Amplified Geochemical Imaging and Microbiological Hydrocarbon Near-Surface Mapping

As most of us know, the term **Macroseepage** refers to **visible oil and gas seeps**. Macroseeps are very localized areas containing large concentrations of hydrocarbons that are restricted to the termination of faults, fractures, and outcropping unconformities or carrier beds. (Link, 1952; Macgregor, 1993).

In **Microseepage**, hydrocarbon compounds pervade the overlying seal and migrate vertically through the stratigraphic sequence to the surface. The leakage is not massive, as with a breach of a structural closure. This process is distinct from the movement of hydrocarbons along breaching faults or fracture swarms (i.e. macro-seepage), with its consequent surface expression of an oil or gas seep (Silliman, 2005). The existence of microseepage is supported by a large body of empirical evidence (Price, 1986; Klusman, 1993; Klusman and Saeed, 1996; Matthews, 1996).

The migration of hydrocarbon compounds is nearly vertical in direction; consequently, the surface expression of these compounds overlay the subsurface accumulations. In this manner, detection of thermal hydrocarbons provides a valuable exploration tool (Silliman, 2005). Surprisingly, migration rates are fairly dynamic, ranging from less than 1 meter per day to tens of meters per day (Arp, 1992; Abrams, 1992)

The surface expression and monitoring of hydrocarbon-induced alteration of soils and sediments can take many forms. Two of the most common measurement technologies are indirect hydrocarbon measurement using microbiological techniques and direct hydrocarbon measurement using ultrasensitive Amplified Geochemical Imaging (AGI).

Bacteria play a role in the oxidation of migrating hydro-carbons, and their activities are directly or indirectly responsible for many of the surface manifestations of hydrocarbon seepage. These activities, coupled with long-term migration of hydrocarbons, lead to the development of near-surface oxidation-reduction zones that favor the formation of a variety of hydrocarbon-induced chemical changes (Schumacher and Abrams, 1996).

These changes in near-surface bacterial activity can be **indirectly** related to subsurface hydrocarbon expressions from petroleum systems. The most widely used method is the Microbial Oil Survey Technique (MOST) – (Beghtel, et. al., 1987; Lopez, et. al., 1994). This method measures the presence and concentration of hydrocarbon oxidizing bacteria in the soil at a depth of 6 to 8 in. The premise being, there is a correlation between the hydrocarbons in the soil and the microbial population.

However, indirect methods, by definition, do not measure hydrocarbons, but rather proxies for hydrocarbons. As a result, indirect methods are subject to false negatives and false positives from interfering refined hydrocarbon sources and biogenic sources.

As a generalization, direct hydrocarbon methods are preferred over indirect methods because they can provide evidence of the very hydrocarbons we hope to find in our traps and reservoirs (Dietmar "Deet" Schumacher, 2000).

Amplified Geochemical Imaging (AGI) is an ultrasensitive hydrocarbon mapping technology that has several advantages over other methods. First and foremost, **AGI is a direct hydrocarbon measurement method**. Thus it is not subject to interferences and false positives from biological, microbiological, mineralogical, radiological, magnetic, geothermal, or hydrologic changes in the near-surface soil conditions as are indirect methods.

Additionally, **the AGI method is a 1,000 times more sensitive than other methods**, both direct and indirect. The AGI passive sampler, see **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 are large enough to allow hydrocarbon molecules to pass through and concentrate on the adsorbent material. Additionally, the AGI method measures ~ 85 compounds, from C_2 – C_{20}, which provides the unique ability to clearly define and differentiate multiple gas, gas condensate, or oil signatures.

Reduce Exploration Costs by 58%

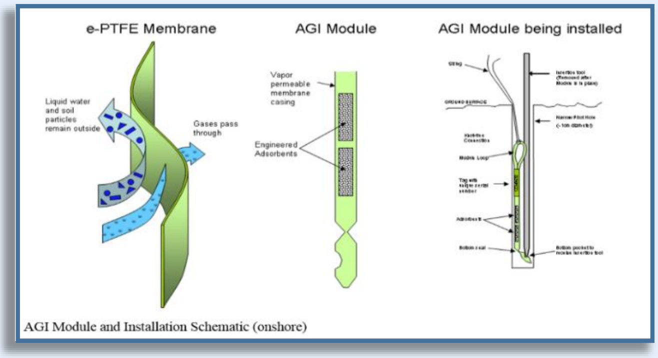

Figure 1.

In this Lithuania case study, presented at the 63rd EAGE Conference & Exhibition by T.M. Haselton of the Lithuania National Oil Company, several fields had been discovered and produced in the region since the 1990. The fields were located adjacent to a regional sealing fault. The Pietu Siupariai field had produced a total of 0.2 MMBO from 3 wells. Productivity of the old wells varied from no production to 160 BOPD. The G-12 well tested 750 BOPD on a DST but was not completed due to mechanical problems. Although the G-18 and G-7 wells both produced 120 BOPD, the latter well only penetrated the uppermost 15 meters of the reservoir.

As seen in **Figure 2**, the red areas represent an 85%-95% probability of finding oil similar to the producing wells, while the yellow shading indicated a 70% probability, the green 50%, and the blue 25%. The survey identified the reason for the poor production. All of the pre-survey wells were either on the edge of high probability zones or in poor zones. Wells PS-2, PS-3, and PS-4 were drilled post-survey based on the survey results. As a result, **production increased 16-fold** to 6,533 BOPD. Note all of the post-survey wells were drilled in red anomaly areas. Haselton also calculated that the correlation between the geochemical probability values and the production field data had an R^2 value of 0.96, see **Figure 3**.

Production Test Data (BOPD)			
Wells drilled before the AGI survey		Wells drilled after the AGI survey	
G6/PS1	160	PS-2	3,350
G7	120	PS-3	2,020
G11	Dry	PS-4	760
G12	------		
G13	Dry		
G14	3		
G18	120		
	403		6,130

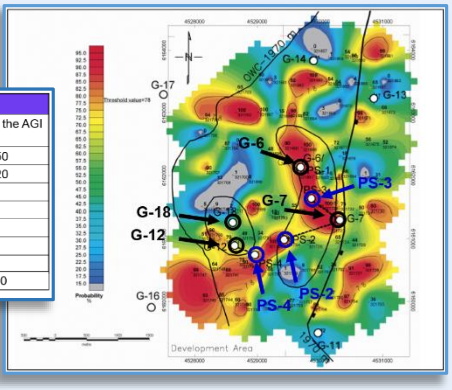

Figure 2.

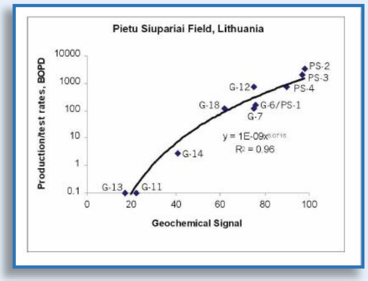

Figure 3.

As published in AAPG Memoir 66 by Santa Fe Minerals, AGI surveys were combined with 3D seismic over a seven year period in North, Central, and South America. As seen in **Figure 4,** AGI data correctly predicted 131 of the 141 post-survey wells. So 96% of the dry wells and 92% of the producing wells were correctly predicted.

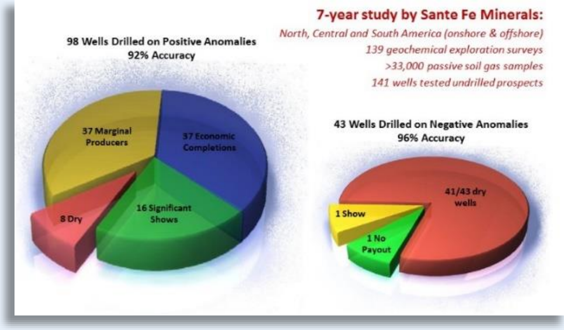

Figure 4.

By the end of the seven year period, Sante Fe Minerals was able to **reduce their exploration costs by 58% by virtually eliminating dry wells** when they combined 3D seismic with AGI data.

Summary: Microbiological hydrocarbon mapping is an inexpensive method for **indirectly** measuring hydrocarbons at the surface. It can, in some cases, detect gas or liquid hydrocarbons near-surface, but **is subject to a lack of sensitivity and specificity**, given it is an indirect tool, and thus, subject to false positives and false negative results. Additionally, it **does not work well in stacked pay scenarios** because it has no way to differentiate hydrocarbons from multiple formations or depths.

The AGI method has advantages in that it:

- is 1000-times more sensitive than other methods,
- can clearly differentiate between multiple gas, condensate, and oil signatures,
- can identify stacked pays,
- can identify multiple petroleum systems,
- has a >90% success rate at predicting dry holes, thus reducing exploration and drilling costs.

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