

# **Organic Facies and Reservoir Characterization of Eagle Ford Shale as Determined by Stratigraphy, Source Rocks, and Oil Geochemistry\***

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## **Abstract**

The source of the Cenomanian to Santonian petroleum systems across East and South Texas has been attributed to the Eagle Ford Shale play. However, little effort has been made to distinguish the relationship between the depositional settings, organic facies, oil families, and lithostratigraphic characteristics of the source rock. This study finds that there are significant variations in stratigraphy, reservoir type, and produced hydrocarbon chemistry between the South Texas Eagle Ford and the so-called East Texas Eagle Ford. The South Texas Lower Eagle Ford Shale reservoir facies is dominated by organic-rich, relatively low clay, foraminifera-rich, coccolith mudstones/marlstones, whereas the superficially equivalent source rocks in East Texas have a much more dominant terrestrial influence. In a regional reservoir modeling study at the confluence of East Texas and South Texas on the San Marcos Arch, the interplay of these depositional systems had to be accounted for to achieve reliable results. The model included analysis of cores from multiple counties combining detailed stratigraphic facies descriptions and petrophysical data from the base of the Austin Chalk to the Buda Formation. Source rock data is available from approximately 118 wells throughout this interval between the Austin Chalk and Buda. The dataset includes TOC, pyrolysis, and vitrinite reflectance data. Based on TOC analyses across the entire trend, the average TOC of the East Texas and South Texas Eagle Ford is 3.43%. Pyrolysis data and visual kerogen descriptions clearly show the South Texas Eagle Ford contains primarily Type II algae-rich oil prone kerogen. In contrast, the East Texas Eagle Ford contains type II kerogen with terrestrially derived mixed kerogen from the northeast. Thermal maturity in the Eagle Ford play area varies systematically with structure independent of the depositional systems from early oil generation to dry gas trending northwest to southeast. Produced oil geochemistry data from 70 oils include bulk molecular compositions, Pristane/nC17, Phytane/nC18, Pristane/Phytane, C13 to C20 isoprenoids, saturate and aromatic carbon isotope compositions, sterane and hopane ratios. The geochemical data suggest that the oils from the South Texas Eagle Ford and East Texas Eagle Ford plays are generated from two distinct types of organofacies. One type is dominantly carbonate mudstone sourced in South Texas, and the other type is siliciclastic marine shale sourced in East Texas.

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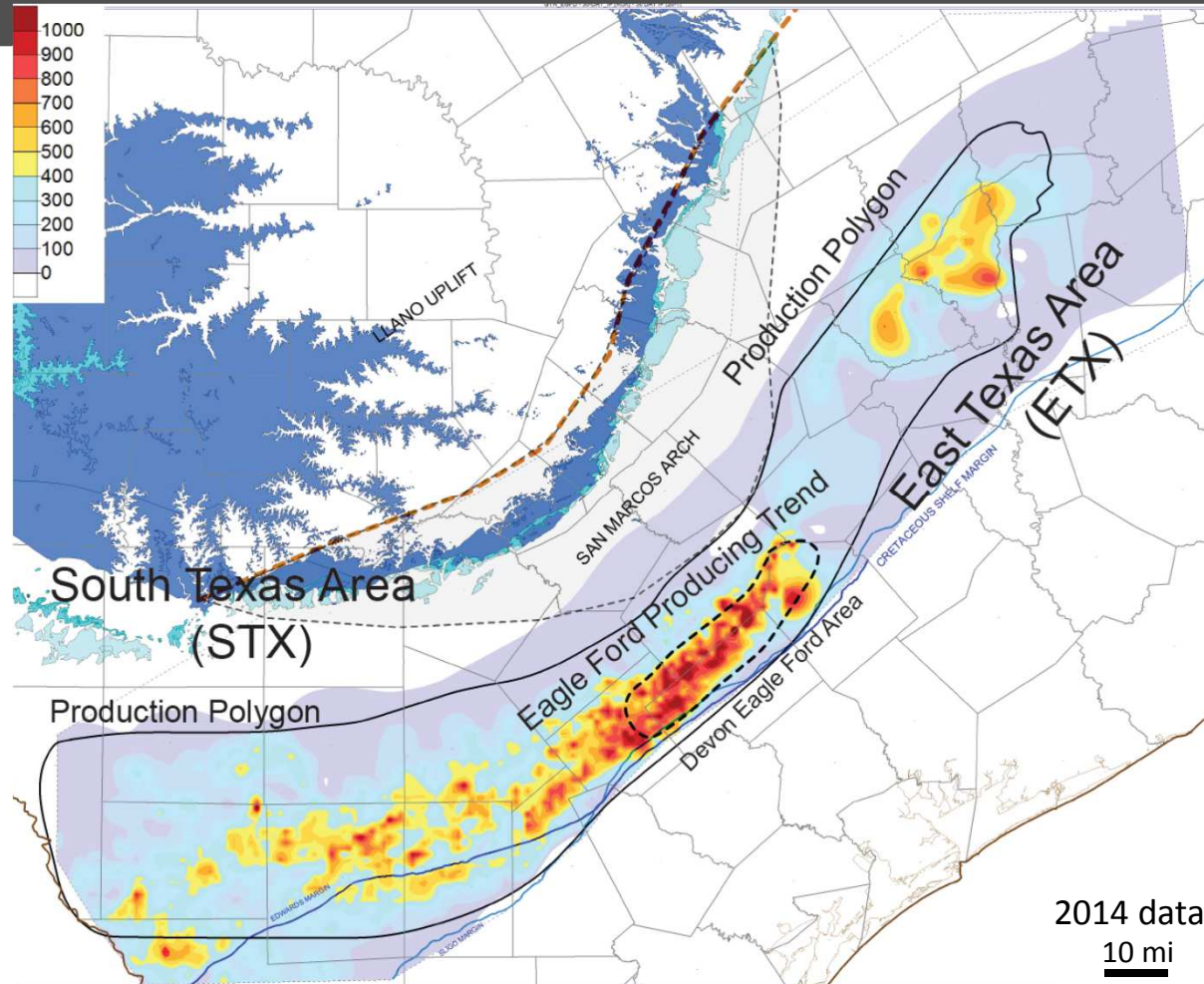
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# Presentation Outline

- Introduction of Eagle Ford Play
- Stratigraphy
- Source Rock Geochemistry
- Produced Oil Geochemistry
- Conclusions

# Eagle Ford Play and 30 Day IP

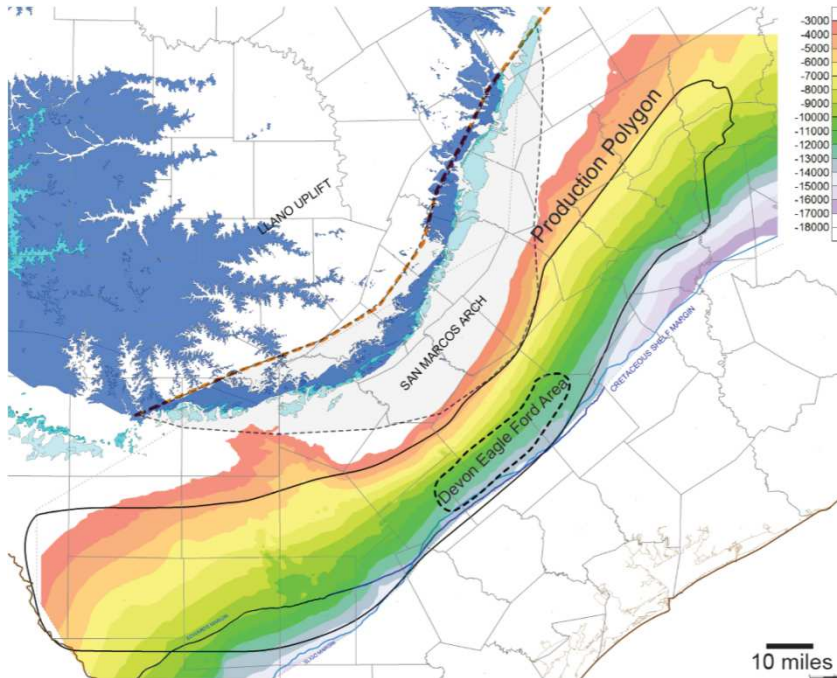


- Eagle Ford production is commonly mapped as a single trend.
- In reality, it is 2 distinct areas with varying geochemistry and stratigraphy.
- These differences need to be addressed to understand the petroleum systems.

