

# Organic Geochemical Evidence of Redox Conditions in the Eagle Ford Formation, Southwest Texas\*

Xun Sun<sup>1</sup>, Yongge Sun<sup>2</sup>, Tongwei Zhang<sup>1</sup>, and Kitty Milliken<sup>1</sup>

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## Abstract

The marine mudrocks of the Eagle Ford Formation in Southwest Texas record variations in organic matter content spanning stratigraphic intervals above and below the Cenomanian to Turonian (C-T) boundary (ca. 95-93 Ma) and the globally distributed interval known as the OAE2. Bulk geochemistry, organic matter biomarkers, and carbon isotope studies of low-mature core reveal that the extractable organic matter is dominantly marine Type II kerogen in both the Lower Eagle Ford (LEF) and Upper Eagle Ford (UEF), although a minor contribution of terrestrial OM occurs in the UEF. Average TOC values for the LEF and UEF are 7.8% wt and 3.1% wt, respectively. The LEF represents Late Cenomanian deposition. The UEF includes the C-T boundary. Redox sensitive biomarkers demonstrate anoxic-euxinic conditions existed in the LEF and persistent oxygenation of the UEF across the C-T transition during OAE2.

To assess temporal variations in water-column oxygenation, arylisoprenoids, which indicate photic-zone euxinia, were analyzed in the aromatic fractions of extracted oil. The arylisoprenoids are thought to derive from carotenoids, which are specific to obligatory anaerobic photosynthetic green sulfur bacteria. Vertical profiles of total arylisoprenoids show concentrations are higher in the TOC-rich LEF, and lower within the less organic-rich UEF and its contained OAE interval. The vertical profile of dibenzothiophene (DBT) in the core samples roughly resembles that of arylisoprenoids, and probably also reflects the presence of H2S implying the presence of sulfur-rich anoxic (i.e., euxinic) waters. These findings support the interpretation that the LEF preserves the greatest evidence for conditions of very low oxygenation, whereas the OAE2-associated UEF represents conditions of greater oxygenation.

## **References Cited**

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# Organic Geochemical Evidence of Redox Conditions in Eagle Ford Formation, Southwest Texas

**Organic Geochemistry Study of Eagle Ford Iona Well**

Xun Sun<sup>a</sup>, Yonge Sun<sup>b</sup>, Tongwei Zhang<sup>a</sup>, and Kitty Milliken<sup>a</sup>

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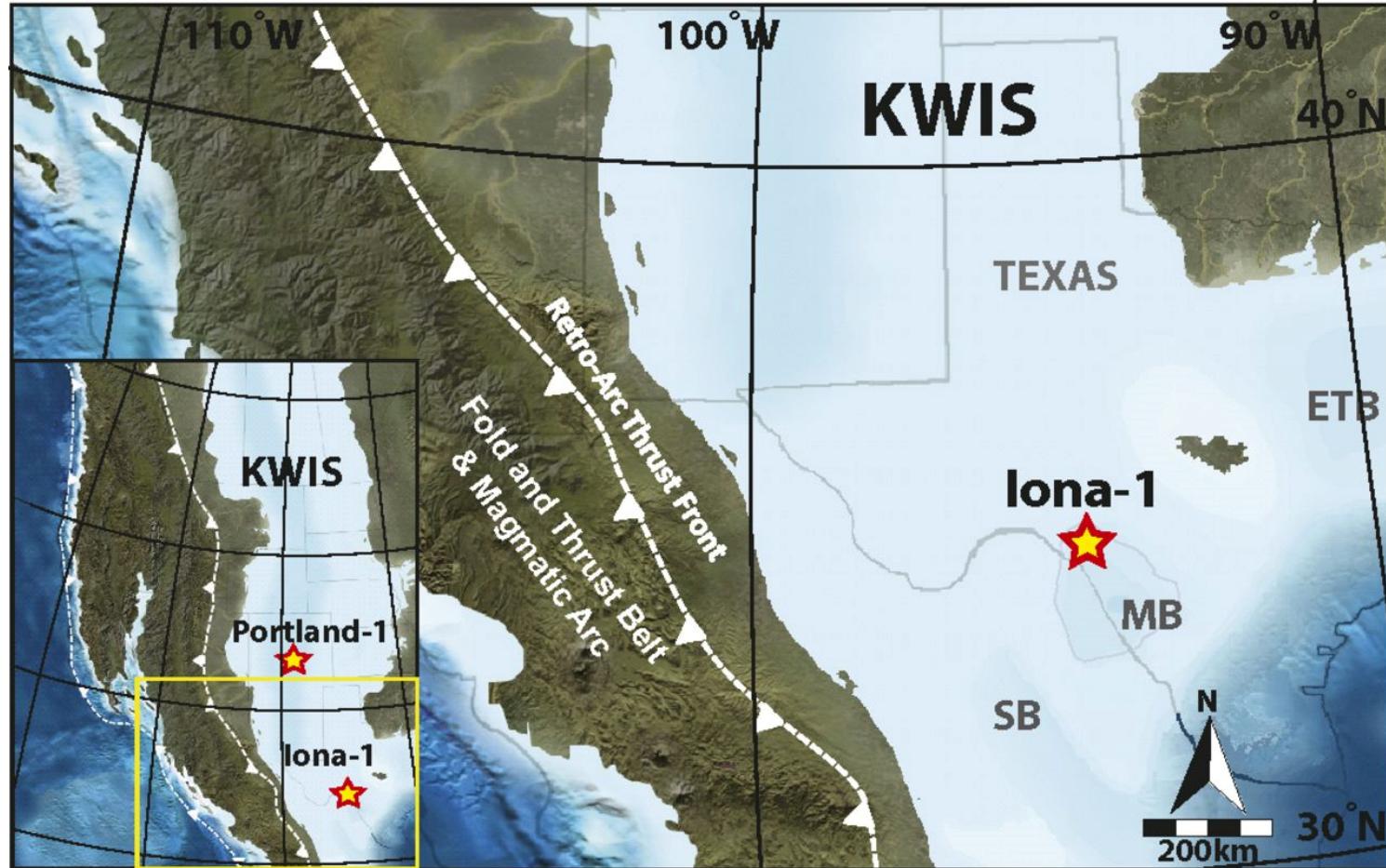
# OUTLINE

- Geology background of Eagle Ford shale in Southwest Texas and the Iona well
- Source appointment of Eagle Ford sedimentary organic matter
- Depositional environment dynamics within Eagle Ford deposits
- Shale oil implications on Eagle Ford shale
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# The Iona core (Eagle Ford Formation Southwest Texas), spanning the early Cenomanian to Coniacian

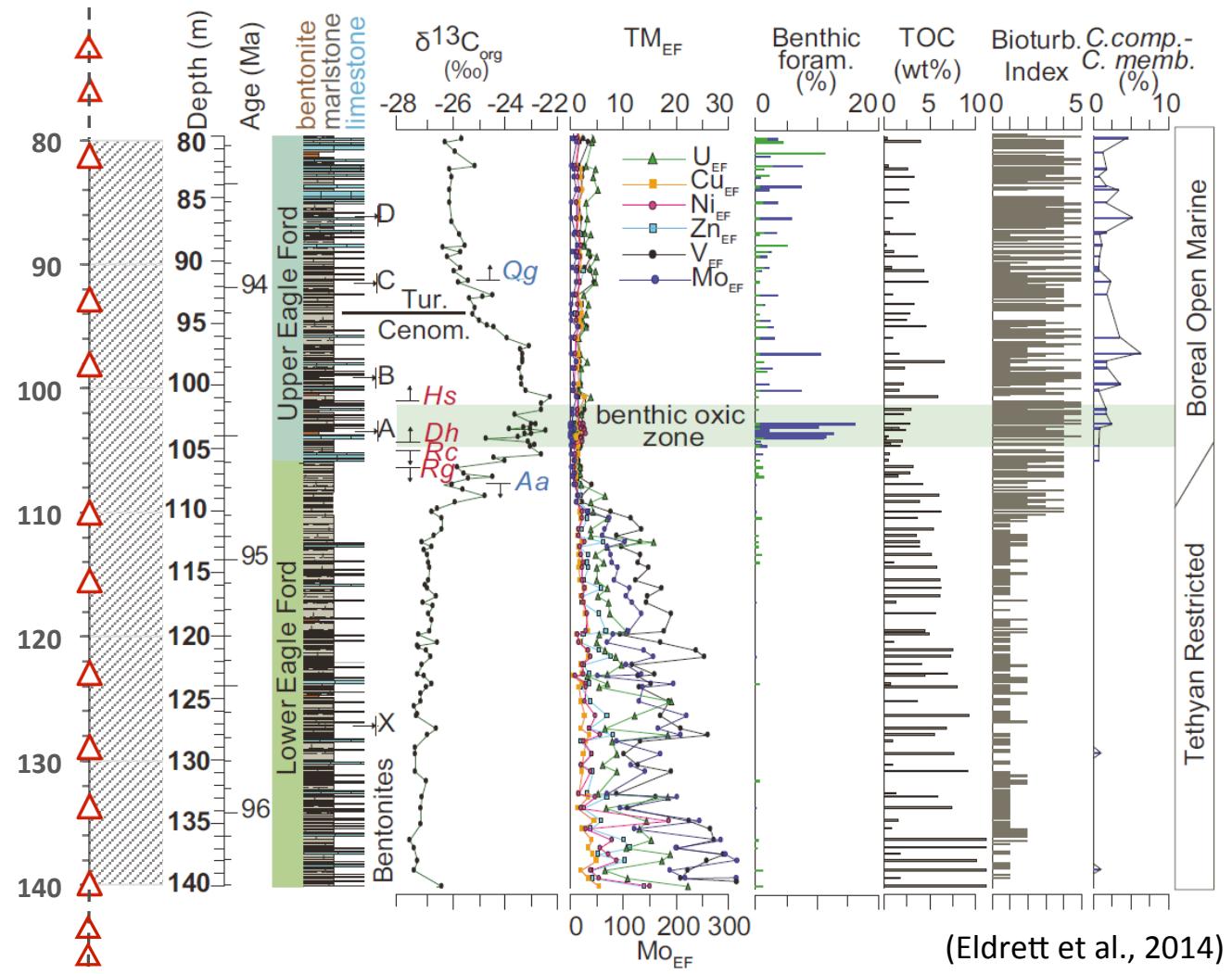


(Eldrett et al., 2014)

- Eagle Ford is an important hydrocarbon shale play.
- Eagle Ford shale is a mixed mineralogical system composed of calcite-dominant mudrocks with variable silica content and ash bed.
- **Factors controlling organic accumulation and preservation are still not well understood.**

