Amplified Geochemical Imaging LLC

Technical Note

Improving Production while Minimizing Completion Costs in the STACK

Shale plays present extremely challenging arenas in which to explore. Lack of heterogeneity is not the only problem. Numerous hydrocarbon sources and multiple stacked zones that vary considerably across the play result in mixed drilling success in the Oklahoma STACK.

Conventional logging technologies provide important information while drilling to infer the presence or absence of hydrocarbons. However, these logging technologies do not directly measure hydrocarbons, but rather measure hydrocarbon proxies and infer hydrocarbon presence and phase based on the aforementioned data. These technologies, while sophisticated, can lack specificity and sensitivity when trying to accurately identify hydrocarbon source, hydrocarbon families, hydrocarbon mixing, compartmentalization and water saturation.

Downhole Geochemical Logging (DGL) provides an ultra-sensitive assessment of the hydrocarbons in a well by analyzing cutting samples to directly characterize the composition of hydrocarbons vertically and laterally through prospective sections. 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 traditional ranges of C_1 - C_5 for mud logs or C_1 - C_8 from laboratory analyses. The result is a detailed granular hydrocarbon characterization in stratigraphic intervals that is a thousand times more sensitive than traditional methods.

For example, in the Blane-1 well hydrocarbons were detected from the lower Manning formation through the Woodford formation. **Figure 1** shows the total hydrocarbon intensity (i.e. C_2 - C_{15}), plotted in green, verses depth. The brown bars show possible lateral landing points with a hundred foot drainage above and below the lateral. The DGL data shows the Upper Meramec formation at ~11,730ôas the most hydrocarbon rich zone in the vertical well with **172,800 ng** of hydrocarbons within the 200ô drainage window. The second best vertical section was in the Lower Meramec at ~12,040ôwith **146,000 ng** of hydrocarbons and the third best vertical section was in the Woodford formation at ~12,370ôwith **121,900 ng** of hydrocarbon richness. Due to the vertical complexity of the STACK play it is not possible to place all laterals in a predetermined location (e.g. the top of the Lower Meramec) and gain maximum production from each well. Each of the five wells tested in this program had a different optimum hydrocarbon rich zone to maximize lateral placement.

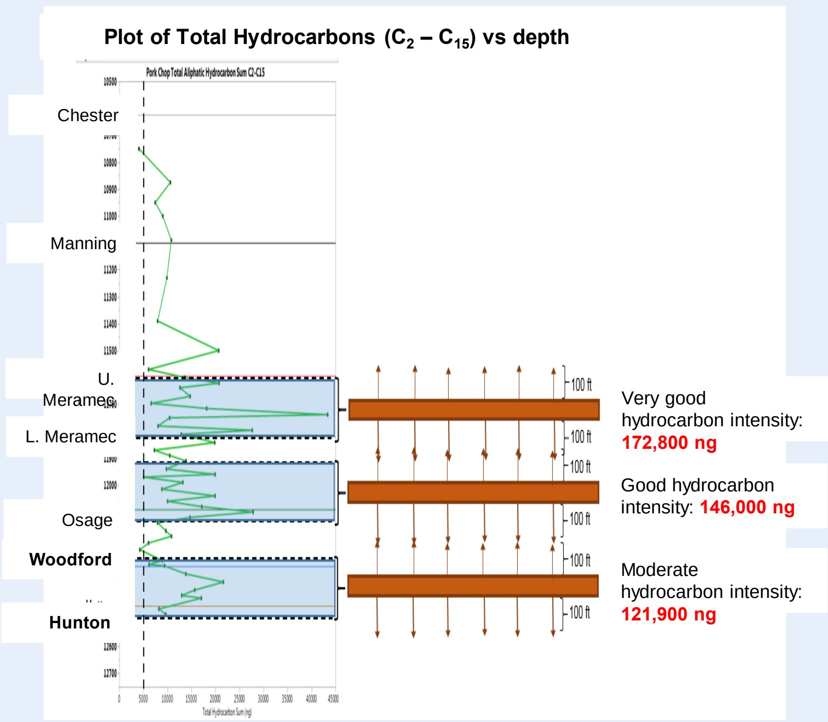

Figure 1.

