

Downhole Geochemical Logging in the Eagle Ford: Hydrocarbon Detection in Vertical and Lateral Wells*

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Abstract

A variety of logging technologies provide information during drilling as to the presence of hydrocarbons. However, these logging technologies do not measure hydrocarbons directly, but rather measure hydrocarbon proxies and infer hydrocarbon presence and phase based on this data. These technologies, while sophisticated can lack specificity and sensitivity when trying to accurately identify hydrocarbons. Additionally, some new technologies can monitor hydrocarbons from n-C₁ (methane) to n-C₈ (octane) and expand the scope of hydrocarbon detection. These new technologies can clearly detect gas range organics and can infer light oils and condensates. However, all of these technologies lack the ability to measure the heart of the oil or liquid hydrocarbon fingerprint of n-C₇ (heptane) to n-C₁₅ (pentadecane). Thus, accurately characterizing and differentiating between multiple oil fingerprints becomes difficult, if not impossible, for current technologies. As such, these limitations negatively affect the ability of companies to properly assess and evaluate plays like the Eagle Ford that have numerous stacked liquid pays.

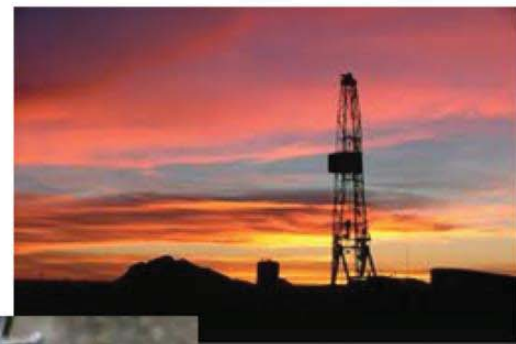
However, advances in well logging technology now provide the ability to analyze downhole cutting samples to directly characterize the composition of hydrocarbons vertically through the prospective section. This provides the unique ability to look at a broad compound range from C₂ to C₂₀, which is significantly more expansive than the limited traditional ranges of C₁-C₅ or C₁-C₈ of most well gas logging techniques. The result is the ability to not only characterize gas and condensate range hydrocarbons, but also characterization multiple liquid or oil phase hydrocarbons contained in the stratigraphic intervals.

The Amplified Geochemical Logging data was able to:

- Identify the most prolific hydrocarbon bearing zones
- Identify the areas of greatest porosity in both the vertical and lateral well
- Clearly distinguish between various hydrocarbon phases
- Distinguish multiple oil signatures
- Identify a zone with a high degree of water saturation
- Indicate where the lateral drilling was below or above the zone of interest
- Infer there were no seals between multiple zones
- Deduce thin shale seals that were not detected by well logs

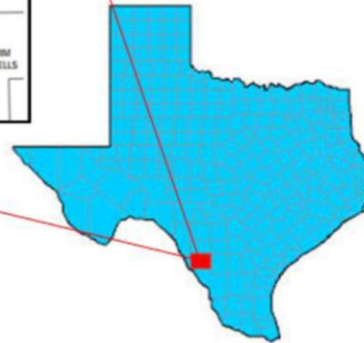
Downhole Geochemical Logging in the Eagle Ford

Hydrocarbon Detection in Vertical & Lateral Wells



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Conventional Hydrocarbon Analyses



Geologic Column South Texas

CRETACEOUS	Gulfian	Escondido
		Olmos
		San Miguel
		Anacacho
		Austin Chalk
	Comanchean	Eagle Ford
		Buda
		Del Rio
		Georgetown
		Edwards / Stuart City
Coahuilan		Glen Rose
		Pearsall
		Sligo
		Hosston

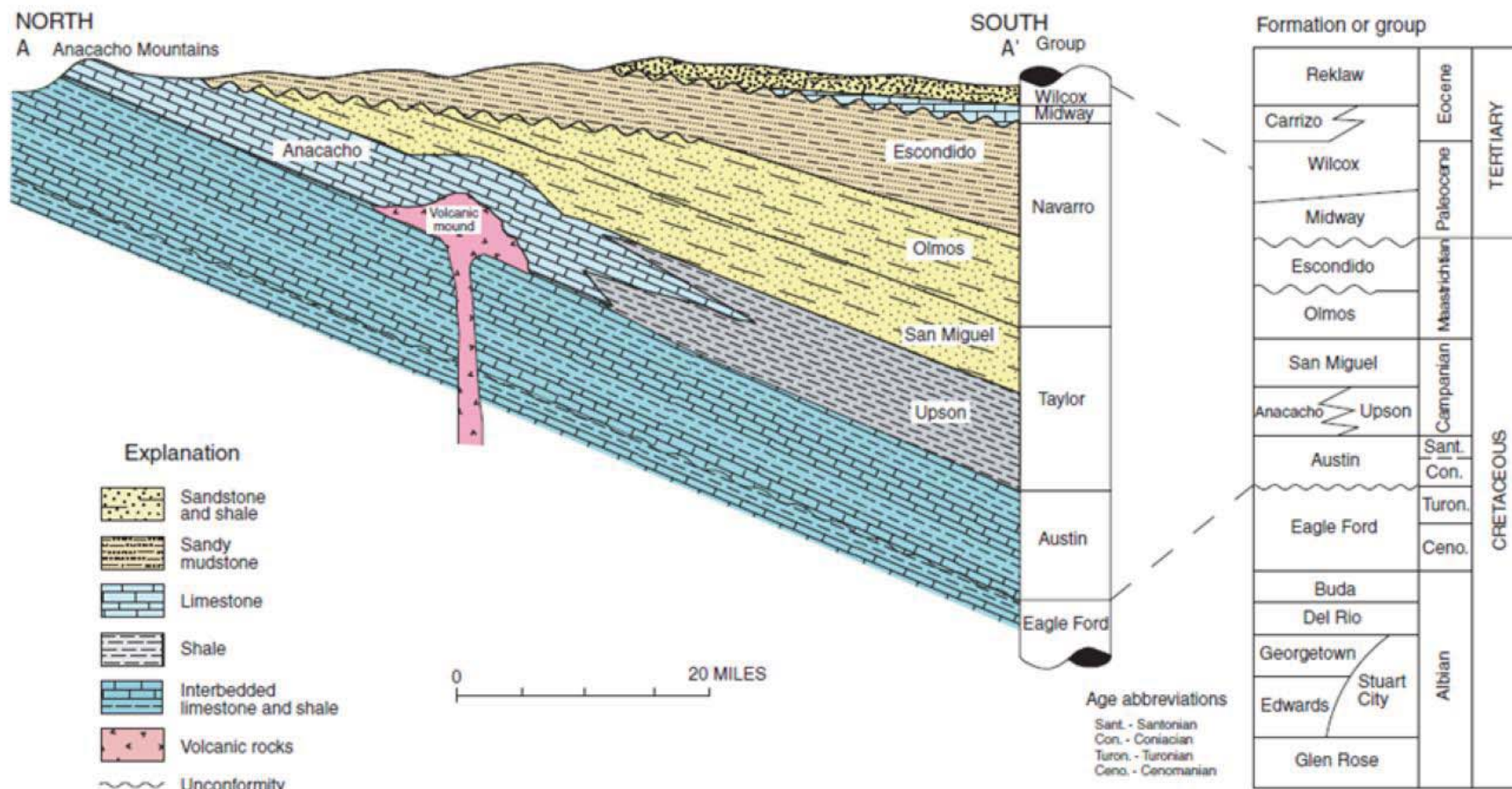
The Maverick Basin in Dimmit County

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Presenter's notes: Study took place in the Eagle Ford in the Maverick Basin in Dimmit County. The study included two wells. Downhole Geochemical Logging (DGL) samples were taken from both wells. Both vertical and lateral cutting samples were collected from the first well and only vertical cutting samples were tested on the second well.

