Creating a 3-D Hydrocarbon Profile in the Eagle Ford Shale Play*

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Update of "Creating a 3-D Hydrocarbon Profile in the Eagle Ford Shale Play and Relating that Information to Field Production", Search and Discovery article #51093.

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Abstract

Shale plays are an extremely difficult arena in which to explore. Lack of heterogeneity is not the only problem. The Eagle Ford play, for example, has numerous hydrocarbon sources and multiple stacked zones. These multiple stacked pays result in mixed drilling success with both economic and noneconomic drilling results. In addition, there are numerous migration pathways in various parts of the field and charge source or kitchen vary with placement in the field as well. Amplified Geochemical Imaging and Downhole Geochemical Logging technologies are two applications that can be used in conjunction to provide a 3-dimentional hydrocarbon profile to enhance understanding and success in unconventional exploration.

Amplified Geochemical Imaging is a direct surface hydrocarbon measurement technique that measures the vertical migration of volatile hydrocarbon compounds from subsurface reservoirs. These microseepage hydrocarbon compounds, up to C20, can be captured and measured at the surface resulting in the ability to identify and map subsurface hydrocarbon systems as well as clearly differentiate between various hydrocarbon phases, such as gas, condensate, or oil. These hydrocarbon maps provide a horizontal assessment of hydrocarbons across the field and can then be used to demarcate transition lines between the various hydrocarbon phases and direct exploration efforts to areas of higher profitability. This ability makes Amplified Geochemical Imaging a unique tool as a "predrill" technology.

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Creating a 3-D Hydrocarbon Profile in the Eagle Ford Shale Play

Hydrocarbon Detection in Vertical & Lateral Wells

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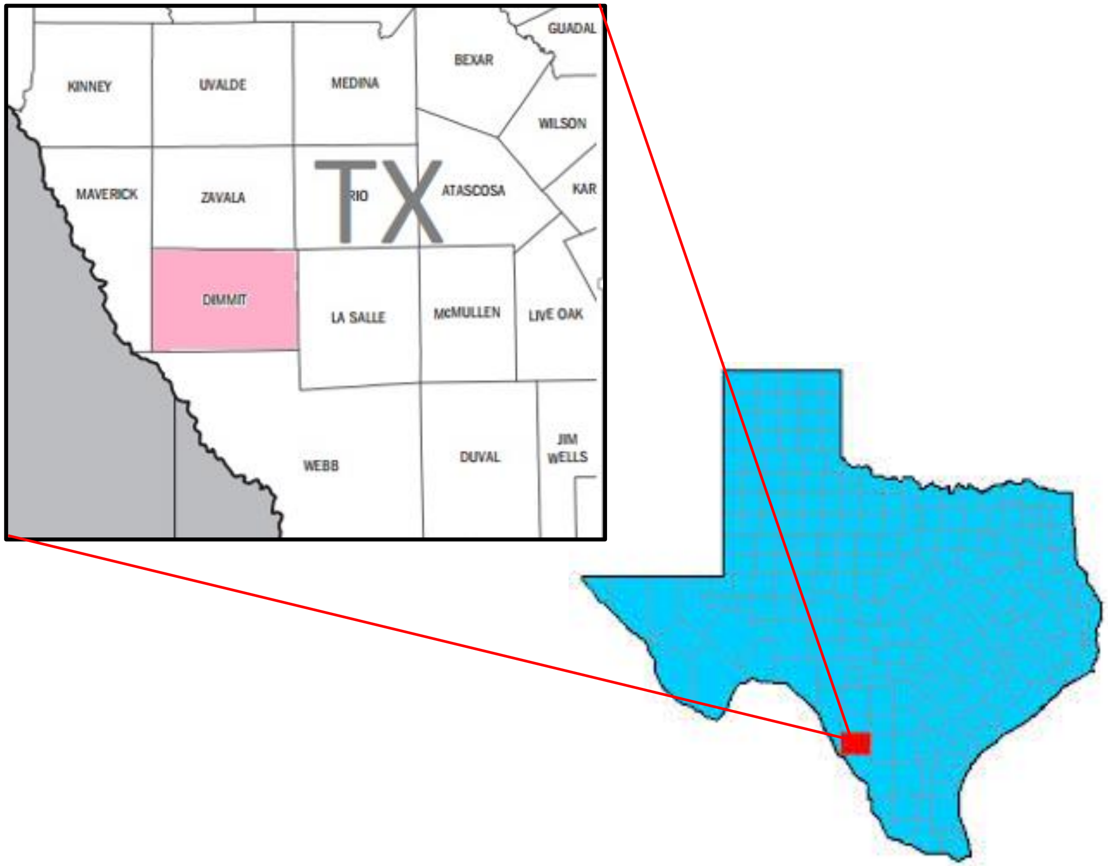
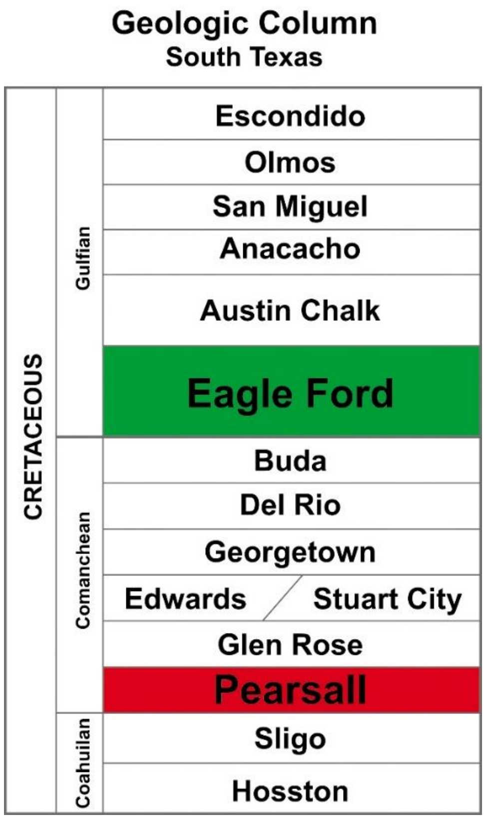
AMPLIFIED GEOCHEMICAL IMAGING, LLC

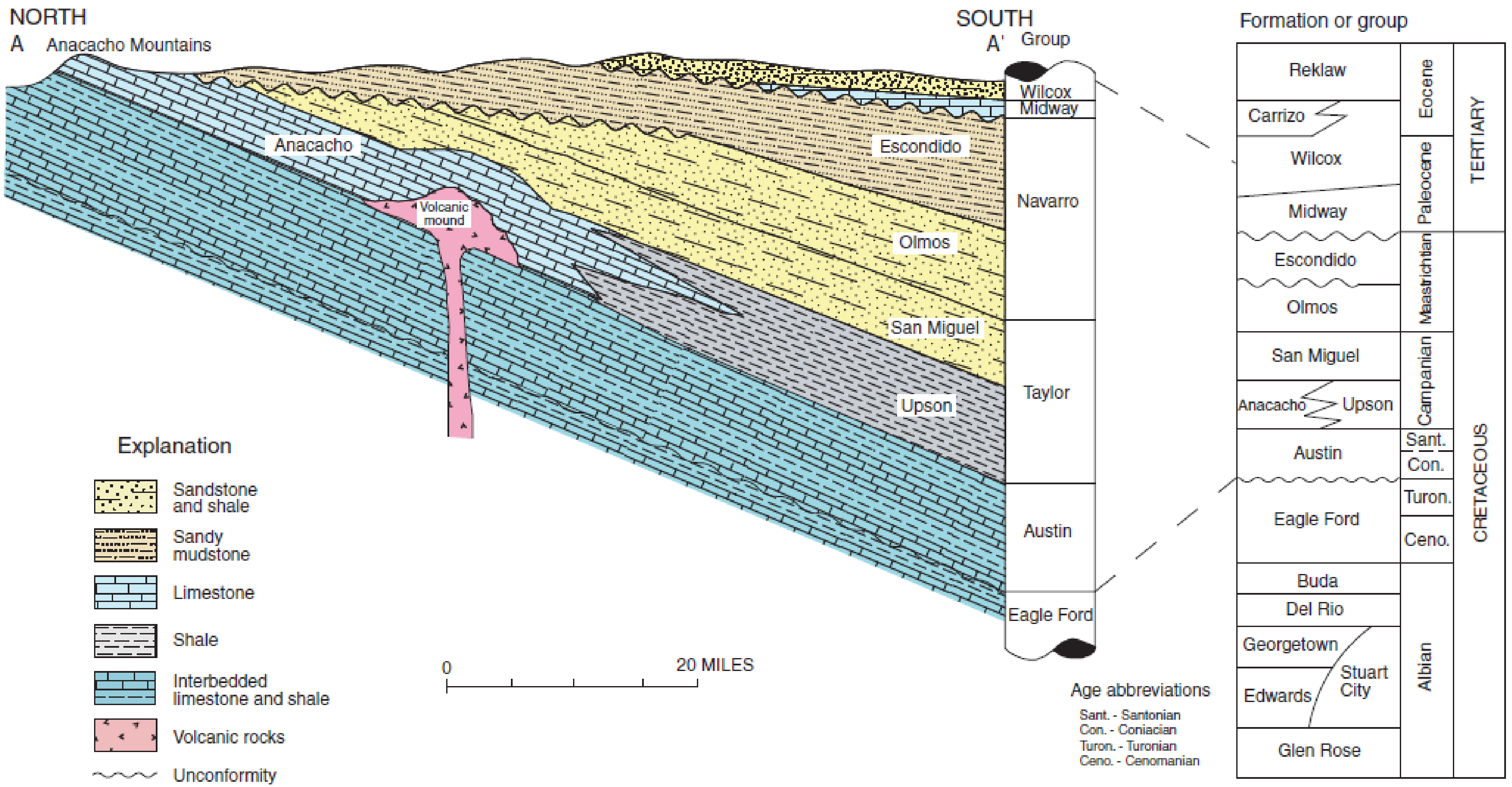
Conventional Hydrocarbon Analyses





The Maverick Basin in Dimmit County

Cross Section of the Maverick Basin



Diagrammatic northwest-southeast cross section through the Maverick Basin (Condon and Dyman, 2003)

Downhole Geochemical Logging

- Cuttings are collected in polypropylene jars, directly from the shaker table during drilling
- Mud blanks are also collected as well
- Analyses normally done in 2 weeks

1,000 time more sensitive than traditional methods

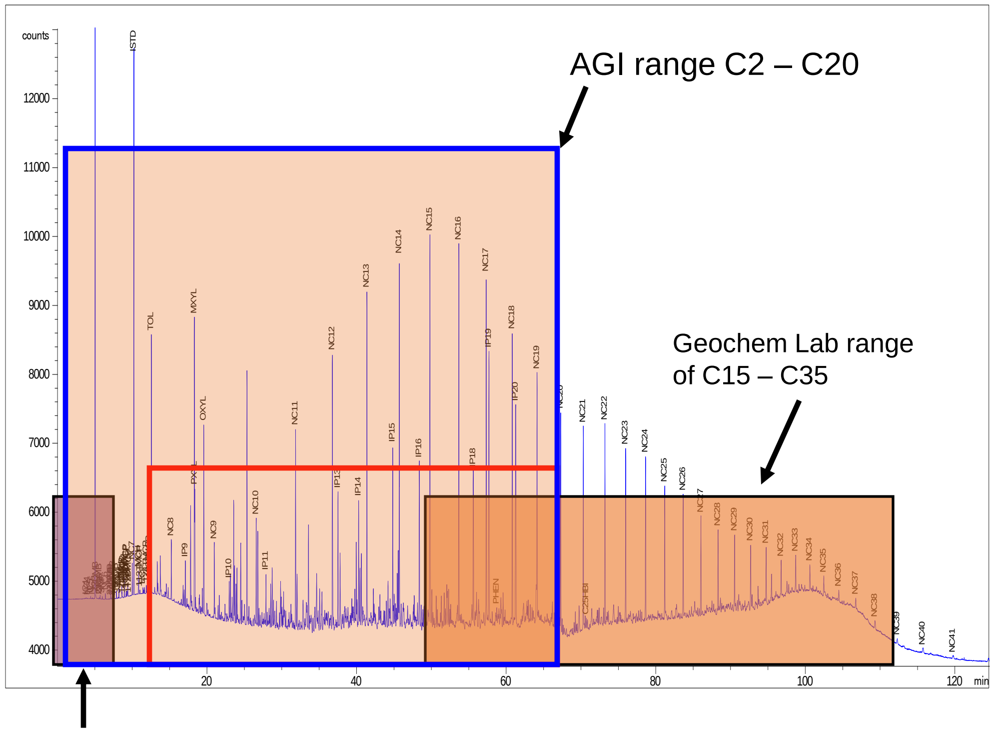
Focuses on hydrocarbon fluids in various zones

- Measures from the C_2 to C_{20} carbon range
- Easily differentiates between multiple phases
- Identifies reservoir compartmentalization
- Identify by-passed pays

Does this work with all drilling muds?

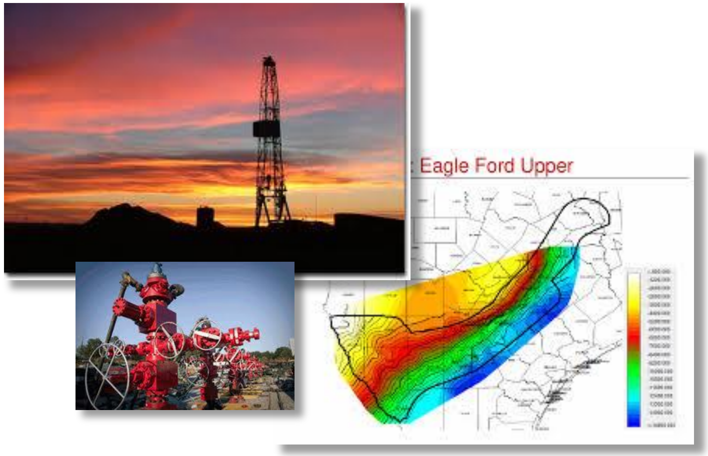
> ***No*** – ***Not with ALL Oil-based muds***