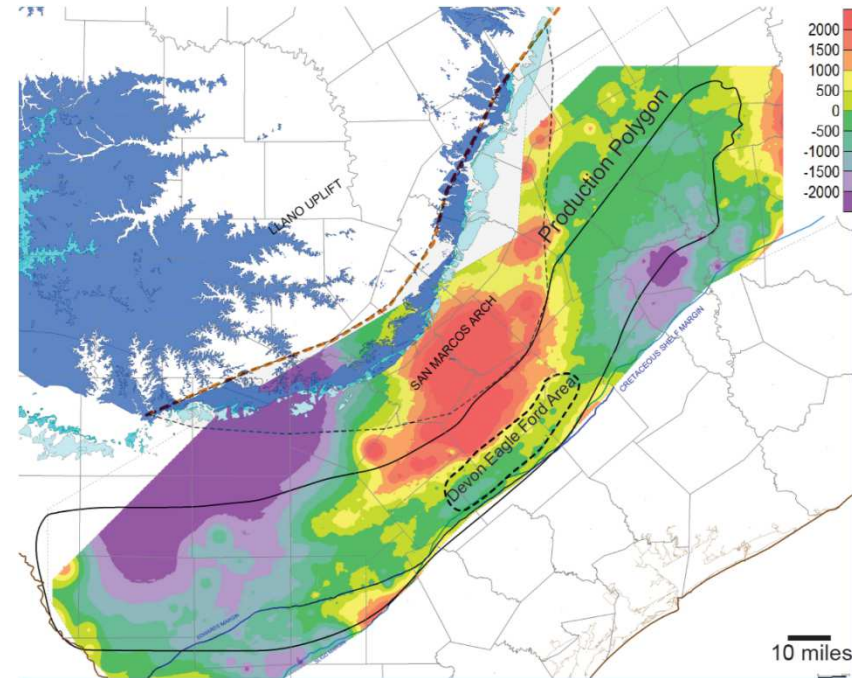


# Structure

Buda Structure

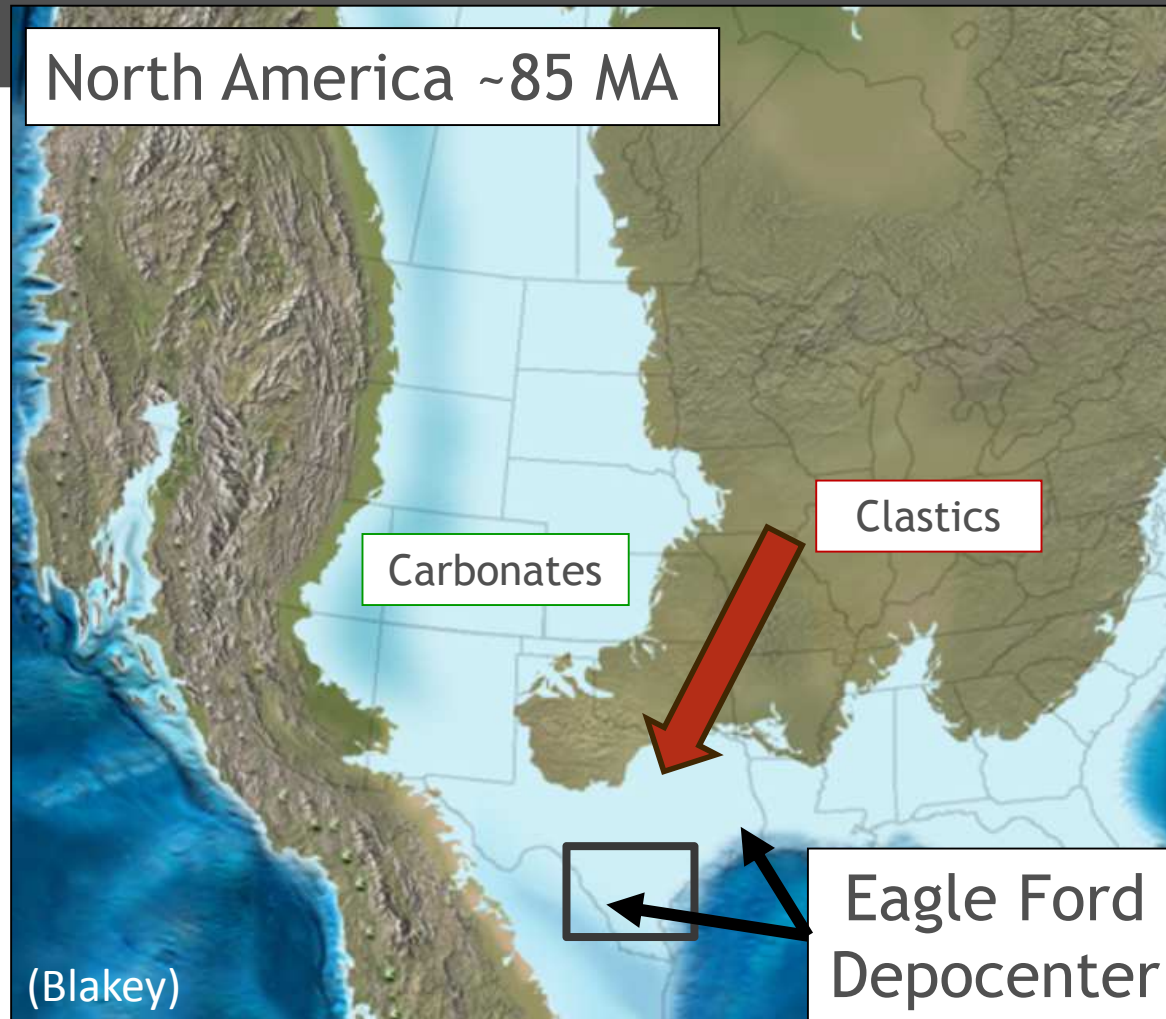


2<sup>nd</sup> Order Residual on Buda Surface



- A quick look at the Buda structure shows the monoclinal dip into the Gulf of Mexico, much of which developed after deposition. It is easy to interpret this as a single system.
- A residual map on that surface removes the regional trend and reveals the key paleogeographic features. It also explains how different stratigraphies and geochemistries developed in the Maverick Basin and East Texas Basin at approximately the same time.

# Eagle Ford Paleogeography



- The structure combined with overall paleogeography allowed for two different litho- and sequence stratigraphies.
- This depends on the opening and closing of the interior sea way as well as clastics influence coming out of Ouachita Orogeny but contained by the San Marcos Arch.

