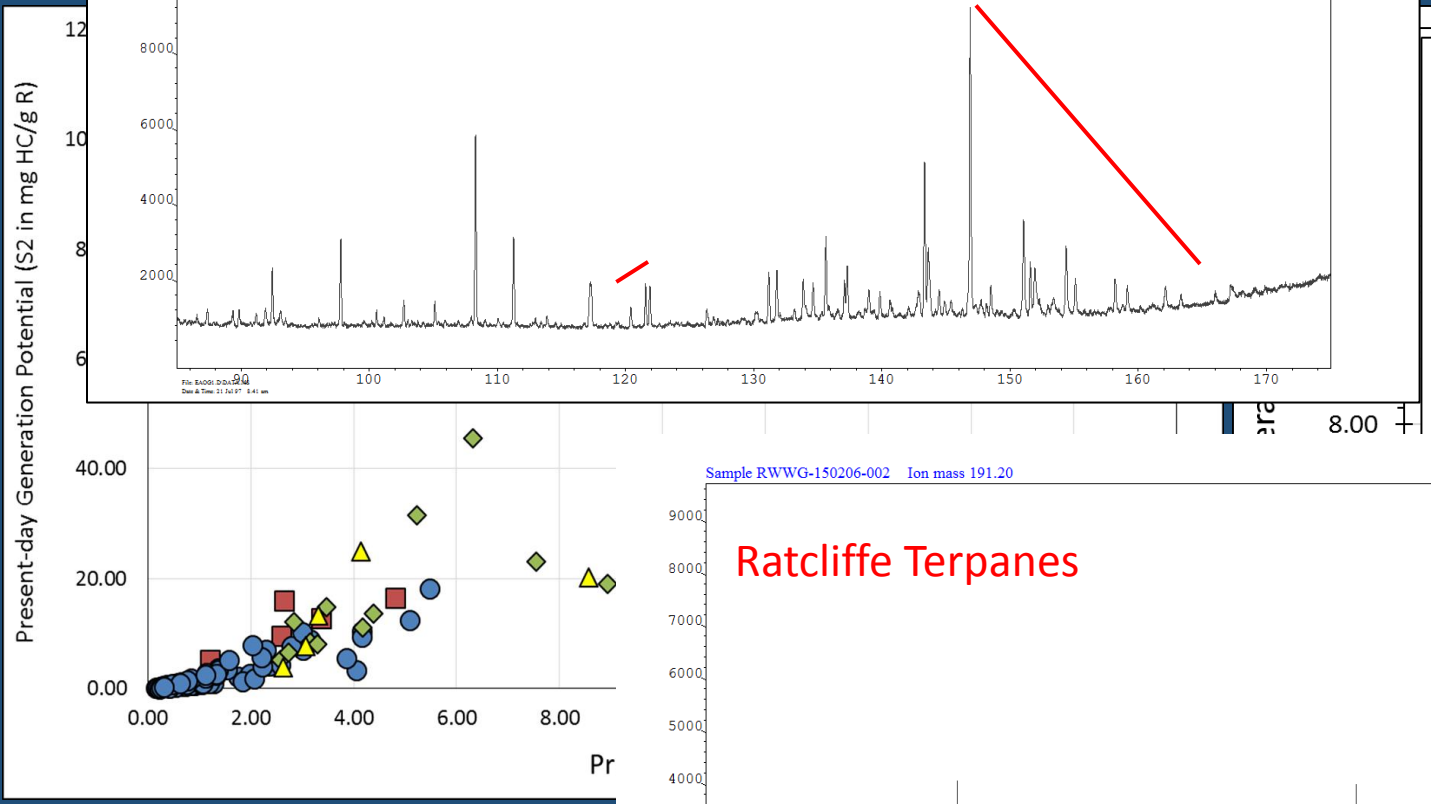
Present-day Values: S2 and TOC

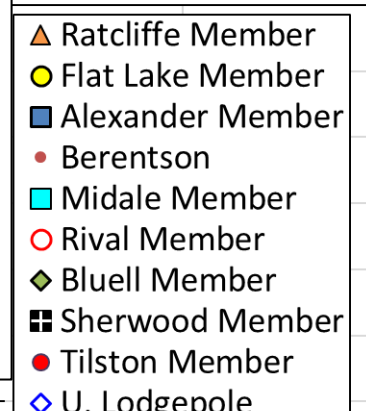


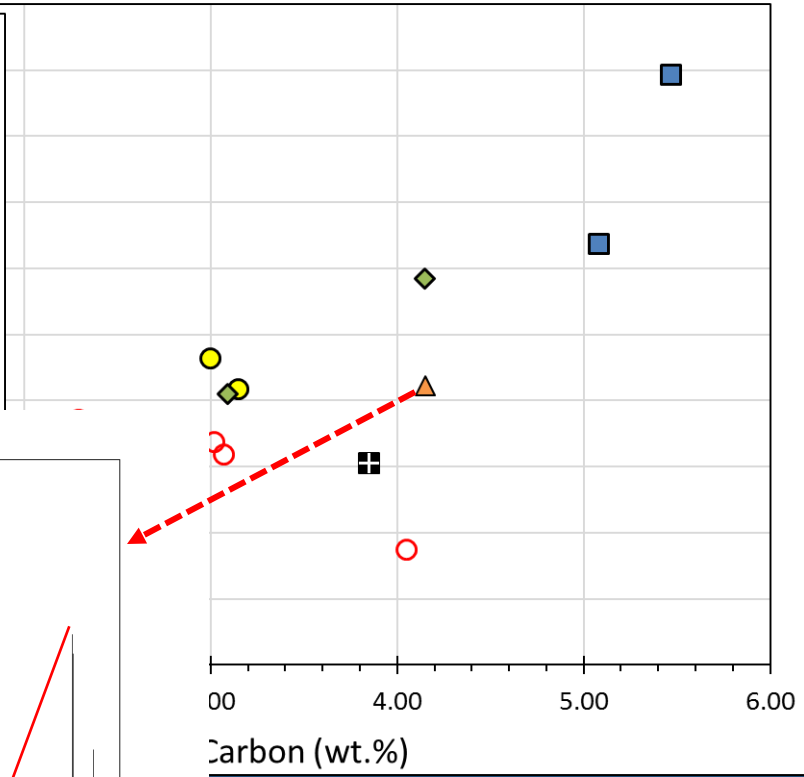


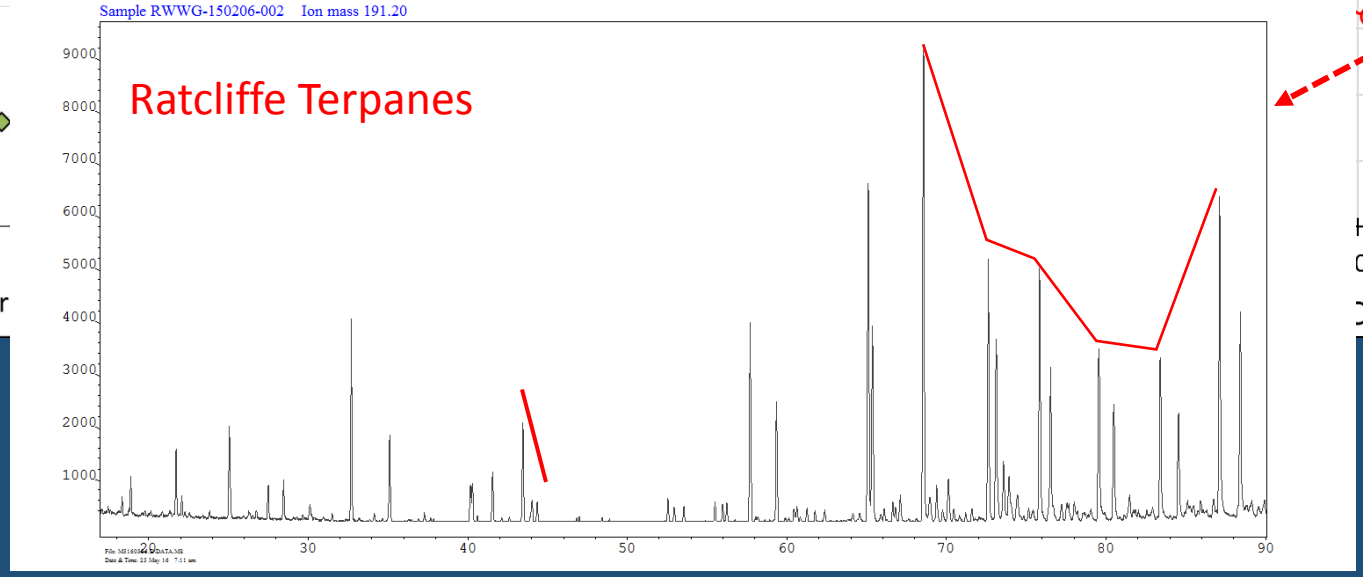
Present-day Values: S2 and TOC