Cross Section of the Maverick Basin



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

Downhole Geochemical Logging Analysis



- Cuttings are collected in glass 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 C₂ to C₂₀ carbon range
- Easily differentiates between multiple phases
- Identifies reservoir compartmentalization
- Identify by-passed pays

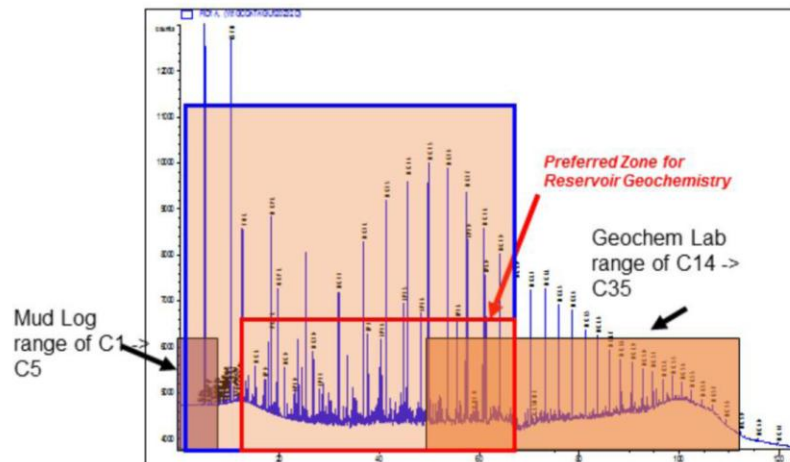


Presenter's notes: One of the most common tools used to understand reservoirs is conventional core analysis. Scientists look at various rock properties like porosity, permeability, variability across a core, grain density, and fluid saturation to better understand how fluids (i.e. oil) will flow through and from a reservoir. This is important in attempting to predict well and field productivity. Additionally, core analysis normally takes many months (*Presenter's notes continued on next slide*)

(Presenter's notes continued from previous slide)

(b/c of the backlog of samples in the various labs. DGL can provide you data in just a few weeks, not a few months. Also, how do you know where to take your cores? The Expl VP at SWM recently said at an AAPG symposium in Vancouver that he prefers to wait a little while into the project to determine where is the most strategic area of the field to take cores, because when little is known they can spend a lot of money taking and analyzing cores from the wrong part of the field. However, while all of these are important properties to measure they do not really focus on hydrocarbons. They focus on rock properties to predict how hydrocarbons will flow from the well bore.

Conventional Hydrocarbon Analyses



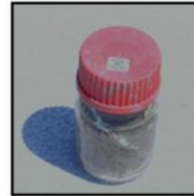
Presenter's notes: This shaded blue box shows the coverage range for DGL. Just looking at the box shows the density of compounds covered by the method. DGL technology measures from C2 -> C20 that enables the data to provide HC fingerprints for gas, condensates, and oils. Notice I did not say that DGL estimates or guesses at the HC phase as other methods do. DGL provides the ability to not only differentiate between gas, condensates, and oils, *(Presenter's notes continued on next slide)*

(Presenter's notes continued from previous slide)

but it allows you to also differentiate between several different oil signatures, which is not possible with other technologies. Also, DGL measures down to the PPB range that is 1,000 times lower than other technologies. This allows the method to measure seals down to the molecular level, which no other method can do. Finally, and probably most importantly, since the AGI method measures many of the Isoprenoids between C₁₀ and C₂₀. This technology provides the ability to assess compartmentalization in the way reservoir geochemists do. While reservoir geochemists look at the entire HC to understand the HC phase (i.e. gas, condensate, or oil), assess alterations effects, and assess similarity between various HC fingerprints, they primarily work with the C₁₀ to C₂₂ range for evaluating compartmentalization for several reasons.

The Basics of Sample Collection

- Cuttings are collected in glass jars, directly from the shaker table during drilling
 - > *well site geologist conducts the sampling*
- At what interval should you collect samples?
 - > *options: regular interval or at target zone(s)*
- Do I need to collect mud blanks?
 - > *yes – these help to determine inherent noise*
- How long do the analyses take?
 - > *rapid turn-around from time of well TD*
- Does this work with all drilling muds?
 - > **No – Not with ALL Oil-based muds**



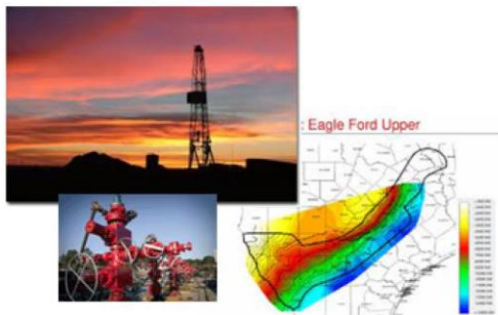
Presenter's notes: No! It works with water based drilling muds, synthetic drilling muds, air drilling, and nitrogen drilling. It does not work with most diesel-based drilling muds b/c you are pouring hydrocarbons down the well and obviously, that interferes with the detection of hydrocarbons because you are essentially contaminating the system. That being said, there is a slight caveat for offshore drilling b/c the oil-based drilling they use often (*Presenter's notes continued on next slide*)

(Presenter's notes continued from previous slide)

times is more of a glycol-based mud instead of a diesel-based mud because of environmental concerns. For offshore they are moving to glycol-based muds b/c they degrade and are less harmful to the environment. As a result, the glycol-based mud is much more highly refined, in other words ranging only from C_{10} - C_{12} . Therefore, we may be able to work with these highly refined oil-based muds, but we would have to get a sample and test it. Many of our unconventional clients use water-based muds through the vertical section of their well and then switch to oil-based muds for the horizontal sections.



Downhole Geochemical Logging in the First Vertical Eagle Ford Well

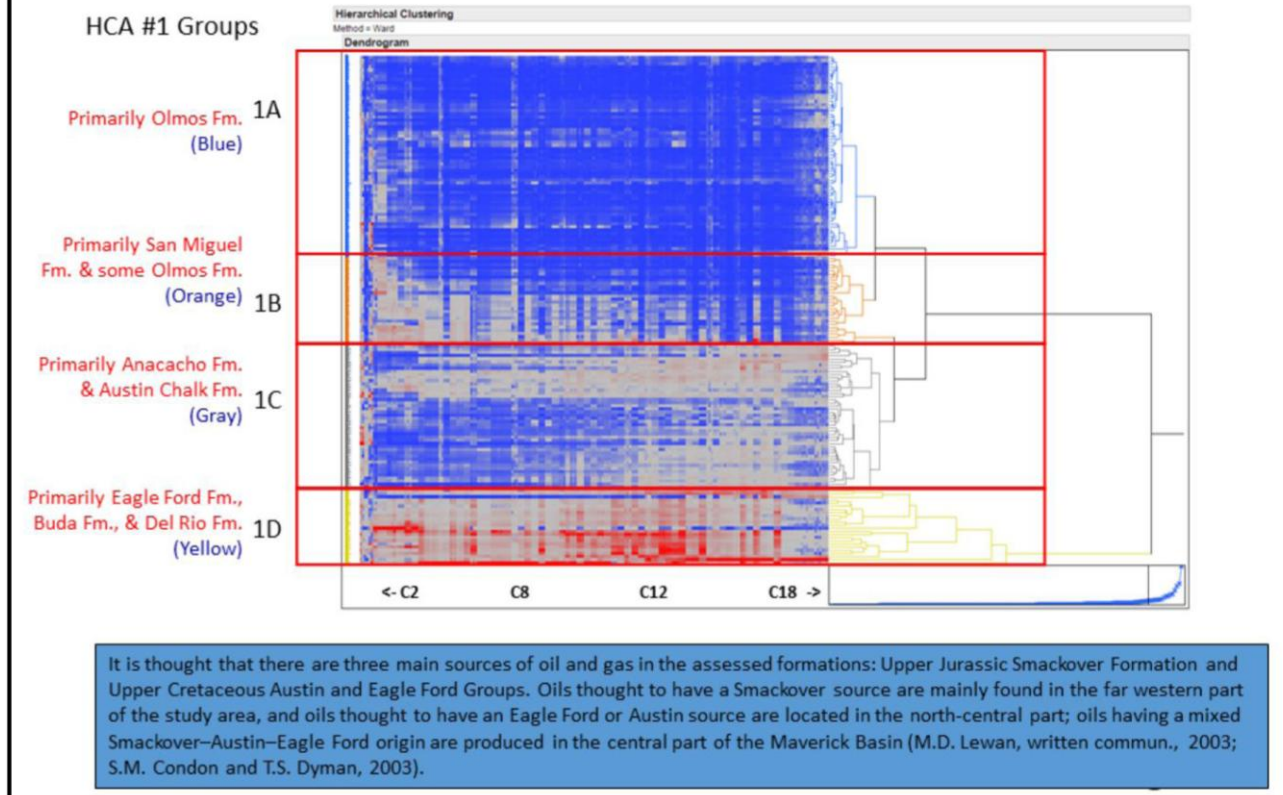


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Presenter's notes: 3-D hydrocarbon detection contains a horizontal component and a vertical component. I will start with a brief overview of the Horizontal component.