Conventional Hydrocarbon Analyses



Traditional gas
range of C1 – C5

Downhole Geochemical Logging in the First Vertical Eagle Ford Well



Hierarchical Cluster Analysis

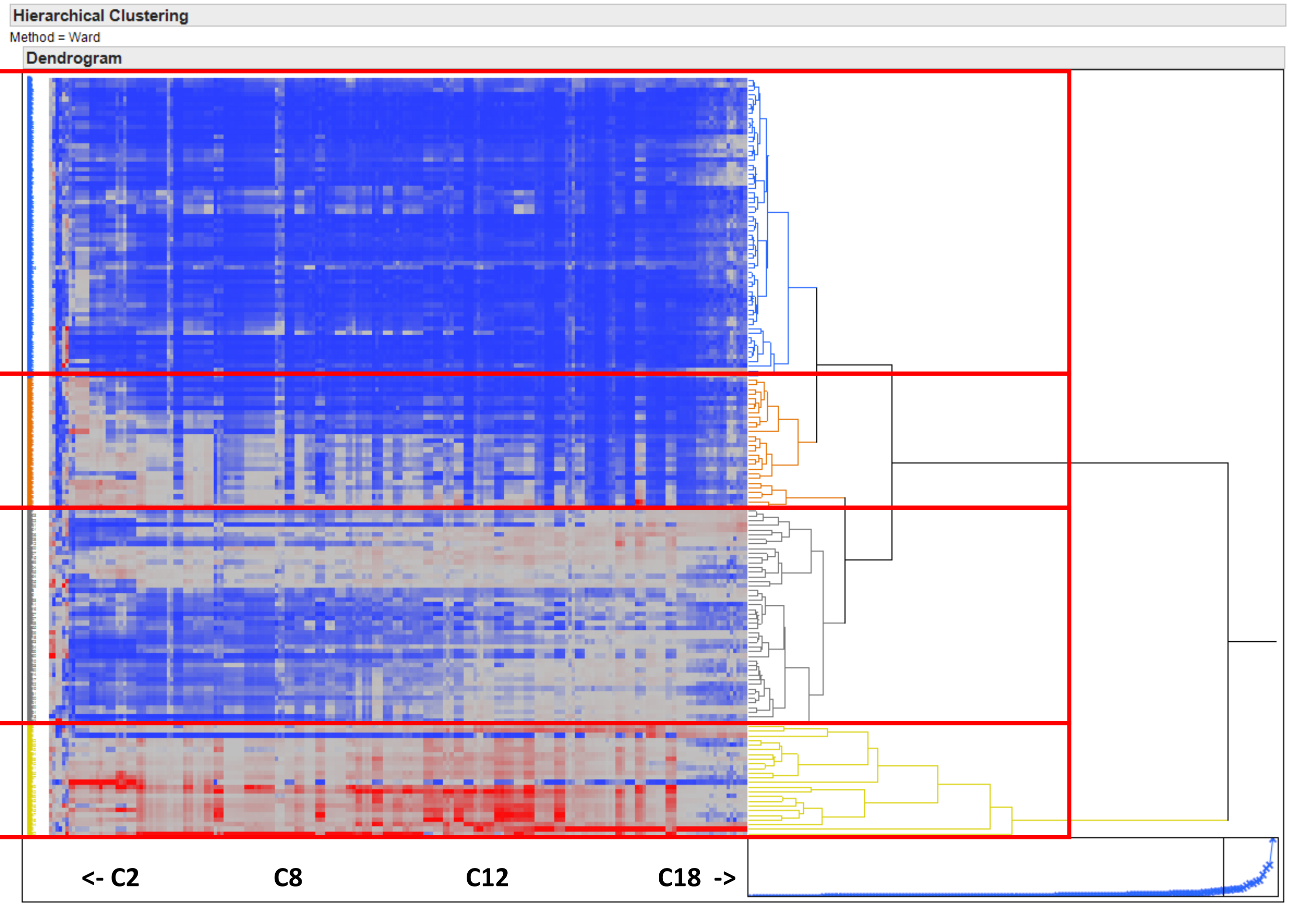
HCA #1 Groups

Primarily Olmos Fm. (Blue) 1A

Primarily San Miguel Fm. & some Olmos Fm. (Orange) 1B

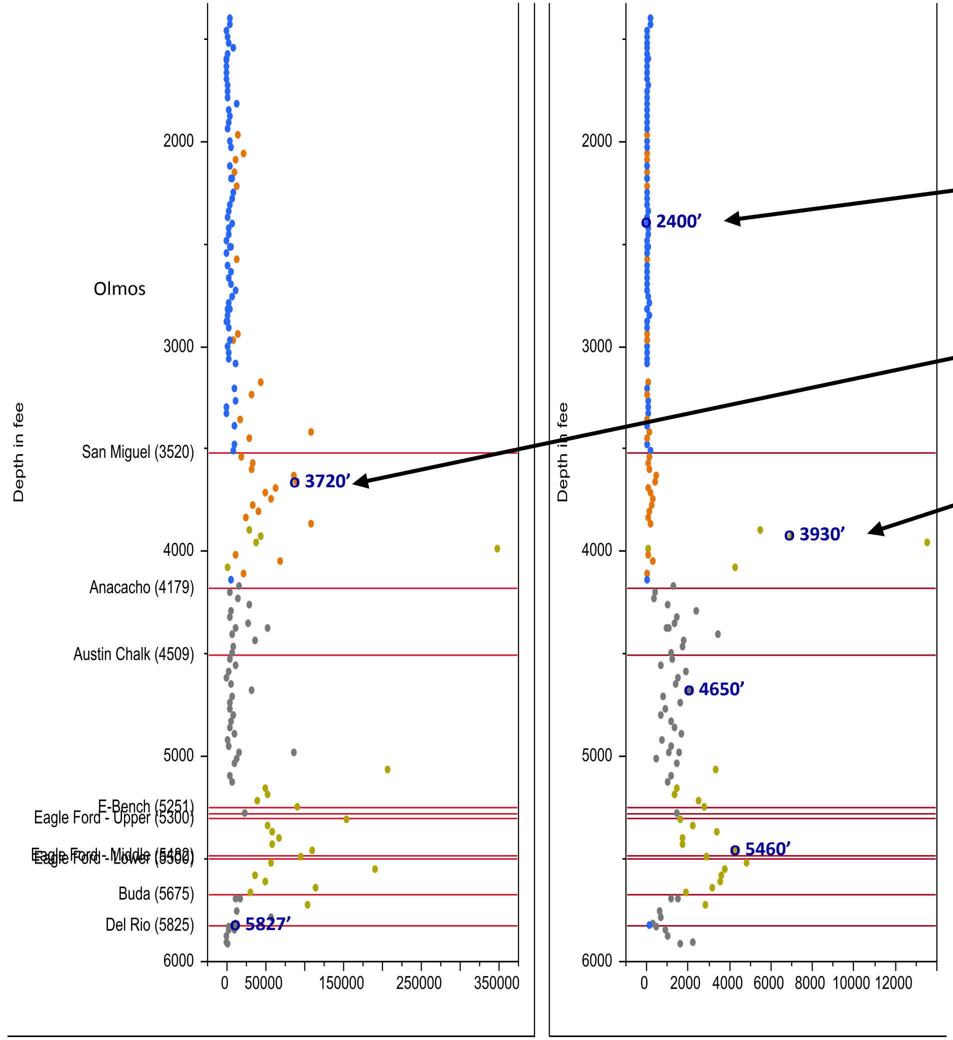
Primarily Anacacho Fm. & Austin Chalk Fm. (Gray) 1C

Primarily Eagle Ford Fm., Buda Fm., & Del Rio Fm. (Yellow) 1D



It is thought that there are three main sources of oil and gas in the assessed formations: Upper Jurassic Smackover Formation and Upper Cretaceous Austin and Eagle Ford Groups. Oils thought to have a Smackover source are mainly found in the far western part of the study area, and oils thought to have an Eagle Ford or Austin source are located in the north-central part; oils having a mixed Smackover–Austin–Eagle Ford origin are produced in the central part of the Maverick Basin (M.D. Lewan, written commun., 2003; S.M. Condon and T.S. Dyman, 2003).

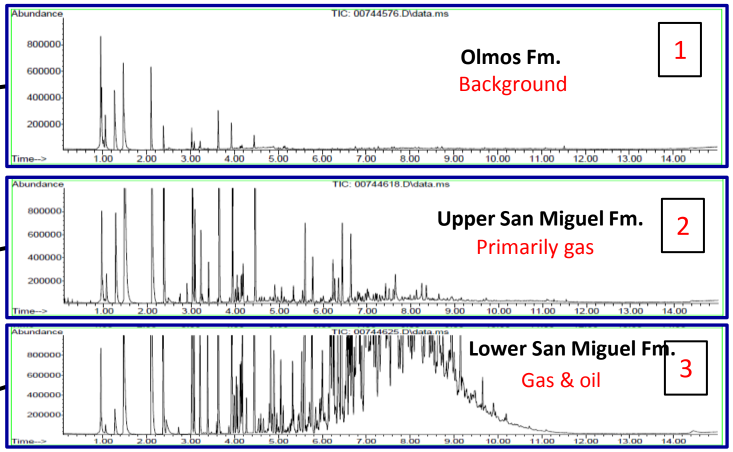
Depth Profile with Fingerprints



Gas Range Sum C2 – C6

Oil Range Sum C10 – C18

Select signatures from various zones showing different hydrocarbon signatures and differing intensities.



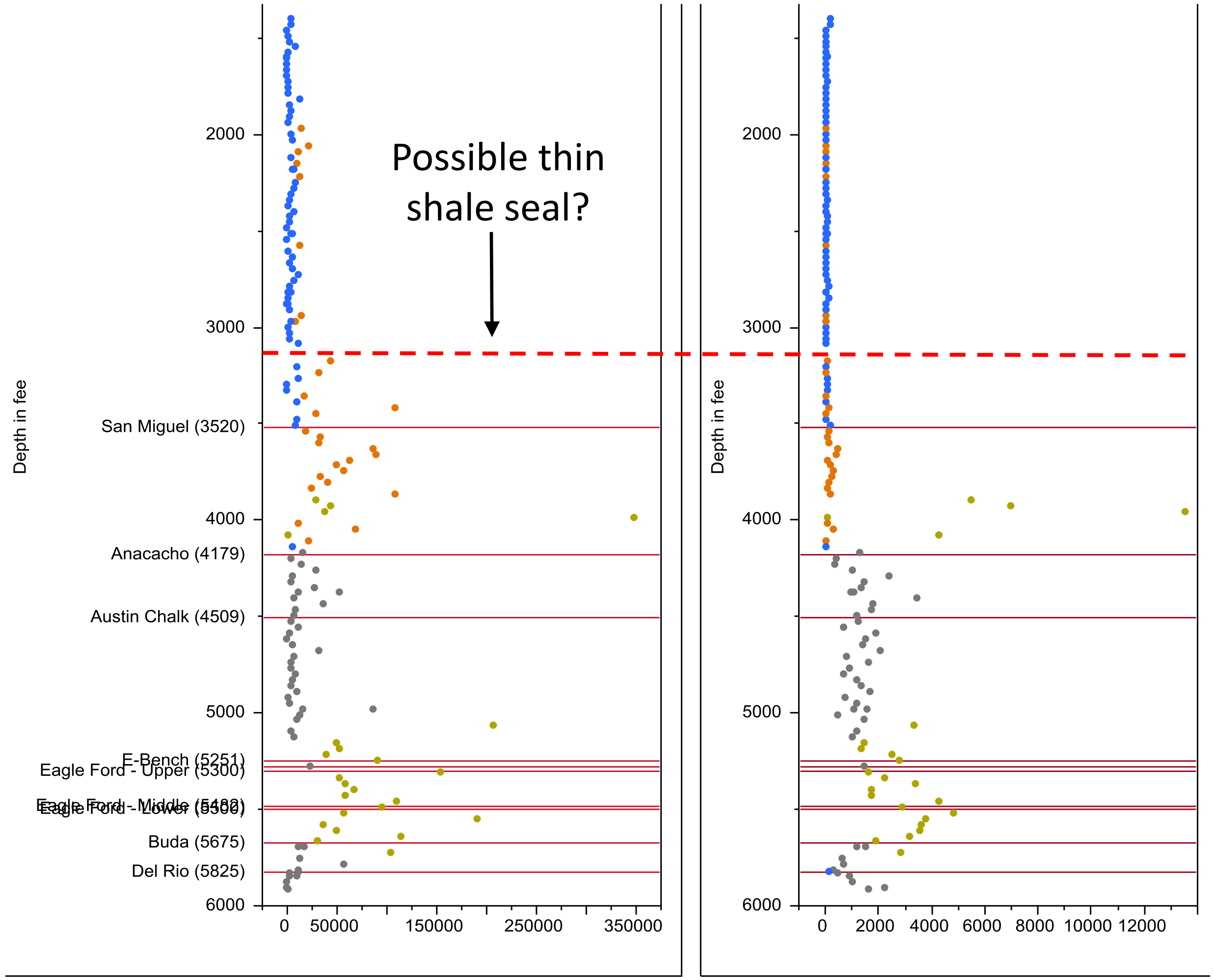
Much of the original porosity of the San Miguel sandstone beds was occluded by kaolinite or calcite cement (Jacka, 1982). Two periods of calcite dissolution created secondary porosity, which was subsequently partly filled by late-stage cements.

Depth Profile

Key Zones of Interest

There appears to be a strong gas-like section in the San Miguel Fm. with a more oil like composition between 3870’ and 4110’. These data also suggest the bottom of the Olmos is not an effective seal as several samples above the San Miguel contain a increased gas response.

> The Olmos Formation in the western depocenter was divided into five sandstone units, which generally coarsen upward and are each less than 150 ft thick, separated by shale breaks (Tyler and Ambrose, 1986).



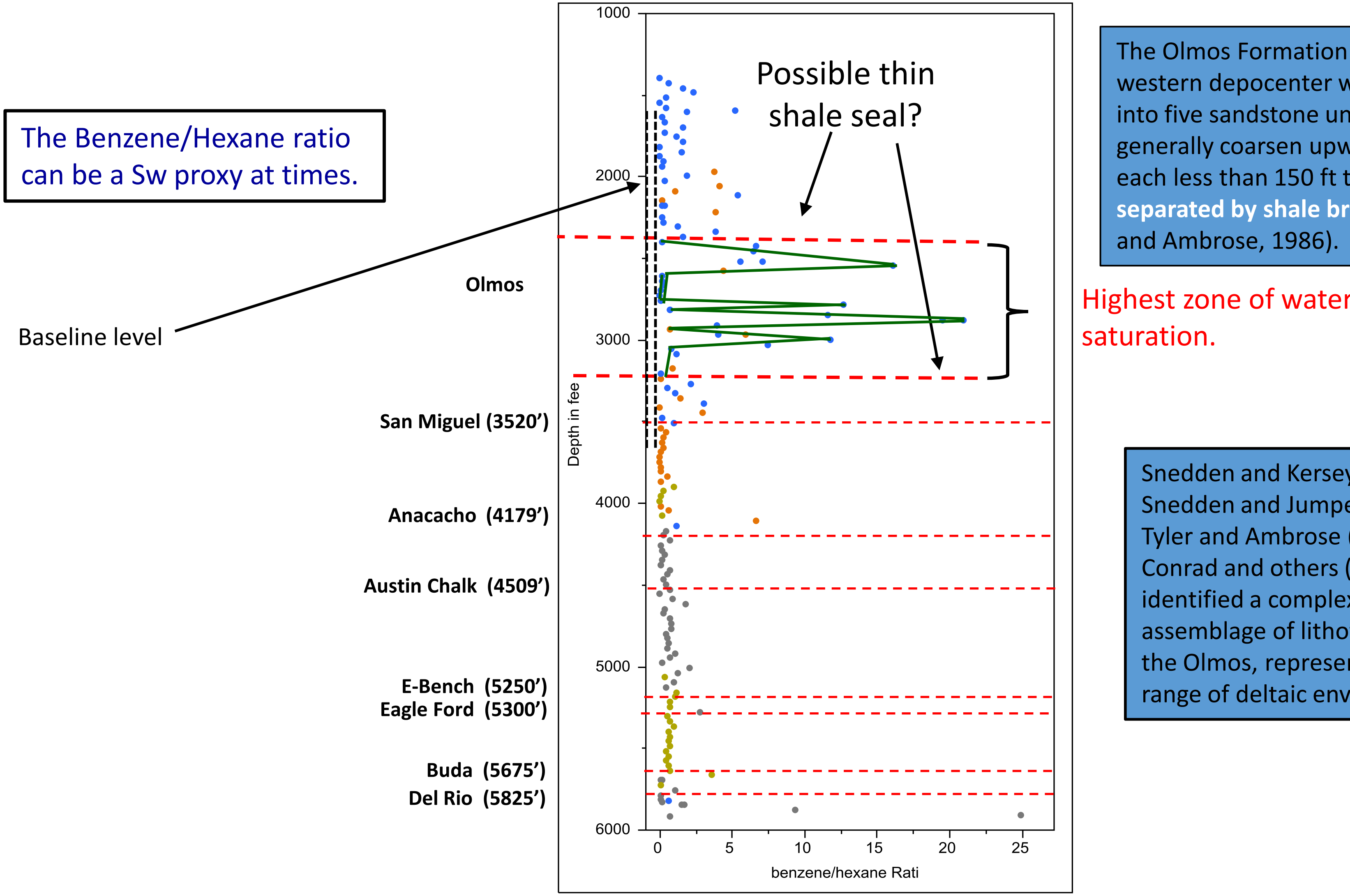
Gas Range Sum C2 – C6

Oil Range Sum C10 – C18

Water Saturation Plot

Depth plot of Benzene/Hexane (nC6)

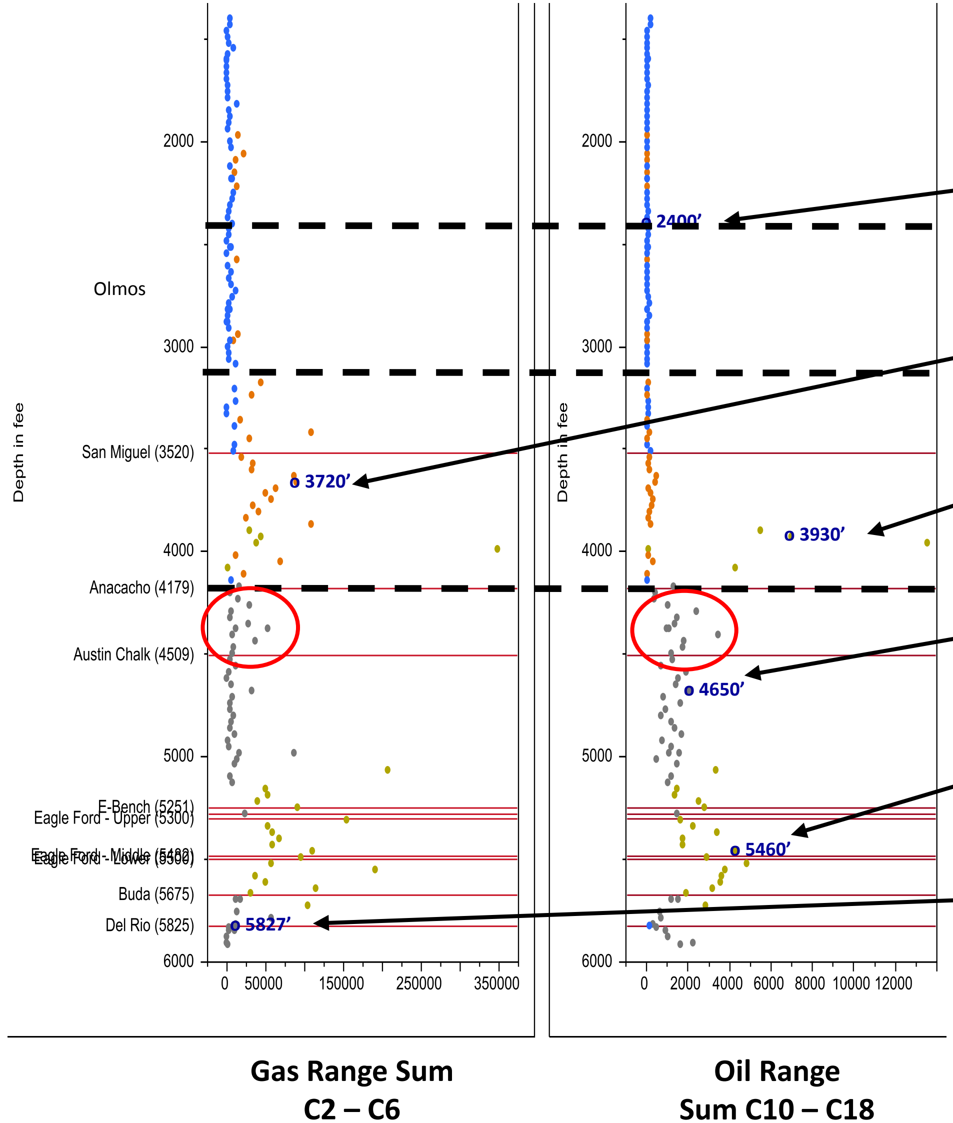
The Benzene/Hexane ratio can be a Sw proxy at times.



