Mass Fraction Maturity — Next Generation Geochemical Constraint of Basin Models*

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Abstract

Thermal maturity measurement on oil accumulations are crucial for resource assessment. However, the current concept of an oil maturity is flawed and simplistic, as all oils are mixtures with different components charged from source rocks at different temperatures. With typical geological heating rates of 1-10 °C/Ma at any location within a petroleum system, this means that source rocks are charging traps for timescales on the order of a few million years, to a few tens of millions of years. During this period of time, the expelled and trapped petroleum shows a progressive evolution of both bulk and molecular compositions. The concentrations of various components in oil vary greatly for a single facies source rock of differing maturities nonetheless for the different facies. However, petroleum geochemists have continued to use relative abundances of, in particular, saturated hydrocarbon and other biomarkers to a large degree in oil-source rock and oil-oil correlations and maturity and facies assessment of reservoired oils, leading to many confusing and inconsistent approaches to characterizing maturity. We have suggested an alternative approach is needed which tracks the maturity/ petroleum mass fraction relationships for a reservoired oil, in a more complex but realistic manner and allows the more effective bracketing of source kitchen maturity. The maturity distribution of oil would then represent the mass fraction versus source temperature at expulsion profile, for all the components in that reservoired fluid. This concept, called Mass Fraction Maturity (MFM), aims to develop the tools, protocols, and calibration data sets to enable the assessment of the reservoired oil mass fraction and source charge temperature interval relationship. Having this relationship, and knowing what a typical complete charge mass fraction maturity profile would look like for a given source rock type, would enable estimation of any missing charge in the basin (validating additional exploration activity), detection of complex multi-history charge scenarios, and also a much more robust and complete data set for calibration of basin model charge history assessments. We will demonstrate the importance of MFM for understanding the properties of reservoir fluids, post-burial uplift and petroleum mass loss, instantaneous versus cumulative charge events and exploration potential by using case studies from Western Canada and elsewhere.

References Cited

Mackenzie A.S., S.C. Brassell, G. Egeinton, and J.R. Maxwell, 1982, Chemical Fossils - The Geological Fate of Steroids: Science, v. 217, p. 491-505.

Wilhelms, A., and S. Larter, 2004, Shaken But Not Always Stirred: Impact of Petroleum Charge Mixing on Reservoir Geochemistry: Geological Society, London, Special Publications, v. 237/1, p. 27-35.

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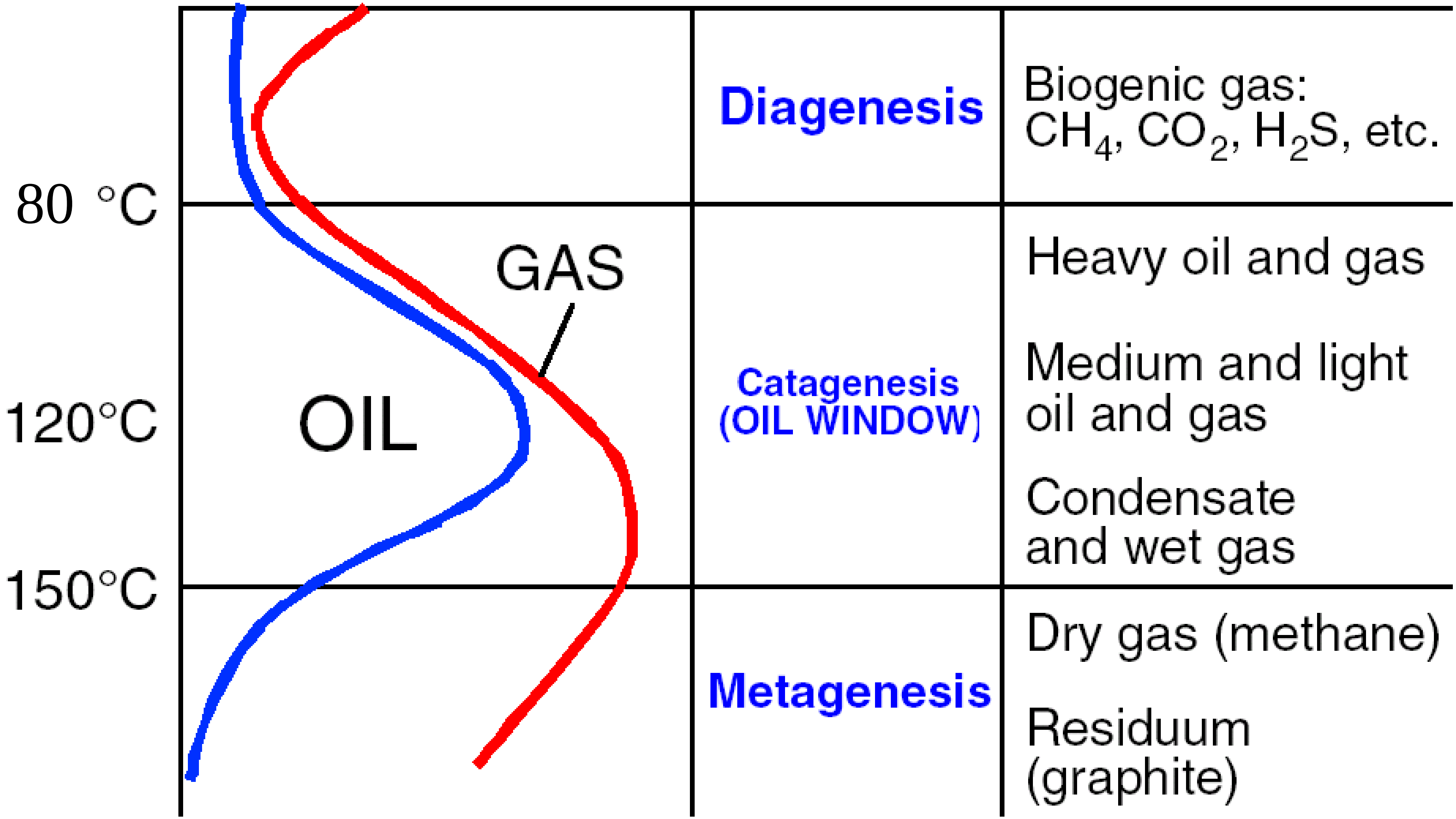
University of Calgary

The oil window



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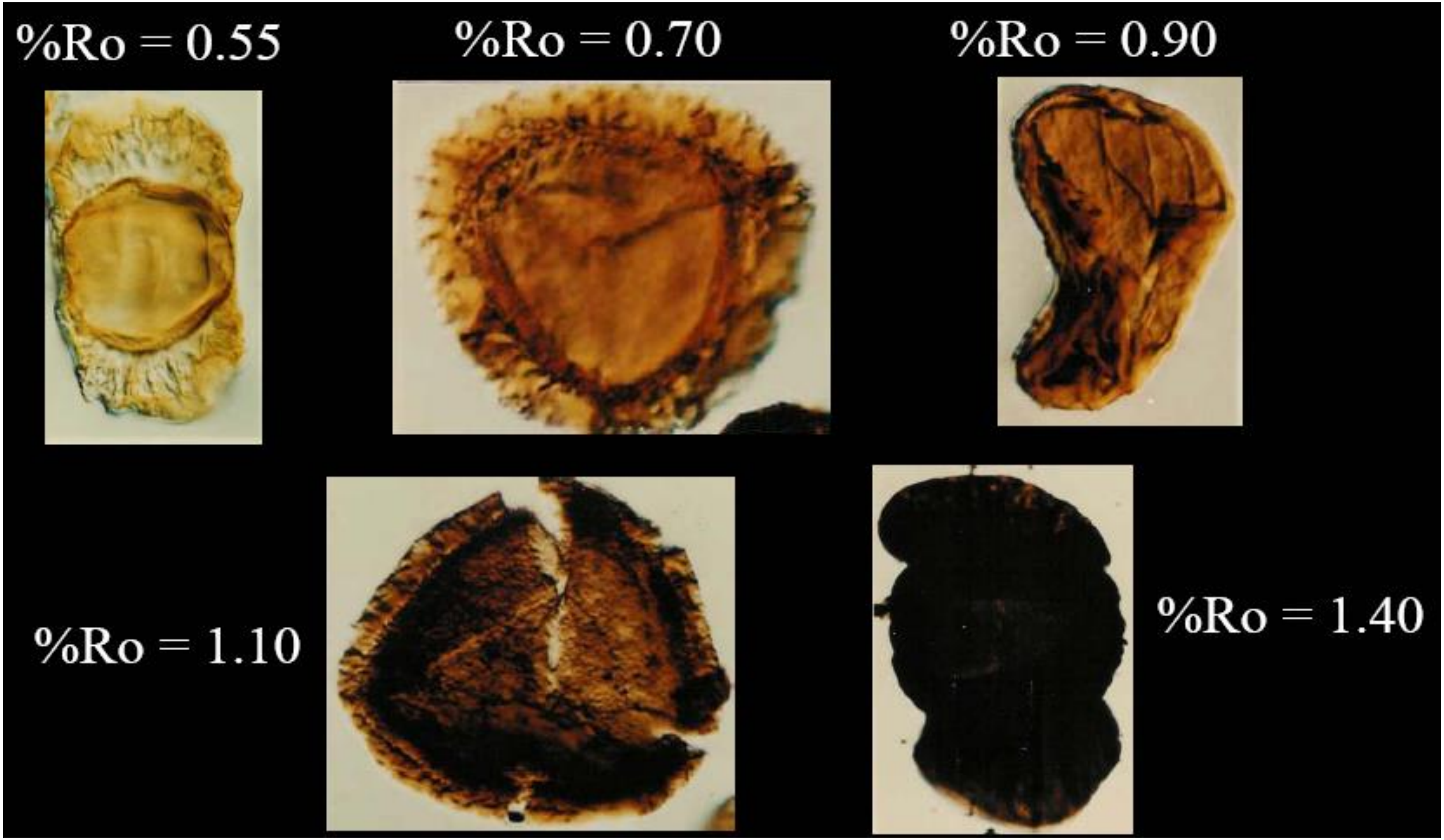
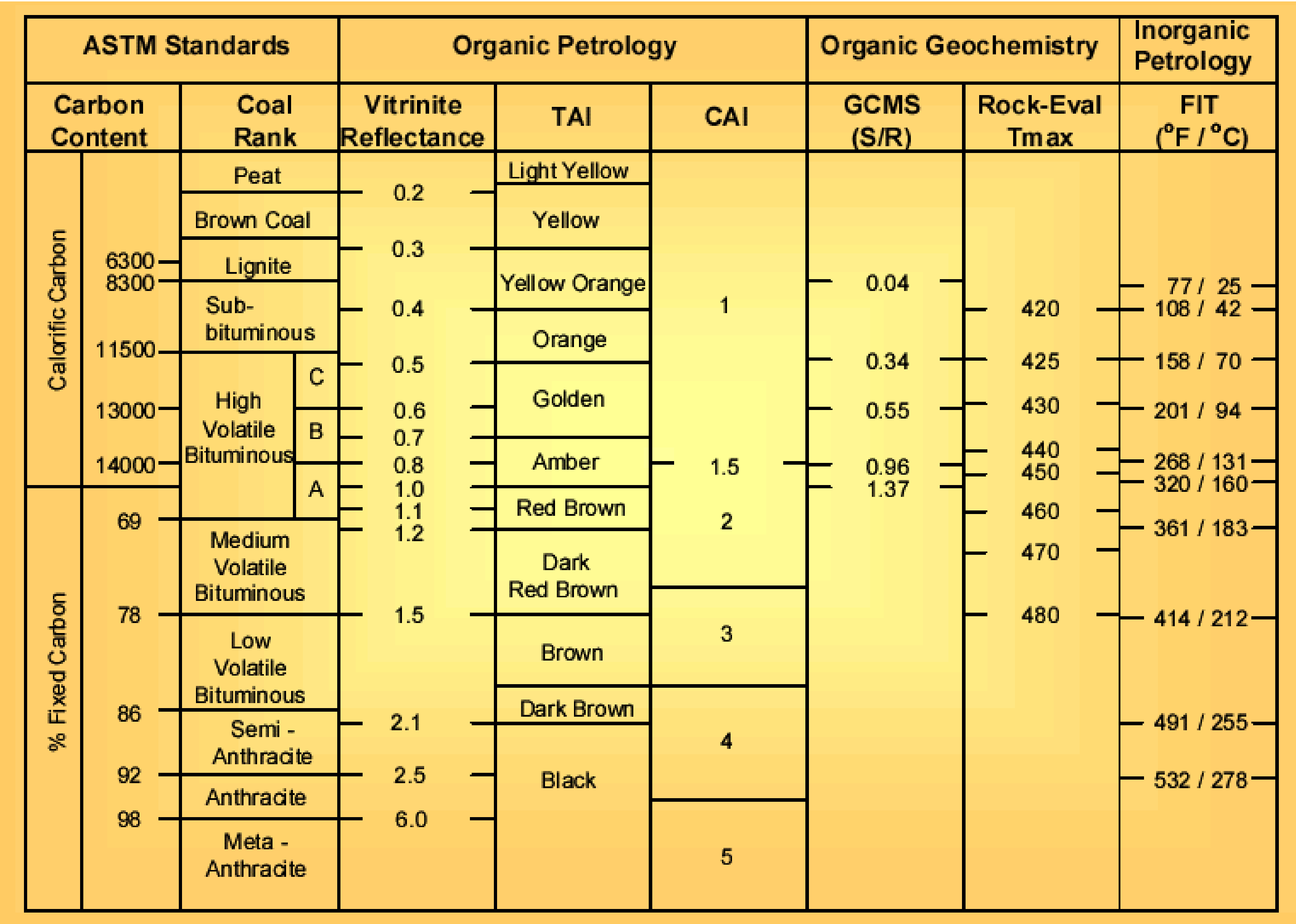
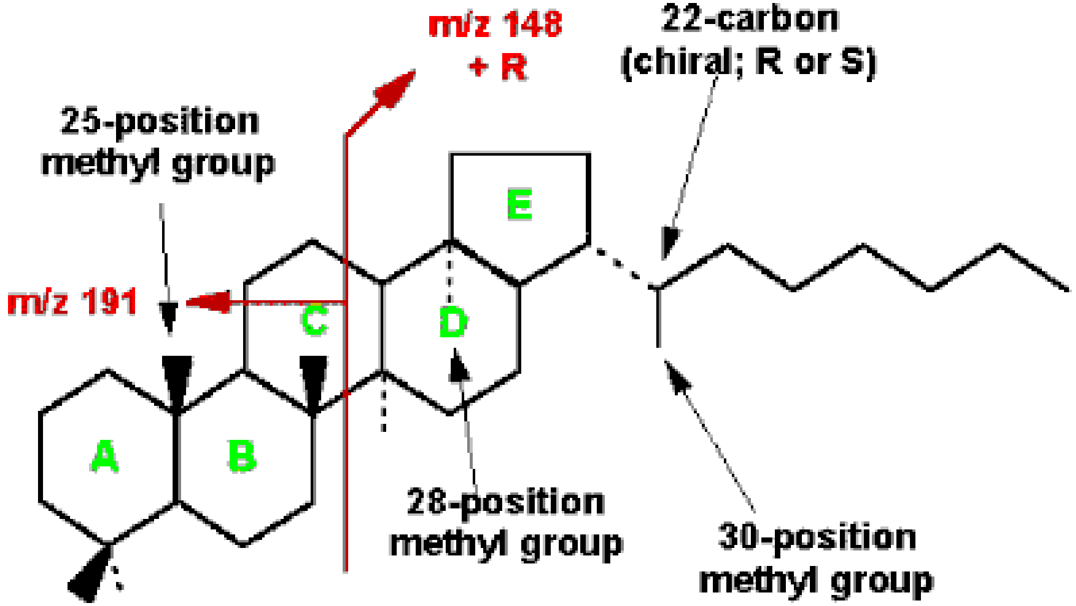
Change in Color and Vitrinite Reflectivity

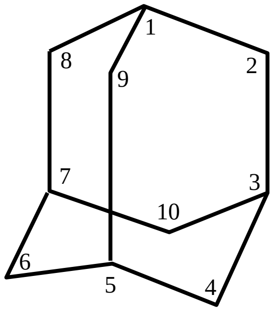


Correlation Chart

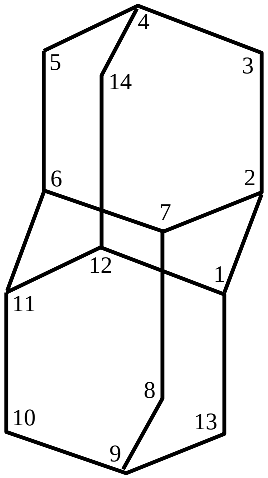


How to assess oil maturity?