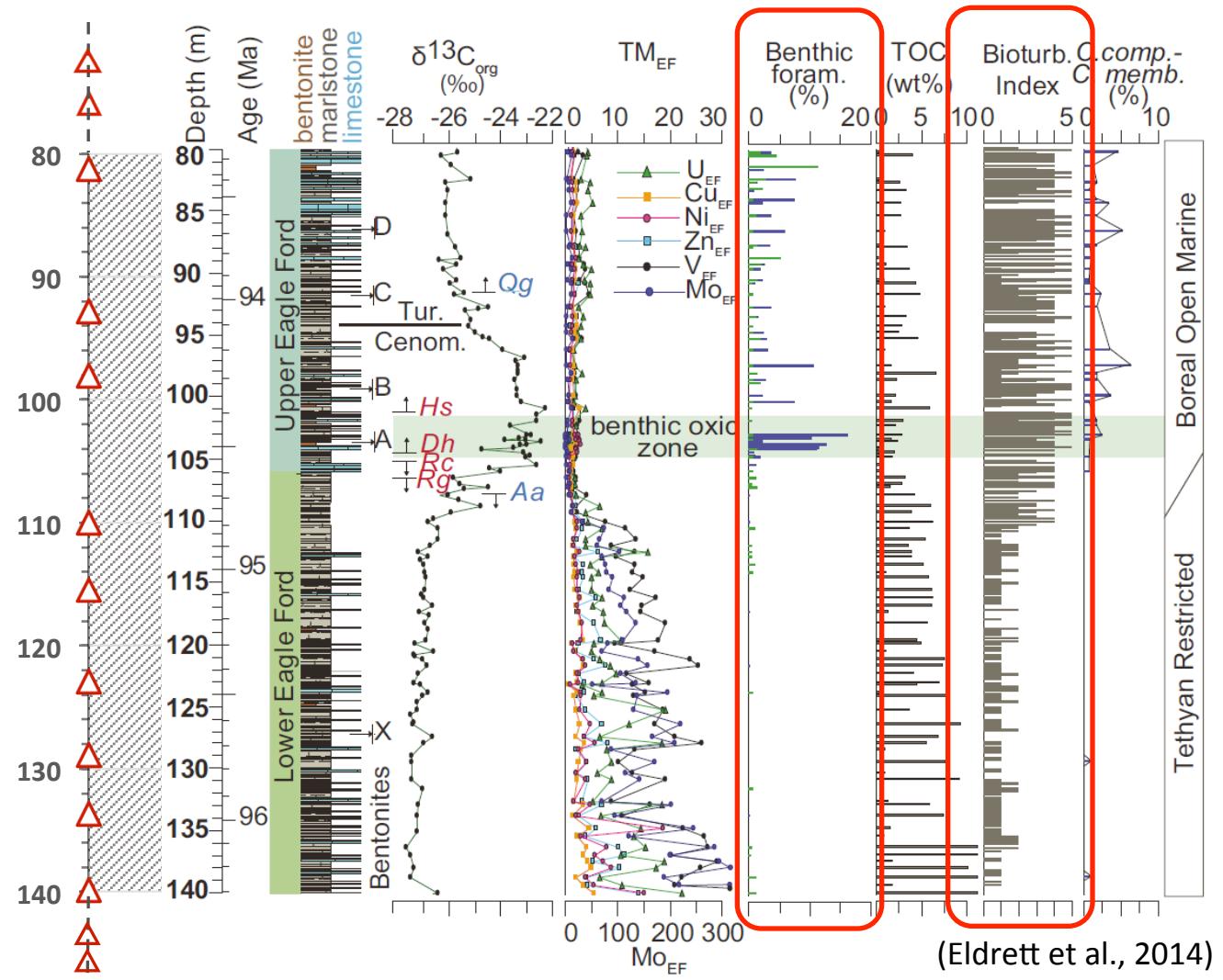
# Samples studied from Iona Core recovered a complete record of the Boquillas (Eagle Ford) formation

FM	Well name	Depth (m)
UEF	Iona	(m)
	23	56.62
	22	57.08
	20	79.67
	19	81.27
	17	92.81
	16	98.08
	12	110.03
LEF	11	115.45
	10	122.92
	8	128.88
	7	133.68
	4	139.85
	2	149.51
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# Organic richness and maturity estimate of Iona core

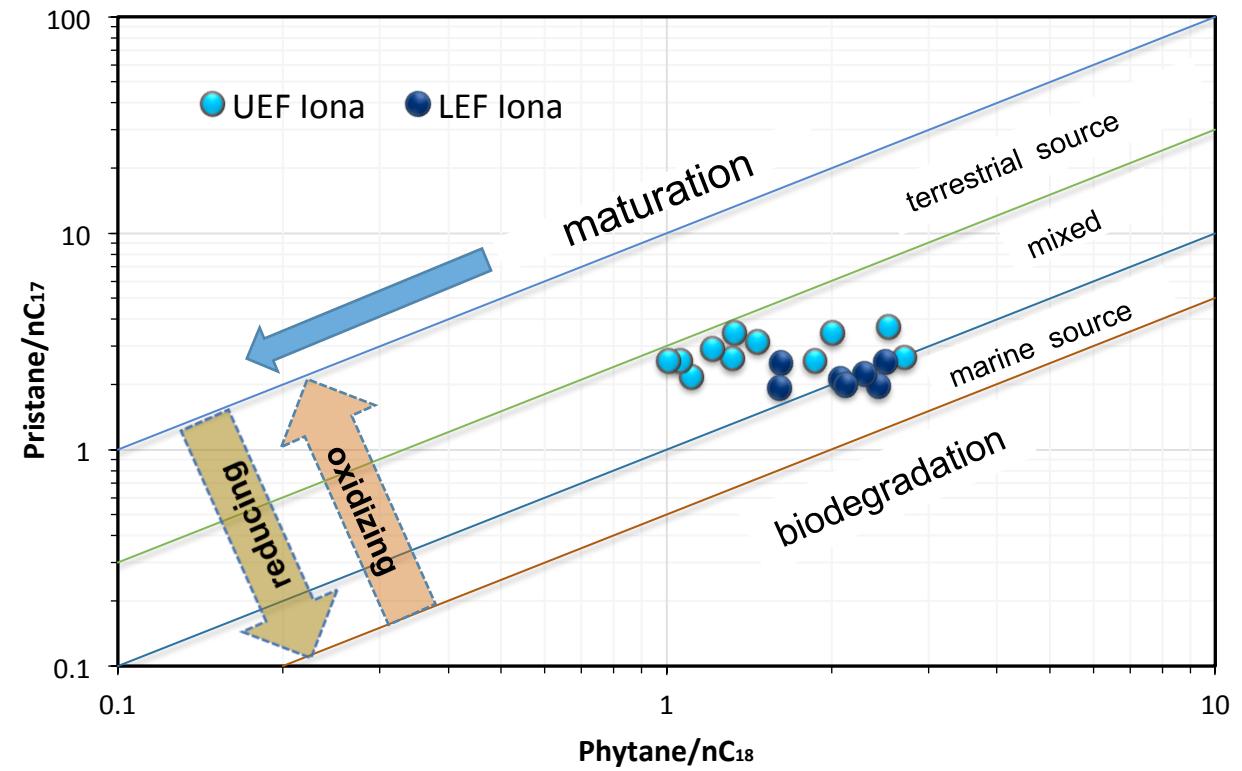
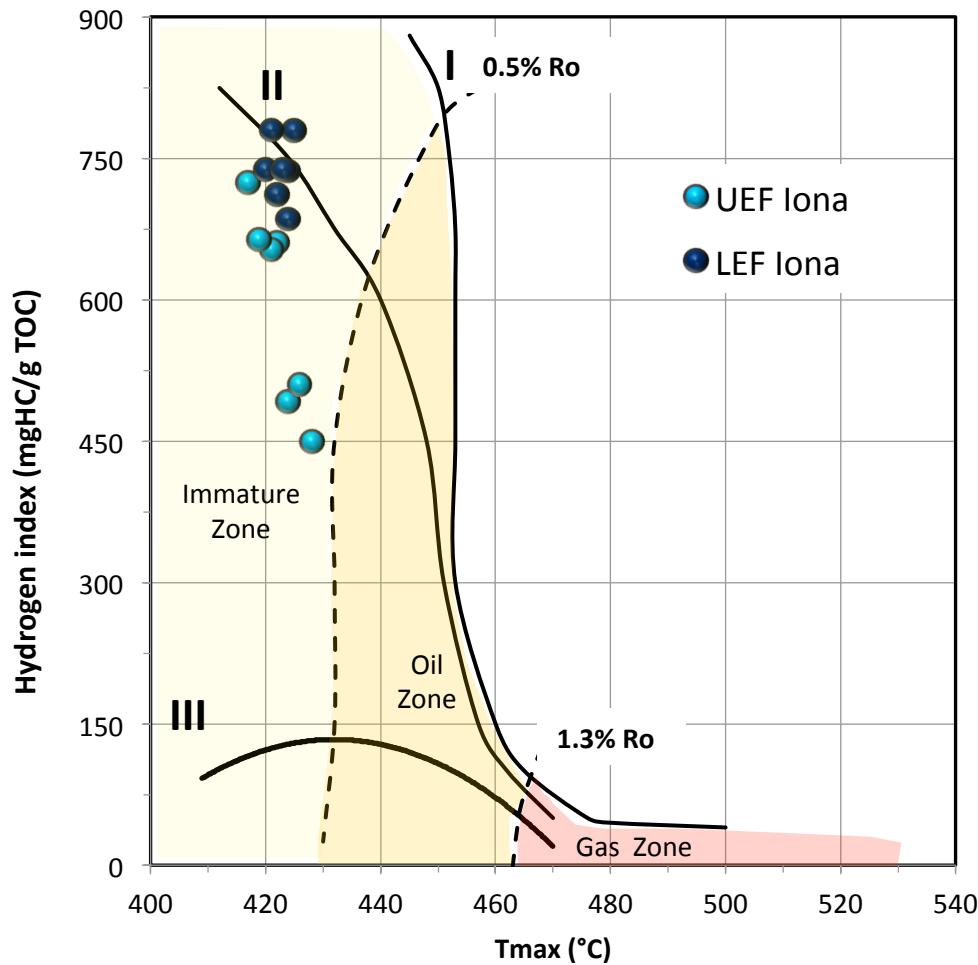
FM	Rock	Depth	Percent	Leco	Rock-Eval-2	Rock-Eval-2	Rock-Eval-2	Rock-Eval-2	Calculated	Hydrogen	Oxygen
	ID		Carbonate	TOC	S1	S2	S3	Tmax	%Ro	Index	Index
		(m)	(wt%)	(wt%)	(mg HC/g)	(mg HC/g)	(mg CO2/g)	(°C)	(RE TMAX)	(S2x100/TOC)	(S3x100/TOC)
UEF	Iona 23	56.6	54.48	2.72	0.45	17.96	0.57	422	0.44	660.29	20.96
	Iona 22	57.1	70.35	3.44	0.64	22.47	0.72	421	0.42	653.20	20.93
	Iona 20	79.7	71.96	2.34	0.31	11.51	0.66	424	0.47	491.88	28.21
	Iona 19	81.3	65.56	1.86	0.22	8.37	0.52	428	0.54	450.00	27.96
	Iona 17	92.8	60.75	2.28	0.28	11.63	0.6	426	0.51	510.09	26.32
	Iona 16	98.1	62.59	4.44	0.72	32.18	0.75	417	0.35	724.77	16.89
	Iona 12	110.0	48.54	5.07	0.82	33.69	0.75	419	0.38	664.50	14.79
LEF	Iona 11	115.5	43.91	5.82	1.1	39.93	0.74	424	0.47	686.08	12.71
	Iona 10	122.9	48.27	5.45	1.27	38.77	0.63	422	0.44	711.38	11.56
	Iona 8	128.9	56.57	6.41	1.69	47.24	0.55	424	0.47	736.97	8.58
	Iona 7	133.7	46.87	5.42	1.61	40.03	0.82	420	0.40	738.56	15.13
	Iona 4	139.8	46.35	11.8	5.13	91.96	0.9	425	0.49	779.32	7.63
	Iona 2	149.5	59.60	7.96	2.8	62.09	0.72	421	0.42	780.03	9.05
	Iona 1	151.9	28.87	13.1	3.68	96.71	0.83	423	0.45	738.24	6.34

