PSRelationship between Reservoir Quality and Hydrocarbon Signatures Measured at the Surface*

Paul Harrington¹ and Alan Silliman¹

Search and Discovery Article #41078 (2012)**
Posted November 26, 2012

*Adapted from poster presentation at AAPG International Convention and Exhibition, Singapore, 16-19 September 20122012

¹W. L. Gore & Associates, Inc., Elkton, Maryland, USA (pharring@wlgore.com)

Abstract

Amplified Geochemical ImagingSM technology has been used to image reservoirs over 7,000 meters deep. A relationship is noted between reservoir quality, as measured by the net pay thickness − porosity product, and strength of surface geochemical signature, as measured by pattern and mass of hydrocarbon compounds. A relationship is also noted between strength of the surface signature and current production volume at numerous well sites. Reservoir pressure is correlated positively with the strength of the surface geochemical signature. Adsorbent-based surface geochemical samplers are used to detect volatile organic hydrocarbon compounds at the surface. Many of these compounds are of thermogenic origin, from underlying petroleum reservoirs. Microbuoyancy theory is a plausible mechanism for the vertical migration of such hydrocarbon compounds through the stratigraphic section to the surface. Saturated compounds up to phytane (C₂₀) are detectable in minute amounts (10-9 grams). Geochemical sample devices are used to collect surface data over exploration areas and from regional petroleum production and dry well sites if available. Geochemical survey data is classified by similarity with production well site data, resulting in a probability of fit between geochemical signatures. Therefore, surface geochemical data may improve understanding of the nature of subsurface reservoirs. This relationship is documented in various surveys from different basins.

^{**}AAPG©2012 Serial rights given by author. For all other rights contact author directly.

Relationship between Reservoir Quality and Hydrocarbon Signatures Measured at the Surface



Paul Harrington* and Alan Silliman, Survey Products Group, W. L. Gore & Associates, Inc., Elkton, Maryland, USA

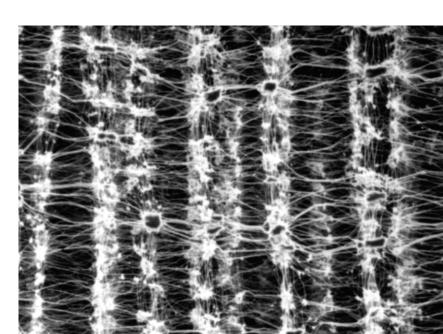
INTRODUCTION

Amplified Geochemical Imaging[™] technology has been used to image reservoirs over 7,000 meters deep. A relationship is noted between reservoir quality, as measured by the net pay thickness – porosity product, and strength of surface geochemical signature, as measured by pattern and mass of hydrocarbon compounds. A relationship is also noted between strength of the surface signature and current production volume at numerous well sites. Reservoir pressure is correlated positively with the strength of the surface geochemical signature. Adsorbent-based surface geochemical samplers are used to detect volatile organic hydrocarbon compounds at the surface. Many of these compounds are of thermogenic origin, from underlying petroleum reservoirs. Microbuoyancy theory is a plausible mechanism for the vertical migration of such hydrocarbon compounds through the stratigraphic section to the surface. Saturated compounds up to phytane (C_{20}) are detectable in minute amounts (10-9 grams). Geochemical sample devices are used to collect surface data over exploration areas and from regional petroleum production and dry well sites if available. Geochemical survey data is classified by similarity with production well site data, resulting in a probability of fit between geochemical signatures. Therefore, surface geochemical data may improve understanding of the nature of subsurface reservoirs. This relationship is documented in various surveys from different basins.



Geochemical sample module used in these studies. Module is approximately 25 cm in length.





Different permeable membrane configurations: a platform technology behind the geochemical sample device (50,000x magnification)



Analysis of samples by automated thermal desorption/ gas chromatography/mass selective detection









Surface geochemical sample acquisition in the soil zone. Samples left in residence for ~20 days, for the equilibration of adsorbents to in situ organic compound signature

ORIENTE BASIN, ECUADOR

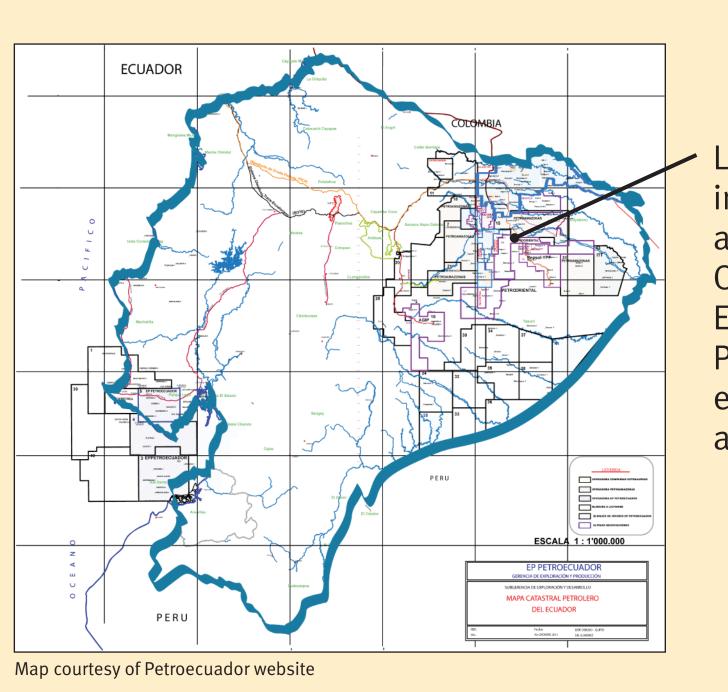
Survey Location: Blocks 14, 17, and Shiripuno, in Eastern Ecuador

Exploration Target: Cretaceous oil (basal Tena, Napo, Hollin formations)

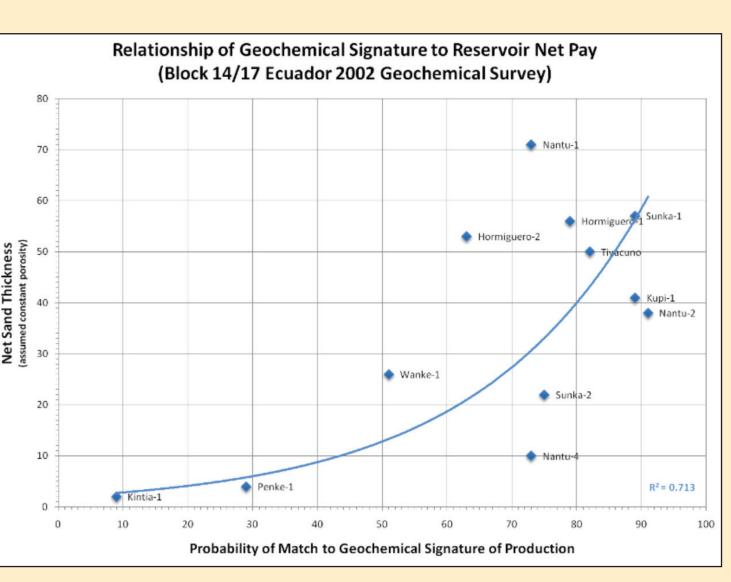
Client: Vintage Petroleum

Work Programs:

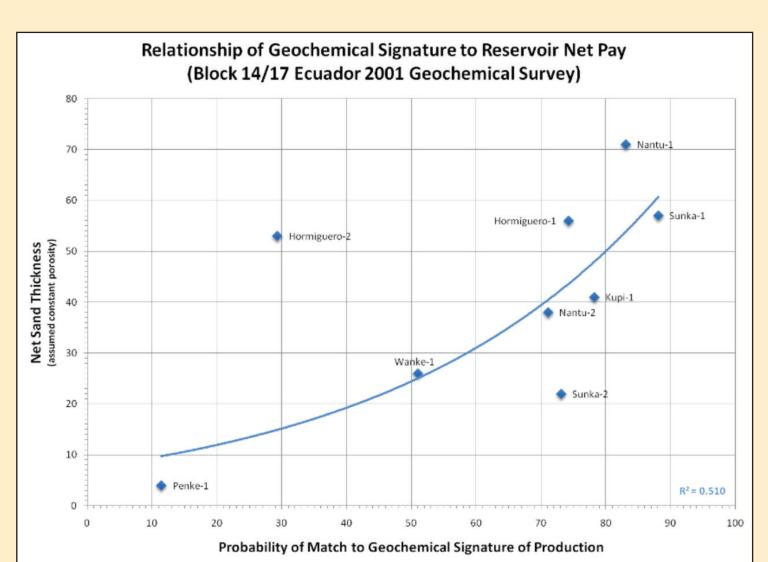
- 1. 2001, 516 km² area, ~1 km resolution, 700 samples (including calibration)
- 2. 2002, 476 km² area, ~1 km resolution, 550 samples (including calibration)



Location of surveys in Blocks 14, 17, and Shiripuno, in the Oriente Basin of eastern Ecuador. Vintage Petroleum held the exploration concessions at that time.



Relationship between geochemical signature and reservoir net pay for nine calibration wells of 2001 survey. Geochemical signature measured as probability of match to the signature of selected oil production ("geochemical model approach"). H-2 well was an outlier to the selected geochemical model.



Relationship between geochemical signature and reservoir net pay for 12 calibration wells of 2002 survey. Geochemical model not the same as prior survey. H-2 well shows better fit to the selected geochemical model for this survey.

PIETU SIUPARIAI FIELD, LITHUANIA

Survey Location: Gargzdai Region of Western Lithuania **Exploration Target:** oil in Middle Cambrian sands

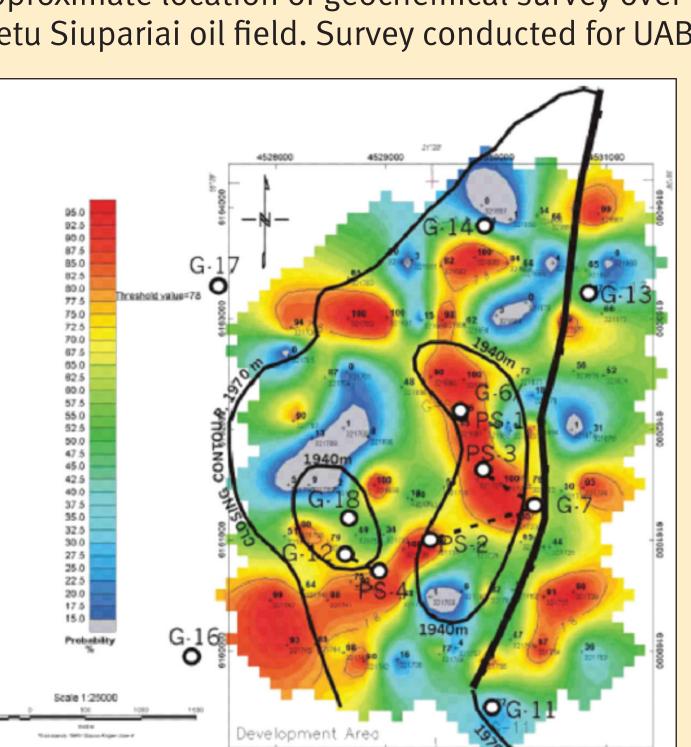
Client: UAB Minijos Nafta **Work Programs:** 1999, 20 km² area, 250-500 m resolution, 130 samples (including calibration)

References: Haselton and Willumsen (2001), 63rd EAGE Conference & Exhibition, and Haselton et al. (2002), World Oil vol. 223, no. 5, pp. 35-39.



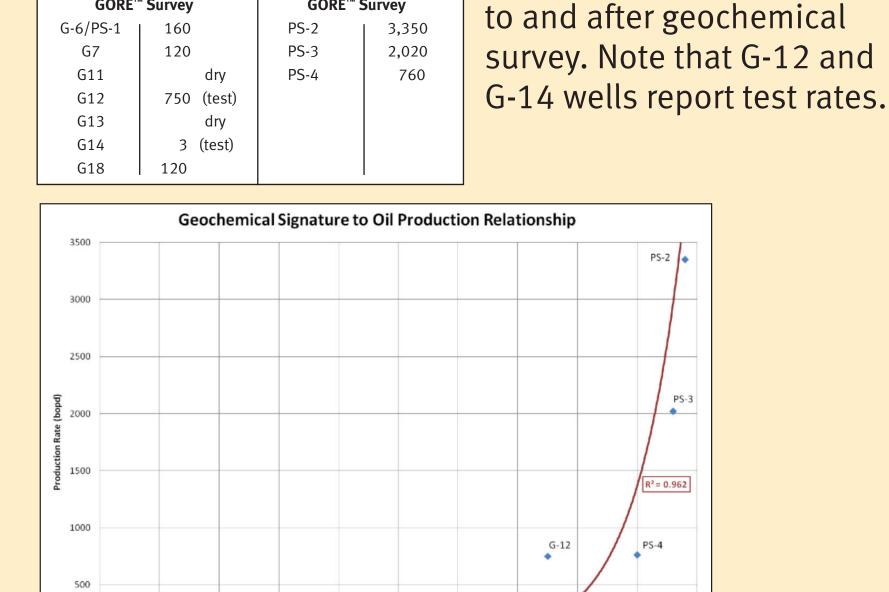
Approximate location of geochemical survey over a portion of the Pietu Siupariai oil field. Survey conducted for UAB Minijos Nafta.

List of wells drilled prior



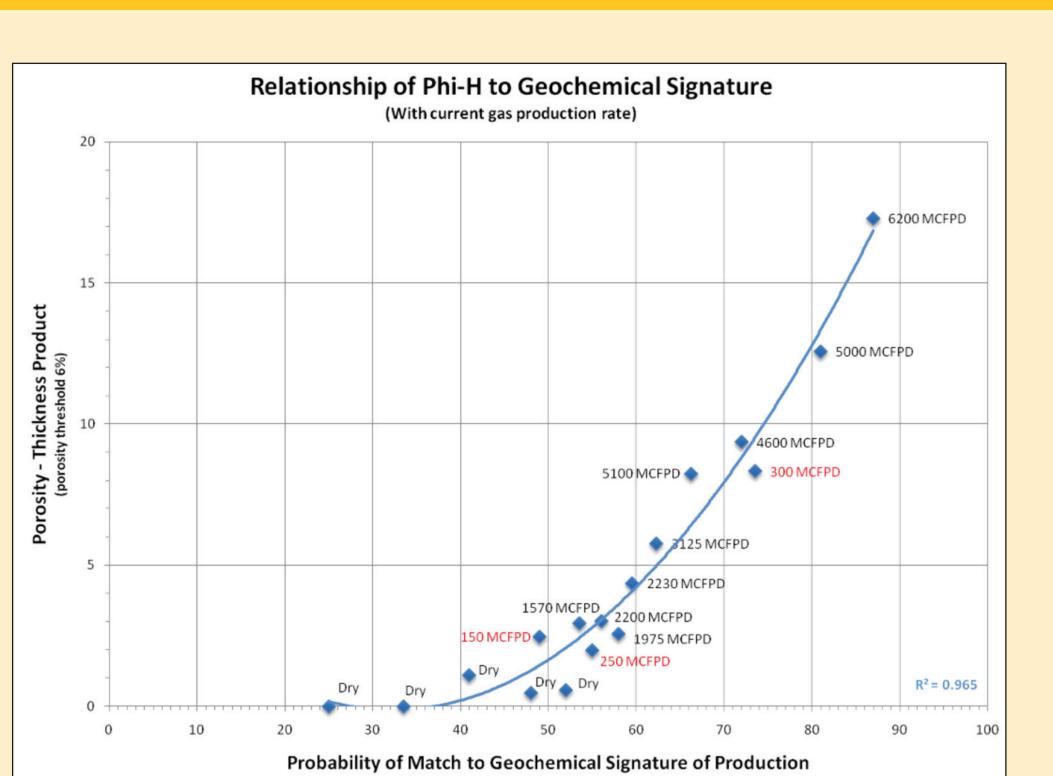
Geochemical results on reservoir outline.

Wells drilled after



Well production rate against geochemical signature (probability of oil character).

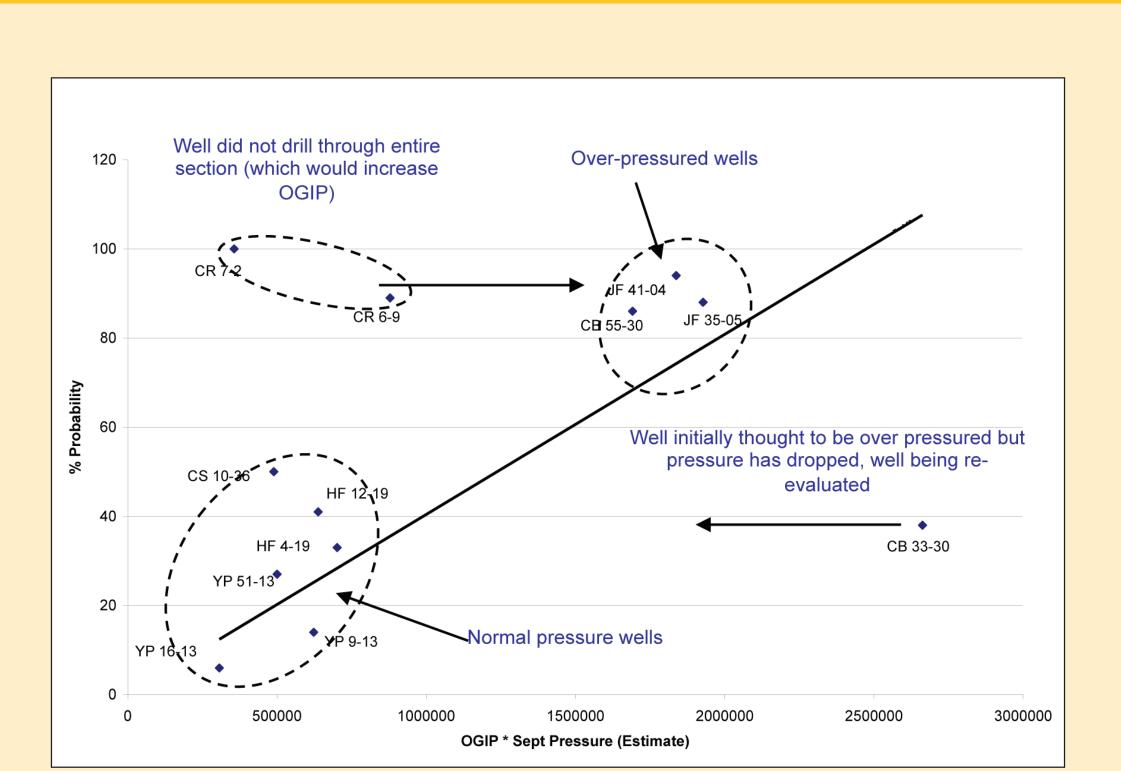
ANADARKO BASIN, OKLAHOMA



Relationship between reservoir parameters and interpreted surface geochemical data, from AAPG Memoir 66, Potter et al. (1996). Work by Santa Fe Minerals.

Graph shows strong correlation between geochemical signature and phi-h for gas reservoirs, with general correlation to contemporaneous production rate. Only wells with >6% porosity were studied. Gas show wells are shown in red font.

GREEN RIVER BASIN, WYOMING



Plot of gas volume – pressure product against geochemical signature. This plot shows the effect of pressure on geochemical signature strength.

Gas production from tight sandstone section, ~400 m thick. Depth to production ~3,000 m.

The two CR wells did not drill entire sand section and should

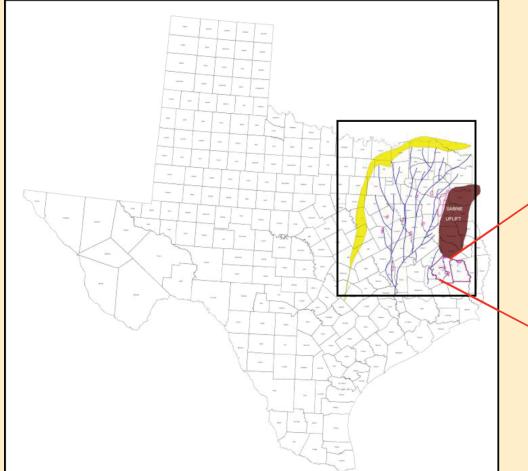
have higher volume-pressure product.

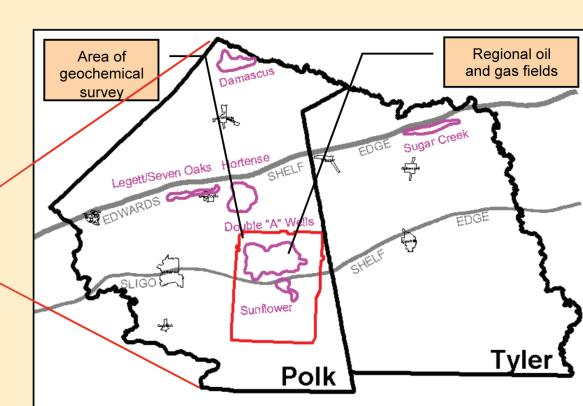
EAST TEXAS SALT BASIN **Survey Location:** Polk County, Eastern Texas

Exploration Target: Upper Cretaceous Woodbine

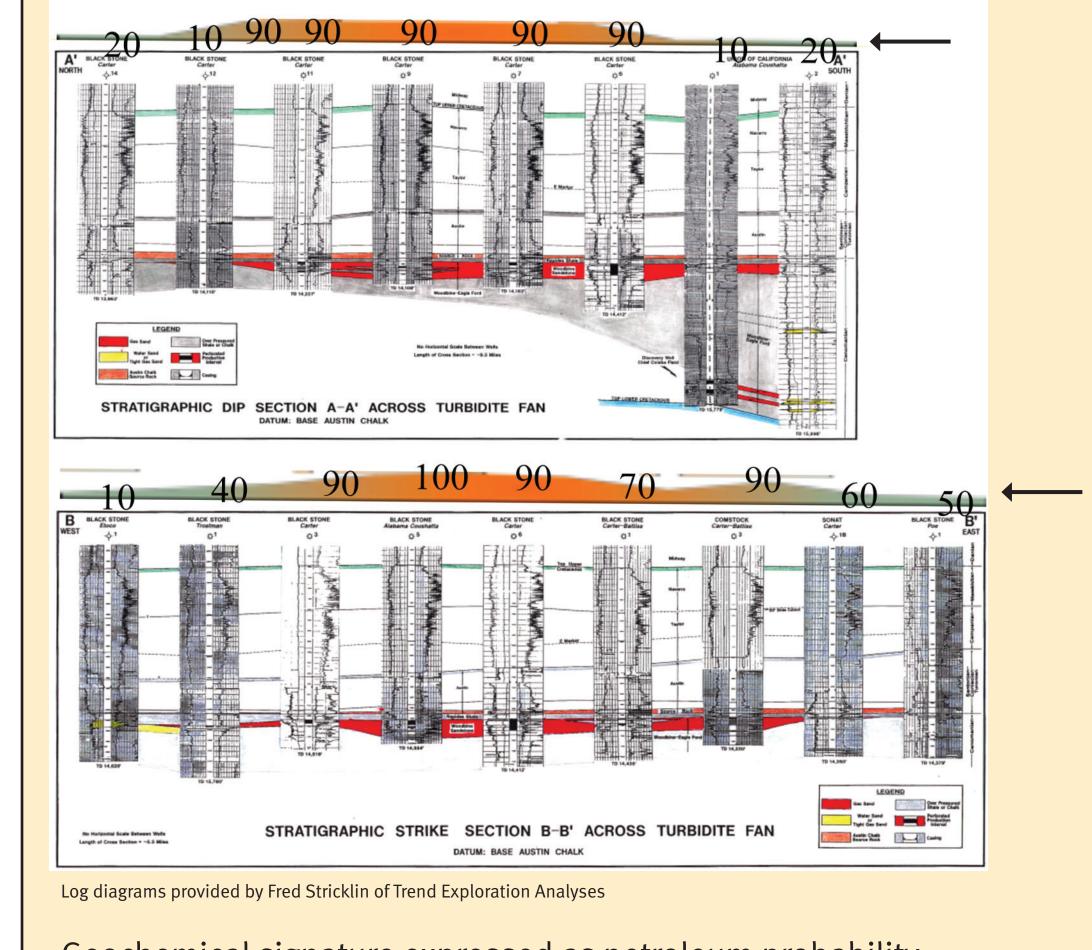
formation, gas-condensate **Client:** Gore proprietary

Work Program: 2003, 398 km2 area (17.7 x 22.5 km), 610 m resolution, 1,200 samples (including calibration)

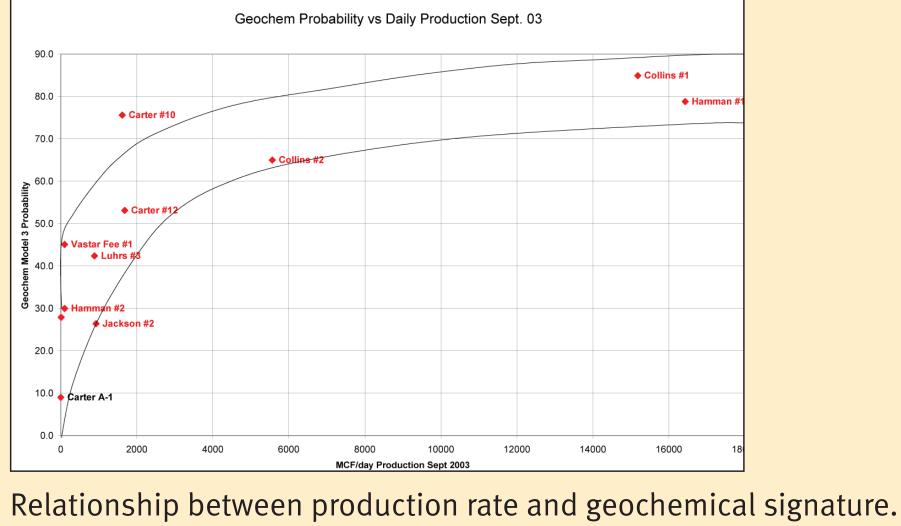


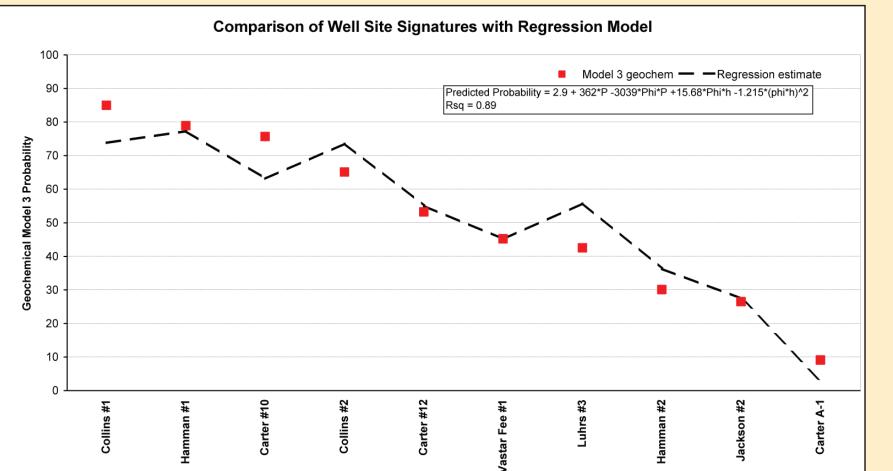


Location of the proprietary geochemical survey in eastern Texas. Survey area included the Double A Wells and Sunflower gas fields. Calibration for gas signatures acquired near wells in both fields, and regional dry wells – 11 sites in total.



Geochemical signature expressed as petroleum probability values (arrows) correlate to actual drilled results and logged sand thickness results across the Double A Wells field.



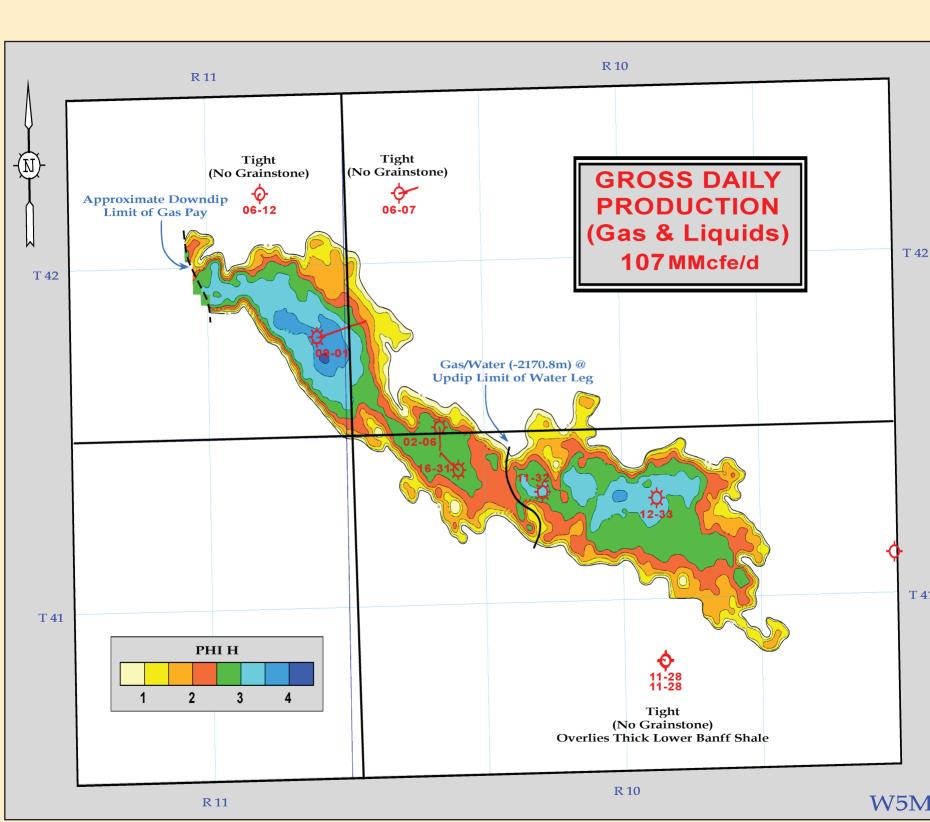


Regression of reservoir parameters with geochemical signature.

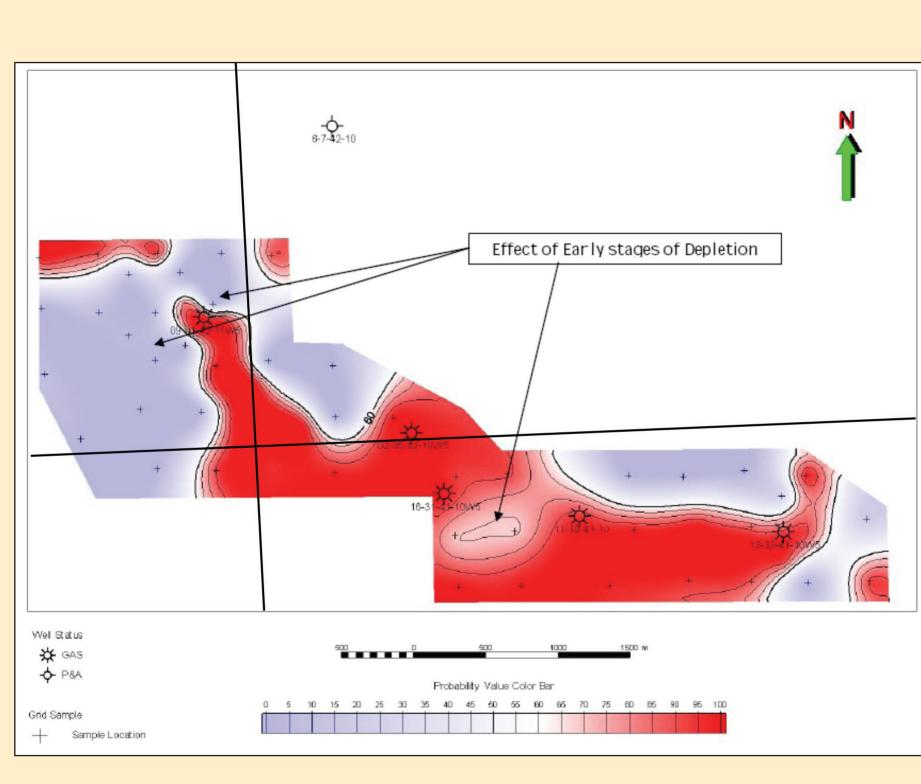
WESTERN CANADIAN SEDIMENTARY BASIN

Survey Location: West Central Alberta, Canada **Exploration Target:** Lower Mississippian Banff formation

Client: Canadian independent **Reservoir Information:** depth to reservoir 3,200 m; porosity 32%, permeability 5.2 darcies; 70 – 90 Bcfe gas in place



Map of porosity – net pay sand section product throughout Lower Banff reservoir.



Corresponding map of geochemical signature, in the form of petroleum probability value, from the classification of survey data against petroleum production calibration data.

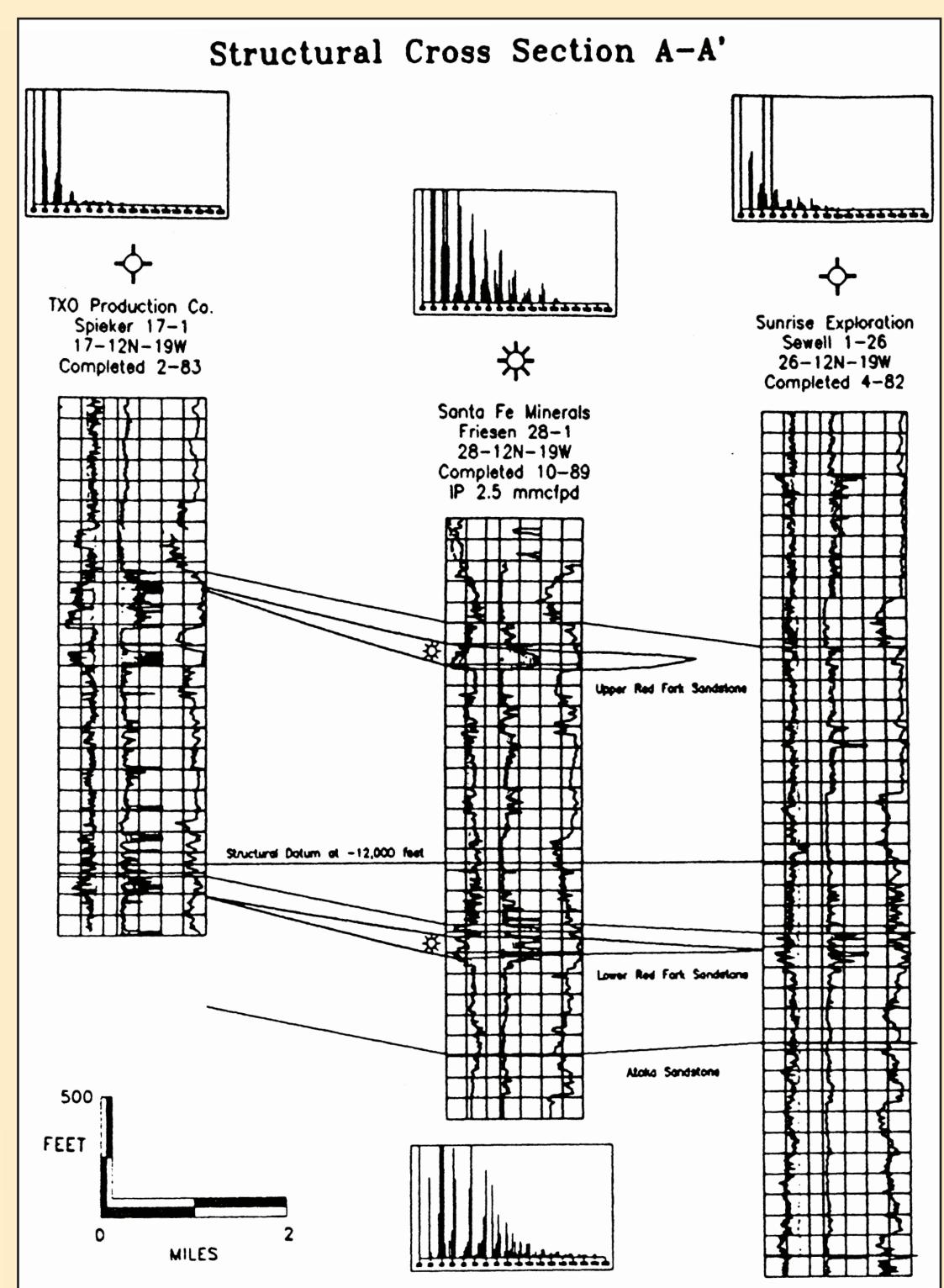
Geochemical anomalies relate to higher porosity-net pay outlines, as seen in the map above.

At the time of the survey two thirds of the recoverable gas from the 9-1-42-11 well had been produced. The geochemical signature was weaker in this area due to depletion.

ANADARKO BASIN, OKLAHOMA Survey Location: Western Oklahoma, USA

Exploration Target: Lower Red Fork formation **Client:** Santa Fe Minerals

Reservoir Information: Depth 4,500 m



Electric logs and mass spectra showing the change in geochemical signature from background (on the left and right) to production (in the middle) from the Red Fork prospect, Oklahoma.

Cross section showing change in geochemical signal at surface going from background to production to background. A comparison of surface signature detected over production is made to a headspace of sidewall core taken from producing zone.

©2012 W.L. Gore & Associates, Inc.

CONCLUSIONS

The relationship between reservoir characteristics and surface geochemical signature is established by several survey results, including the original citation (Anadarko Basin), as well as Oriente and Green River Basins. Practical applications are indicated by several additional cases, which demonstrate enhanced surface geochemical signatures over reservoir production zones. Surface geochemical signatures may reveal bypass pay sections in existing fields. The interpretation of geochemical signatures over an area may allow priority assignment and ranking of prospects. The application has been used in unconventional hydrocarbon plays to define regions of higher pressure and may also be used to screen broad areas to define regions that may be more liquid rich. When properly integrated with other geological and geophysical information, this surface geochemical technique can significantly reduce exploration risk.

ACKNOWLEDGEMENTS:

Dr. Robert Potter for his original work on the phi-h relationship in the Anadarko Basin. Harry Anderson of Gore for his work on the East Texas Salt Basin production and phi-h relationships. Thomas Haselton and Peter Willumsen for their original work over the Pietu Siupariai field.

* For correspondence, please email to author at: pharring@wlgore.com