A Geochemical Appraisal of the Potential Source(s) of Oils in the STACK and SCOOP Plays in the Anadarko Basin, Oklahoma*

R. Paul Philp[1] and Carl Symcox[1]

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Abstract

The SCOOP and STACK plays in the Anadarko Basin, Oklahoma, have developed rapidly over the past decade into significant oil producing regions. These areas have a long history of oil production for over 100 years from conventional wells and the majority of the oil produced over that time has been ascribed to having a Woodford source. As a result, many operators have automatically assumed that the source of the oils in the SCOOP and STACK areas are also sourced primarily from the Woodford with little evidence to support such an origin. Previous work on the Woodford has shown that oils derived from this source have certain very characteristic geochemical features that appear to be absent from the STACK and SCOOP oils. For example, conventional Woodford oils contain a series of arylisoprenoids, and depending on the level of maturity, carotenoids, that can be associated with green sulfur bacteria prevalent during the deposition of the Woodford under euxinic conditions. In addition, the Woodford sourced oils also contain a characteristic terpane signature with both tricyclic and pentacyclic terpanes present. However, the STACK and SCOOP oils do not appear to contain the arylisoprenoids and many of the oils are dominated by tricyclic terpanes with an absence of the pentacyclic hopanes. This leads to the question as to whether the geochemical signature associated with oils could result from the maturation of a typical Woodford or represent a different source facies. Data will be presented in this paper suggesting that it is unlikely that maturity is the only factor responsible for the characteristic fingerprints of the STACK and SCOOP oils. Various Mississippian source facies in the area have been shown to have similar geochemical characteristics to those observed in the oils. Extracts from certain cores have shown these characteristic fingerprints, dominated by the tricyclic terpanes, at depths between extracts that contain both the tricyclics and pentacyclic terpanes. If maturity were responsible one would expect with increasing depth that the hopanes would be absent in the deeper samples. In summary it is proposed that while in certain areas of the STACK and SCOOP plays the Woodford may be contributing to the source of the oils, in other areas there is probably a significant contribution from Mississippian sources.

References Cited

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Galvis-Portilla, H.A., 2017, Detailed Lithostratigraphic Characterization and Sequence Stratigraphy of a Complete Woodford Shale Outcrop Section in Southern Oklahoma: M.S. Thesis, University of Oklahoma, Norman, OK, 156 p.

van Graas, G.W., 1990, Biomarker Maturity Parameters for High Maturities: Calibration of the Working Range Up to the Oil/Condensate Threshold: Organic Geochemistry, v. 16/4-6, p. 1025-1032. doi.org/10.1016/0146-6380(90)90139-Q

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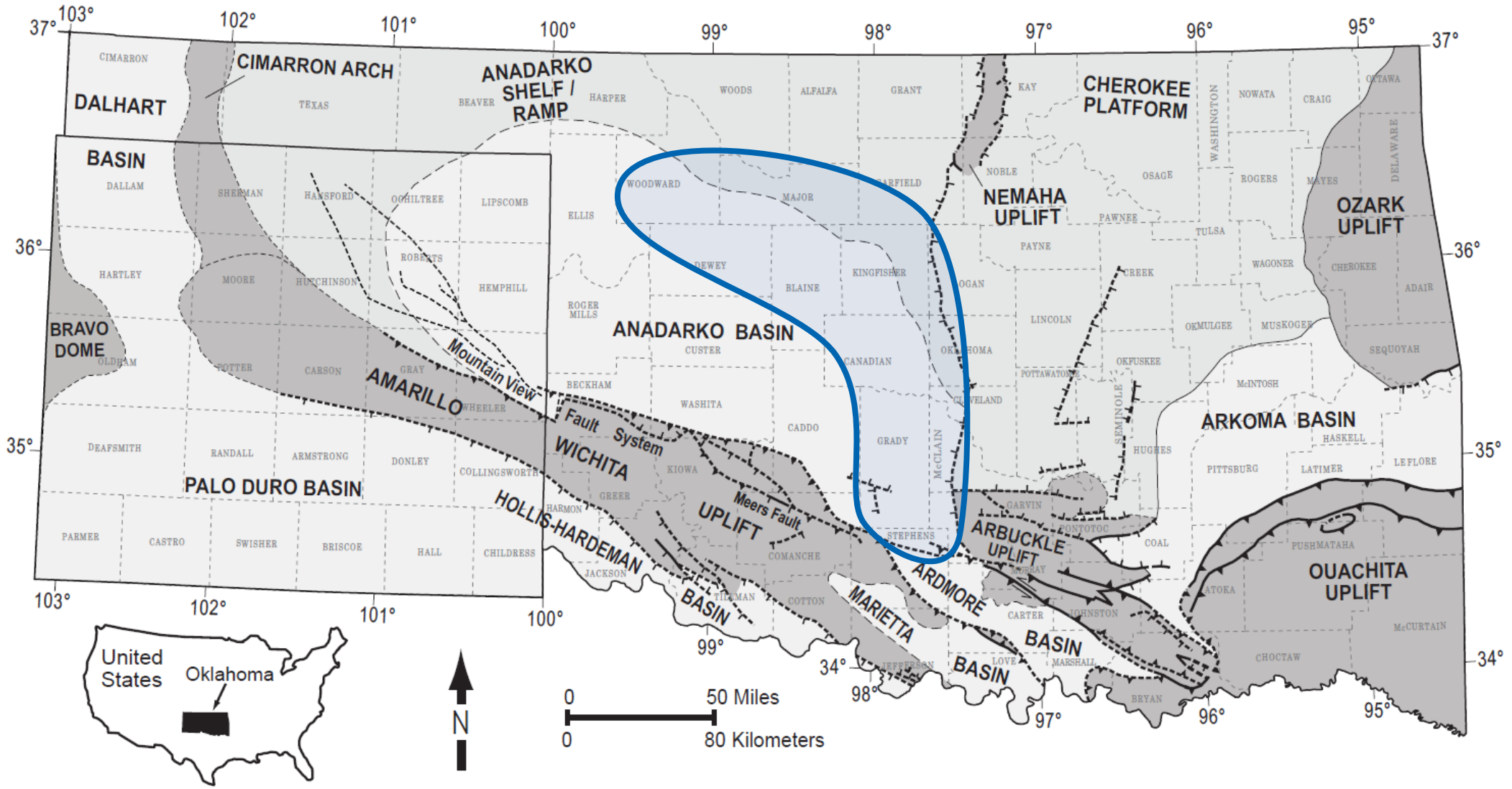
Introduction

- The STACK Mississippian is commonly believed to be sourced by a Woodford-only hydrocarbon charge, but supporting evidence is often anecdotal at best

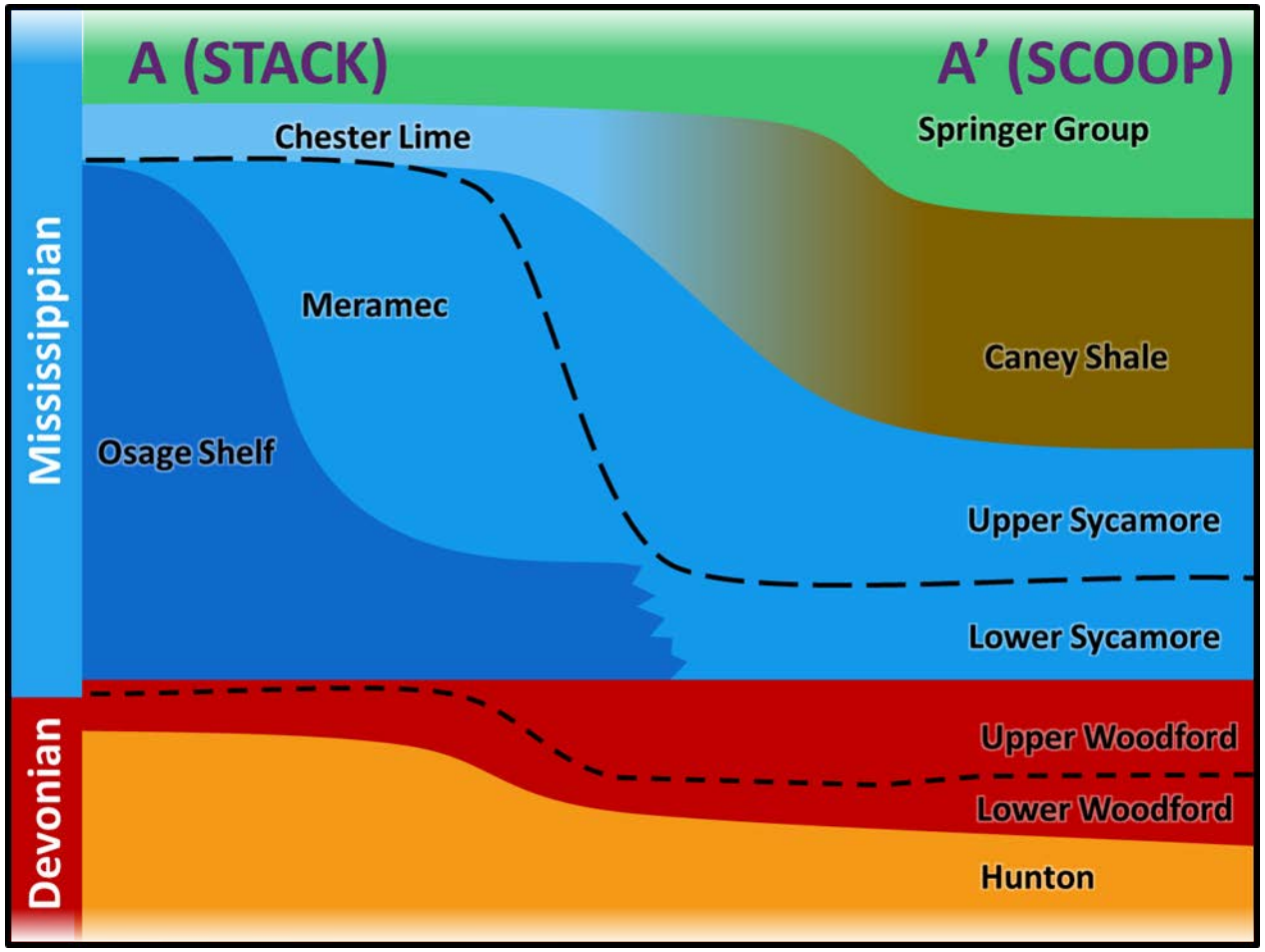
- Well-defined trends in organofacies end-members are observed regionally, yet are often ascribed to changes in maturity; however few, if any, oils show a direct relationship to known Woodford sources

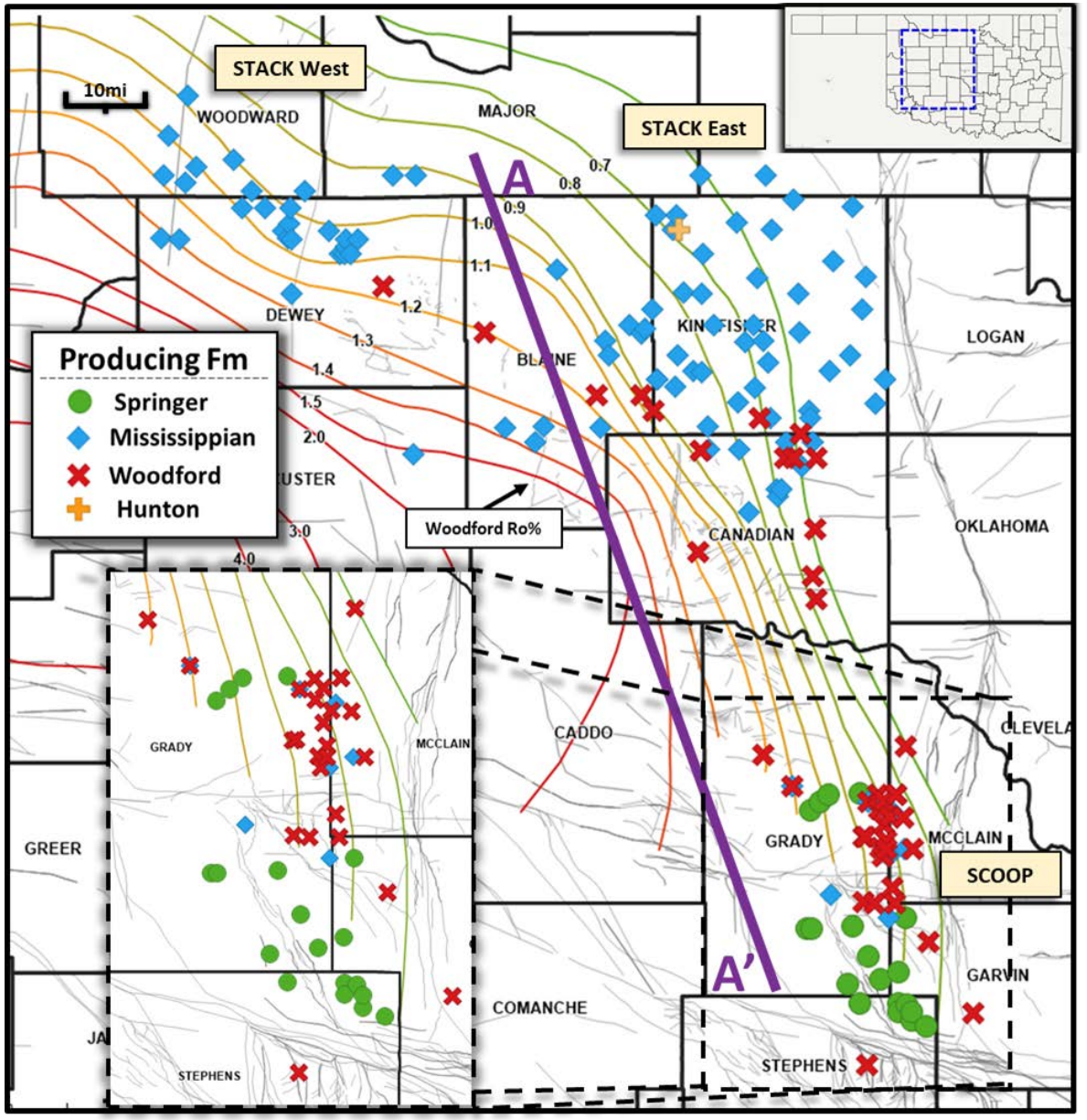
- This presentation will discuss several inconsistencies in a Woodford-only sourced model and some of the geochemical challenges in describing the STACK/SCOOP Petroleum System

Dataset—156 oils and 11 Cores Across 12 Counties



Regional Map and Data Set



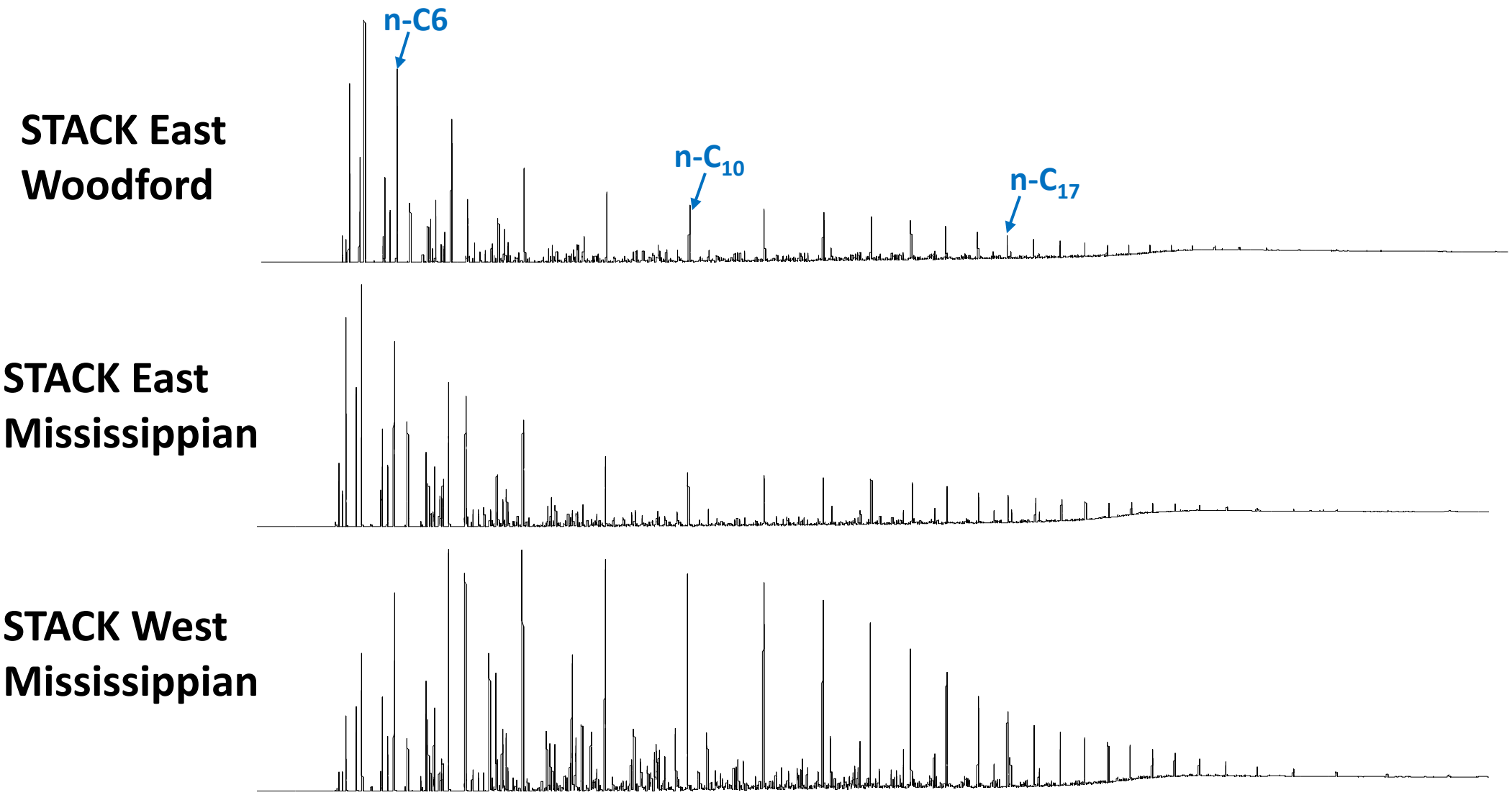


Outline

Part 1: Geochemical inconsistencies in STACK Oils and “Conventional” Woodford Oils

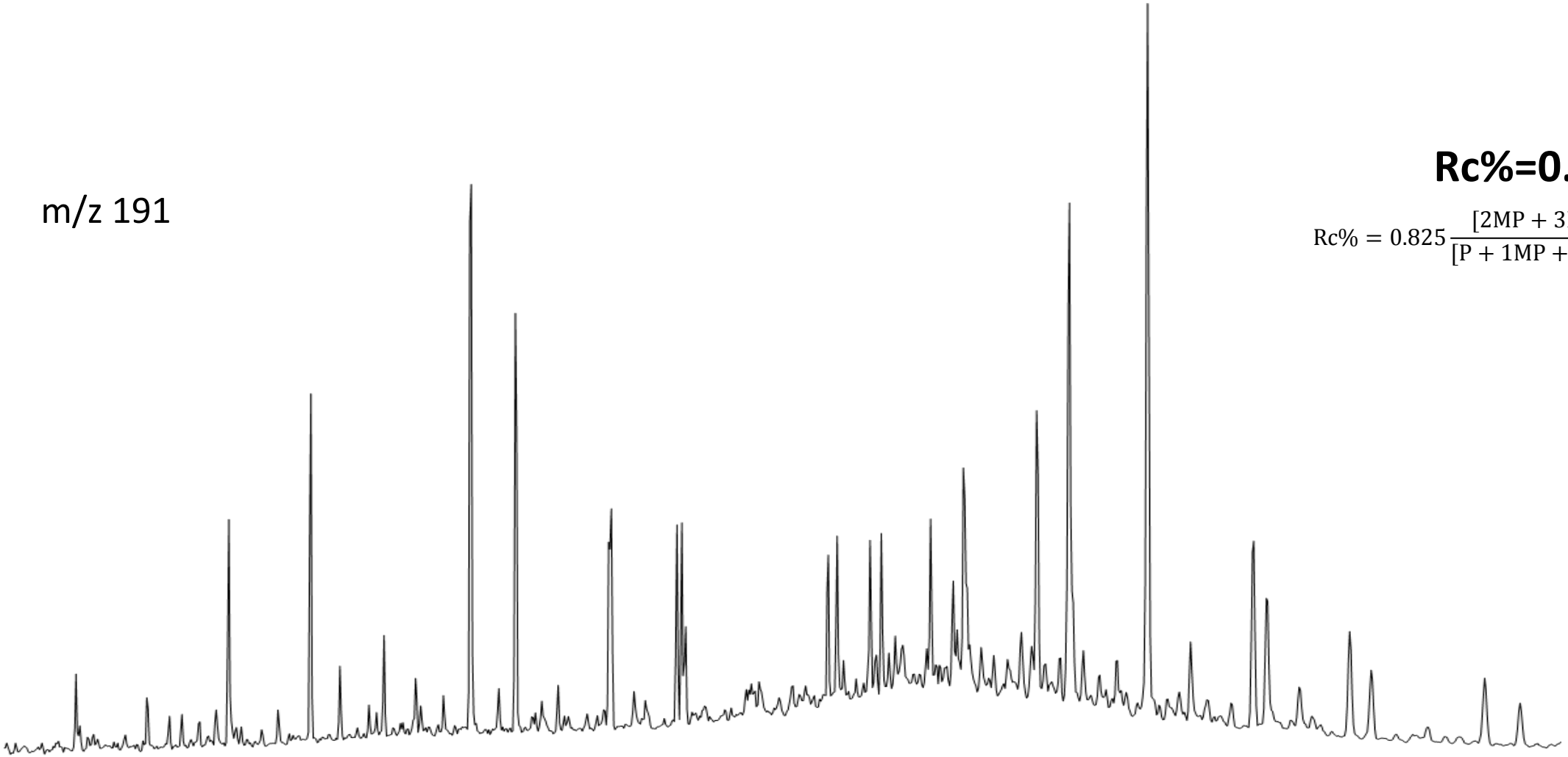
Part 2: Comparison to Core Extracts from Osage, Meramec, and Chester

Whole Oil Chromatogram



Terpanes: Typical “Conventional” Woodford Produced Oil

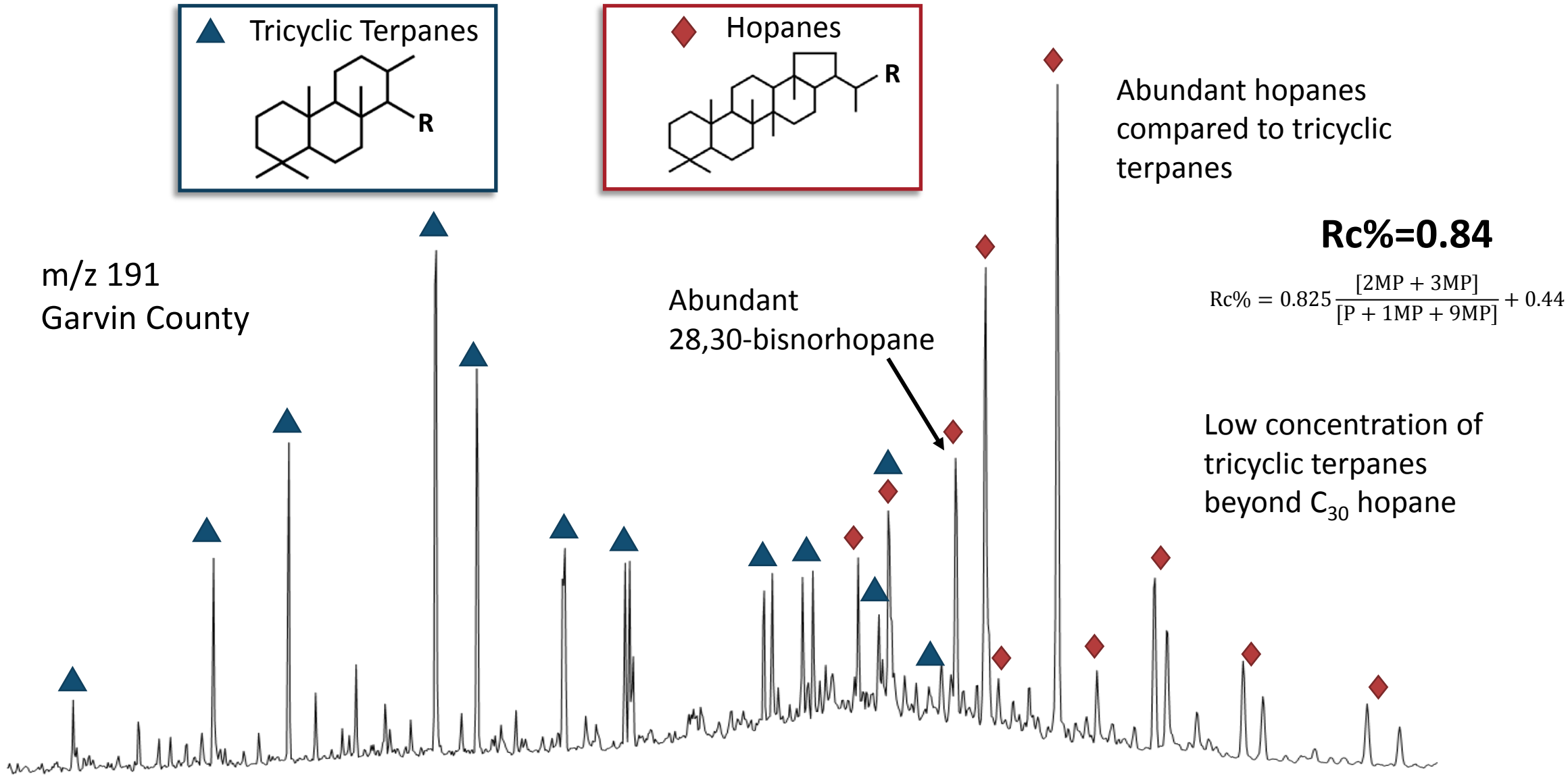
m/z 191



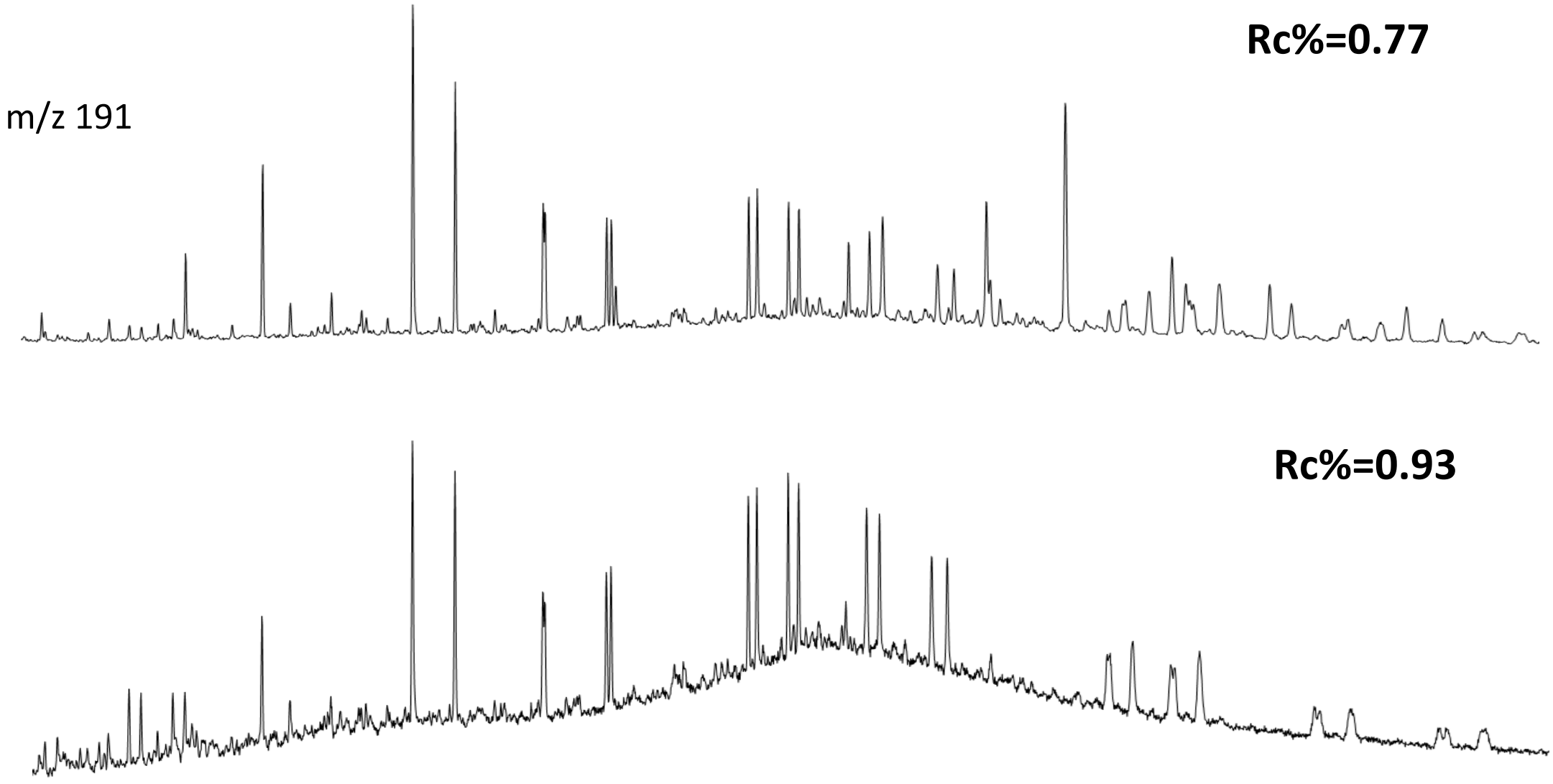
Rc%=0.84

$$\mathrm{Rc\%} = 0.825\frac{[2\mathrm{MP} + 3\mathrm{MP}]}{[\mathrm{P} + 1\mathrm{MP} + 9\mathrm{MP}]} + 0.44$$

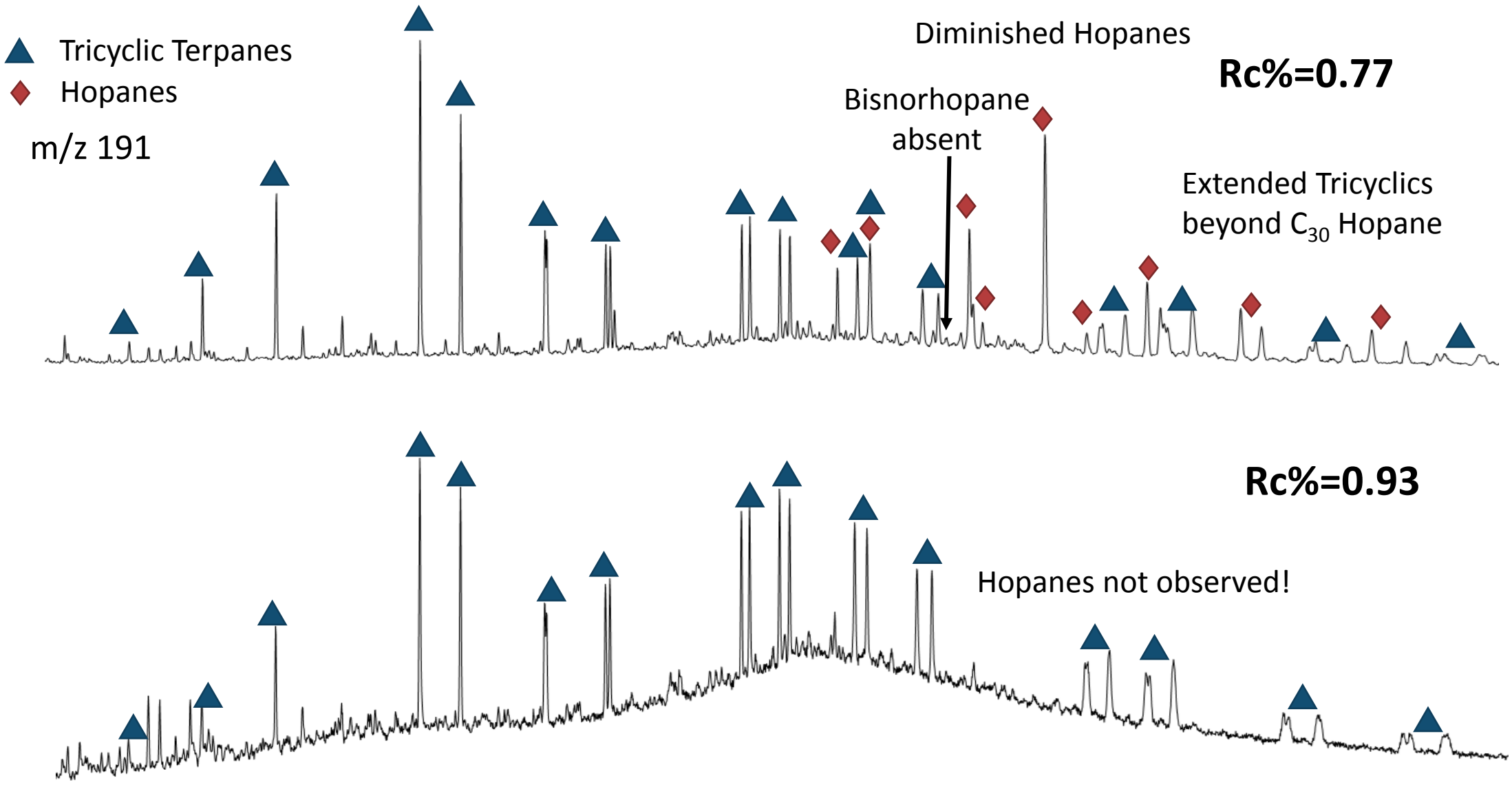
Terpanes: Typical “Conventional” Woodford Produced Oil



Typical STACK Oil Terpanes—Kingfisher County



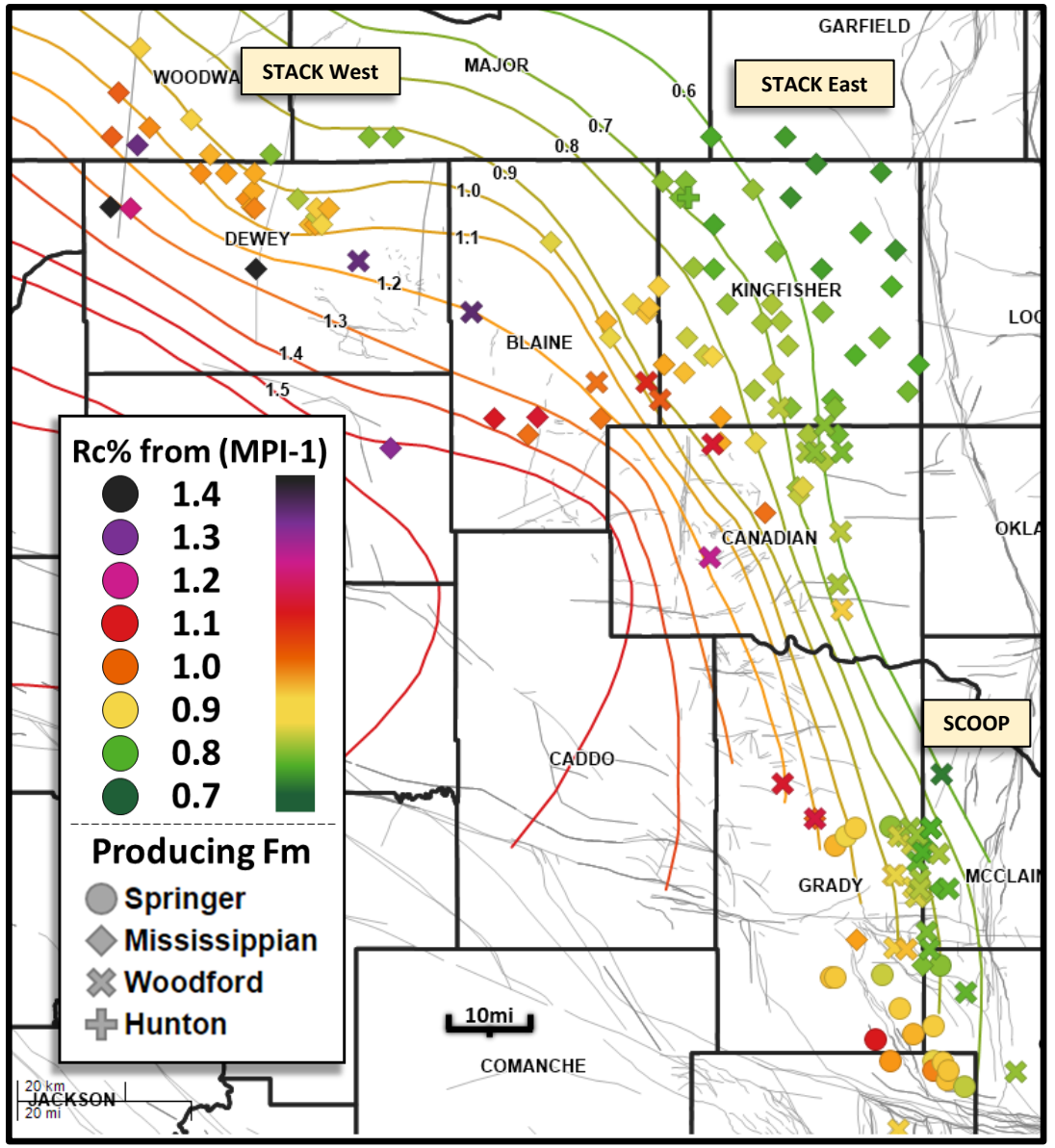
Typical STACK Oil Terpanes—Kingfisher County



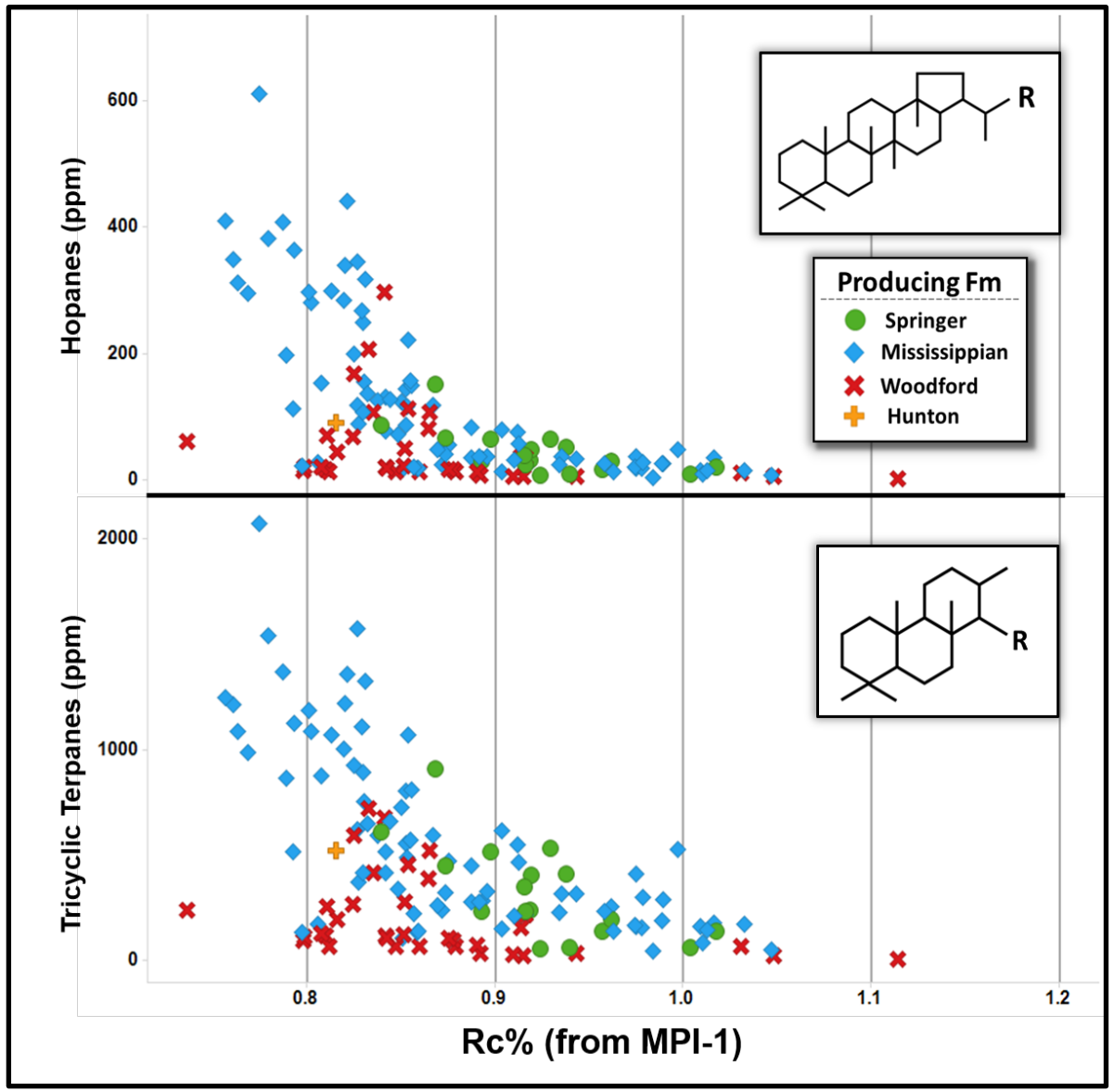
Thermal Maturity

Methylphenanthrene has proven a useful maturity indicator for this dataset.

Oils range from Rc%=0.7-1.4



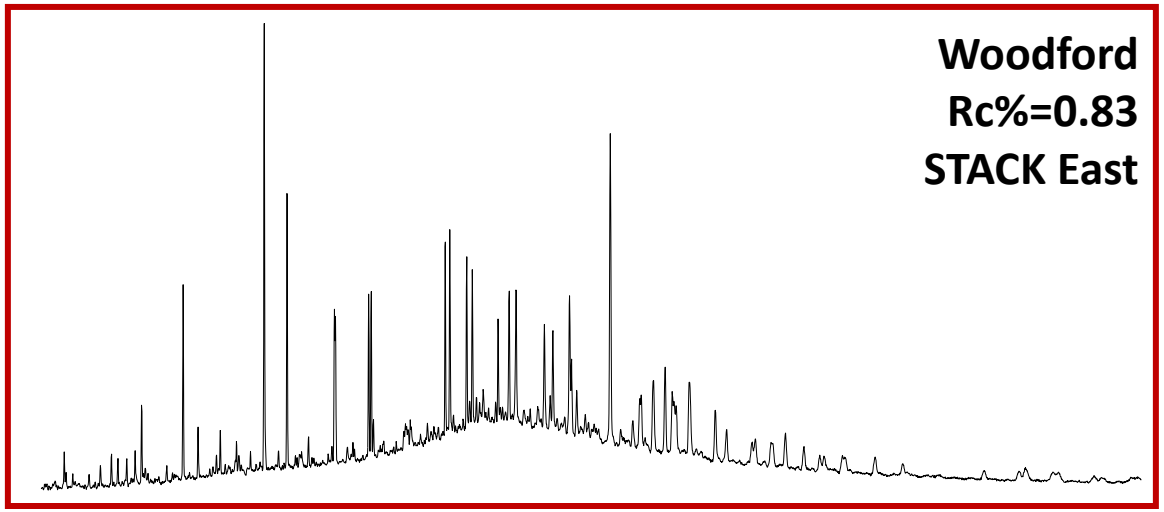
Terpanes and Thermal Maturity

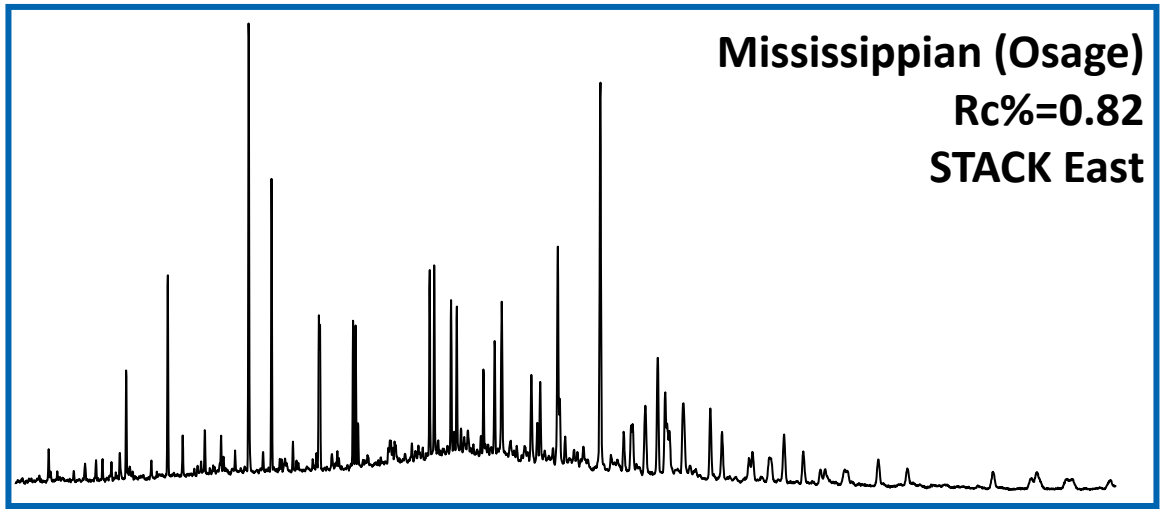


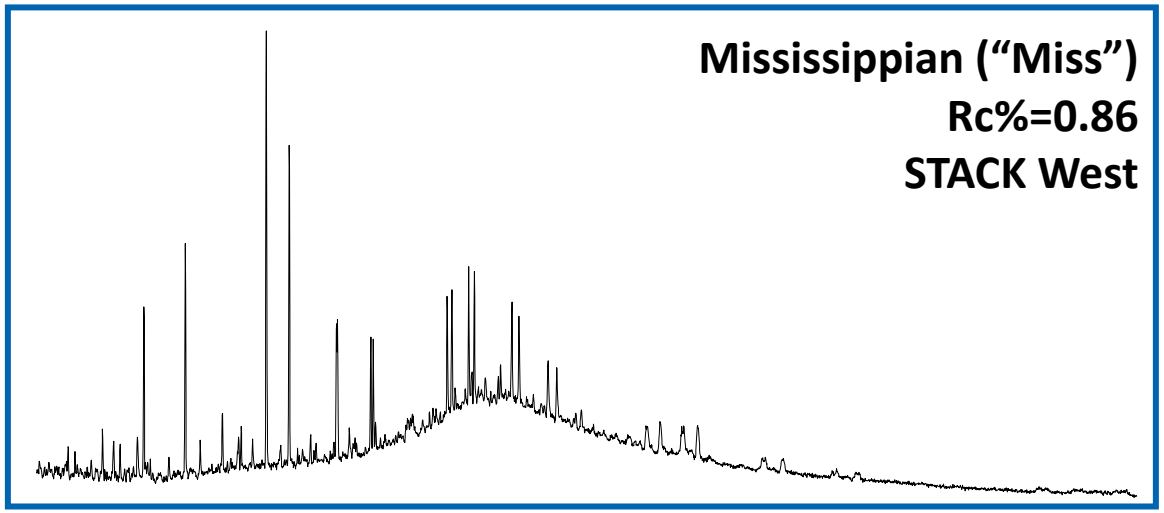
It has been shown previously that tricyclic terpanes are thermally more stable that the hopanes (Graas, 1990).

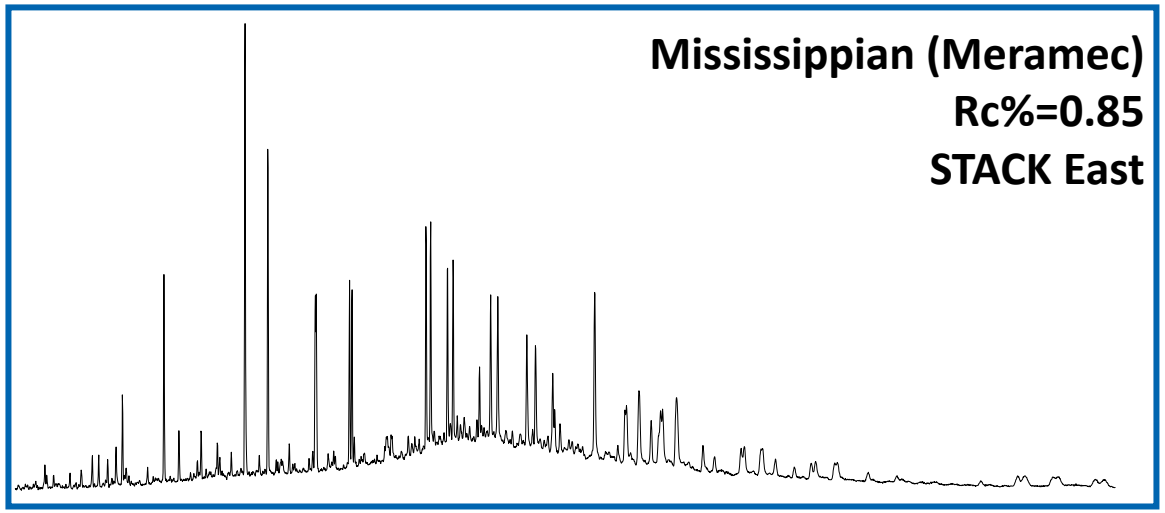
STACK/SCOOP oils appear to agree—terpanes are observed to diminish continuously until Rc%=0.9-1.1.

STACK Endmember Oils—Maturity?



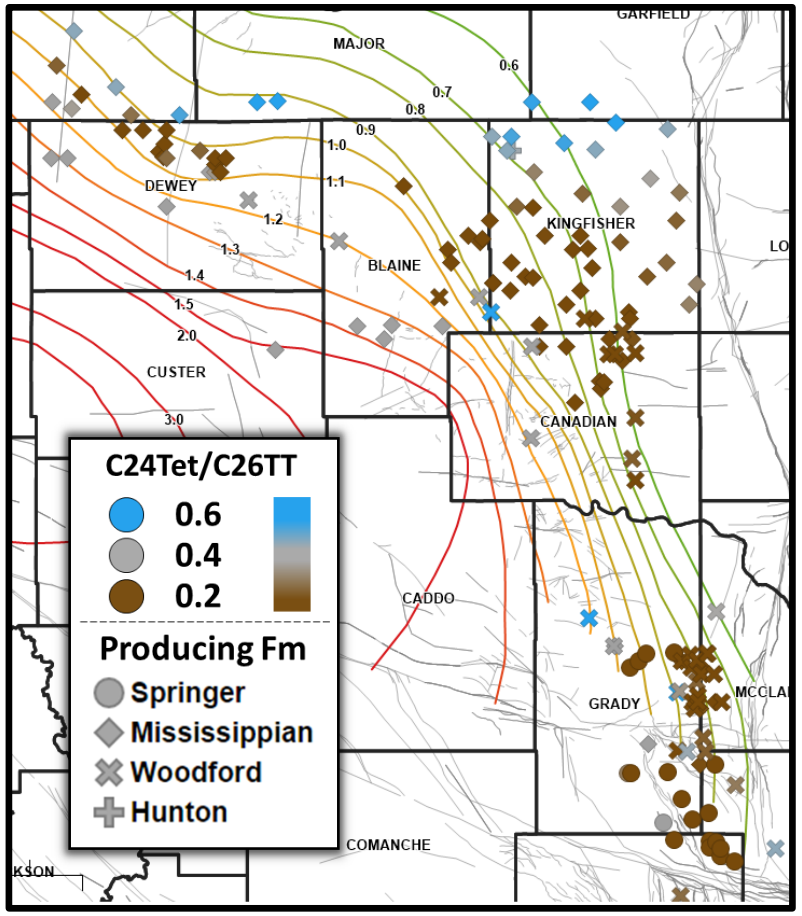




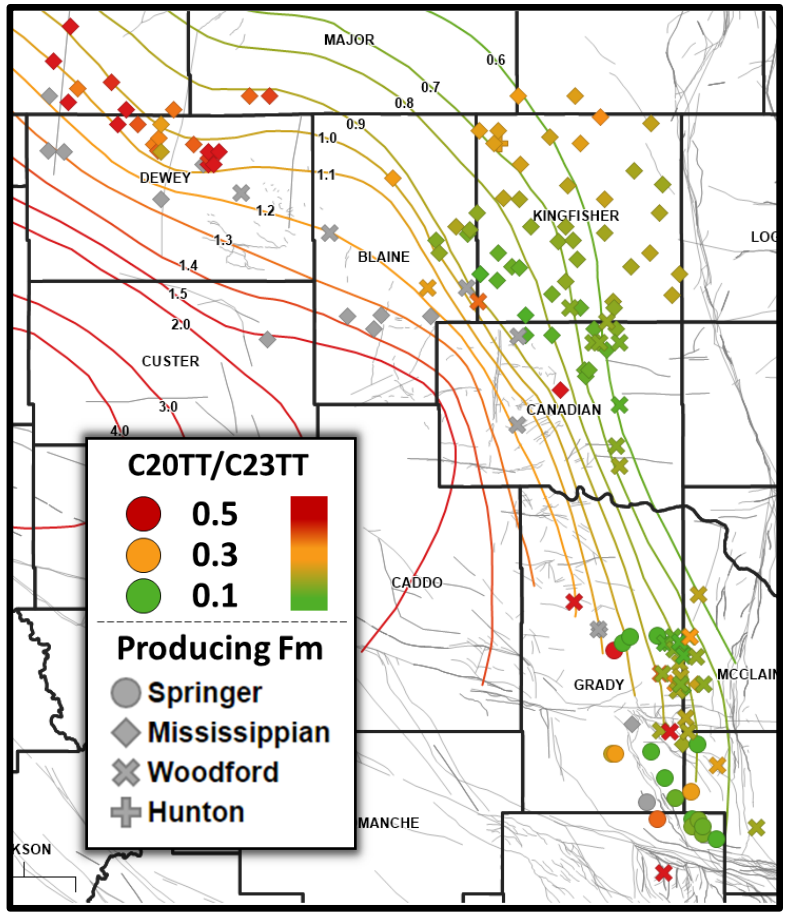


Variability in Source-Specific Tricyclic Terpane Ratios

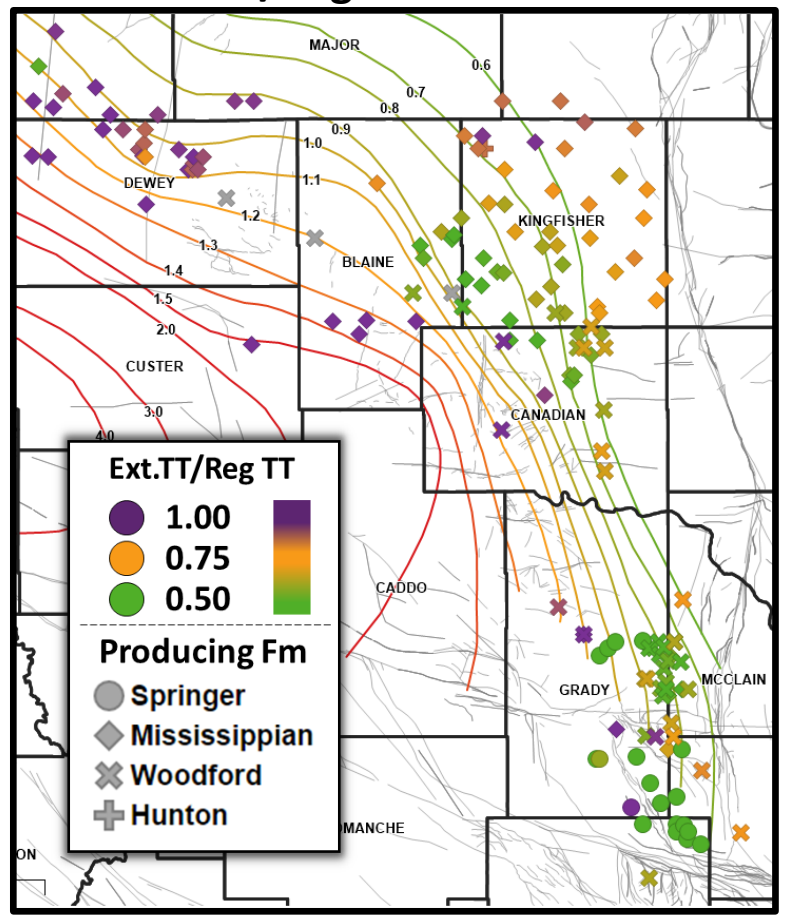
C24Tet/C26TT



C20TT/C23TT

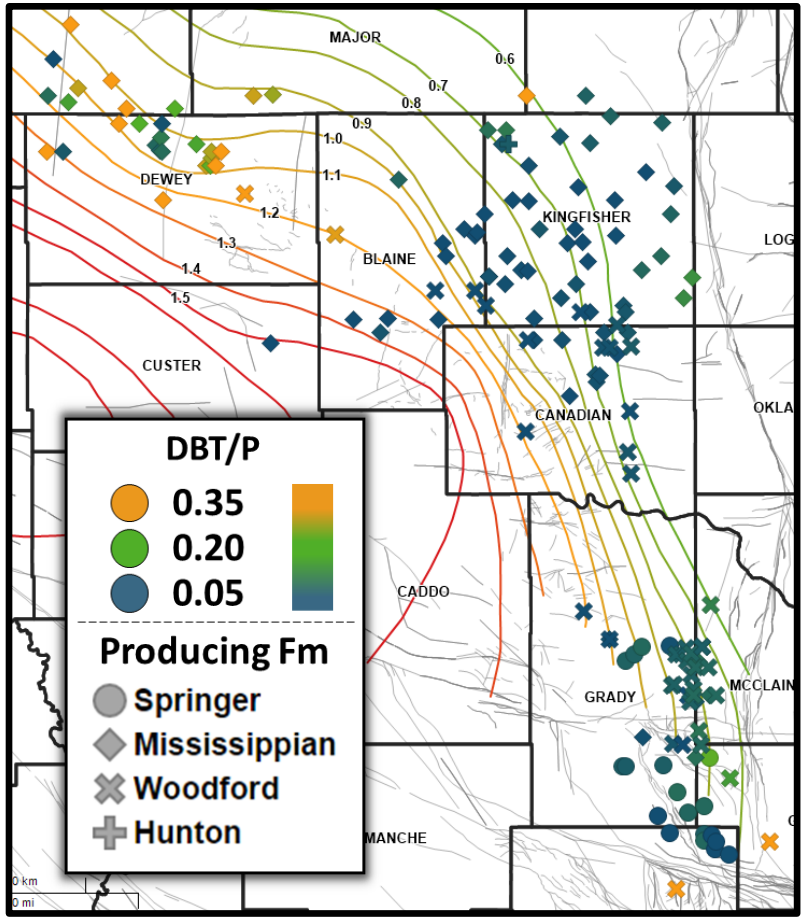


Extended TT/Regular TT

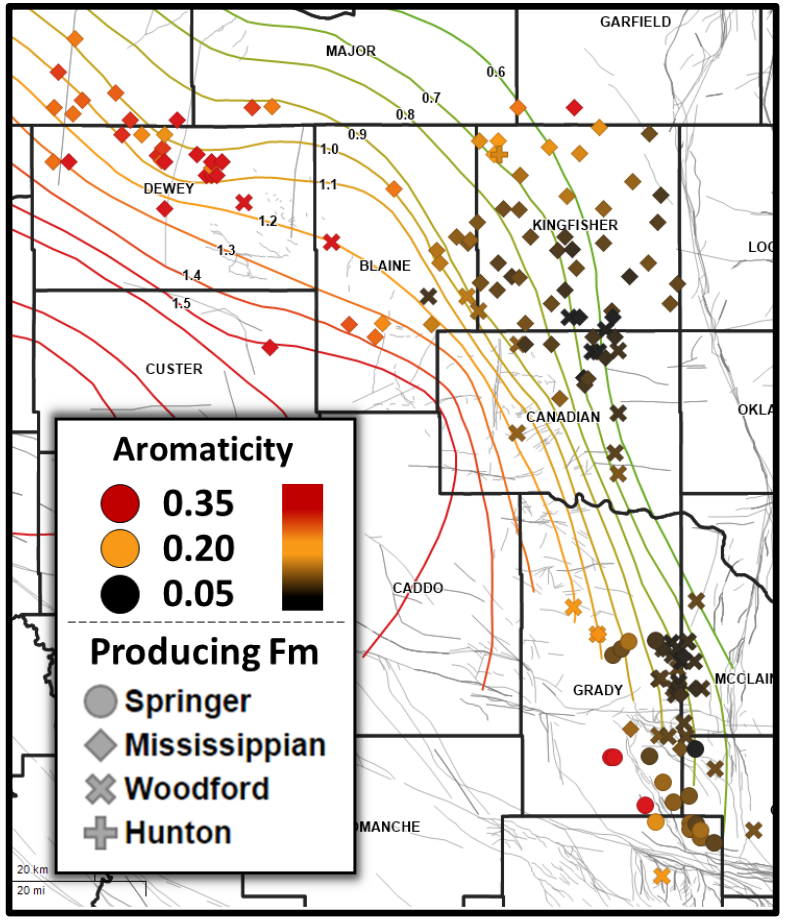


Variability in Source—Corroborating Parameters

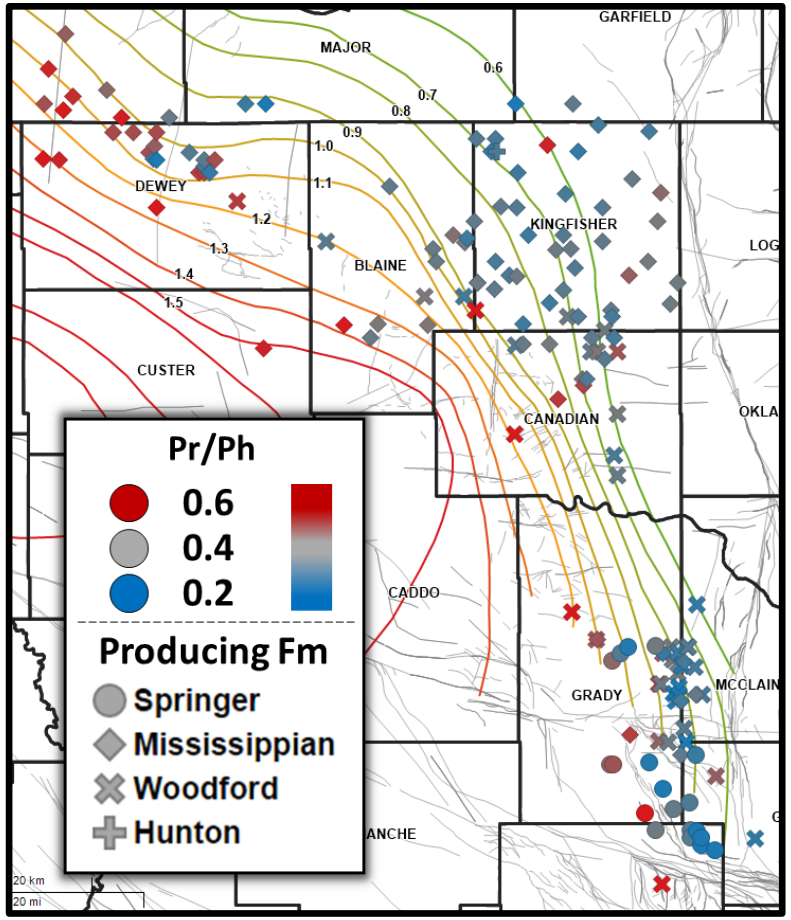
Dibenzothiophene/Phenanthrene



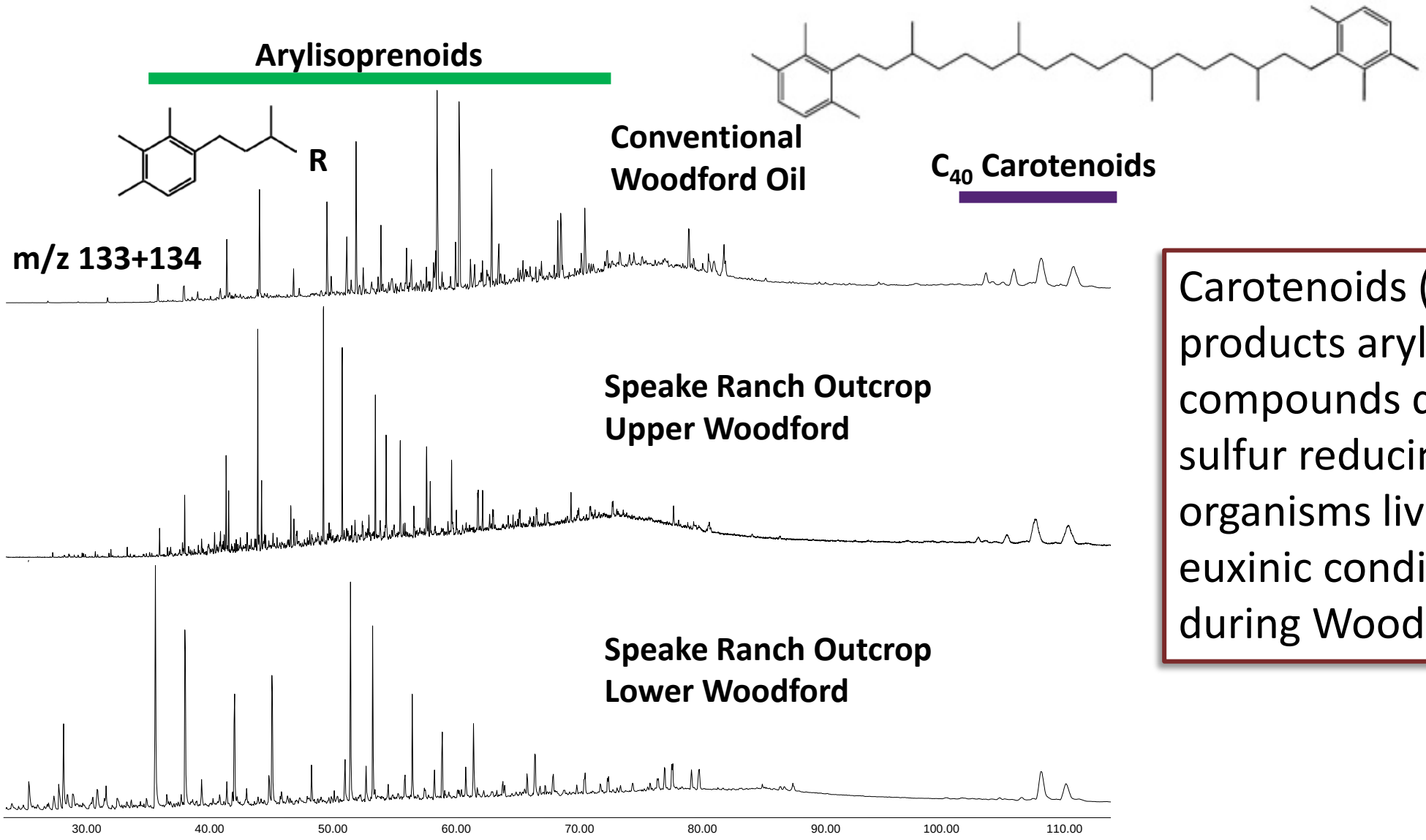
Aromaticity



Pristane/Phytane

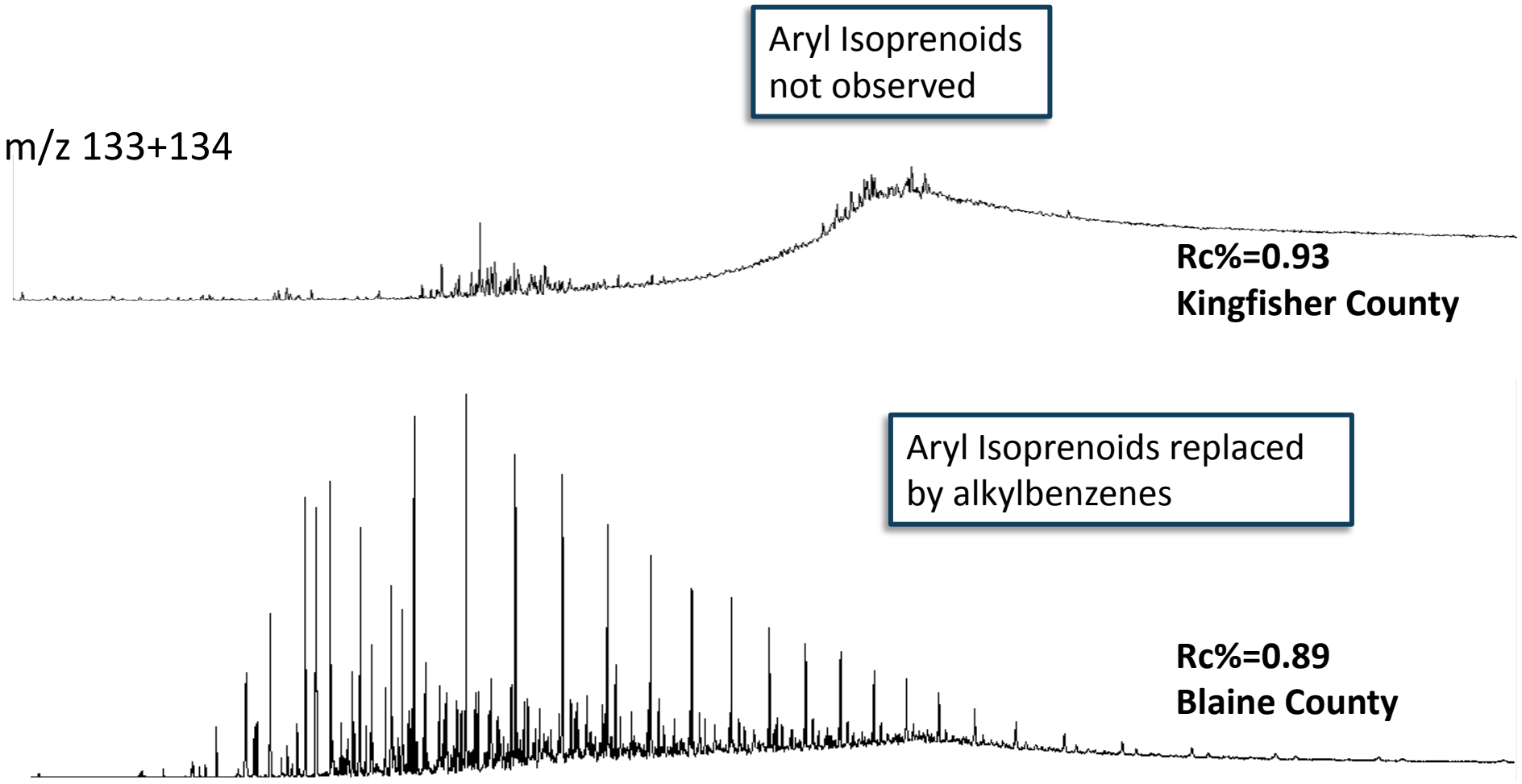


Arylisoprenoids and Carotenoids in Extracts and Oils

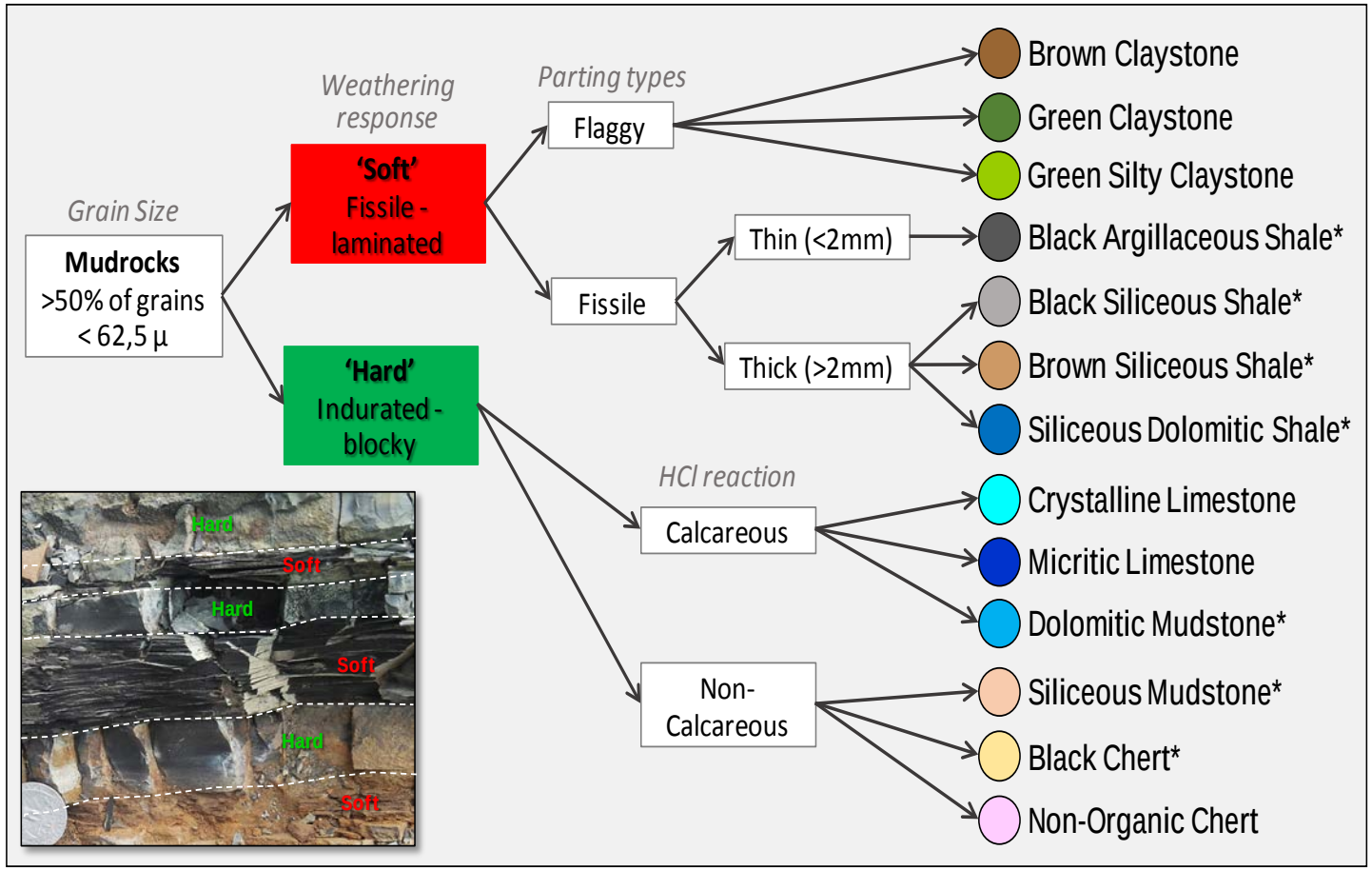


Carotenoids (and degradation products aryl isoprenoids) are compounds derived from green sulfur reducing bacteria. These organisms live in photic zone euxinic conditions prevalent during Woodford deposition.

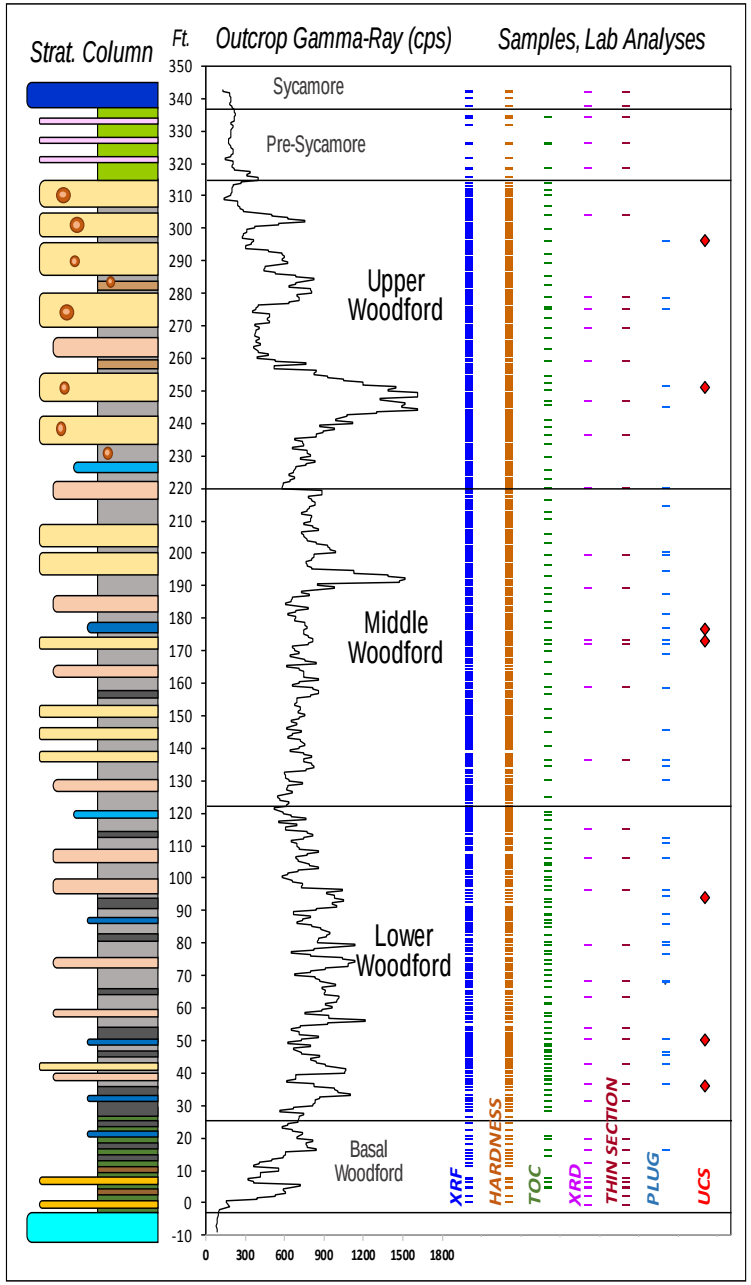
Aryl Isoprenoids from STACK Mississippian Produced Oil



Field-based Lithofacies of Woodford Shale



Galvis (2017) and Becerra(2017)

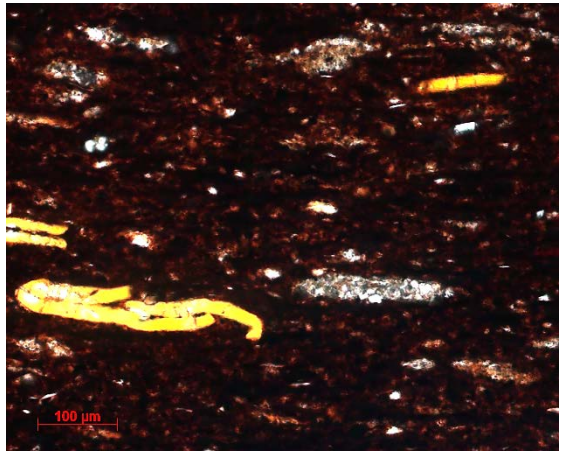


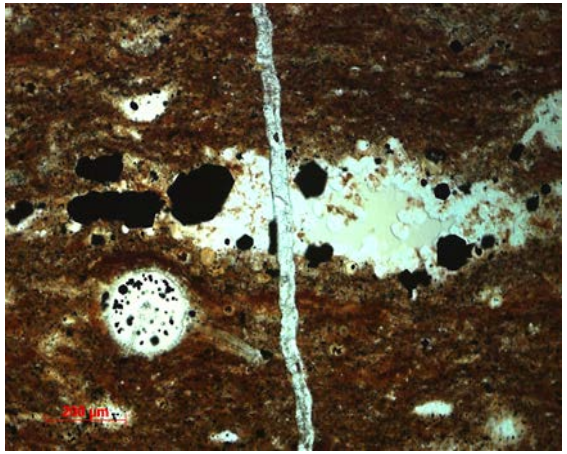
Galvis (2017)

Lithofacies Description of Woodford Shale

Siliceous shale lithofacies

Matrix mostly microcrystalline authigenic quartz and clays; embedded coarser particles include silt-sized detrital quartz in laminae and flattened *Tasmanites*.



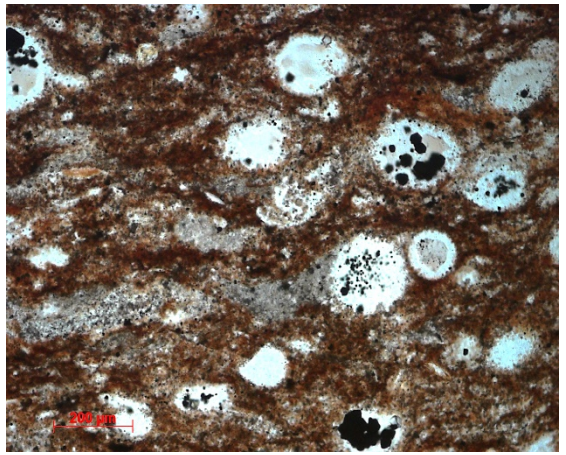


Siliceous mudstone lithofacies

Aggregates of micro-crystalline quartz (no visible discrete grains contacts). Abundant well-preserved radiolarian and *Tasmanites* filled with chalcedony and pyrite.

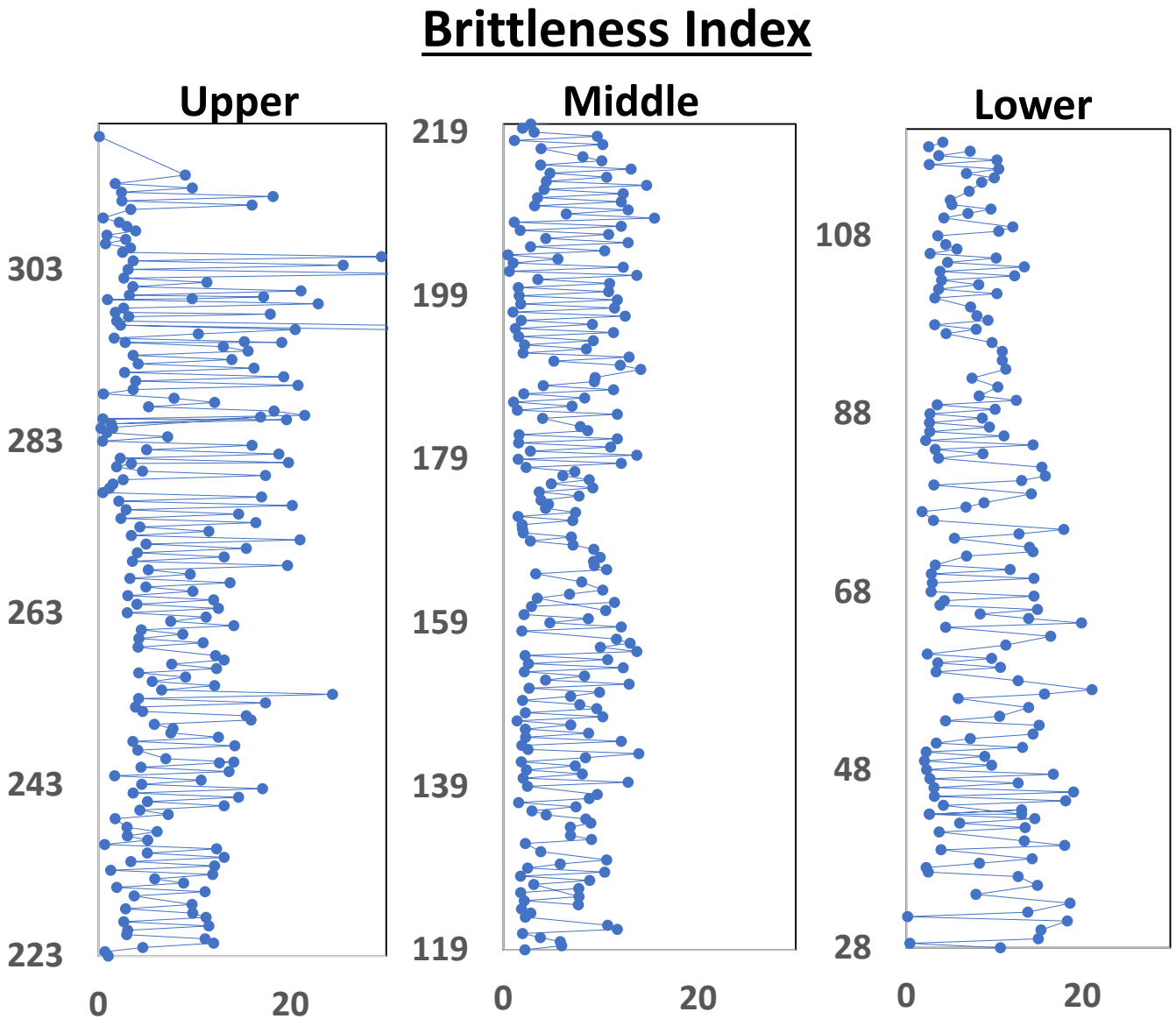
Chert lithofacies description

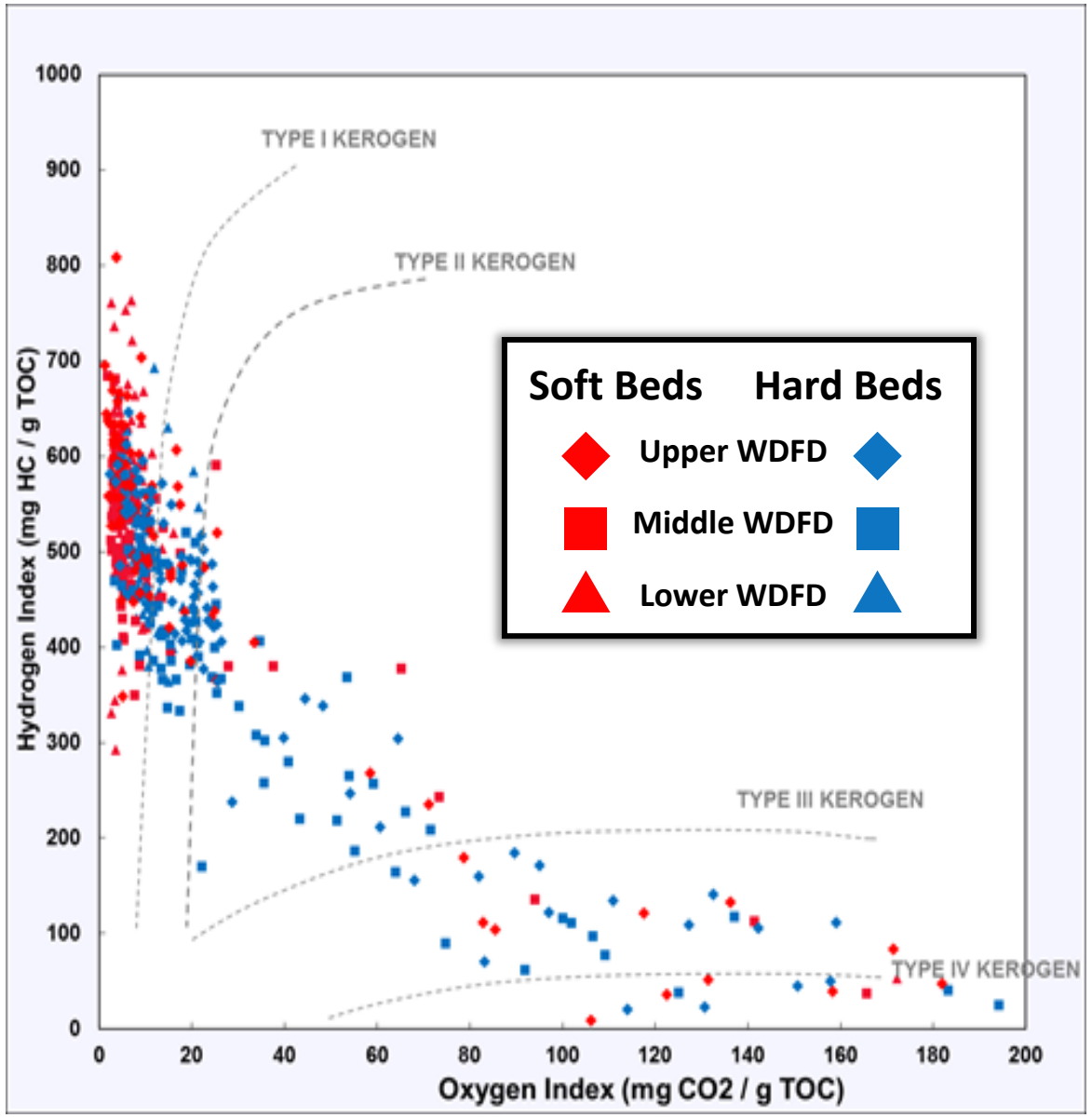
Dominated by micro-crystalline quartz aggregates. Well-preserved radiolarian tests and *Tasmanites* are replaced by chalcedony quartz.



from Galvis (2017)

Woodford Lithology and Source Rock Analysis—Speake Ranch

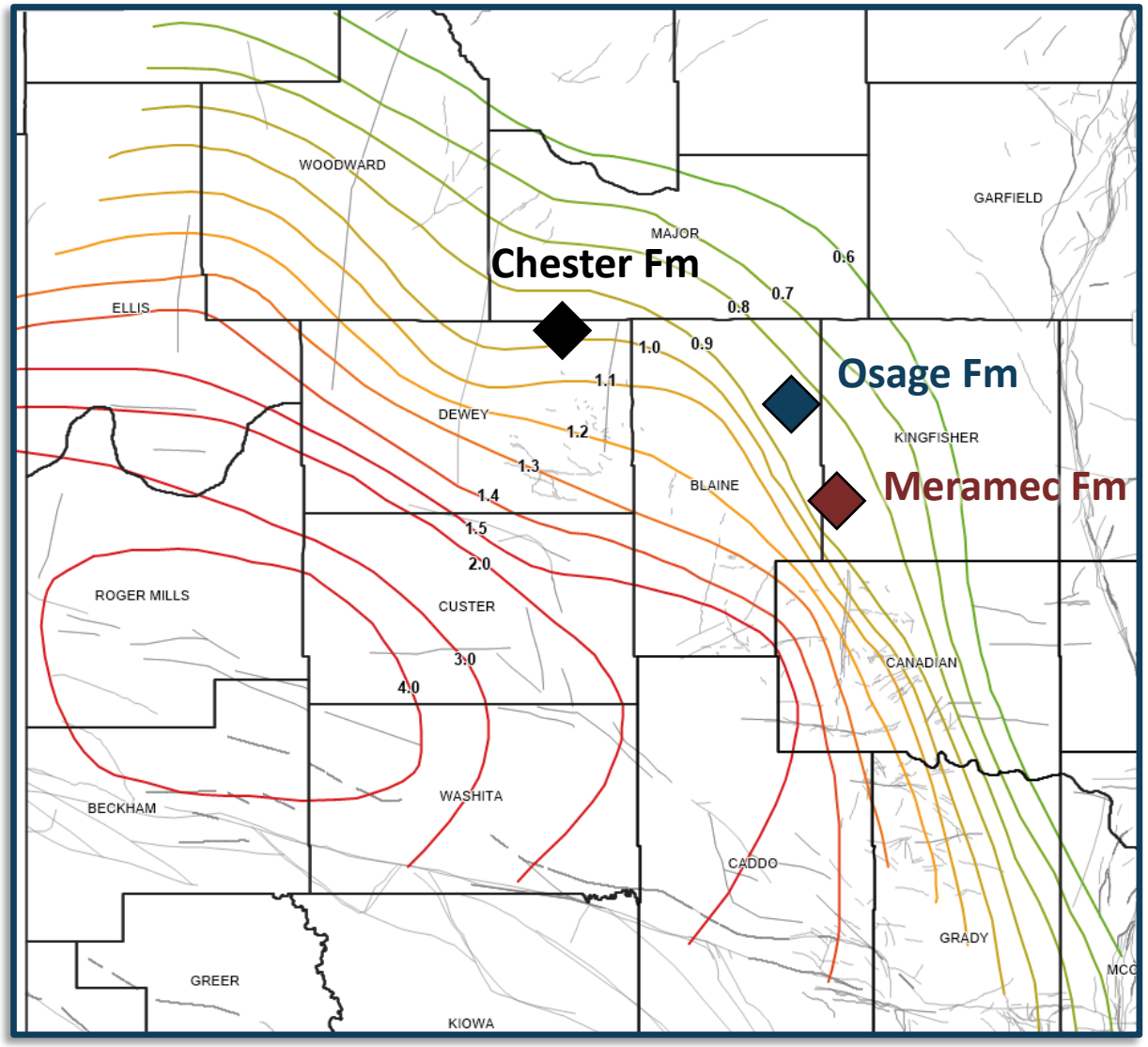




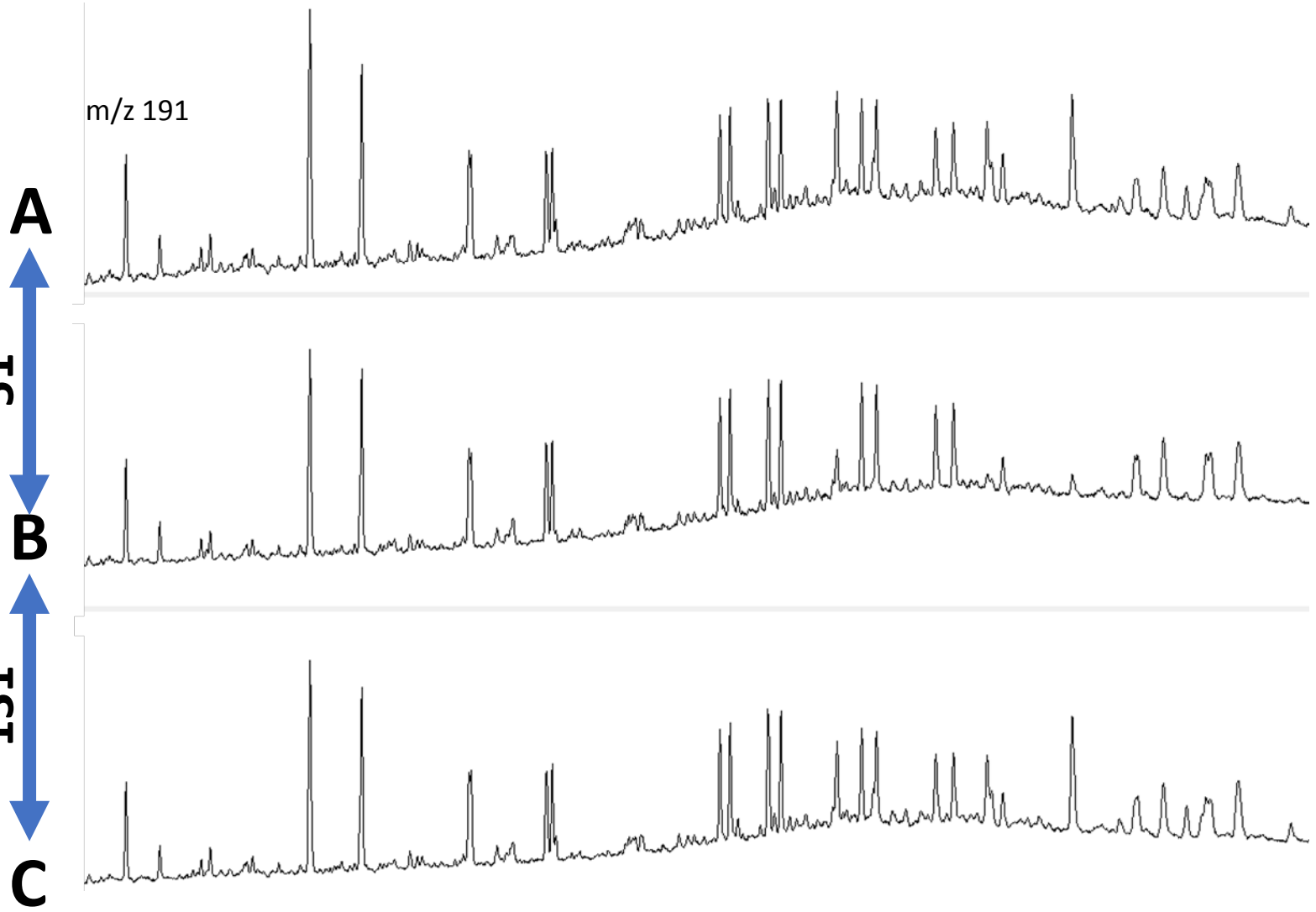
Case Studies—Core Extracts

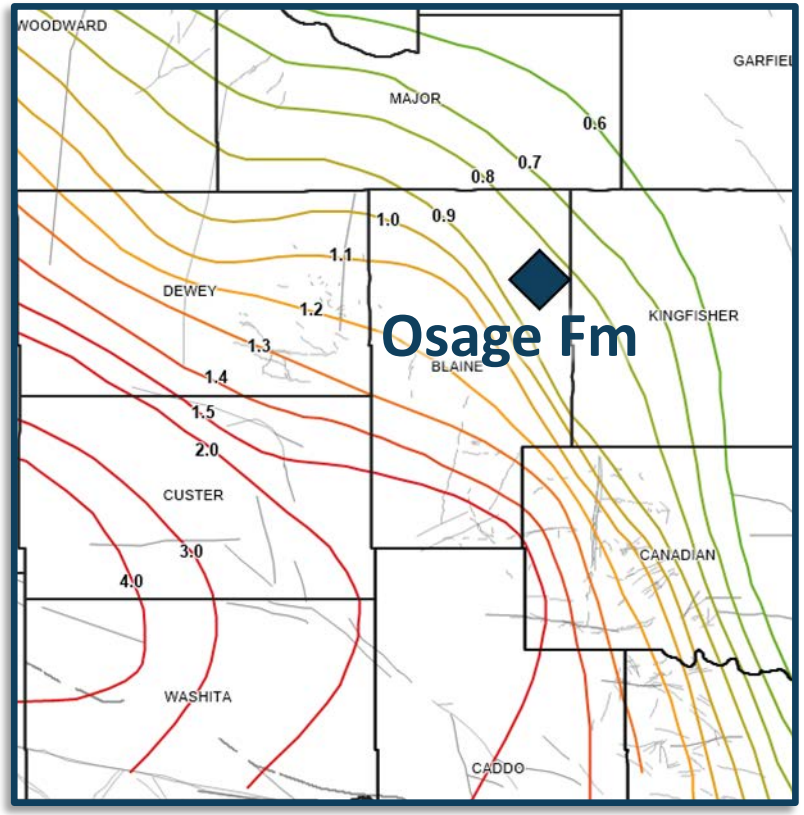
Three cores were analyzed over major Mississippian intervals

Organic matter was extracted from numerous core depths

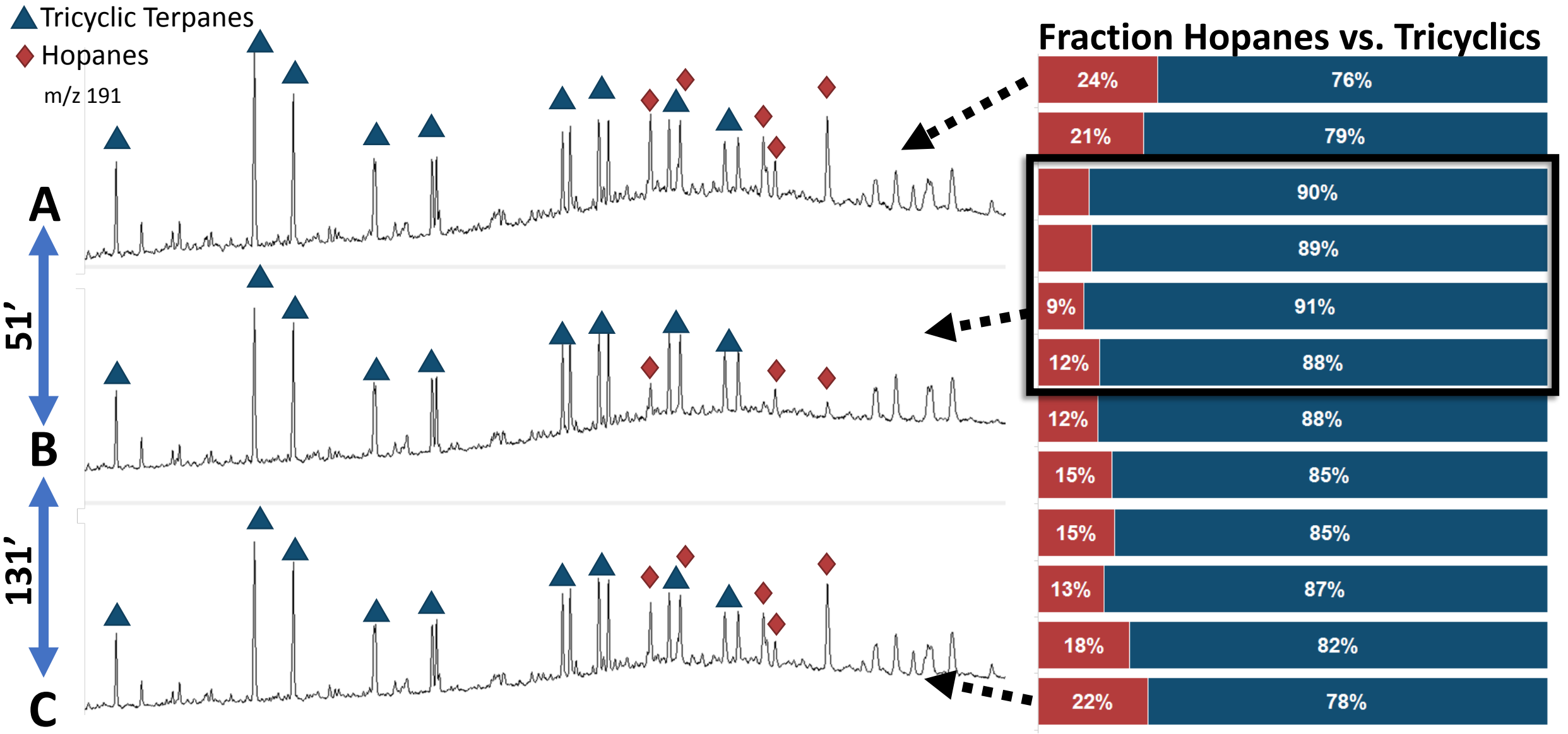


Osage Core in Blaine County *~8,700’-8,900’*

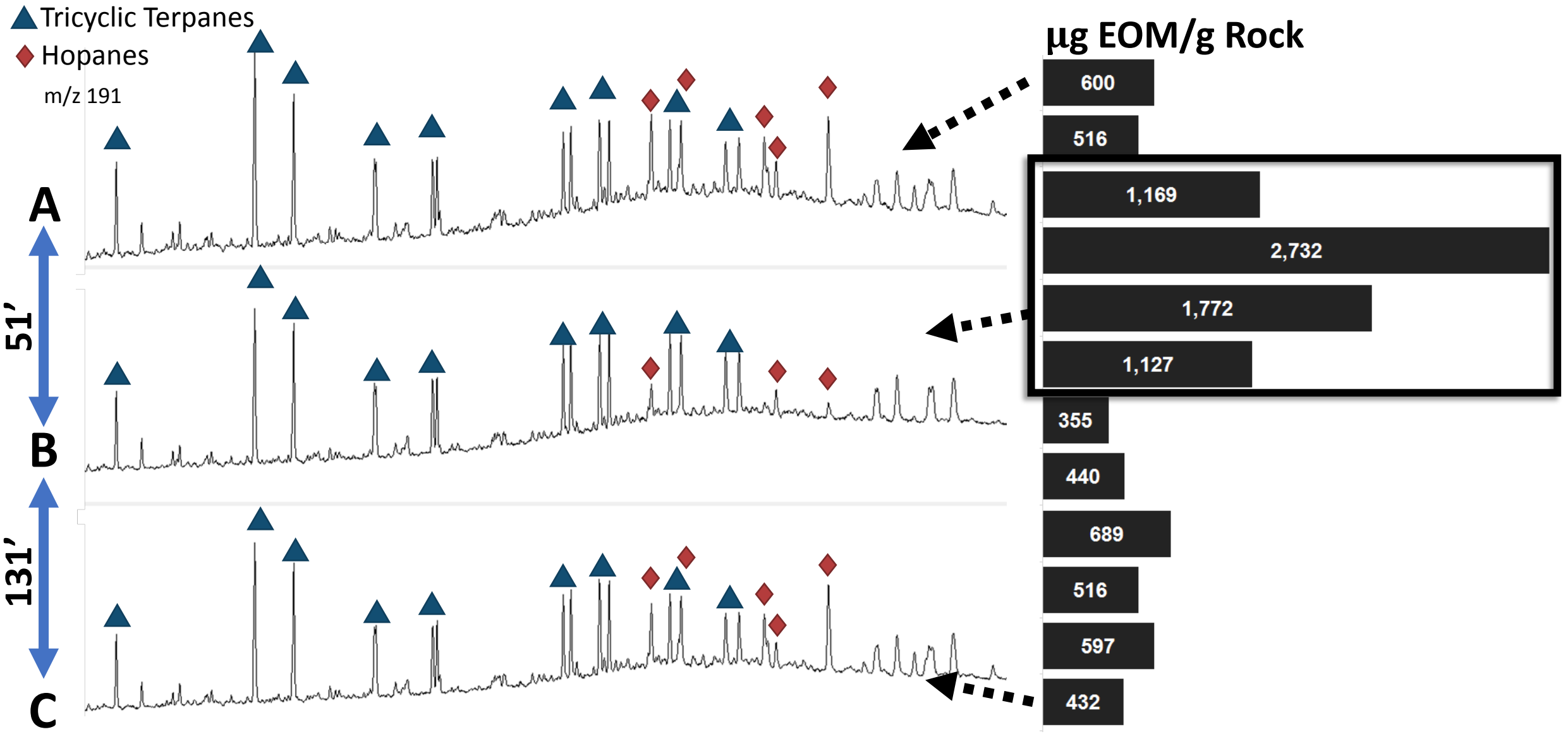




Osage Core in Blaine County *~8,700'-8,900'*



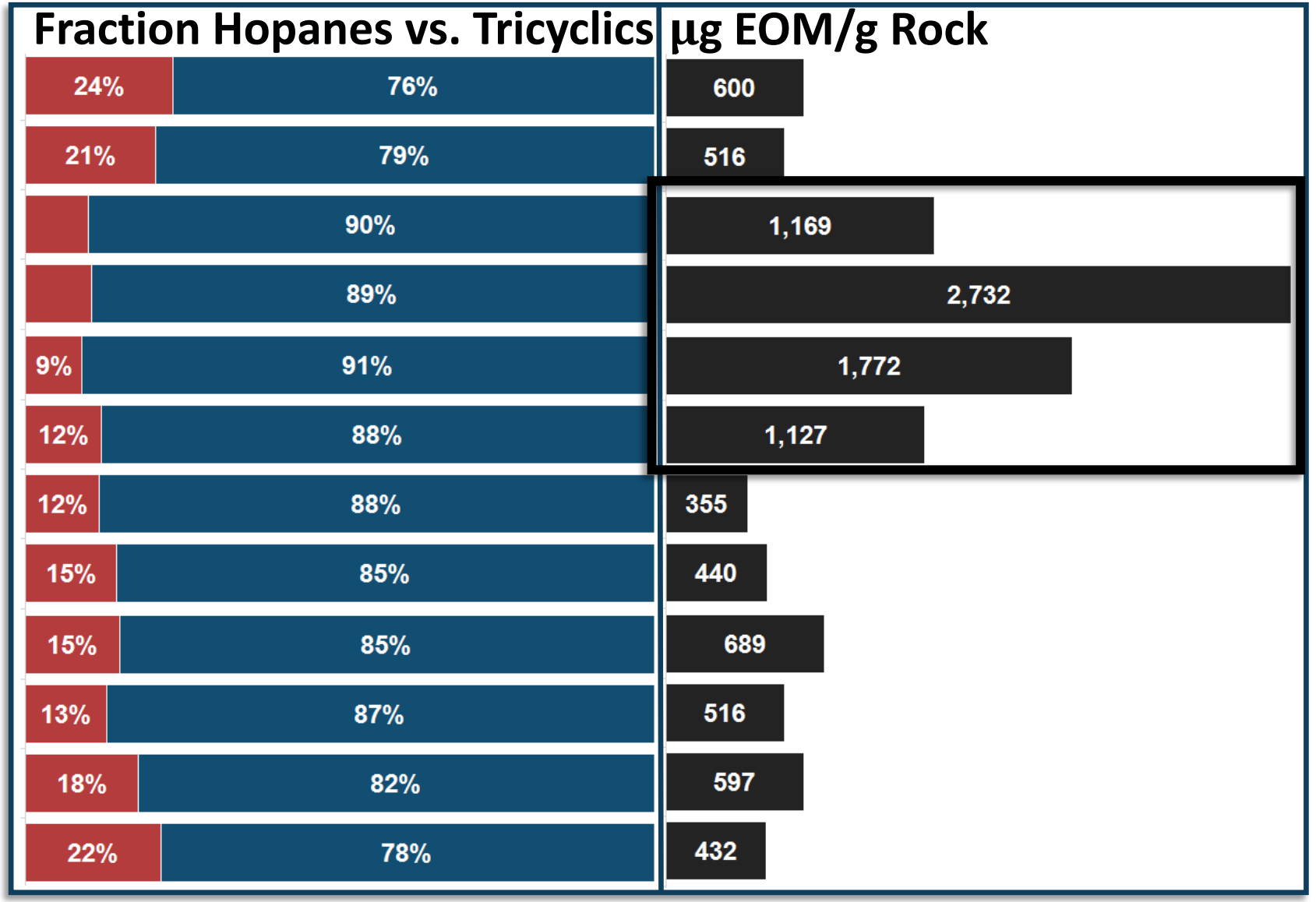
Osage Core in Blaine County *~8,700'-8,900'*



Osage Core in Blaine County *~8,700'-8,900'*

EOM/g Rock correlates well with changes in organic facies

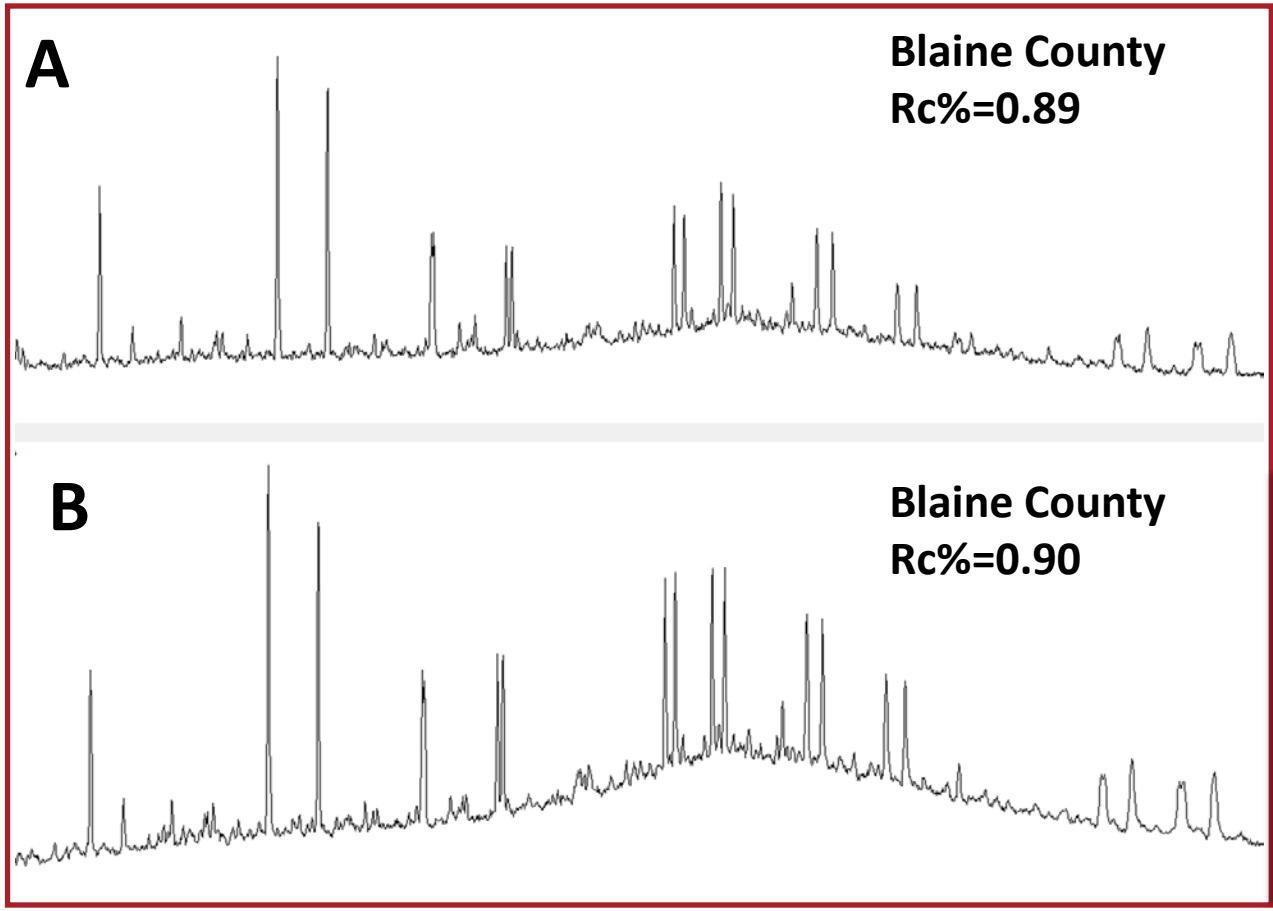
If hydrocarbons are Mississippian sourced, high EOM/g Rock facies are most likely source facies



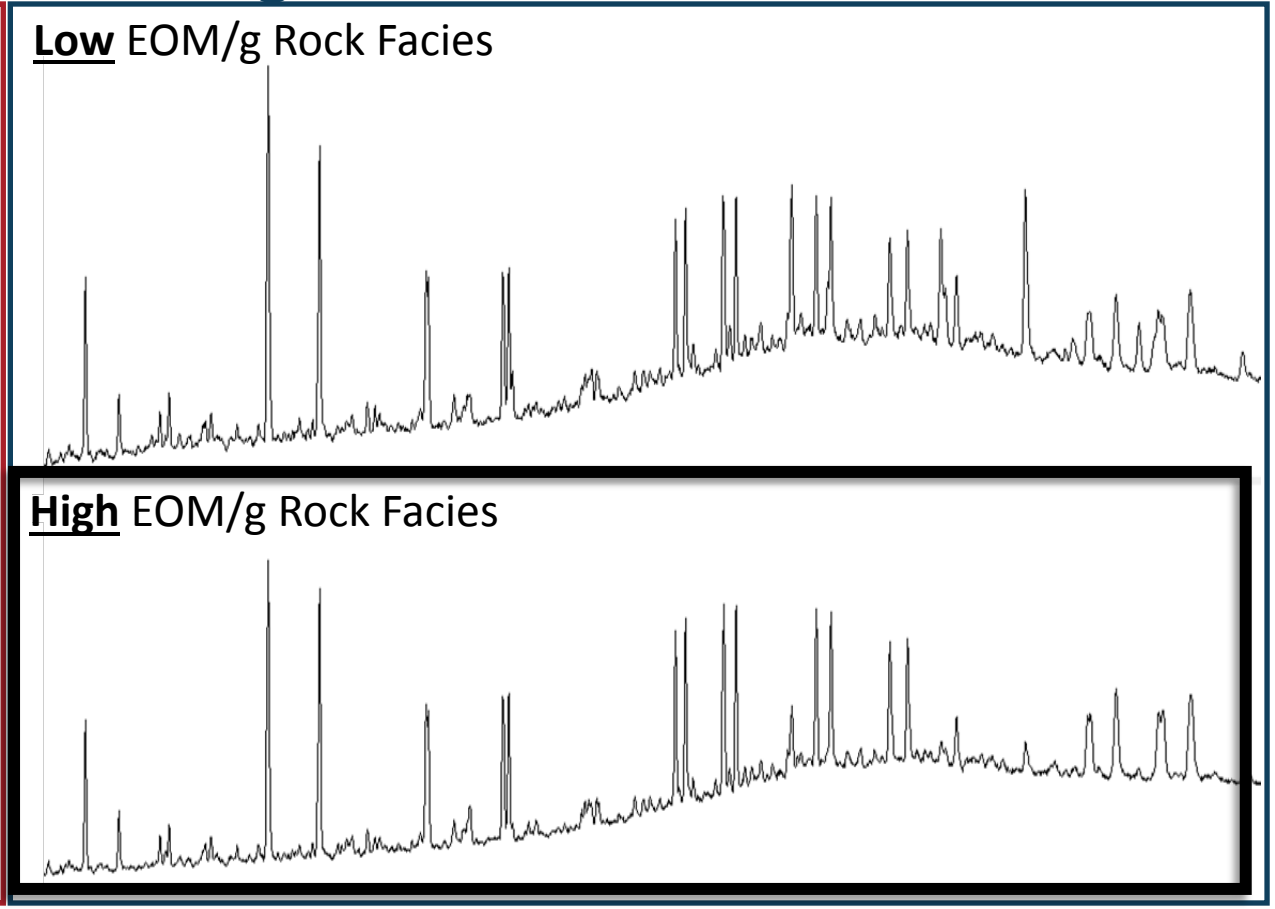
Nearby Oils to Osage Core in Blaine County *~8,700'-8,900'*

! High EOM/TOC facies more closely resemble STACK Oils

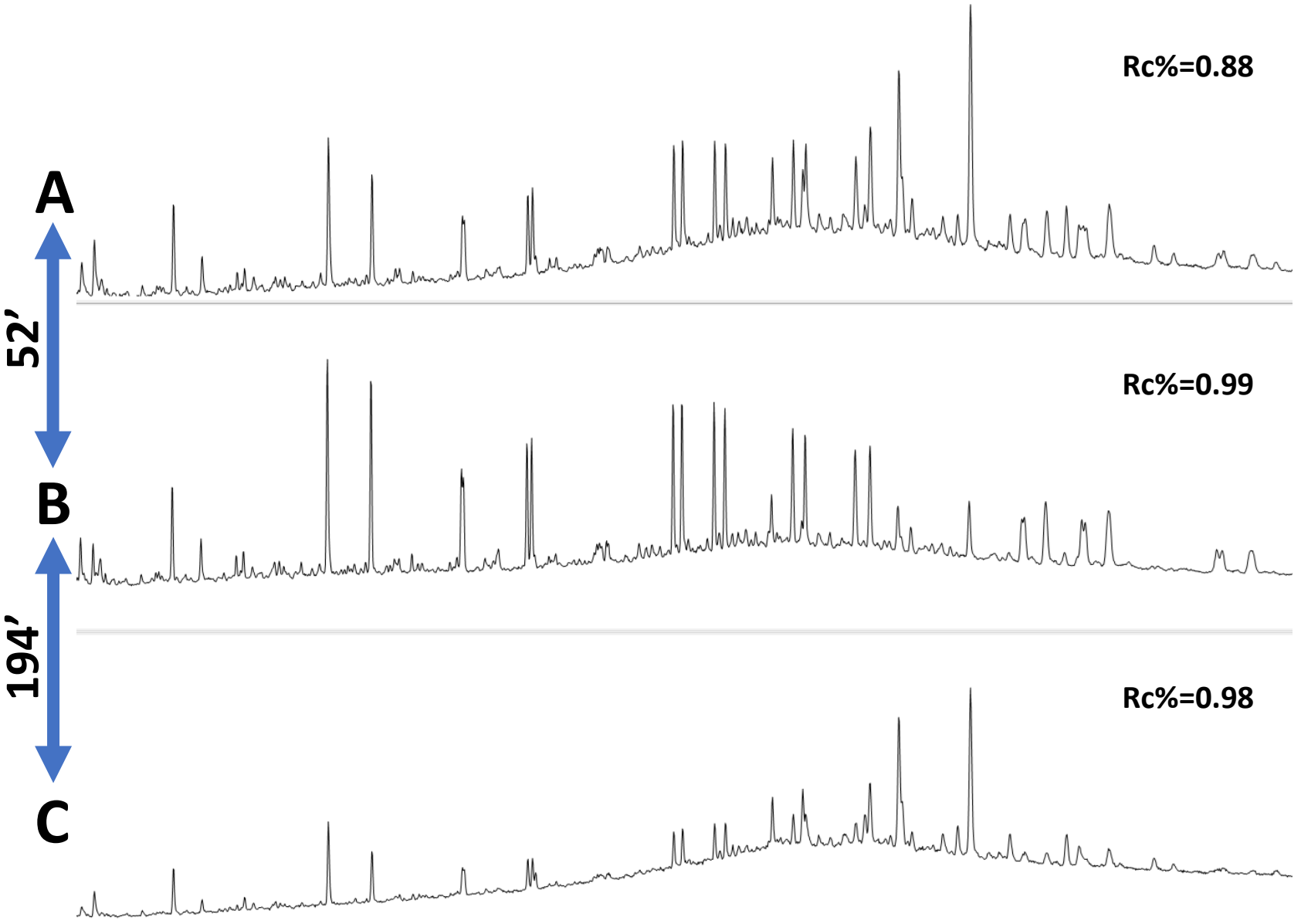
Nearest Oils

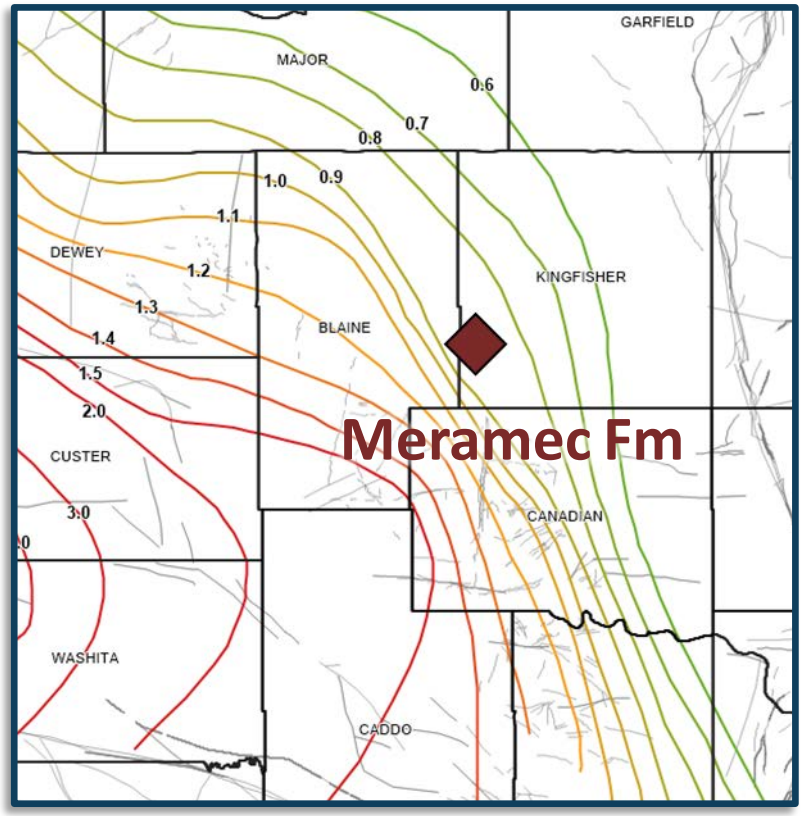


Core Organic Facies

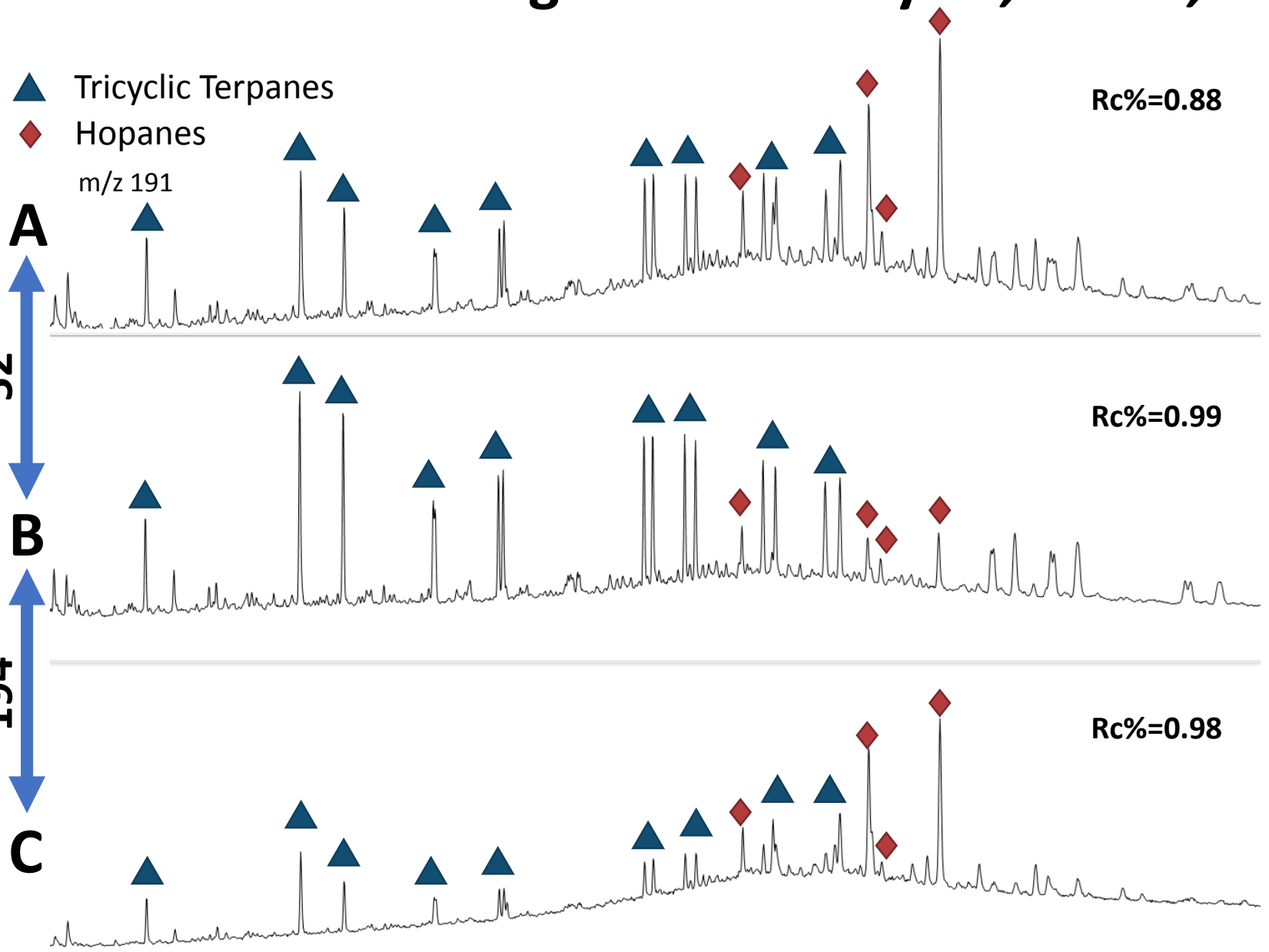


Meramec Core in Kingfisher County *~9,600’-9,850’*

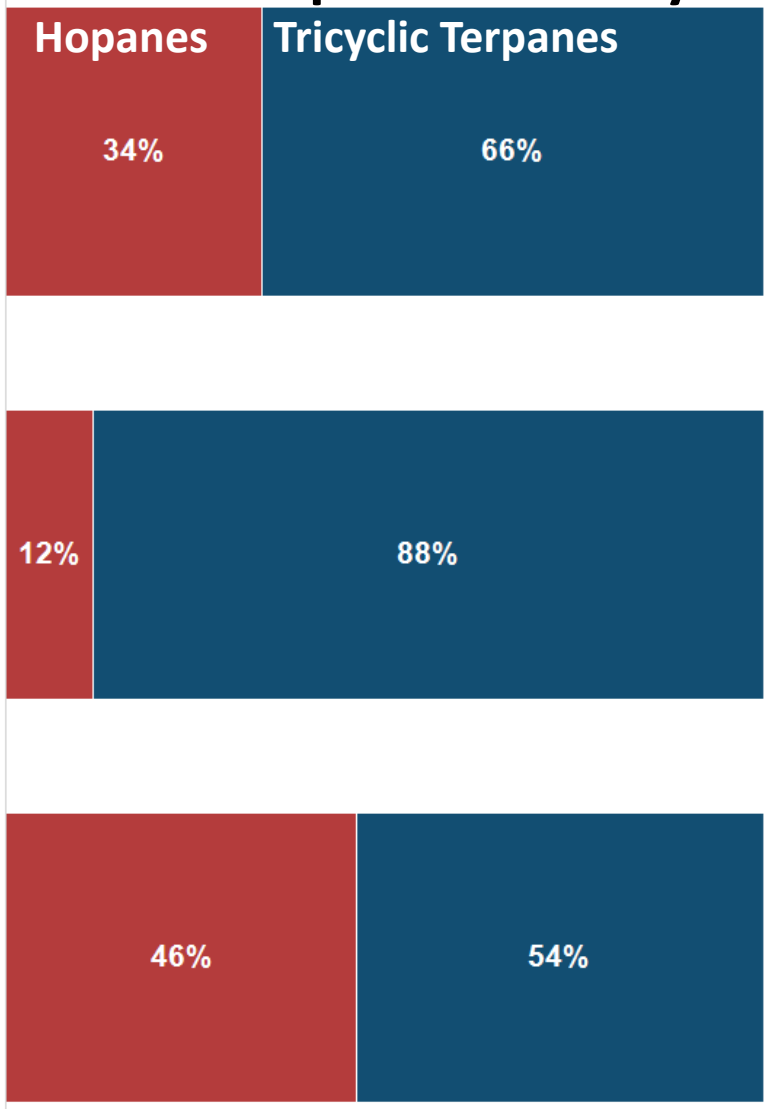




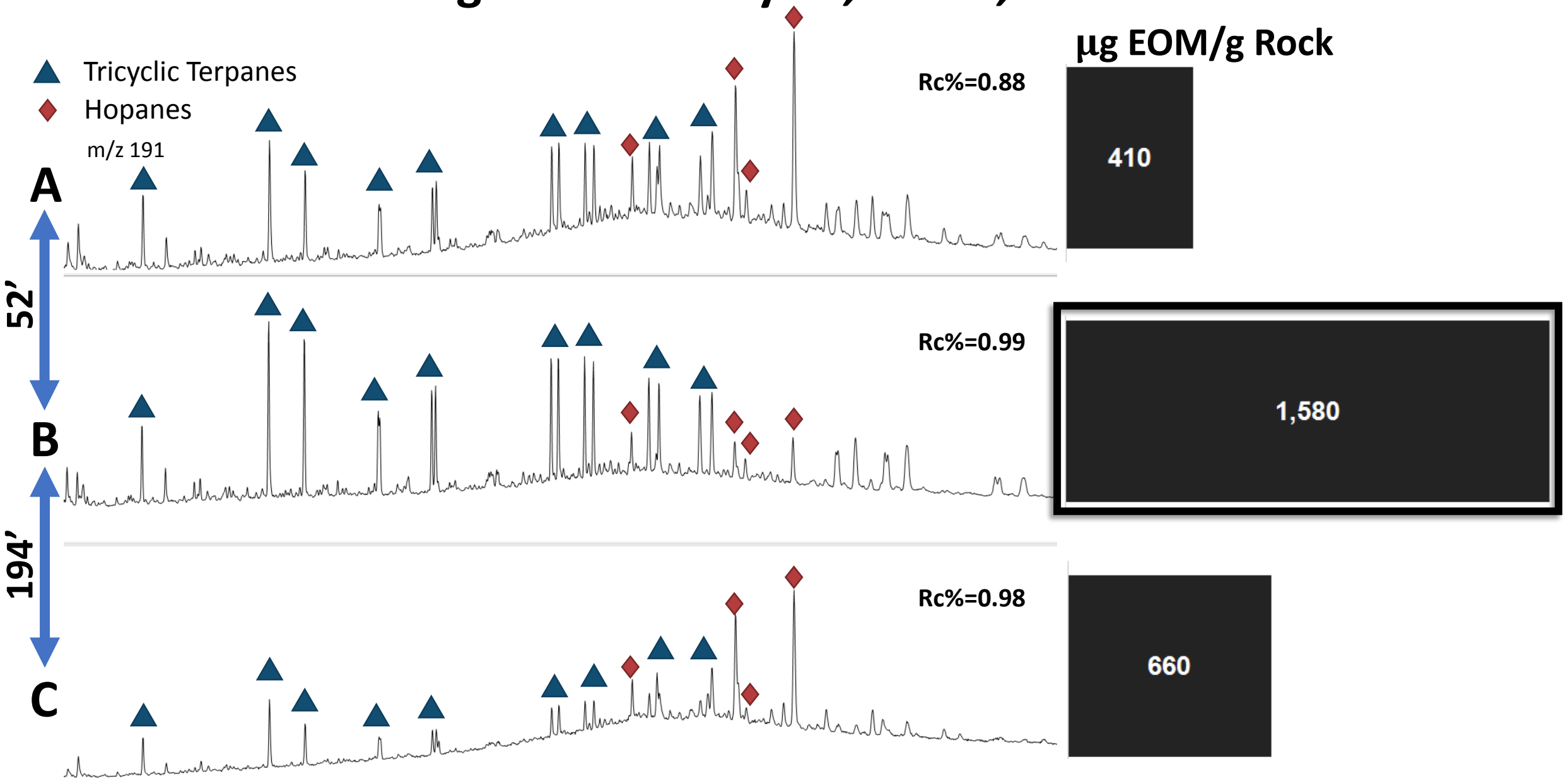
Meramec Core in Kingfisher County *~9,600'-9,850'*



Fraction Hopanes vs. Tricyclics



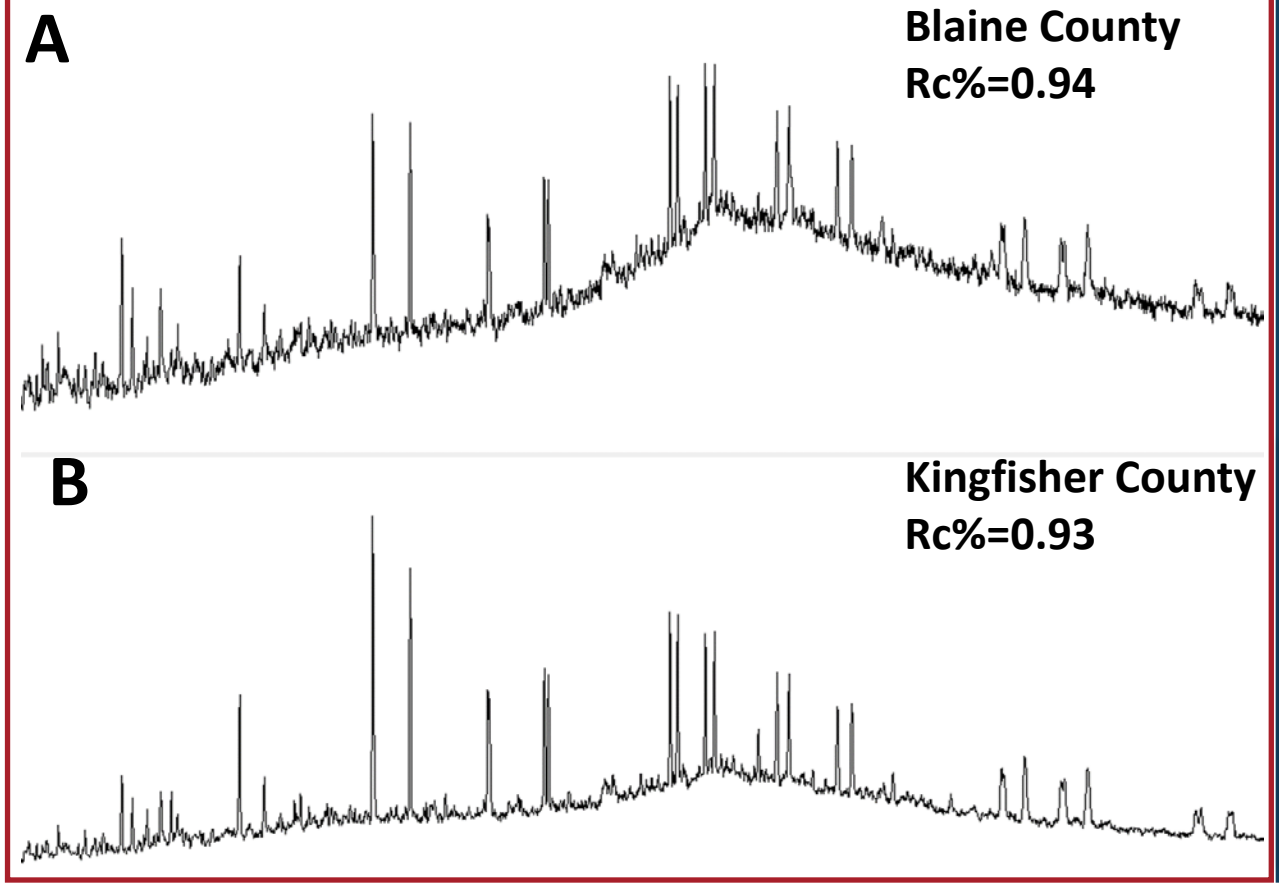
Meramec Core in Kingfisher County *~9,600'-9,850'*



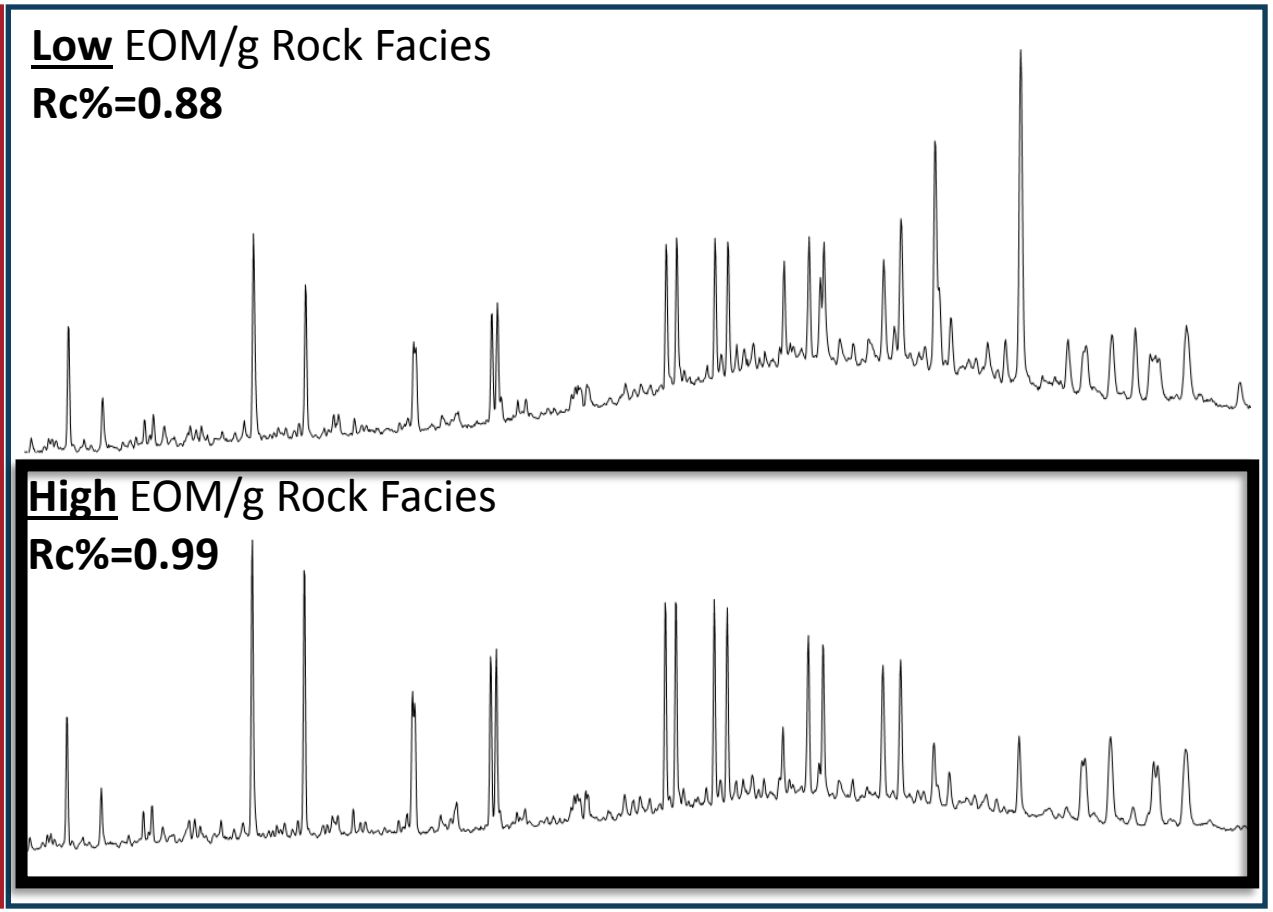
Nearby Oils to Meramec Core in Kingfisher County *~9,600'-9,650'*

! High EOM/TOC facies more closely resemble STACK Oils

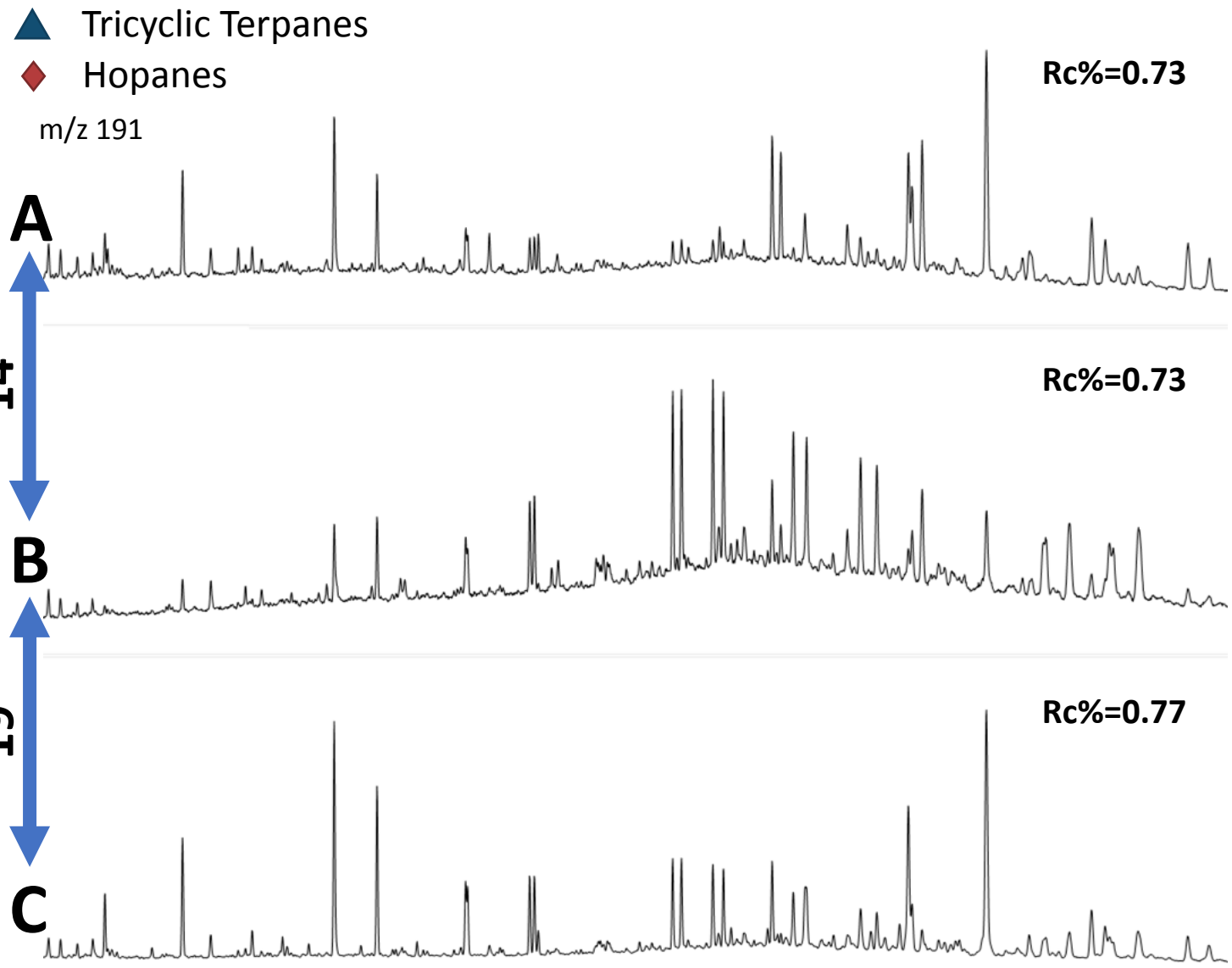
Two Nearest Oils

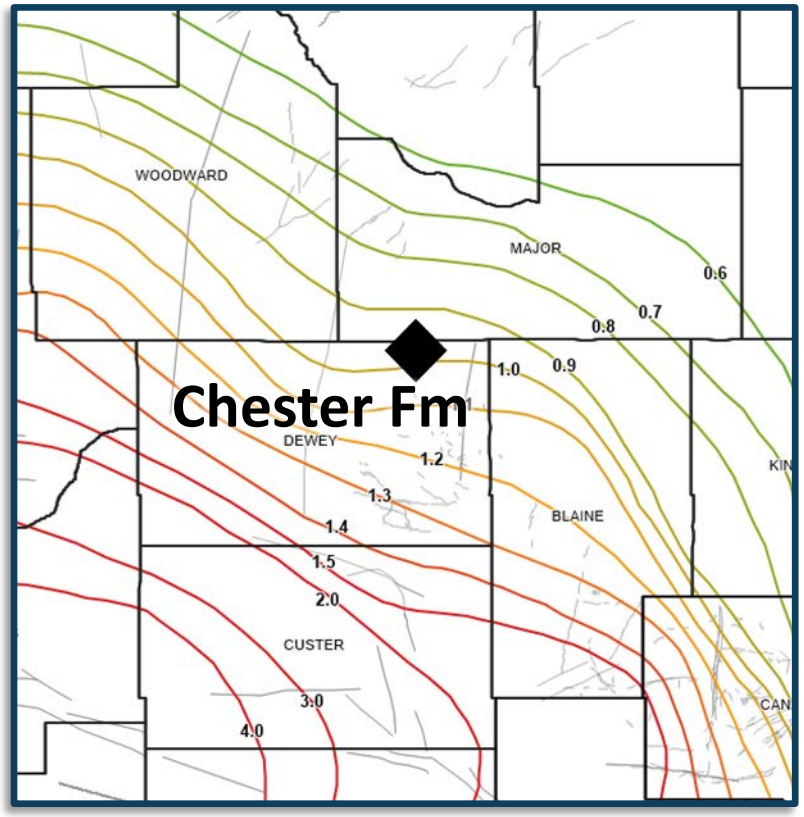


Two Core Facies

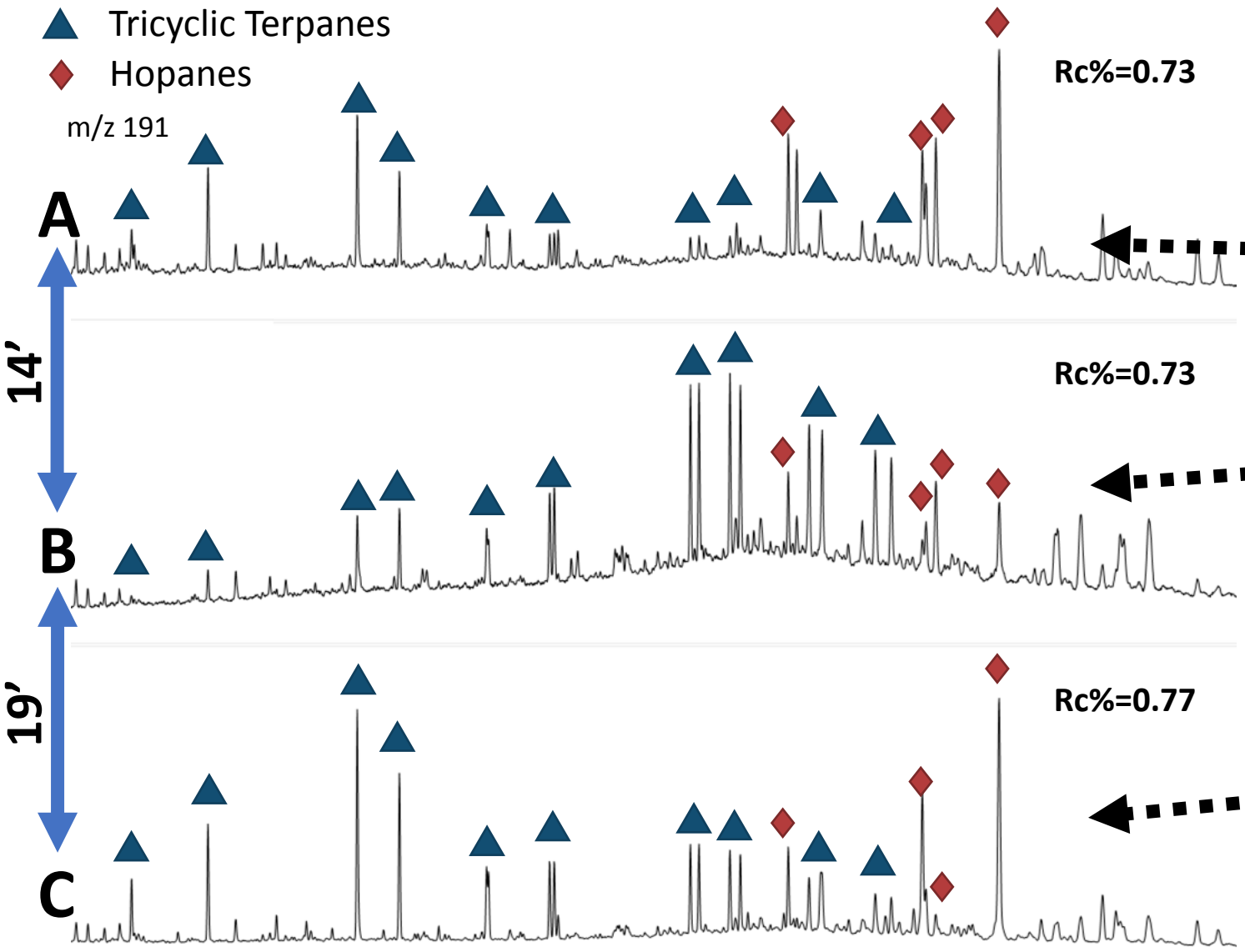


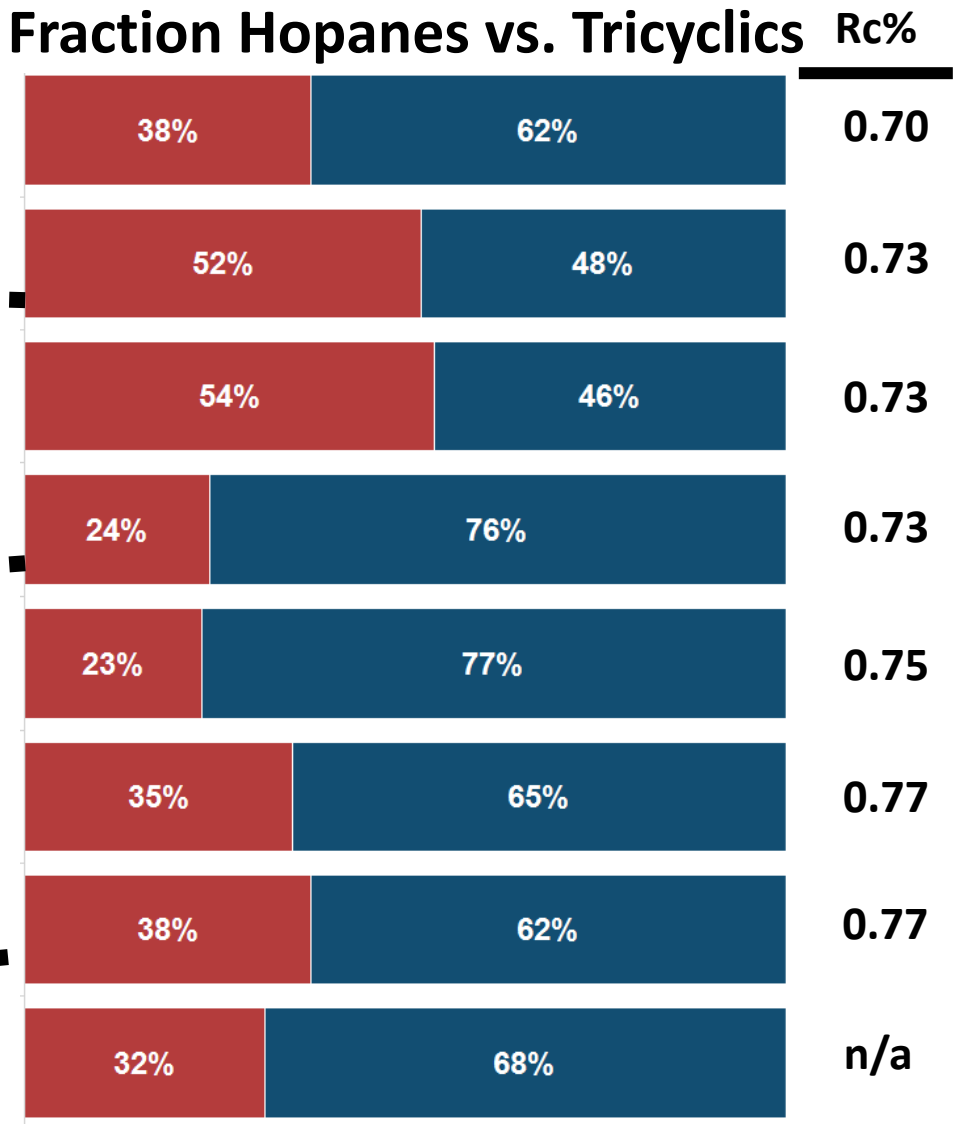
Chester Core in Dewey/Blaine/Major Tricounty *~8,300'-8,400'*





Chester Core in Dewey/Blaine/Major Tricounty *~8,300'-8,400'*

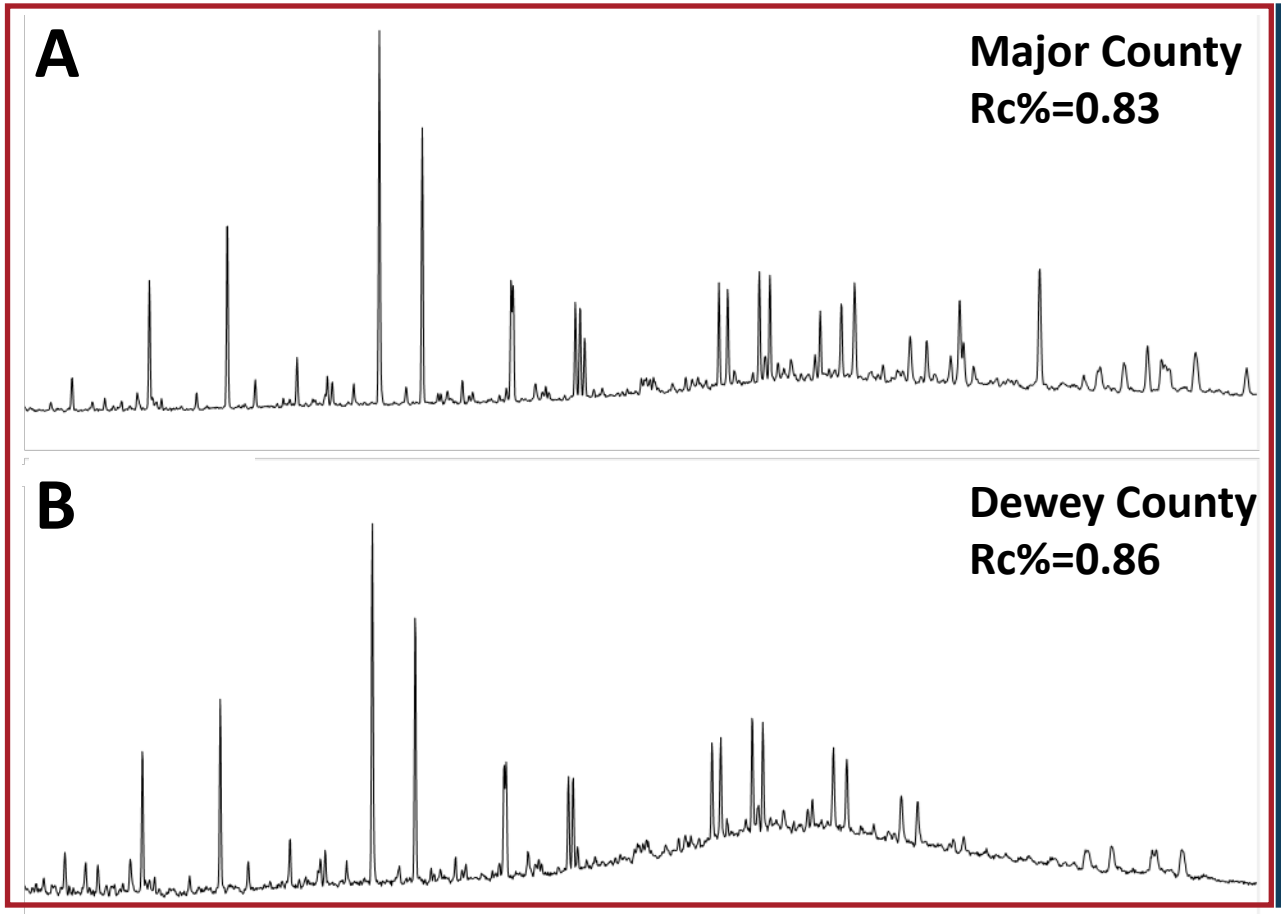




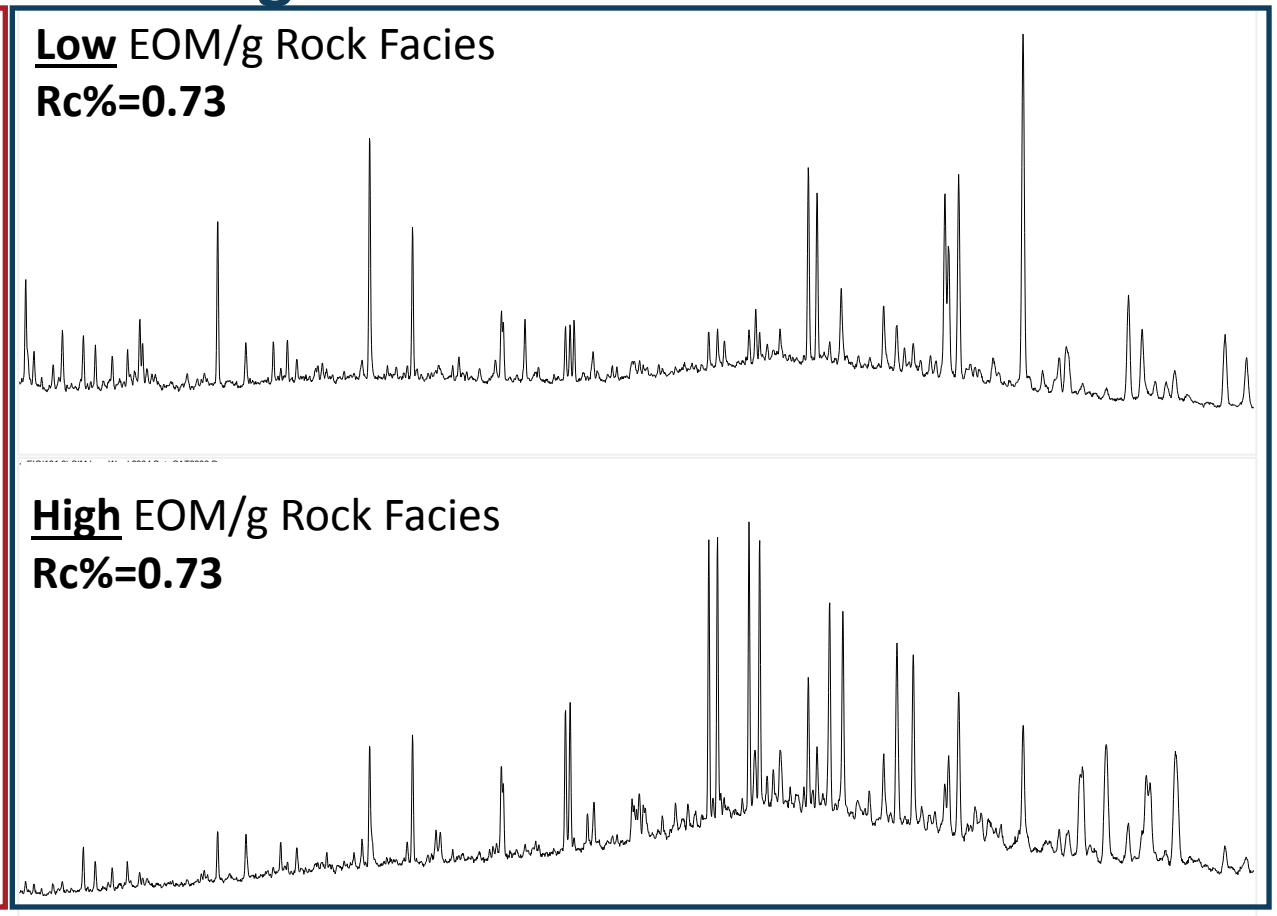
Nearby Oils to Dewey County Chester Core *~8,300'-8,400'*

Trend less obvious in Chester Core

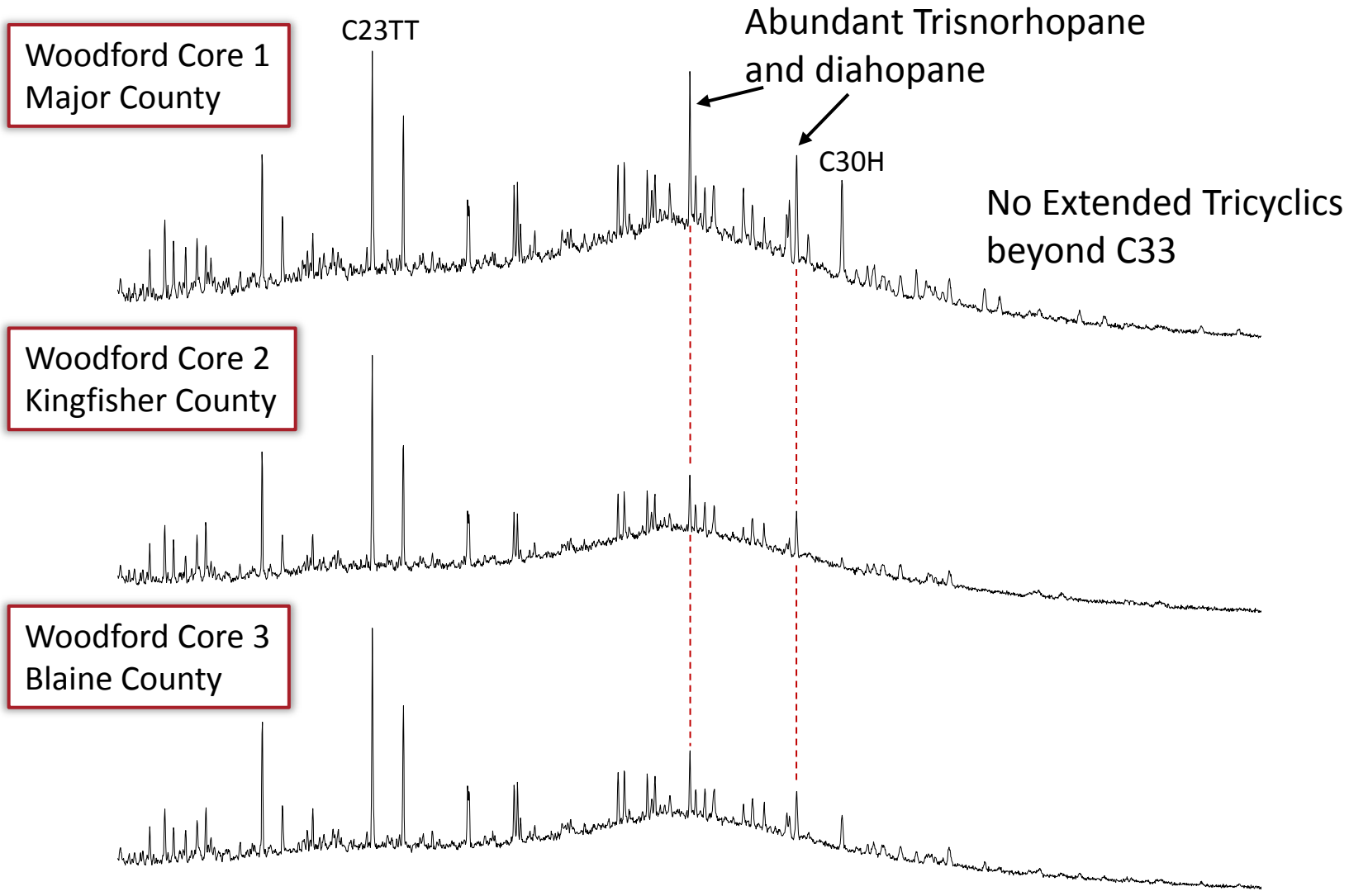
Nearest Oils



Core Organic Facies



Ongoing Woodford Core Extract Analysis



Although diminished hopanes are observed, these Woodford extracts also do not directly resemble STACK oils.

Conclusion

- Changes in organic facies observed across STACK do not correlate with “Conventional Woodford.”
- Unlikely maturity alone results in the changes in terpanes and aryl isoprenoids observed between Woodford extracts and STACK oils
- High EOM rock intervals in the Mississippian STACK most closely resemble STACK Oils
- New Woodford core from STACK oil window do not resemble “Conventional Woodford,” but also do not resemble STACK oils. A Mississippian- or multi-source model can not be ruled out