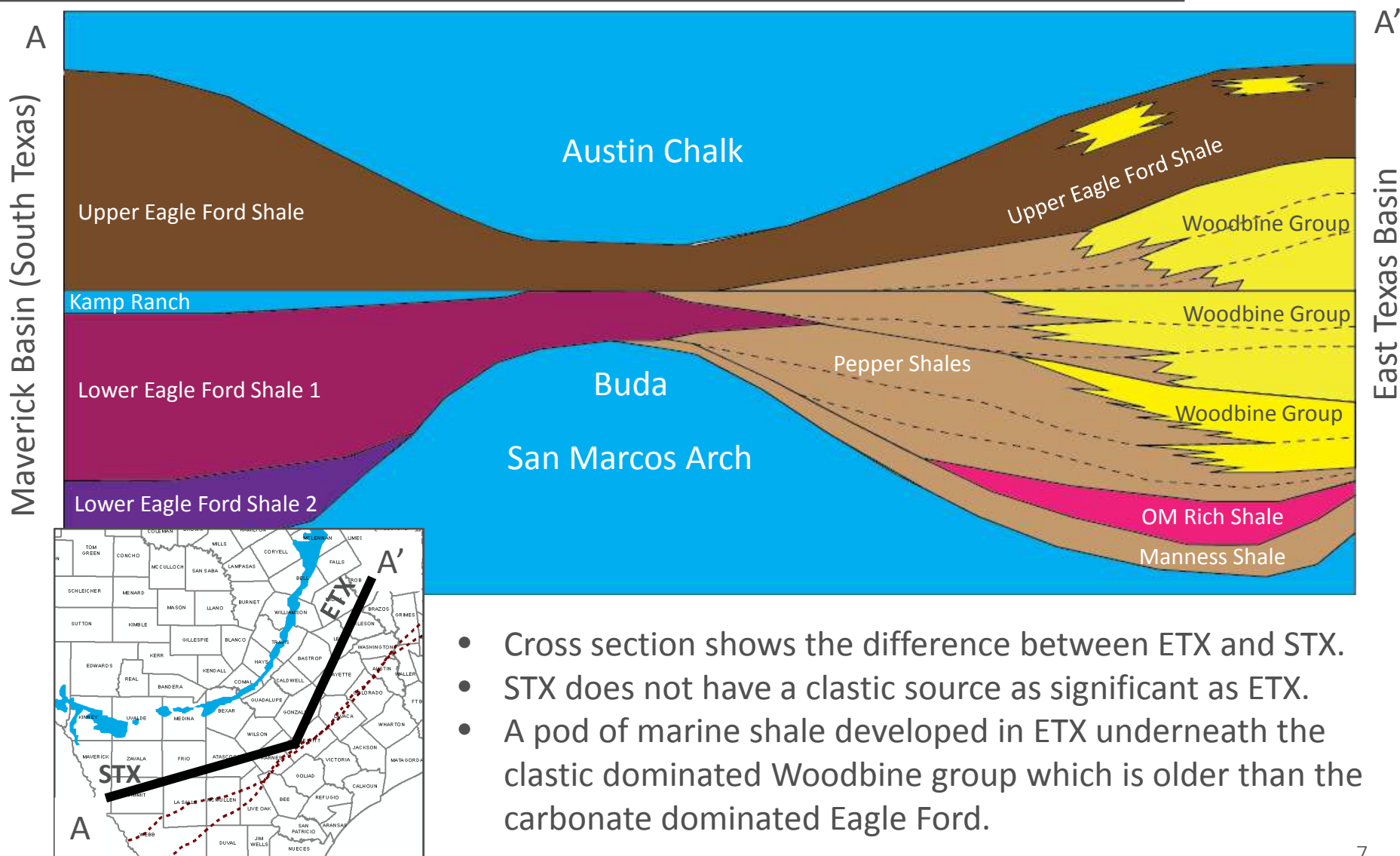
# East Texas vs South Texas Stratigraphy

Stage	South Texas	East Texas
Santonian-Coniacian	Austin Chalk	Austin Chalk
Turonian	Upper Eagle Ford	Eagle Ford Group
Cenomanian	Kamp Ranch	Sub-Clarksville
	Lower Eagle Ford	Pepper Shale
	Non-deposition	Woodbine Group (Lewisville, Harris, and Dexter)
		Organic Basinal Shale
		Maness Shale
	Buda	Buda

- East Texas stratigraphy between Austin Chalk and Buda is significantly more clastic rich.
- 2 separate source rocks fuel these two basins.
  - The carbonate marl-rich Lower Eagle Ford Shale in South Texas
  - The clastic dominated organic basinal shale in East Texas

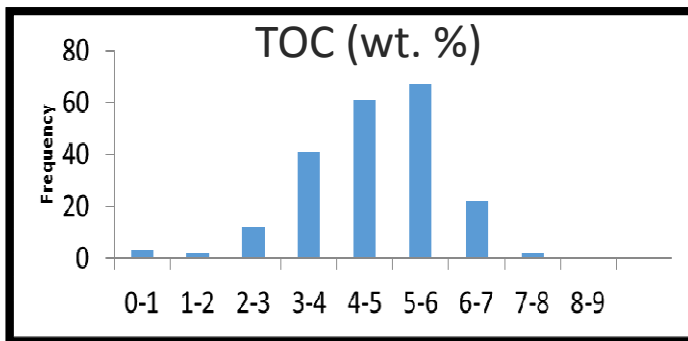
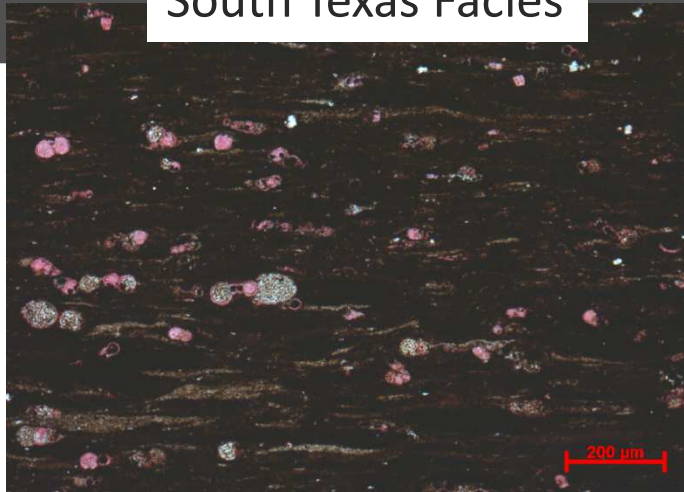


# Schematic Cross Section



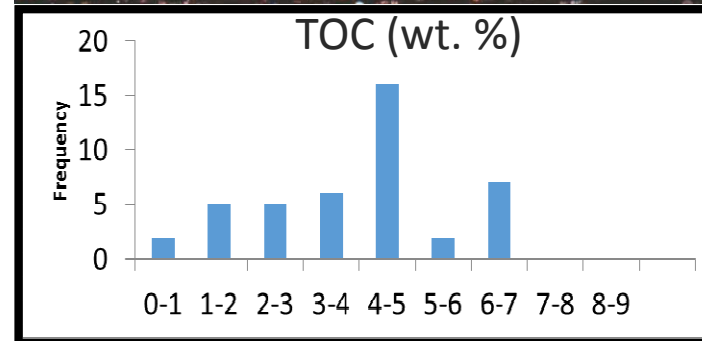
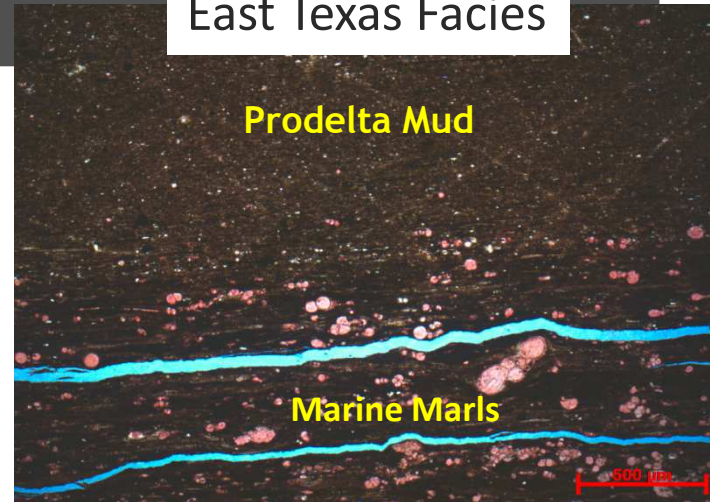
# Facies: South Texas vs East Texas

South Texas Facies



- Type II organics: algae
- Grains are: pellets, planktonic forams, and *Inoceramus*. Less clay and quartz but more calcite