DGL was also used to determine a water saturation (Sw) proxy by ratioing benzene/ hexane. For the Blaine-1 well, see **Figure 2**, the Sw proxy was plotted verses depth. Increasing ratios on the Sw proxy scale from left to right indicate increased water saturation. The data surprisingly indicated very high water saturation in the deeper Hunton formation as well as high water saturation in the Woodford formation. This result was contrary to previous results obtained from wells in Canadian Co., Blaine Co., and Garfield Co. in which the Woodford formation typically had very low water saturation.

However, a geologic map of the area showed a fault near the well. It is believed that the fault was acting as a conduit to transfer water from the deeper Hunton formation into the Woodford and Osage formations, thus creating unusually high water saturation levels.

Identify Proper Lateral Placement

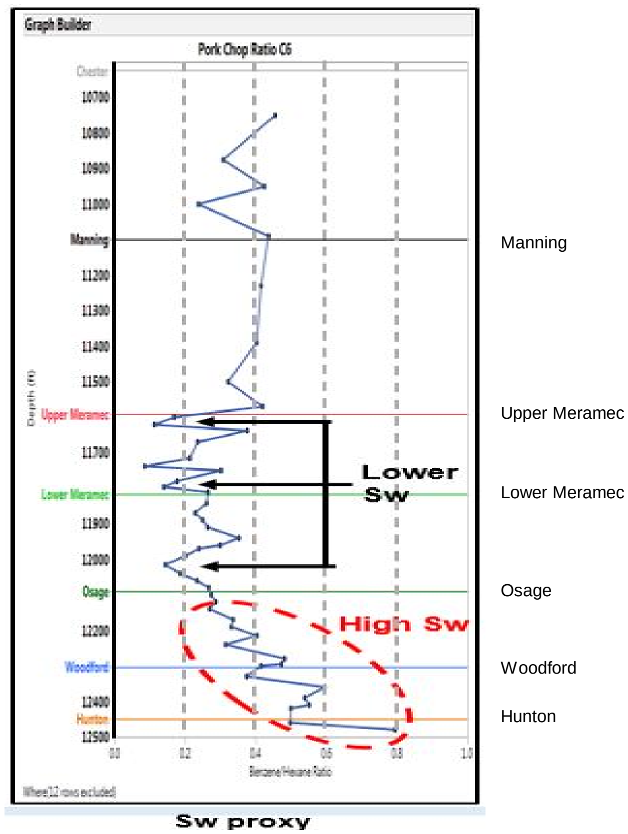

Figure 2.

Given the DGL data indicated that the Upper Meramec formation as the most hydrocarbon rich zone with the lowest water saturation, **it appeared the Upper Meramec at ~11,730' to be the most productive zone to land the lateral and maximize production**.

DGL was also used to evaluate horizontal drilling. While the results in these examples have been sanitized and modified for presentation purposes the message remains the same. For example, in Figure 3 samples were collected every 150ô along a 10,000ô lateral. The green bars represent hydrocarbon intensity while the light blue line indicates the Sw proxy. The red bars indicate frac stages spaced at 500ôintervals. Note there appears to be good hydrocarbon richness along the lateral with the exception of ~11,600ô ï 13,600ô where the lateral enters Zone 3. This section of the lateral appears to not only have very low hydrocarbon richness, but also extremely high water saturation. **Setting frac stages in this 2,000' section would add very little production and also add tremendous volumes of water**. Eliminating four frac stages in this 2,000ô section would dramatically reduce water disposal costs and **reduce completion costs by ~$800,000** (i.e. $200K per frac X 4 fracs = $800K).

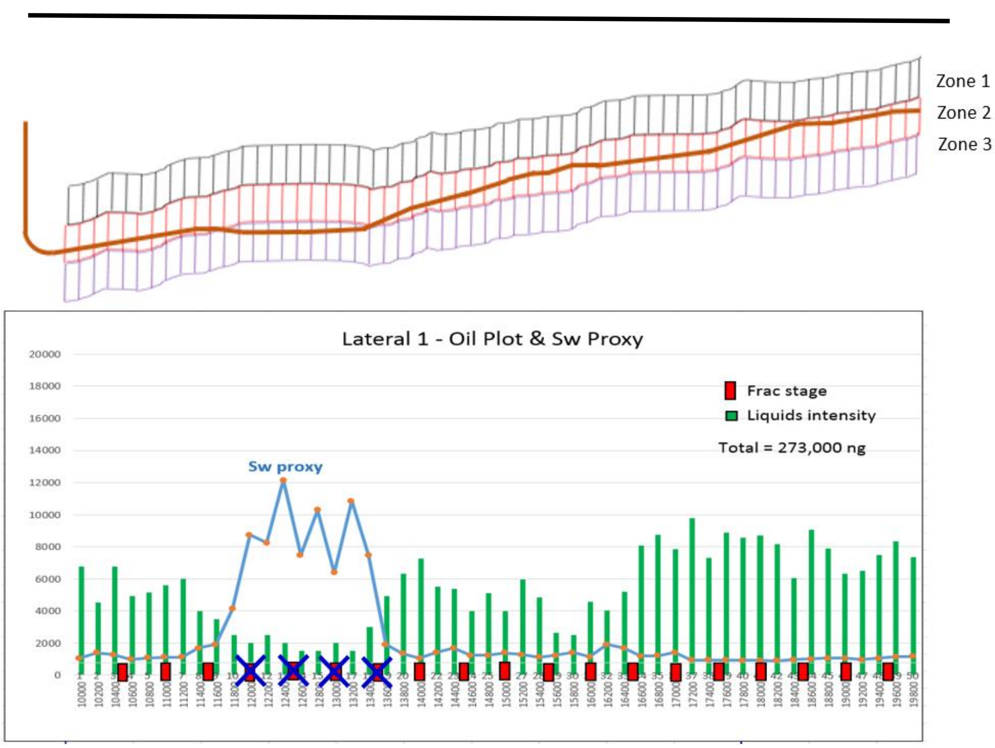

Figure 3.

Lateral 2, see Figure 4, shows a low Sw proxy throughout the lateral, but also shows poor hydrocarbon richness as the lateral is primarily landed in Zone 3 until the toe of the lateral rises into Zone 2. With **hydrocarbon richness 52% less than Lateral 1, one would not expect high production from this well**.

Lateral 3, see Figure 5, showed good hydrocarbon richness throughout the well with exceptional hydrocarbon response as the lateral penetrated Zone 1. With hydrocarbon richness of **345,000 ng** as compared to **273,000 ng** in Lateral 1 (i.e. **26% higher**) and very low water saturation throughout **it is expected that Lateral 3 would be one of the highest producers in the field**. Thus, it is believed that with all things being equal between wells (e.g. lateral length, number of frac stages, frac stage spacing, propant, etc.) that **the lateral DGL hydrocarbon summation and Sw proxy may be a good general indicator of well production performance**.