Hierarchical Cluster Analysis

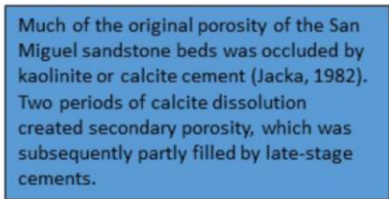


Presenter's notes: This chart shows the output from a hierarchical cluster analysis (HCA #1) using all of the samples (shown here in individual rows of data). The Y-axis is simply each individual cutting sample and the x-axis is the carbon range from C₂ - C₂₀. Red indicates a positive HC response at that range and blue indicates a negative or no response at that carbon range. Therefore, this process groups the samples together based on their *(Presenter's notes continued on next slide)*

(Presenter's notes continued from previous slide)

similar geochemical signatures indicating the program does not look at what depth, lithology, or stratigraphy and samples was taken from. It simply clusters samples based on similar signatures. This data set identified four main groups which are shown with the red rectangles and which are numbered 1-4 on the far left. What is interesting about the data is when you begin to look at what samples comprise these four groups you find a very interesting pattern. You find most of the Olmos samples fall in Group 1A. Most of the samples from the San Miguel Fm fall collectively in Group 1B, the Group 1C samples are primarily comprised of samples from the Anacacho & Austin Chalk, while Group 1D is comprised of samples taken from the deeper Eagle Ford, Buda, & Del Rio Fms. What is interesting about this breakdown is that the cluster analysis correlates to published oil & gas sources for the Maverick Basin. Published data ascribes the Eagle Ford as a known HC source, which most likely charges the Eagle Ford, Buda, & Del Rio and the Austin Chalk as a source for the Austin Chalk & the overlying Anacacho. The San Miguel appears to be a third and distinct HC signal while the Olmos is a background signal.

prints



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Presenter's notes: This slide includes the same two depth profile charts, with the addition of some select TIC signatures (total ion chromatograms) for various horizons. Of particular note is the change in the TIC patterns as the well was drilled and the apparent increase/decrease in response from the samples. One of the first things that strikes you is that in the Lower San Miguel Fm you have a gas/oil signature. As you move from *(Presenter's notes continued on next slide)*

(Presenter's notes continued from previous slide)

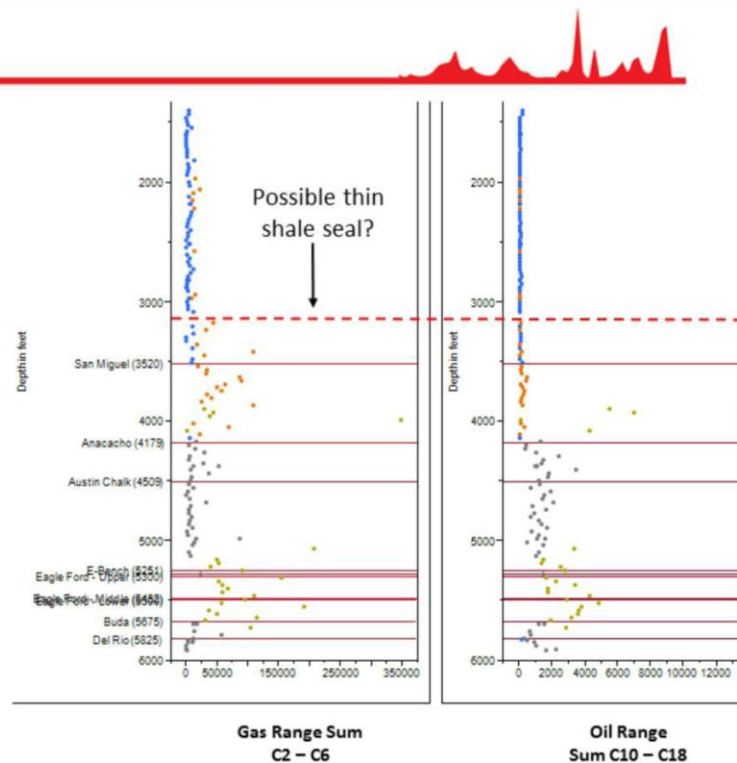
the bottom TIC to the middle TIC, you notice a start similarity. The gas signature in the Upper San Miguel looks just like the HC in the Lower San Miguel without the liquid portion. It is almost as if you have a gas cap over the oil formation. Then as you look into the Olmos Fm the HC signature looks like a reduced version or background version of the Upper San Miguel gas signature. The transition between the three HC zones is intriguing. Beneath this (between 3,870' and 4,110') is a different signature with more oil-like characteristics appears. These samples are all within the San Miguel Fm. and perhaps a facies change or gradation towards the bottom of this formation may explain the change in the geochemical response. Note the intensity of the oil signature in the Lower San Miguel. This is the highest oil intensity in the entire well, including the Eagle Ford. This prolific liquid rich area could be missed if people were only focused on the Eagle Ford and drilled right through to the Eagle Ford. As we mentioned in the previous slide the cluster analysis separated the San Miguel samples as a unique group or cluster that was noticeably different from the Austin Chalk production and the Eagle Ford generation. However, the San Miguel is not known as a potential source; so, we do not really have an explanation for this unique HC signature in the San Miguel Fm. We also know that, by definition, HCs must have a space to reside. Therefore, the more HCs detected, typically, the greater porosity. So, the greater porosity inferred here by the DGL data is supported by the well logs and the data reported by Jacka in 1982.

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 an 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).

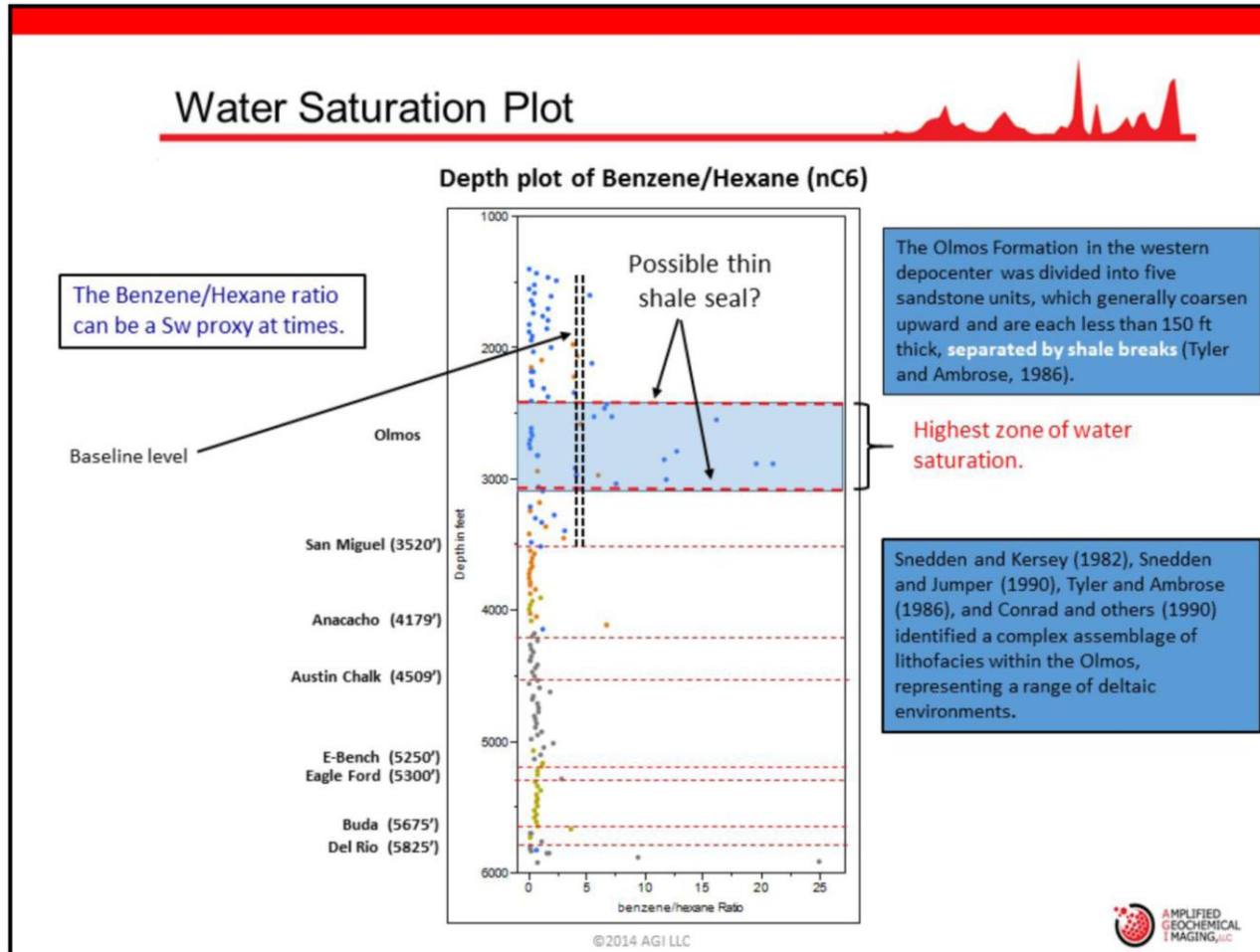


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Presenter's notes: As we drill a little deeper into the data, notice the gas increase starts just above the San Miguel Fm. around 3,100'. Therefore, this would imply that the gas in the San Miguel is also in the Olmos and there is no seal between the two. Yet why does the gas in the San Miguel begin to substantially increase at 3,100'? One explanation may be due to a thin seal in the Olmos. Tyler & Ambrose reports that the Olmos is divided into multiple sections and whether that number is three or five depends in what portion of the field you are located. However, the point is, there are thin shale seals interlaced within the Olmos. So, the question can be raised to we have a small undetectable seal at about 3,100'?