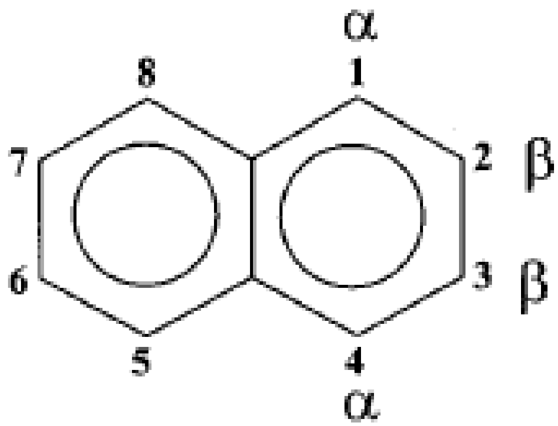




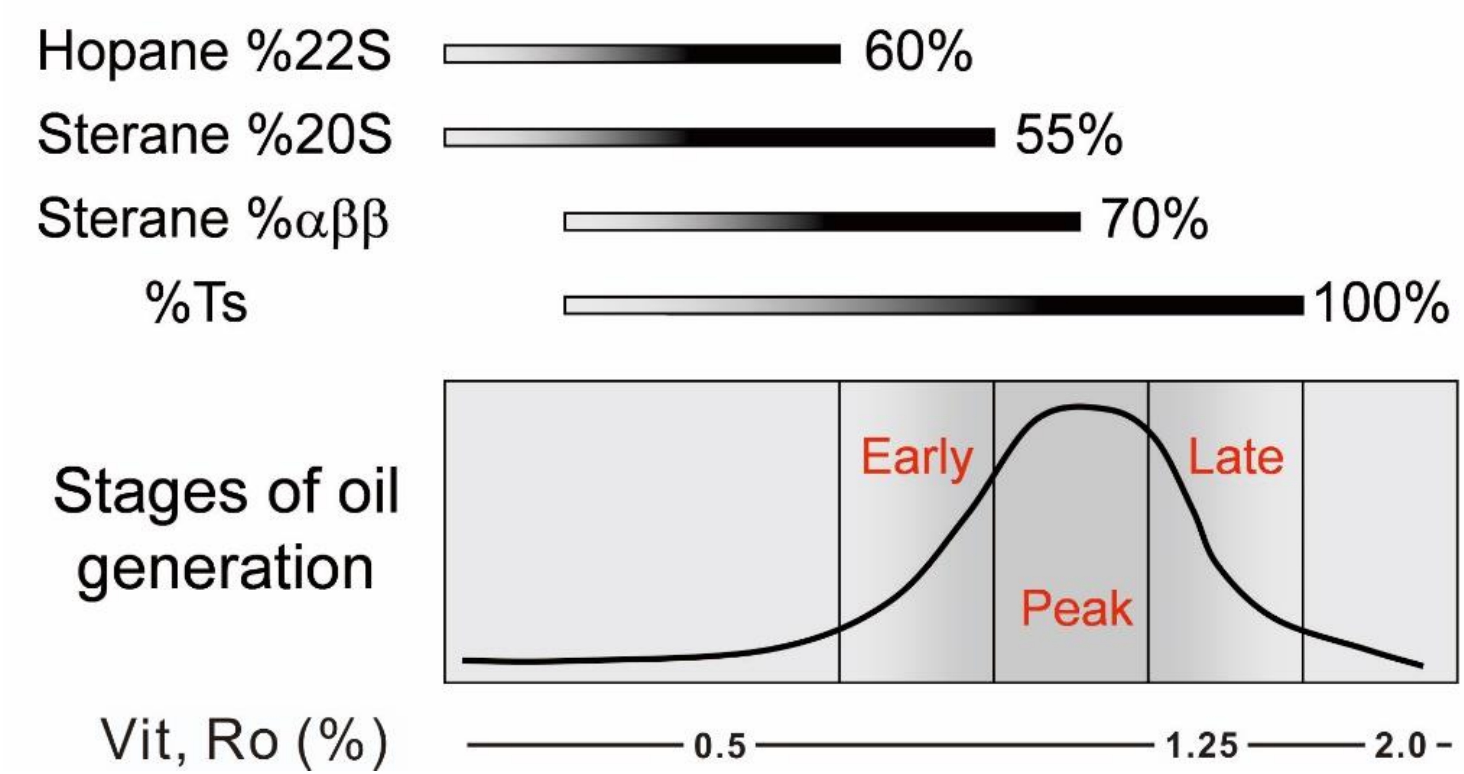
I adamantane



II diamantane



Ranges of individual biomarker molecular measurements for thermal maturation



Use several different parameters to define the stage of maturation with respect to oil generation

(Modified from Mackenzie et al., 1982)

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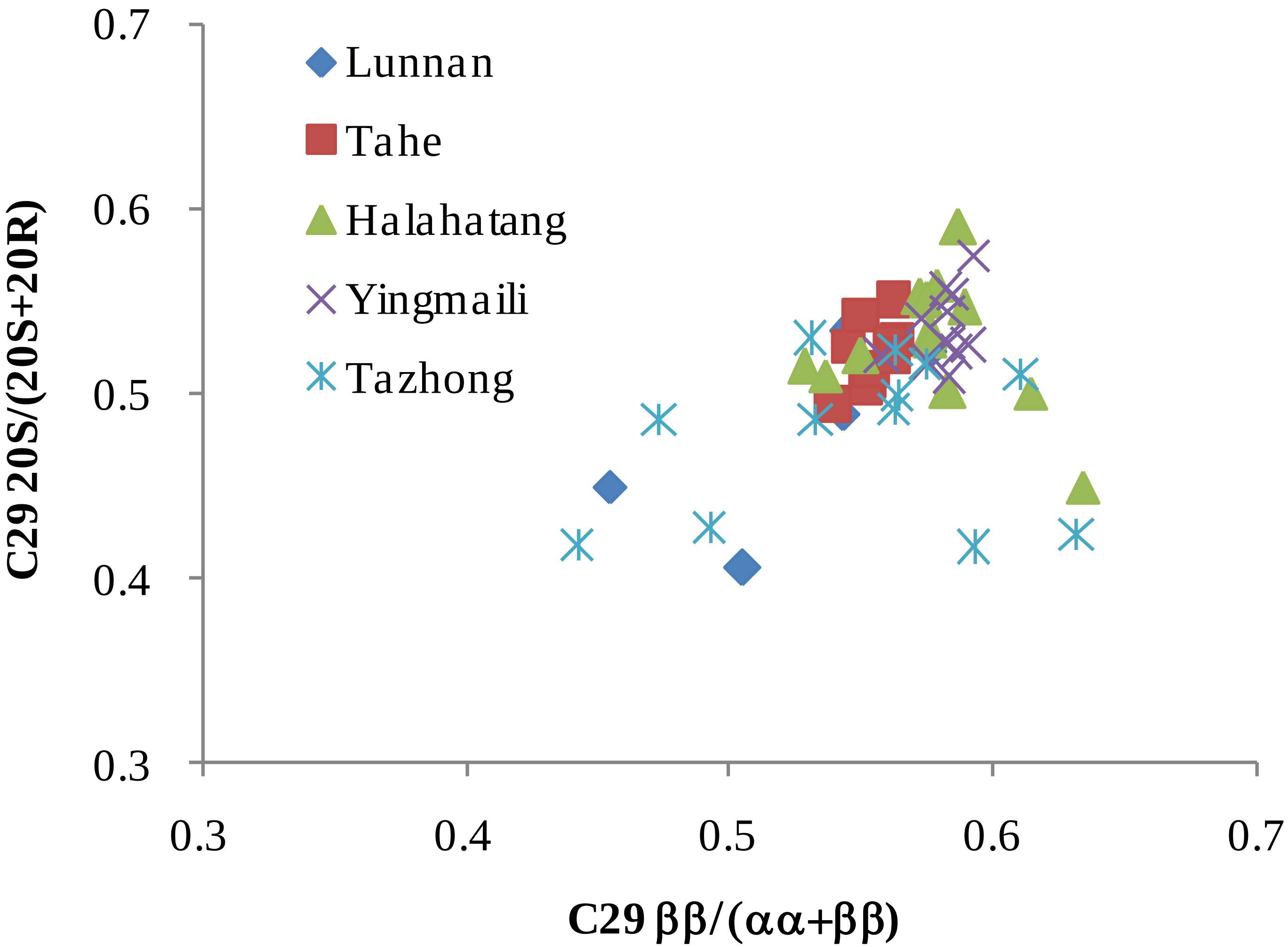
Oil maturity derived from biomarkers



Estimated Ro ～0.6–0.7%

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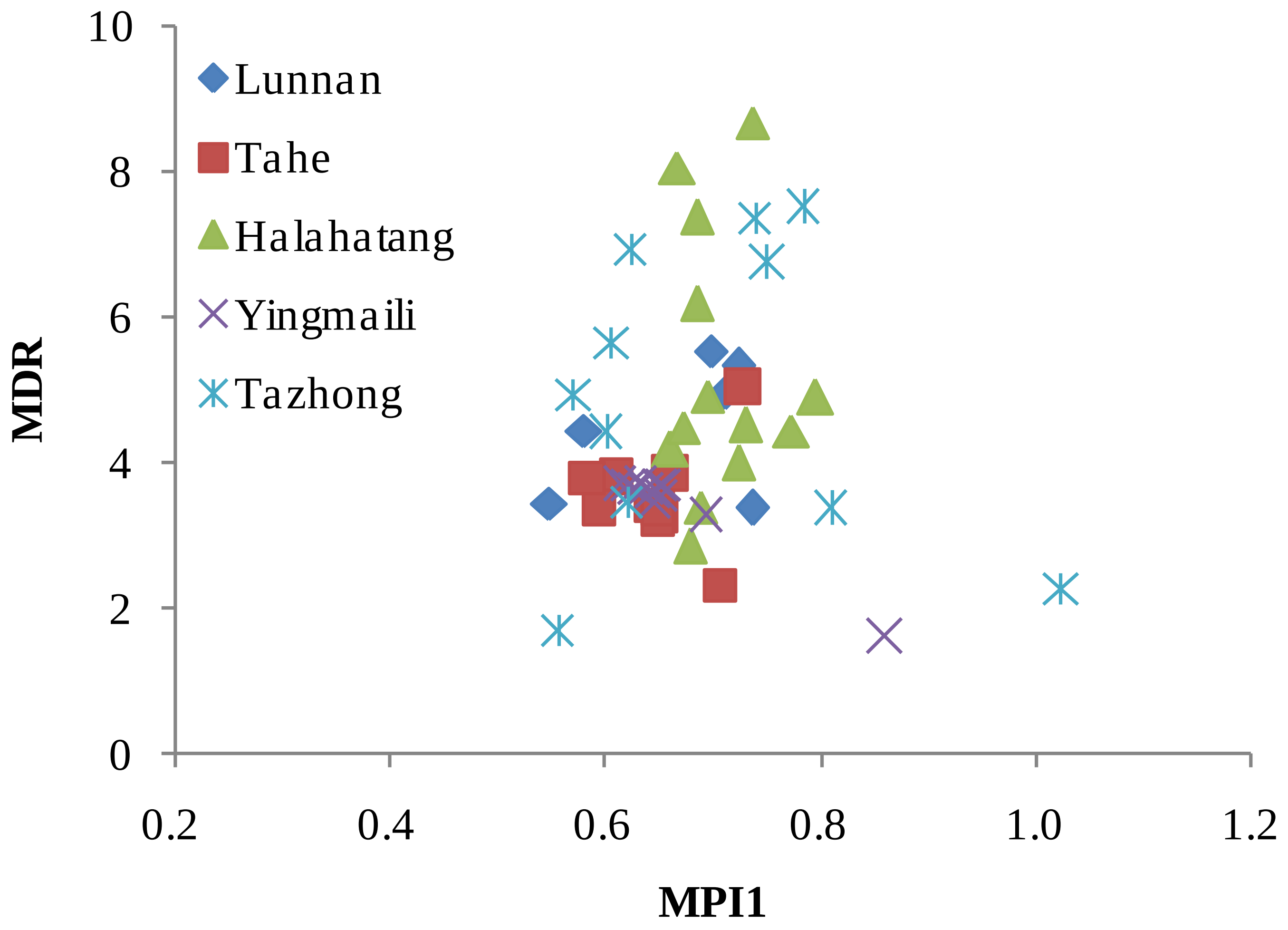
Oil maturity derived from PAHs