# Organic richness and maturity estimate of Iona core

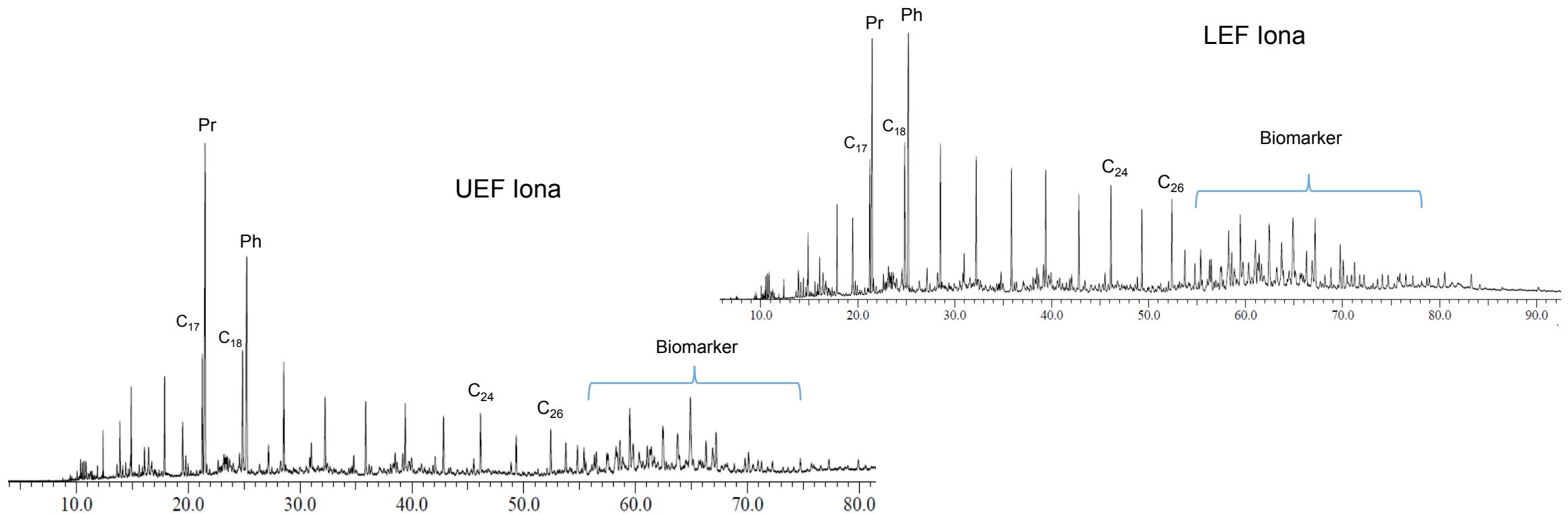
## Organic rich, Low maturity

FM	Rock	Depth	Percent	Leco	Rock-Eval-2	Rock-Eval-2	Rock-Eval-2	Rock-Eval-2	Calculated	Hydrogen	Oxygen
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		(m)	(wt%)	(wt%)	(mg HC/g)	(mg HC/g)	(mg CO2/g)	(°C)	(RE TMAX)	(S2x100/TOC)	(S3x100/TOC)
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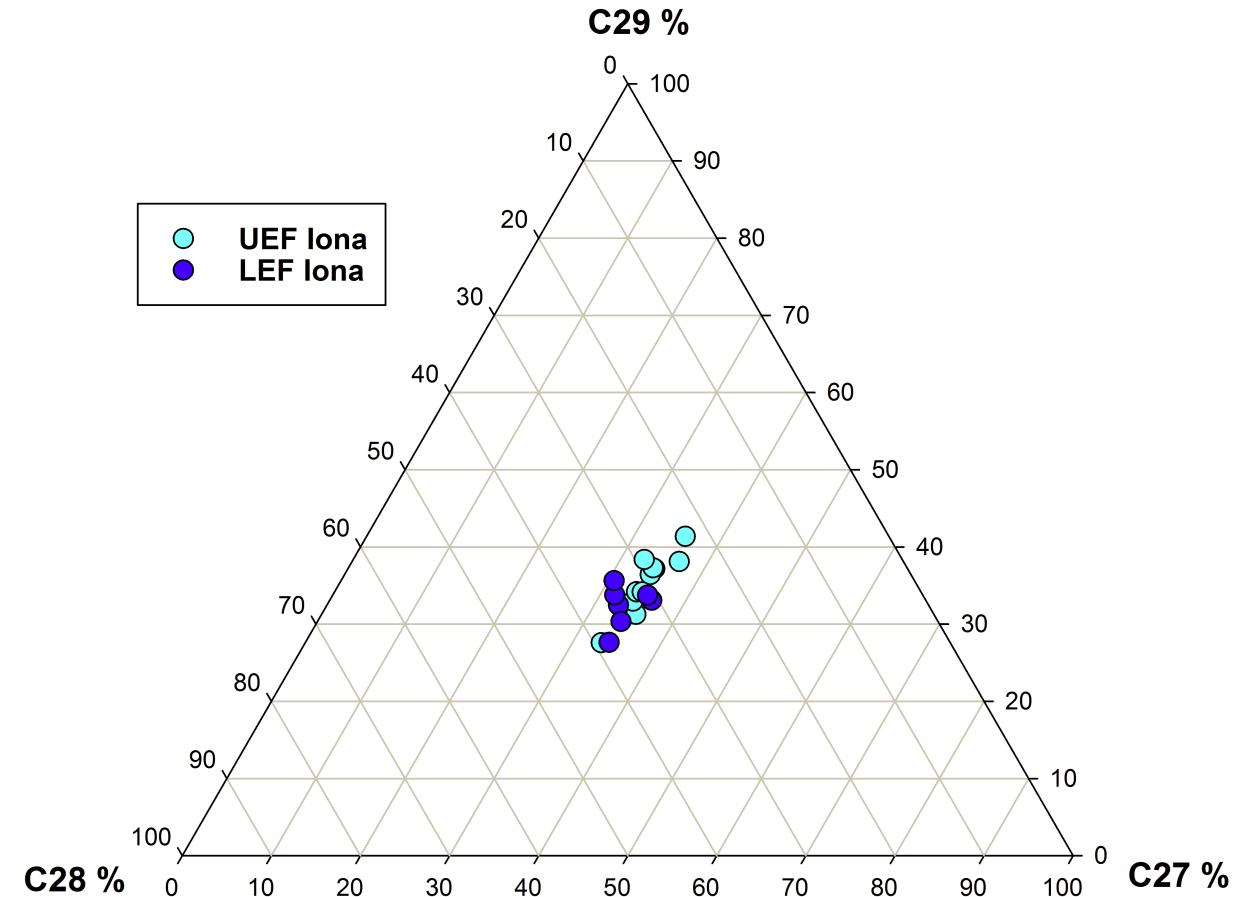
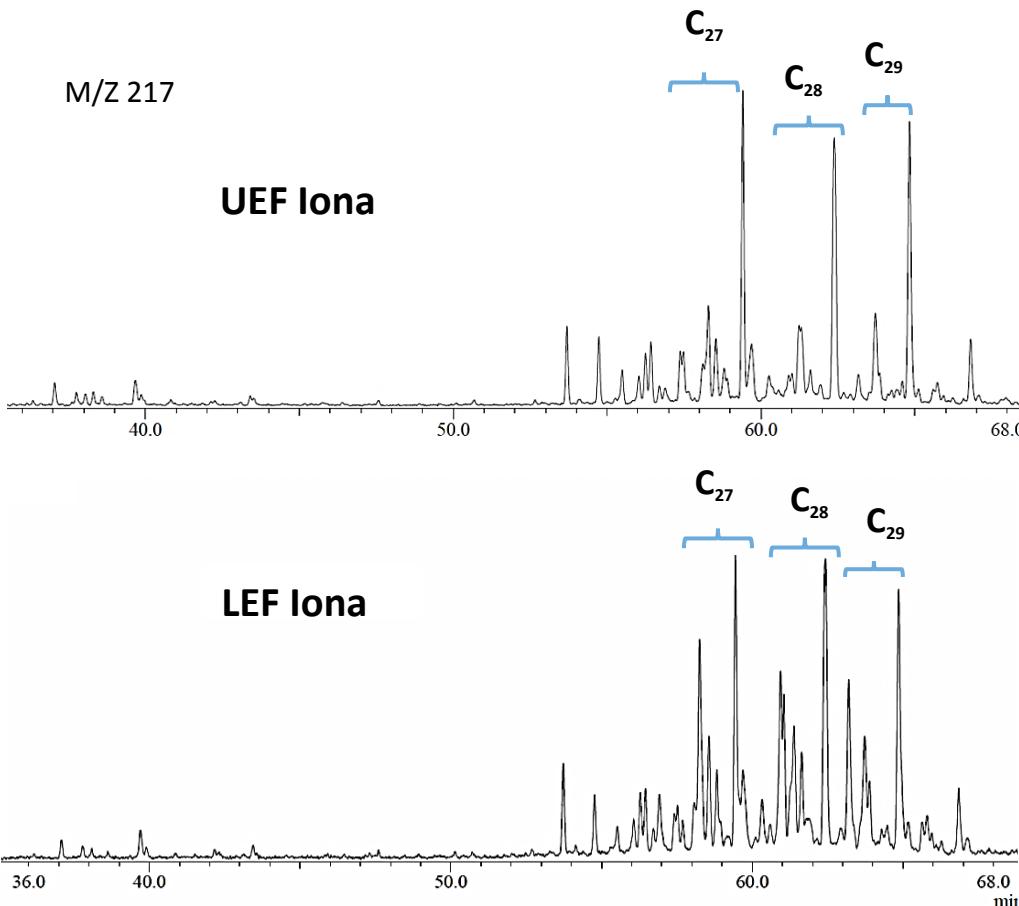
# Organic type: EF shales dominated by type II, LEF is better than UEF due to development of benthic algae in UEF



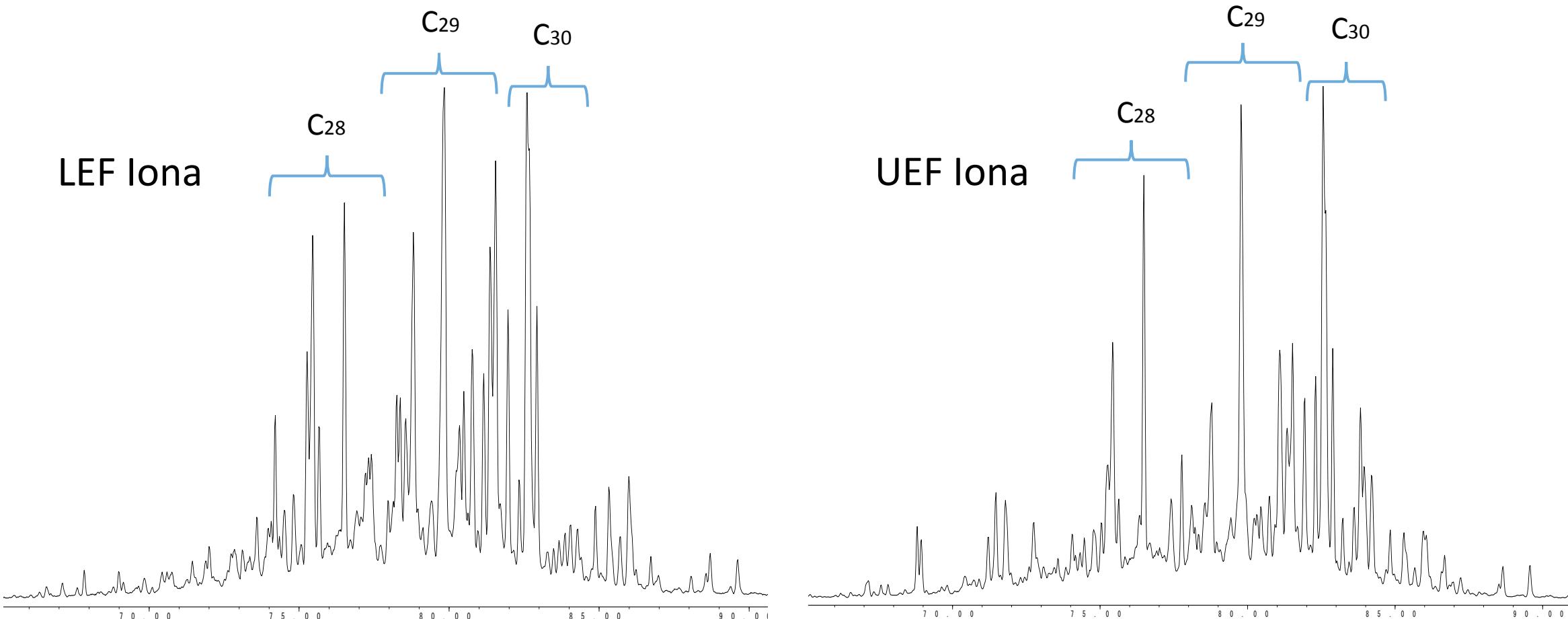
# Short chain *n*-alkanes predominance in EF shales suggests that marine algae is a main contributor to sedimentary organic matter