Water Saturation Plot

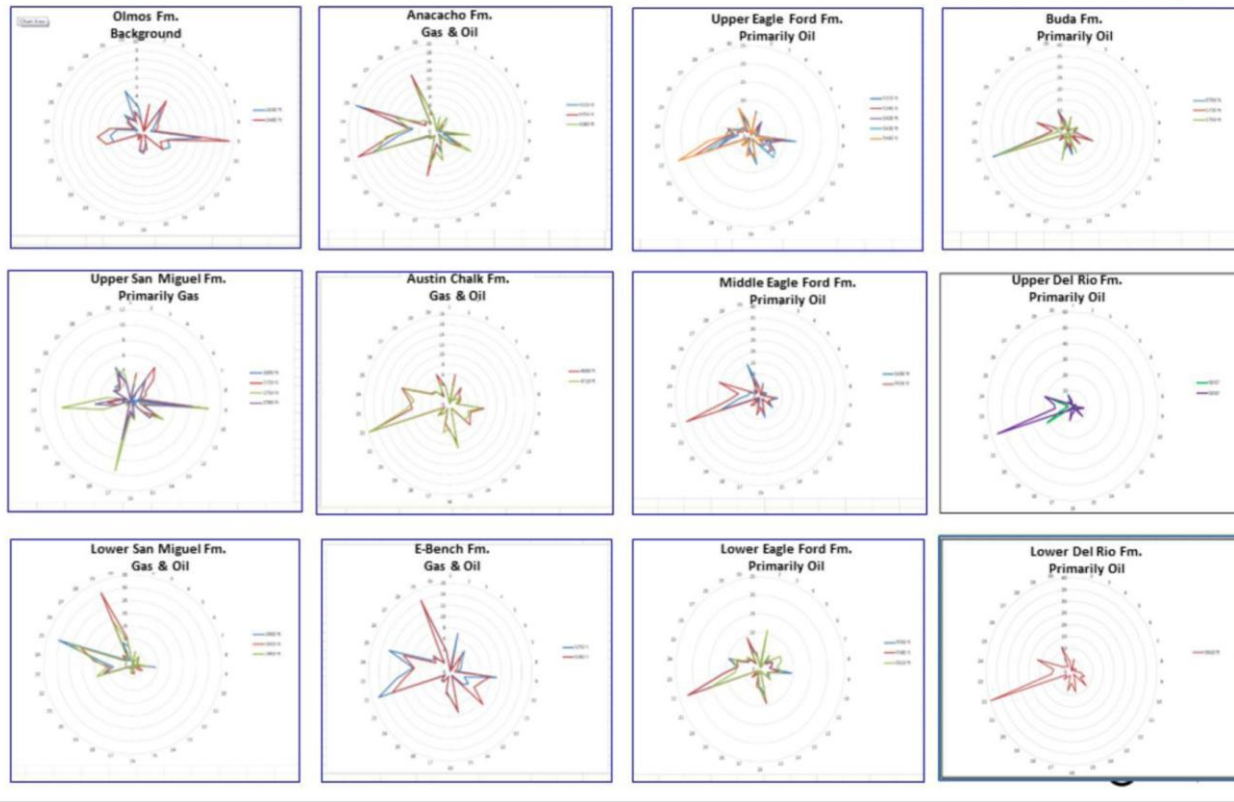


Presenter's notes: This graph plots the ratio of Benzene over Hexane (nC₆) versus depth. The premise is that in a hydrocarbon zone the ratio of Benzene to hexane is roughly 1.0. However, in water saturated zone benzene preferentially dissolves in the water because benzene is very water-soluble because it is a polar compound while hexane, a nonpolar compound, does not readily dissolve in water. Thus, the benzene (*Presenter's notes continued on next slide*)

(Presenter's notes continued from previous slide)

concentration increases substantially over the hexane concentration. We can see from the plot that Benzene/Hexane ratio is consistently low throughout the hydrocarbon bearing zones. However, we see in the Olmos a dramatic increase in the ratio. There appears to be a background ratio of 2 - 4 that then dramatically increases to 2,400' - 3,100'. So, why is this? From literature, we know that the Olmos in this area is deltaic sandy shale as reported by Snedden others. So, we would expect higher water saturation in this zone, which we see between 2,400'-3,100'. So this begs the question does the geochemical data indicate small thin sealing shale sections at 2,400' and 3,100'? The gas plot and the Sw proxy might indicate that.

Hydrocarbon Radar Plots



Presenter's notes: These star plots are generated using compound ratios from C₁₀ - C₂₀. The absolute shape of the star plot is not what is important. What is important is how they relate to each other. The first thing that jumps out at you is that there appears to be three groups of patterns. You have the back background Olmos and San Miguel gas pattern the Lower San Miguel, Anacacho, Austin Chalk, E-Bench Pattern and the third group (*Presenter's notes continued on next slide*)

(Presenter's notes continued from previous slide)

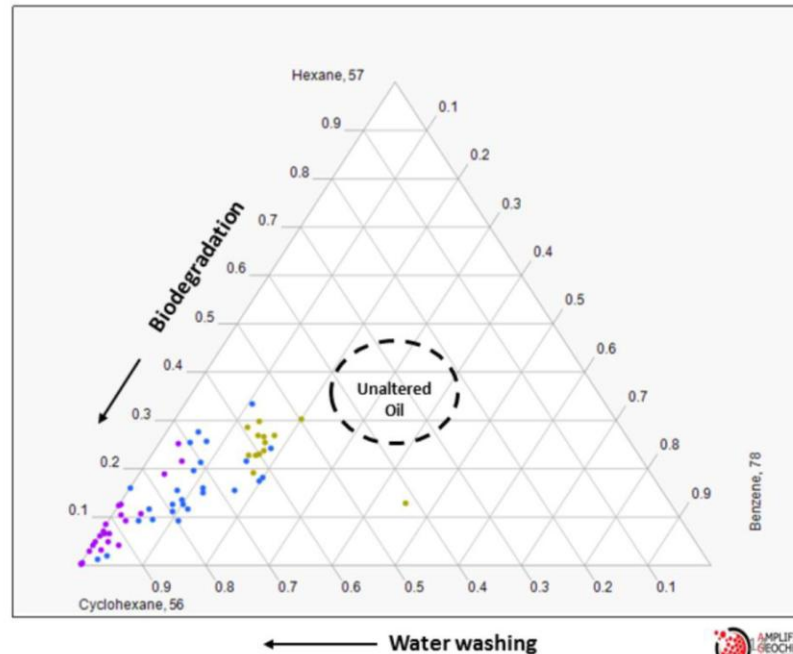
which is everything below (i.e. the Upper, Middle, & Lower Eagle Ford, the Buda and Del Rio). This is similar to the cluster analysis where we saw three clusters that broke out essentially in the same manner. What is also interesting is that there are similarities between the Lower San Miguel oil-bearing zone, the Anacacho Fm and the Austin Chalk. There does appear to be a similarity also with the E-Bench, but this Fm. is so thin there is no discrete sample directly in the EBench. Therefore, the geochemical data does appear to agree with literature references that say there are two major source rocks in the Maverick Basin and those are the Austin Chalk and the Eagle Ford. From this data, it appears the Austin Chalk is charging the Anacacho and San Miguel Fms.

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.

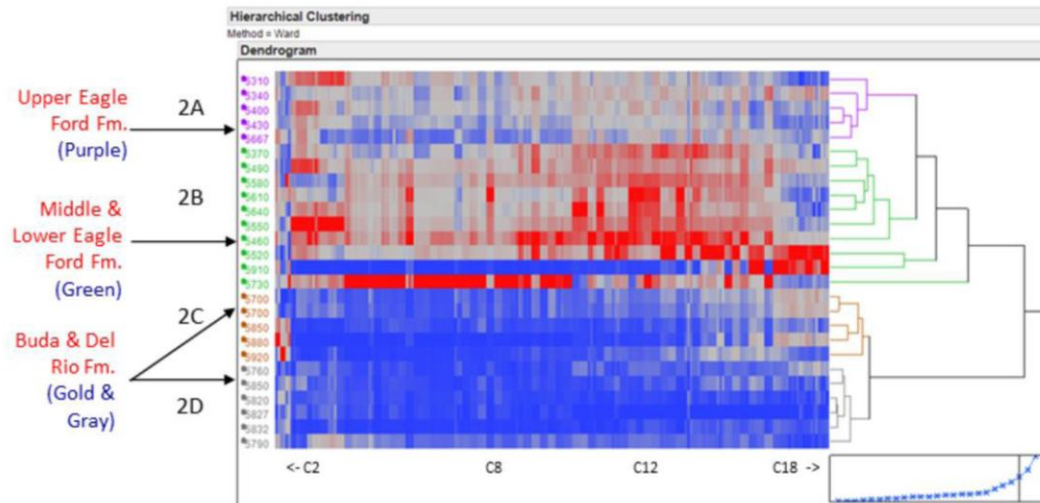
- San Miguel
- Austin Chalk
- Eagle Ford



Presenter's notes: This ternary plot also lends some credence to that assumption. Here we have plotted Benzene, Cyclohexane, and Hexane in an attempt to differentiate the degree of alteration between oil sets. As seen here, there is a distinct difference between the geochemical make-up of Eagle Ford Fm. samples and the San Miguel Fm oil samples. Therefore, the Star plots and the ternary plot seem to indicate that the San Miguel oil is different from the Eagle Ford and may well be sourced from the Austin Chalk.