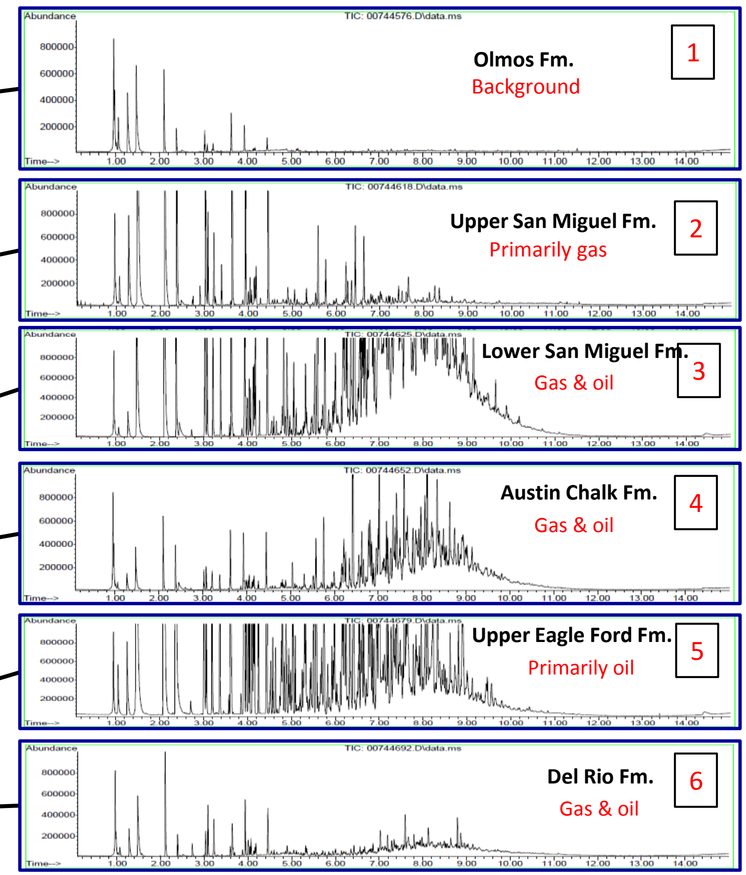
The Olmos Formation in the western depocenter was divided into five sandstone units, which generally coarsen upward and are each less than 150 ft thick, **separated by shale breaks** (Tyler and Ambrose, 1986).

Snedden and Kersey (1982), Snedden and Jumper (1990), Tyler and Ambrose (1986), and Conrad and others (1990) identified a complex assemblage of lithofacies within the Olmos, representing a range of deltaic environments.

Depth Profile with Hydrocarbon Fingerprints



Select signatures from various zones showing different hydrocarbon signatures and differing intensities.



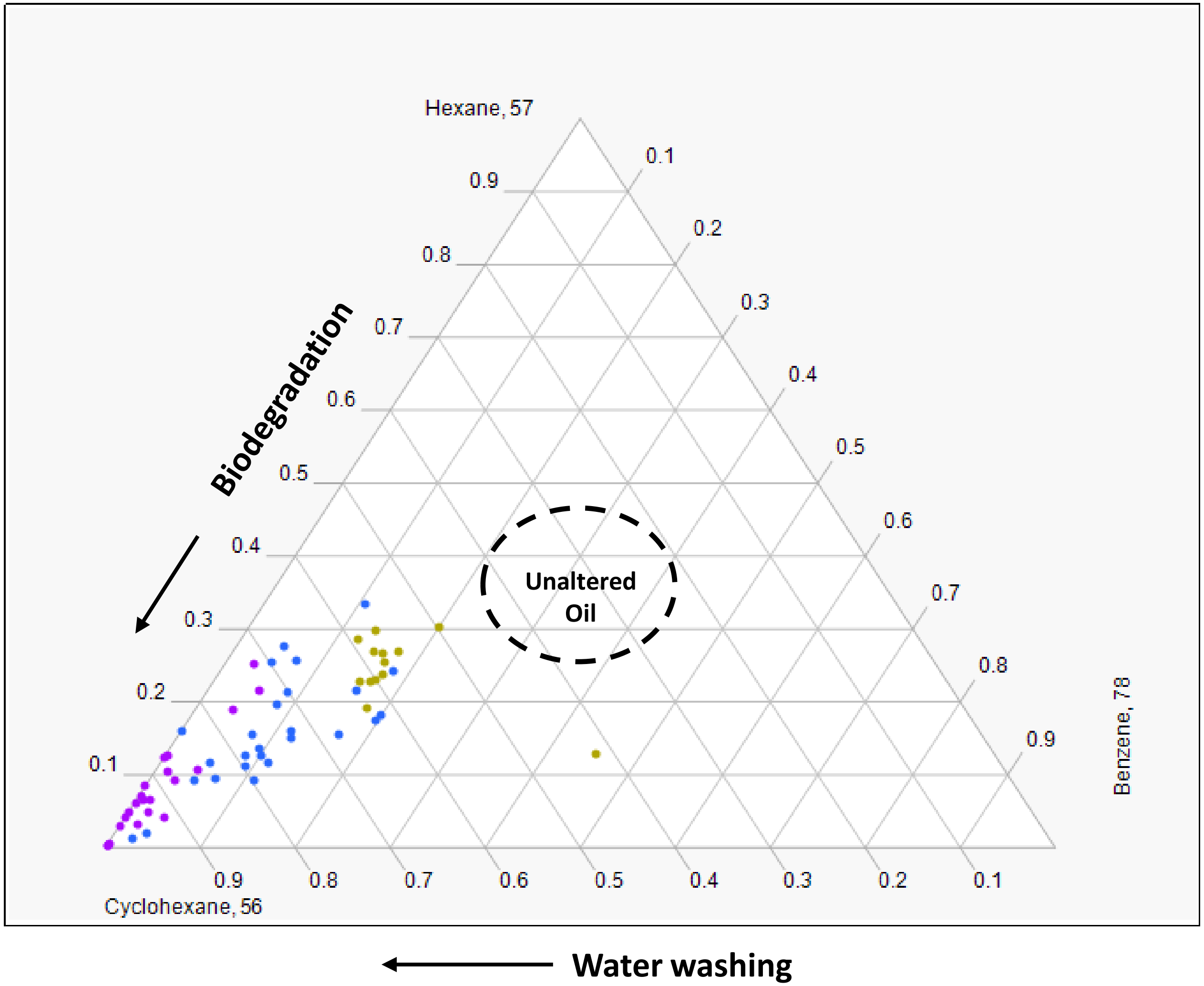
The causes of the reduction in porosity and permeability in the Austin Chalk are carbonate recrystallization, which resulted from compaction and pressure solution, and crystallization of secondary ferroan calcite as cement (Dravis, 1981).

Oil Alteration Plot

The geochemistry data seems to indicate a separate source for the San Miguel Fm.

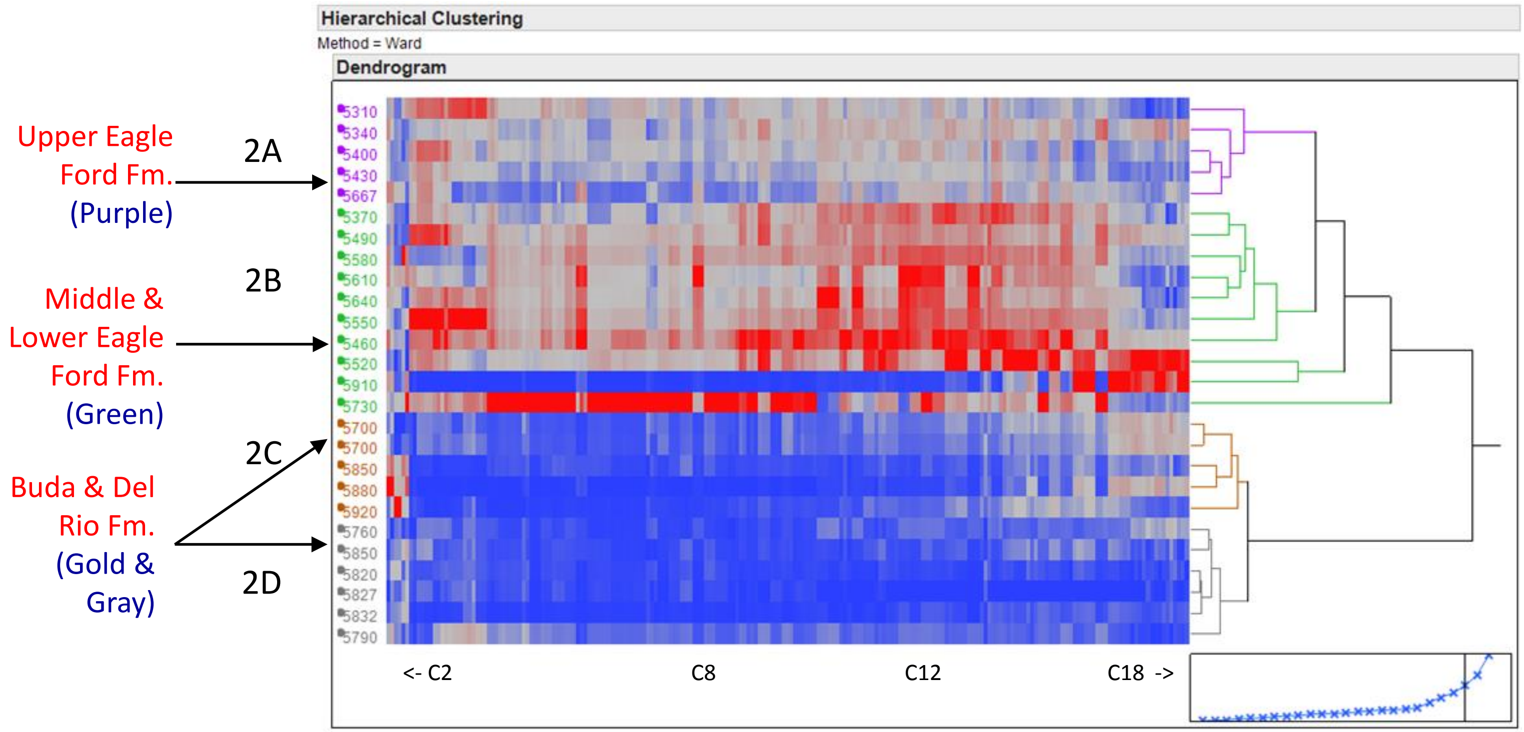
This C6 ternary plot shows that the Eagle Ford samples are more typical of an unaltered oil signature, and there appears to be increased oil alterations (i.e. water washing and/or biodegradation) as you move through the Austin Chalk & San Miguel.

- San Miguel
- Austin Chalk
- Eagle Ford

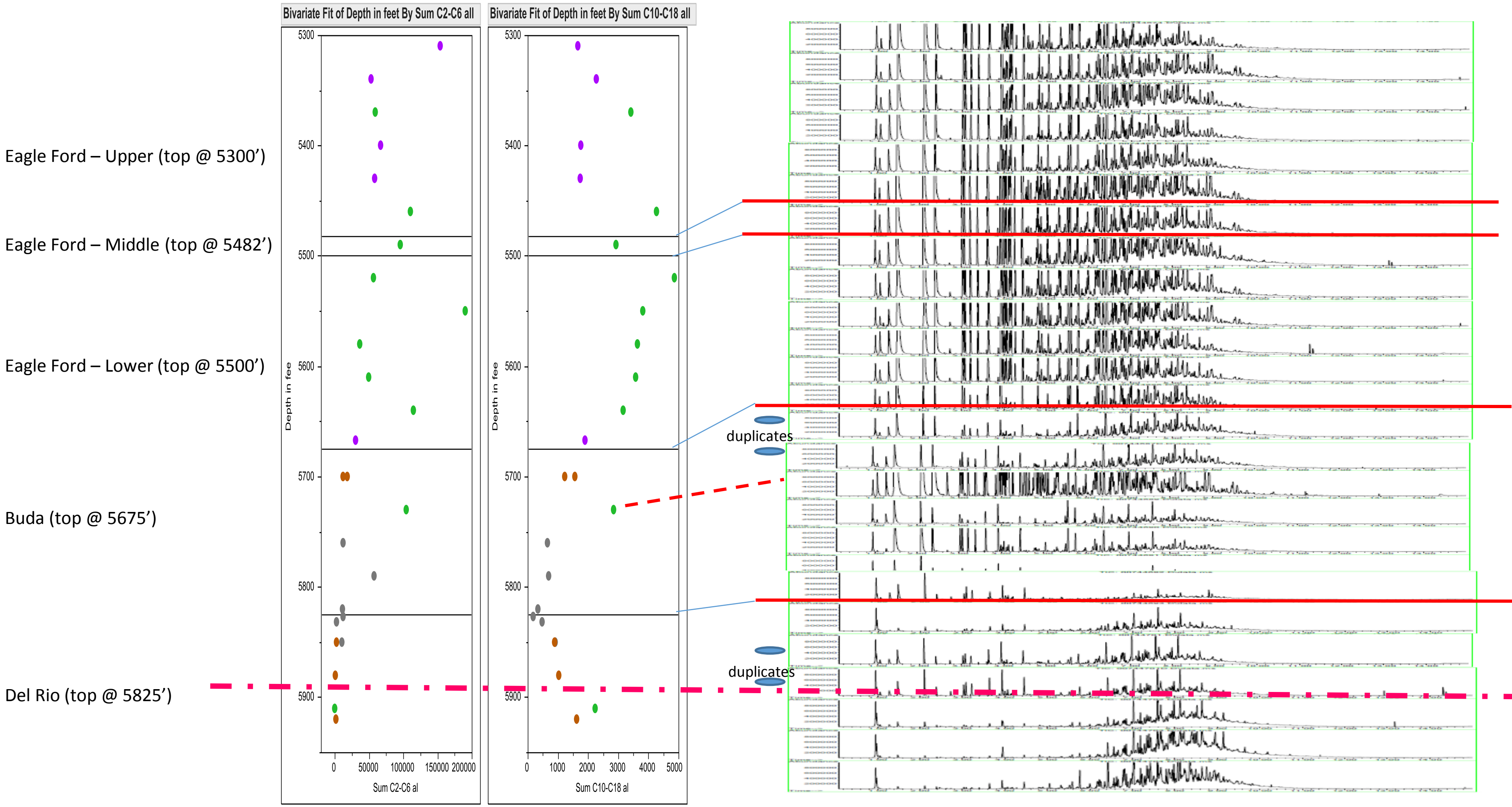


Hierarchical Cluster Analysis for the EF-1

Cluster analysis for the Eagle Ford, Buda, & Del Rio formations

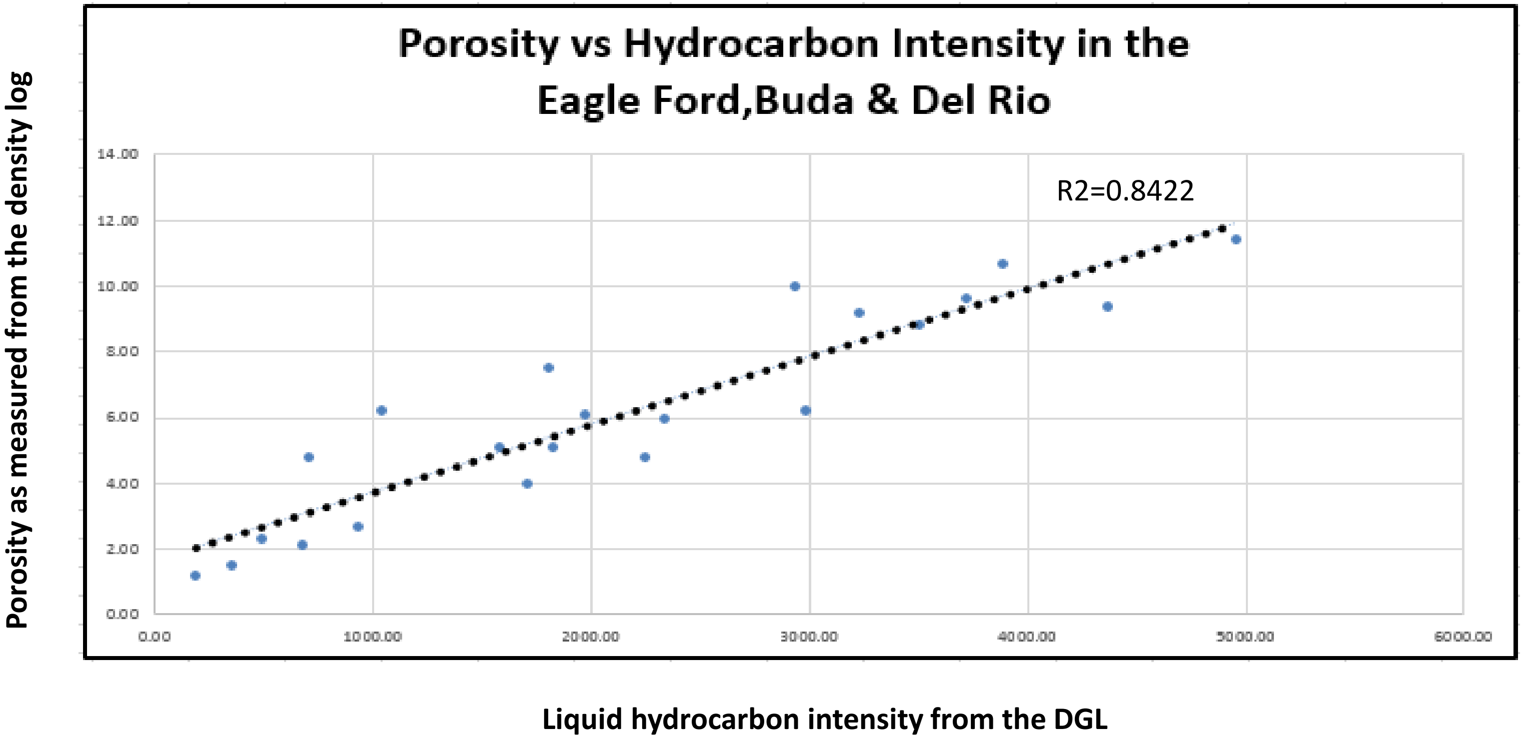


Depth profile by summed mass, color-coded by HCA group, with Fm tops and TIC profiles



The organic-rich lower shales and condensed section have the highest hydrocarbon-generating potential of any part of the Eagle Ford Group (Dawson, 2000).