# Sterane distributions differentiate source input between UEF and LEF Iona



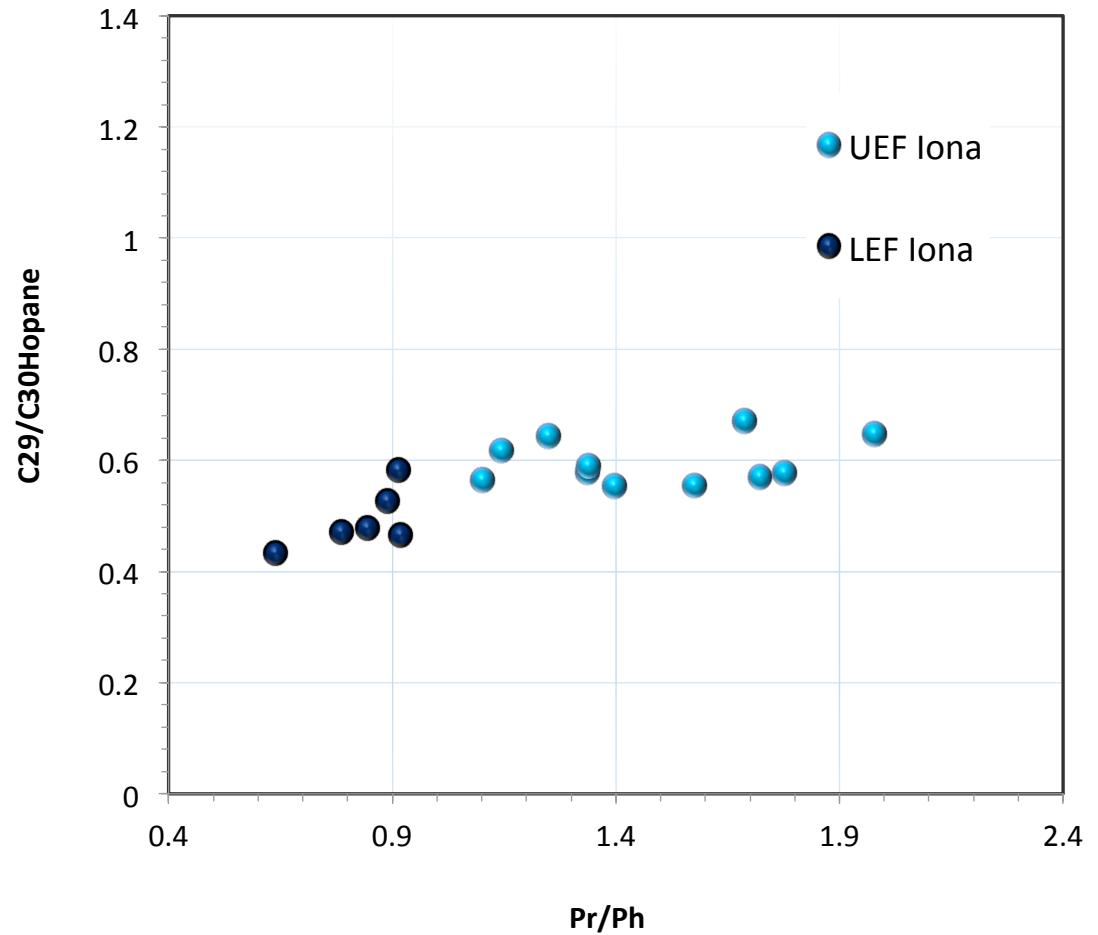
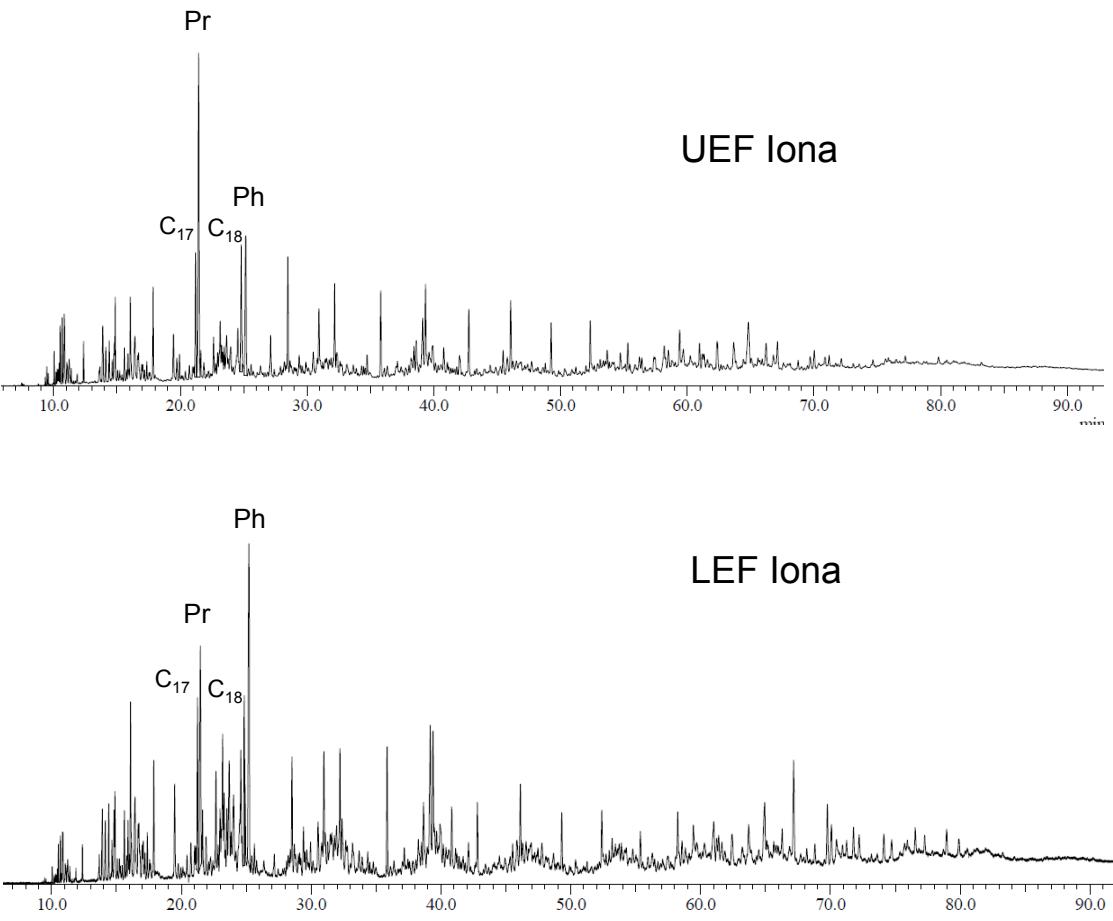
# The distribution of 4-methylsterane in EF shales strongly suggests marine dinoflagellate input