Hierarchical Cluster Analysis for the EF-1

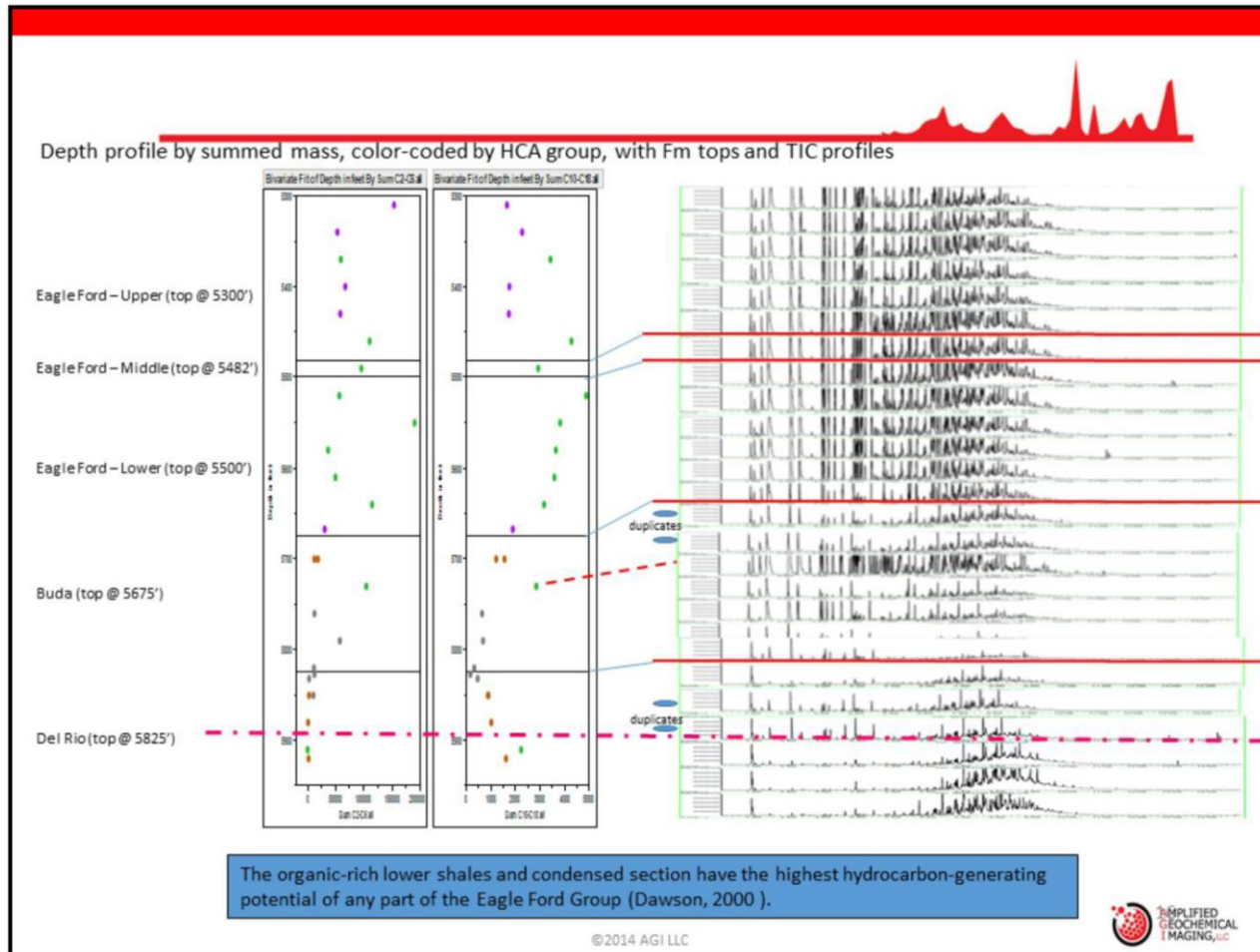
Cluster analysis for the Eagle Ford,
Buda, & Del Rio formations



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Presenter's notes: This is the output from another HCA processing (HCA 2), which only included the samples from the Eagle Ford, Buda, and Del Rio Fms. In this process, we have identified four groups as shown. The top two groups clearly have a greater mass response.



Presenter's notes: This is a similar depth profile through the Eagle Ford, Buda and Del Rio sections. The TICs to the right indicate a very consistent and high mass response for all of the samples throughout the Eagle Ford (Upper, Middle and Lower). The TICs throughout the Eagle Ford support what was seen in the star plots in that there is a similar hydrocarbon signature throughout the Eagle Ford. Additionally, the data (*Presenter's notes continued on next slide*)

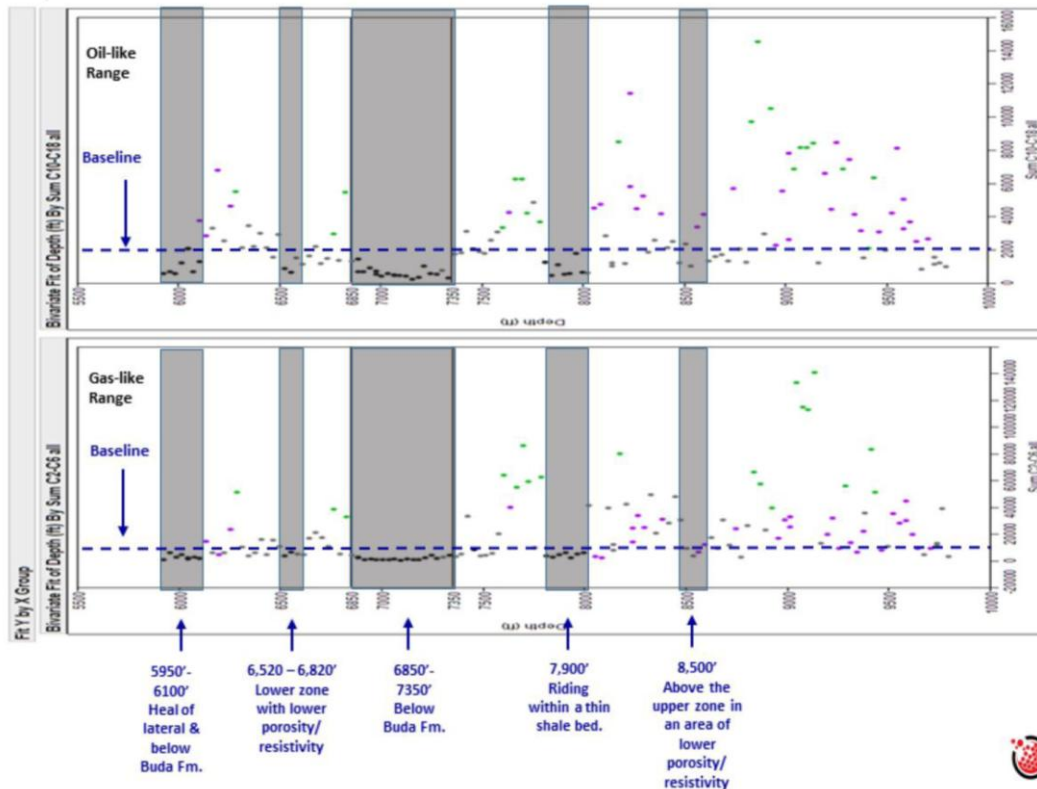
(Presenter's notes continued from previous slide)

shows the highest HC intensity is found in the Lower Eagle Ford section, which is consistent with literature that says the Lower Eagle Ford has the highest HC generating capacity due to its higher organic content. The TICs in the Buda seem visually different from the Eagle Ford. However, the radar plots in the previous slide indicate the HC's in the Eagle Ford and the Buda are very similar. Therefore, the variance in the HC signatures between the Eagle Ford and the Buda is most likely due to a decrease in intensity. That is confirmed in the depth plot. The Eagle Ford samples have an intensity range from about 2,500 ng - 5,000 ng while the intensity for the Buda is roughly less than 2,500. Therefore, the fact that the star plots indicate a similar HC between the two Fms and that the intensity decreases from the upper Buda to the lower Buda seems to support the concept that the Eagle Ford is charging the Buda. One of the powerful messages from this slide is the fact that the decrease in HC intensity correlates to a decrease in porosity as well. We know from the well logs that the Buda generally has a lower porosity than the Eagle Ford. Therefore, the decrease in HC intensity trends with the porosity data. This porosity assertion is supported by the fact that there is one sample in the Buda at 5,730' that clusters with the Eagle Ford samples, shows an increase in intensity, and the TIC pattern is similar to the Eagle Ford section and the well logs indicate this sample point has a higher porosity than the rest of the Buda. Based on this you see the Lower Eagle Ford seems to have the highest porosity of the various Eagle Ford sections. The Upper Del Rio Fm. also has an oil-like signature and is very similar to the Buda. This may indicate that the Eagle Ford is also charging the top of the Del Rio. Notice half way through the Del Rio Fm. the HC signature begins to change and the intensity increases. This may indicate that the bottom of the Del Rio may be charged from the underlying Georgetown Fm. What this also indicates is that there does not appear to be any seals between the Upper Eagle Ford down through the Georgetown Fm.

