AMPLIFIED GEOCHEMICAL IMAGING LLC

Differentiating stacked pay

Predicting Channel Sand Wells with a 90% Accuracy: an Anadarko Basin Case Study

Ultrasensitive hydrocarbon mapping can be used in conjunction with seismic programs to dramatically derisk exploration and field development efforts. This is particularly true in channel sand fields where seismic resolution is not sufficient to map these sinuous sand beds. Additionally, Amplified Geochemical Imaging (AGI) can identify phase for the charged sands which cannot be elucidated by seismic data.

AGI's hydrocarbon mapping technology is unique among surface technologies in that it uses passive monitoring to detect hydrocarbons at parts per billion (ppb) levels **which is 1,000 times more sensitive than traditional methods**.

The AGI passive sampler, **Figure 1**, contains a specially engineered oleophilic (i.e. oil loving) adsorbent encased in a microporous membrane. These membrane pores are small enough to prevent soil particles and water from entering, but large enough to allow hydrocarbon molecules to pass through and concentrate on the adsorbent material. Additionally, the AGI method measures >100 compounds, from C_2 – C_{20}, which provides the unique ability to clearly define and differentiate multiple gas, condensate, or oil signatures.

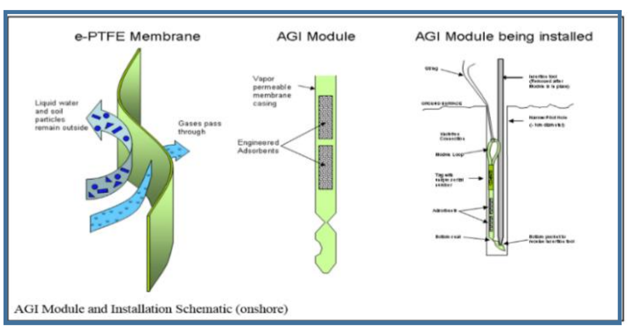

Figure 1.

The surface surveys took place in southwestern Custer County and southeastern Roger Mills County of western Oklahoma, along the axis of the Anadarko Basin. The purpose of the survey was to map over pressured gas condensate from the Pennsylvanian Red Fork channel sands at a depth of ~14,000'. The data set encompassed nine surveys covering over 120 mi² over a three year period. One of the difficulties of the project was that the Anadarko Basin includes numerous oil and gas charged horizons throughout the Paleozoic section.

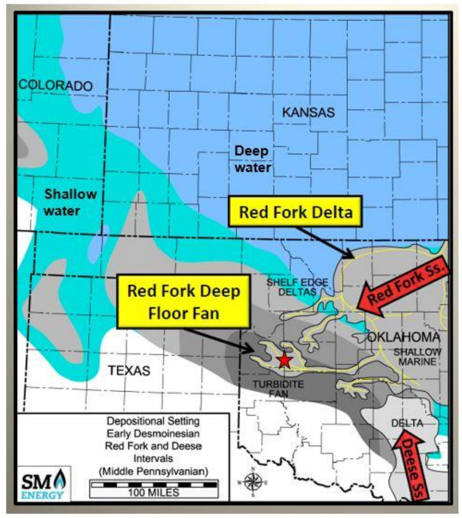

Figure 2. (Mitchell, 2012)

The paleodepositional model, **Figure 2**, shows the Red Fork sand system that consists of a deltaic complex to the north, with significant oil and gas production, with deep water turbidite fans and channels to the west, and over-pressured gas production from numerous fields across Roger Mills and Custer counties. The red star represents the survey location.

Figure 3 shows a cross-section of the basin from South to North, showing depth of the Paleozoic section and the primary petroleum production targets, and the Red Fork sands. The Red Fork channel sands are isolated. The over-pressured section was actually charged, pressured, and then uplifted. Thus, it is more mature and has higher pressure than would be expected, resulting in a higher pressure than surrounding prospects.

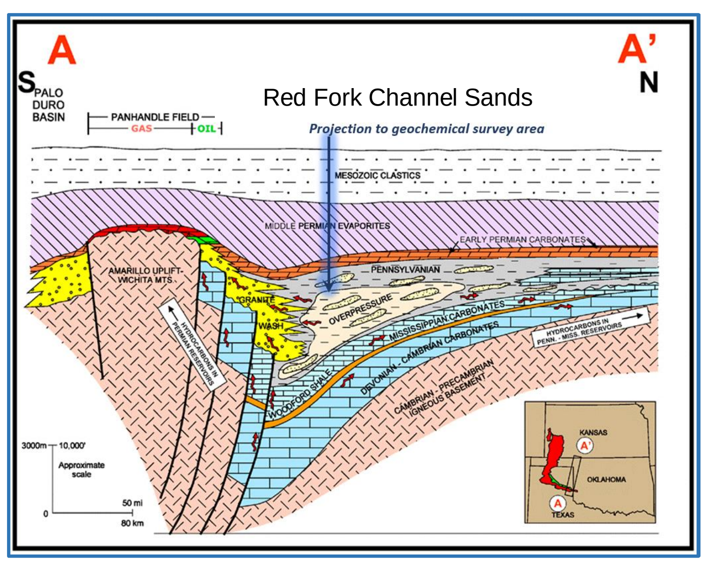

Figure 3. (Fierstien, *2014)*

Mapping Sweet Spots and Depletion Affects

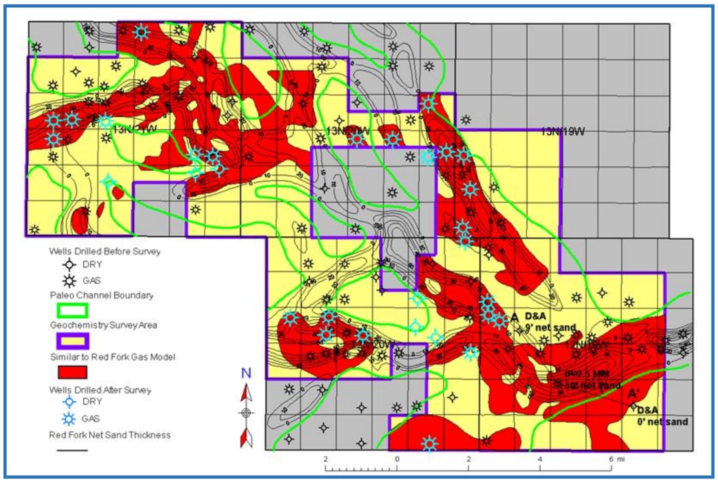

Figure 4.

In the hydrocarbon probability map, **Figure 4**, the red shading indicates areas of high probability (~85% - 95%) for Red Forks gas condensate, while the yellow represents poor probability. The purple line outlines the boundaries of the survey areas. The light blue wells were drilled post-survey. There are older producing wells in the yellow and gray areas showing depletion affects of reduced hydrocarbon richness across the field.

Figure 5 shows a plot of the AGI probability factor on the Y axis versus porosity* net pay (phi-h). **The plot shows strong correlation (i.e. $r^2 = 0.87$) between effective reservoir porosity (ϕ), net pay thickness (h), and the surface geochemical expression.** The

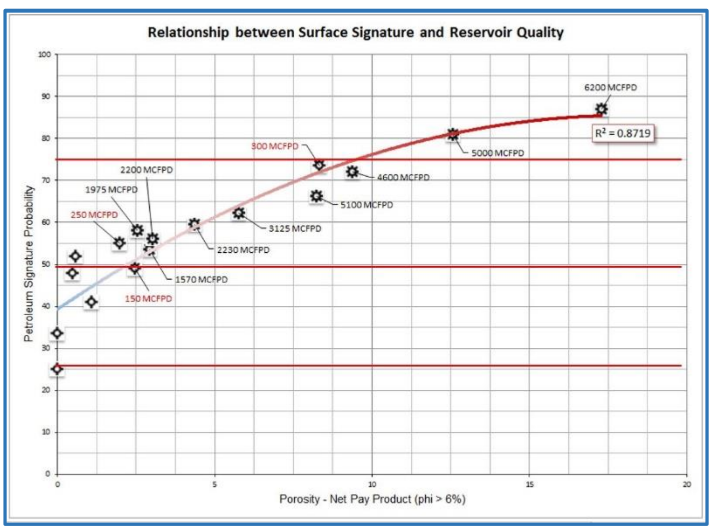

Figure 5.

AGI probability factor is also a function of reservoir pressure, but pressure is assumed to be constant across the over-pressured channel sands. The graph shows dry wells and sub-economic wells with a probability factor ranging from ~50% - 60%. This is important to note because phi-h in channel sands or turbidite complexes can be highly variable due to the extension and retraction of turbidite fans. Thus, the graph demonstrates the ability of the AGI data to identify and map areas of higher porosity and net pay thickness (**i.e. Sweet Spots**).

Note also the strong correlation with the AGI survey probability factors and production. Field production increases proportionally with AGI surface survey probability values.

The graph can also identify potential completion problems. For example, the well reporting only 300 MCFPD has an elevated probability factor (i.e.~73%) and phi-h, suggesting possible additional behind-pipe pay.

Geochemical results were confirmed by post-survey wells. Thirty (30) wells were drilled post-survey for which AGI has information:

Å **22 wells drilled on positive geochemical anomalies** for Red Fork gas, with **21 commercial discoveries** and 1 dry well,

Å **8 wells drilled out of anomalies** (no hydrocarbons), with **5 P&A'd** and three gas discoveries (**one failed to pay completion cos**t)

The AGI ultrasensitive hydrocarbon mapping data correctly predicted 27 (90%) of 30 wells drilled post-survey in the narrow Red Forks channel sands.

Summary:

Å With multiple hydrocarbon signatures the AGI data was still able to distinguish Red Fork condensate charge from other petroleum systems in the area (e.g. Granite Wash, Cleveland sands),

Å The survey was **able to map Sweet Spots (i.e. areas of higher production**) with better hydrocarbon richness, porosity, and net-pay over 5 townships.

Å The field production history and post-survey wells validated the survey results,

Å The survey identified depletion affects,

Å **The survey optimized production in areas where seismic resolution was insufficient to do so**.

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