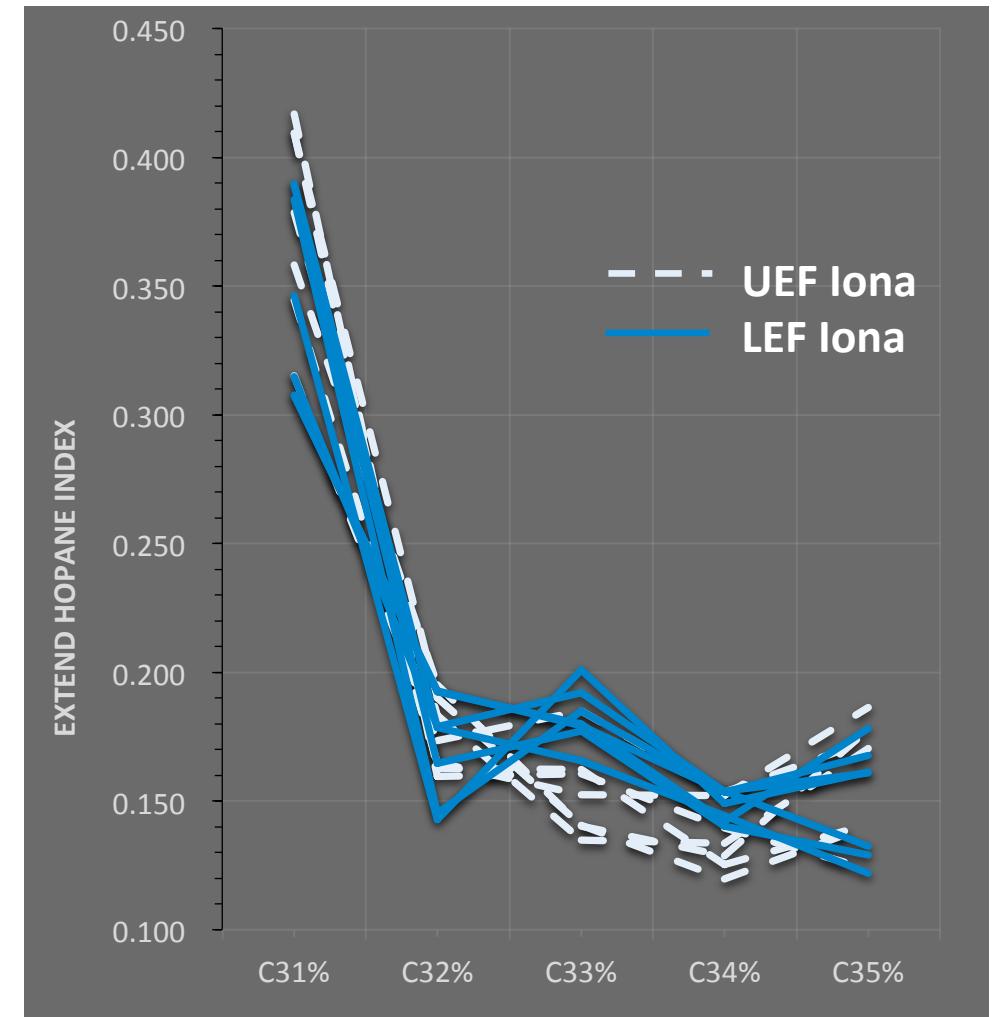
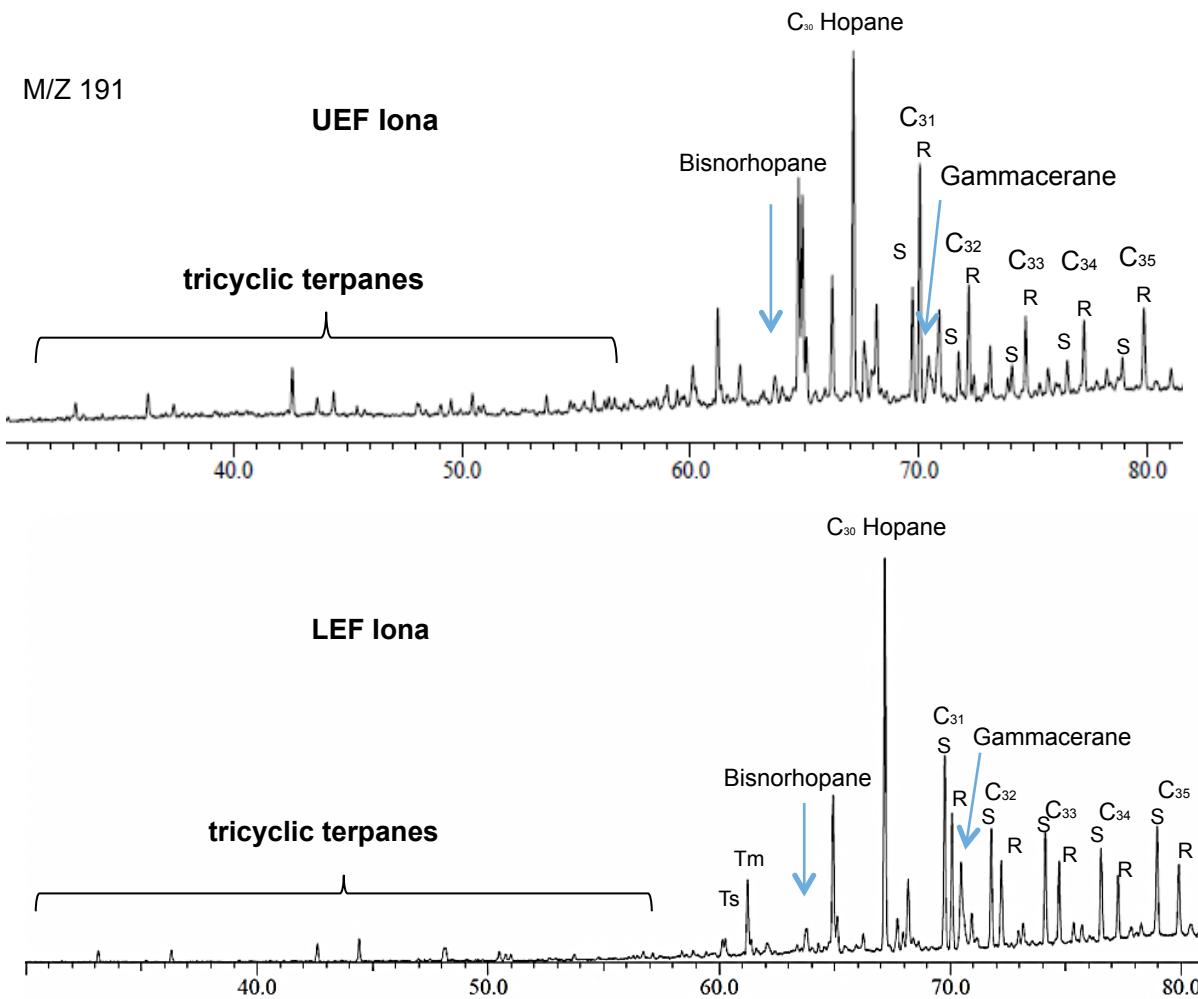
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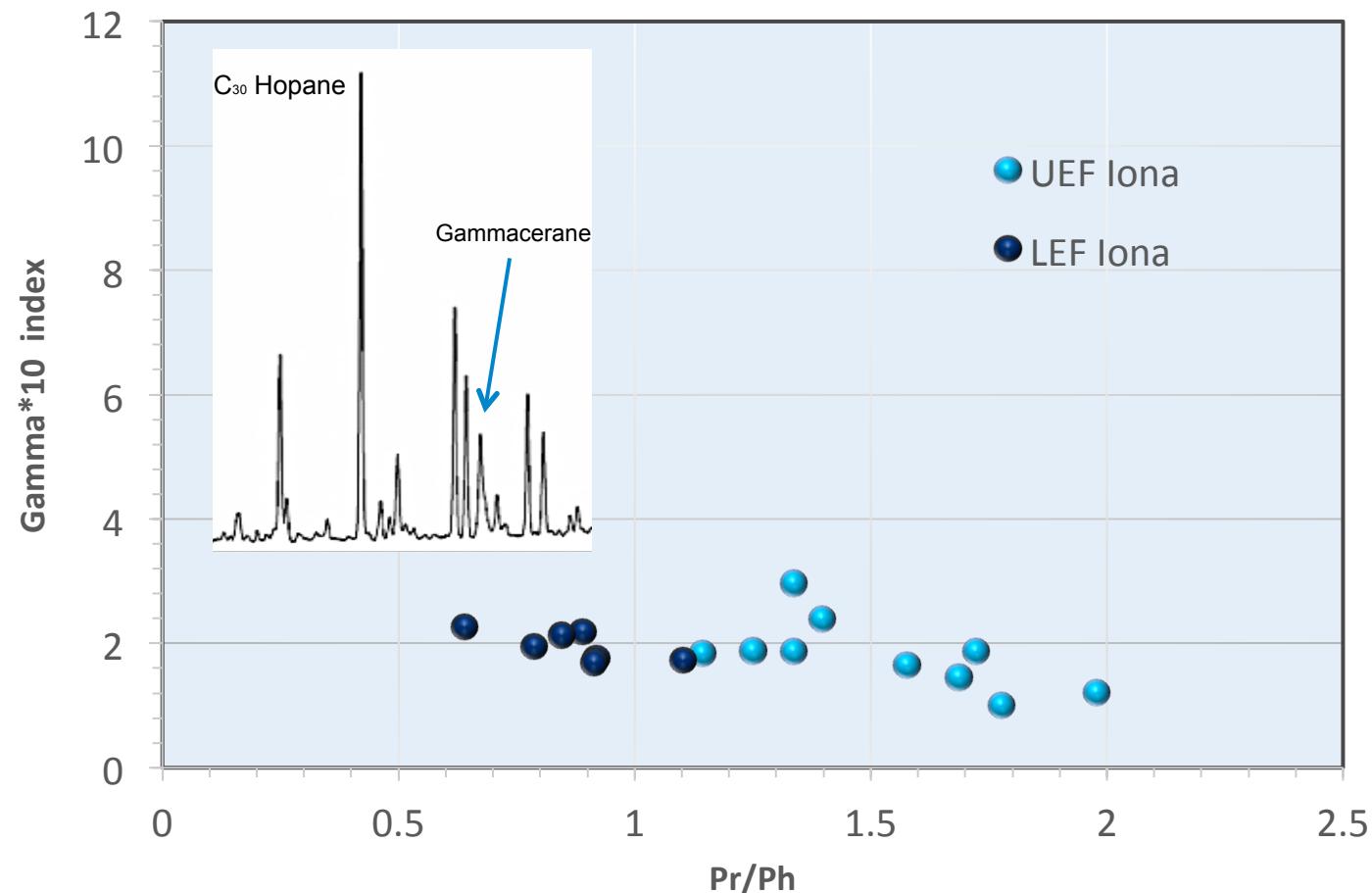
# Lower EF is more reducing than Upper EF



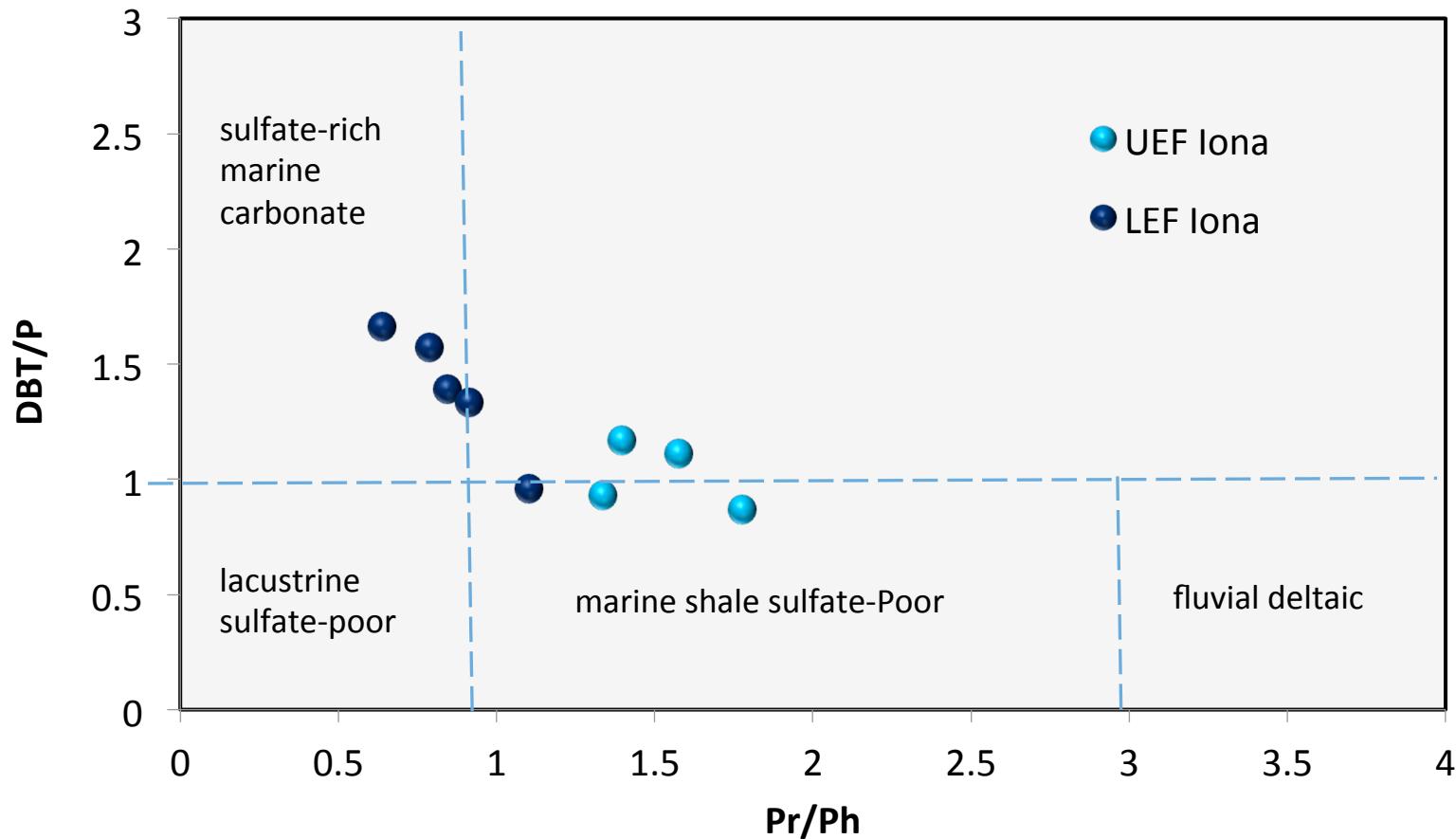
# Homohopanes distribution from EF shales shows the LEF is more anoxic and UEF deposited in a dysoxic environment