East Texas Facies



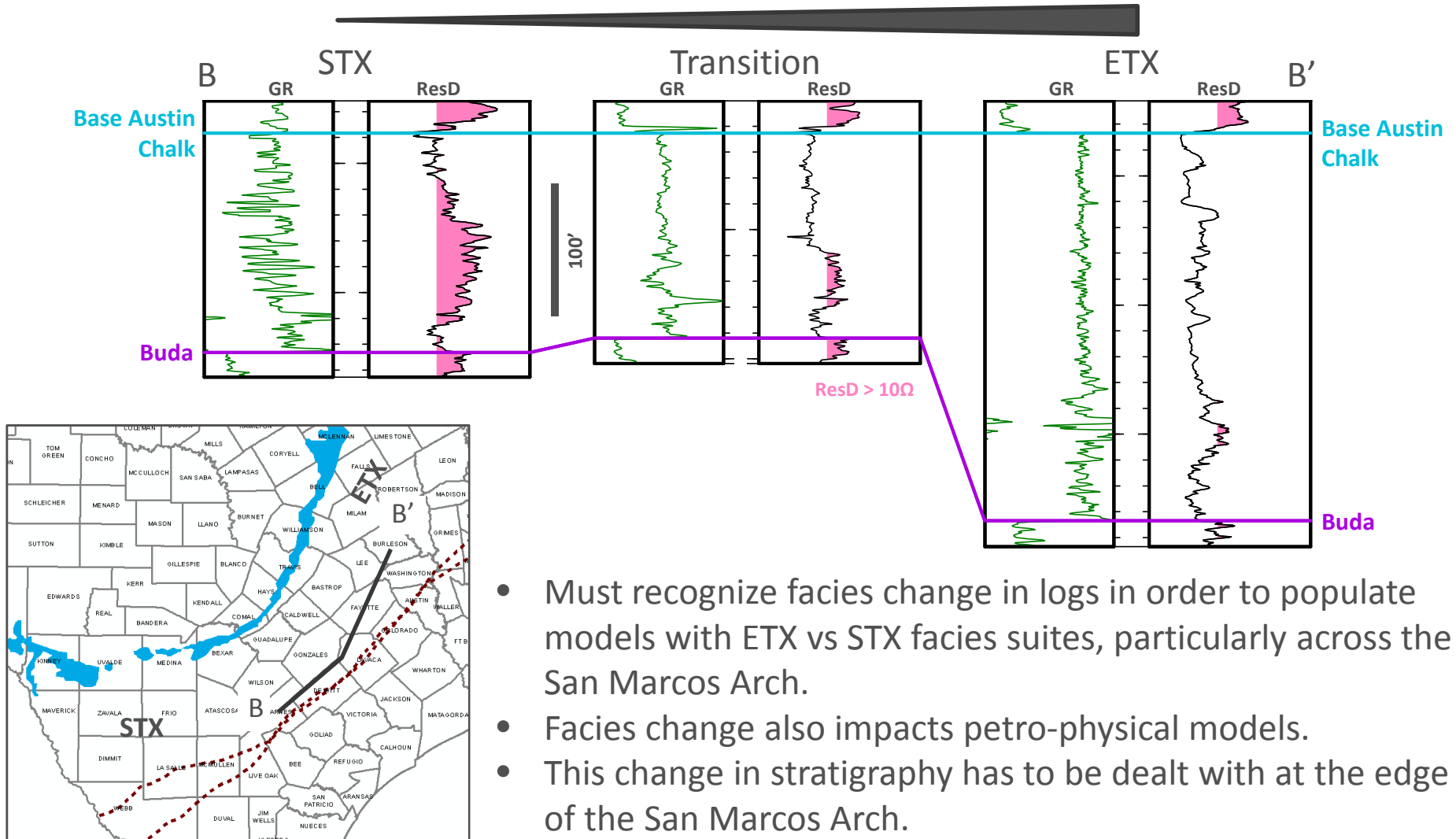
- Higher clay and quartz, lower marine fauna, and less TOC
- More terrestrial OM compared to South Texas EGFD

- Must recognize if a model should be populated with ETX or STX dominated facies as they have different properties.

# Logs: South Texas vs East Texas



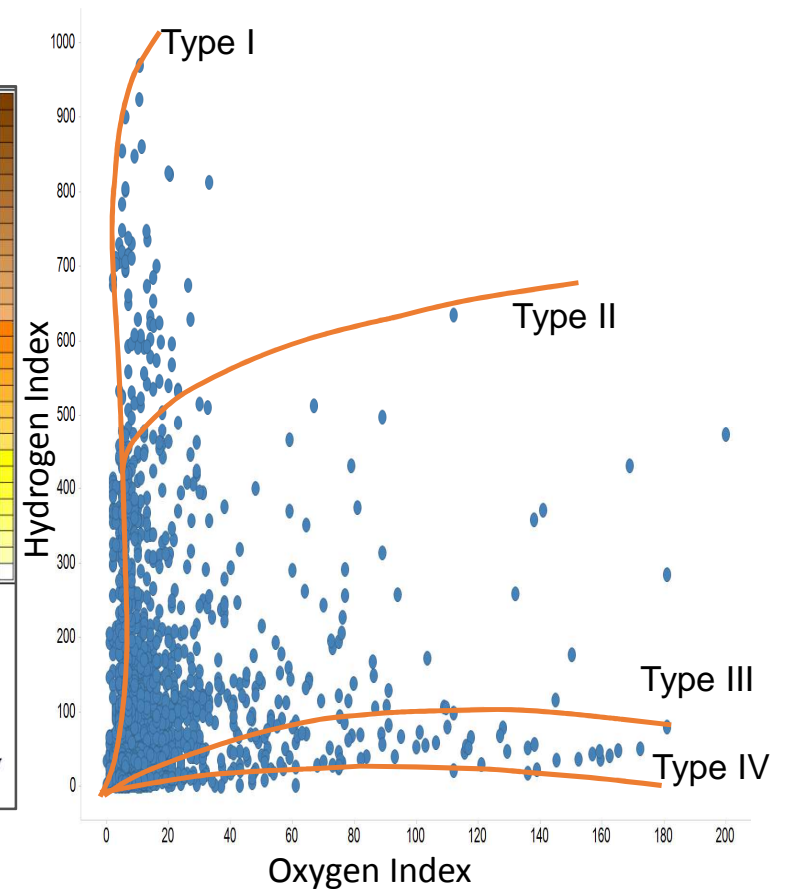
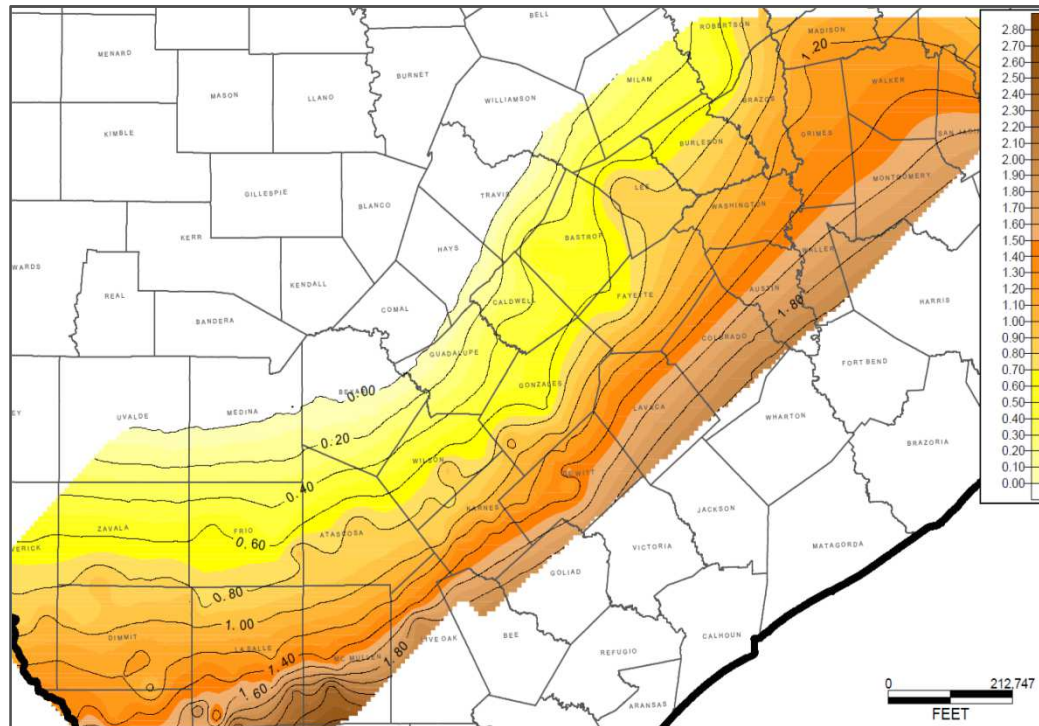
Increasing Clay, QTZ, and terrestrial OM