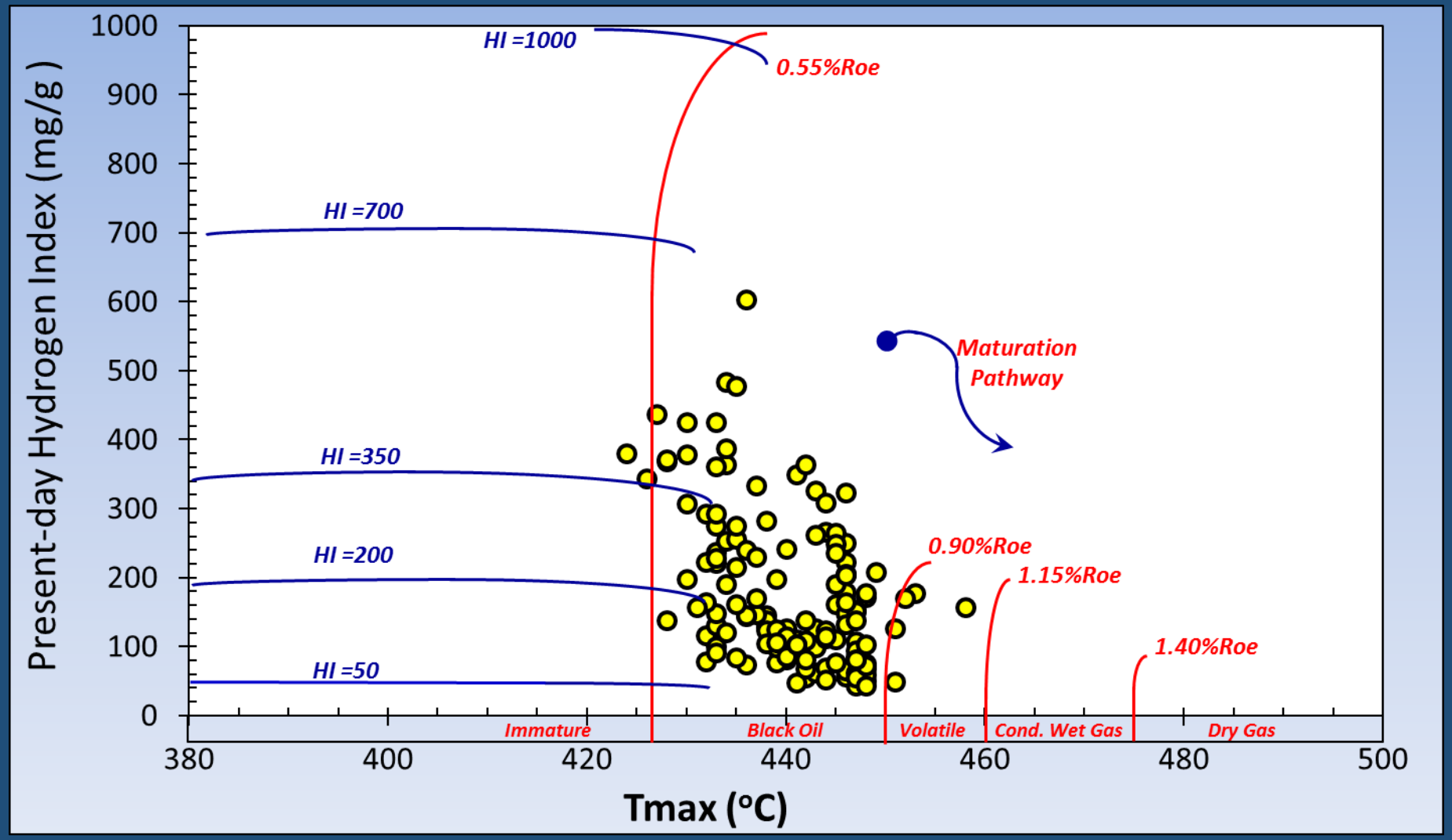






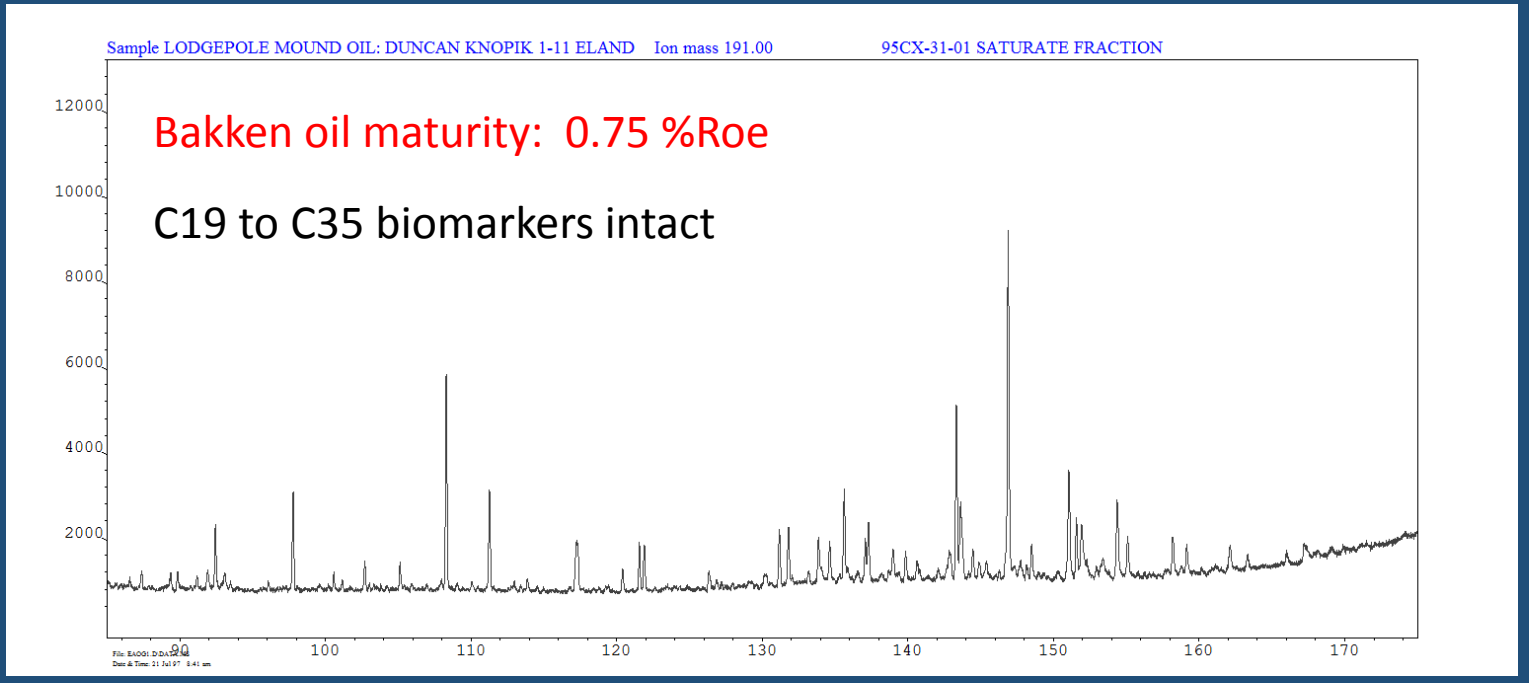


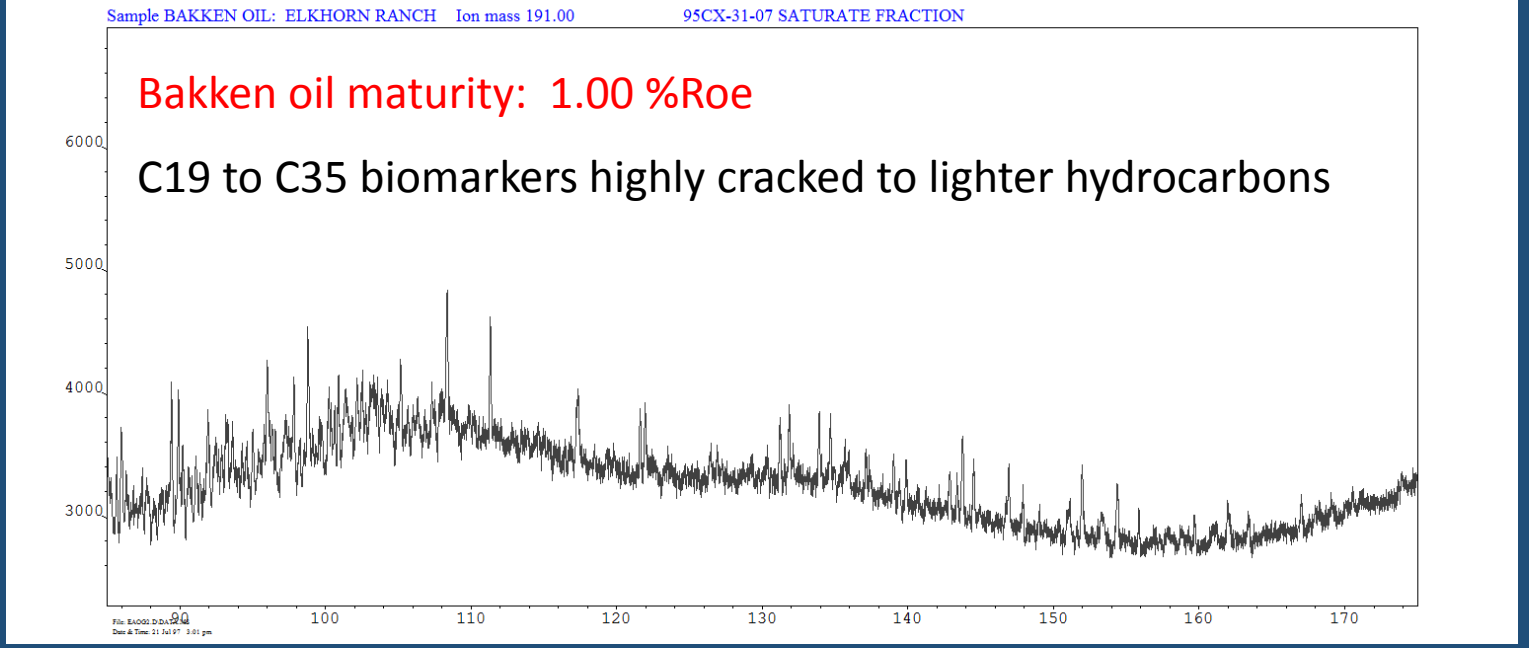
Relative Hydrogen Content and Maturity Madison Group



Bakken Shale and Bakken Shale sourced oils have