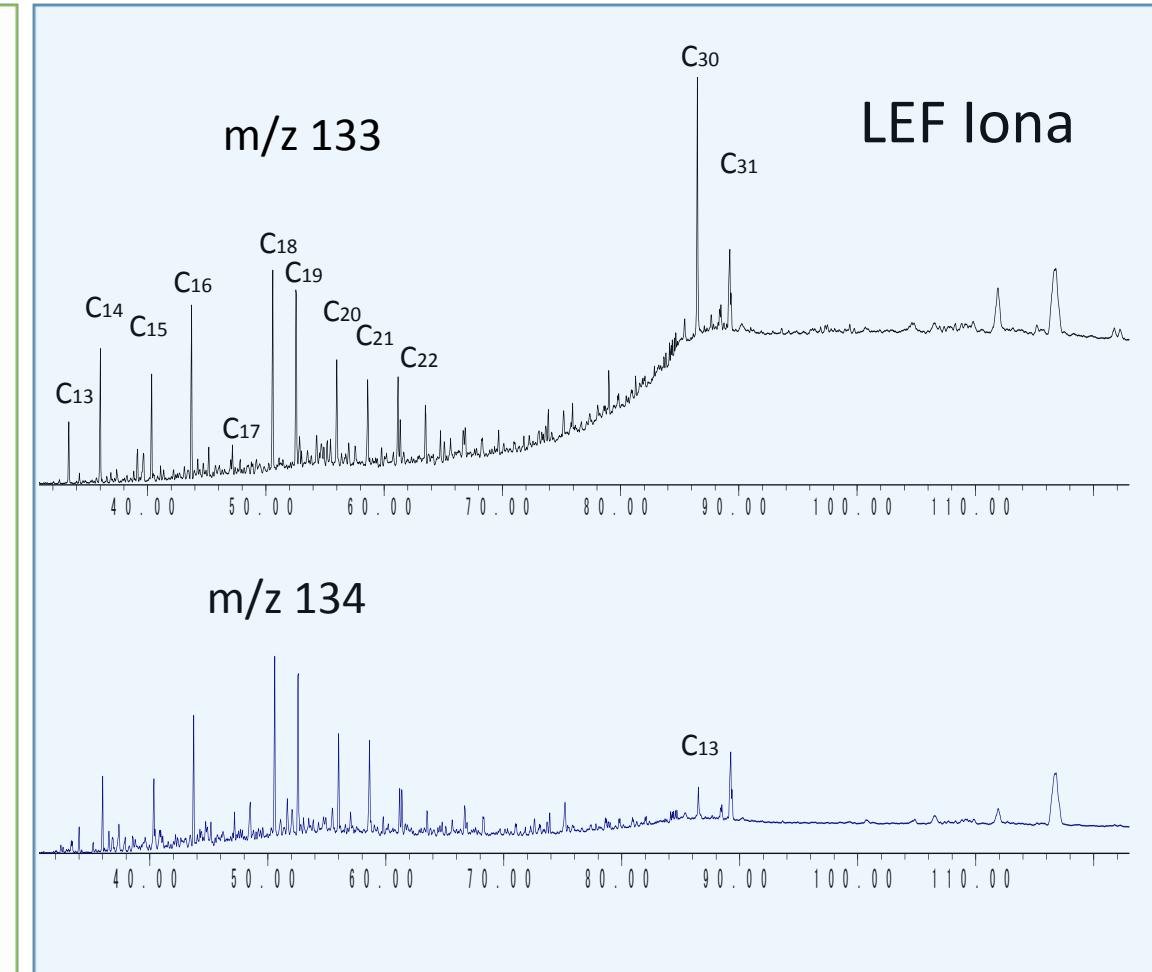
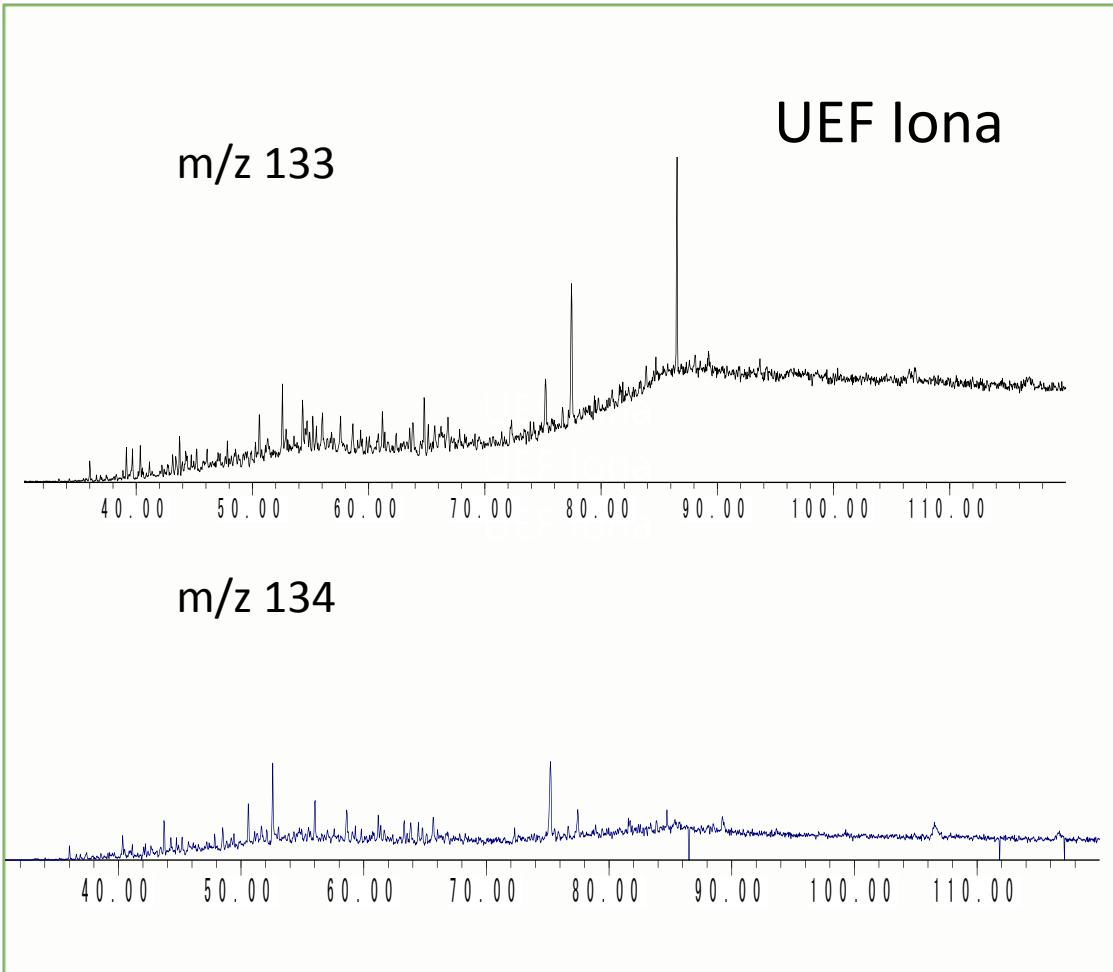
# Relative concentrations of Gammacerane EF shales indicate the water column stratification was not fully broken in UEF



# Depositional environments and associated water body evolution from Lower EF to Upper EF



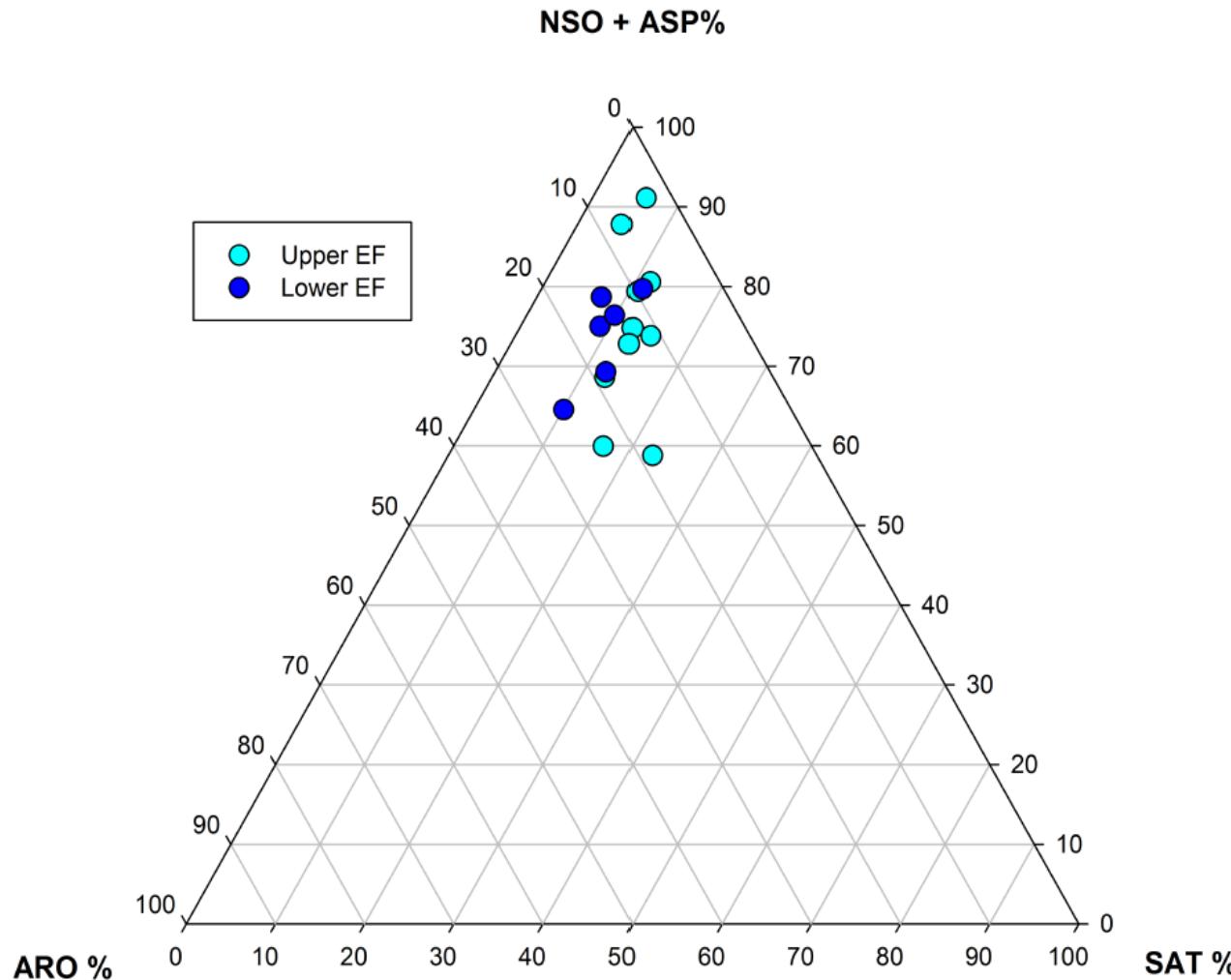
# Sulfur-rich water existed in LEF is evidenced by the distribution of Arylisoprenoids



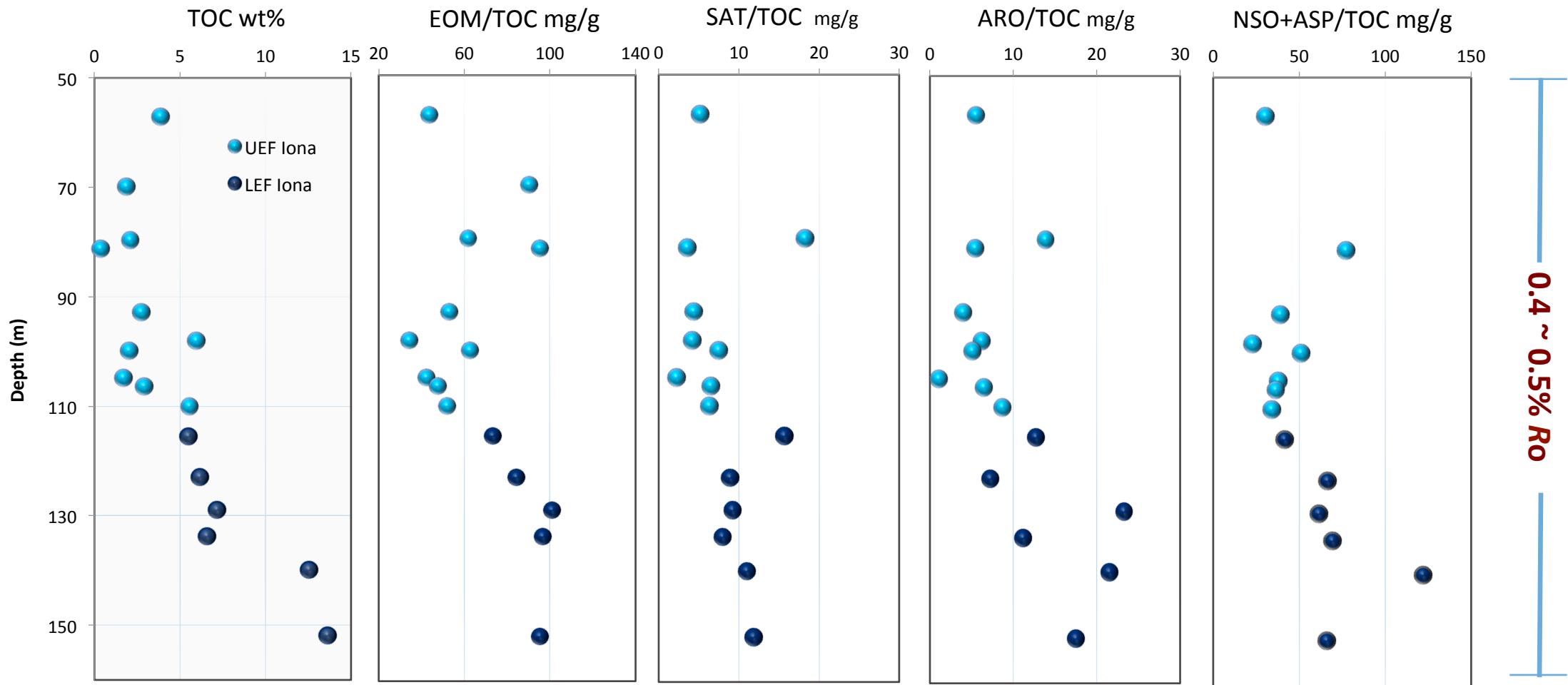
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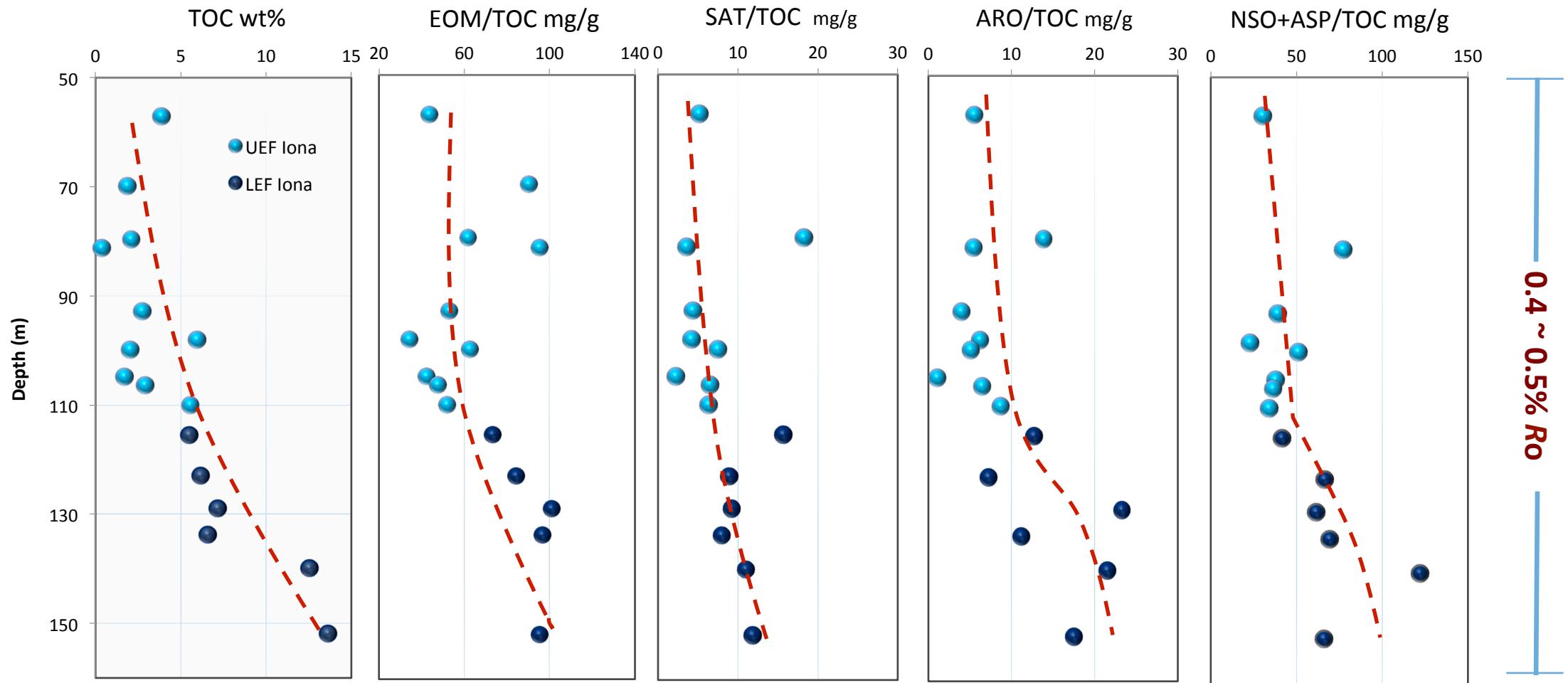
# Ternary diagram of compound-grouped fractions in EOM from Eagle Ford shales



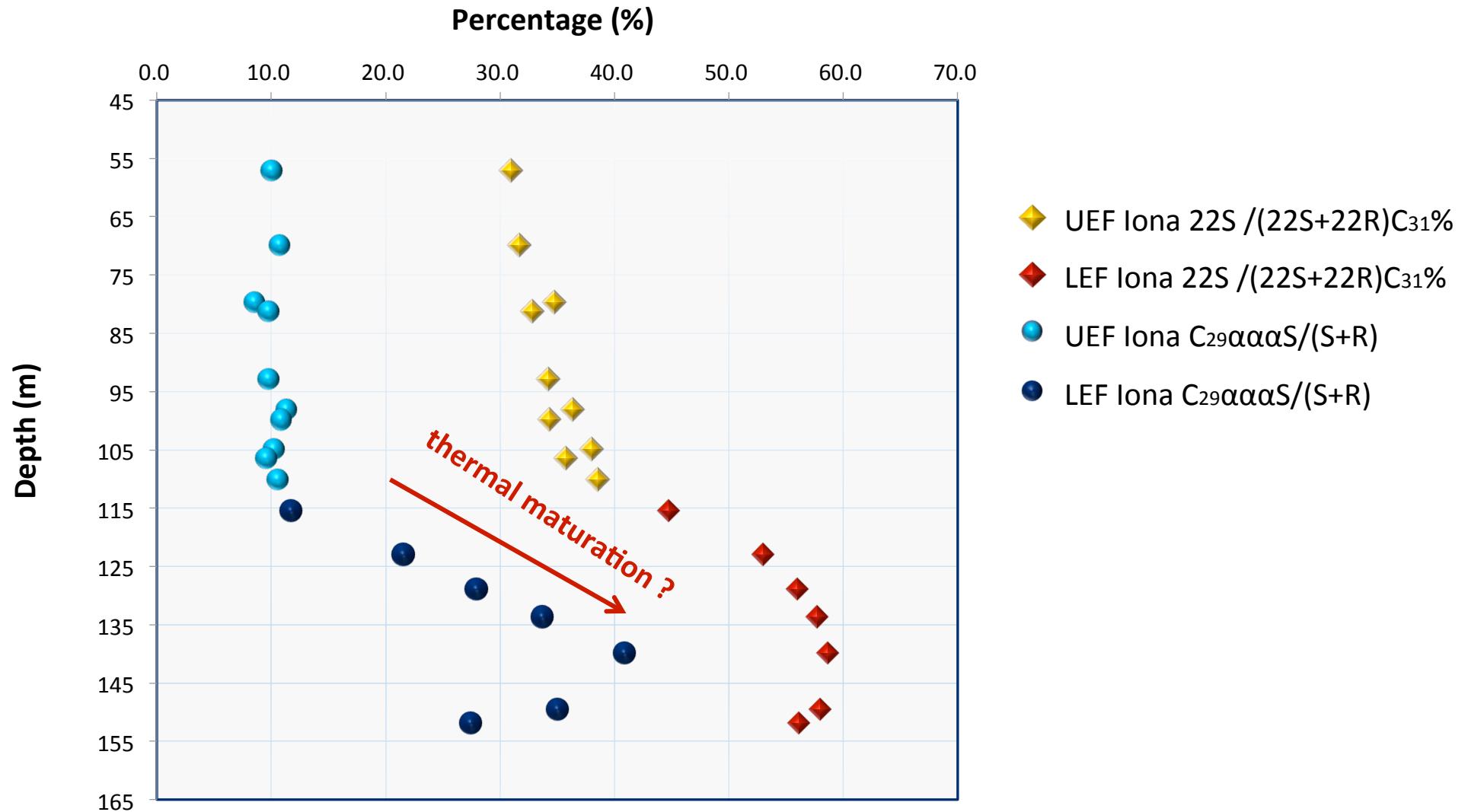
# OM conversion difference between UEF and LEF mainly depends on polar fraction conversion



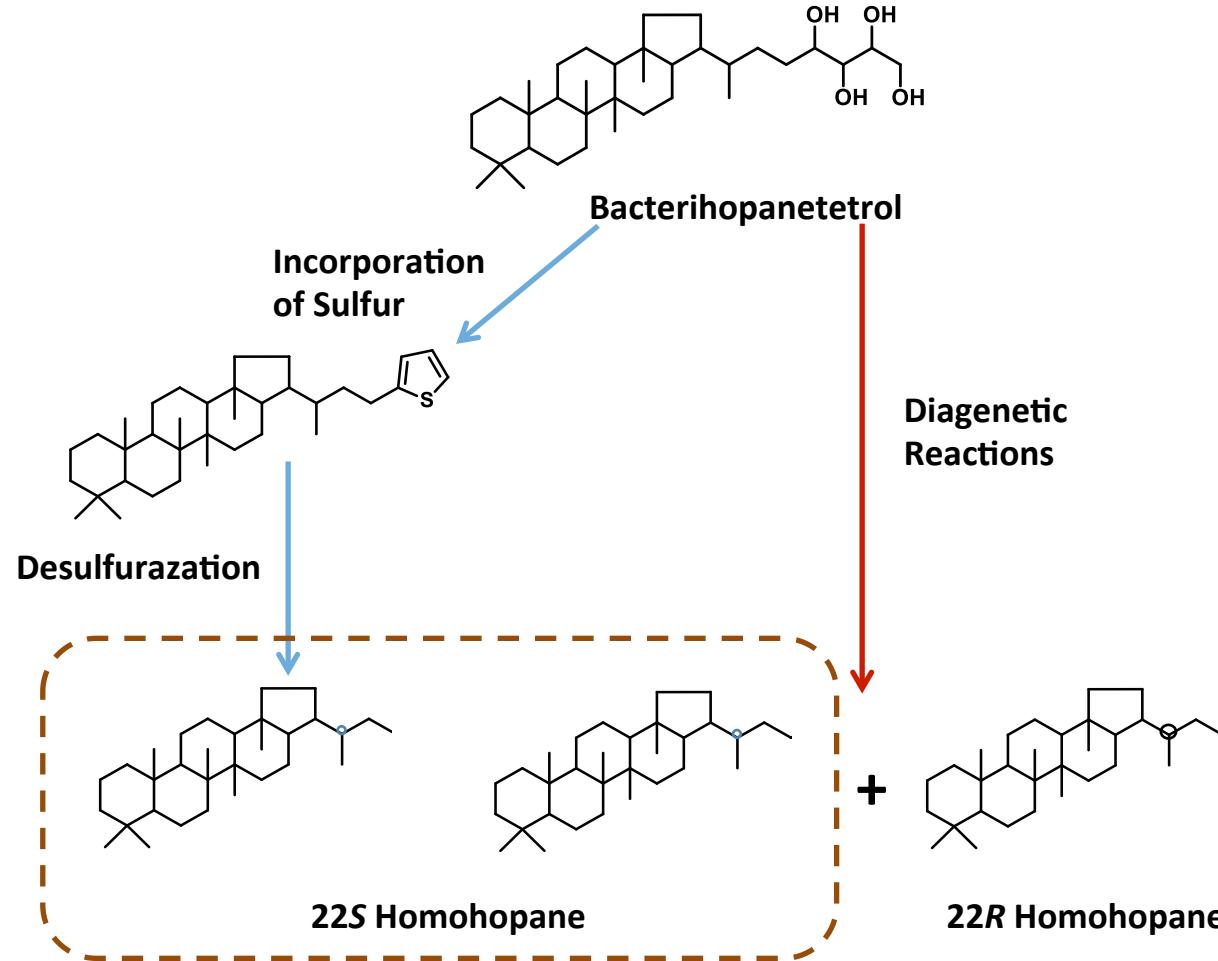
# OM conversion difference between UEF and LEF mainly depends on polar fraction conversion



# Abnormal distribution of stereochemistry of extend homohopane and sterane

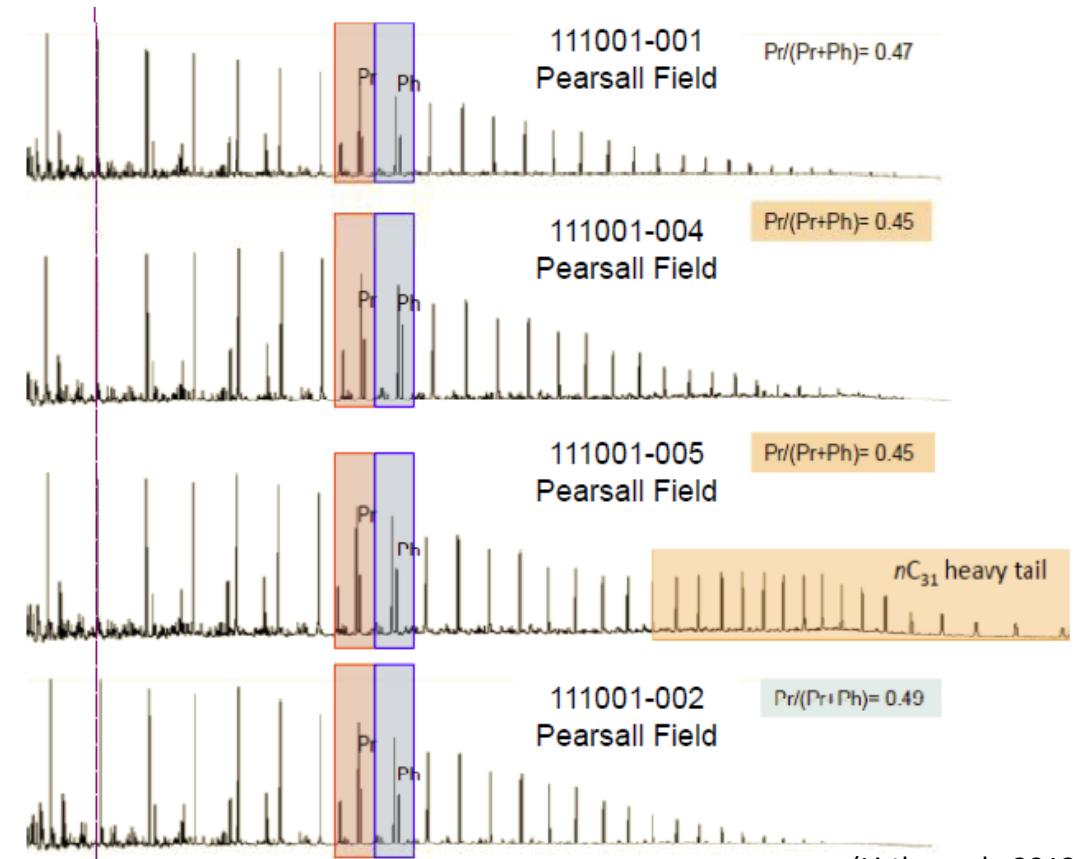
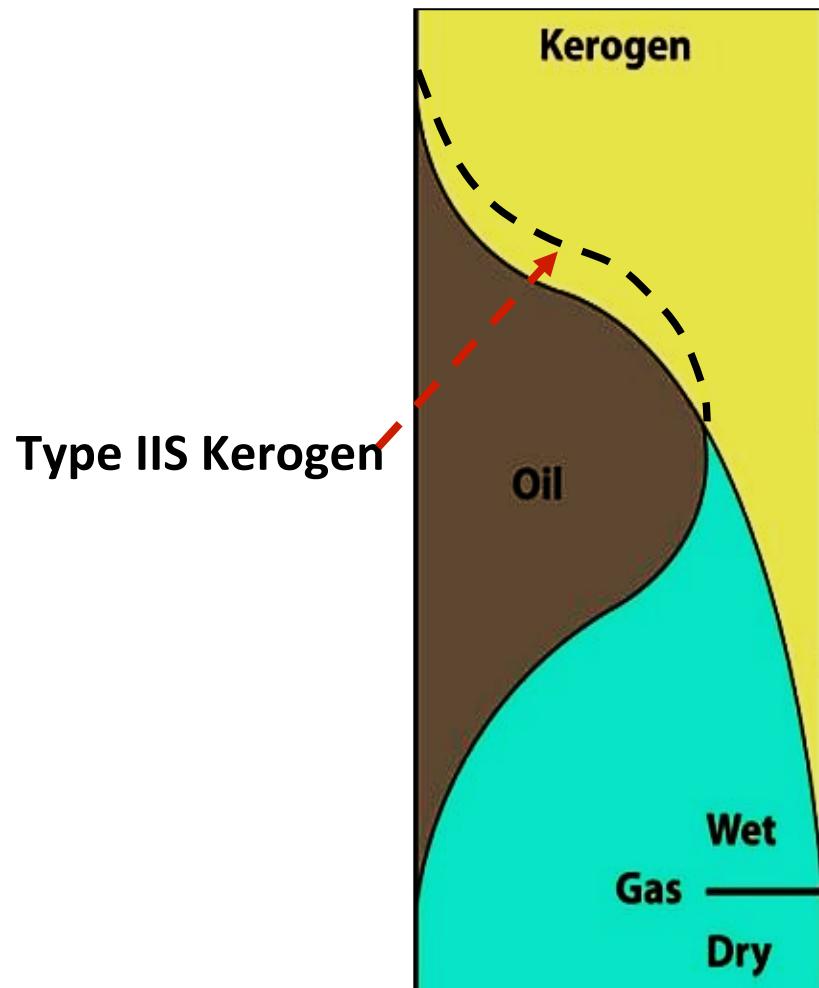


# Possible mechanism: type IIS kerogen developed in Lower Eagle Ford?



After Koster et al., 1997, GCA

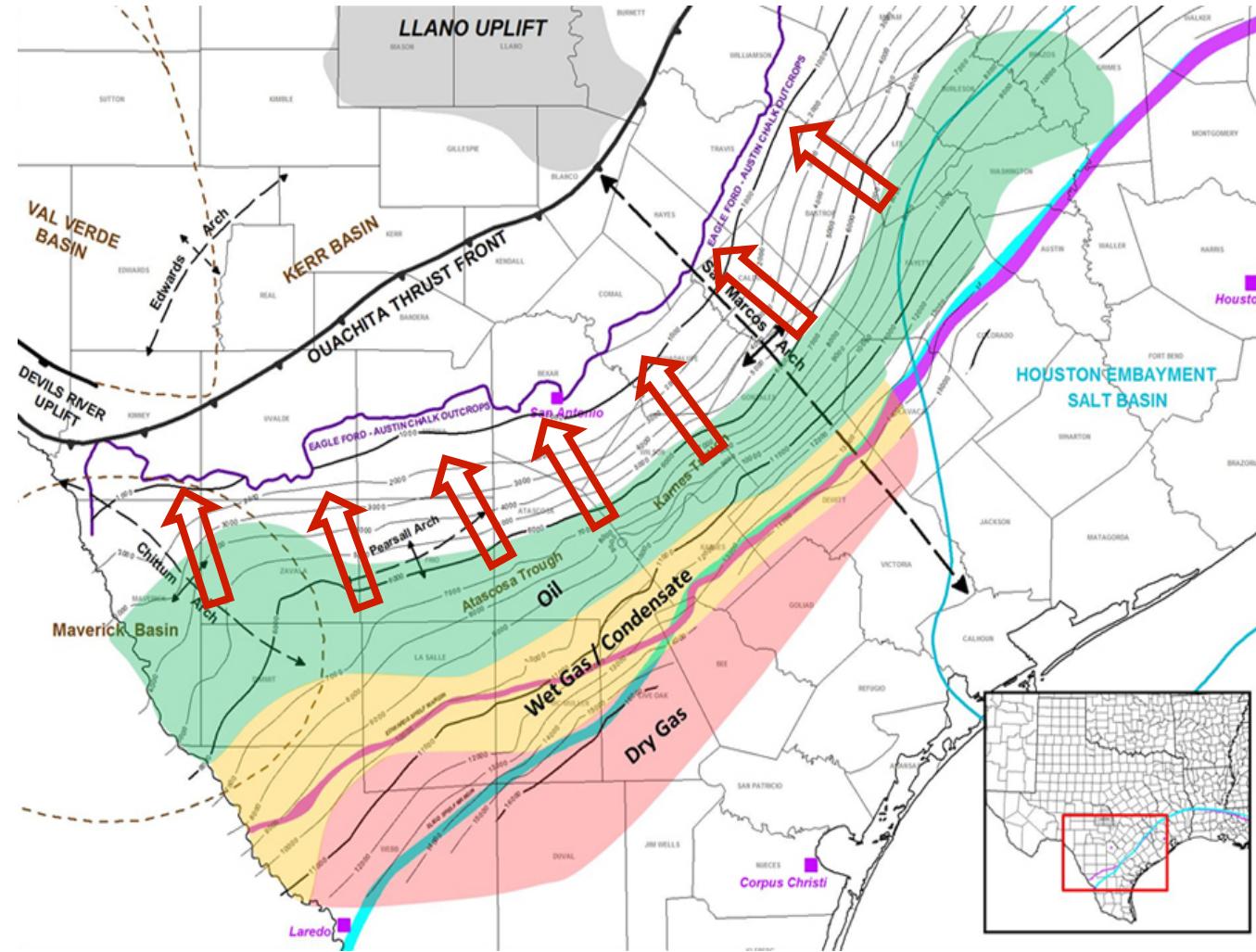
Type IIS kerogen normally generates heavy oil enriched in polar fractions at  $\sim 0.5\% Ro$ , which is easily cracking



(Little et al., 2012)

Shale oil discovered in Eagle Ford formation

# Early generation of type IIS kerogen suggests Eagle Ford shale oil generation potential might be underestimated



# Summary

- Eagle Ford shale in Southwest Texas is OM rich calcite-dominant mudrocks with variable silica content and ash bed. LEF shale contains higher TOC than UEF one.
- Although OM source of EF shale is generally dominated by type II, OM quality of LEF is better than that of UEF due to the increasing input of benthic algae.
- LEF shale was deposited in an anoxic and high sulfur content environment while UEF is more dysoxic.
- Abnormal molecular geochemistry in LEF might suggest that type II S kerogens developed in LEF. High sulfur content oil is easily cracking which is more favor for shale oil exploration and exploitation.

# Acknowledgement



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