Downhole Geochemical Logging in the Lateral Eagle Ford Well



Zones of Low Hydrocarbon Response



Presenter's notes: The Buda was subdivided into eight different zones based on porosity and resistivity. Three zones appeared to have higher porosity, resistivity, and perhaps more fractures. Oil-like components are plotted on the top scale while gas-like components on the lower scale. The X-axis on each plot is the depth and the Y-axis is the HC intensity. The depth chart has been turned on its side to more easily represent a lateral view of *(Presenter's notes continued on next slide)*

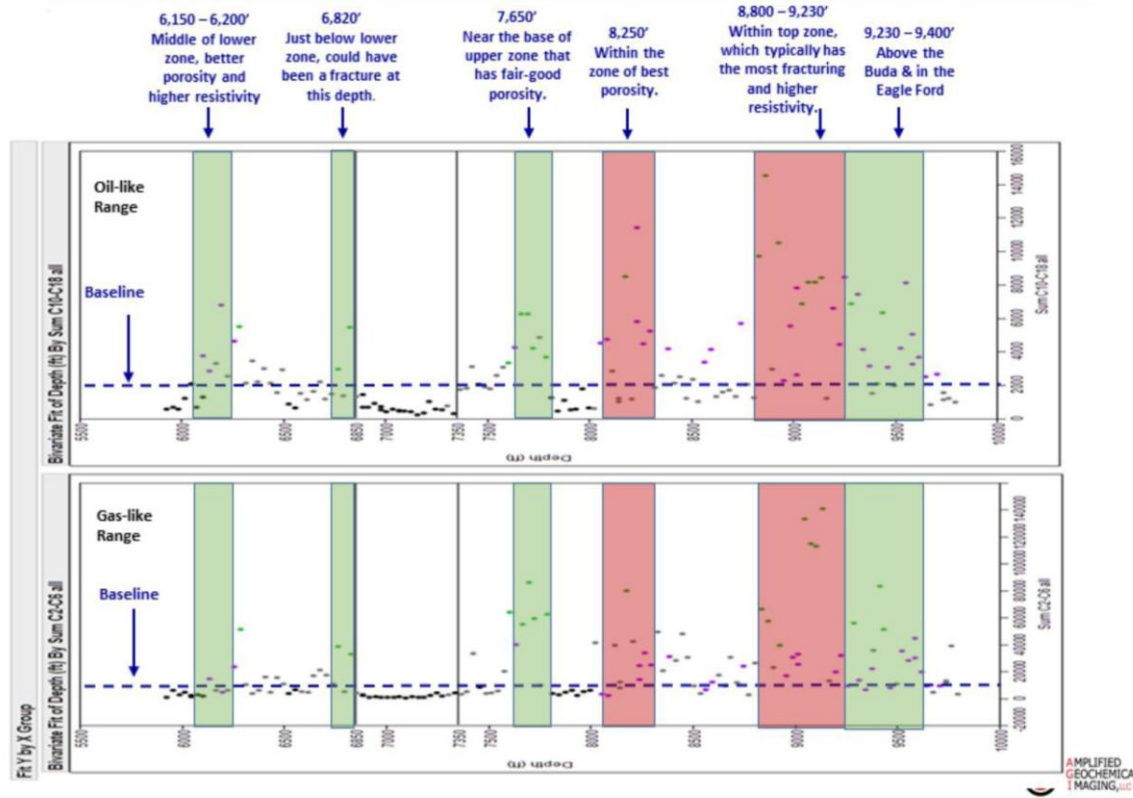
(Presenter's notes continued from previous slide)

the data.

The color of the dots or data points relates to cluster analysis, which we will not go into except to say the green cluster appears to have the highest degree of intensity and the black has the lowest degree of intensity. We have also added dashed blue line to indicate the approximate HC baseline. The gray shaded areas indicate areas of low HC response according to the DGL data. Conversations with the client indicate correlations between these low DGL readings and well notes. For example, the low DGL concentration from 5,950'-6,100' related to the heel of the lateral drilling where the drill bit was below the intended Buda fm. The downturn in HC concentration from 6,520'-6,820' corresponded to a zone of lower porosity/resistivity. Well logs indicate the decrease in HC concentration from 6,850'-7,350' was due to drilling out of zone beneath the Buda fm. The decrease in HCs at 7,900' was likely due to riding in a thin shale bed.

Around 8,500' the lateral drilling was above the upper target zone within the Buda, which was identified as an area with lower porosity/resistivity that would explain the decrease in there. Therefore, in each case where there is a significant decrease in HC concentration in the lateral drilling event, the DGL detects that decrease and it relates to geologic anomalies on the formation.

Zones of Elevated Hydrocarbon Response



Presenter's notes: As mentioned previously there were 3 subdivisions within the Buda that had been identified as zones of higher porosity, resistivity, and perhaps more fractures. These three zones were middle of the lower zone, the base of the upper zone, and the top zone. As seen in the plot above, the increases in HC concentrations from the DGL plot tracked well with these known zones of enhancement. For example, a kick in the oil (*Presenter's notes continued on next slide*)

(Presenter's notes continued from previous slide)

components is seen between 6,150'-6,200' in the middle of the lower zone. It was believed the HC kick at 6,820' coincided with a small naturally occurring fracture. At 7,650' and 8,250' the drill in the upper zone which was known to have better porosity and resistivity. At 8,800'-9,230' they reach the top zone which typically has the most fracturing and highest resistivity. The red shading shows that these two sections, 8,250' and 8,800' are by far the most prolific HC bearing zones in the lateral well and stand-out in terms of HC concentration. In addition, the final section between 9,230'-9,400' the lateral went out of the Buda and into the Lower Eagle Ford, which we know from the vertical data, was the second most HC prolific section of the well. It is also very interesting to note that besides the 50' section at 6,150' there are no strong HC responses in the lateral until you get to 7,650'. This may indicate, at least in this well, that fracturing before 7,650' may not be economically advantageous.

Downhole Geochemical Logging in the Second Vertical Eagle Ford Well



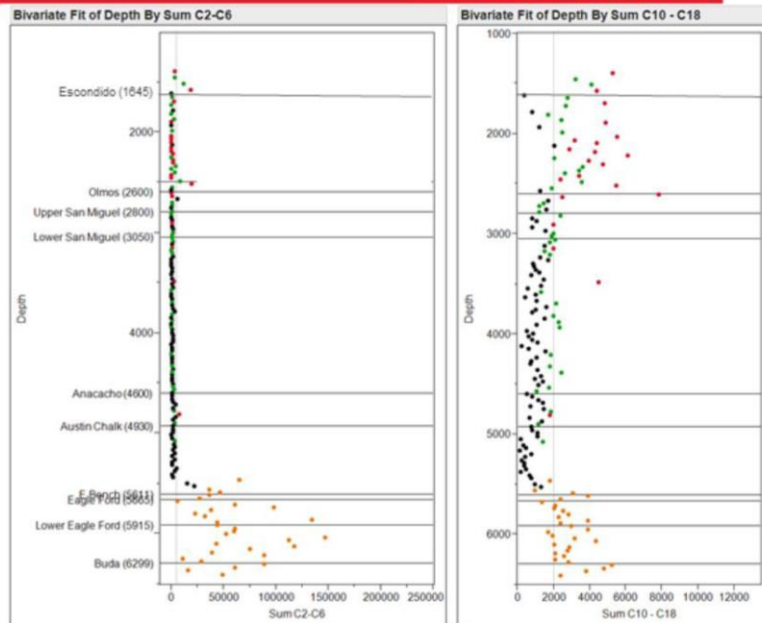
Key Zones of Interest

Depth profile of samples collected (Y axis) showing their mass response (X axis) for the light compounds (C2-C6) and the high molecular weight compounds (C10-C18), left and right respectively.

There appears to be a strong oil-like section above the Olmos, but with little or no gas component.

The Eagle Ford section contains both light, mid-range and high MW compounds suggesting a high API oil. More focus is warranted on this section.

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).



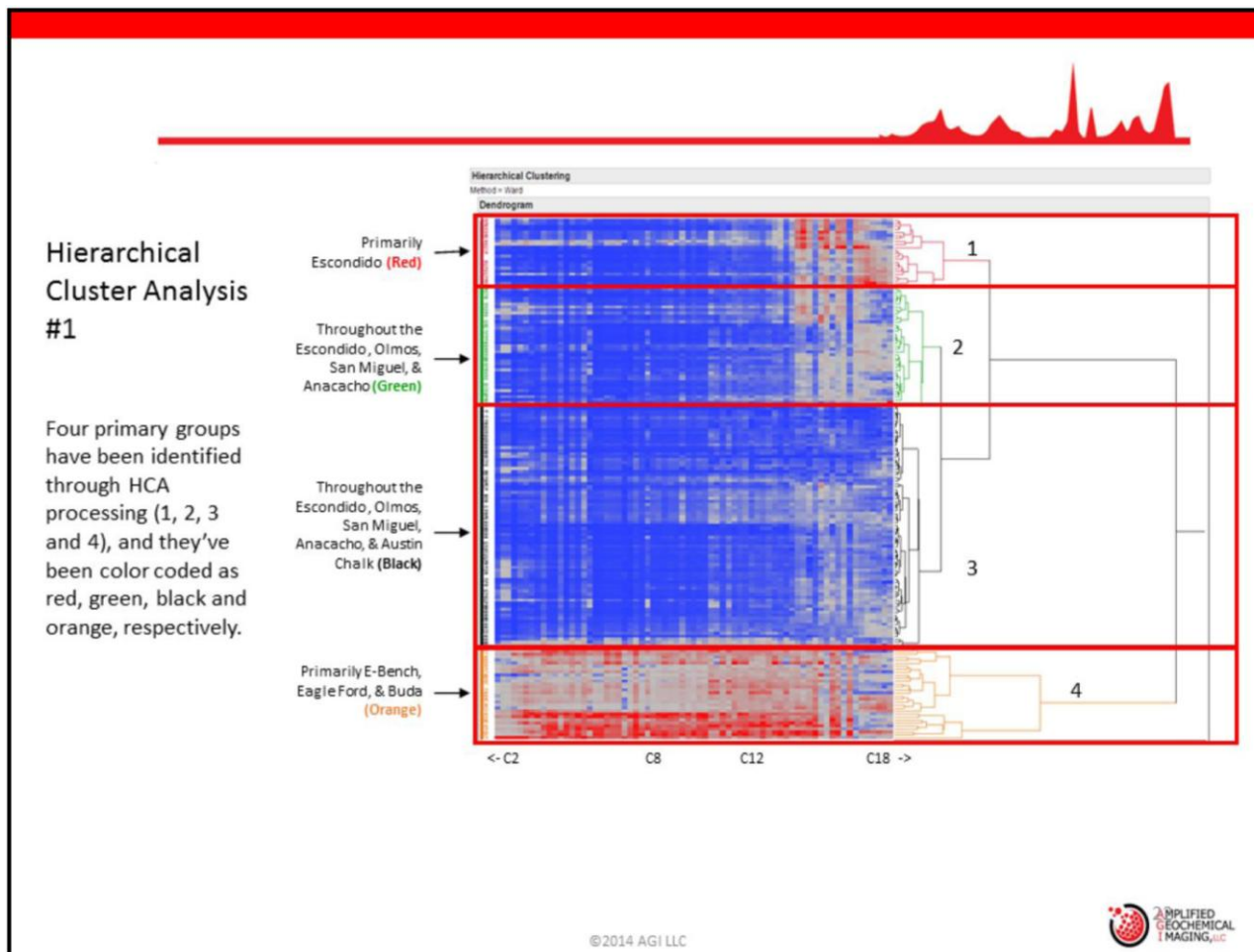
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Presenter's notes: Forget about the coloration of the dots for a minute and just look at the gas and liquid HC profiles for this Well 2. Obviously, we are looking at the summed light compounds (C₂-C₆) to the left, and the heavy compounds (C₁₀- C₁₈) to the right once again. First notice the HC pattern in this well is dramatically different from the first well. In Well 1, you had a very light gas tinge in the Olmos Fm while here there is no gas, just a *(Presenter's notes continued on next slide)*

(Presenter's notes continued from previous slide)

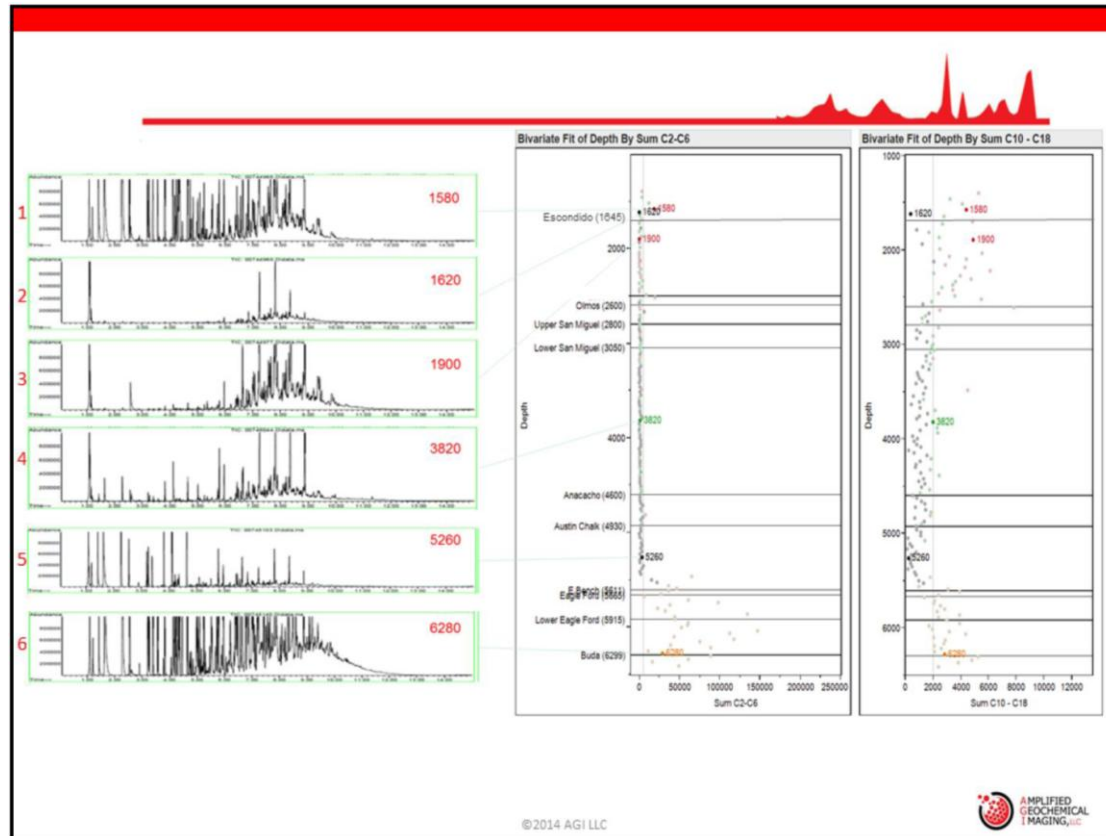
liquid signature. In Well 1, we had a strong gas-only response in the Upper San Miguel and a prolific oil-like signature on the Lower San Miguel. Here in Well 2 there is no gas signature at all and only a low concentration oil signature throughout the section. In Well 1, there was a gas/oil signature throughout the Anacacho and the Austin Chalk Fms, while in Well 2 there was no gas and the same oil-only signature seen in the San Miguel. These charts show the same color scheme as was used in the HCA 1, and it shows the mass response. The cluster diagram indicates that the hydrocarbons in the E-Bench, Upper Eagle Ford, Lower Eagle Ford, and Buda Fm. appear to be similar or the same. Literature indicates that the Lower Eagle Ford is the primary hydrocarbon source in the Maverick Basin. If true, it appears that there may be no seal between the Lower Eagle Ford and the adjacent formations (i.e. Upper Eagle Ford, E-Bench, and Buda) and the Lower Eagle Ford may be charging these formations. It is interesting to note, just like in Well 1, the Eagle Ford cluster of hydrocarbons essentially stops at the base of the Austin Chalk. Literature also indicates that the Austin Chalk is a hydrocarbon source as well. It appears this Austin Chalk signature is pervasive upward (i.e. cluster group 3) through the Anacacho, San Miguel, and Olmos with no compartmentalized seals between these various formations.



Presenter's notes: This chart shows the output from a hierarchical cluster analysis (HCA #1) using all of the samples (shown here in individual rows of data). This process groups the samples together based on their geochemical similarities, and from this process, we have identified four main groups which are shown with the red rectangles and which are numbered 1-4 on the far left. The dendrogram structure on the far right of this (*Presenter's notes continued on next slide*)

(Presenter's notes continued from previous slide)

chart shows how the samples are related to each other, and from this structure, it is clear that Group #4 is distinct from the other 3 groups. The blue-grey-red section of this chart shows the mass response for each compound that has passed signal to noise processing; the compounds are in elution-time order, which means the most volatile compounds are on the left of this chart and the higher molecular weight compounds are to the right. The colors are scaled according to the mass response for that compound and for that sample in terms of standard deviation, either below the mean for all samples (blue), at the mean (grey), or above the mean (red). As seen by the red color indication the Escondido Fm. displayed a liquid hydrocarbon with little light or gas contribution and primarily a backend liquid portion (C_{14} - C_{20}), while the hydrocarbons in group 4 a gas/oil hydrocarbon signature ranging from C_2 to C_{20} .



Presenter's notes: This slide includes the two depth profile charts, with the addition of some select TIC signatures (total ion chromatograms) for various horizons. Of particular note is the change in the TIC patterns as the well was drilled and the apparent increase/decrease in response from the samples. The pattern that is evident in TICs two and five represent a background-like signature, and although the signatures from one and six appear visually similar, the statistical processing is able to discriminate between these patterns. You can see in this well that there is an increase in both light end and heavy end components as you reach the bottom of the Austin Chalk Fm. This is visually apparent from the TIC signature from the sample selected at 6,280'. The HC signature seen at 6,280' is similar in fingerprint and intensity (roughly 4,000 -4,500 ng) to the HC seen in the Eagle Ford Fm in Well 1.

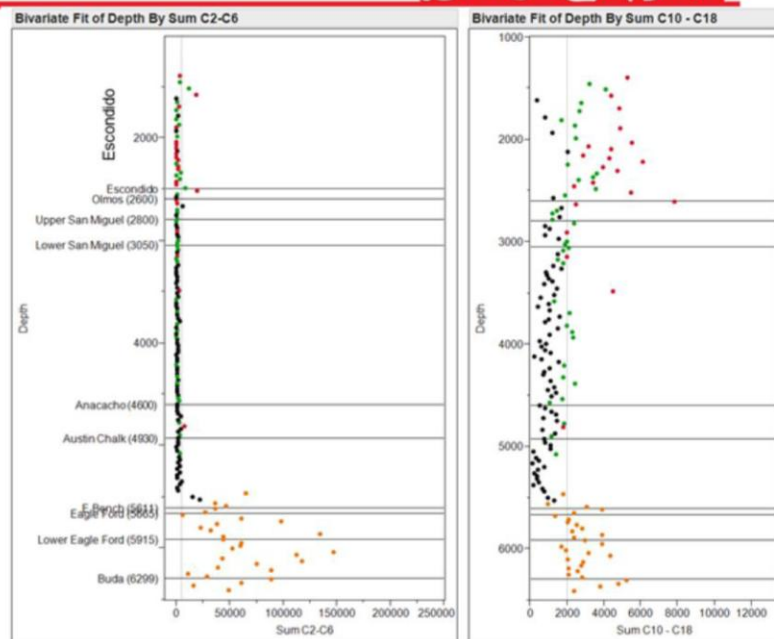
Key Zones of Interest

Depth profile of samples collected (Y axis) showing their mass response (X axis) for the light compounds (C2-C6) and the high molecular weight compounds (C10-C18), left and right respectively.

There appears to be a strong oil-like section above the Olmos, but with little or no gas component.

The Eagle Ford section contains both light, mid-range and high MW compounds suggesting a high API oil. More focus is warranted on this section.

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).



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Presenter's notes: These charts show the same color scheme as was used in the HCA 1, and it shows the mass response for the summed light compounds (C2-C6) to the left, and the heavy compounds (C10-C18) to the right. The cluster diagram indicates that the hydrocarbons in the E-Bench, Upper Eagle Ford, Lower Eagle Ford, and Buda Fm. appear to be similar or the same. Literature indicates that the Lower Eagle Ford is the *(Presenter's notes continued on next slide)*

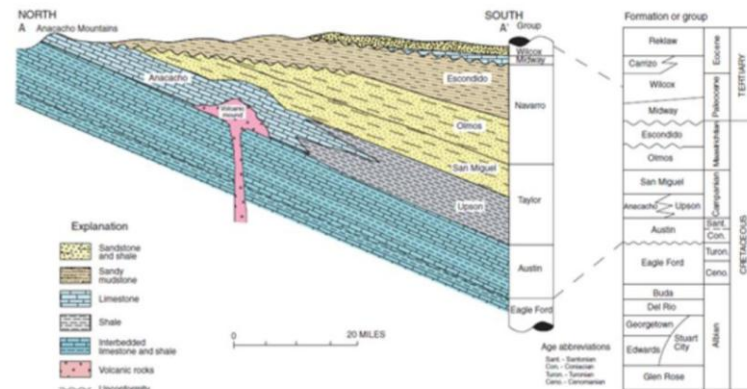
(Presenter's notes continued from previous slide)

primary hydrocarbon source in the Maverick Basin. If true, it appears that there may be no seal between the Lower Eagle Ford and the adjacent formations (i.e. Upper Eagle Ford, E-Bench, and Buda) and the Lower Eagle Ford may be charging these formations. It is interesting to note, just like in Well 1, the Eagle Ford cluster of hydrocarbons essentially stops at the base of the Austin Chalk. Literature also indicates that the Austin Chalk is a hydrocarbon source as well. It appears this Austin Chalk signature is pervasive upward (i.e. cluster group 3) through the Anacacho, San Miguel, and Olmos with no compartmentalized seals between these various formations.

Field Variability

Why the difference in the two Hydrocarbon well profiles?

Well 2 was only 2.5 miles away from Well 1, but was 200' structurally lower and closer to the sourcing restricted mini-basin in Dimmit Co.



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Presenter's notes: Had you drilled Well 2 first, you would have been lead to believe there was a strong oil content in the Escondido and not much else until you got to the Eagle Ford. You may well have by-passed the most prolific zone in the well in the San Miguel Fm. If you looked at Well 1, first you may have completely missed the liquid portion of HCs in the Escondido. It is dramatic how different the HC profiles can be in two wells (*Presenter's notes continued on next slide*)

(Presenter's notes continued from previous slide)

in the same field only 2.5 miles apart. This is the perfect example of why you need to develop HC profiles in unconventional shale plays because no two wells are normally the same.

You might say all we are interested in is drilling laterals in the Eagle Ford and we do not need new or additional information to do that. And there is some truth to that. Then let us also be honest in saying you may be grossly under-estimating or overestimating your reserves because you do not have an accurate picture of your hydrocarbons in place and there could be some significant by-passed pays, such as the Lower San Miguel in Well 1, which you are leaving in the ground.

Lateral Well Summary



- The DGL hydrocarbon data correlated nicely with well porosity and resistivity logs.
- The DGL data was able to accurately predict Sweet Spots of higher porosity, hydrocarbon concentration, and natural fracturing.
- In this well, DGL data was able to identify when drilling efforts were in or out of the target formation
- **In this well, fracing stages between 6000' – 7500' may not be economical given the low hydrocarbon intensity in this range.**

Vertical Well Summary



What if this were the 1st well in the Eagle Ford? What would you know?

- The Sw proxy indicated a deltaic sandy shale section in the Olmos may have had a significant increase in water saturation.
- An evaluation of the Del Rio hydrocarbon fingerprints indicated the Upper Del Rio may have been charged from the Lower Eagle Ford Fm. while the Lower part of the Del Rio may have been charged from the Georgetown Fm.
- There appeared to be no formational seals from the San Miguel down through the Georgetown Fm.

Vertical Well Summary



What if this were the 1st well in the Eagle Ford? What would you know?

- There were four major hydrocarbon groups according to cluster analysis:
- The Lower Eagle Ford may have charged all portions of the Eagle Ford, Buda, & Del Rio
- The Austin Chalk Fm. may have charged the Anacacho & E-Bench
- The Olmos Fm. was essentially devoid of hydrocarbons.
- The San Miguel Fm. had a unique gas and oil signature
- The San Miguel gas appeared to move up-zone and charge a small portion of the lower Olmos Fm.
- The San Miguel gas signature and the Sw index suggested possible subtle shale seals in the Olmos Fm.

Downhole Geochemical Logging

- is 1,000 times more sensitive than other methods
- Is the only method that measures from C2 – C20
- can be a powerful proxy for porosity
- can guide your fracing stages

Thank You!