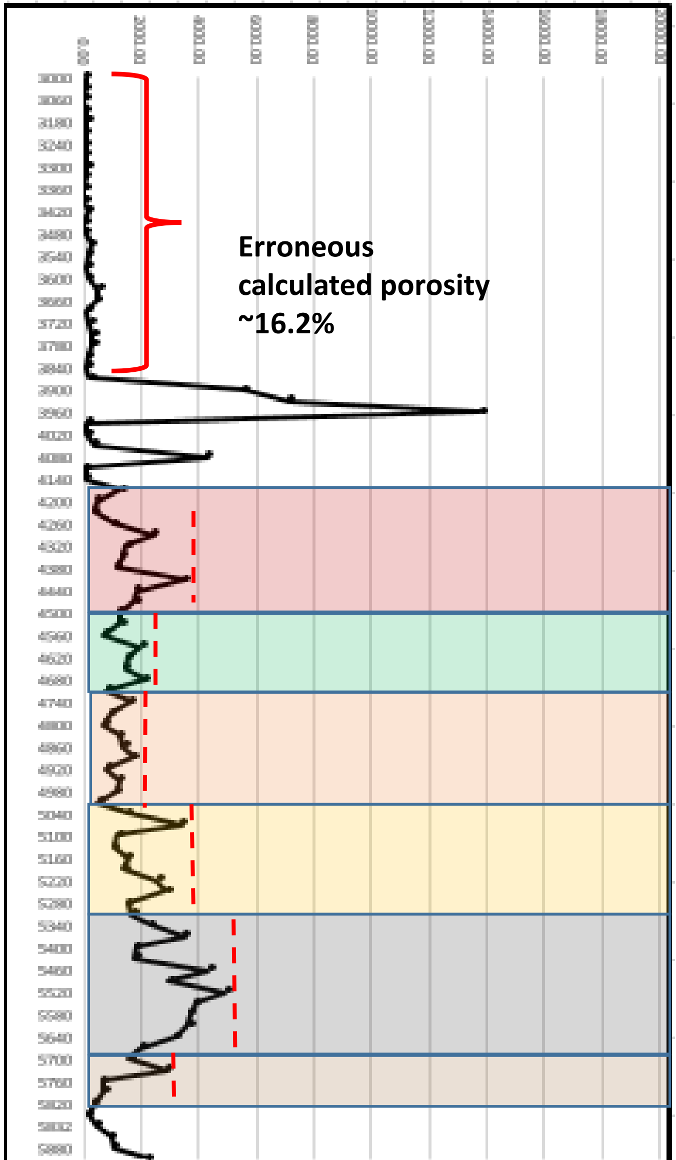
Hydrocarbon Intensity Relates to Porosity



Hydrocarbon Intensity Relates to Porosity

All porosity data obtained from density logs

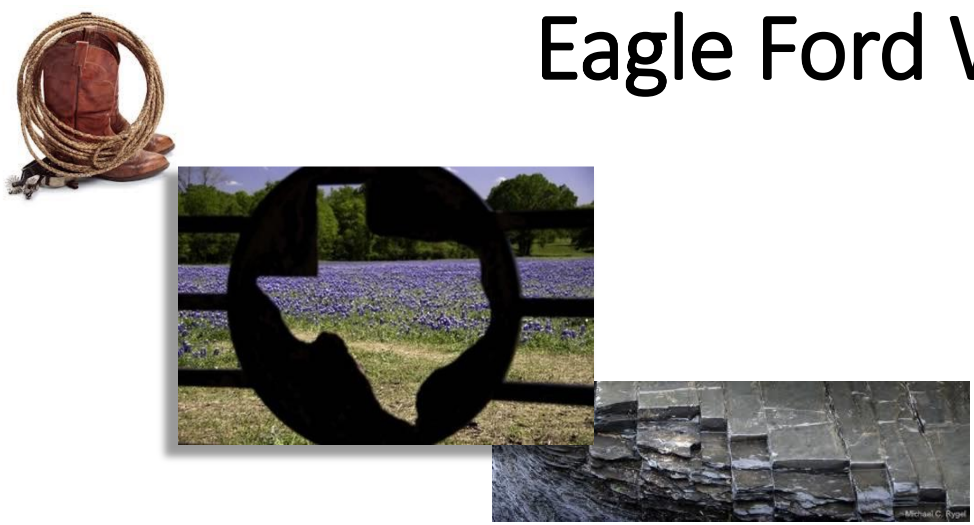
Porosity roughly estimated from the DGL data averaged 1.3%.



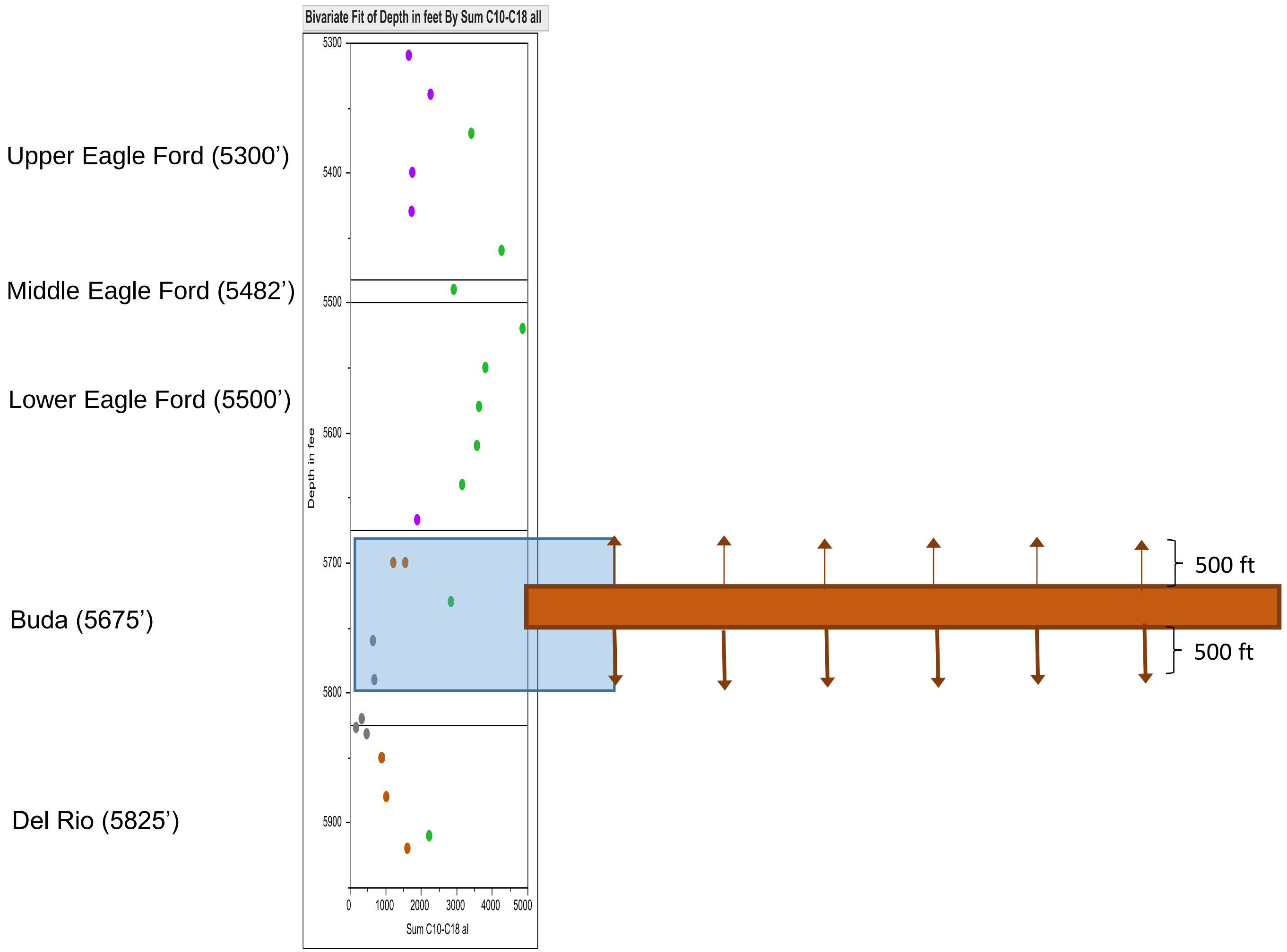
Porosity data inaccurate and unusable above 4,100' due to high washout.

Anacacho (4179')	Porosity ~5.5%
Austin Chalk (4509')	Porosity ~3-6%
Lower Austin Chalk (4700'-5000')	Porosity ~3%
Chalk-a-Ford (5000'-5300') Transition zone	Porosity ~6%
Eagle Ford (5300'-5675')	Porosity ~9-15%
Buda (5675'-5825')	Porosity ~4.4%

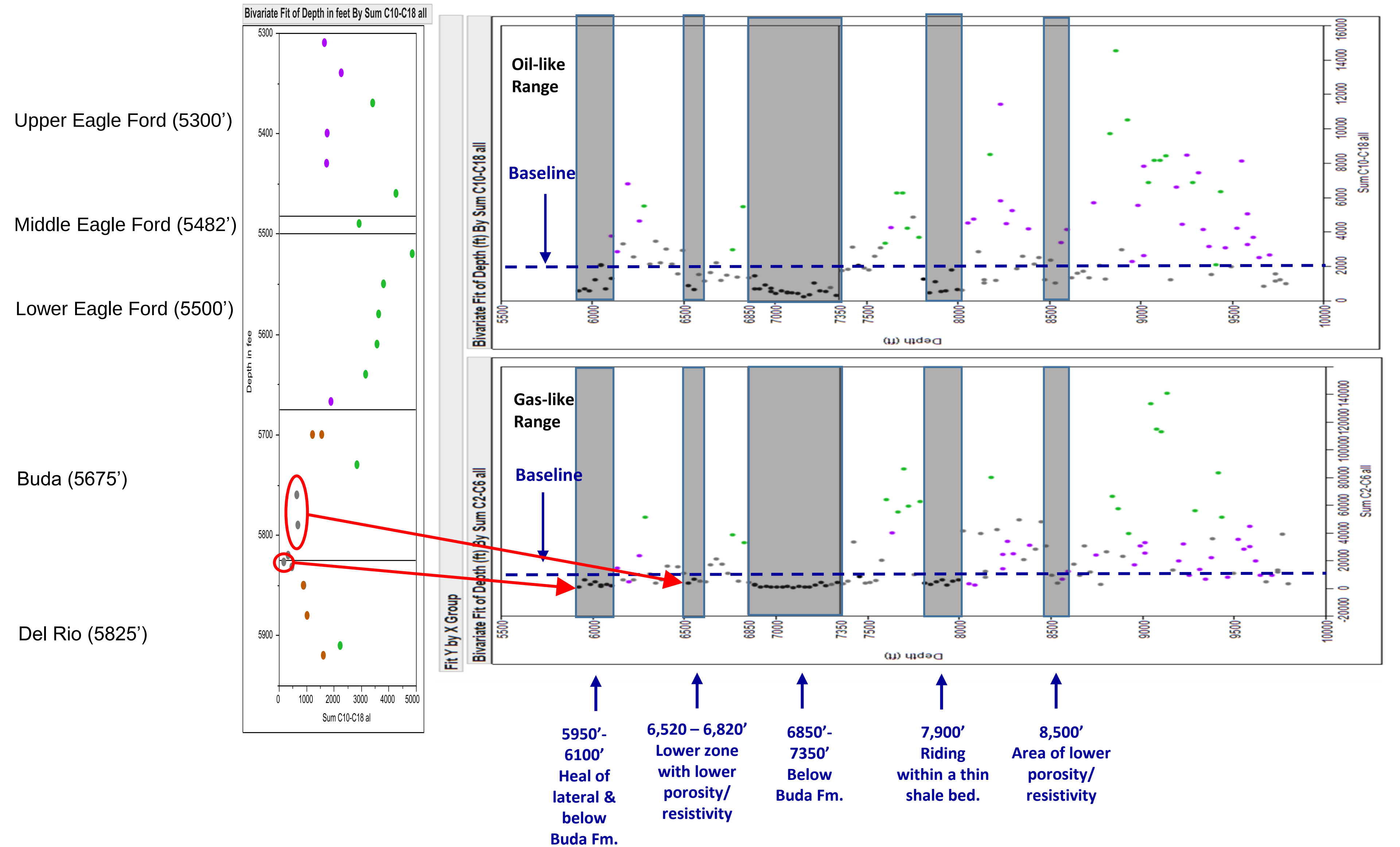
Downhole Geochemical Logging in the Lateral Eagle Ford Well