relatively weak response among terpane biomarkers.

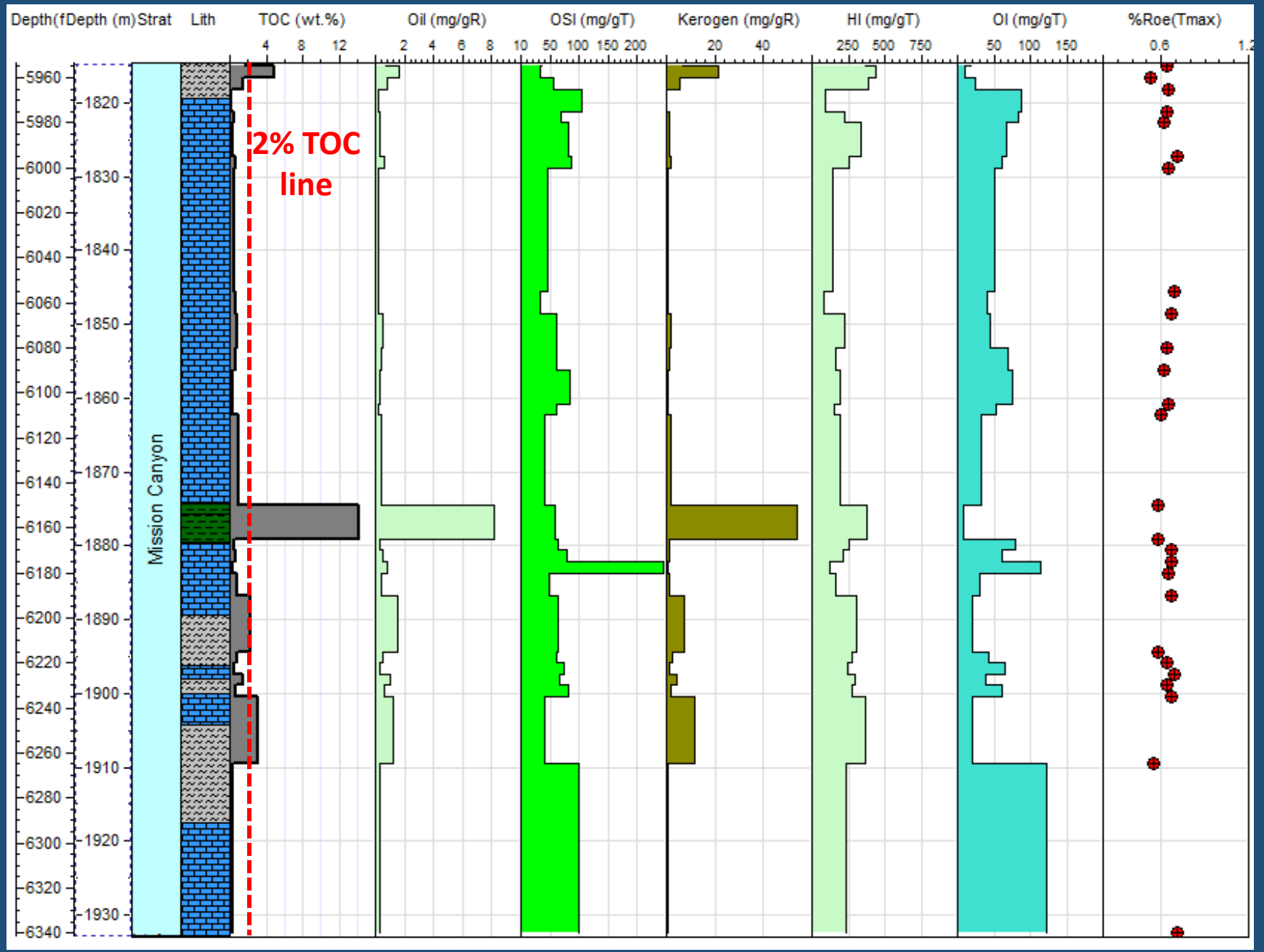
At modest levels of thermal maturity (ca. 1.0 %Ro) these biomarkers are cracked to lighter hydrocarbons and have a very weak response.