Estimated Ro ～0.7–1.0%

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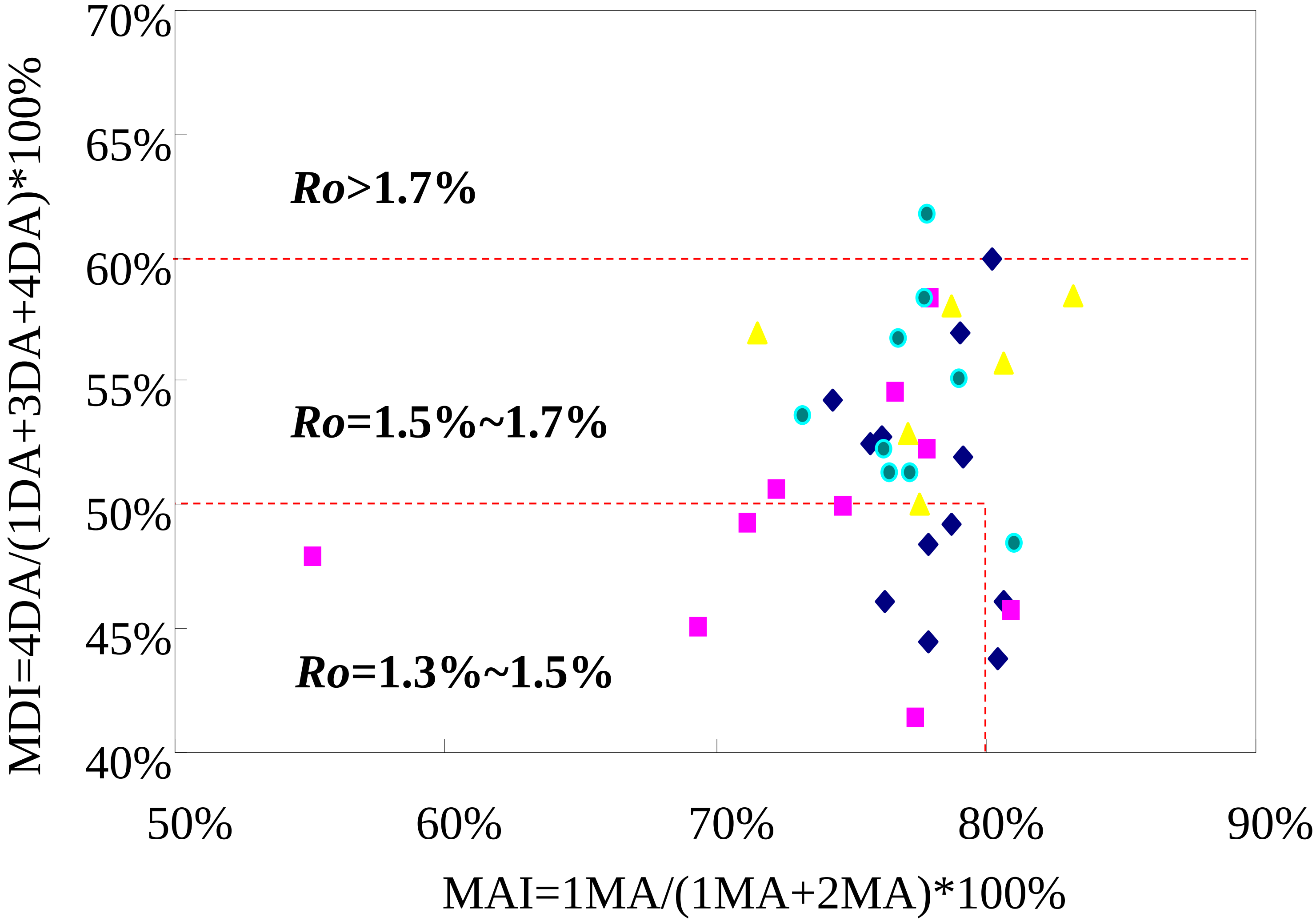
Oil maturity derived from diamondoids



Estimated Ro >1.2%

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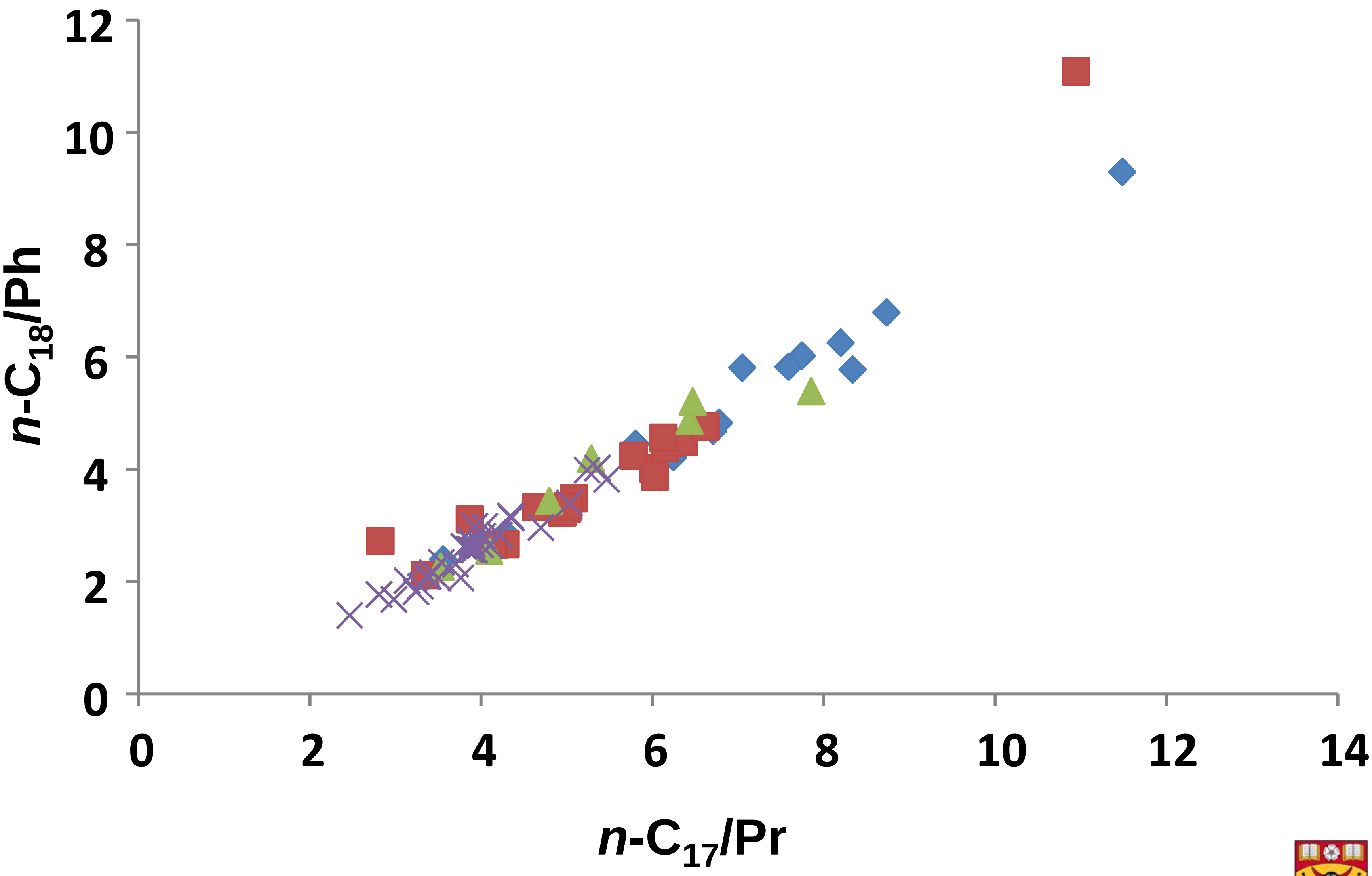
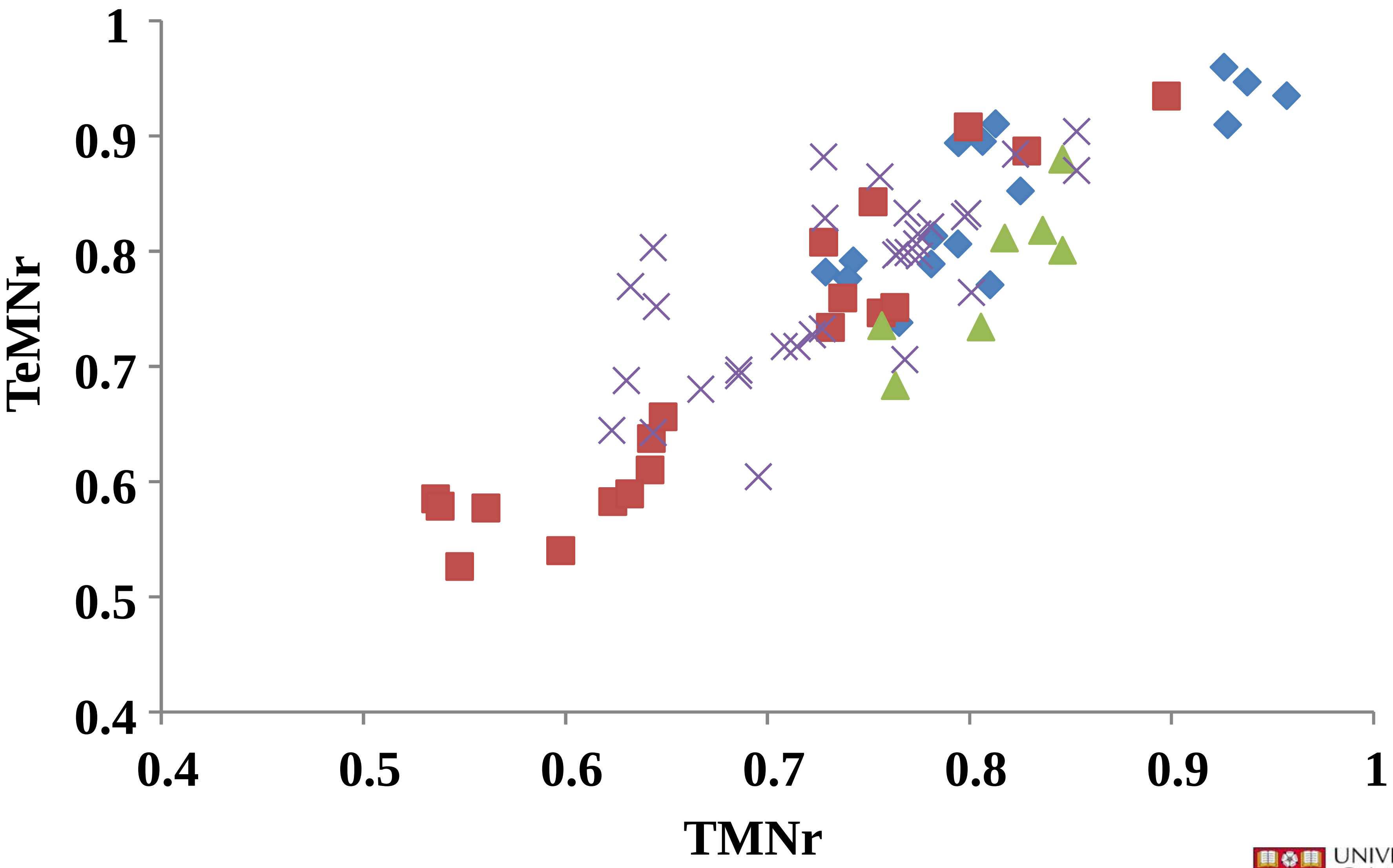
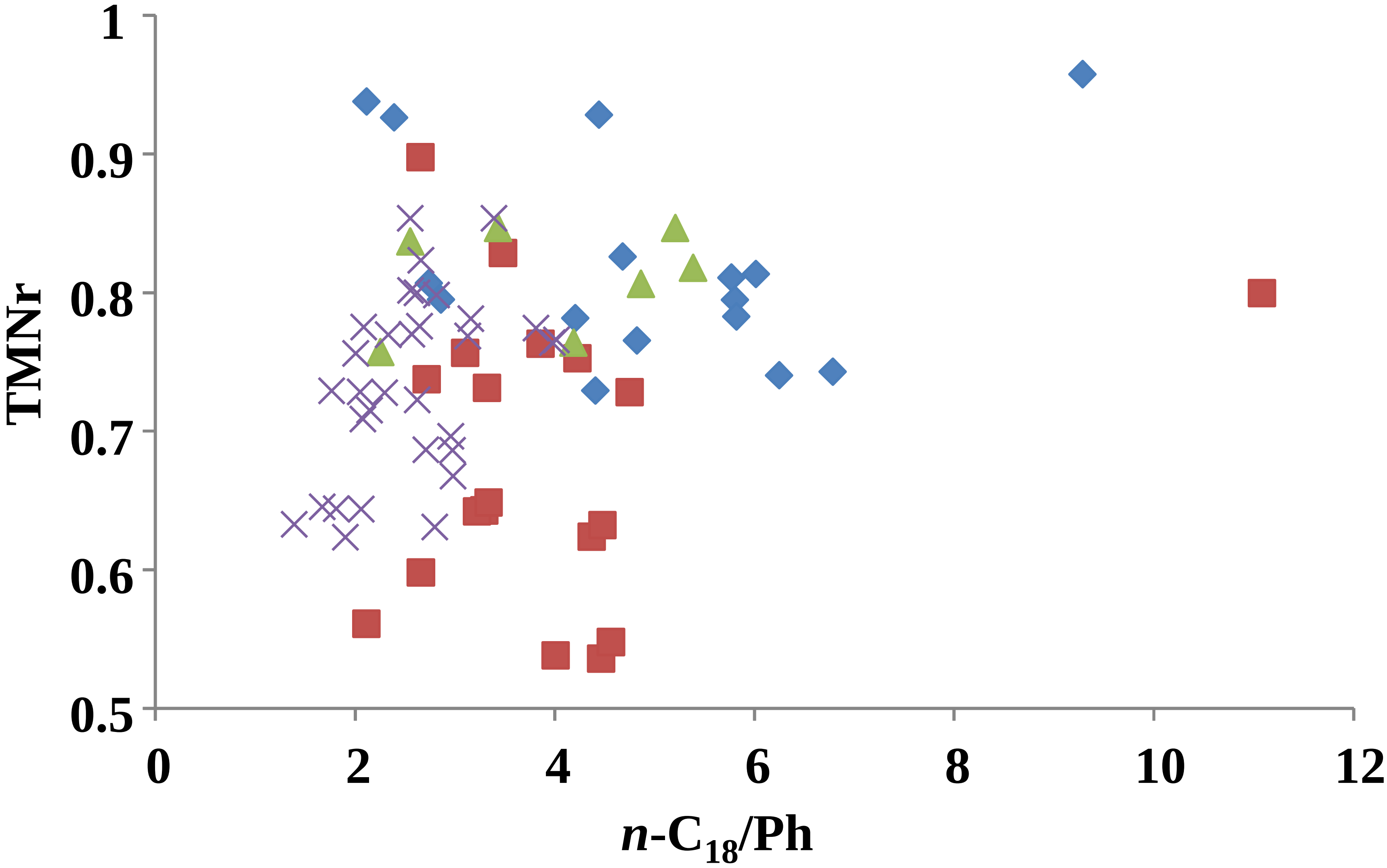
n-C_{17}/Pr *vs.* *n*-C_{18}/Ph



TMNr *vs.* TeMNr



n-C_{18}/Ph *vs.* TMNr



Almost no correlation!