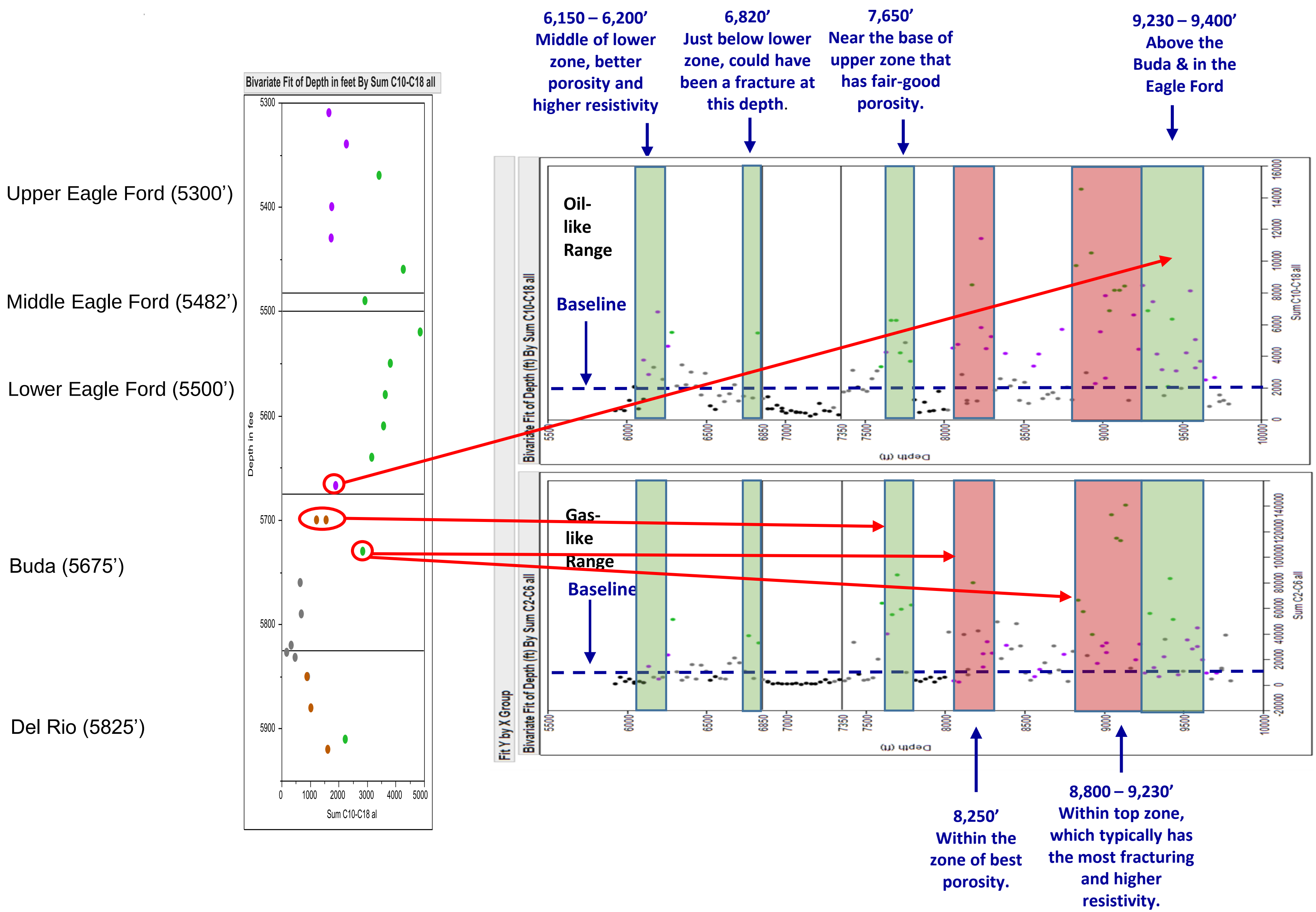
Lateral Placement



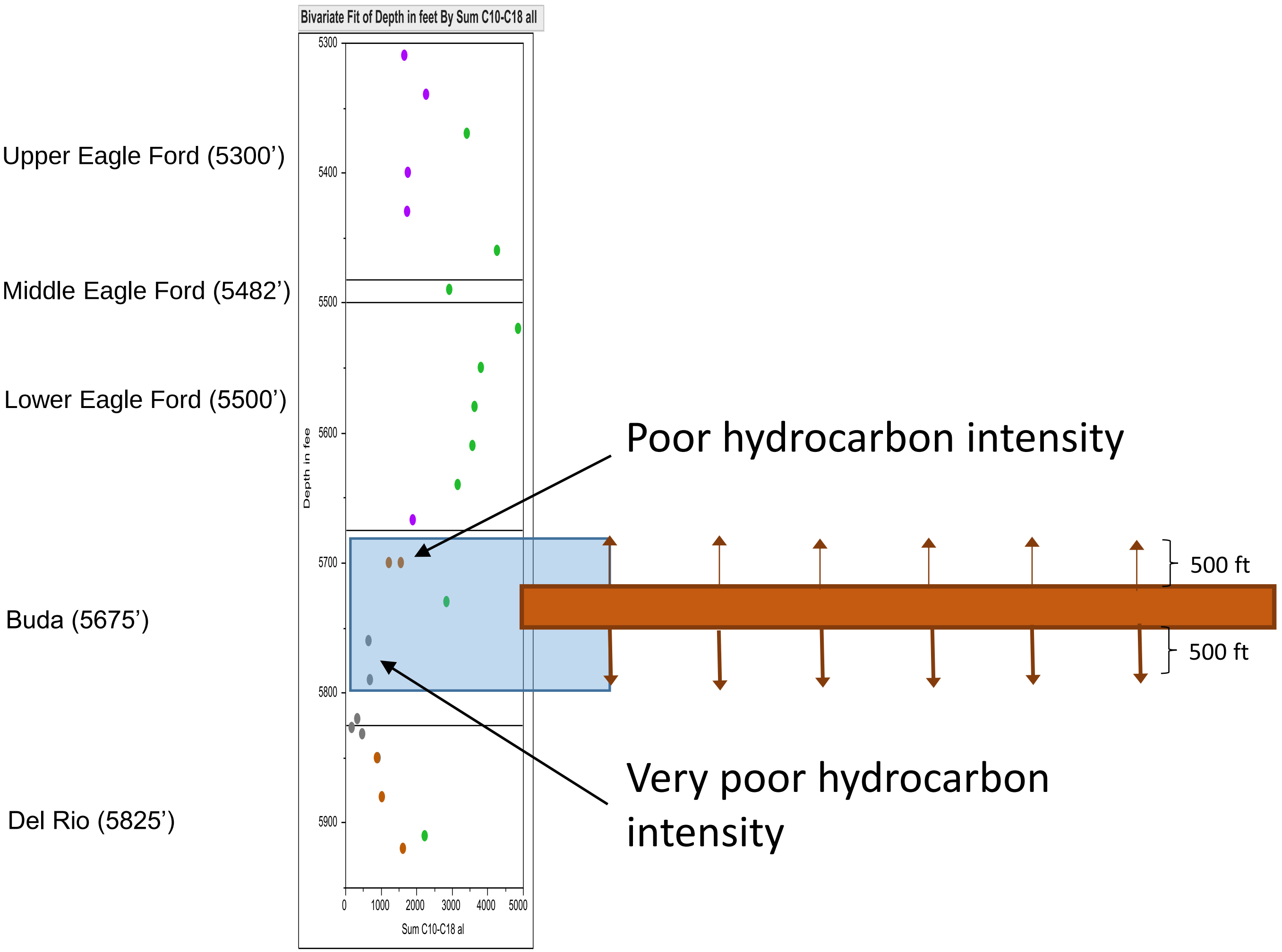
Zones of Low Hydrocarbon Response



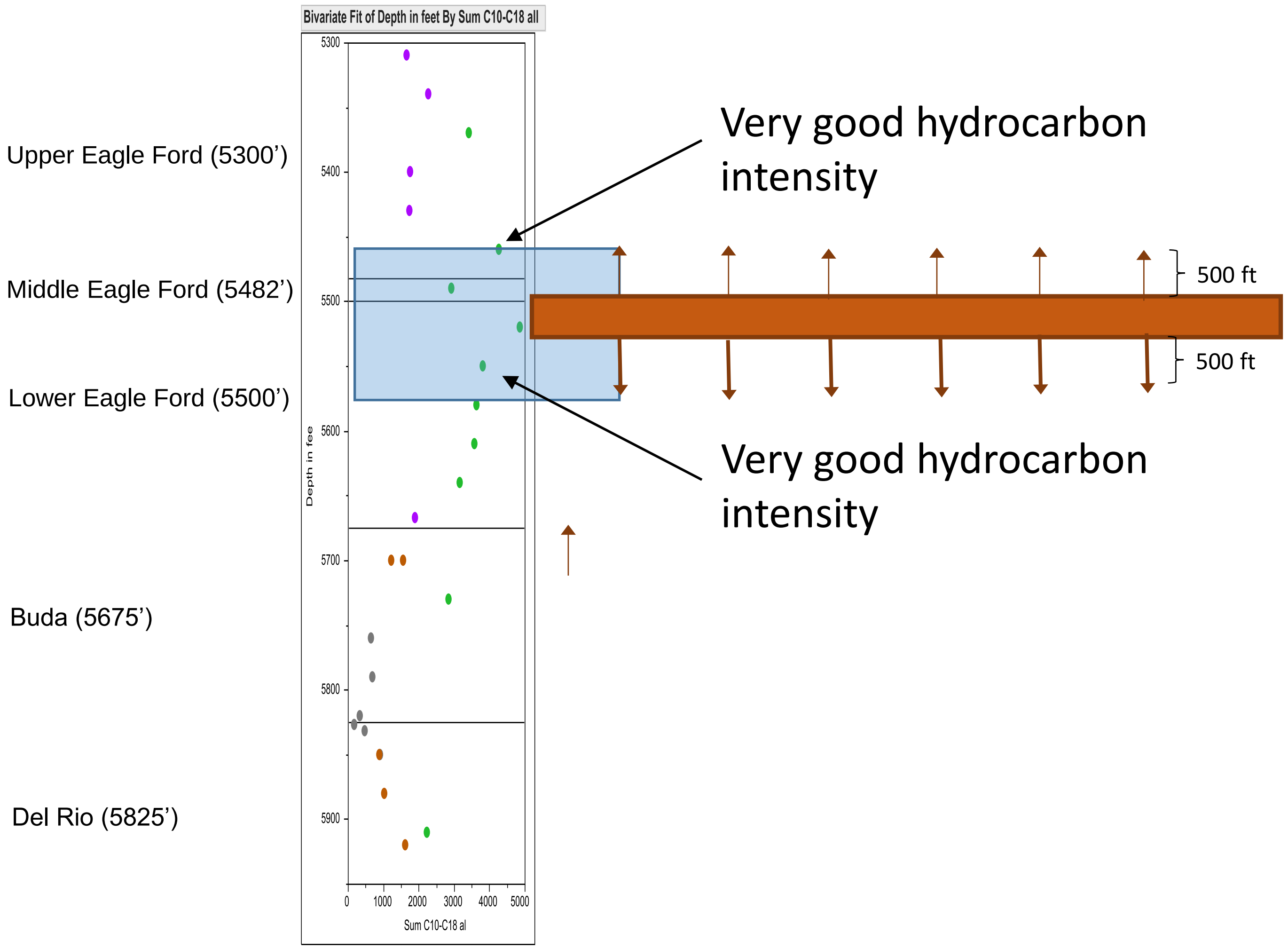
Zones of Elevated Hydrocarbon Response



Poor Lateral Placement

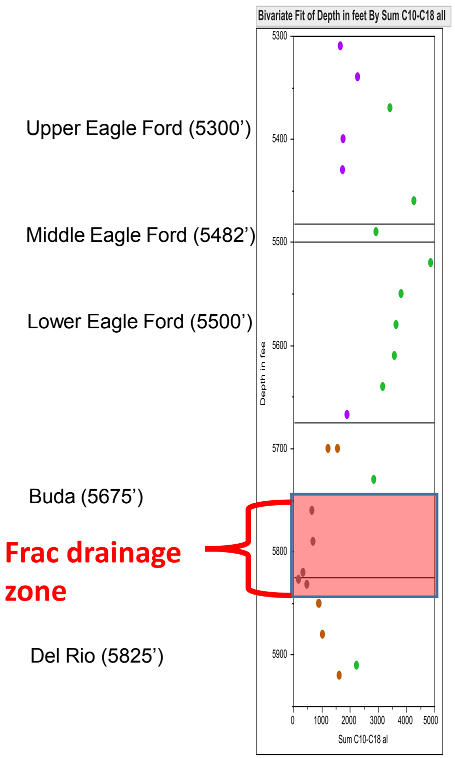


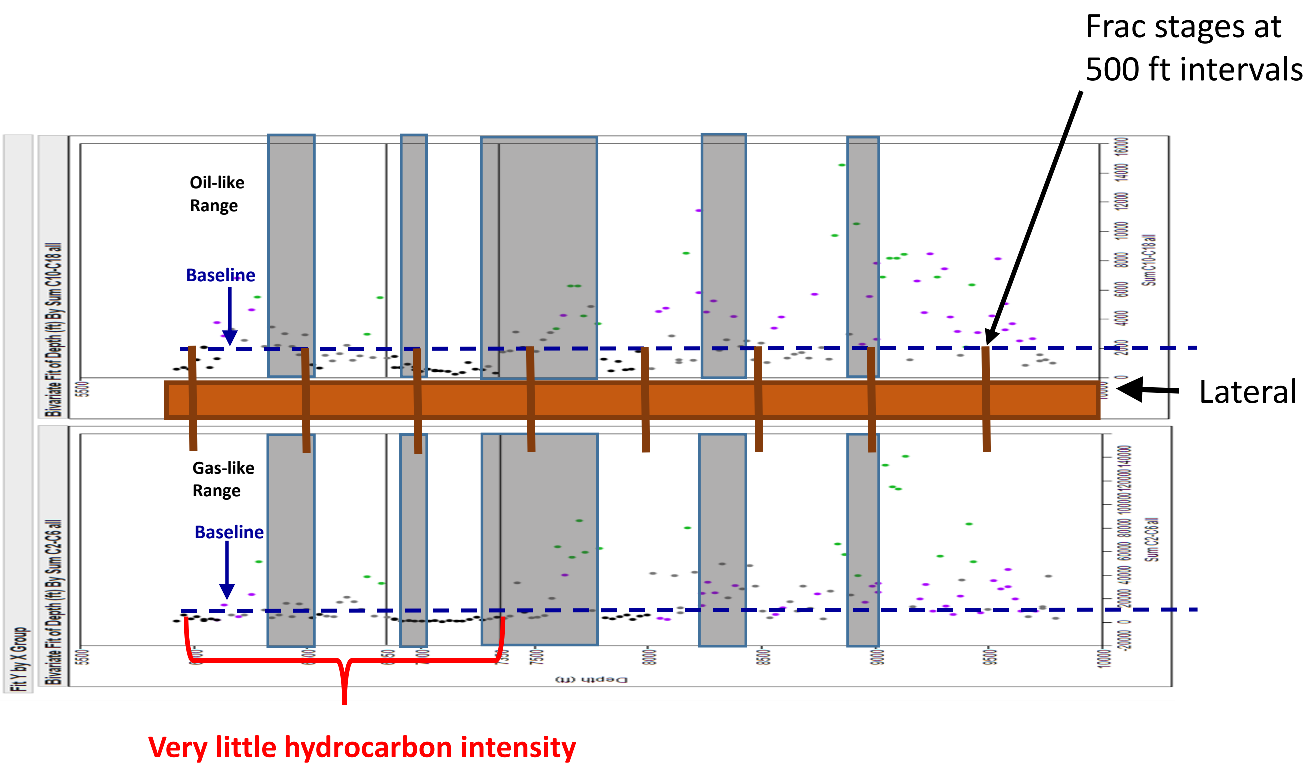
Excellent Lateral Placement



Optimizing Fracing Stages

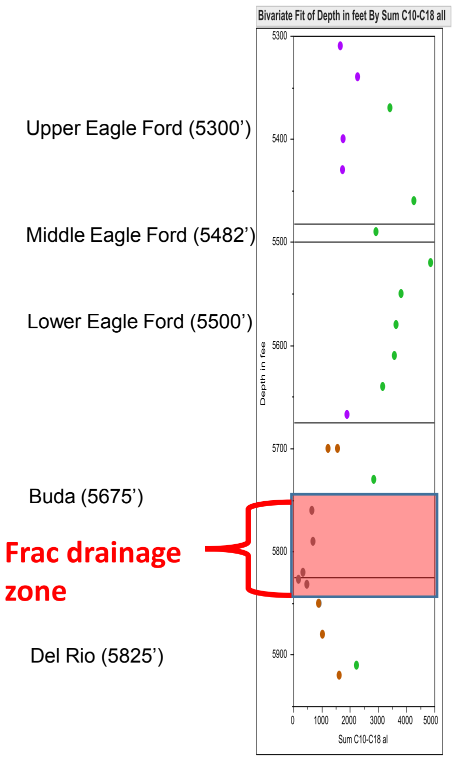
8 Frac stages at $200,000 each = **$1.6 mm**

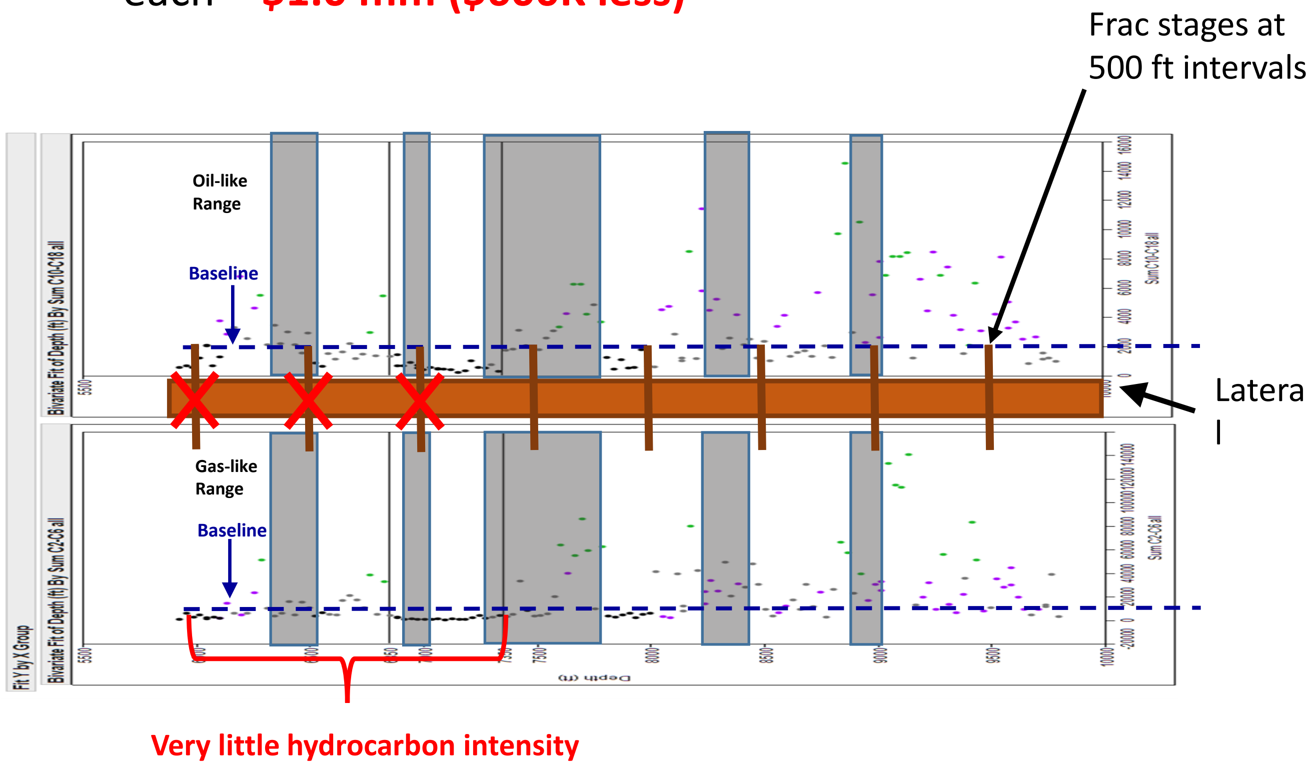




Optimizing Fracing Stages

5 Frac stages at $200,000 each = **$1.0 mm ($600K less)**



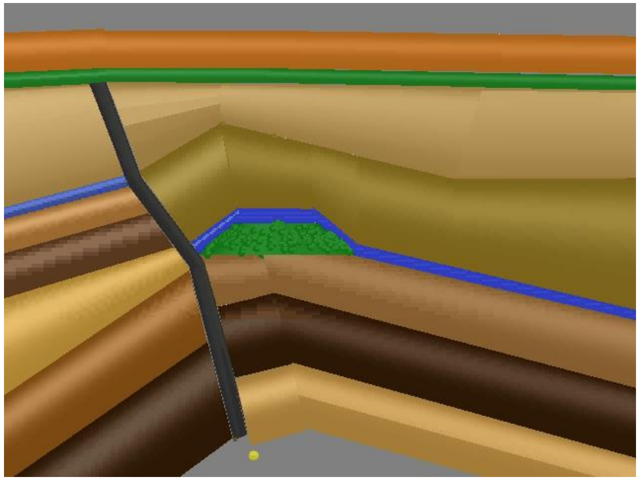


Amplified Geochemical Imaging, LLC.