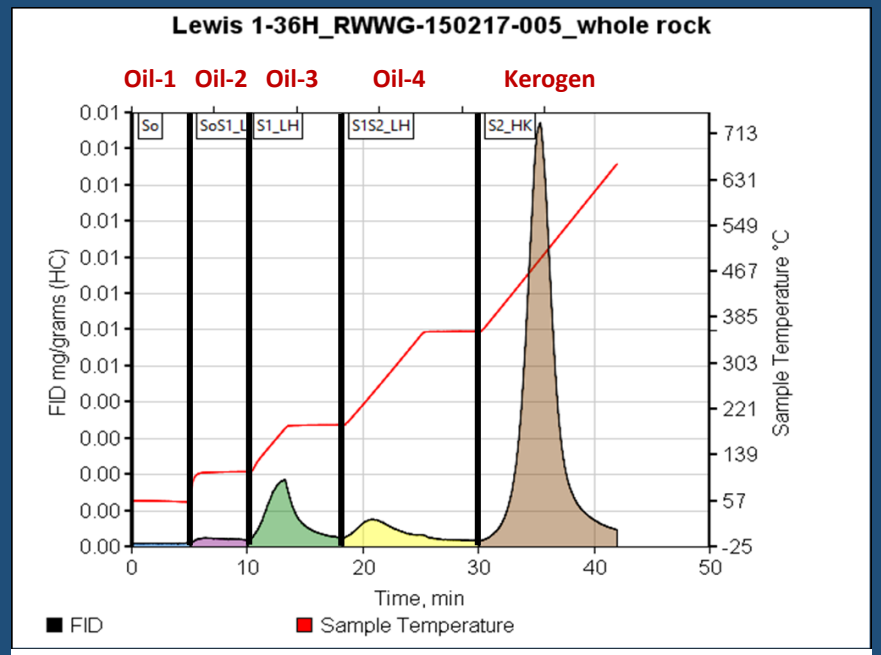


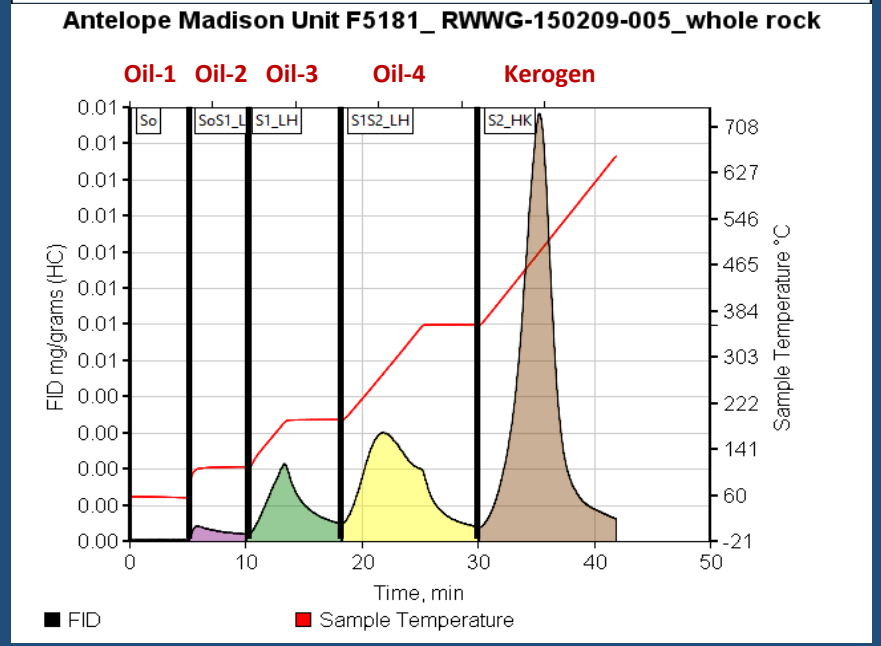
Geochemical Logs

Well profile with ca. 130 m of Mission Canyon

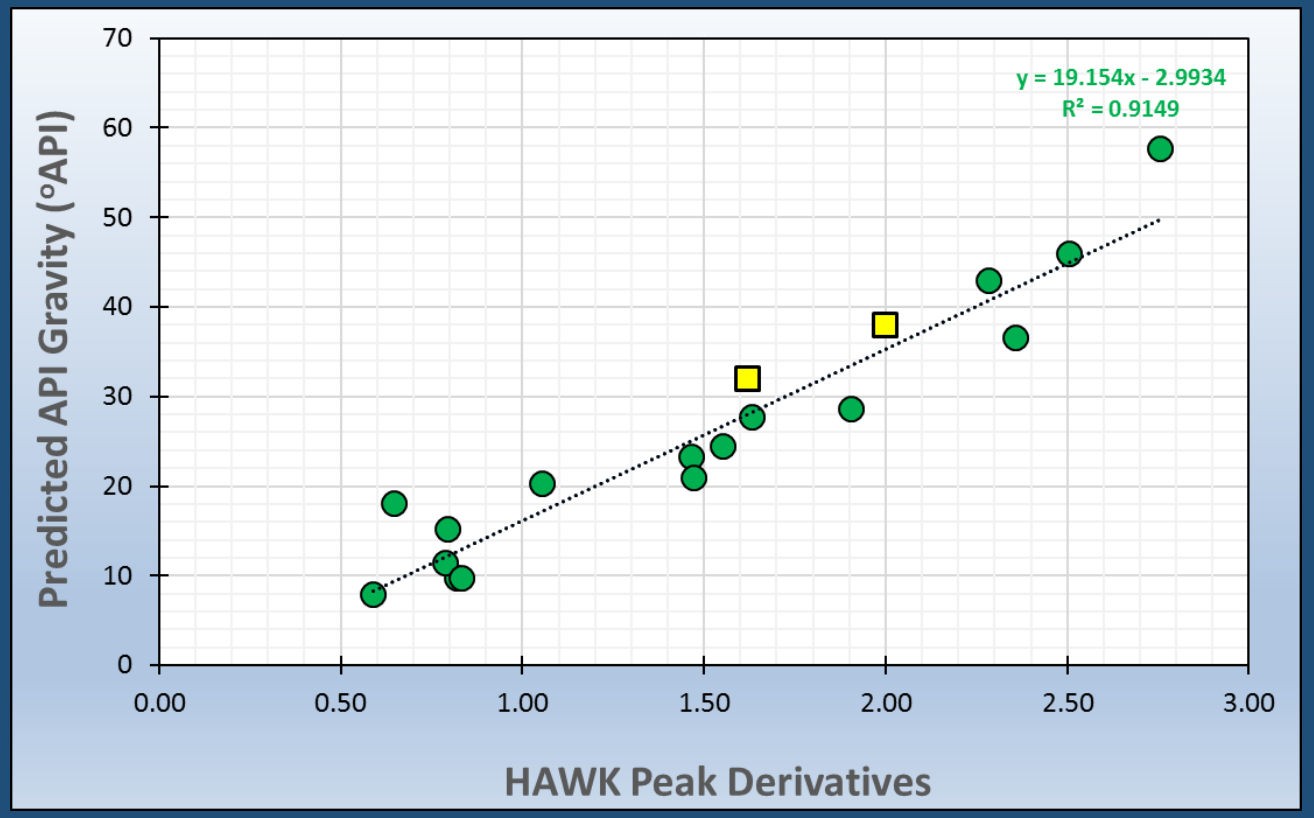


HAWK Retained Petroleum Assessment Method (PAM)