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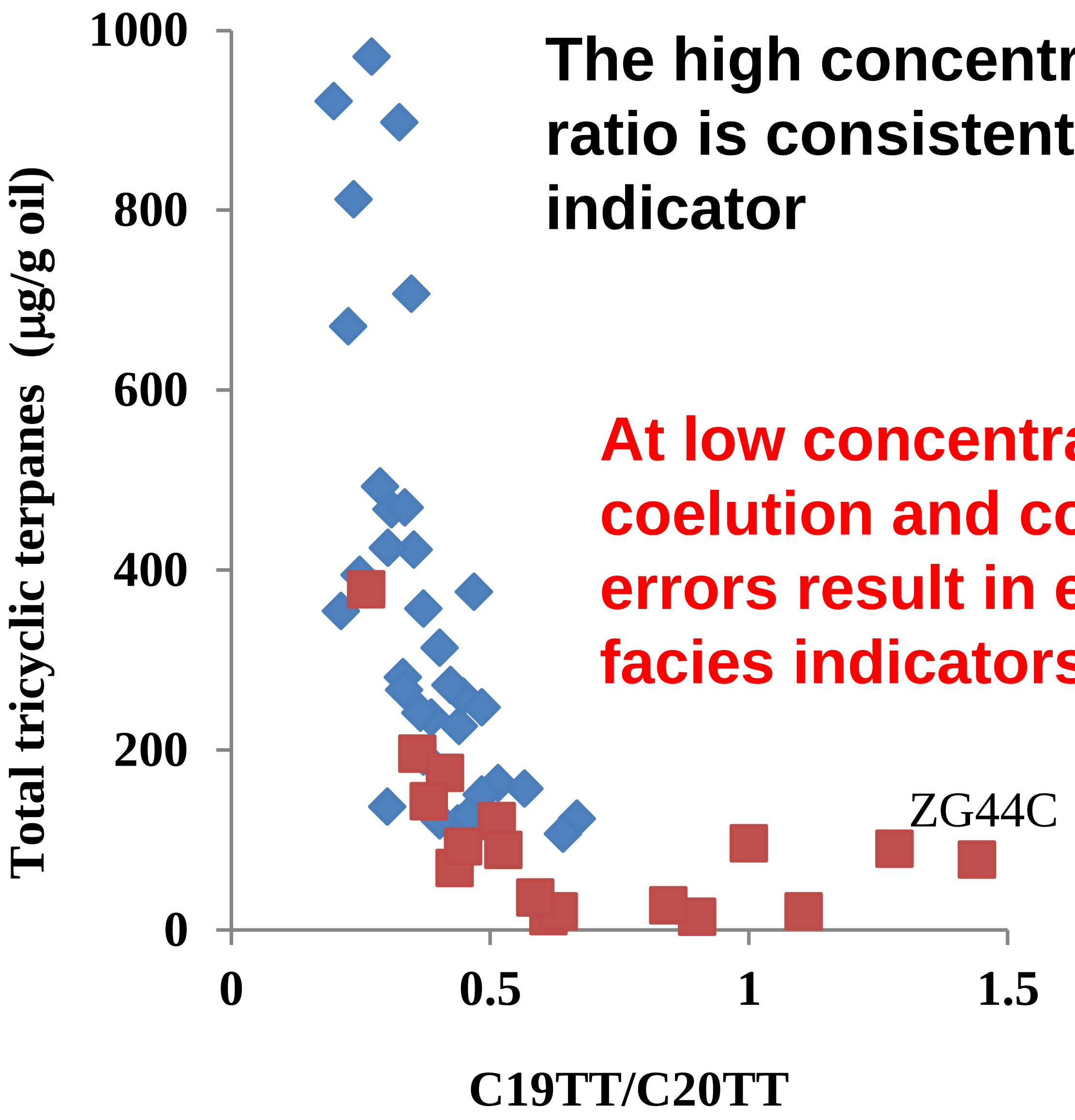
Concentration effects on molecular ratios!



The high concentrations ratio is consistent facies indicator

At low concentrations coelution and concentration errors result in erroneous facies indicators.

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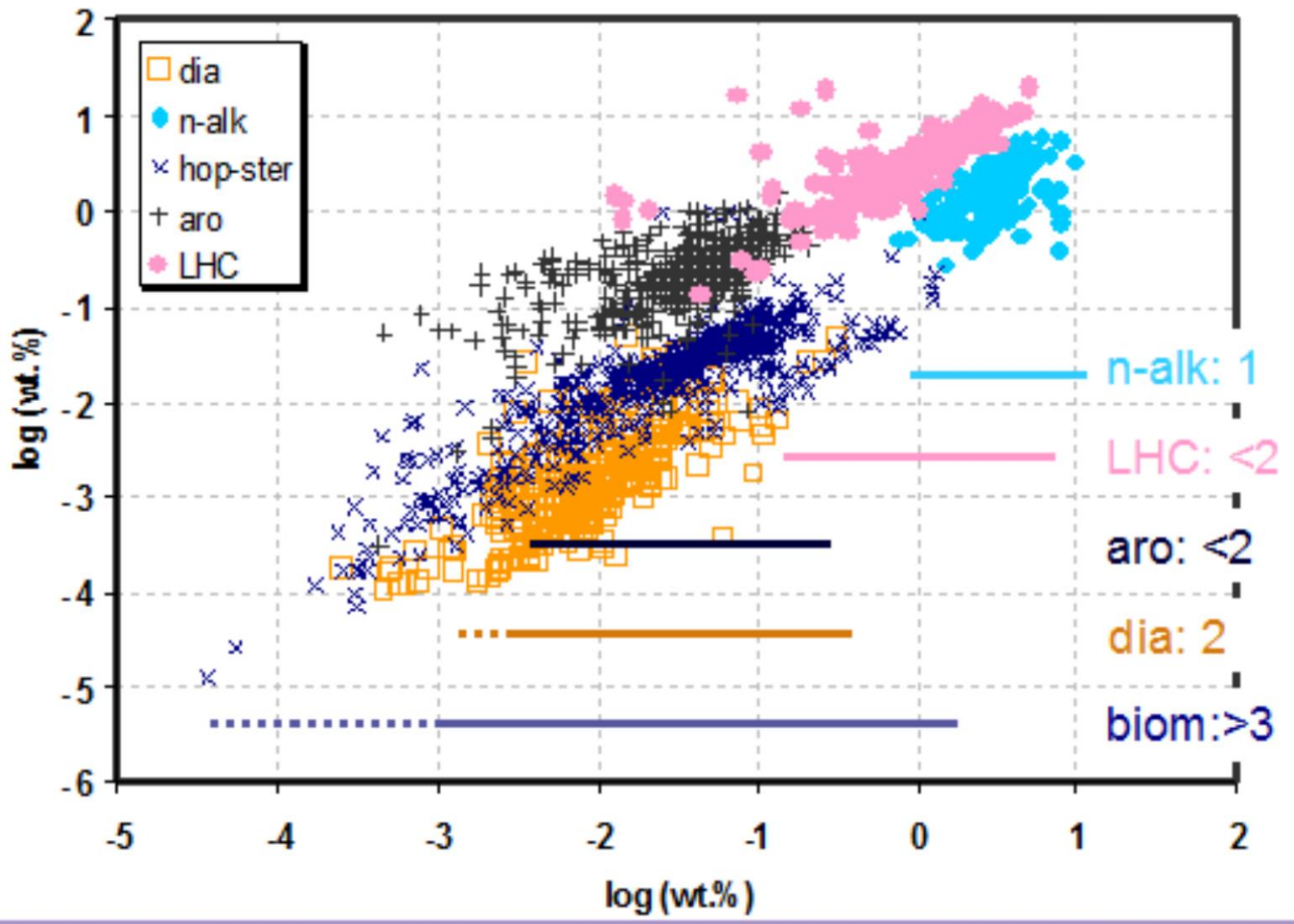
Concentrations of major compound classes in oils



(Wilhelms and Larter, 2004)

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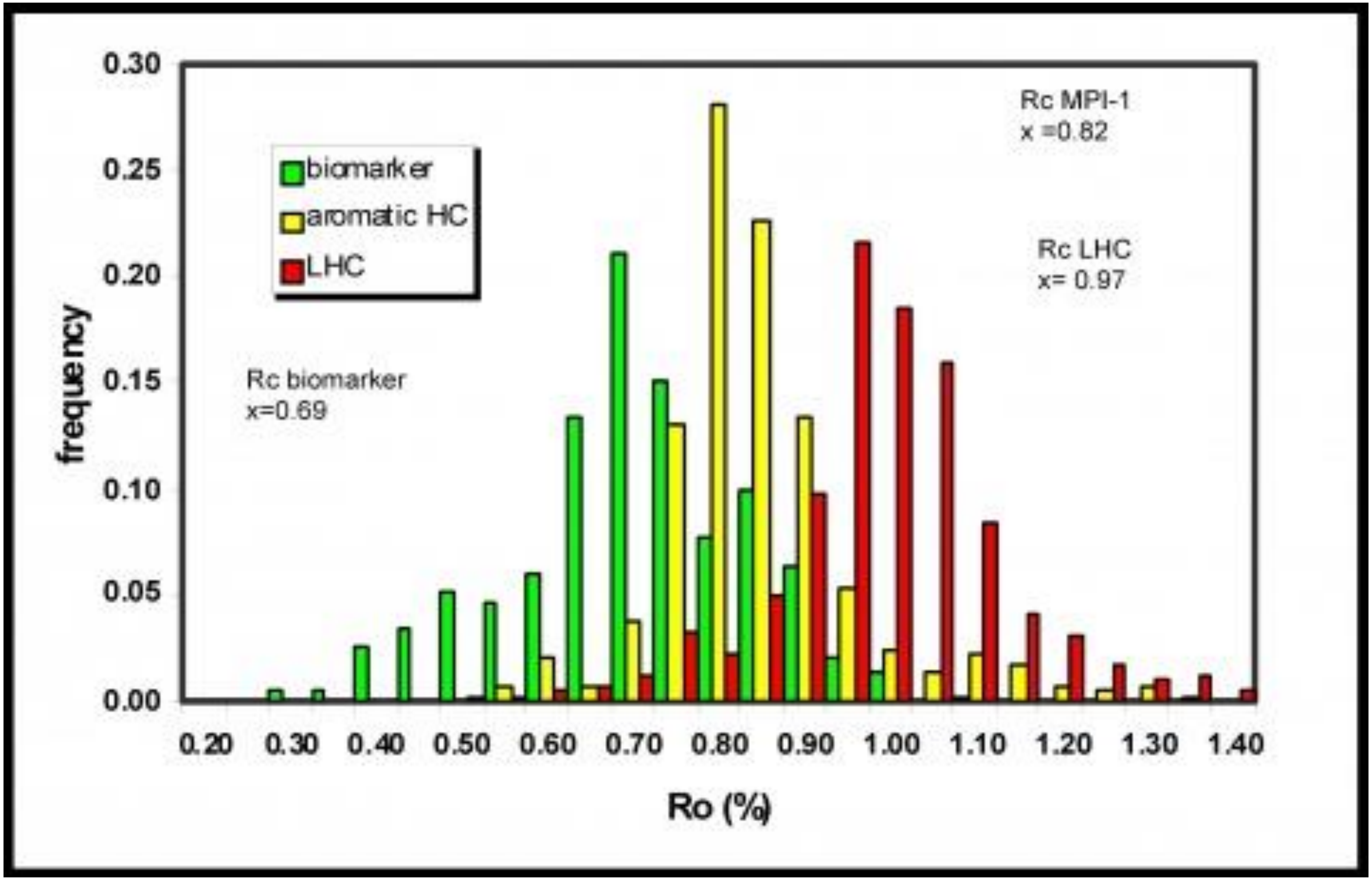
The distribution of fraction specific maturity for the oils and condensates



(Wilhelms and Larter, 2004)

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Summary of oil matuirty

- Most commonly used maturity parameters have very different correlations to measured vitrinite reflectance;
- Biomarker parameters are sensitive at low to moderate maturity range;
- PAH parameters are sensitive at moderate to high maturity range;
- Light HCs and diamondoids are sensitive at high maturity range;
- Current oil maturity is a misconception as oil is mixture of charges;
- An alternative approach to track petroleum mass fraction relationships for a reservoired oil (mass fraction maturity) is needed.

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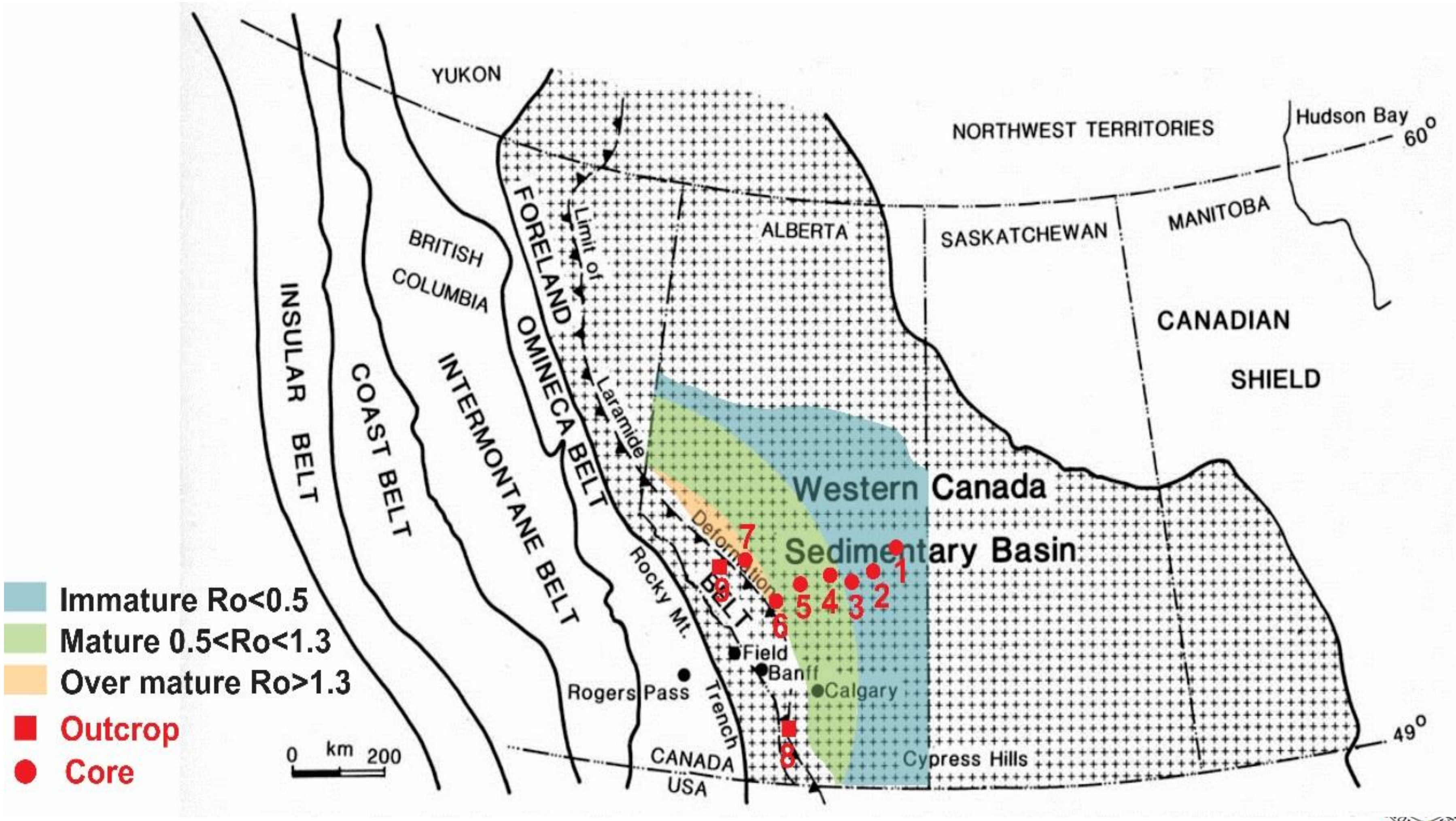
Case History of MFM

- Samples collected from the Second White Specks Formation (SWS) in WCSB ranging from immature to high mature form a natural evolution case history



