Using Ultra-Sensitive Hydrocarbon Mapping to Elucidate the Carbonate Dahl Reef Complex*

Rick Schrynemeeckers[1] and Robert Potter[2]

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[1]Affliation Amplified Geochemical Imaging, LLC, Houston, TX (Schrynemeeckers@AGIsurveys.net)
[2]GeoChem Tech

Abstract

Dahl Reef is an isolated carbonate patch reef complex located in British Columbia. Production is gas and chiefly focuses on the up-dip northern end of the reef margin. Surface geochemistry acquired from microseepage was used to delineate areas of gas hydrocarbon accumulations and to define the extent and boundaries of those accumulations. It is important to note that the mechanism that affects microseepage hydrocarbons and their transport to the surface are a combination of reservoir pressure, porosity, and net pay thickness. Thus, as the combination of these three variables increases, so does the hydrocarbon response at the surface.

Amplified Geochemical Imaging^{SM} is a high-end surface geo-chemistry technology that uses passive adsorbent sampling which contains a specially engineered hydrophobic adsorbent encased in a layer of microporous expanded polytetrafluoro-ethylene (ePTFE). This proprietary membrane has pores that are specifically engineered to allow hydrocarbon molecules to pass through while excluding soil particles and water droplets. Consequently, Amplified Geochemical Imaging is able to obtain a thousand fold increase in sensitivity as compared to traditional methods. Additionally, the technology has the ability to measure approximately 90 compounds from C2 – C20 that not only measure hydrocarbon intensity, but also provide a probability map of hydrocarbon presence over an area. That probability factor is the probability of finding hydrocarbons similar to a referenced or modeled signal. In the Dahl Reef survey multiple gas well and dry well signatures were used for modeling purposes. Examples will be shown that these probability percentages can be proxies for reservoir pressure, porosity, and/or net pay in a field.

In the case of the carbonate Dahl Reef complex both hydrocarbon probability and intensity were used to map gas hydrocarbon influence over the reef structure. At the northern reef margin, where the majority of the drilling had taken place, probability factors ranged between 80% - 100% indicating strong fingerprint similarities to the model wells. Butane intensities ranged from 300-900 ion counts, which appeared to be the norm for the Dahl Reef gas trapped in the conventional limestone reservoir.

The gas signatures from the anomaly in the center of the reef complex displayed probability factors between 80% - 100% as well; however, butane intensities for these samples were approximately 1,500 ion counts. It was believed the higher intensities were indicative of larger accumulations in natural fractures within the dolomitized core section.

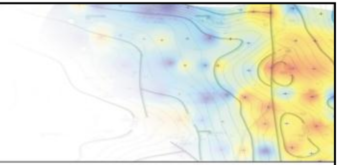
Additionally, the survey results identified gas accumulations off-reef that were initially believed to be patch reef systems. However, some of these accumulations had significantly different hydrocarbon intensities than the known reef complex. While the composition of the gas was similar at all locations of the survey, as indicated by probability factors ranging from 80% - 100%, the hydrocarbon intensities over the reef complex had a maximum value of 900 ion counts, and the anomaly to the southeast of the reef had a maximum value of almost 5,000 ion counts, and the gas anomaly to the northeast had a maximum value of 125,000 ion counts.

When placed in a geologic context, the data was interpreted to mean the anomaly to the southeast was actually not a carbonate patch reef complex, but rather the Muskwa Shale with a higher porosity than the Dahl Reef. Thus, the increased porosity in the shale resulted in higher butane intensity at the surface.

It was also believed the higher butane intensities of 25,000 in the northeast anomaly were a result of increased porosity from hydrothermal dolomitization of carbonates. The carbonate dissolution from the influx of hot brine solutions resulted in a dramatic increase in porosity, which would release significantly larger amounts of gas to the surface through microseepage.

In conclusion, the high probability factors for the gases in the survey area suggested a similar hydrocarbon gas was found throughout the survey area. The implication being that the detected gas throughout the survey was from a similar source, possibly the Muskwa Shale. The varying butane intensities, when combined with important geologic and seismic data, inferred differing combinations or pressure/ porosity/ net pay across the survey area. For example, increased intensity in the center of the Dahl Reef may be due to increased fracture porosity. The southeast anomaly may have been Muskwa Shale instead of a patch reef as previously thought, and the increase in butane intensities in the northeast anomaly may have been a result of increased porosity due to hydrothermal dolomitization. Thus, the probability factors and hydrocarbon intensities from the Amplified Geochemical Imaging survey provided insightful information in clarifying the Dahl Reef carbonate complex.