# Source Rock Geochemistry



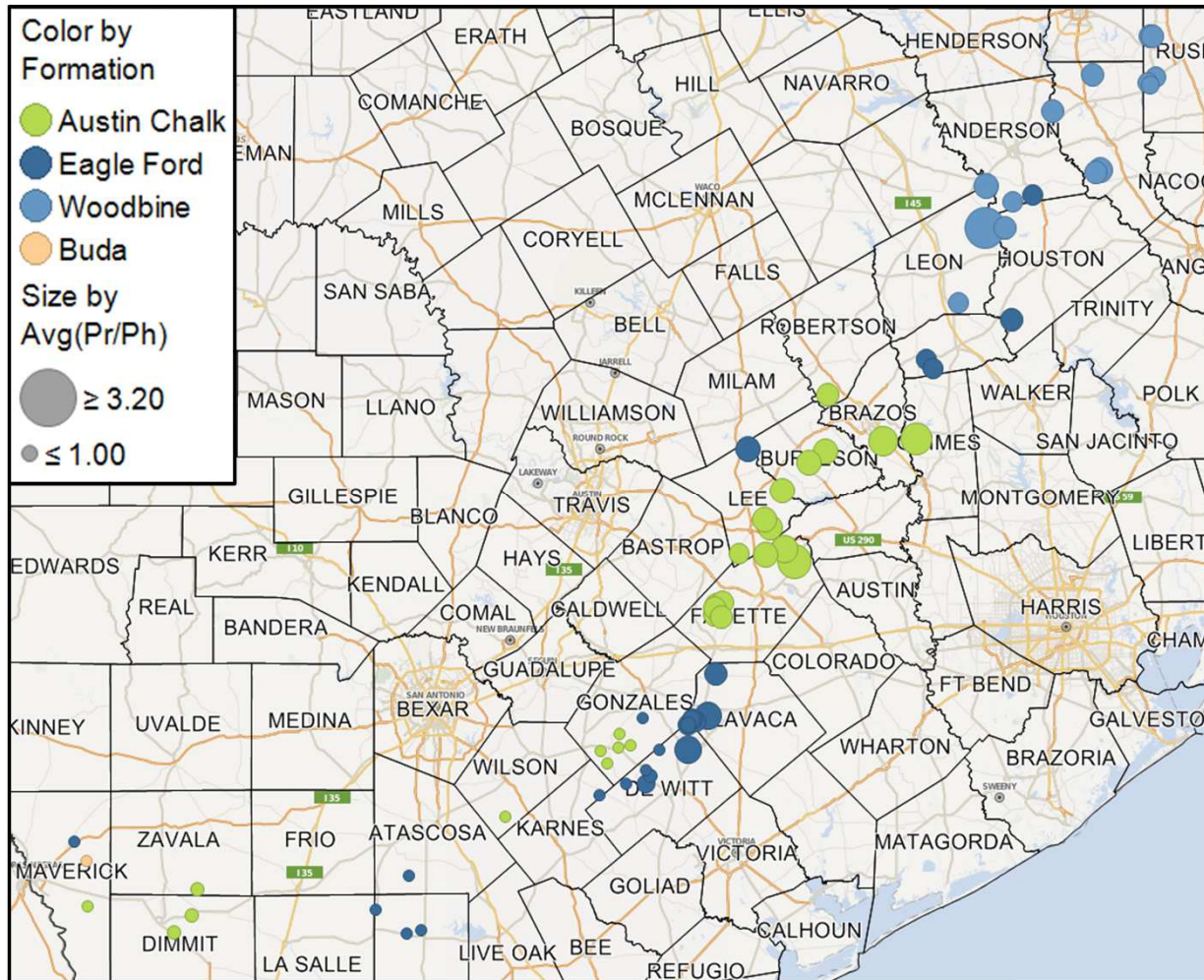
Thermal Maturity (EGFD)



- Based on 2,353 TOC analyses across the entire play, the Eagle Ford average TOC is 3.43%
- Significantly Type II organic matter with some terrestrial organic matter in the East Texas



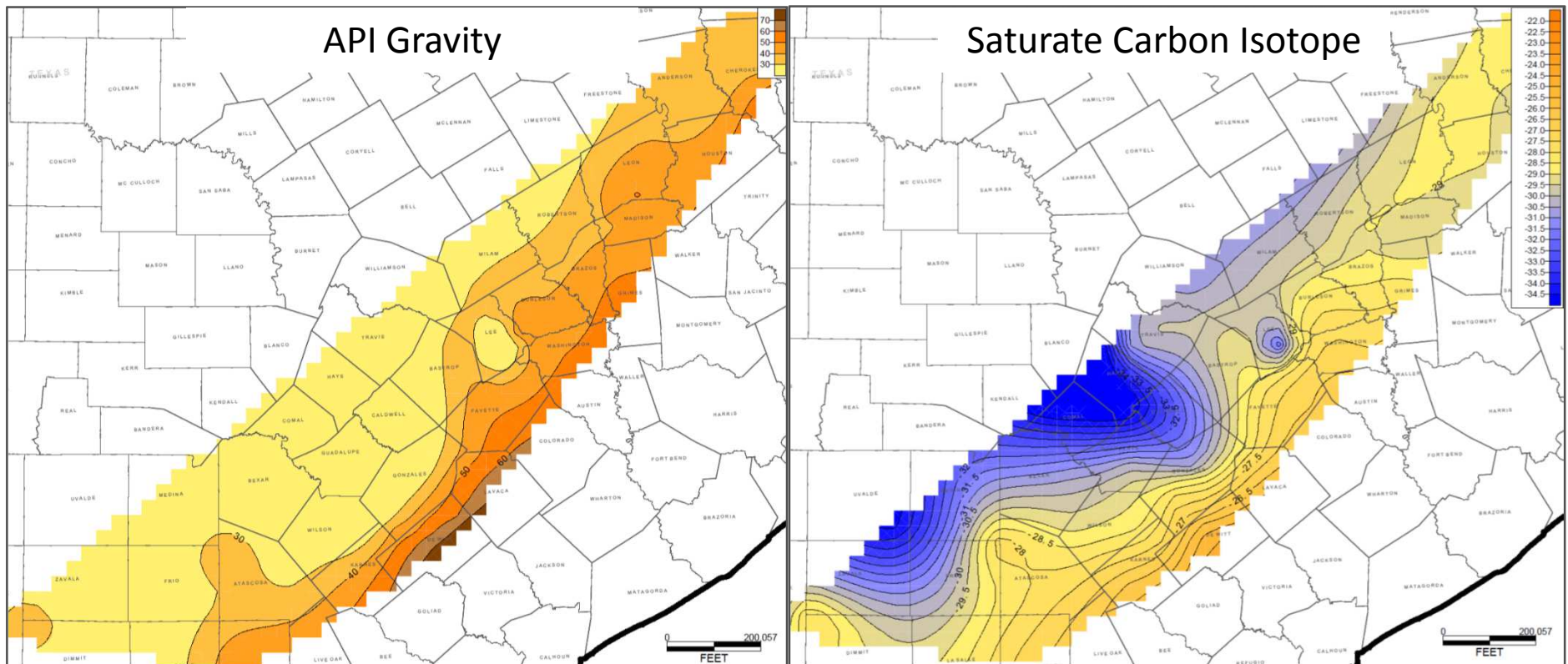
# Produced Oil Geochemistry



- ✓ S wt. %
- ✓ API Gravity
- ✓ Whole Oil GC
- ✓ Isoprenoids (Pr/Ph)
- ✓ Carbon isotopes
- ✓ Saturate biomarkers
- ✓ Aaromatic biomarkers