Inferring Well Production

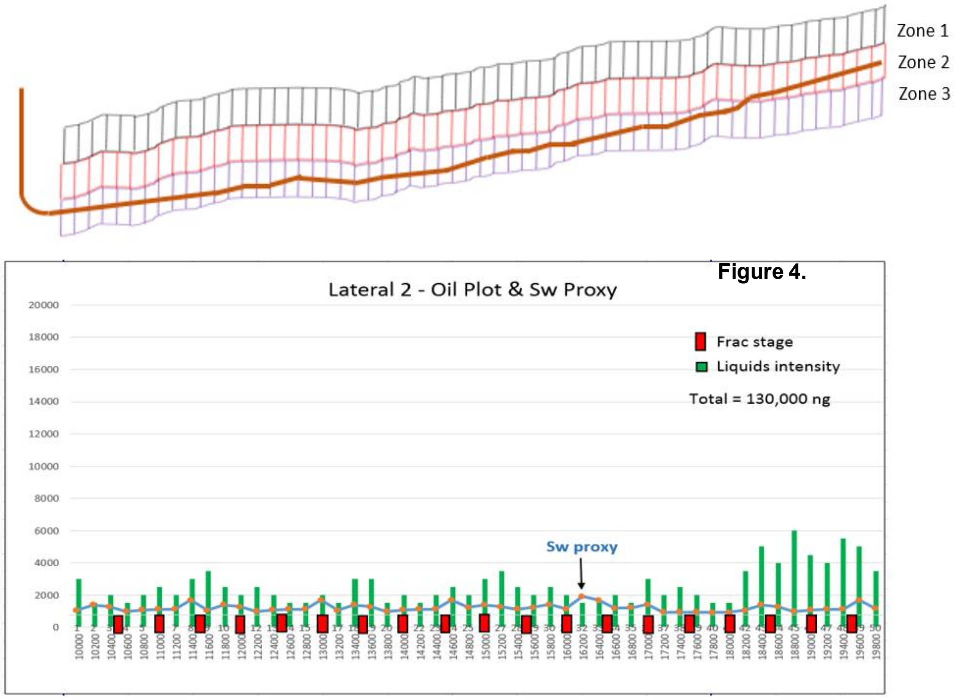

Figure 4.

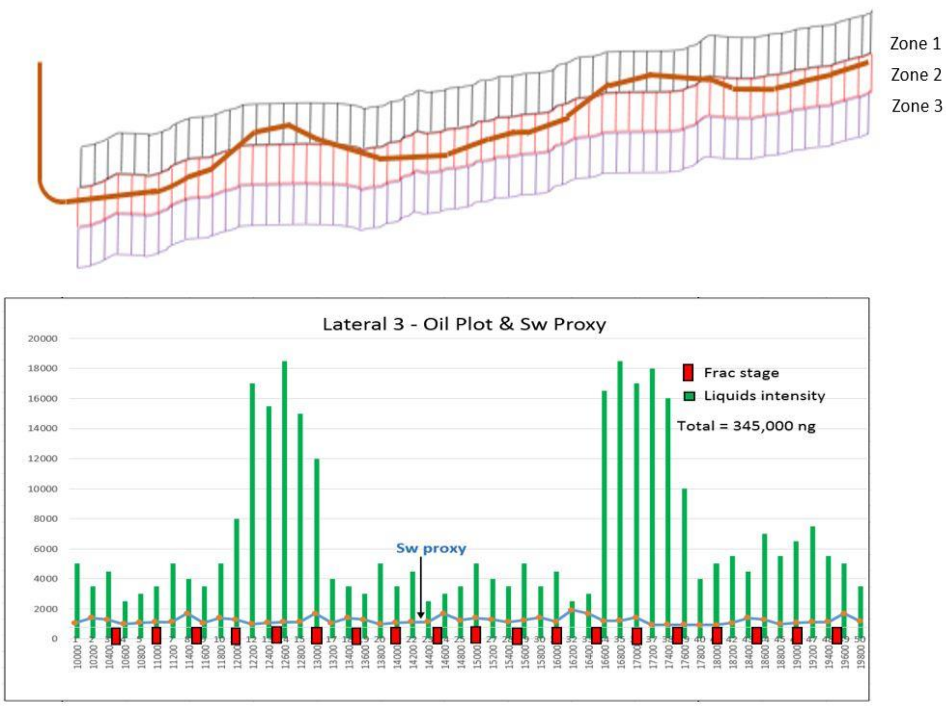

Figure 5.

Summary:

While there is not room to discuss all of the project details in this brief document, the Downhole Geochemical Logging data helped to:

Å Clearly distinguish between multiple gas, condensate, and oil signatures vertically and laterally in the field,

Å Infer separate hydrocarbon sources,

Å Identify by-passed pay,

Å **Increase production by focusing lateral placement in hydrocarbon rich and porosity rich zones**,

Å Identify a thermal maturity transition across the field,

Å **Identify zones with high water saturation which would decrease production economics**,

Å **Compare water saturation levels across the field**.

The client also discovered:

Å The data coincided well with well logs and gave them more confidence in and a better understanding of their logs,

Å The **DGL hydrocarbon intensities correlated well with moveable oil and porosity** in their well logs,

Å The **Sw proxy coincided well with moveable water** in their logs,

Å The water saturation proxy ratio became very important because it related to economics (i.e. the more water in a zone the less profitable the zone),

Å The data gave them valuable information they were not aware of (i.e. an increasing gas trend in the Lower Manning Fm or higher Sw in deeper formations in the Blaine-1 well).

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