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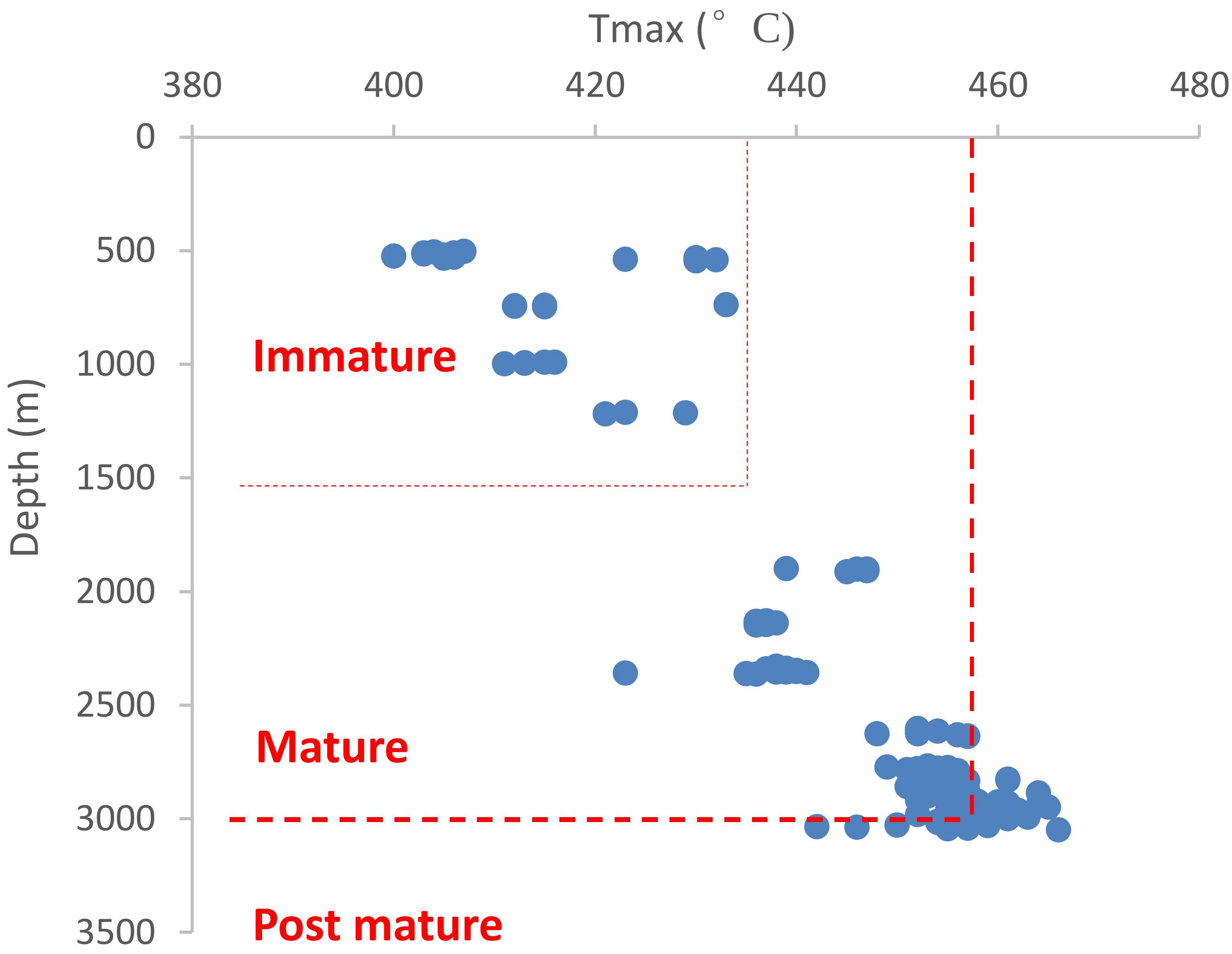
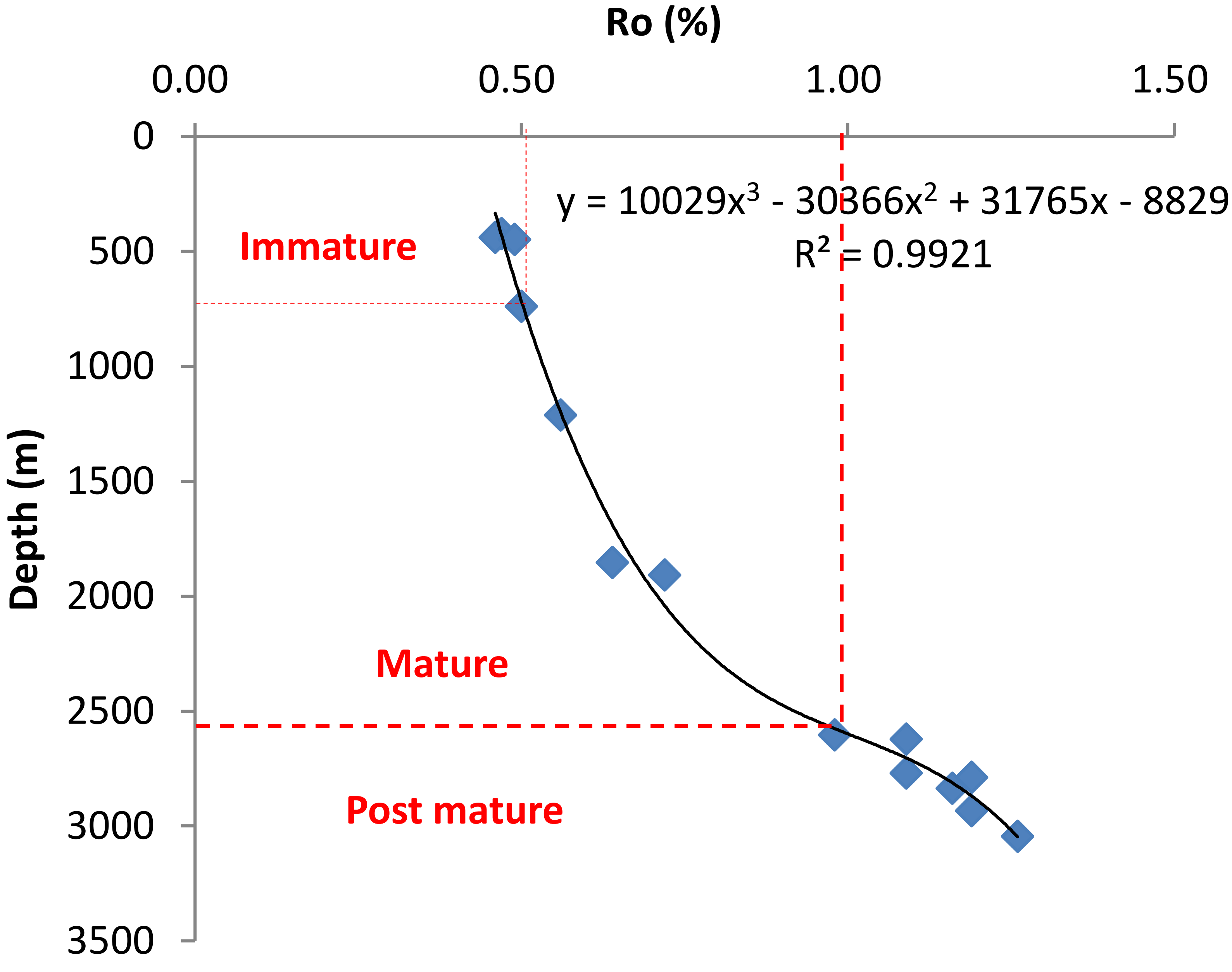
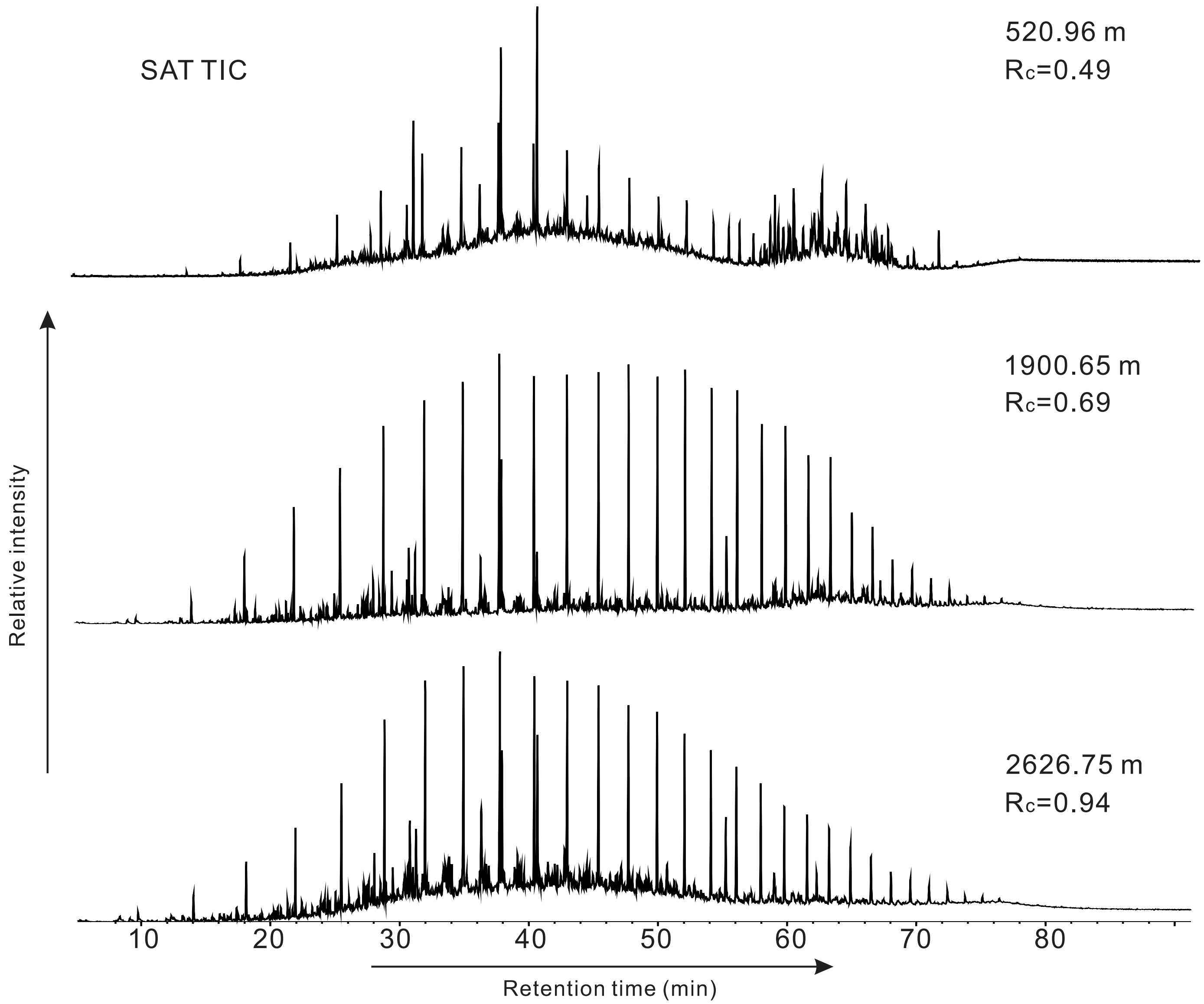
Tmax increase with burial depth



Ro is controlled by burial depth



Representative total ion current show systematic variation with increasing maturity



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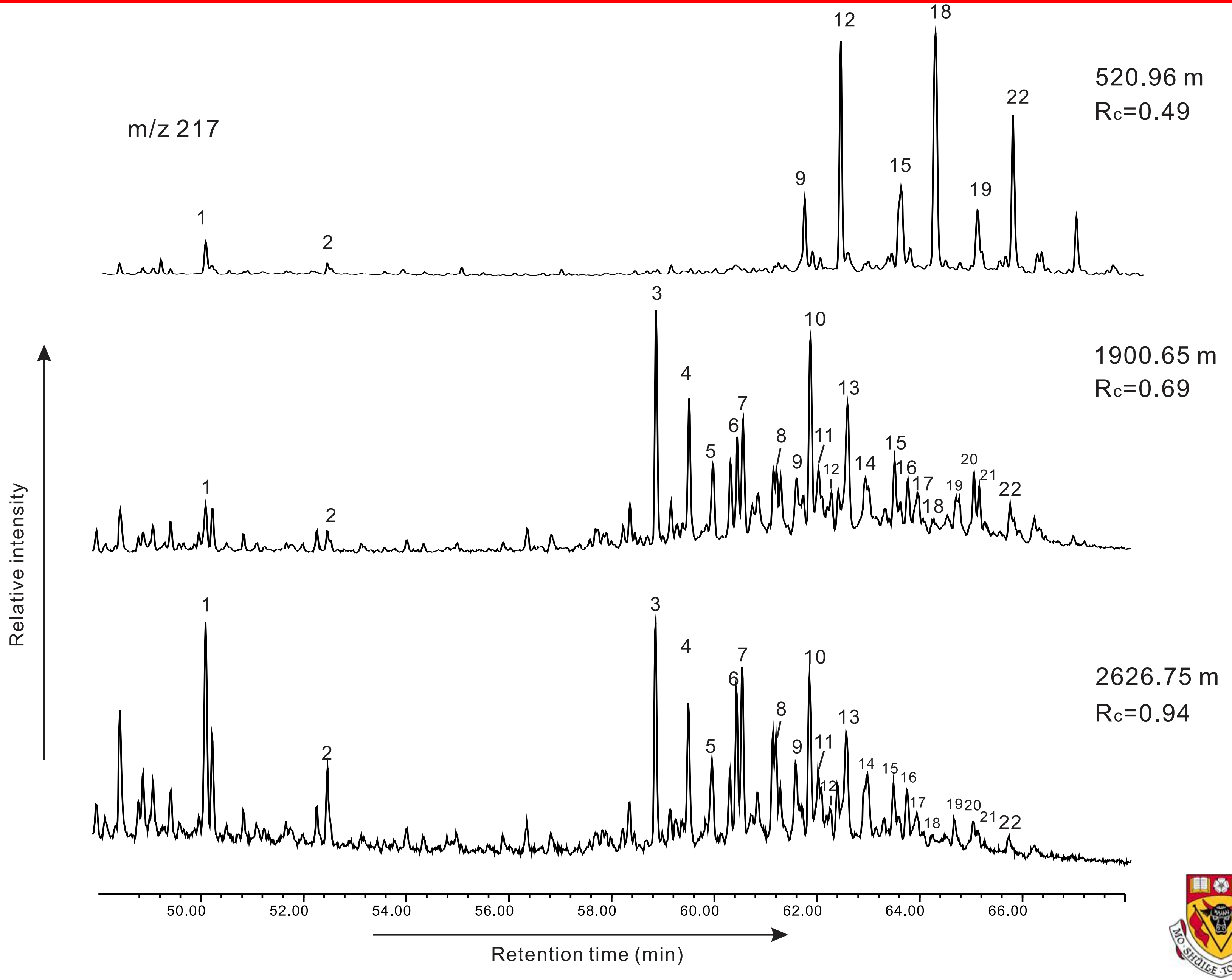
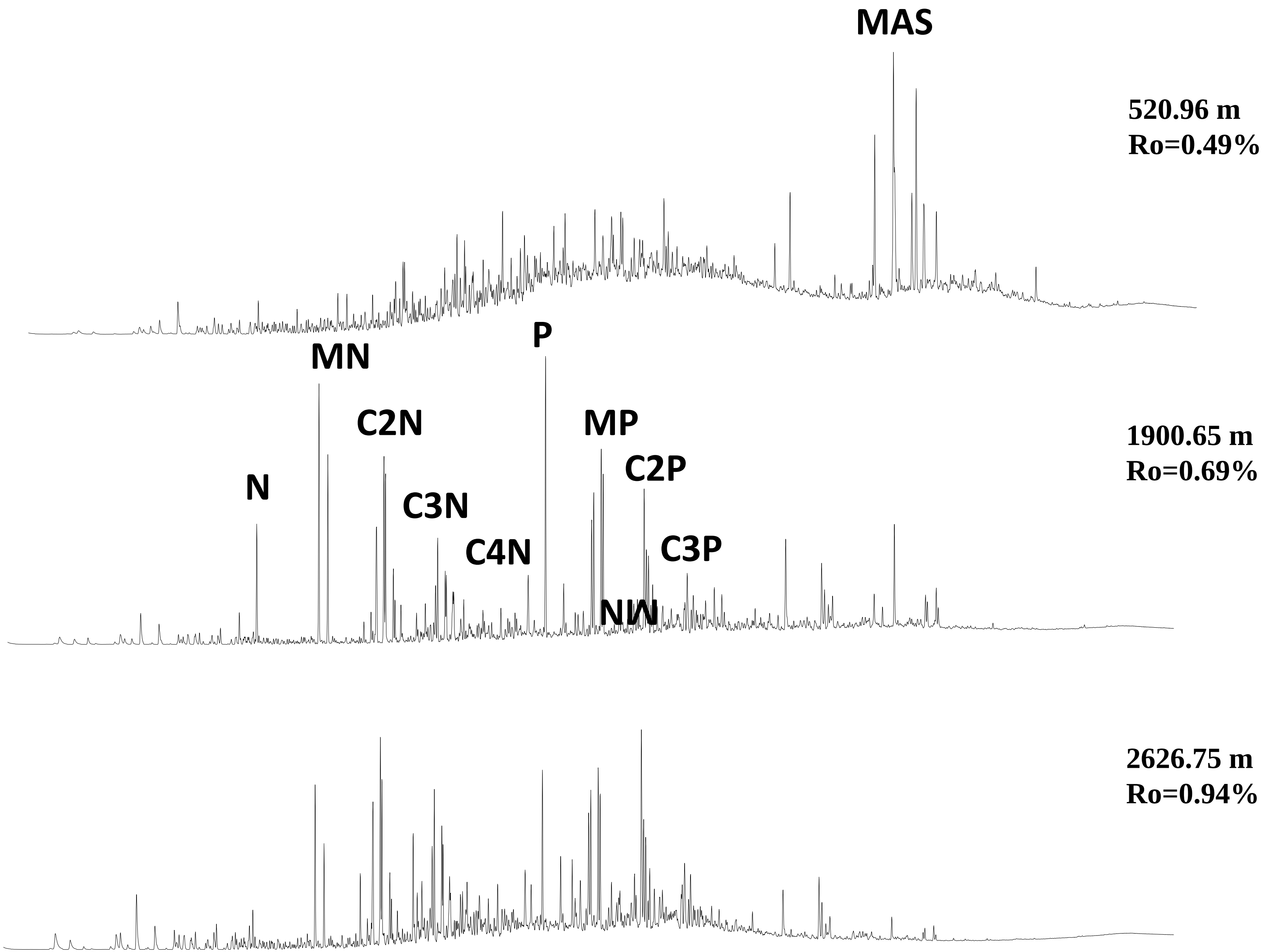
Representative sterane distributions in different maturity samples



