AMPLIFIED GEOCHEMICAL IMAGING LLC

Technical Note

Optimizing Lateral Placement and Production while Minimizing Completion Costs Using Downhole Geochemical Logging

Amplified Geochemical Imaging LLCös Downhole Geochemical Logging (DGL) provides **an ultra-sensitive assessment of hydrocarbons in a well**.

DGL analyzes downhole cutting samples to directly characterize the composition of hydrocarbons vertically and laterally through prospective sections and **is 1,000 times more sensitive than traditional methods**.

This methodology has the unique ability to look at a broad compound range from **C_2 to C_{20}**, which is significantly more expansive than the limited mud logging range of C_1-C_5 or the C_1-C_9 of other laboratory techniques.

The result is a detailed characterization of petroleum phase, **the ability to infer seals and compartmentalization, infer multiple hydrocarbon sources and detect water saturation**. DGL provides the most detailed and granular hydrocarbon data available on the market today.

While this study took place in the Eagle Ford field in the Maverick Basin of Dimmit County, Texas, the technology is applicable for conventional or unconventional wells and has been used both onshore and offshore.

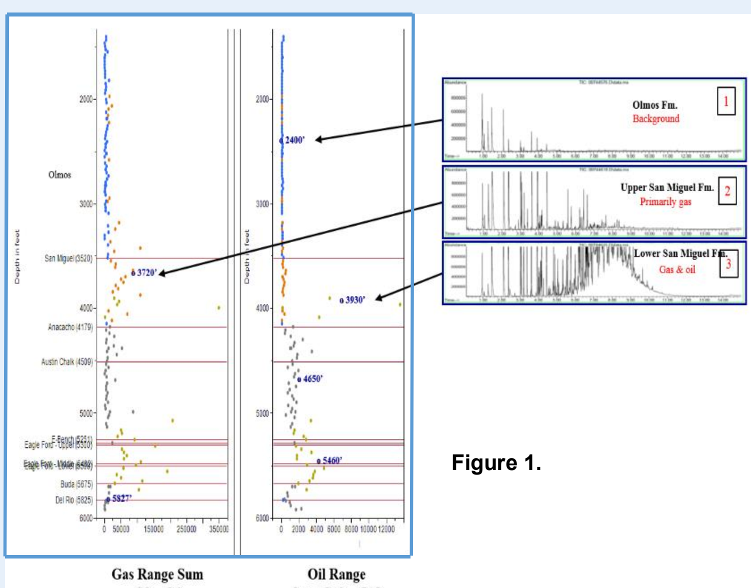

Figure 1.

For this project samples were collected by the mud logger at the shaker table at 30 ft intervals. Sampling intervals can vary from every 10 ft to every 100 ft depending on the project objectives. The samples did not require cleaning or drying. The samples, along with mud blanks, were then sent to Amplified Geochemical Imagingös (AGIös) laboratory for analysis by gas chromatography/mass spectroscopy. Analyses typically take two weeks.

The data were then subjected to Hierarchical Cluster Analysis (HCA) to evaluate the number of differing hydrocarbon families. The cluster analysis indicated four primary hydrocarbon families. Background samples were primarily associated with the Olmos Fm., a gas and oil family was associated with the San Miguel Fm., a second oil family was found in the Austin Chalk and Anacacho Fm., while the third oil family was associated with the Eagle Ford, Buda, and Del Rio formations. The cluster analysis implied that the Olmos Fm. was essentially uncharged, and that the San Miguel, Austin Chalk/Anacacho, and Eagle Ford, Buda, and Del Rio formations had distinct charges.

Figure 1 shows a plot of the light hydrocarbons (i.e. C_2 ï C_6) on the left and the heavier hydrocarbons (C_{10} ï C_{18}) on the right, plotted verses depth. Note that the Olmos Fm. shows essentially no hydrocarbon presence in the gas range or liquid range depth plots, as well as, the Total Ion Chromatogram (TIC) on the right.

The data shows the upper San Miguel Fm. as being gas prone and the lower portion being gas and oil prone. **Figure 1** also shows, by the orange dots from the HCA data, similar gas in the upper San Miguel Fm. and the Olmos Fm. **This implies there is no seal between the two formations.** However, the majority of the San Miguel-type gas seems to stop around 3100 ft. implying a possible seal there

Figure 2 displays a plot of the ratio of benzene over hexane versus depth. This ratio serves as a proxy for water saturation (Sw). This is based on the fact that benzene (C_6) is highly water soluble while hexane (nC_6) is not. Thus, in a water saturated zone, benzene

Identify Proper Lateral Placement

preferentially dissolves in the water while hexane does not, resulting in a dramatic increase in the benzene/hexane ratio in water saturated zones. This can be seen by the strong green peaks in **Figure 2** in the deltaic sandy shales of the Olmos Fm. Note the strong increase in the ratio between 2400 ft. and 3100 ft., once again implying seals at those two depths. The resistivity log also registered significant change between 2400 ft. - 3100 ft. This Sw proxy can be particularly helpful in fields, like the Woodford Shale, with high water saturation issues.

Figure 3 shows the depth profile with related TICs. Even a cursory review of the TICs shows distinct differences between the profiles for the various formations, a level of detail not available from well logs or other technologies.