Pre-drill Mapping
Hydrocarbons in Shale Plays

The Science Behind the Technology

Vertical Migration - Microseepage



Microseepage signal affected by:

- **Pressure (P)**
- **Porosity (θ)**
- **Net Pay (h)**

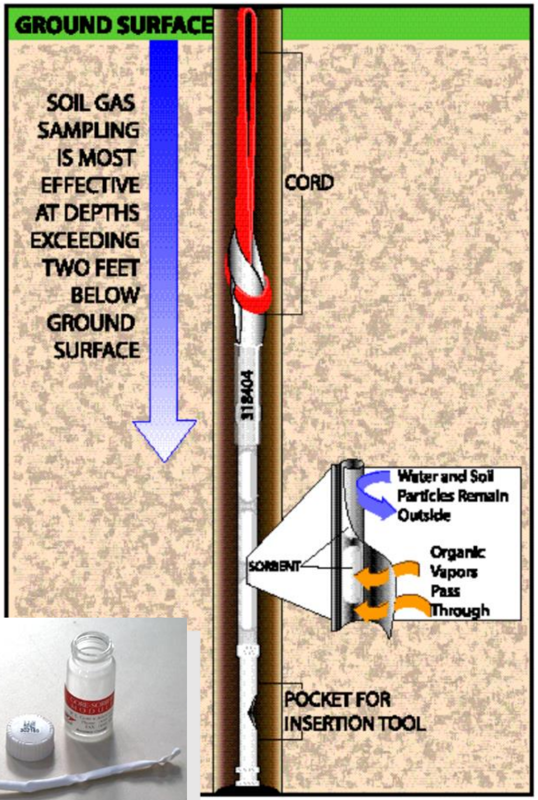
Macroseepage:
- Detectable in visible amounts
- Pathway follows discontinuities
- Offset from source/reservoir

VS

Microseepage:
- Detectable in analytical amounts
- Pathway is nearly vertical
- Overlie source/reservoir

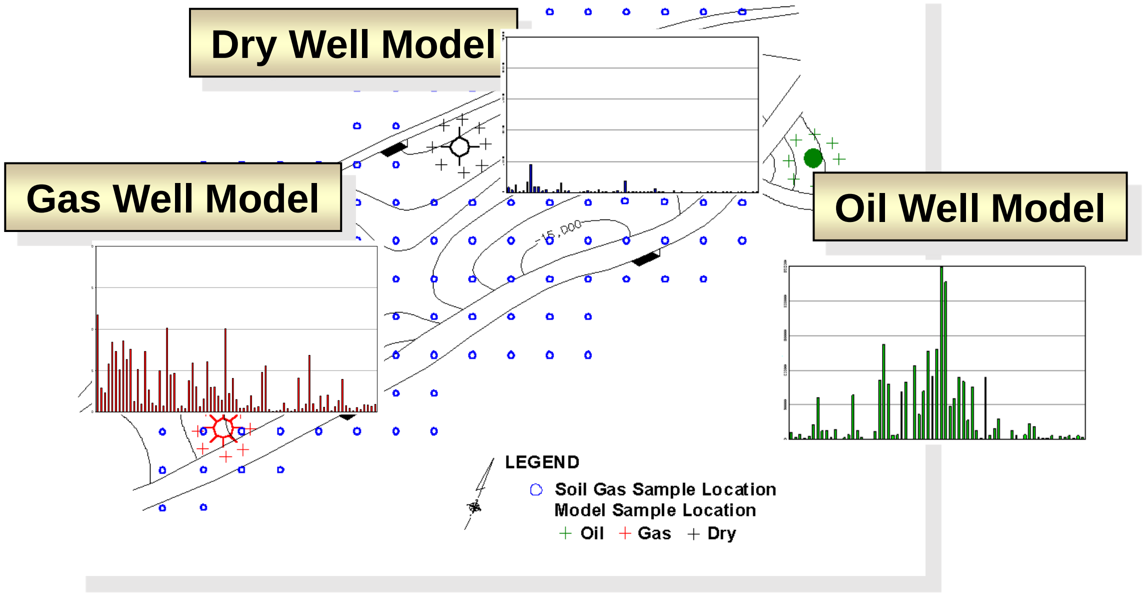
Passive Sorbent Modules

- Patented, passive, sorbent-based
  - Chemically-inert, waterproof, vapor permeable
  - Direct detection of organic compounds
  - Sample integrity protected
- Engineered sorbents
  - Consistent sampling medium
  - Minimal water vapor uptake
- Time-integrated sampling
  - Minimize near-surface variability
  - Maximize sensitivity (up to C20)
  - Avoids variables inherent in instantaneous sampling
- Duplicate samples



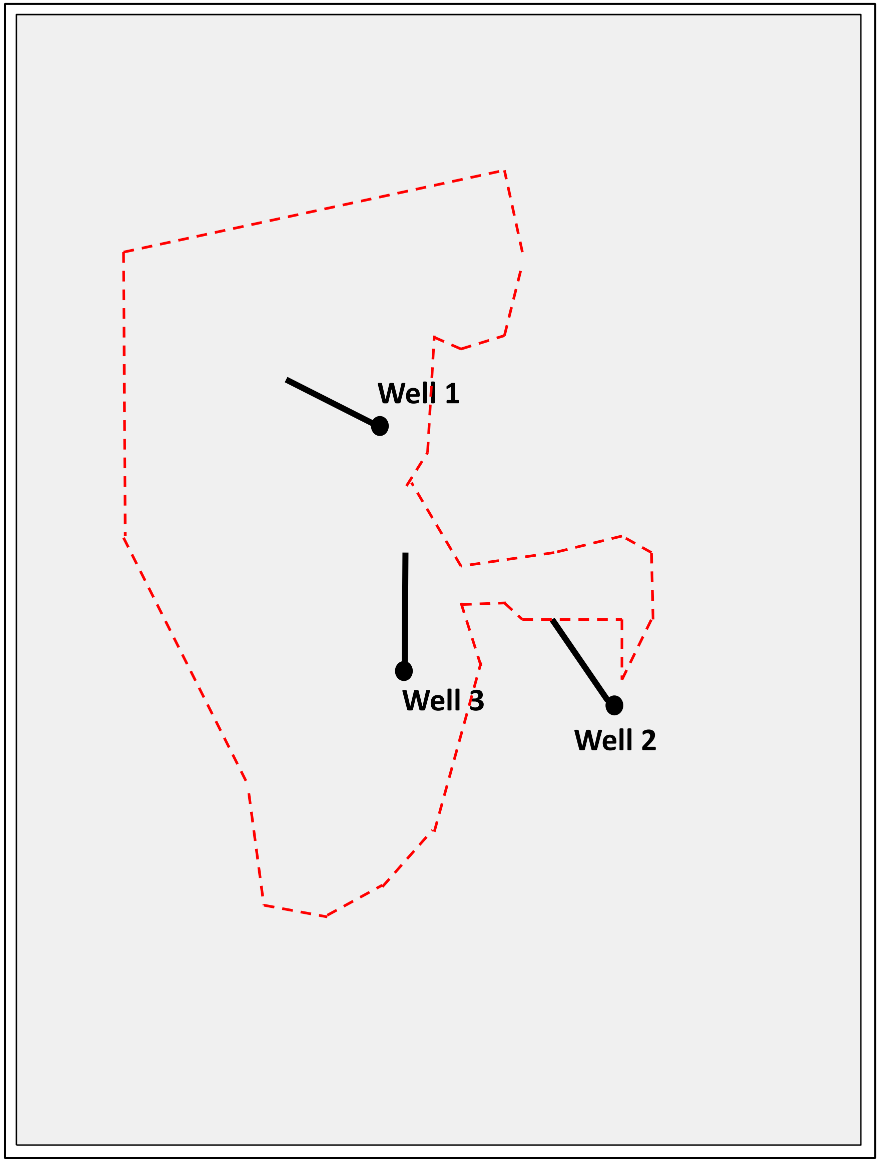
Typical Survey Design

Model development..

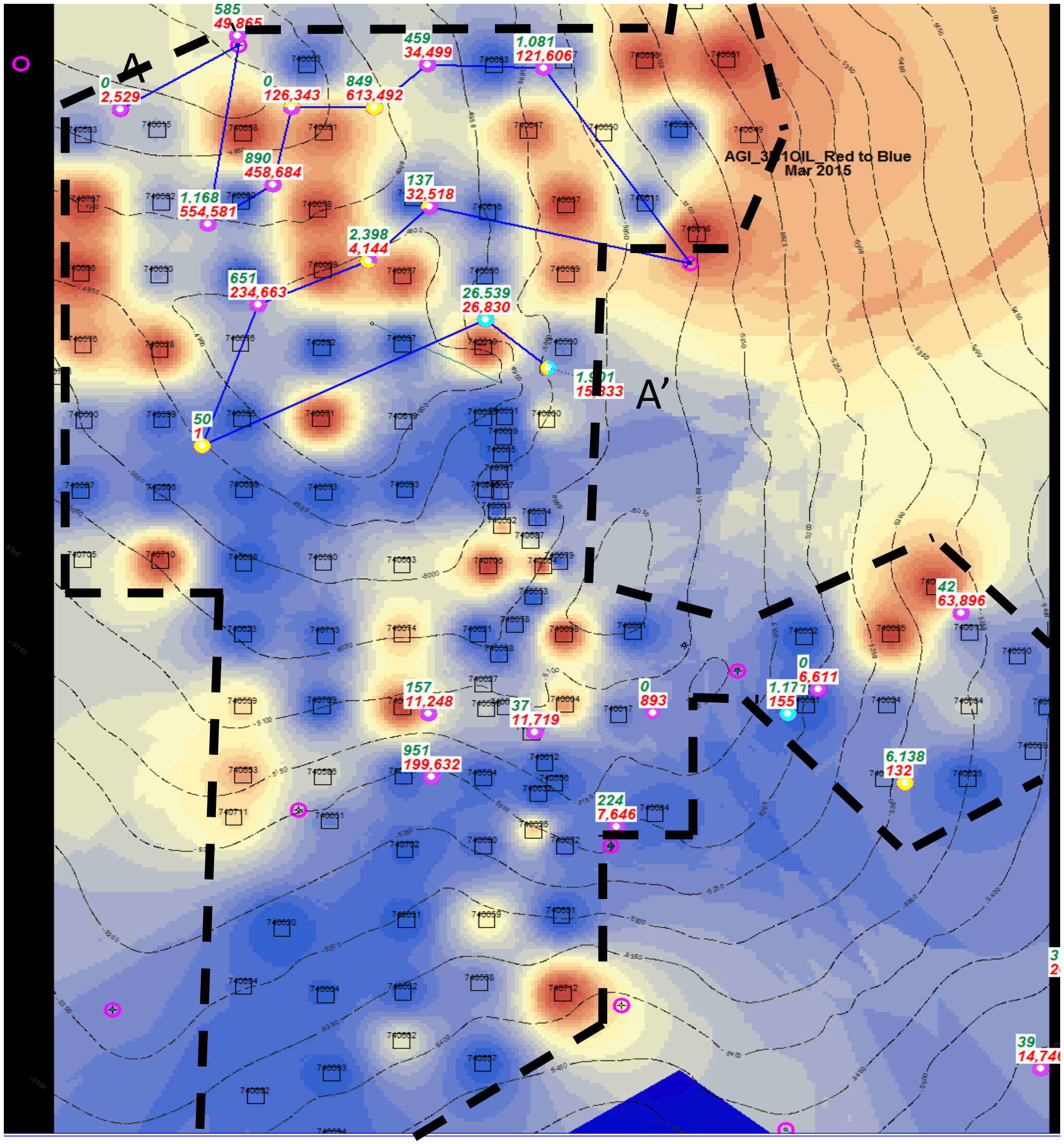


The Eagle Ford Surface Survey Results

Surface Survey Probability Map



Oil Probability Map with Production Data



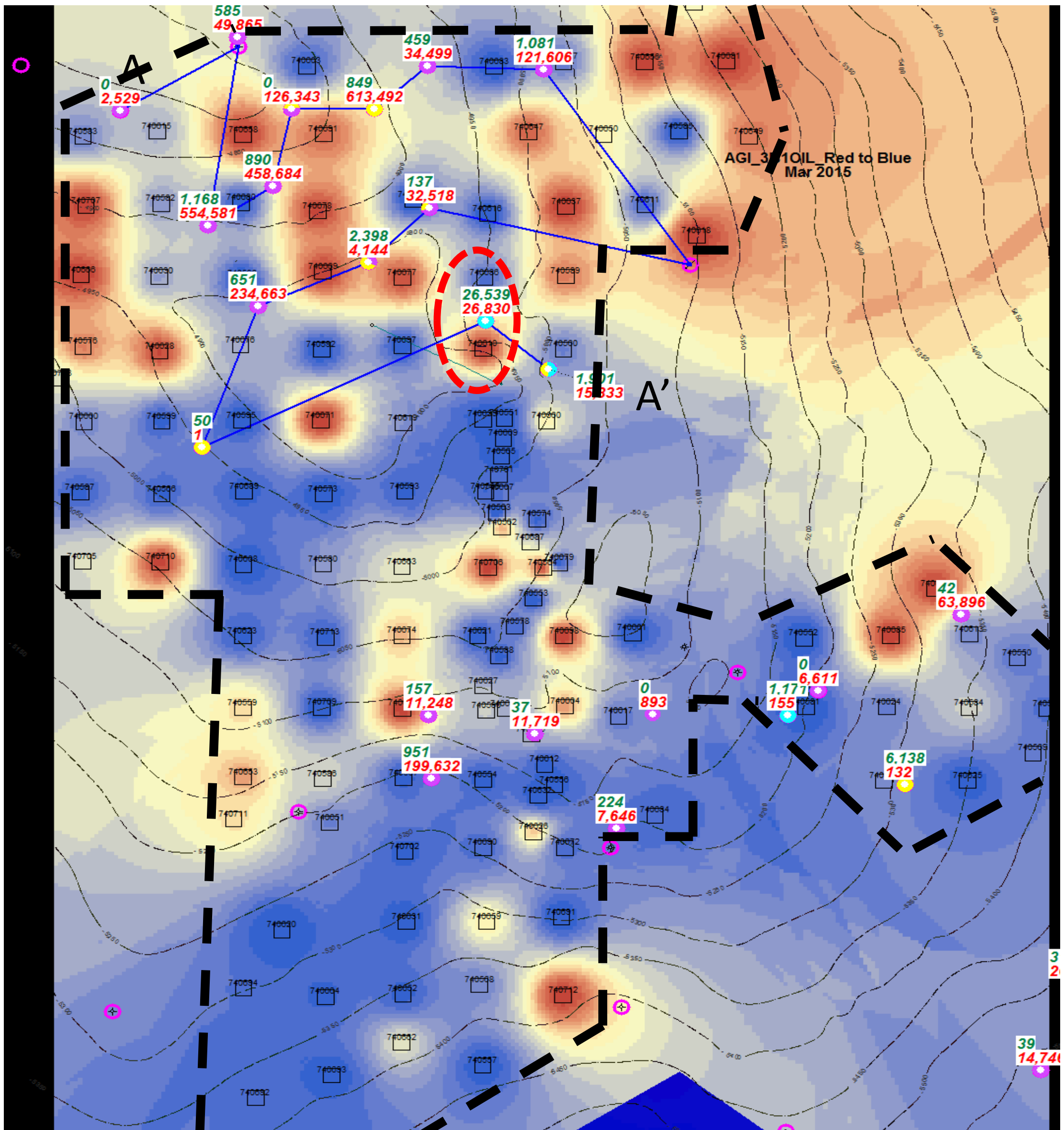
It appears the surface hydrocarbon mapping results do not match the production data