Representative TIC of aromatic fraction in different maturity samples



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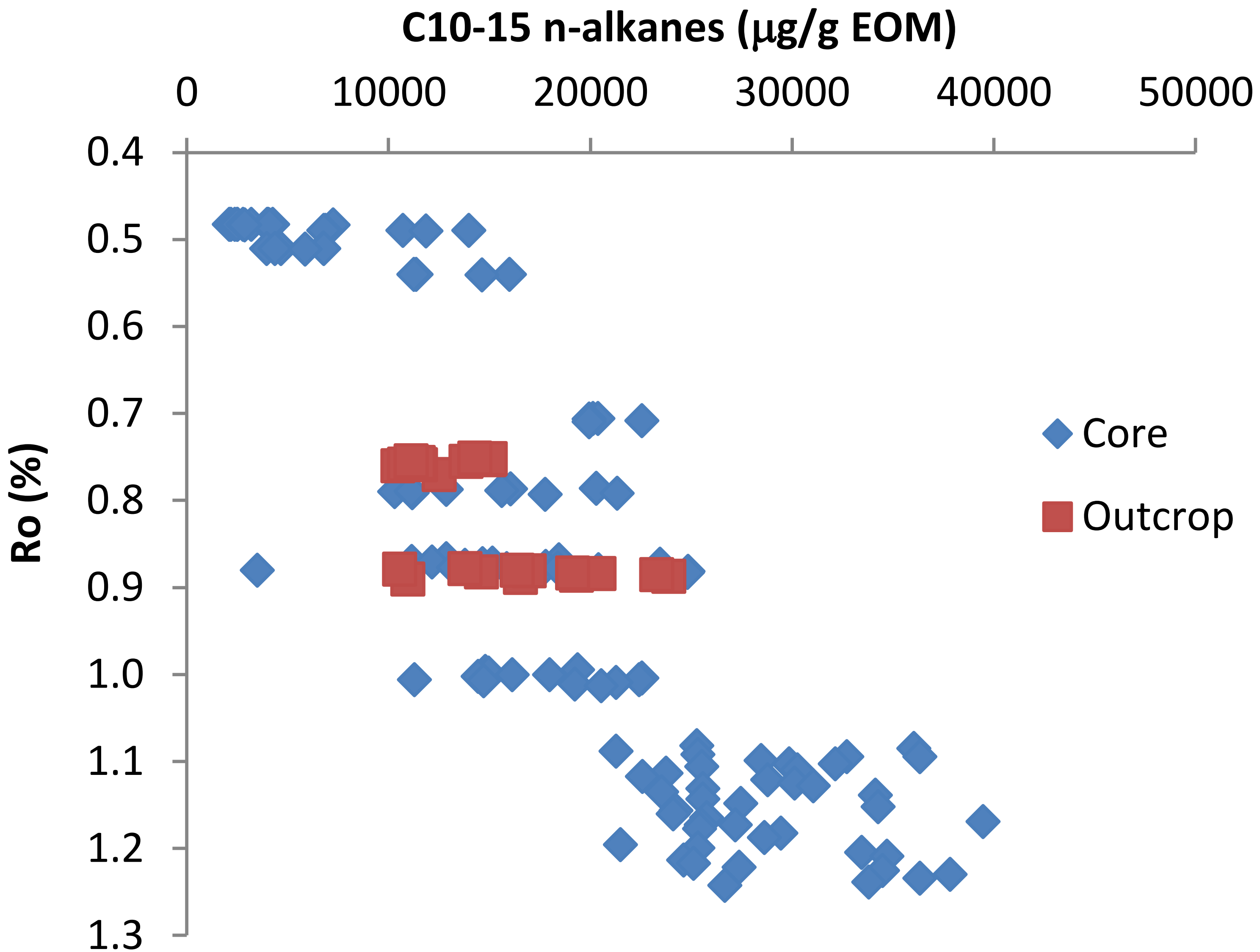
n-Alkane concentration profile



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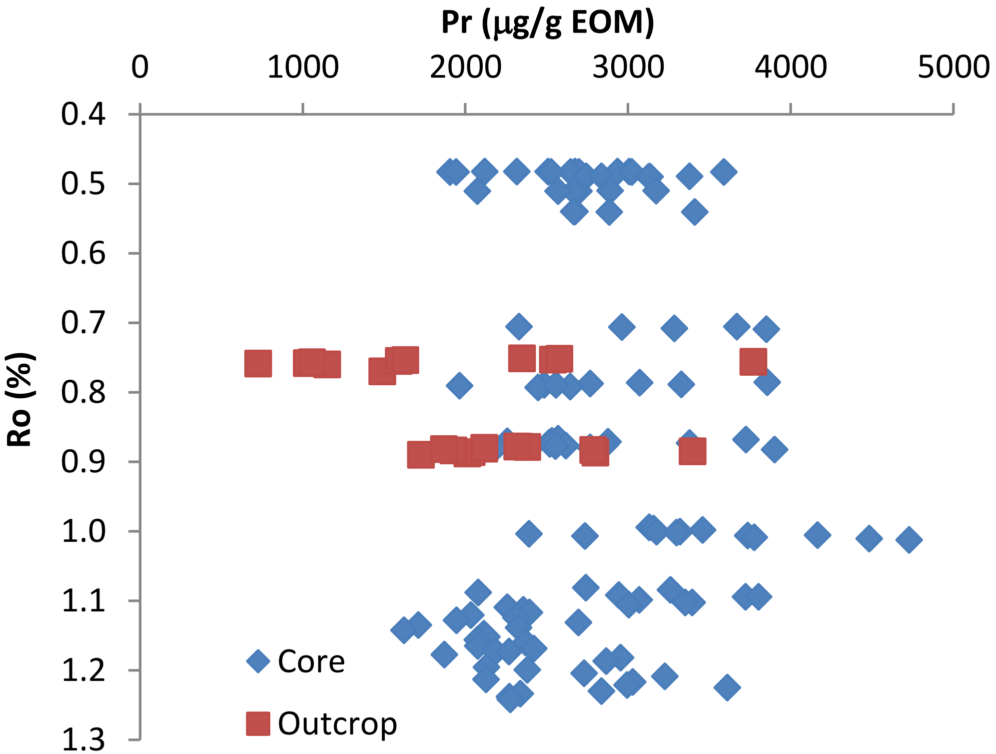
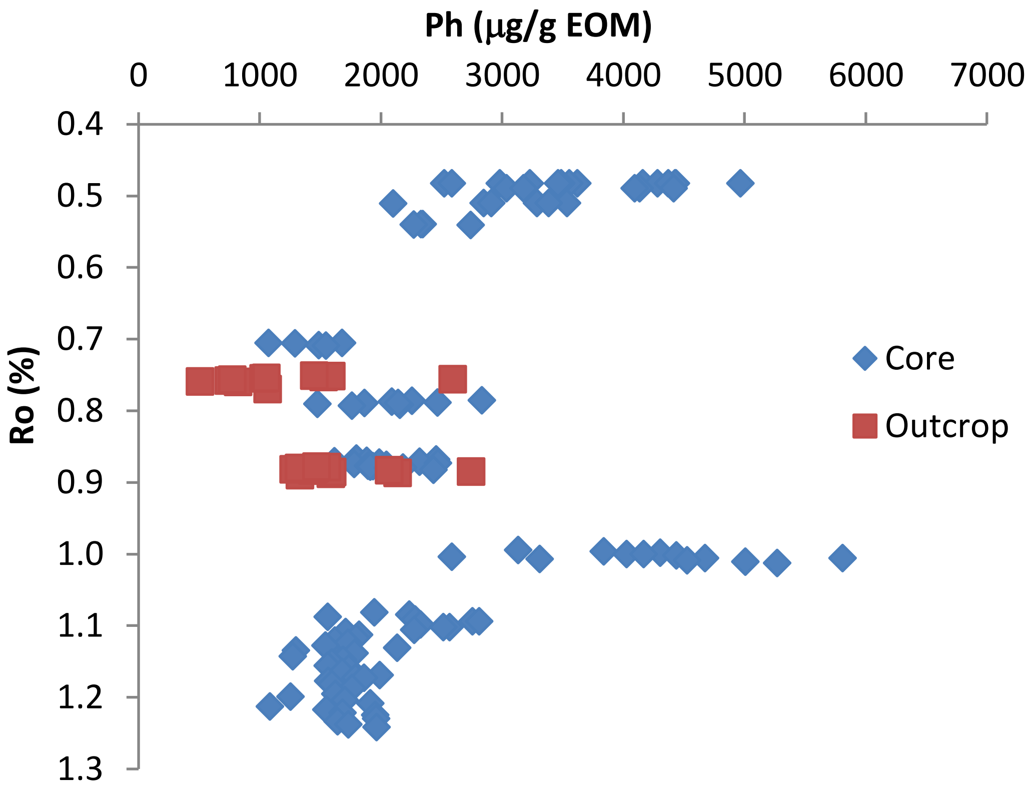
Isoprenoids concentration profiles





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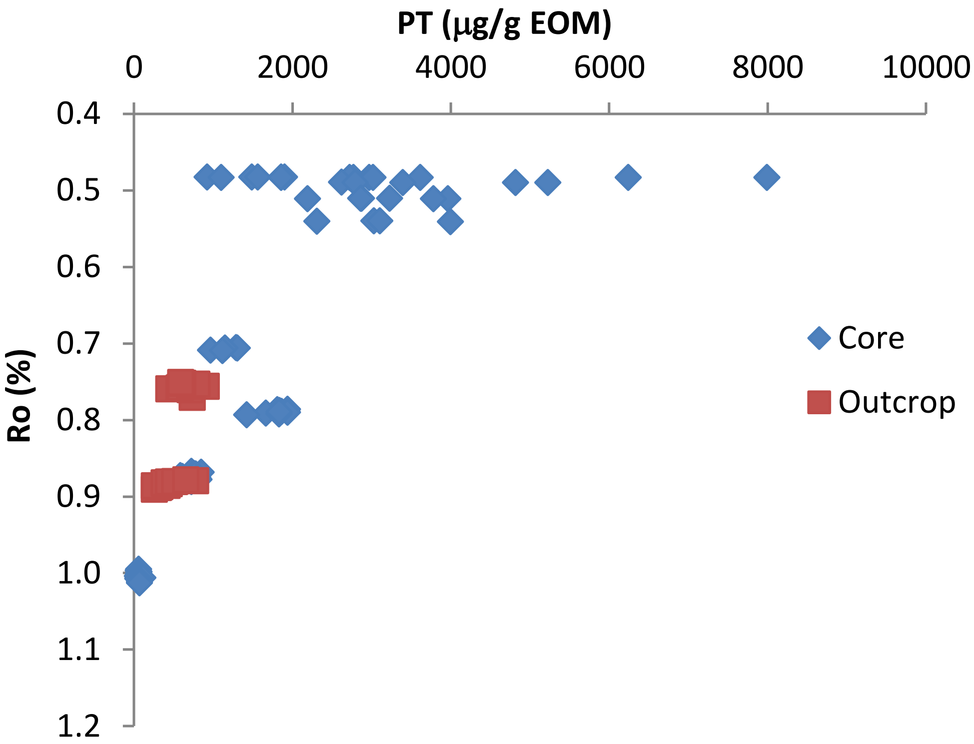
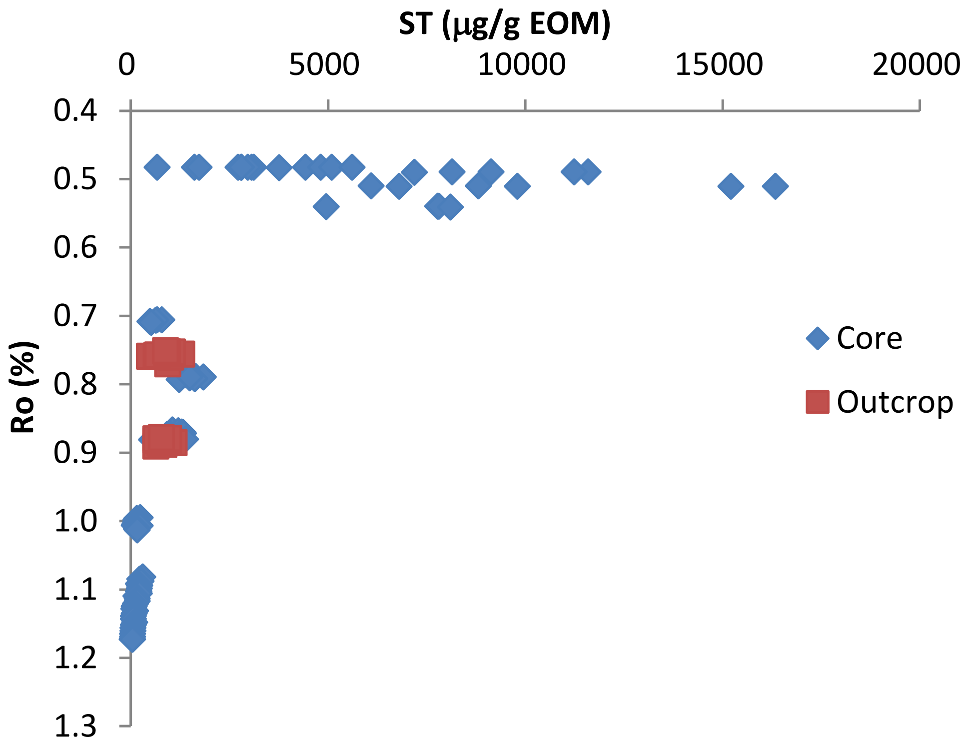
Biomarkers concentration profiles