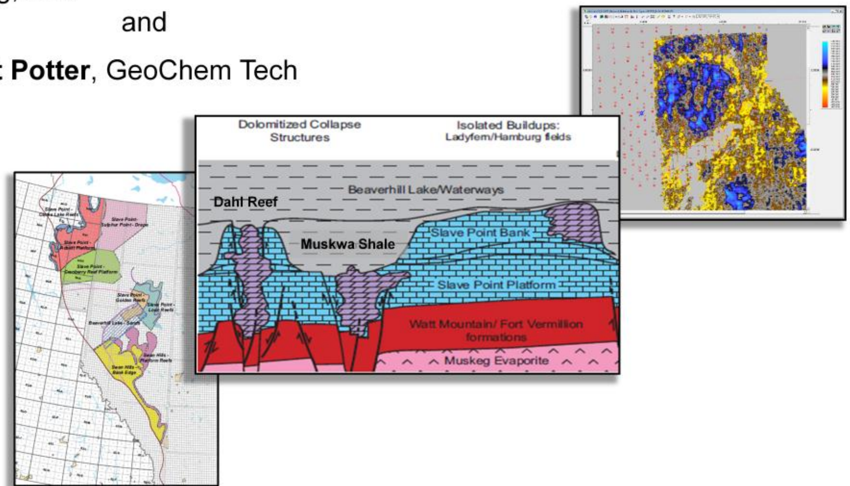
Using Ultra-Sensitive Hydrocarbon Mapping to Elucidate the Carbonate Dahl Reef Complex