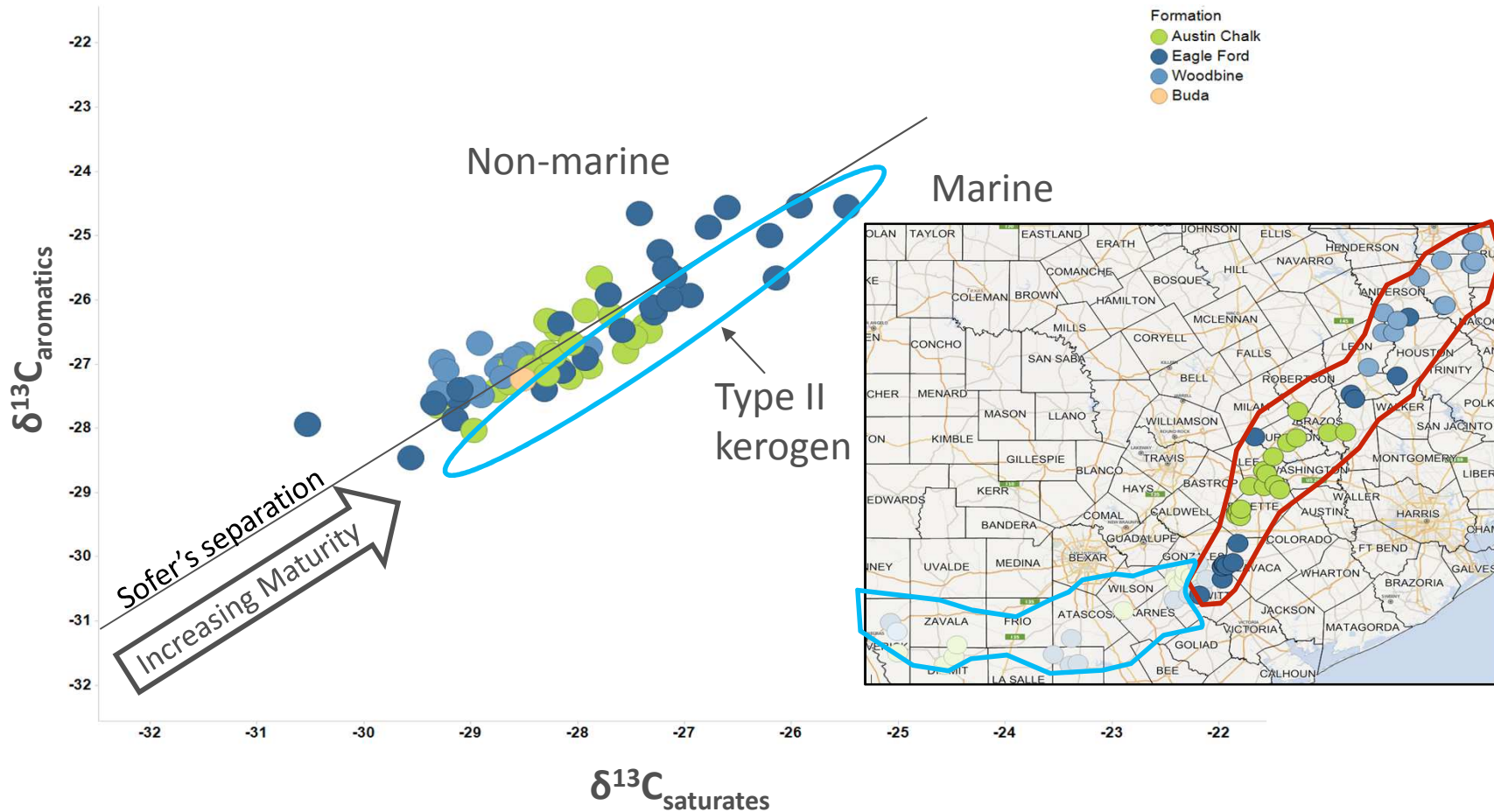


# API Gravity and Carbon isotope



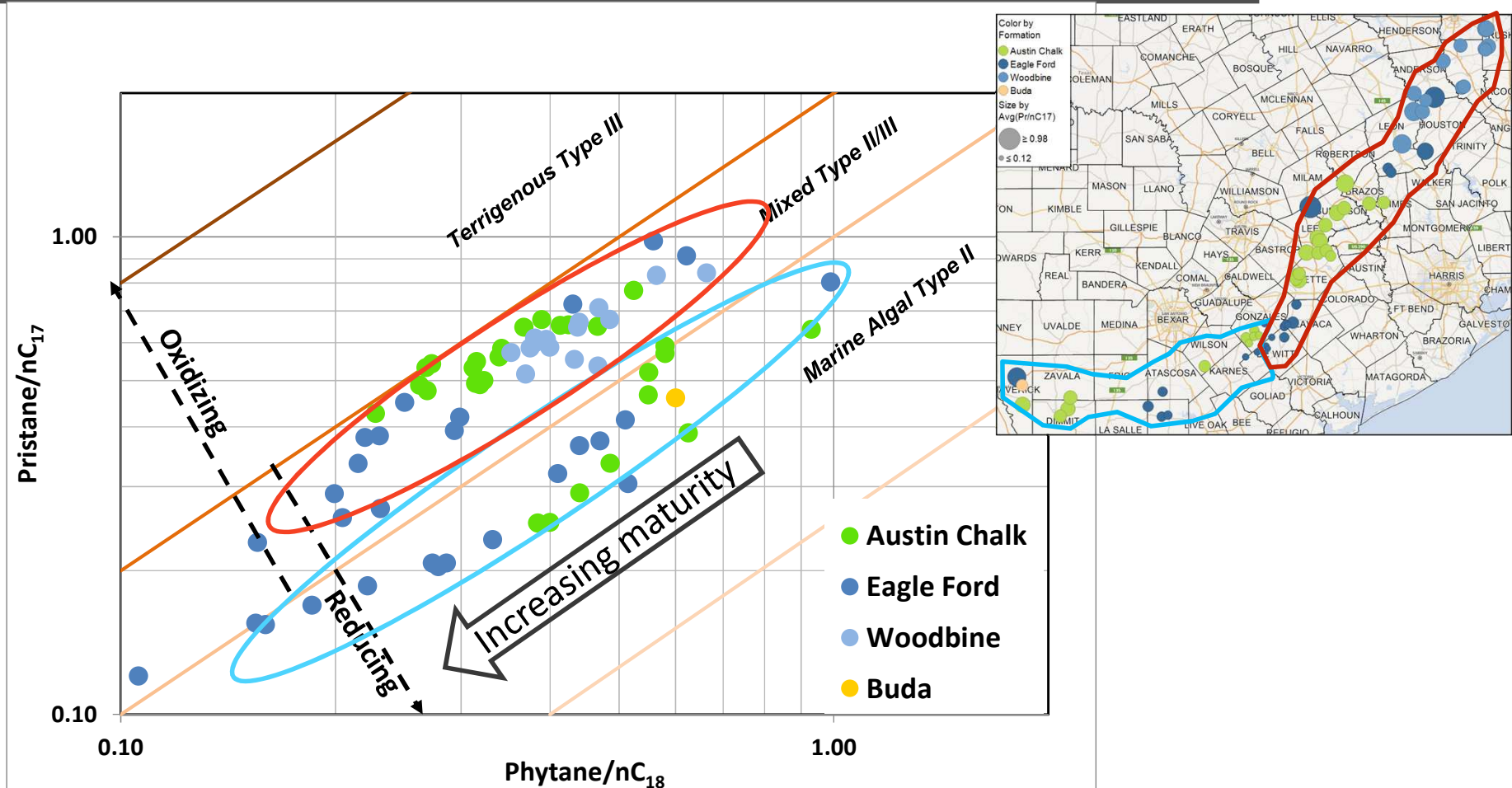
- API gravity reflects the respective petroleum fluid behavior and thermal maturity or VRE
- Carbon isotope ratios from saturated portion of oil follow the same trend
- These data can be very predictive tools for reservoir fluid phases such as gas-oil ratio (GOR)

# Carbon Isotope



- Arrow indicates  $\delta^{13}\text{C}$  in oils become heavier with increasing maturity
- East Texas oils show mixed type kerogen; and South Texas oils show Type II/IIS kerogen

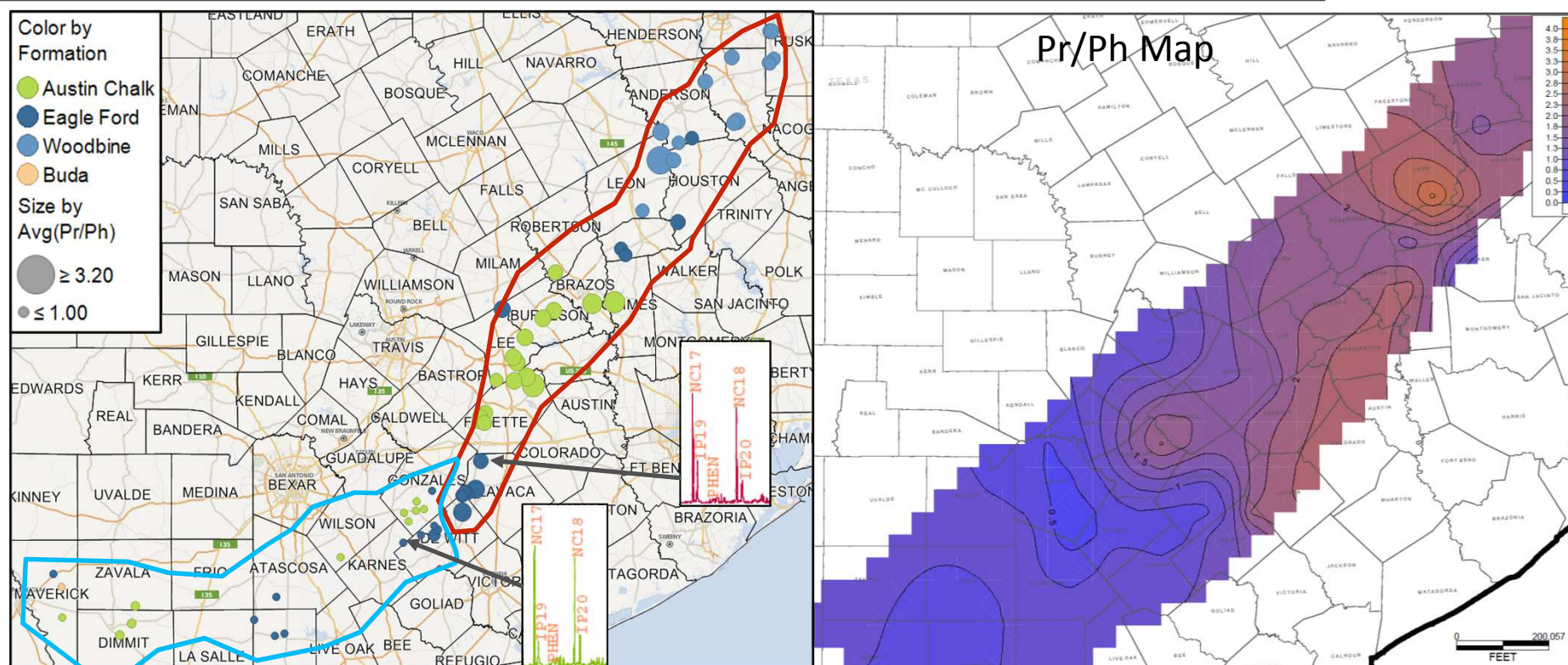
# Depositional Environment and Kerogen Type



- South Texas oils show algae dominant facies and reduced environment
- East Texas oils show strongly mixed kerogen facies and oxidizing environment

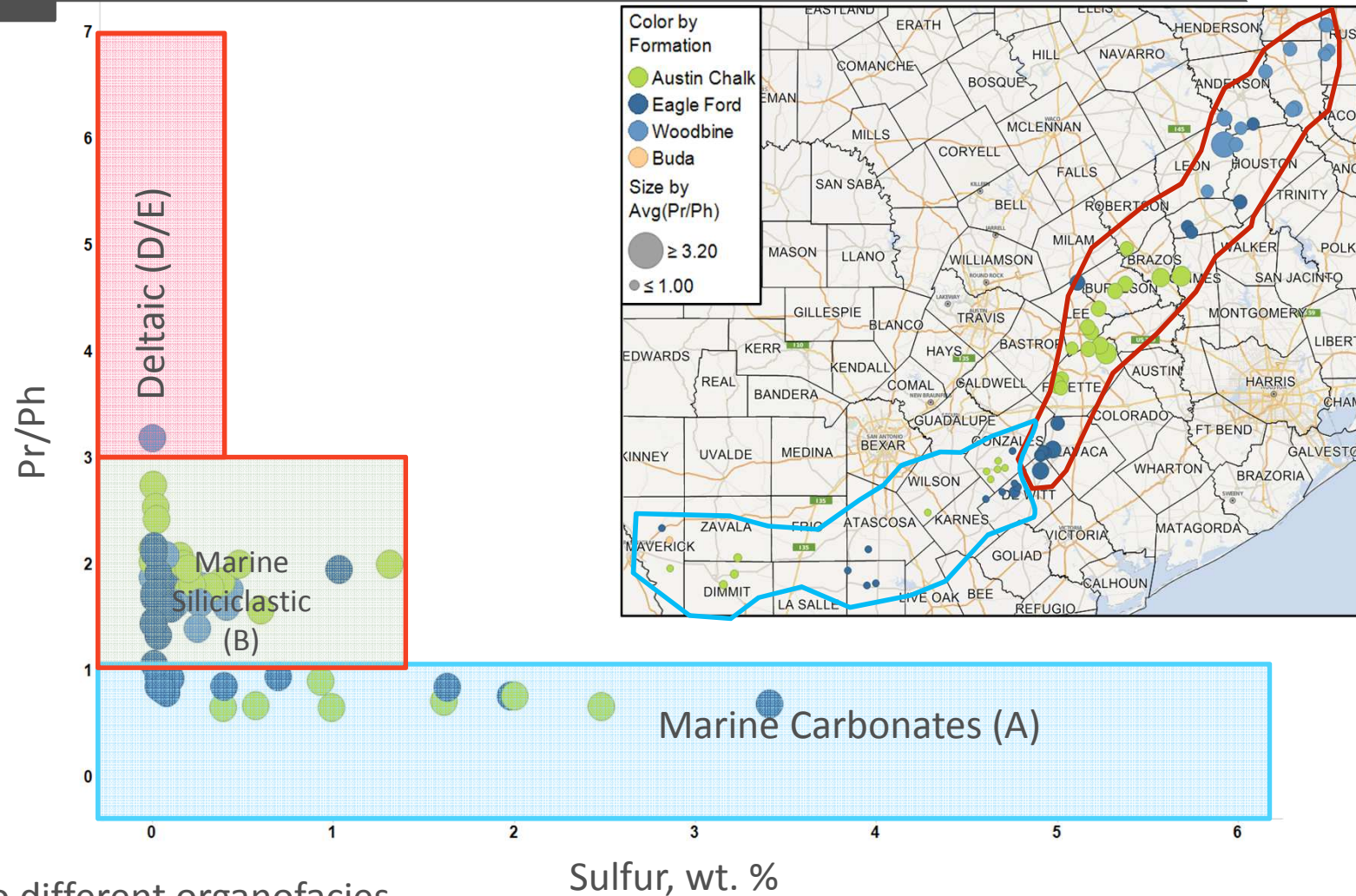


# Pr/Ph Ratios



- Pr/Ph ratio of  $\sim < 1$  from oils produced in South or South-West Eagle Ford suggests dominantly Type II organic matter.
- Oils produced in Northeast or East Texas show higher Pr/Ph ratios of  $\sim > 1$ , suggesting siliciclastic marine Type II organic matter with dominant terrestrial cuticles and spores from plants.