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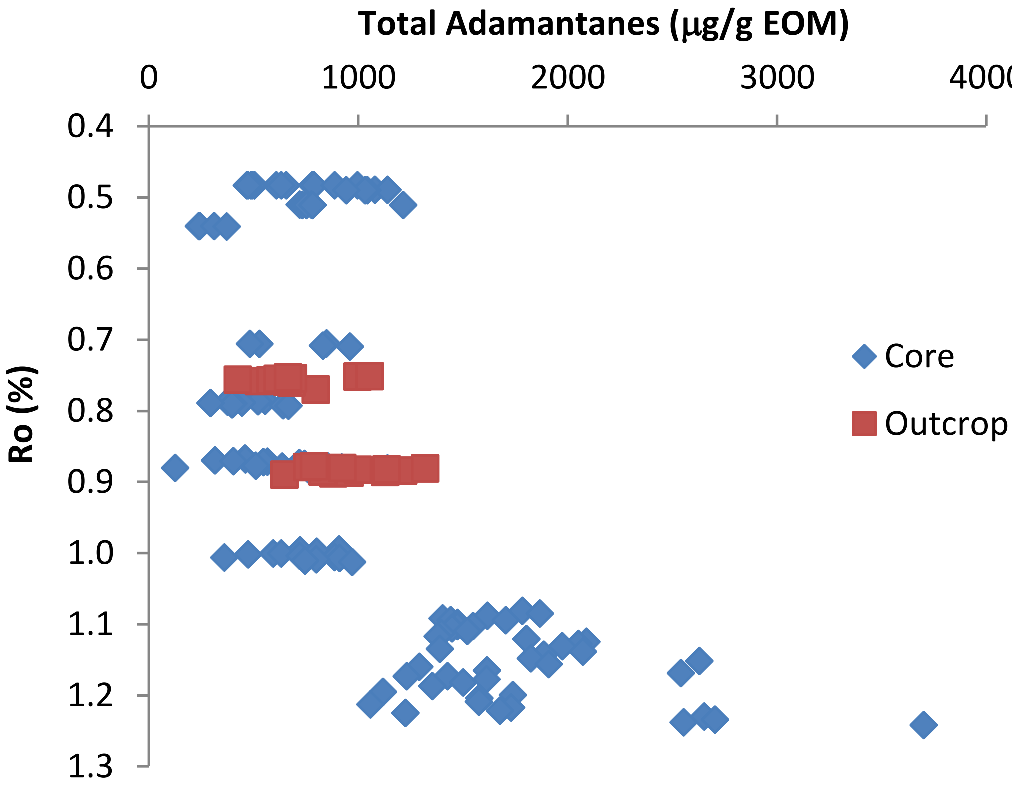
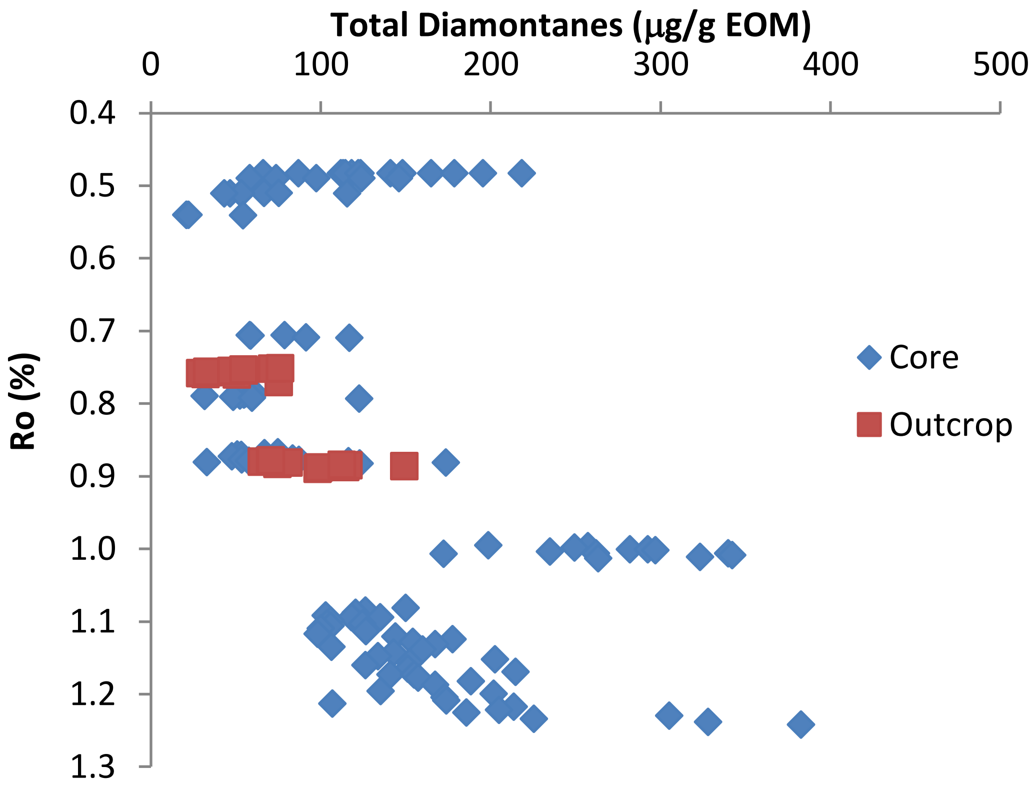
Diamondoids concentration profiles





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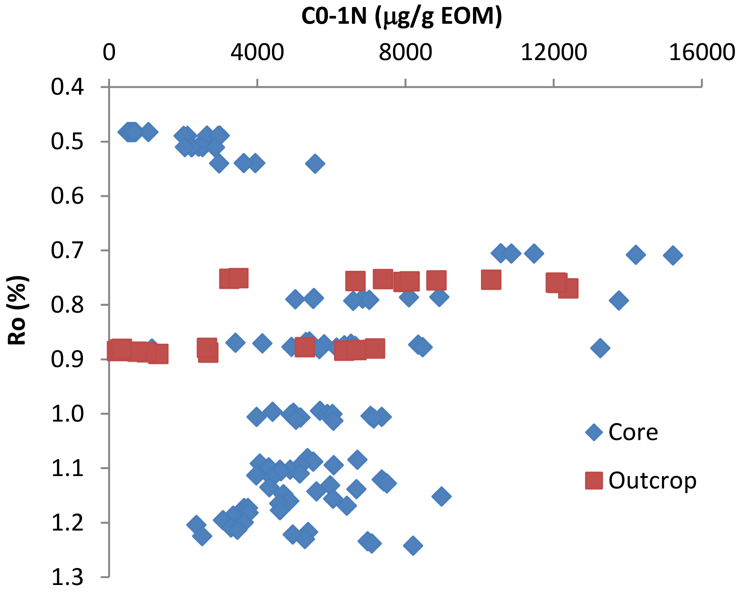
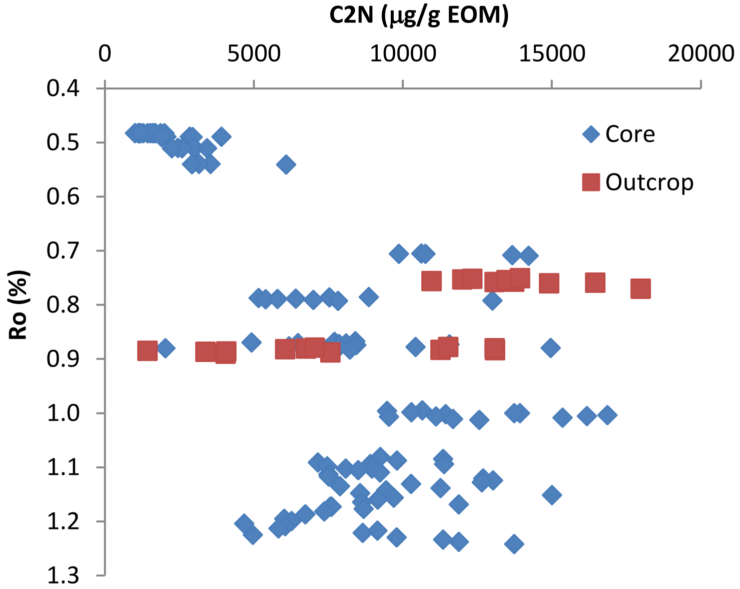
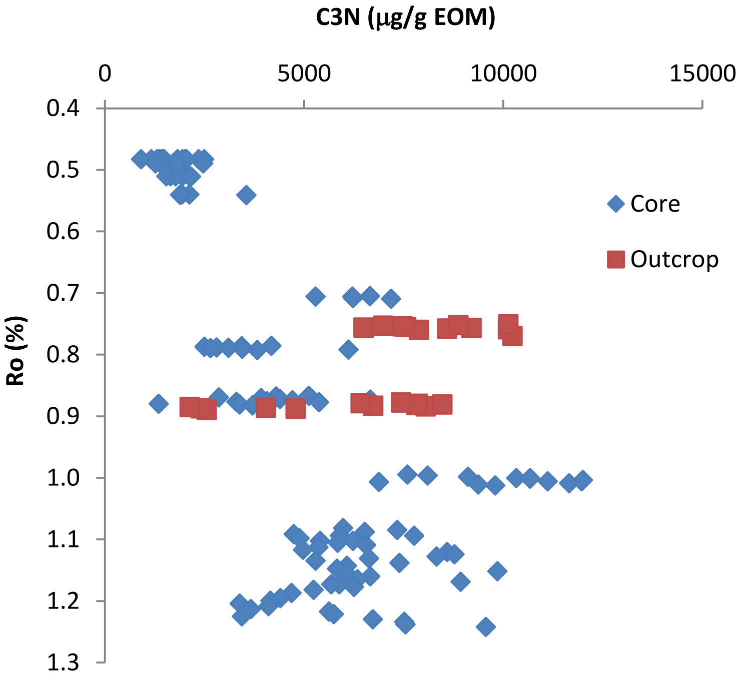
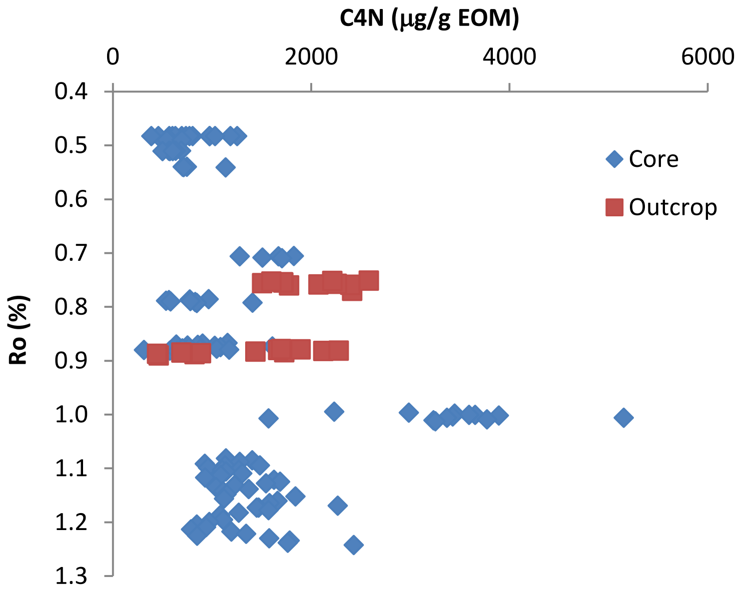
Concentration profiles of alkylnaphthalenes









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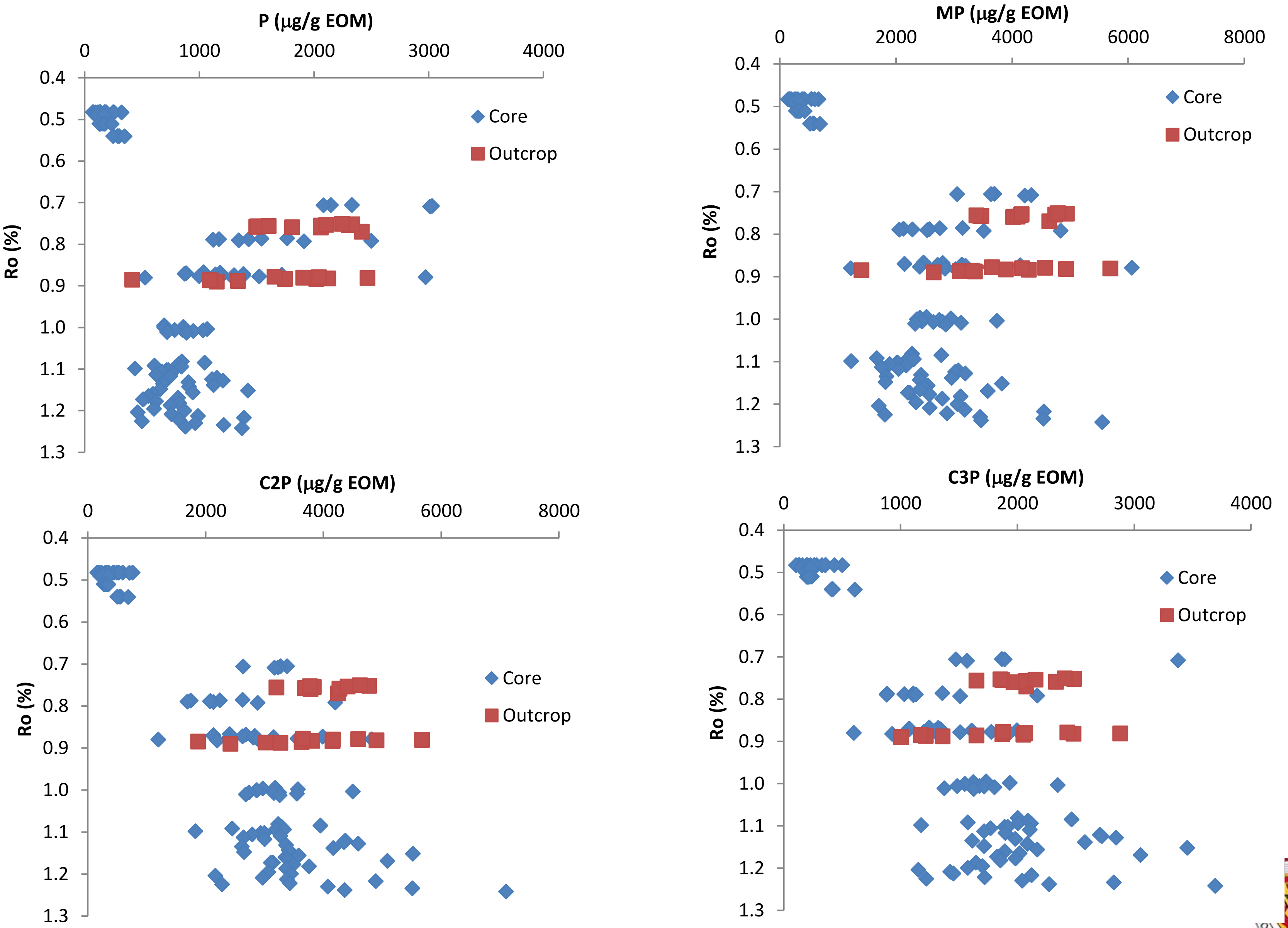
Concentration profiles of alkylphenanthrenes