Yellow = Olmos Fm

Aqua Blue = Austin Chalk Fm

Pink = Georgetown Fm

Oil Probability Map with Production Data



Yellow = Olmos Fm

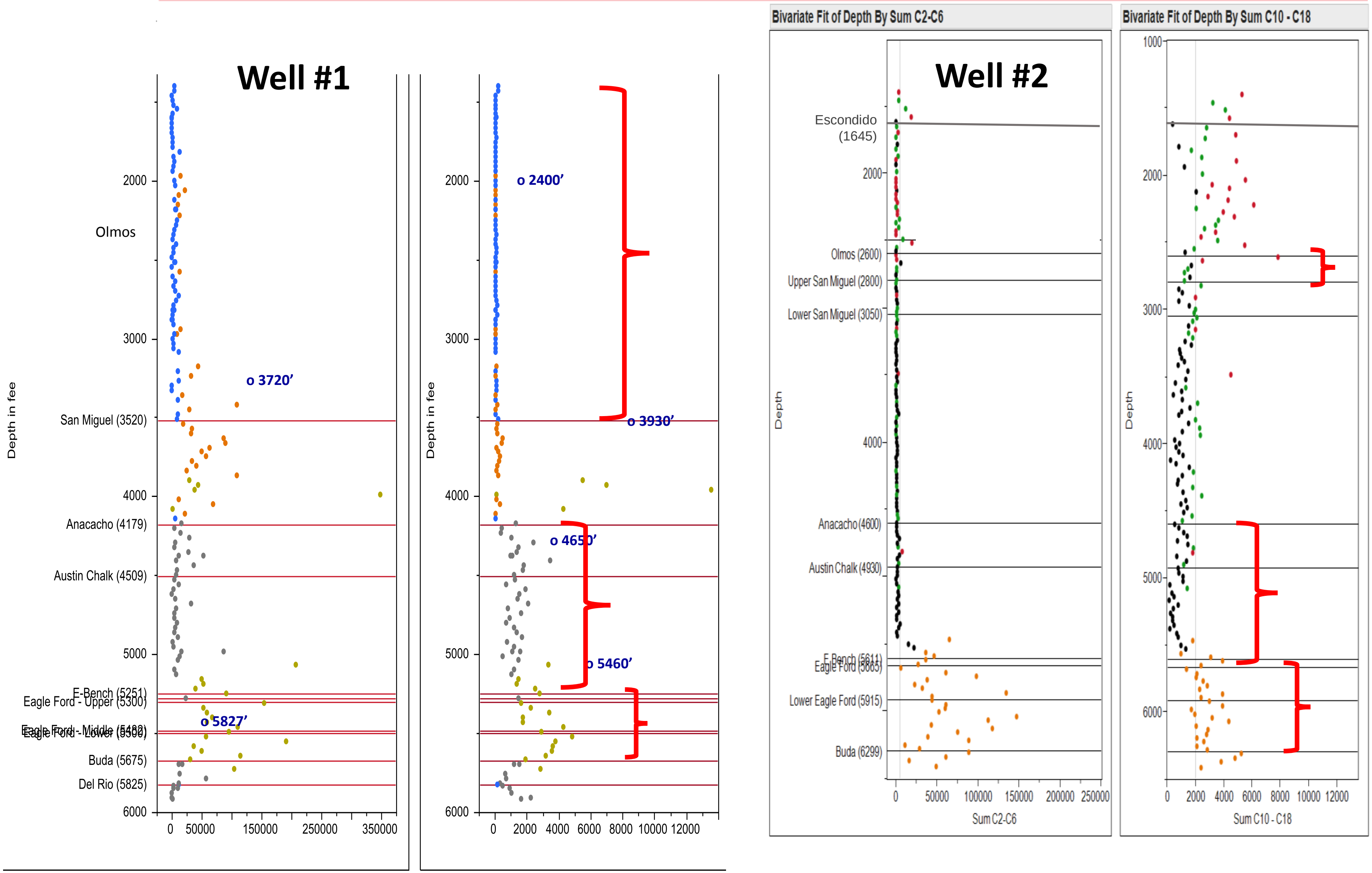
Aqua Blue = Austin Chalk Fm

Pink = Georgetown Fm

But, what about this one well that has produced 26,539 BOO when most other oil production ranges from 0 – 2,000 BOO.

Further review of the data shows the oil production is from the shallow Olmos Fm.

DGL for Austin Chalk in Two Wells



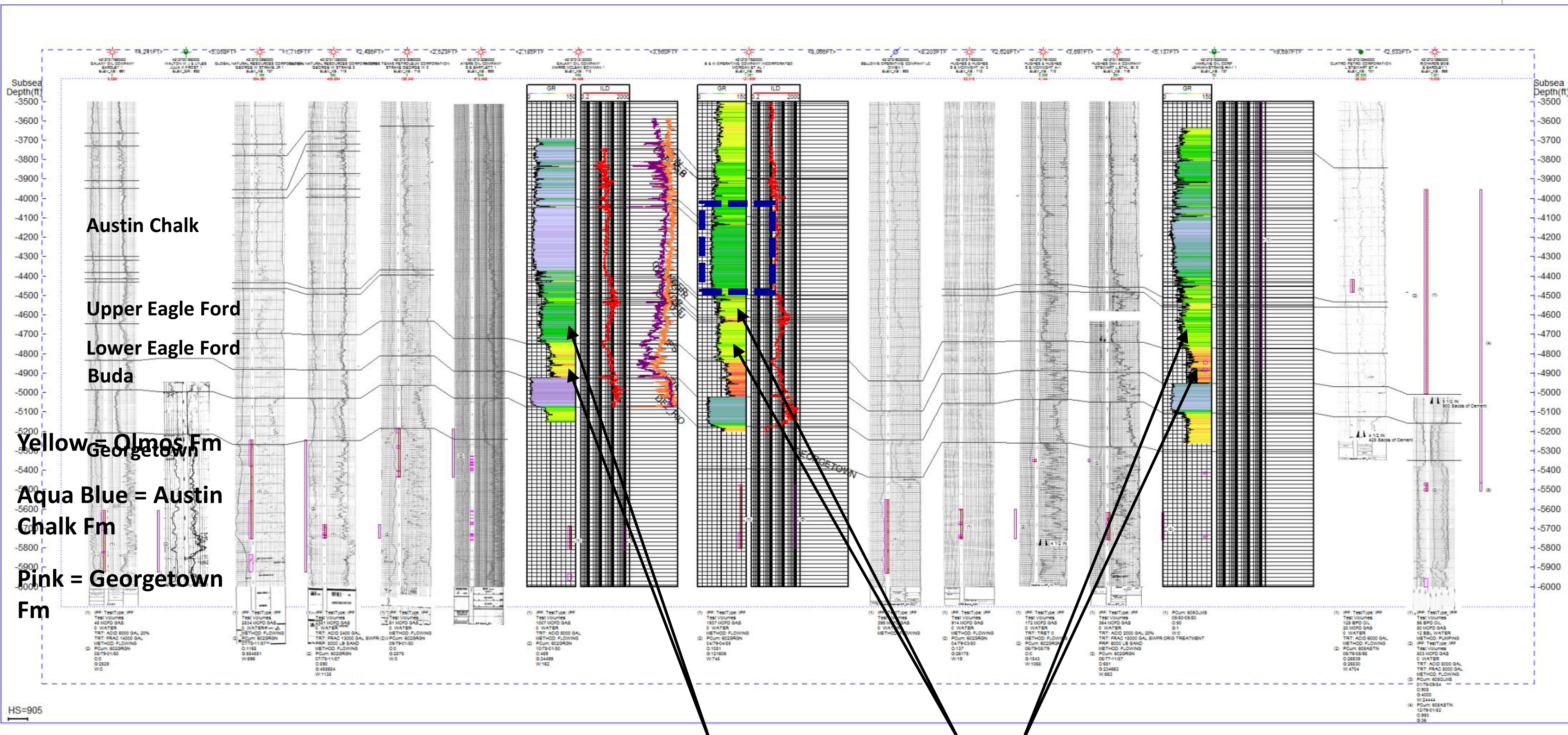
Gas Range Sum C2 – C6

Oil Range Sum C10 – C18

Gas Range Sum C2 – C6

Oil Range Sum C10 – C18

Structural Cross Section



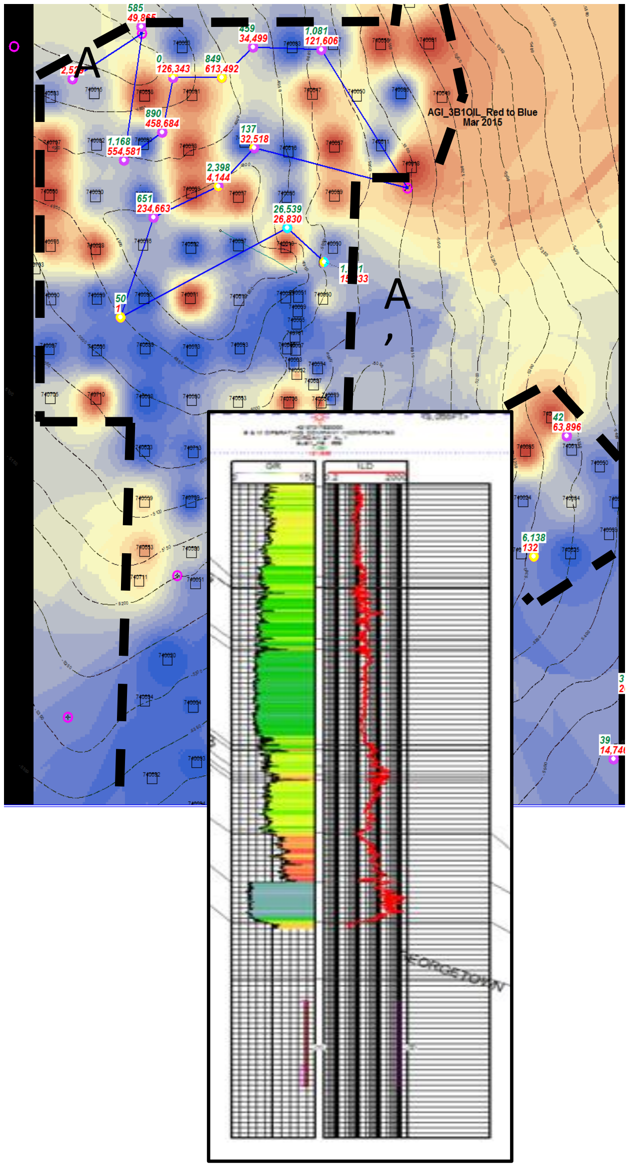
Gamma Ray Scale

Purple = Low
Green = Medium
Yellow = High
Red = Very high

Note high detection of hydrocarbons in the L. Eagle Ford & moderate hydrocarbon detection in the Upper Eagle Ford

Note VERY high detection of hydrocarbons in the L. Eagle Ford & moderate hydrocarbon detection in the Upper Eagle Ford

Well Completion & Sweet Spot Prediction



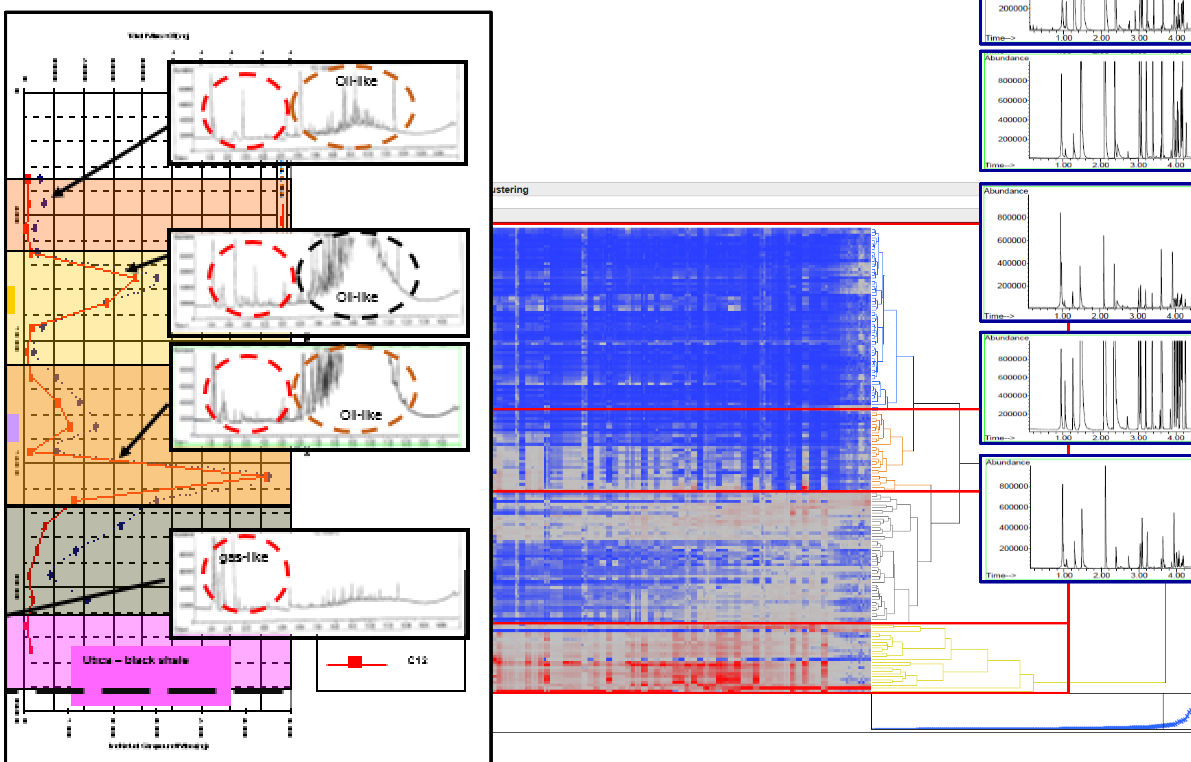
- The hydrocarbon surface survey highlighted areas highest oil probability (Sweet Spots).
- Surface hydrocarbon mapping detects total subsurface hydrocarbons, not just hydrocarbons from a single producing zone.
- While production data did not match these anomaly maps, production had been from the shallow Olmos Fm.
- Downhole Geochemical Logging and Well Logs both indicated the primary oil accumulations were in the Eagle Ford Fms

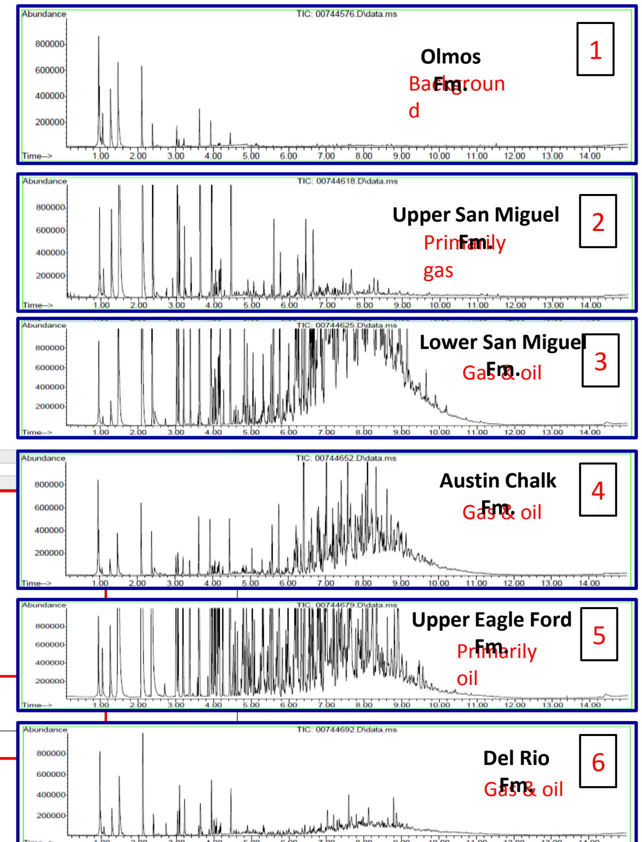
Just drilling the Austin Chalk is not the answer either!