Rick Schrynemeeckers, Amplified Geochemical Imaging, LLC

and

Robert Potter, GeoChem Tech

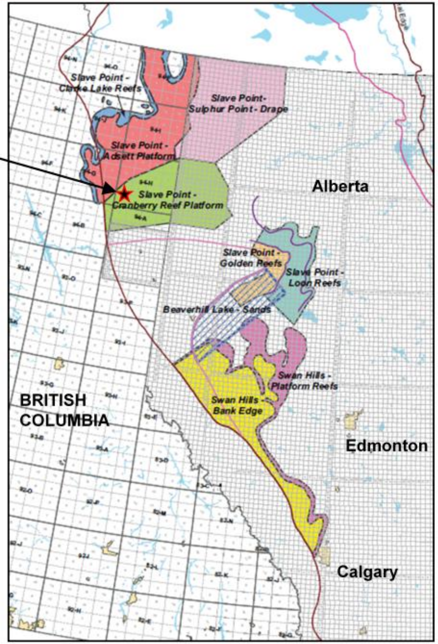


GEOCHEMTECH SURFACE GEOCHEMICAL INNOVATION

AMPLIFIED GEOCHEMICAL IMAGING, LLC

Mid-Devonian Map

Dahl Reef Complex



- Beaverhill Lake - Sands Play
- Slave Point - Adsett Platform Play
- Slave Point - Clarke Lake Reefs Play
- Slave Point - Cranberry Reef Platform Play
- Slave Point - Golden Reefs Play
- Slave Point - Loon Reefs Play
- Slave Point-Sulphur Point - Drape Play
- Swan Hills - Bank Edge
- Swan Hills - Platform Reefs
- Mannville Erosional Edge
- Mannville Erosional Edge
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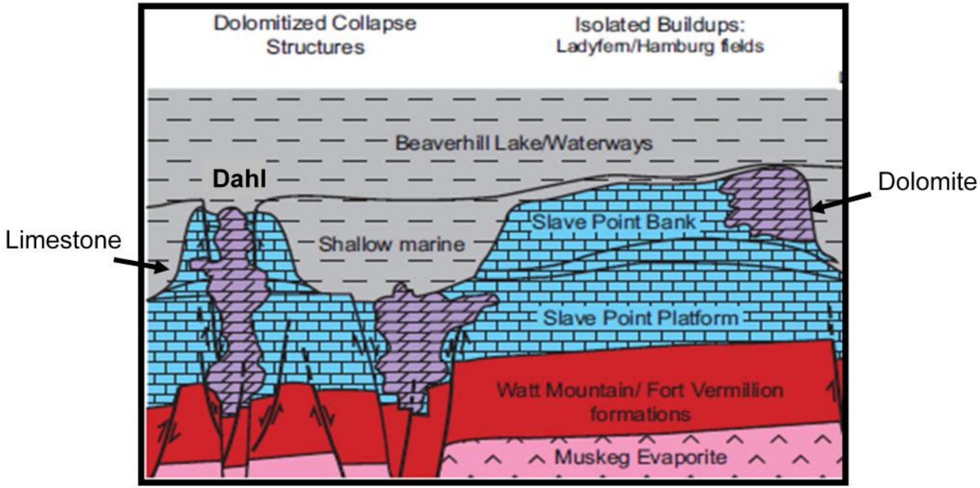
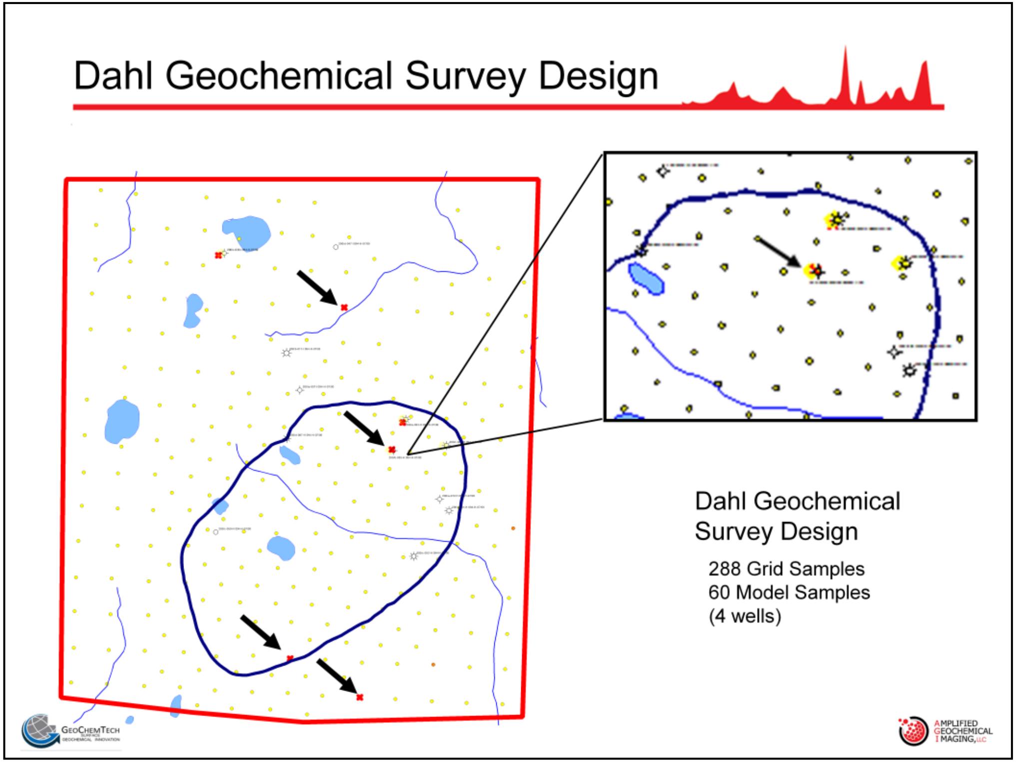
Map from
www.CanadianDiscovery.com

GeoChemTech

Amplified Geochemical Imaging, LLC

Slave Point Geological Model





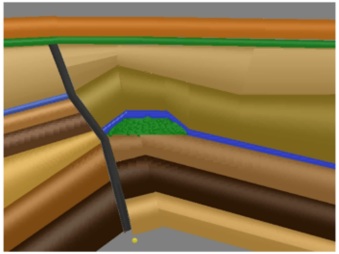
Presenter’s notes: A Mid-Devonian map which directly connects to the Slave Point-Cranberry Reef Platform and shows the paleogeography of the play.

The Science Behind the Technology

Presenter's notes: Here you see the Dahl Reef is an isolated carbonate patch reef complex on the left. The limestone is shaded in blue with the Dolomite in purple. There are three dolomitic sections indicated on the illustration. You can also see the Muskeg evaporitic section in the deeper sections.

Macroseepage & Microseepage

Vertical Migration



Microseepage signal affected by:

- **Pressure (P)**
- **Porosity (θ)**
- **Net Pay (h)**

Macroseepage:
- Detectable in visible amounts
- Pathway follows discontinuities
- Offset from source/reservoir

VS

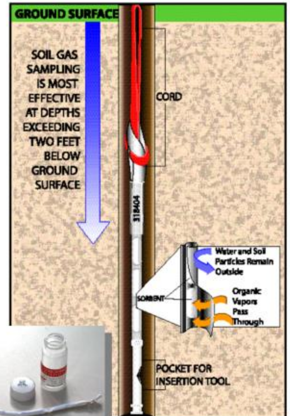
Microseepage:
- Detectable in analytical amounts
- