Downhole Geochemical Logging in the Eagle Ford - Hydrocarbon Detection in Vertical & 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 $n-C_1$ (methane) to $n-C_8$ (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 $n-C_7$ (heptane) to $n-C_{15}$ (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 Eagleford 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 prospect section. This provides the unique ability to look at a broad compound range from C_2 to C_{20}, which is significantly more expansive than the limited traditional ranges of C_1-C_5 or C_1-C_8 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 increased sensitivity and carbon range provides the ability to clearly distinguish between various hydrocarbon phases, distinguish multiple oil signatures, identify by-passed pay, infer compartmentalization, and avoid false positives from mud log data (C_1-C_5) for fracture or fault gases. In addition, it helps to avoid false negatives from mud gas line monitoring for, under-pressured

formations, thick mud systems, can be used for 3-D evaluation field wide, infers sulfur content of oils, and assess depositional environment, thermal maturity age, biodegradation with geochemical plots, which you cannot do with other technologies.

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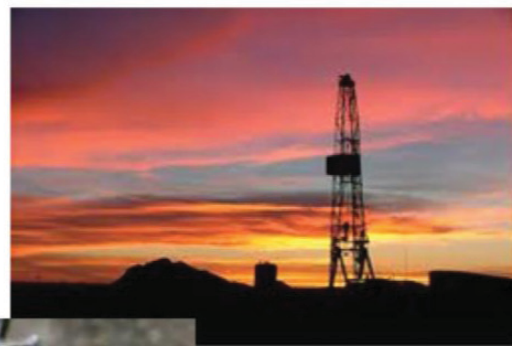
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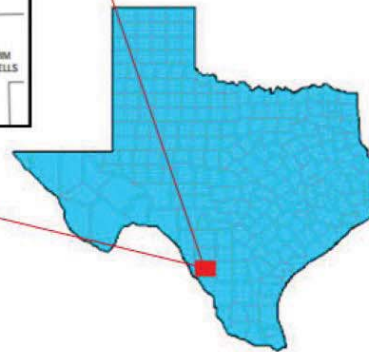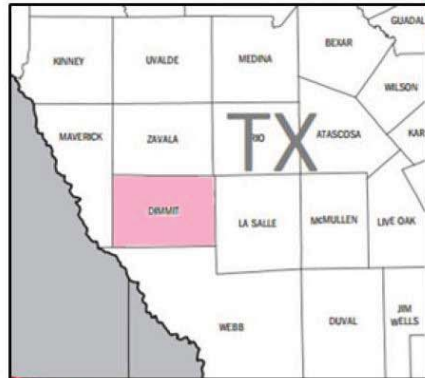
Downhole Geochemical Logging in the Eagle Ford

Hydrocarbon Detection in Vertical & Lateral Wells

by Rick Schrynemeeckers
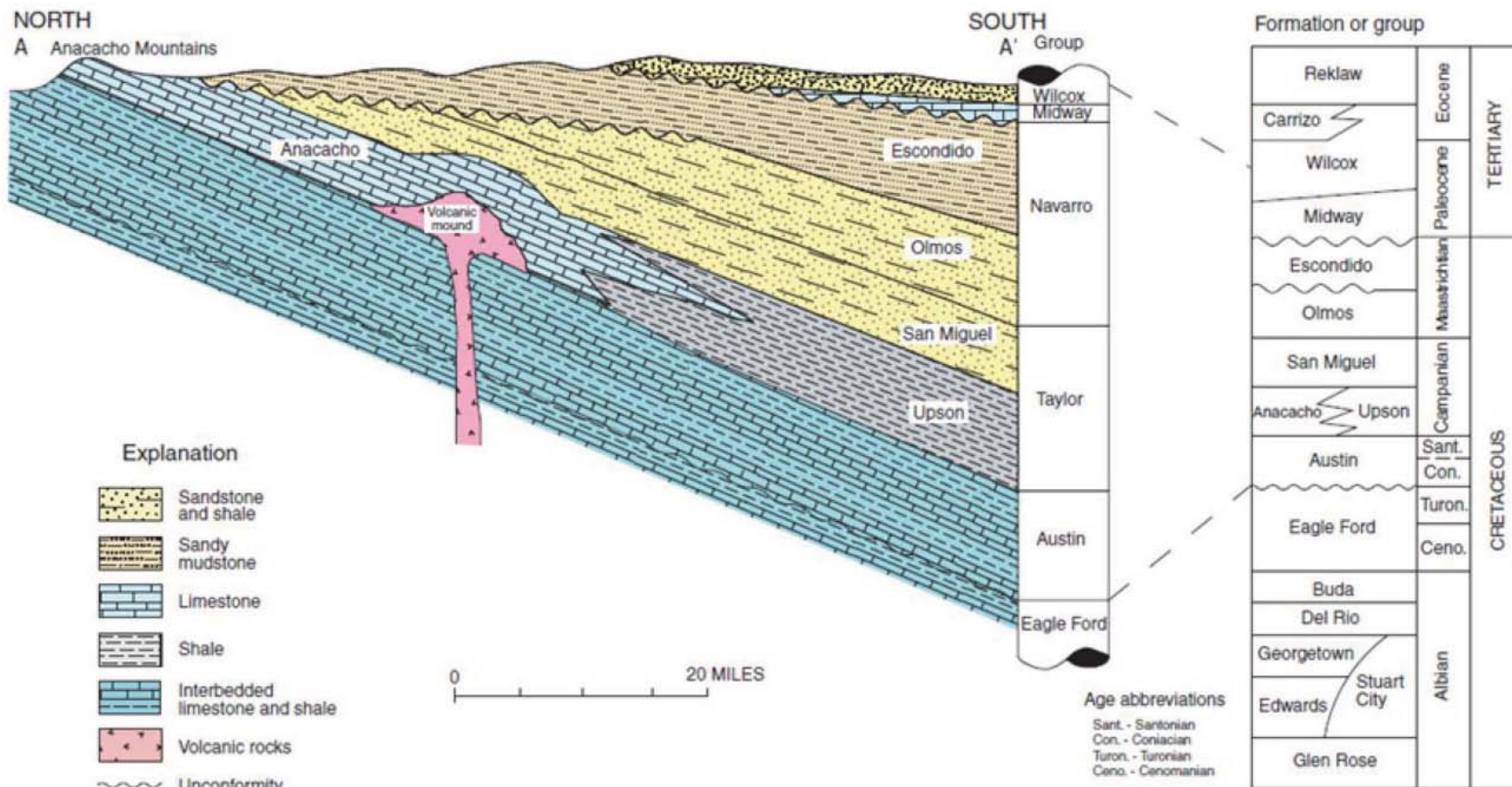Schrynemeeckers@AGIsurveys.net
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Presenter's notes: Study took place in the Eagle Ford in the Maverick Basin in Dimmit County. The study included two wells. Downhole Geochemical Logging (DGL) samples were taken from both wells. Both vertical and lateral 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)

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 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. In addition, how do you know where to take your cores. The Exploration 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 spent 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

Mud Log range of C1 -> C5

Preferred Zone for Reservoir Geochemistry

Geochem Lab range of C14 -> C35
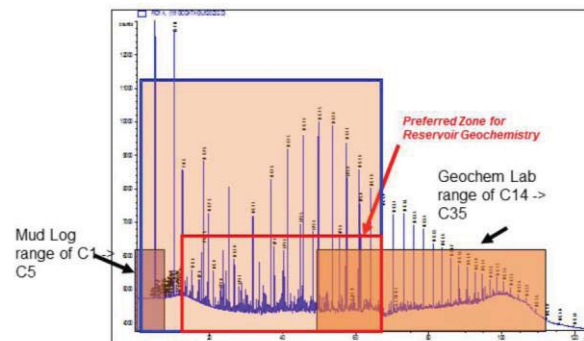
Presenter's notes: This shaded blue box shows the coverage range for DGL. Just looking at the box shows the density of compounds covered by the method. DGL technology measures from C_2 -> C_{20}, which enables the data to provide hydrocarbon fingerprints for gas, condensates, and oils. Notice I did not say that DGL estimates or guesses at the hydrocarbon phase as other methods do. DGL provides the ability to not only differentiate between gas, condensates, and oils, but it allows you to also differentiate between several different oil signatures, which are not possible with other technologies. In addition, DGL measures down to the PPB range, which is a thousand 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 C_{10} and C_{20}. This technology provides the ability to assess compartmentalization in the way reservoir geochemists do. While reservoir geochemists look at the entire hydrocarbon to understand the hydrocarbon phase (i.e. gas, condensate, or oil), assess alterations effects, and assess similarity between various hydrocarbon fingerprints, they primarily work with the C_{10} to C_{22} 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 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.
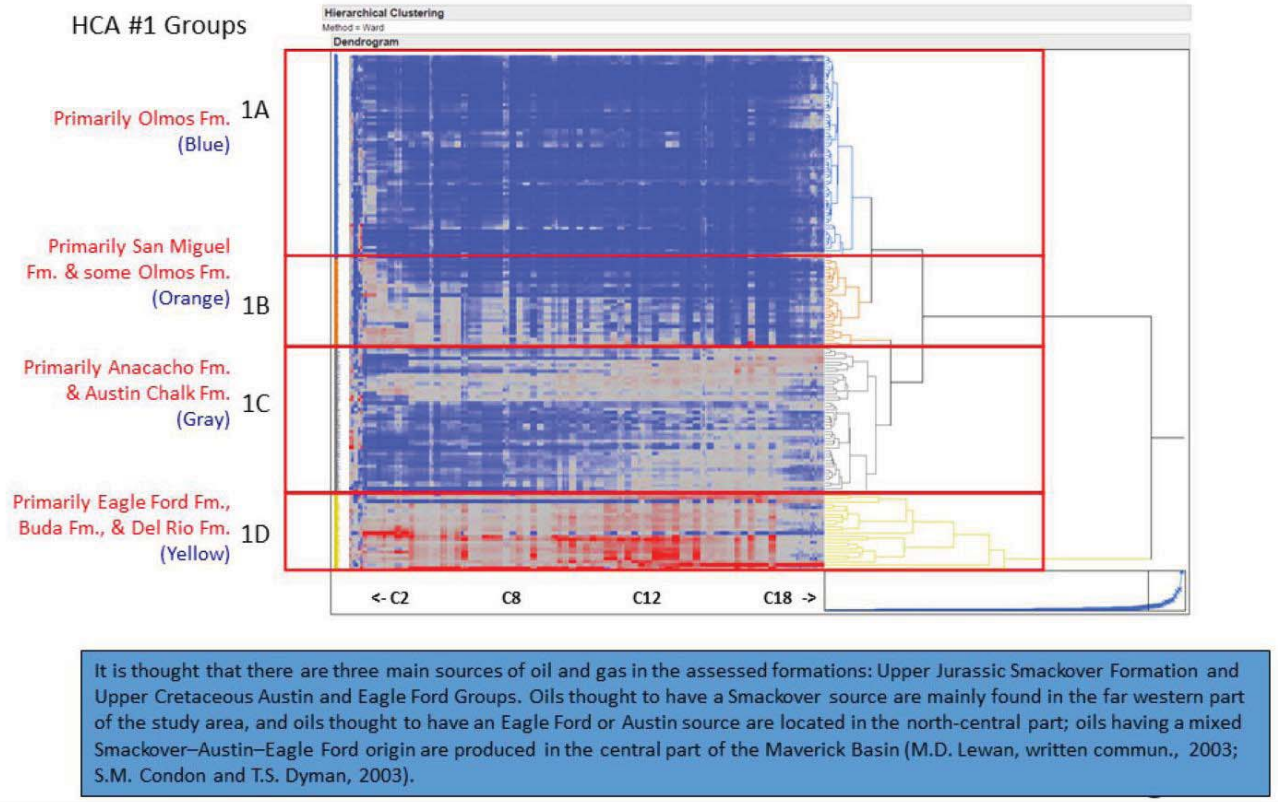
Many of our unconventional clients use water-based muds through the vertical section of their well and then switch to oil-based muds for the horizontal sections.

Downhole Geochemical Logging in the First Vertical Eagle Ford Well
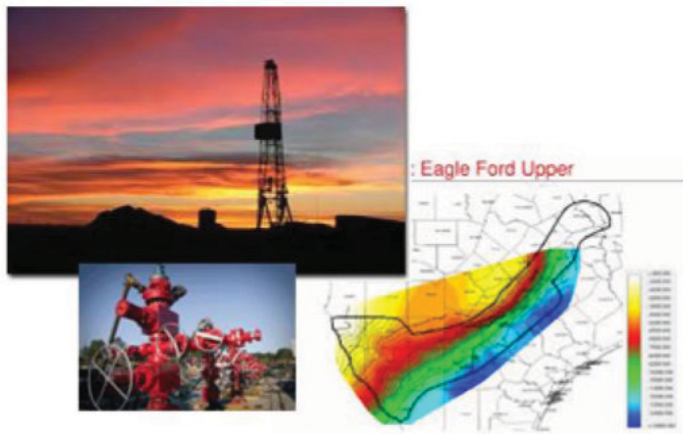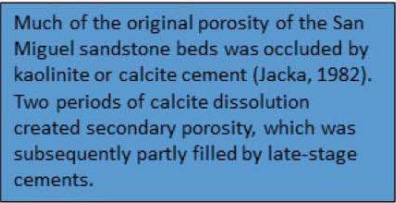
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Presenter's notes: This chart shows the output from a hierarchical cluster analysis (HCA #1) using all of the samples (shown here in individual rows of data). The Y-axis is simply each individual cutting sample and the x-axis is the carbon range from C_2-C_{20}. Red indicates a positive hydrocarbon 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 similar (*Presenter's notes continued on next slide*)

geochemical signatures. Therefore, the program does not look at what depth, lithology, or stratigraphy the samples were 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 and Austin Chalk, while Group 1D is comprised of samples taken from the deeper Eagle Ford, Buda, and Del Rio Formations.

What is interesting about this breakdown is that the cluster analysis correlates to published oil and gas sources for the Maverick Basin. Published data ascribes the Eagle Ford as a known hydrocarbon source, which most likely charges the Eagle Ford, Buda, and Del Rio and the Austin Chalk as a source for the Austin Chalk and the overlying Anacacho. The San Miguel appears to be a third and distinct hydrocarbon signal while the Olmos is a background signal.

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 strike you is that in the Lower San Miguel Fm you have a gas/oil signature. As you move from the bottom TIC to the middle (*Presenter's notes continued on next slide*)

TIC, you notice a start similarity. The gas signature in the Upper San Miguel looks just like the hydrocarbon 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 hydrocarbon signature looks like a reduced version or background version of the Upper San Miguel gas signature. The transition between the three hydrocarbon 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 hydrocarbon signature in the San Miguel Fm. We also know that, by definition, hydrocarbons must have a space to reside. Therefore, the more hydrocarbons detected, typically, the greater porosity. Therefore, the greater porosity inferred here by the DGL data is supported by the well logs and the data reported by Jacka (1982).
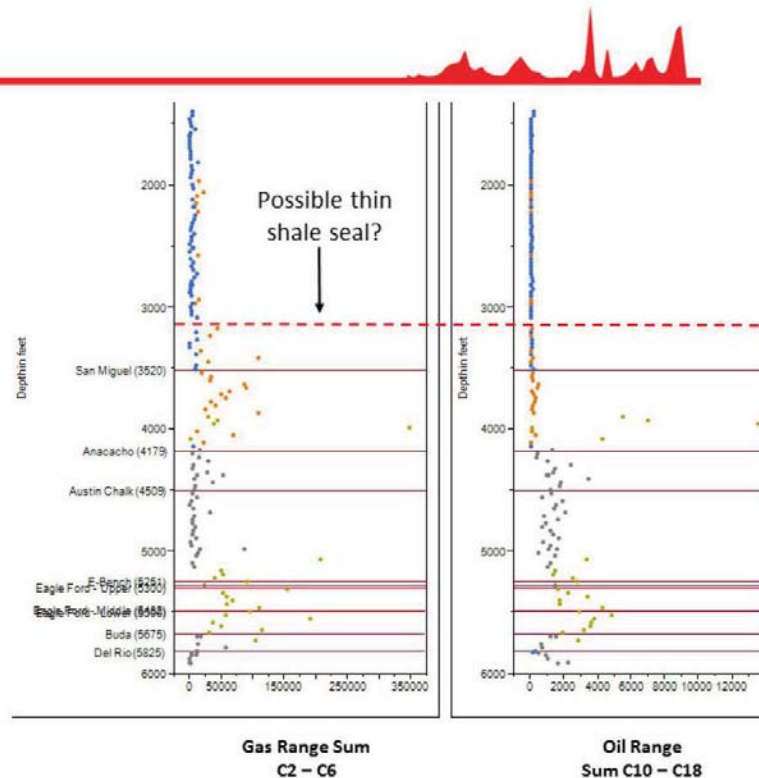
Presenter's notes: As we drill a little deeper into the data, notice the gas increase starts just above the San Miguel Formation around 3,100'. Therefore, this would imply that the gas in the San Miguel is also in the Olmos and there is no seal between the two. Yet why does the gas in the San Miguel begin to increase at 3100'? One explanation may be due to a thin seal in the Olmos. Tyler and Ambrose reports that the Olmos in divided into multiple sections and whether that number is three or five depends in your position in the field. 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'?
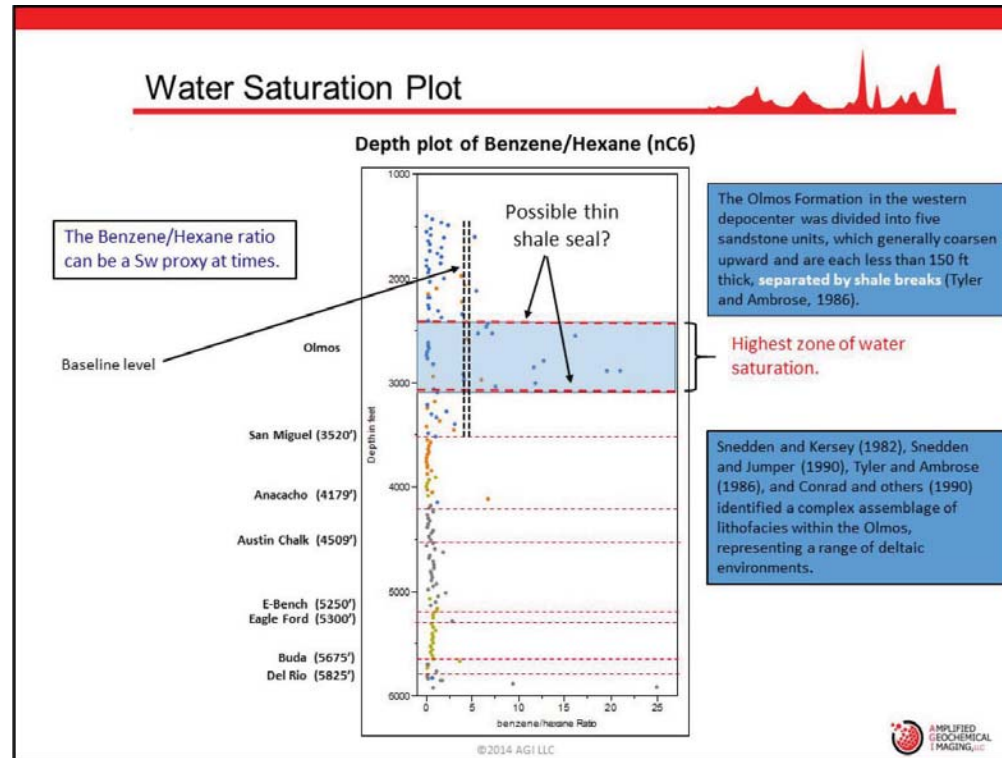
Presenter's notes: This graph plots the ratio of Benzene over Hexane (nC6) versus depth. The premise is that in a hydrocarbon zone the ratio of benzene to hexane is roughly 1.0. However, in water-saturated zones, benzene preferentially dissolves in the water because benzene is very water-soluble because it is a polar compound while hexane, a nonpolar compound, does not readily dissolve in water. Thus, the benzene concentration increases substantially over the hexane concentration. We can see from the plot that the 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 between 2-4 which then dramatically increases between 2,400'-3,100'. So, why is this? From literature, we know that the Olmos in this area is a deltaic sandy shale as reported by Snedden others. So, we would expect a 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.
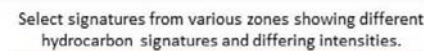
Presenter's notes: As you move into the Anacacho and the Austin Chalk, the hydrocarbon fingerprint changes into a gas/oil signature, which is lower in intensity than both the Lower San Miguel and the Eagle Ford. You can see by the gray dots that this is a distinct hydrocarbon signature from other formations and is consistent with literature that implies the Austin Chalk is self-sourcing and sources the Anacacho. The cluster analysis indicates that as you enter the Eagle Ford you switch to a different hydrocarbon signature, which is predominately oil, and the intensity increases dramatically. Then in the Del Rio Formation, you see dramatic decrease in hydrocarbon intensity and once again switch to a gas/oil signature. So, several hydrocarbon signatures are observed as you move vertically along the well and the highest accumulations of oil are found in the Lower San Miguel Formation and the Eagle Ford Formation, respectively.
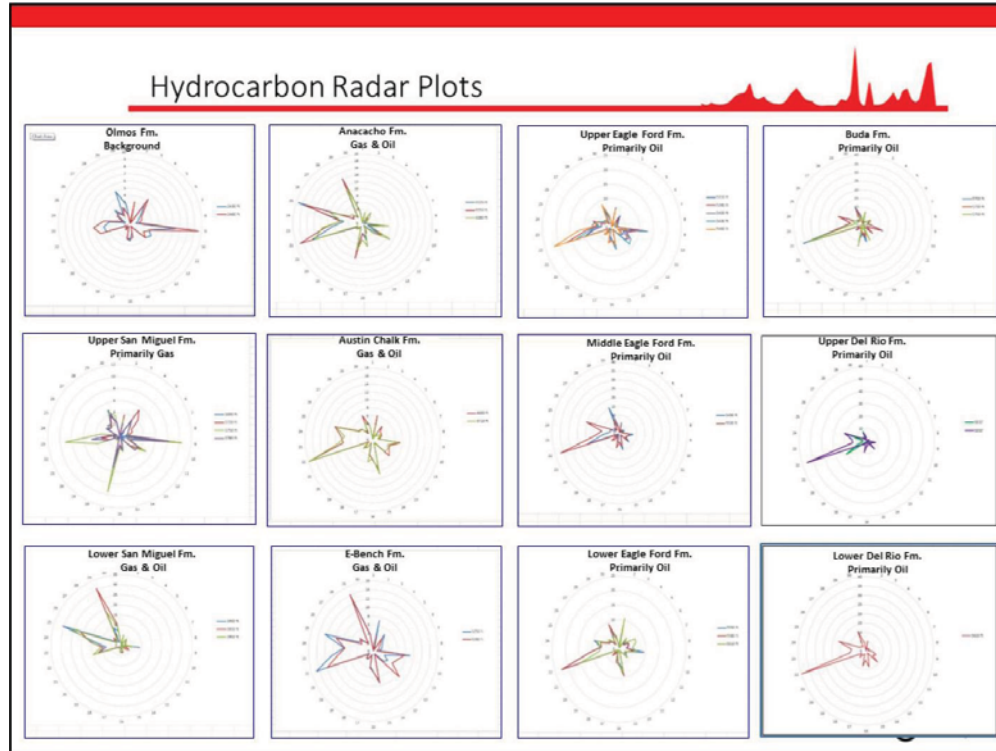
Presenter's notes: These star plots are generated using compound ratios from C_{10}-C_{20}. The absolute shape of the star plot is not what is important. What is important is how they relate to each other. The first thing that jumps out at you is that there appears to be three groups of patterns. You have the back background Olmos and San Miguel gas pattern the Lower San Miguel, Anacacho, Austin Chalk, E-Bench Pattern and the third group which is everything below (i.e. the Upper, Middle, and 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 Formation, 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 discreet 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 formations.
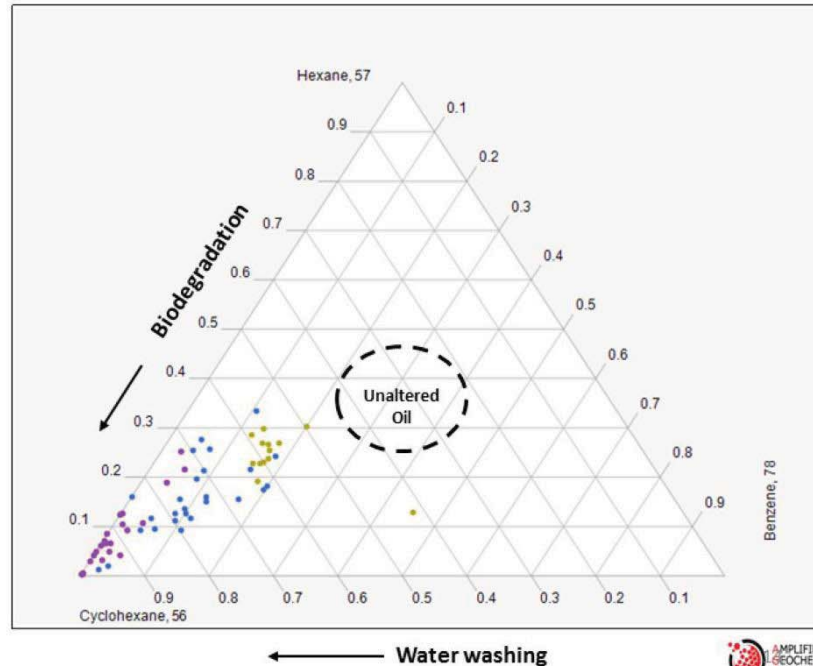
Presenter's notes: This ternary plot also lends some credence to that assumption. Here we have plotted Benzene, Cyclohexane, and Hexane in an attempt to differentiate the degree of alteration between oil sets. As seen here, there is a distinct difference between the geochemical make-up of Eagle Ford 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.
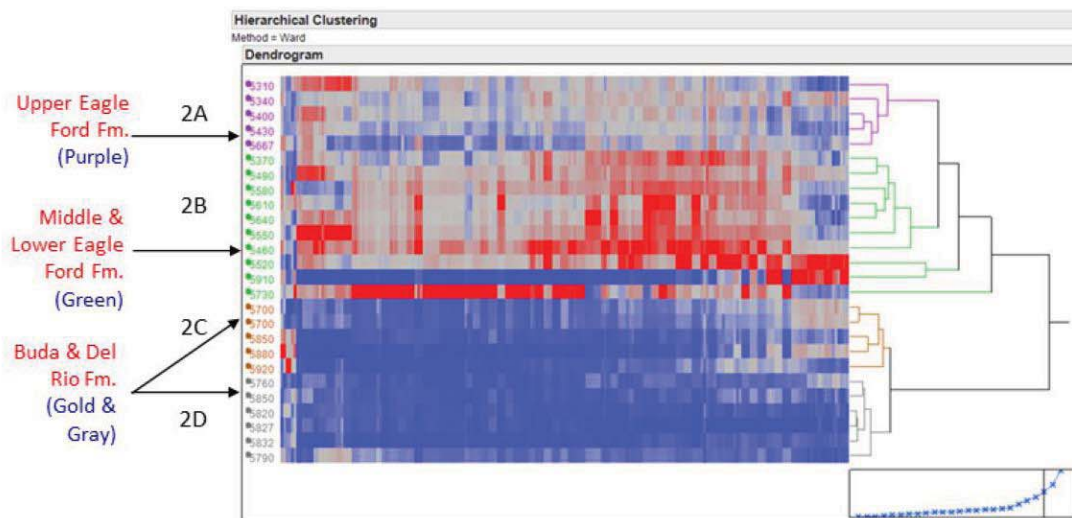
Presenter's notes: This is the output from another HCA processing (HCA 2), which only included the samples from the Eagle Ford, Buda, and Del Rio formations. In this process, we have identified four groups as shown. The top two groups clearly have a greater mass response.

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 shows (*Presenter's notes continued on next slide*)

the highest hydrocarbon intensity is found in the Lower Eagle Ford section, which is consistent with literature that says the Lower Eagle Ford has the highest hydrocarbon 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 hydrocarbons in the Eagle Ford and the Buda are very similar. Therefore, the variance in the hydrocarbon 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 hydrocarbon between the two formations 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 hydrocarbon 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 hydrocarbon 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 Formation the hydrocarbon 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 Formation. What this also indicates is that there does not appear to be any seals between the Upper Eagle Ford down through the Georgetown Formation.

Vertical Well Summary

The DGL data showed that:

- There were four major hydrocarbon groups according to cluster analysis:
  - Group 1 - the Olmos,
  - Group 2 – the San Miguel,
  - Group 3 - the Anacacho, Austin Chalk, and E-Bench
  - Group 4 – the Eagle Ford, Buda, & Del Rio

- The cluster groups and radar plots corresponded with literature indicating 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.

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Vertical Well Summary

The DGL data showed that:

- 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.

Downhole Geochemical Logging in the Lateral Eagle Ford Well

Presenter's notes: The Buda was subdivided into 8 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 hydrocarbon intensity. The depth chart has been turned on its side to more easily represent a (*Presenter's notes continued on next slide*)

lateral vies of the data. The color of the dots or data points relates to cluster analysis, which will 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 hydrocarbon baseline. The gray shaded areas indicate areas of low hydrocarbon 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 hydrocarbon concentration from 6,520'-6,820' corresponded to a zone of lower porosity/resistivity. Well logs indicate the decrease in hydrocarbon concentration from 6,850'-7,350' was due to drilling out of zone beneath the Buda fm. The decrease in hydrocarbons 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, which would explain the decrease in there. Therefore, in each case where there is a significant decrease in hydrocarbon concentration in the lateral drilling event, the DGL detects that decrease and it relates to geologic anomalies on the formation.
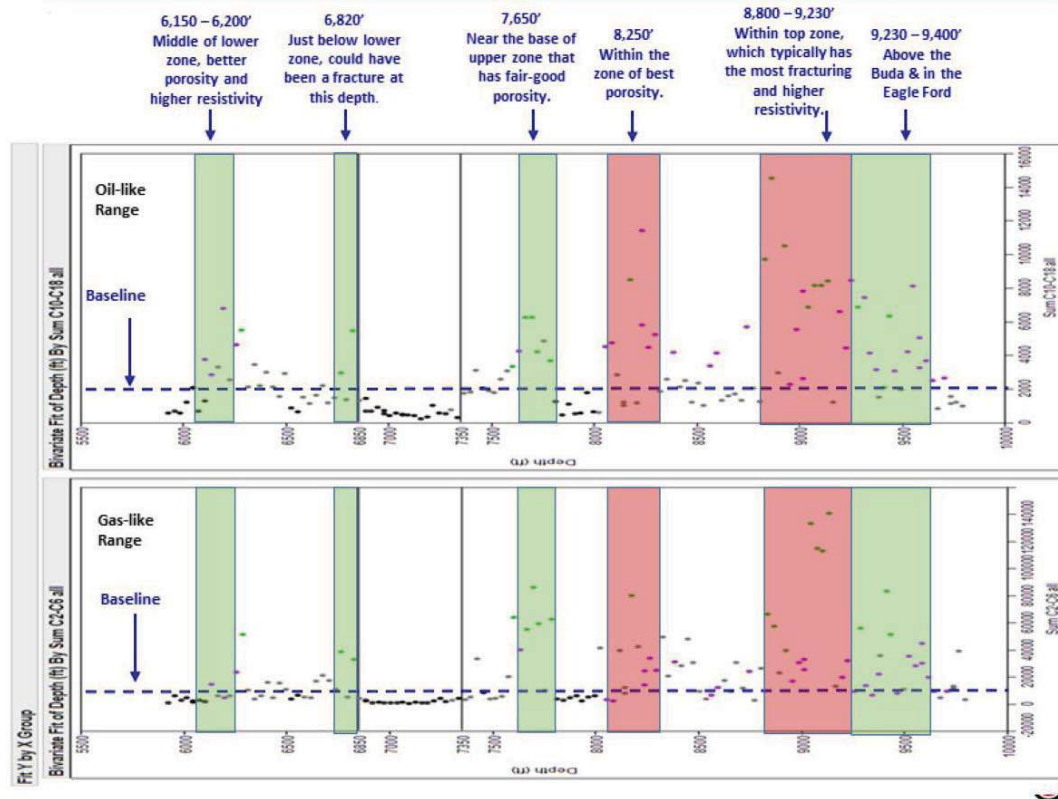
Presenter's notes: As mentioned previously there were three subdivisions within the Buda that had been identified as zones of higher porosity, resistivity, and perhaps more fractures. These three zones were middle of the lower zone, the base of the upper zone, and the top zone. As seen in the plot above, the increases in hydrocarbon concentrations from the DGL plot tracked well with these known zones of enhancement. For example, a kick in the oil components (*Presenter's notes continued on next slide*)

is seen between 6,150'-6,200' in the middle of the lower zone. We believe the hydrocarbon kick at 6820' 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 8800' are by far the most prolific hydrocarbon bearing zones in the lateral well and stand-out in terms of hydrocarbon 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 hydrocarbon prolific section of the well. It is also very interesting to note that besides the 50' section at 6,150' there are no strong hydrocarbon responses in the lateral until you get to 7,650'. So, this may indicate, at least in this well, that fracturing before 7,650' may not be economically advantageous.

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.

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Downhole Geochemical Logging in the **Second Vertical Eagle Ford Well**
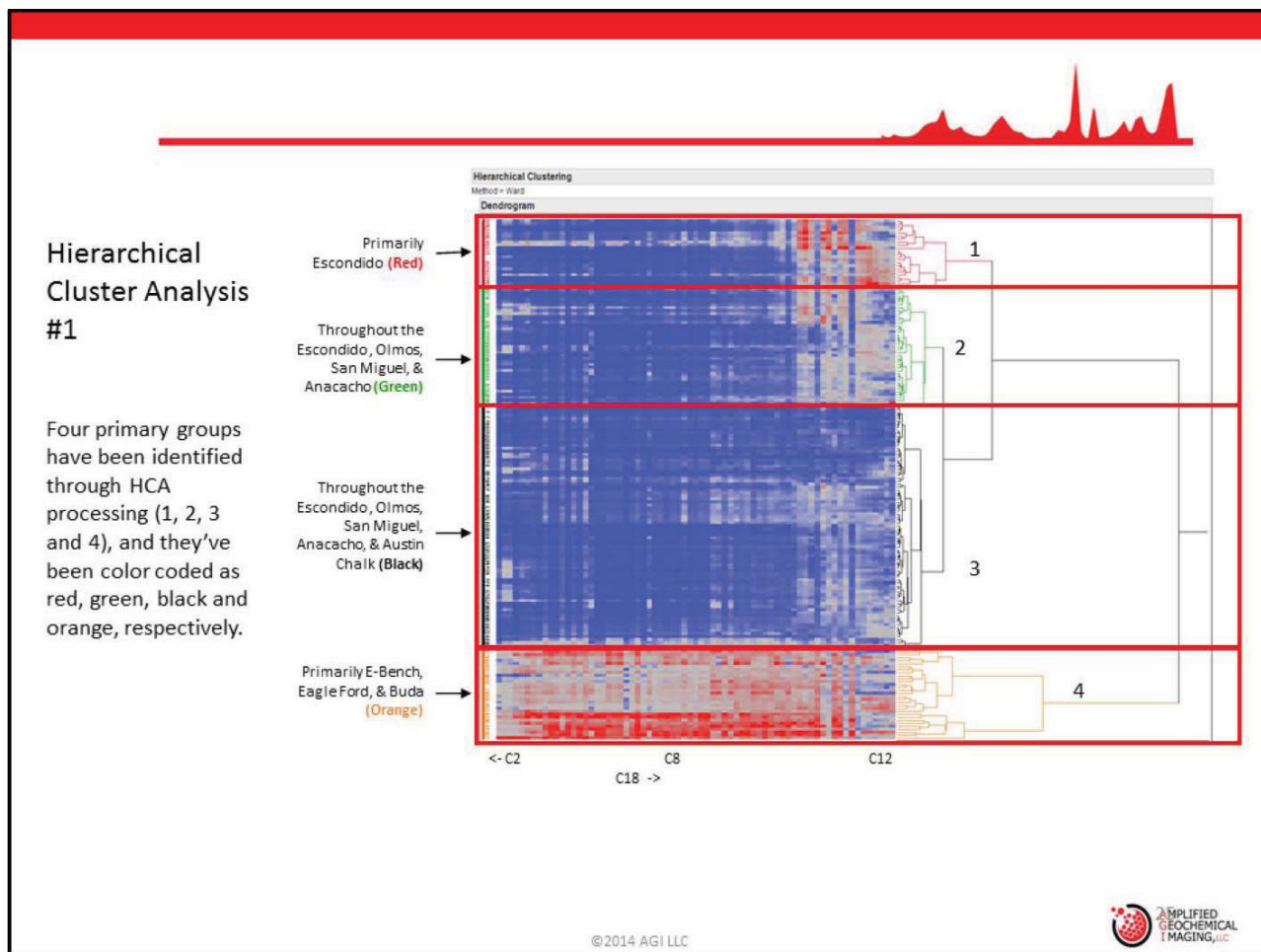
Presenter's notes: Forget about the coloration of the dots for a minute and just look at the gas and liquid hydrocarbon profiles for this Well 2. Obviously, we are looking at the summed light compounds (C_2-C_6) to the left, and the heavy compounds (C_{10}-C_{18}) to the right once again. First, notice the hydrocarbon 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, (*Presenter's notes continued on next slide*)

just a 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 formations, 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 theses 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. If that is true, 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 formation.

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 4 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 chart shows how the samples (*Presenter's notes continued on next slide*)

are related to each other, and from this structure, it is clear that Group #4 is distinct from the other three 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 Formation 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 is a gas/oil hydrocarbon signature ranging from C_2-C_{20}.
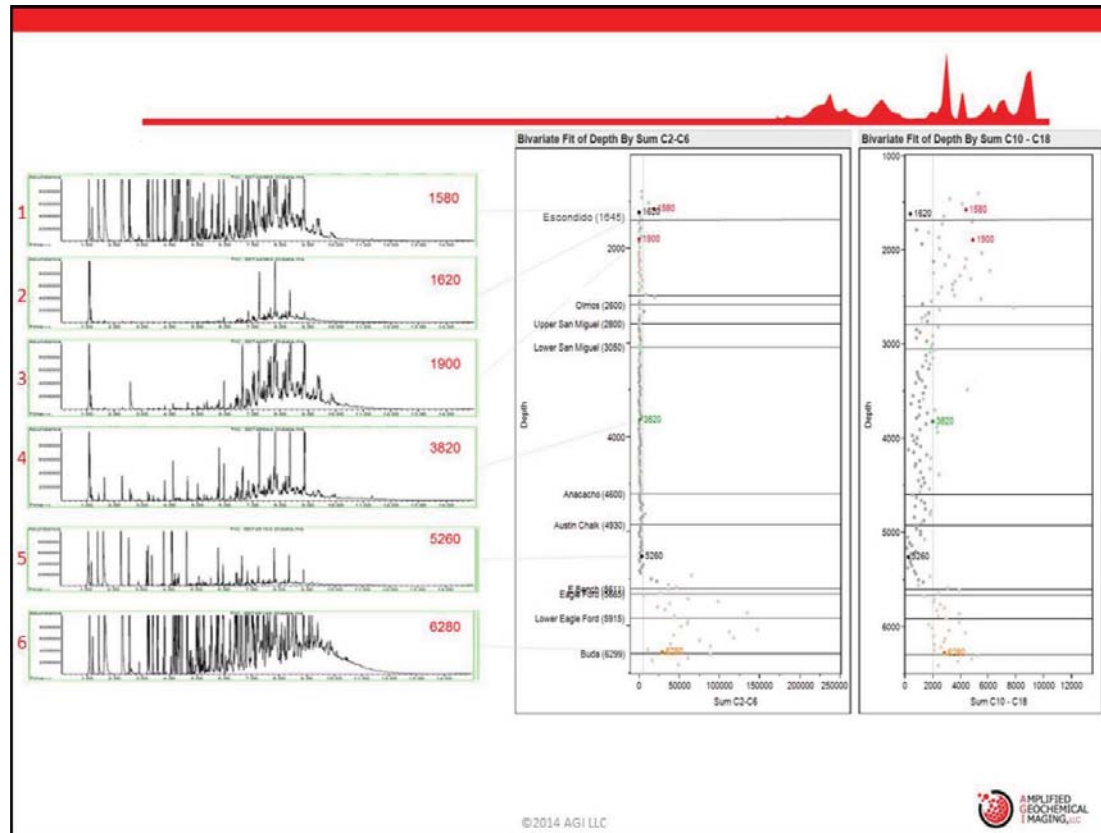
Presenter's notes: This slide includes the two depth profile charts, with the addition of some select TIC signatures (total ion chromatograms) for various horizons. Of particular note is the change in the TIC patterns as the well was drilled and the apparent increase/decrease in response from the samples. The pattern that is evident in TICs 2 and 5 represent a background-like signature, and although the signatures from 1 and 6 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 hydrocarbon signature seen at 6,280' is similar in fingerprint and intensity (roughly 4,000-4,500 ng) to the hydrocarbon seen in the Eagle Ford Fm in Well 1.
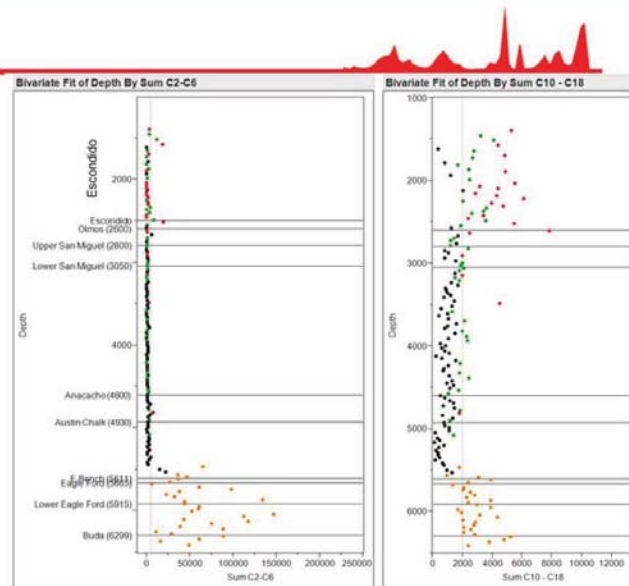
Presenter's notes: These charts show the same color scheme as was used in the HCA 1, and it shows the mass response for the summed light compounds (C_2-C_6) to the left, and the heavy compounds (C_{10}-C_{18}) to the right. The cluster diagram indicates that the hydrocarbons in the E-Bench, Upper Eagle Ford, Lower Eagle Ford, and Buda Fm. appear to be similar or the same. Literature indicates that the Lower Eagle Ford is the 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 theses 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. If that is true, 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 formation.
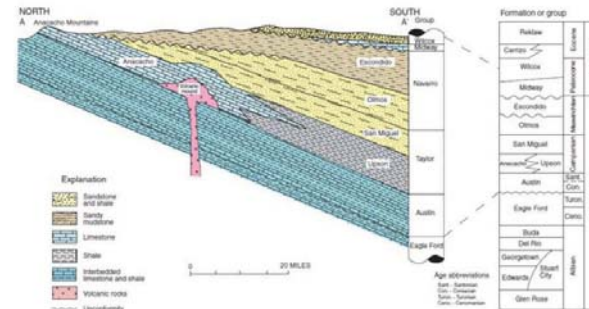
C6 Ternary Plot

This ternary (C6) chart supports the differences between the two primary signatures (orange vs. green/red samples). Also, the separation suggests that the green/red signature is more biodegraded or water-washed compared to the orange samples.
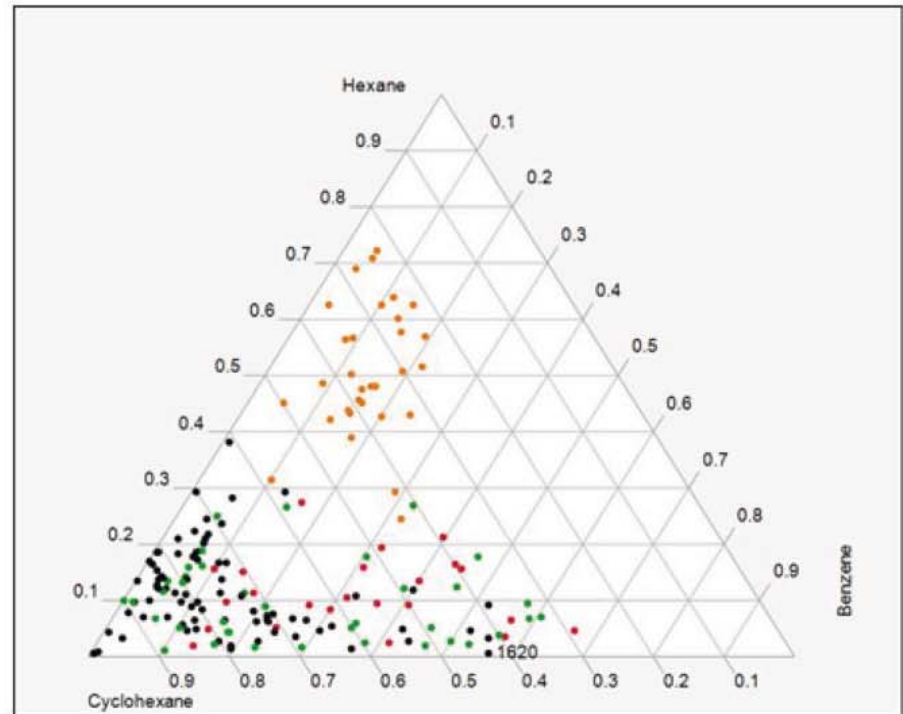
Presenter's notes: Had you drilled Well 2 first, you would have been lead to believe there was strong oil content in the Escondido and not much else until you got to the Eagle Ford. You may well have by-passed the most prolific zone in the well in the San Miguel Formation. If you looked at Well 1 first, you may have completely missed the liquid portion of hydrocarbons in the Escondido. It is dramatic how different the hydrocarbon profiles can be in two wells in the same field only 2.5 miles apart. This is the perfect example of why you need to develop hydrocarbon 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. In addition, there is some truth to that. But then let's also be honest in saying you may be grossly under-estimating or overestimating your reserves b/c you don't 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, that you are leaving in the ground.

Presenter's notes: Yes, we showed how the data could be used for understanding many important factors like identifying hydrocarbon families, hydrocarbon sources, subtle seals that may not be identified by traditional means, water saturation, and many other things. However, the message I want you to take away is that, particularly in shales where you often have hydrocarbons in every zone, DGL can be a very powerful porosity and Sweet Spot indicator. In both the vertical and the lateral data for this well the increase or decrease in hydrocarbon concentration was related to specific changes in porosity. You cannot have hydrocarbons without space for the hydrocarbons to reside. Since DGL is a direct hydrocarbon measurement technology, it provides an ultra sensitive tool for measuring porosity and identifying Sweet Spot. I hope that you saw that in both the vertical section and particularly in the lateral data that was shown today. Thank you!