The Use of Amplified Geochemical Imaging to Monitor and Optimize EOR Floods and CO_2 Injection

Secondary recovery techniques extend a field's productive life generally by injecting water or gas to displace oil and drive it to a production wellbore. In addition to the beneficial effect of increased pressure, these methods sometimes aid recovery by reducing the viscosity of the crude oil as it mixes with gas.

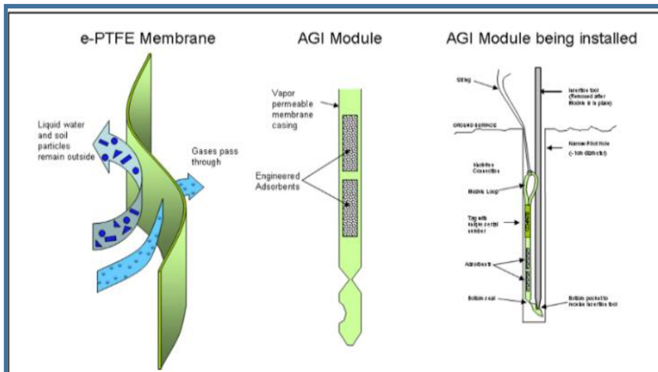
However, in some cases geologic factors such as extensive faulting, natural fractures, swelling, thrusting, changing permeability, and other issues can add great complexity to these programs. For example, water floods and CO_2 injection may by-pass entire portions of a field due to compartmentalization. Additionally, operators can sometimes be at a loss to explain why they note increases in production in some portions of the field with no increases in adjacent wells. They may also struggle to understand why they seem to be using excessive volumes of water or CO_2 with little positive impact on production.

Advances in geochemical sampling, analysis, and interpretation have led to a robust technology called Amplified Geochemical Imaging that allows for ultrasensitive detection and measurement of hydrocarbons emanating from the reservoir. This patented technique uses a passive collection device, see **Figure 1**, that works in dry environments, water-saturated soils, or directly in water. These results can then be mapped to indicate areas of hydrocarbon charge, sweet spots, gas-water contacts, oil-water contacts and depletion effects.

Figure 1.

Amplified Geochemical Imaging's (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 time more sensitive than traditional methods**.

The internal portion of the AGI sampler, see **Figure 2**, 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.



AGI Module and Installation Schematic (onshore)

Figure 2.

Additionally, the AGI method measures ~ 85 compounds, from C_2 – C_{20}, which provides the unique ability to clearly define and differentiate gas, condensate, or oil signatures.

Case Study: This project took place in Oklahoma in the Arkoma basin and consisted of two surface surveys conducted three years apart to monitor hydrocarbon movement. This program is an example of how geochemical mapping can be used to augment the understanding of hydrocarbons in a field as well as depletion effects.

Gas was produced from the upper Hartshorne Fm. and the lower Booch Fm. The gas was 99% methane and sourced from deeper coal beds. Thus, the same gas charged both formations and could not be differentiated. The field, see **Figure 3**, has channel sands descending from the northeast that terminate against the fault, as illustrated by the black line. The sand thickness changes from 0 ft to 120 ft, and then back to 0 ft, as you move from east to west. The SW portions of the field consist of a structural trap in the deeper Booch Fm.

In **Figure 3**, the purple areas represent an 85%-95% probability of finding gas similar to the producing wells, while the yellow shading indicates a 70% probability, the green 50%, and the blue is nonprospective at 25%.

Identify Compartmentalization & By-passed Pay

Calibration was conducted around wells 1, 2, 3, & 4. Wells 2 & 3 were used to determine the dry well or background signature. Samples around Well 1 were used to define the gas signature. Well 1, drilled in the channel sands, produced gas from the upper Hartshorne Fm. and water from the Booch Fm. Well 4, also used to define the gas signature, produced gas from the structural trap in the deeper Booch Fm and produced no gas from the Hartshorne as it was outside the channel sands.

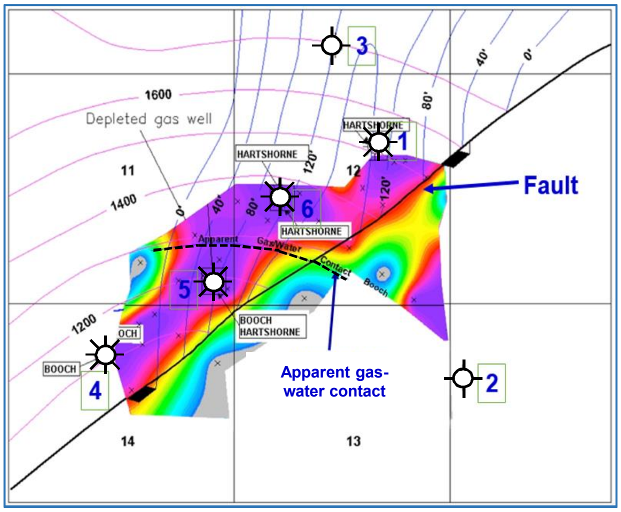


Figure 3.

Well 6 was drilled post-survey and produced gas from the Hartshorne Fm. and water from the Booch Fm. Well 5 was drilled post survey as well and produced gas from both formations inferring a gas-water contact between Wells 5 & 6.

The survey was repeated 3 years later with an extension into Section 13. In Phase II a grid pattern for sampling locations was employed. Part of the reason for repeating the survey over sections 4, 11 &12 was that after three years Well 5 had watered-out indicating a movement in the gas-water contact. So, the sample density was increased to help define the new gas-water contact.

The Phase II survey results can be seen in **Figure 4**. It is immediately apparent that there is a dramatic difference between the Phase I survey 3 years earlier and the Phase II anomaly map. Notice Well 5, which is now depleted no longer has a hydrocarbon anomaly associated with it. Thus, **the geochemical survey results are ground-truthed by the production data**. Note the depletion affects of producing Well 5 are some-what extensive, as indicated by the expanded blue and green areas. Additionally, hydrocarbons are also detected now in the NW corner of section 13 which was not the case thee years earlier.

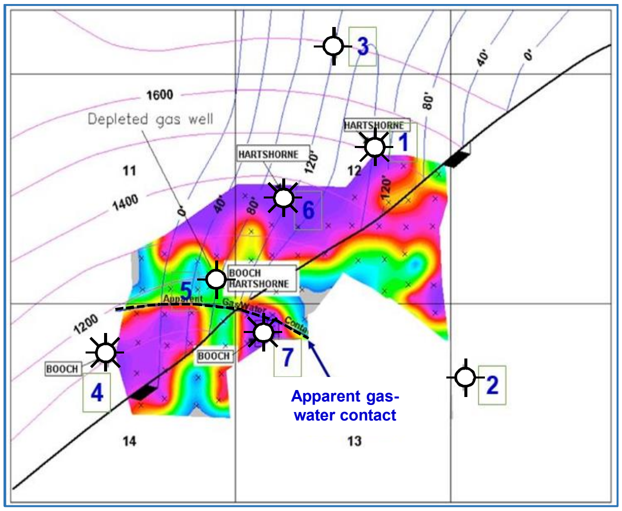


Figure 4.

Based on the survey results, a post-survey well, Well 7, was drilled on the up-thrown side of the fault. This well became a gas producing well from the Booch Fm., indicating it was above the gas-water contact. It can be seen that the gas-water contact had moved southward.

Project Summary:

Å The survey identified Sweet Spots or higher prospectivity areas of the field.
Å Post-survey wells ground-truthed Phase I and Phase II survey results.
Å Depletion affects were accurately defined as ground-truthed by well production data.
Å Movement of the gas-water contact was accurately defined.

Uses for EOR Projects:

Å Can define oil-water & gas-water contacts and their movement over time.
Å Can define high prospectivity & poor prospectivity areas.
Å Can identify by-passed portions of the field due to compartmentalization.
Å Can indicate sub-seismic faults (i.e. faults that may not be apparent on 2-D seismic data).
Å Can save millions of dollars by identifying where, and perhaps more importantly where not, to install injection wells due to compartmentalization boundaries.

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