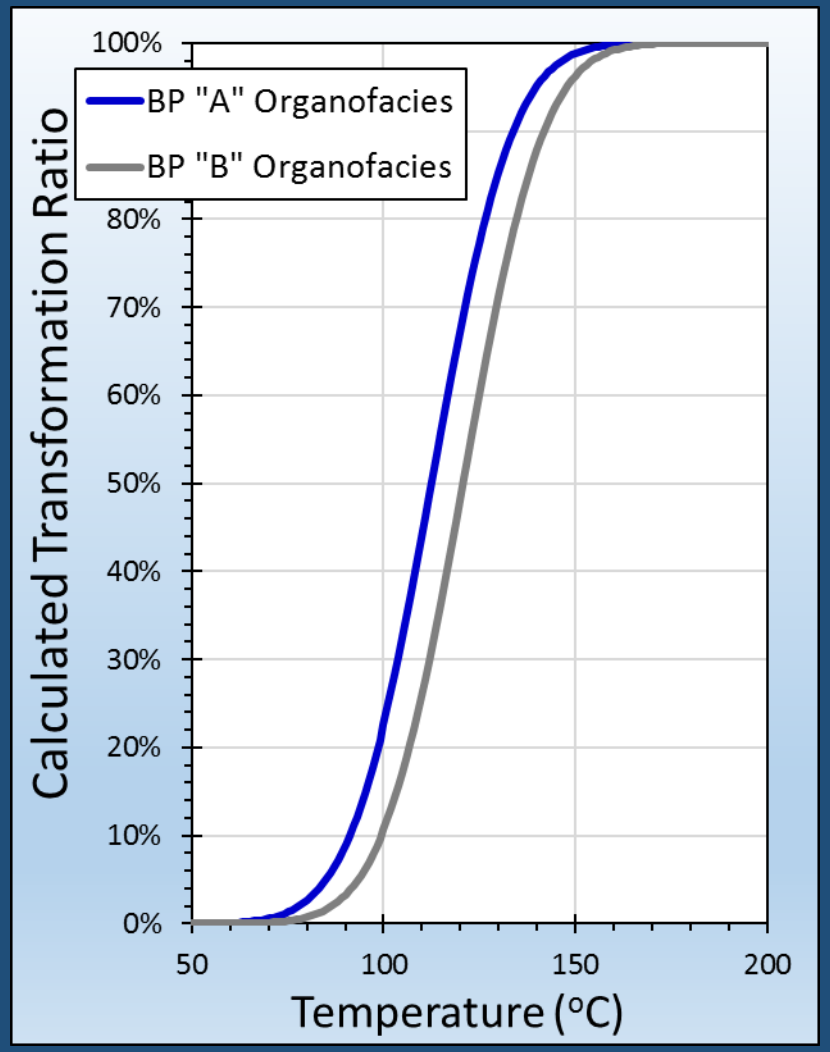
	Oil-1	Oil-2	Oil-3	Oil-4
Petroleum	C1-C5	C6-C7	C8-C12	C13-C40
Fractions	Saturates and Aromatics			Polars

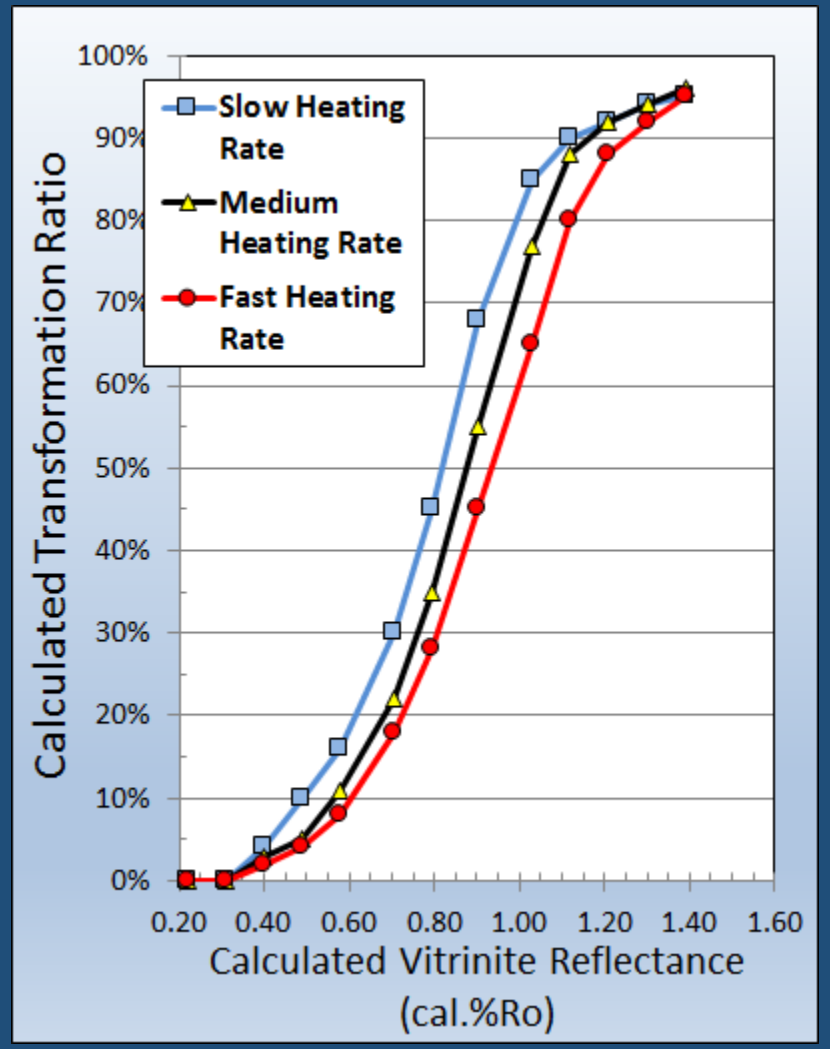


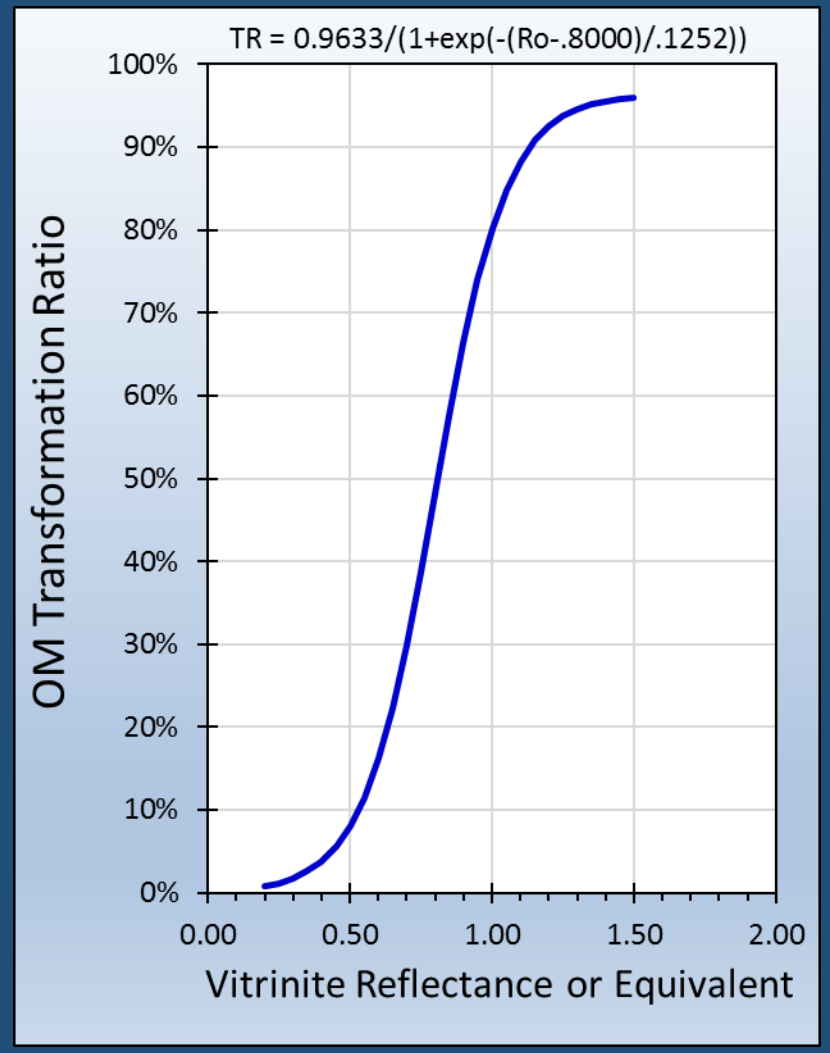
Maende and Weldon, 2016

Estimating Extent of Madison Group Organic Matter Conversion:

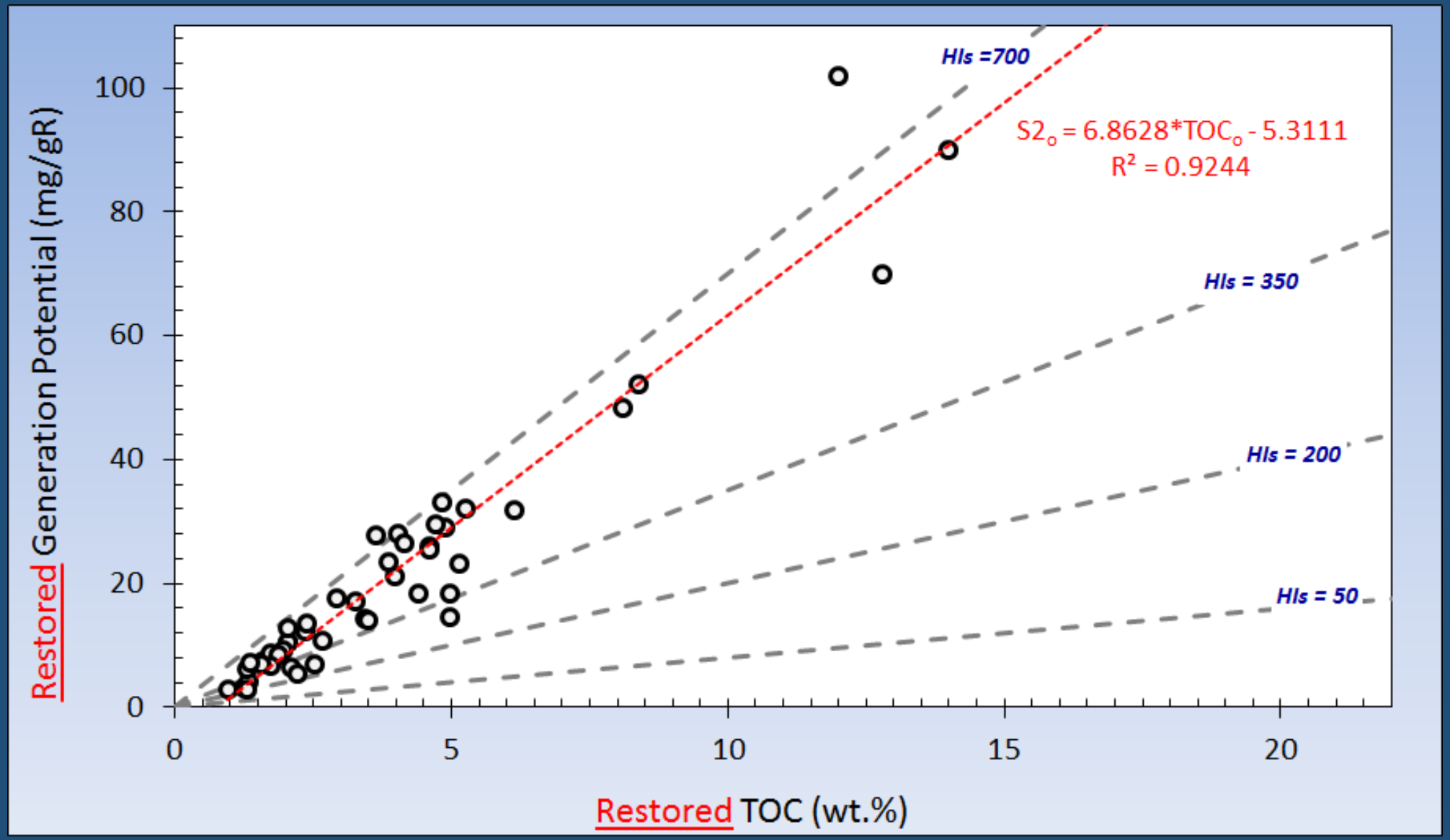
organic matter kinetics, heating rate, and TR