Summary

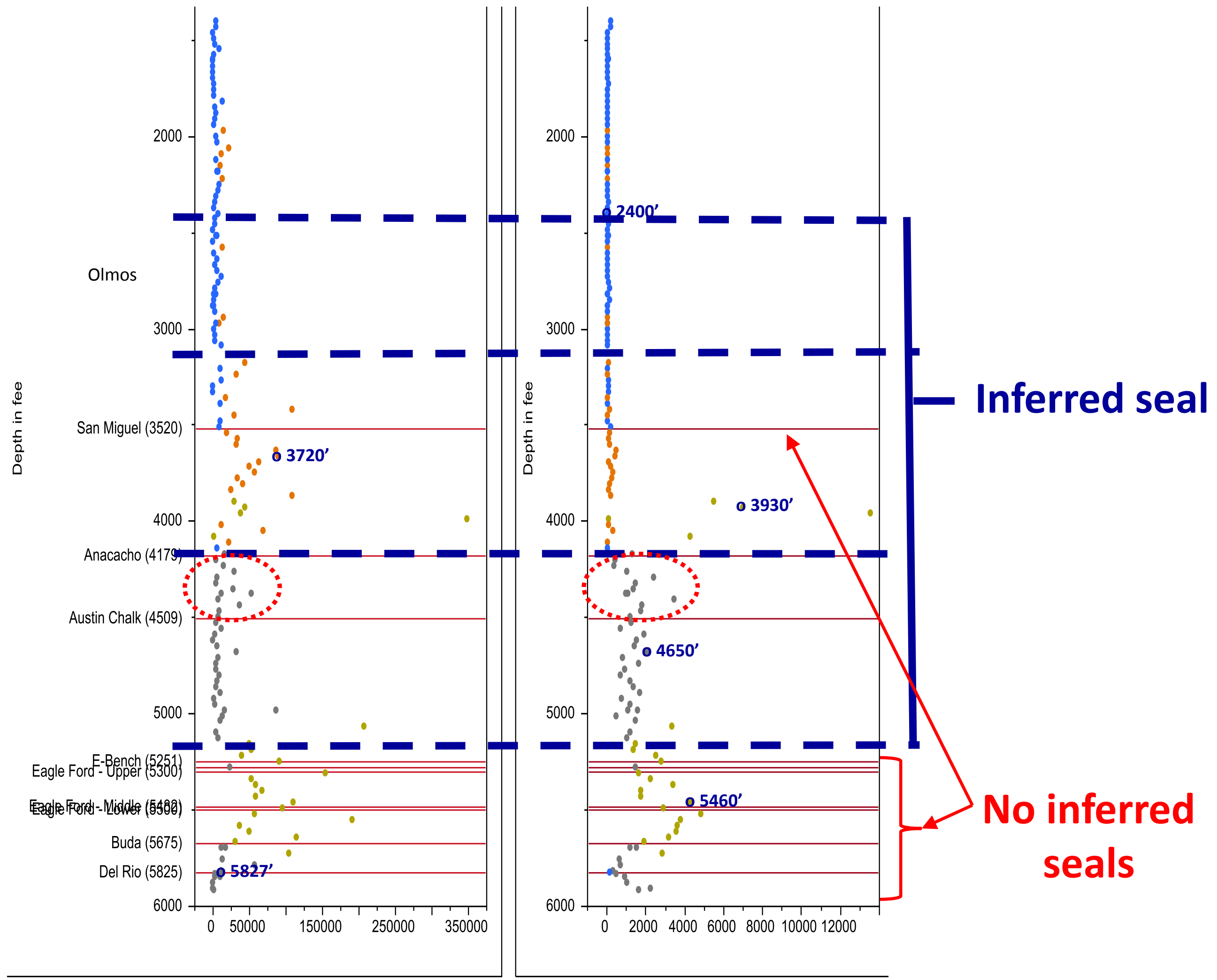
Measures C2 – C20

It's the only technology able to measure 80 – 90 compounds from C2 – C20





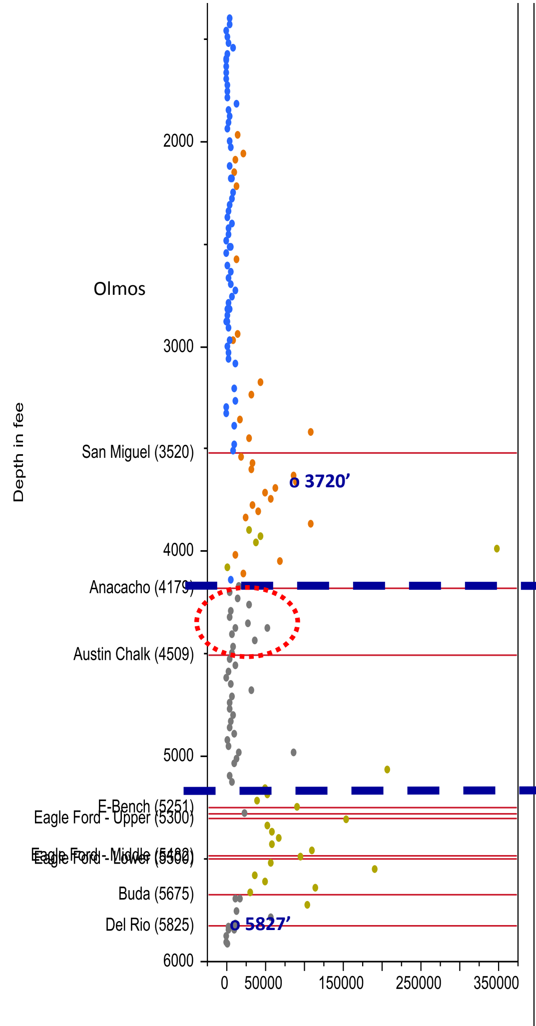
Can Infer Seals



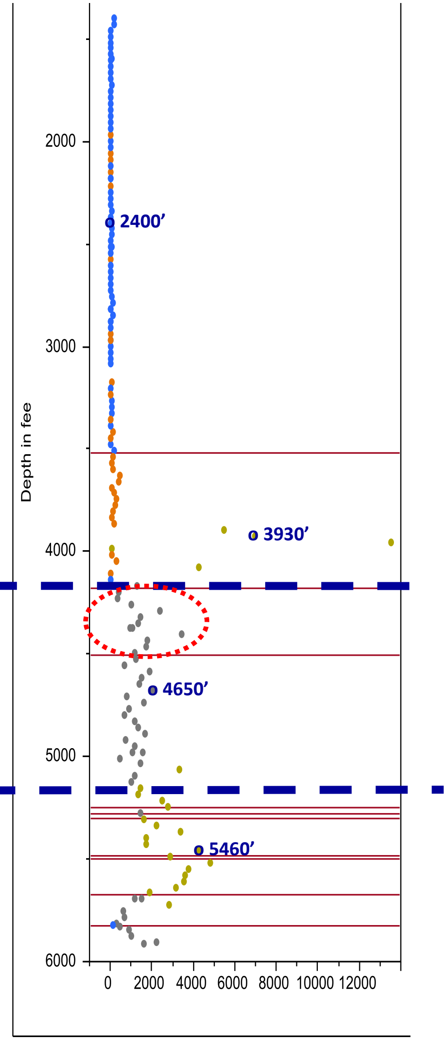
Gas Range Sum
C2 – C6

Oil Range
Sum C10 – C18

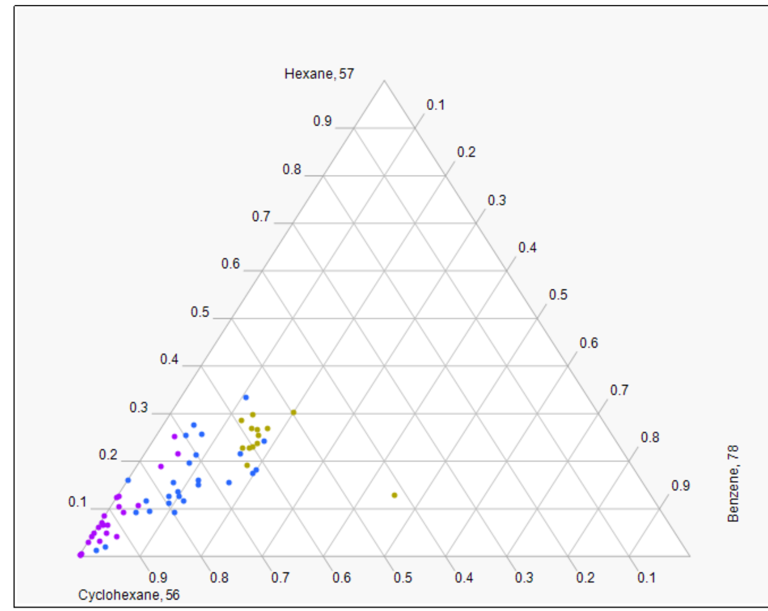
Can Infer Source and Migration



Gas Range Sum
C2 – C6



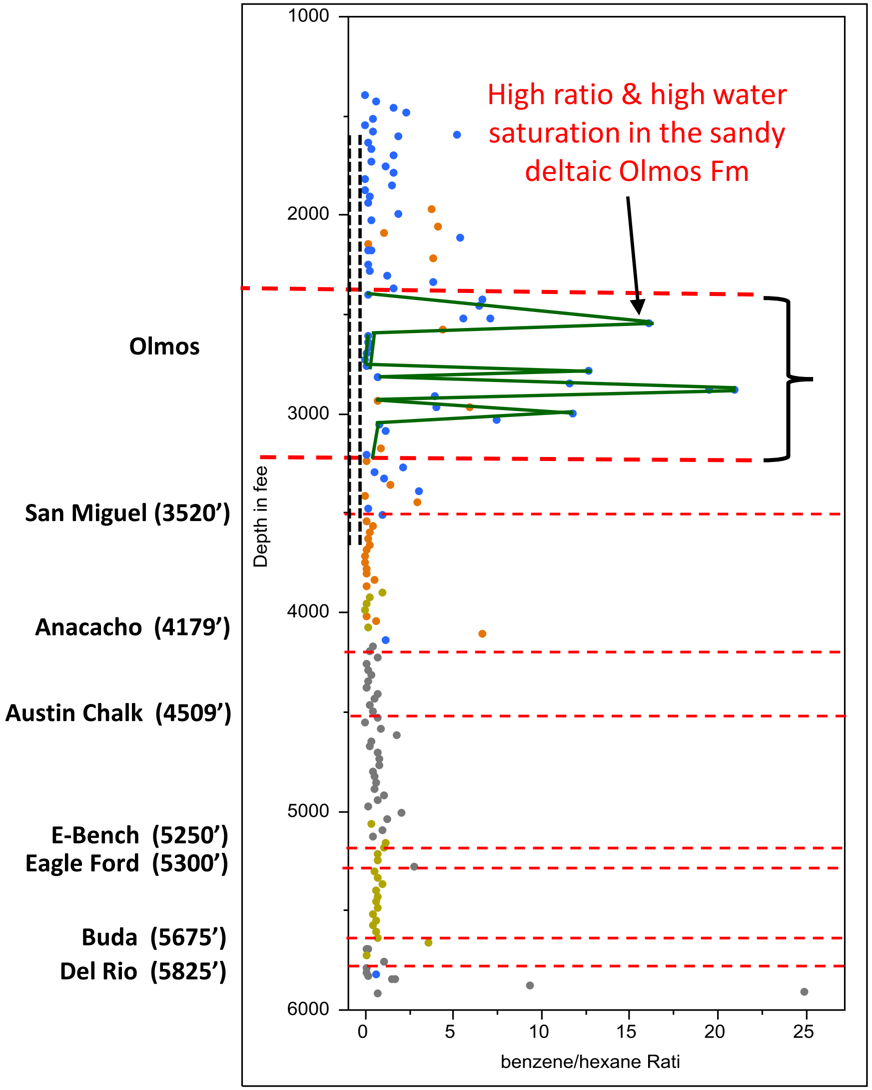
Oil Range
Sum C10 – C18

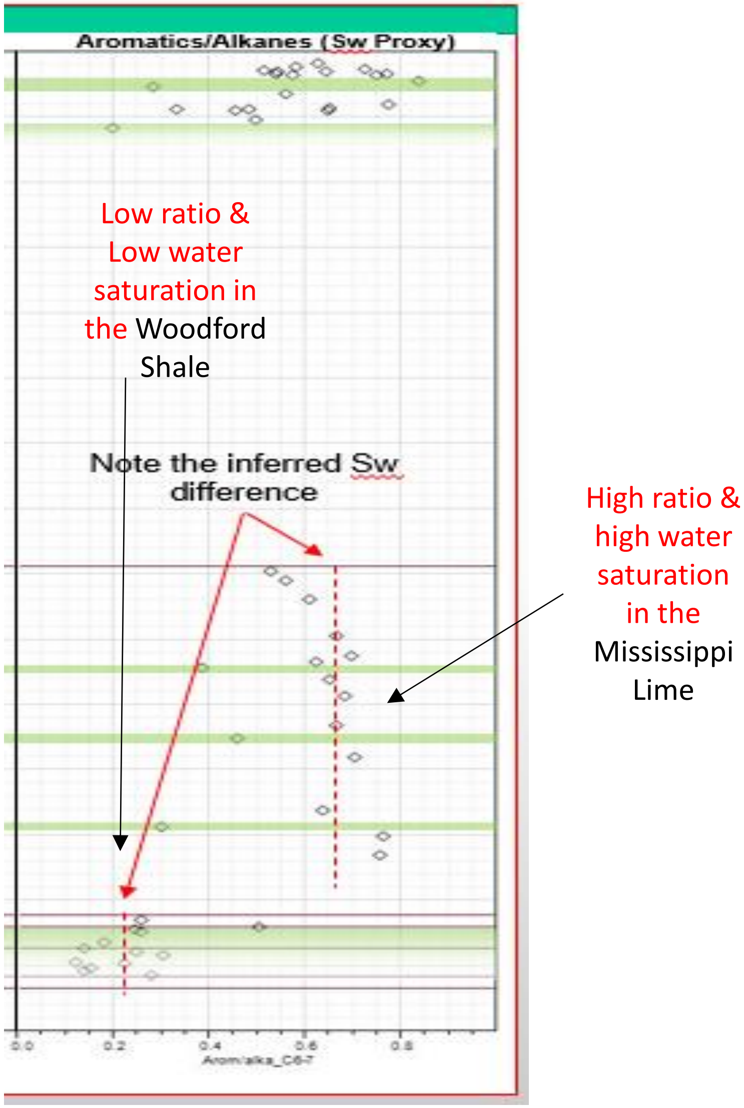


- San Miguel
- Austin Chalk
- Eagle Ford

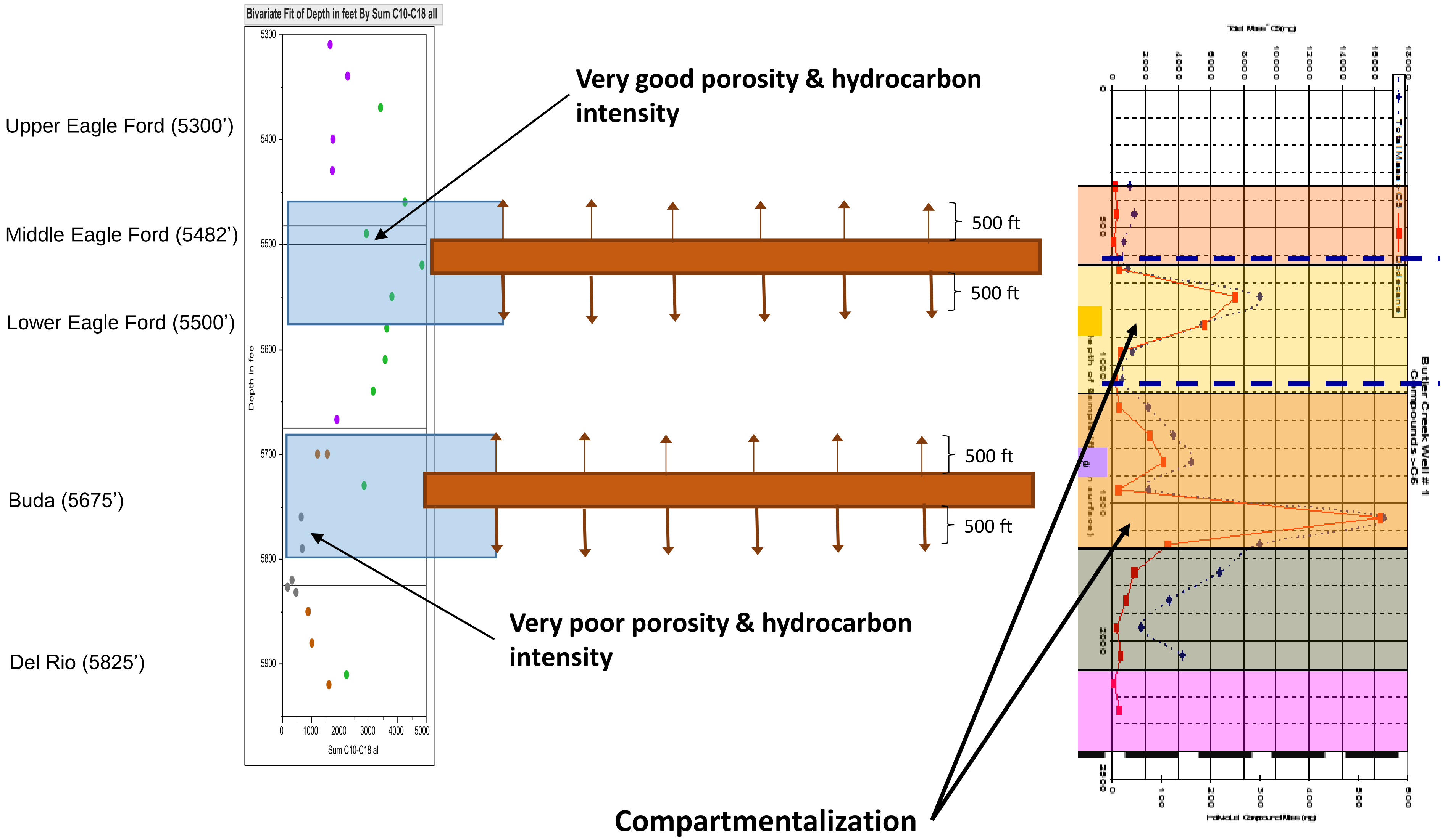
Can Serve as a Proxy for Sw

Depth plot of Benzene/Hexane (nC6)





Can Optimize Production



A New Pre-Drilling Paradigm

3D Seismic and Amplified Geochemical Imaging can help to **optimize pre-drilling efforts**.

3D Seismic can provide:

- Stress orientation
- Brittleness proxy (Young's modulus)
- Open fracture proxy (azimuthal anisotropy)

Fractures, Faults, & Rock properties

AGI Surface Hydrocarbon Mapping can:

5% the cost of 3D Seismic

- Identify charged and noncharged portions of the field
- Map phase across the field
- Map thermal maturity
- Identify sweet spots of pressure, porosity, & net pay
- Potentially identify geohazards (i.e. faults)

Hydrocarbon, Structural, & Rock properties

AMPLIFIED GEOCHEMICAL IMAGING, LLC