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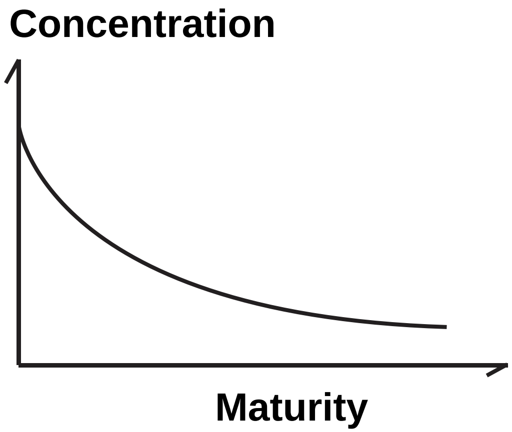
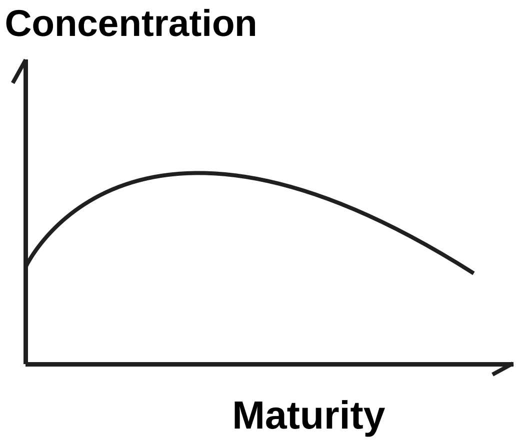
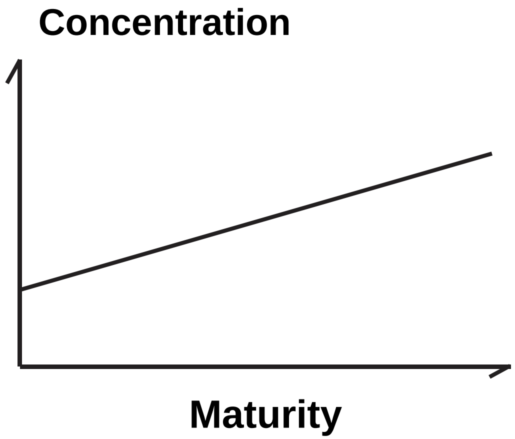
Conceptual concentration profile of various components



1,2 – Biomarkers



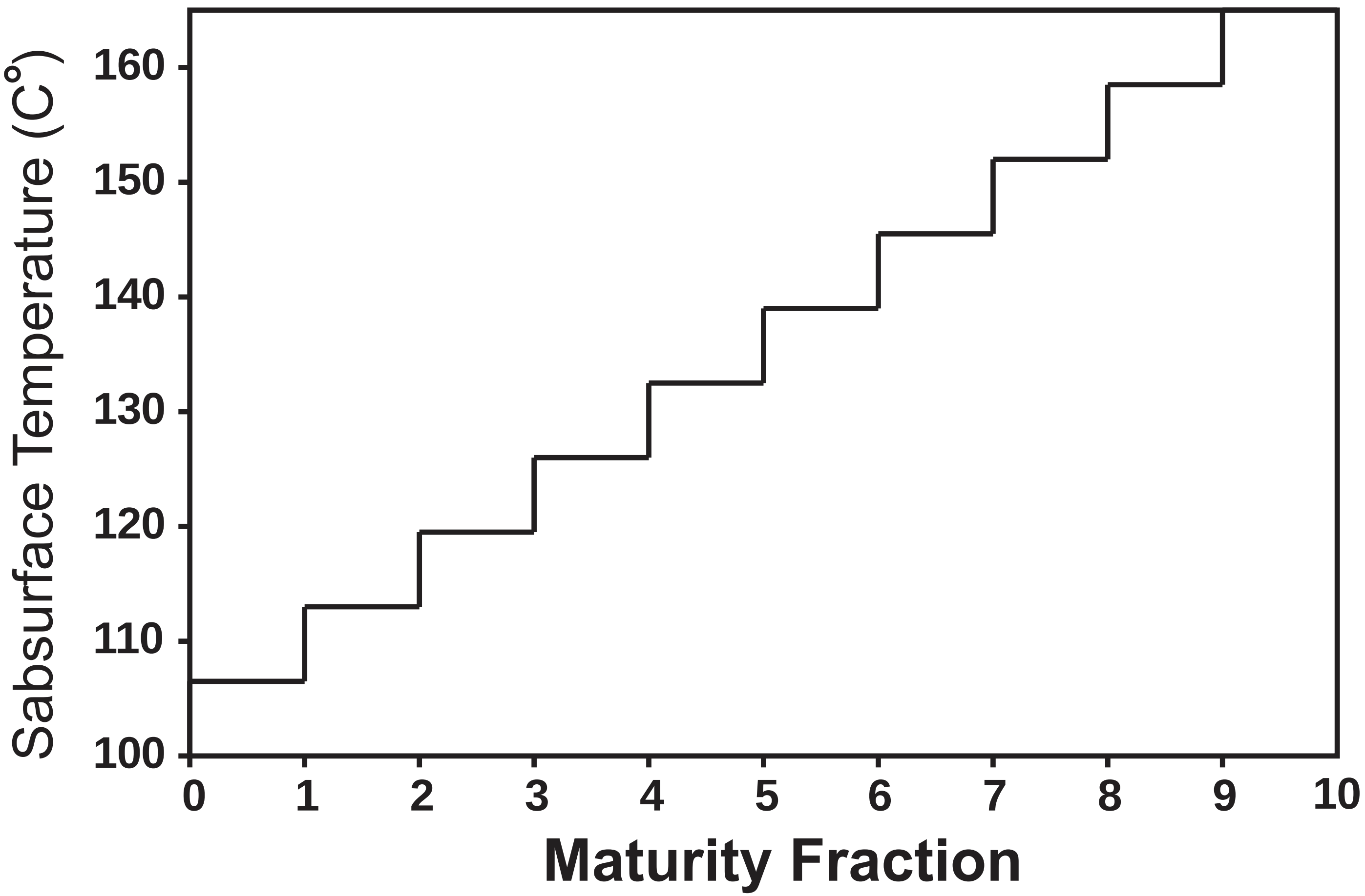
3,5 – Aromatic Hydrocarbons



6,7 – Light Hydrocarbons

8-10 – Diamondoids

Concept of mass fraction matuity



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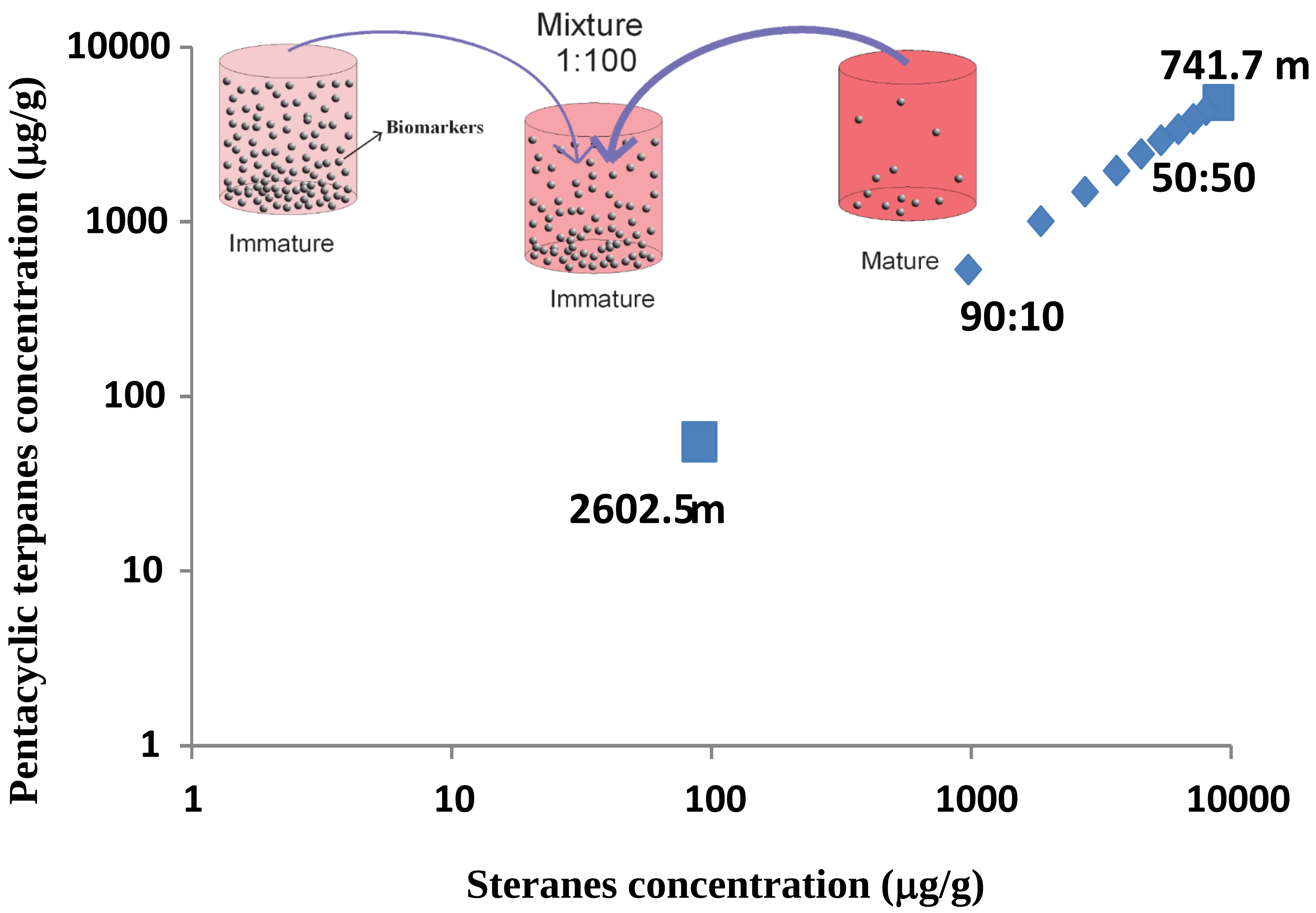
Both concentrations and molecular ratios are applied for maturity constraints



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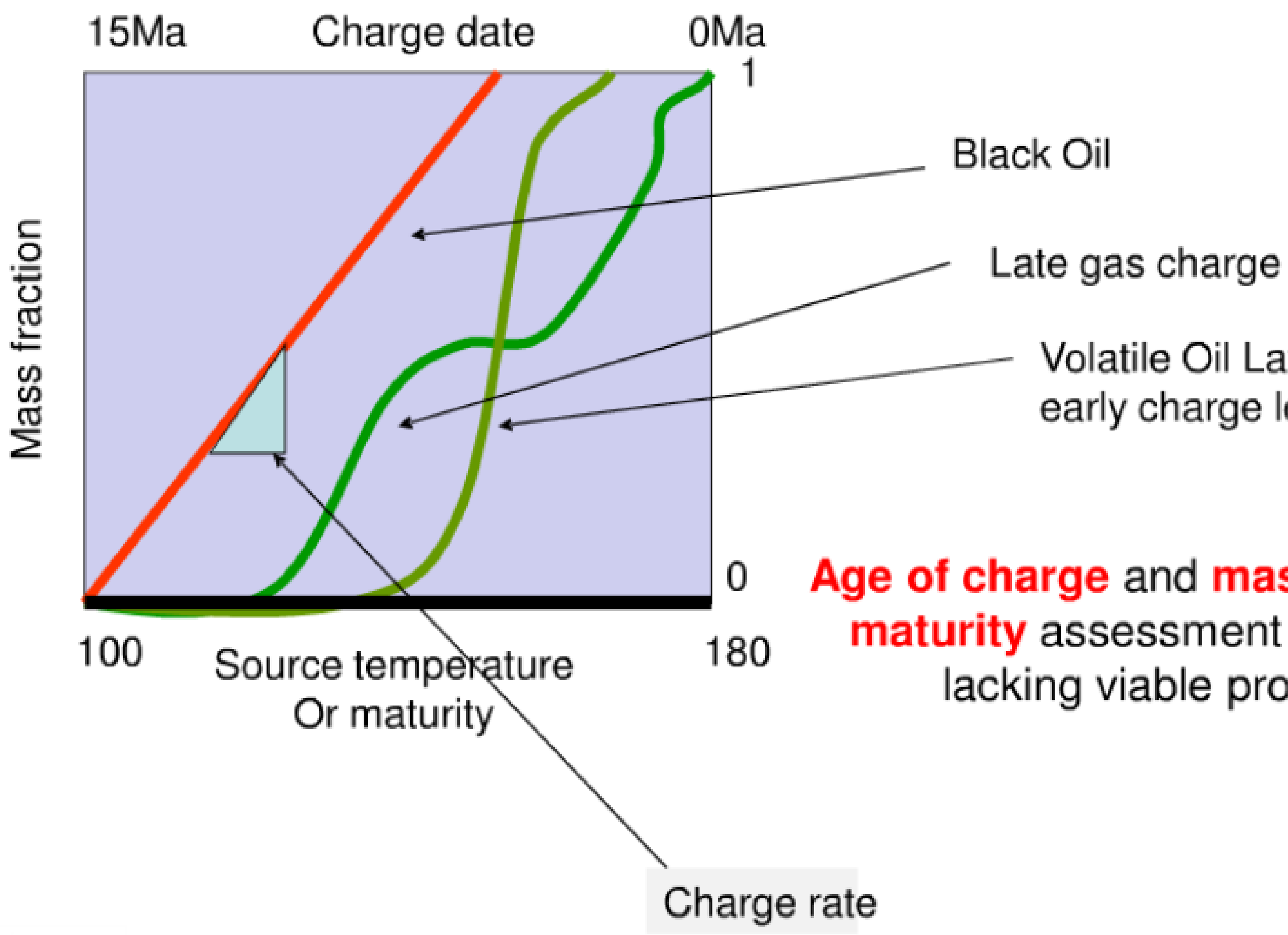
Mass fraction maturity in a trap

If this could be assessed, it would be a game changing tool!



Age of charge and **mass fraction maturity** assessment currently lacking viable proxies

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Summary

- Tracking petroleum mass fraction relationships for reservoired oils.
- Elucidation of complex charge histories.
- Defining a quantitative approach to assess kitchen maturity in oil and gas accumulations basins.
- If this could be assessed, it would be a game changing tool!

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Acknowledgement

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Chaires de recherche du Canada

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Chaires d'excellence en recherche du Canada

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