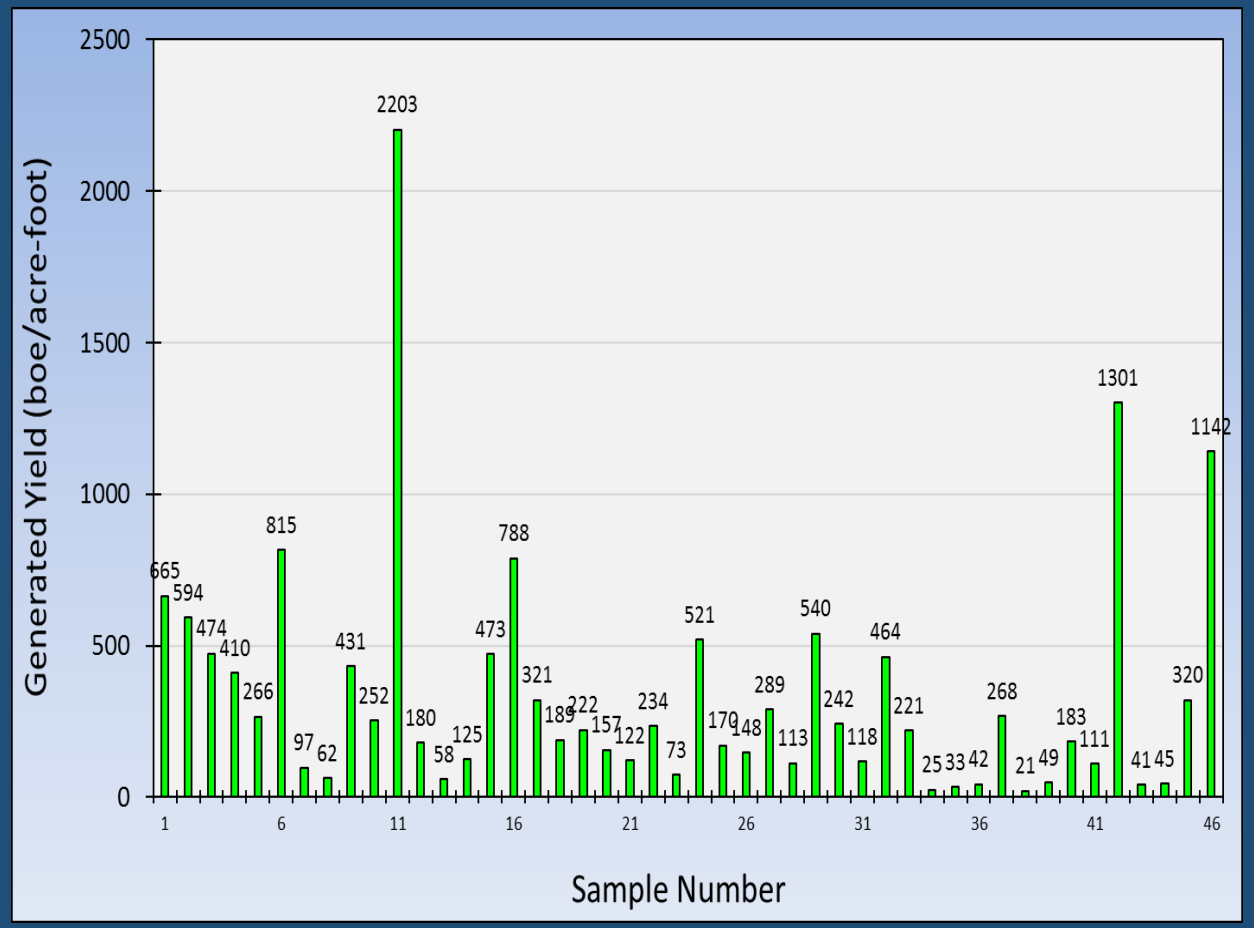


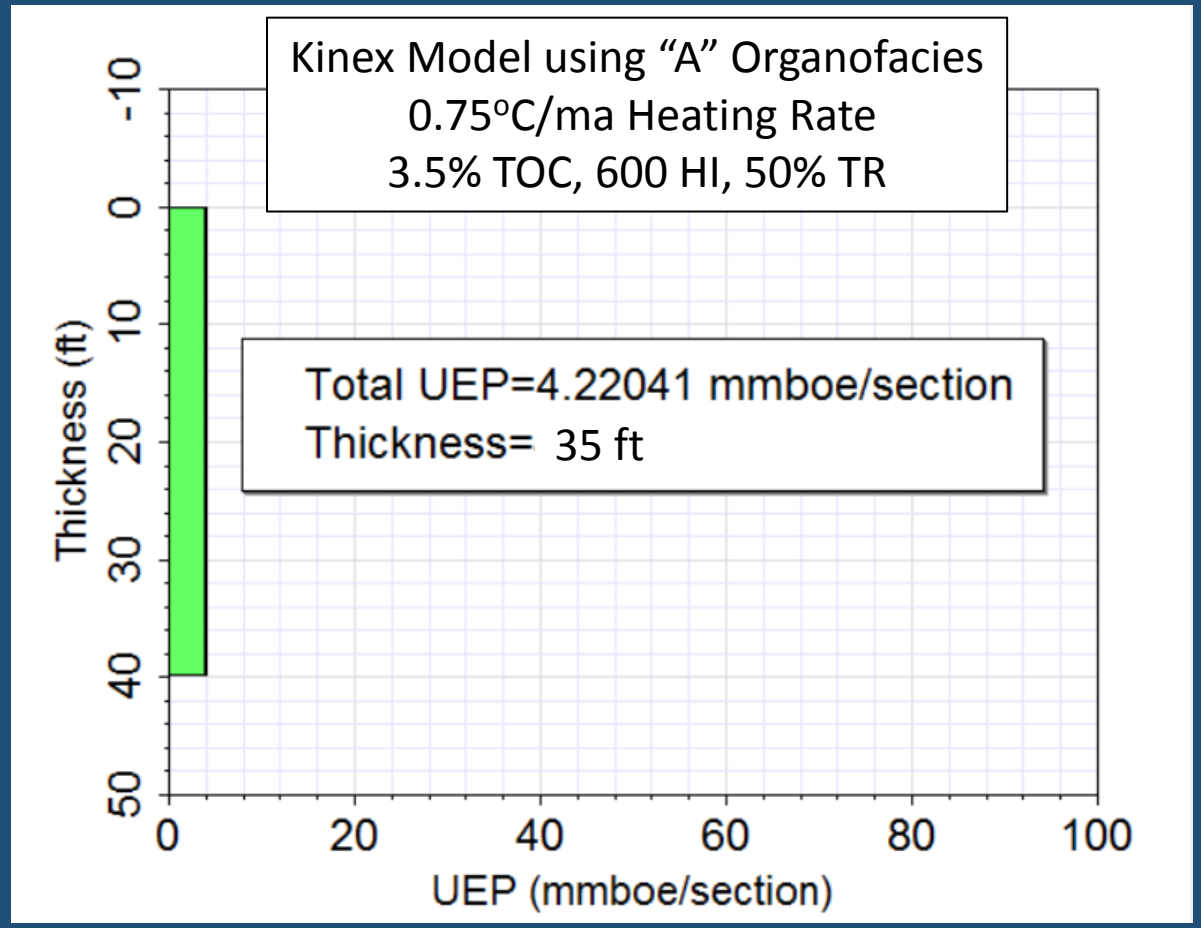


Restored Generation Potentials (S2) and TOC Values

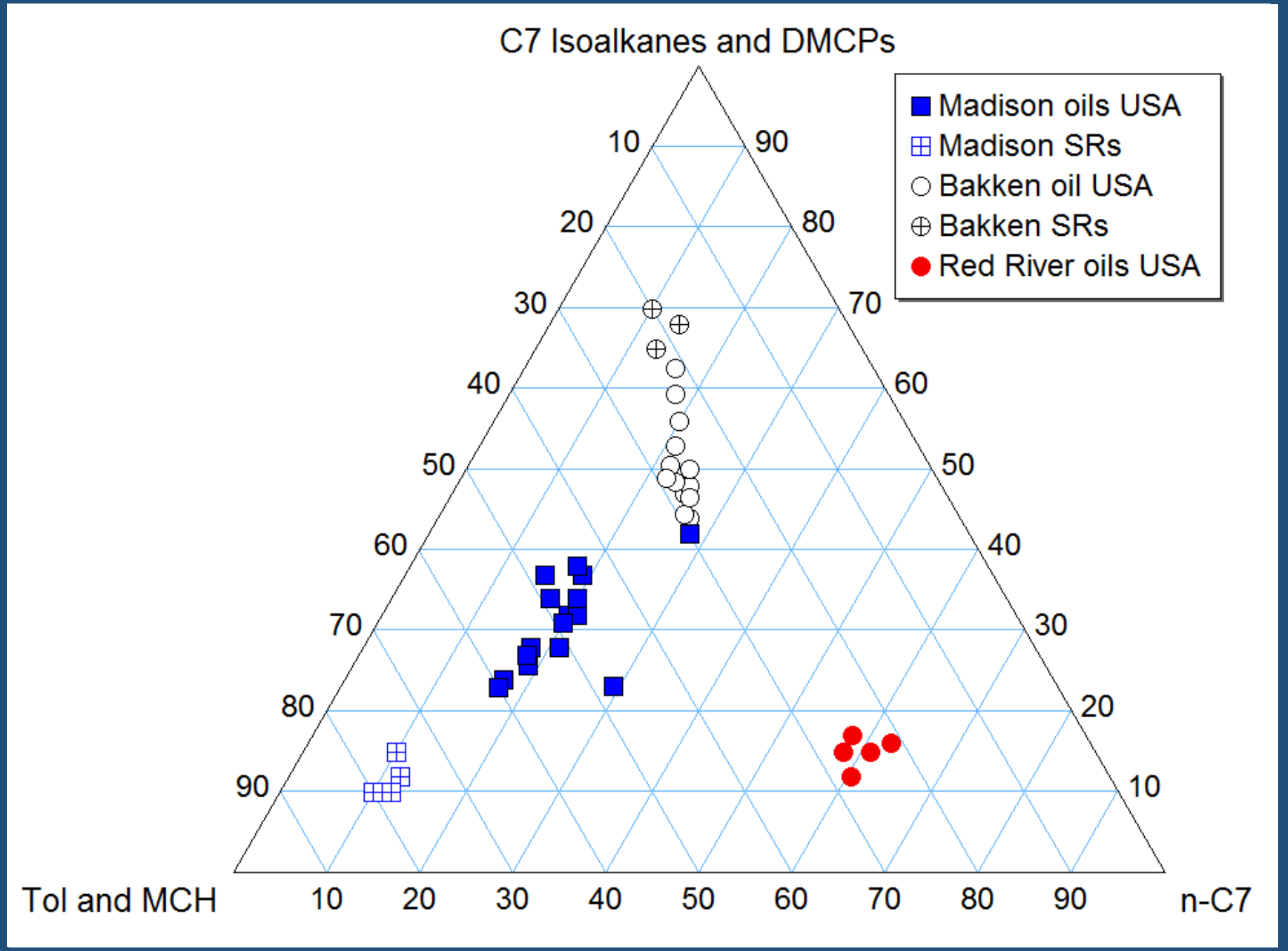


Individual Madison Source Rocks Generation Potentials at 0.85%Ro

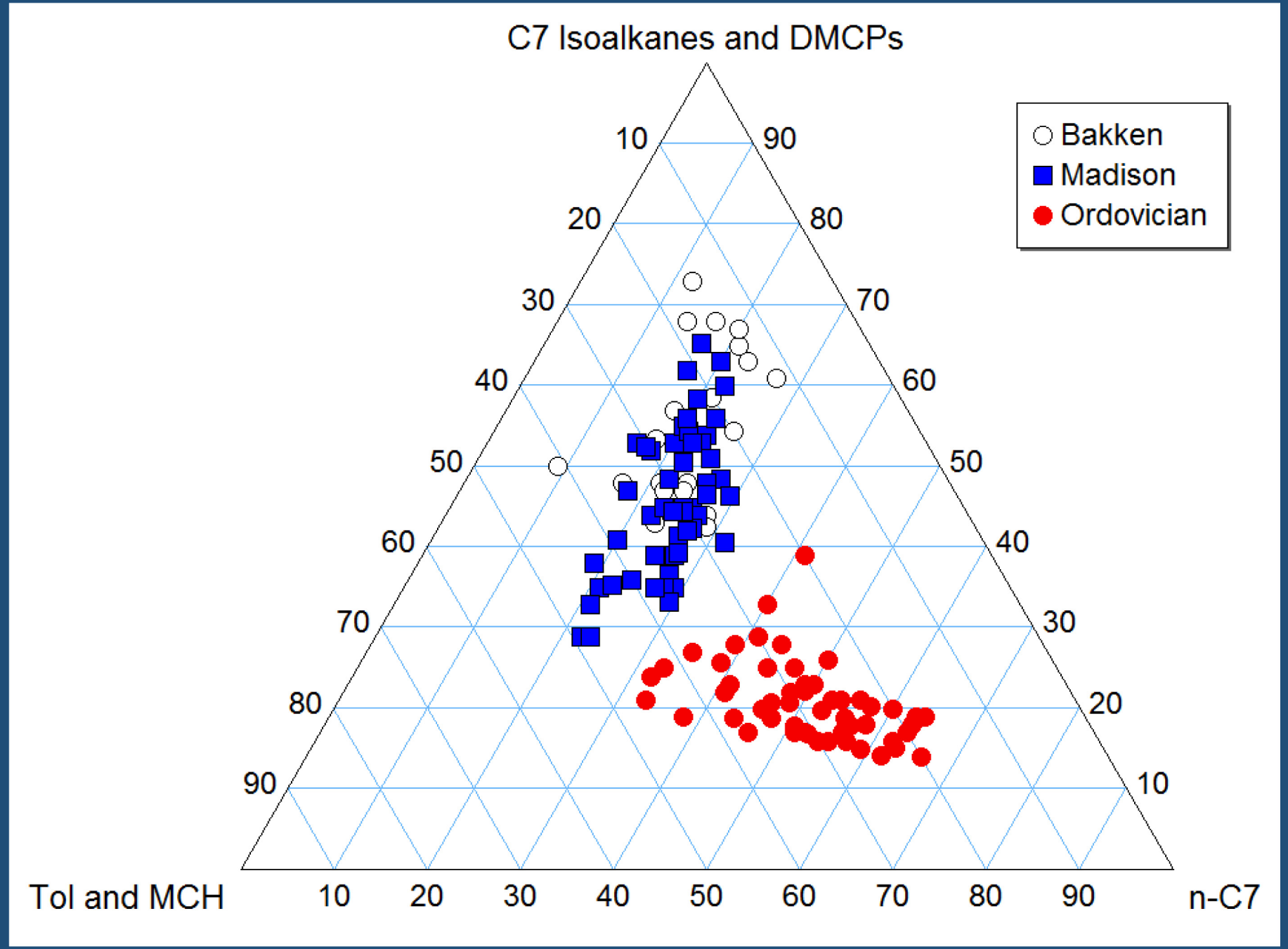




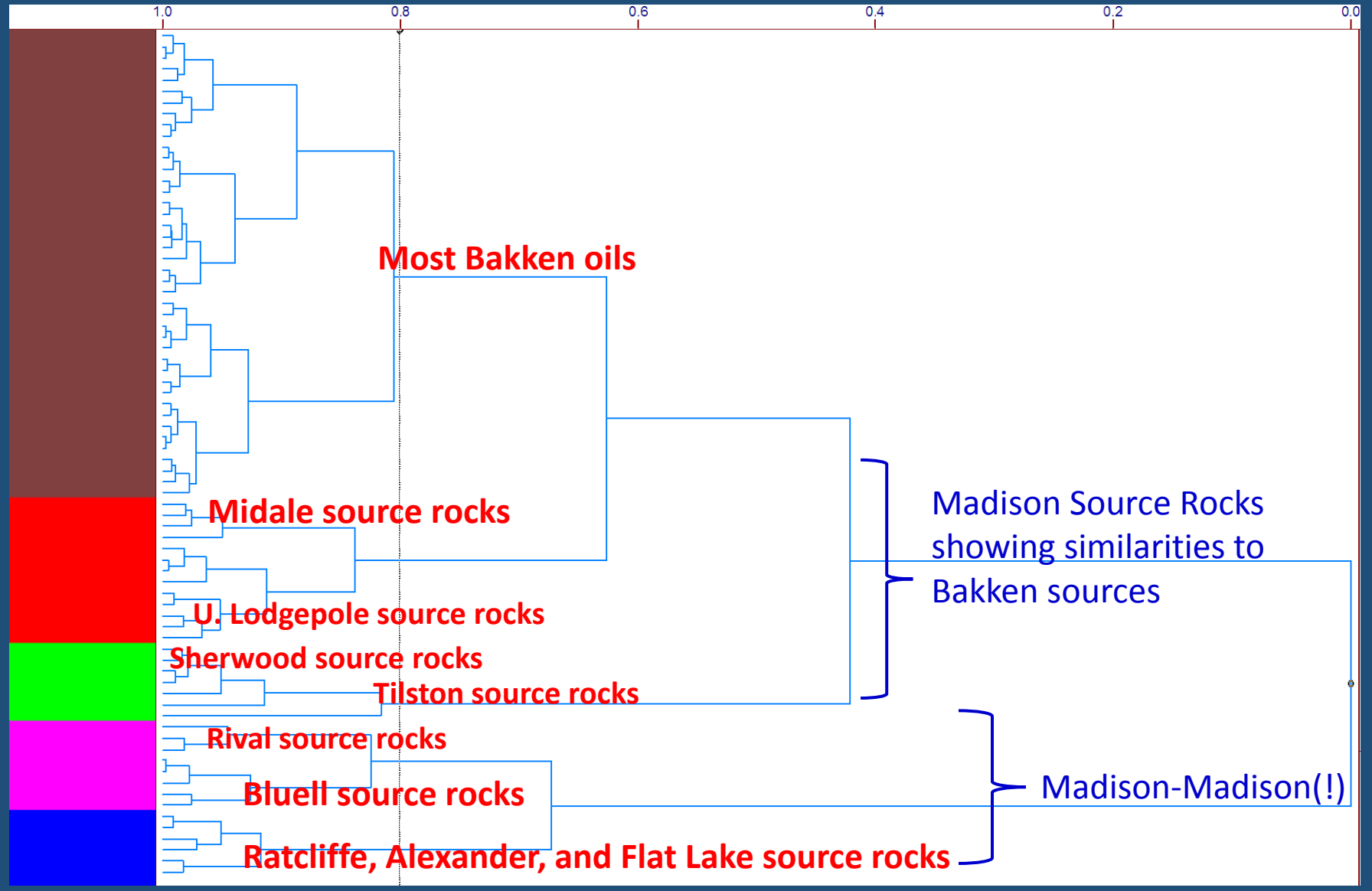
C_7 hydrocarbons of Madison and Bakken oils and source rocks plus Red River oils all USA



C_7 hydrocarbons of Madison and Bakken oils and source rocks plus Red River oils all Canadian Williston oils



Biomarker HCA of Madison Source Rocks relative to Madison and Bakken Oils in RFDbase



Synopsis

- Oil-prone organic-rich (3-14%) are present in Madison (USA)
- Bulk volumetrics can readily account for produced oil (ca. 1 billion bo) from Madison reservoirs.
- Light hydrocarbons and biomarker data shows variability in organofacies among Madison source rocks and are distinctly different from Bakken Shale sources
- There are Bakken-sourced Madison reservoirs (e.g., Lodgepole mound oils)
- It is not obvious from these results (to me) whether there is mixing of Bakken and Madison oils but mixing is certainly obvious in the Canadian Williston Basin.

Thank you !

Questions ?