# Organofacies: Pr/Ph vs. Sulfur

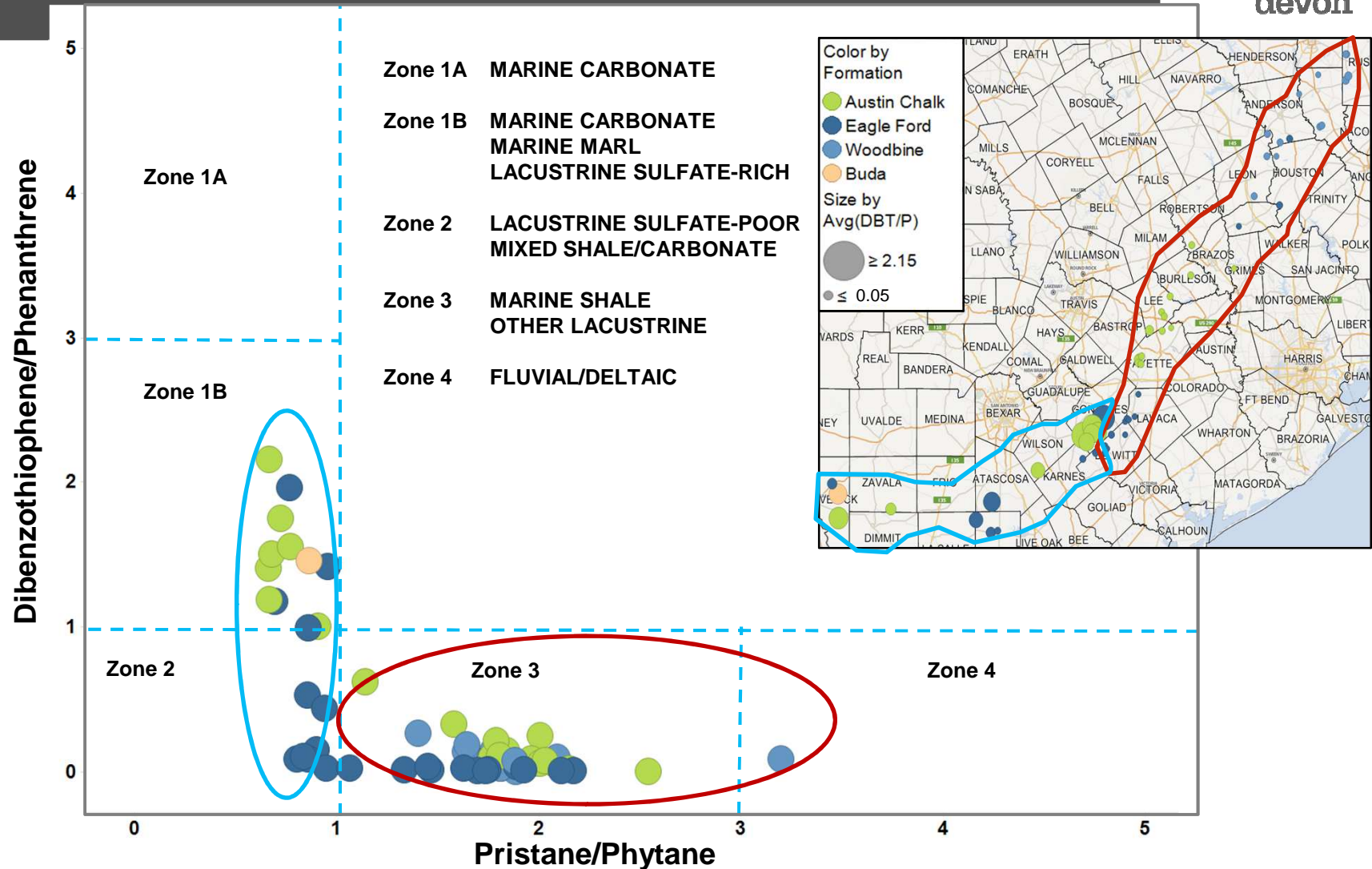


- Two different organofacies
- South Texas strongly shows carbonate dominant source facies compared to East Texas



# Aromatic and Saturate Biomarkers

Source rock Lithofacies

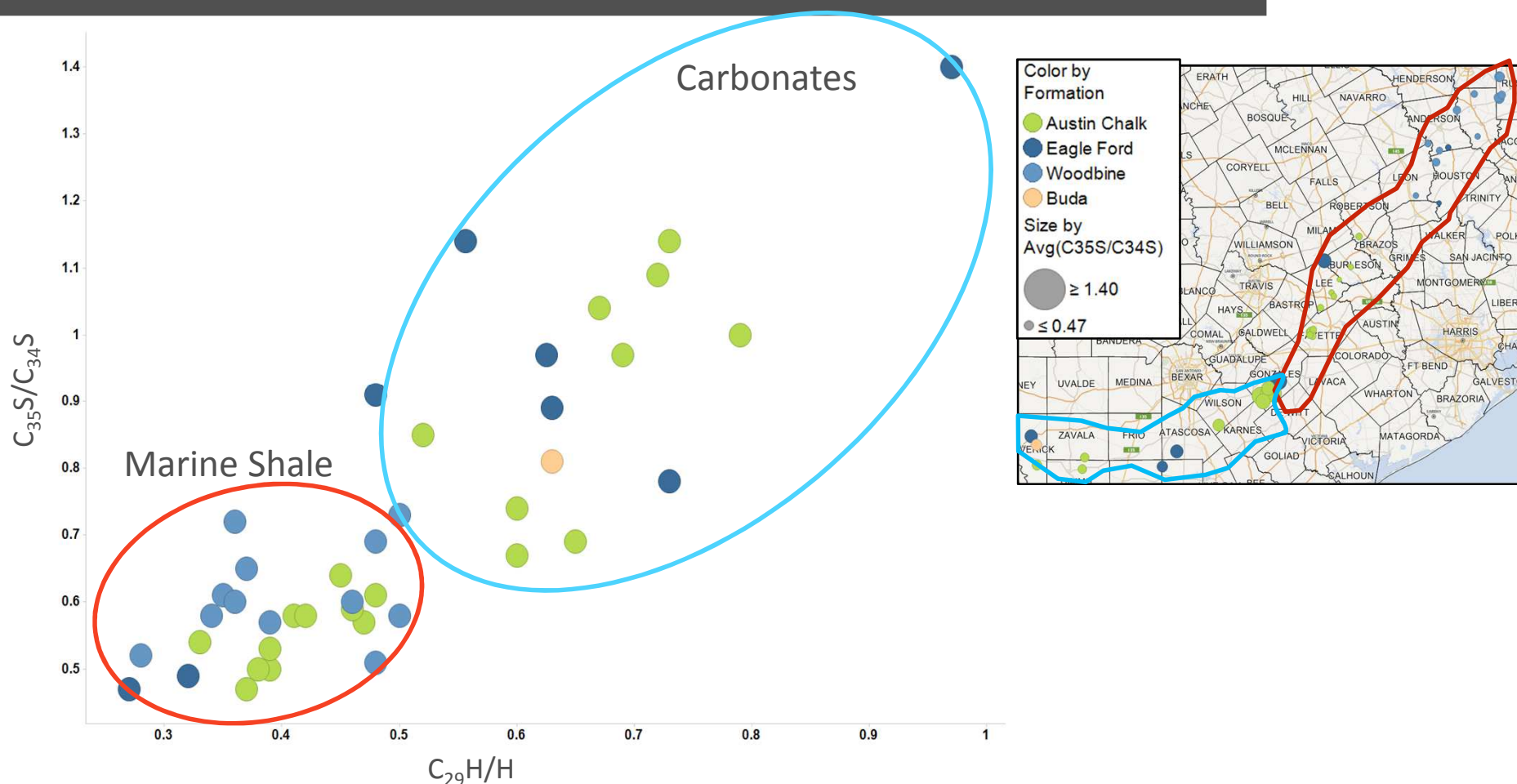


- South Texas strongly shows carbonate marl dominant source facies compared to East Texas. Almost all East Texas Oils show very low DBT/P ratios

Hughes et al., 1995

# Saturate Biomarkers

$C_{35}S/C_{34}S$  vs  $C_{29}H/H$



- Carbonate facies sourced oils in South Texas show high hopane ( $C_{29}H/H$ ) and homohopane ( $C_{35}S/C_{34}S$ ) ratios
- Mixed facies sourced oils in East Texas have low hopane and homohopane ratios

Zumberge et al. 2005

# Conclusions



- The South Texas Lower Eagle Ford Shale reservoir facies is dominated by organic-rich, relatively low clay, foraminifera-rich, coccolith mudstones/marlstones, whereas the superficially equivalent source rock in East Texas has a much more dominant terrestrial influence.
- Produced oil's chemistry strongly suggest:
  - South Texas oils are from a carbonate marl facies (Type II/IIS).
  - East Texas oils are from a siliciclastic dominated Type II marine shale.

# Acknowledgements



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Thank you.