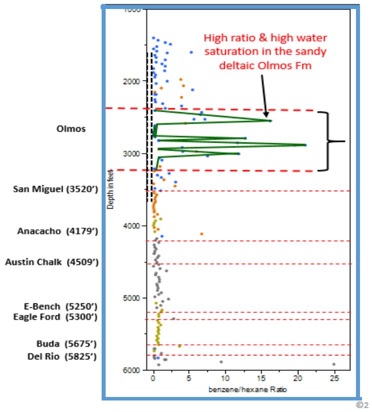

Figure 2.

For example, the depth profile for liquids shows the lower San Miguel has the highest intensity of liquid hydro-carbons, even more than the Eagle Ford. This **by-passed pay** would be missed since most companies drill directly to the Eagle Ford Fm. for completions. The client opted to land their lateral in the Buda believing that natural fractures from the Lower Eagle Ford would charge the Buda below. But, the hydrocarbon intensities shown in **Figure 4** show this not to be the case. Assuming 100 ft drainage above and

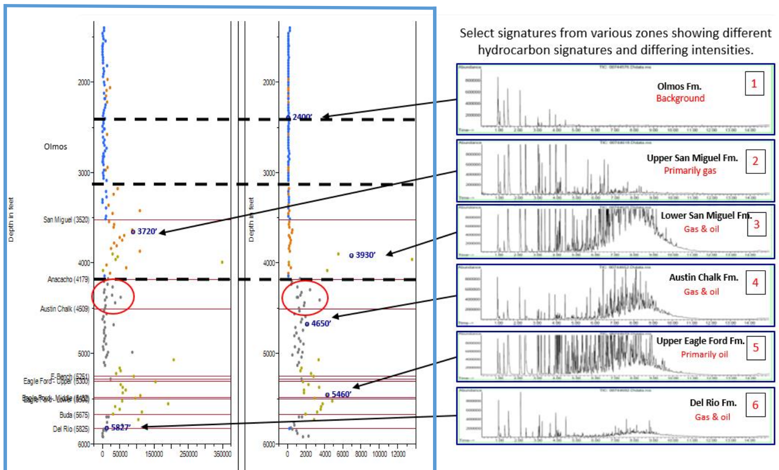

Figure 3.

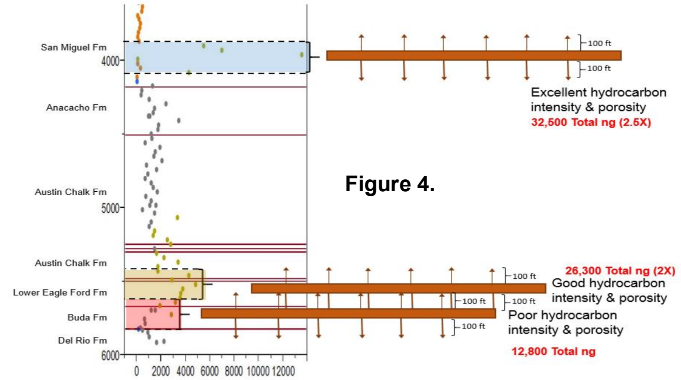

Figure 4.

below the lateral, the Buda has 12,800 ng of hydrocarbon in the drainage area, while the Lower Eagle Ford has 26,300 ng (2 times that in the Buda) and the San Miguel has 32,500 ng (2.5 times that in the Buda). Thus, the optimum landing point for the lateral, based on hydrocarbon richness and porosity, would be the lower San Miguel Fm.

Figure 5 shows the results for cutting samples in the lateral from 5,500 ft ï 10,000 ft. The oil intensity is shown across the top and the gas intensity on the bottom. The data shows no gas response and very little oil response for the first 1,500 ft. The hydrocarbon rich zones (shaded in rose) are at ~7,600 ft, ~8150 ft, and ~8,800 ft ï 9,600 ft.

Placing frack stages every 500 ft would have required 8 stages and cost ~$1.2mm. But, given the DGL data indicated there were few hydrocarbons in the first 1,500 ft, the operator could have eliminated the first three frack stages, **saving $600K and still maintained the same production.** Thus, the DGL data was able to **optimize the location of the lateral in the most hydrocarbon rich zone** and **save $600K in unnecessary fracking costs**.

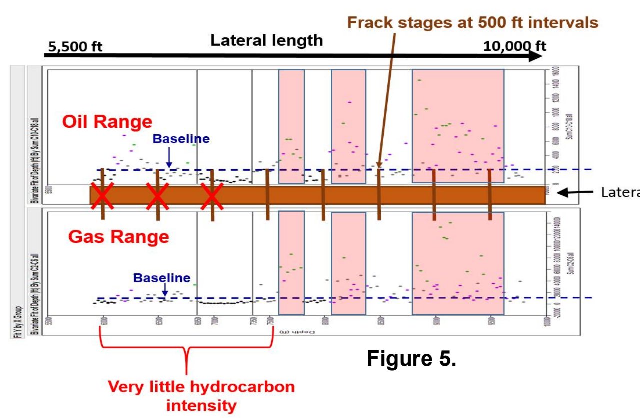

Figure 5.

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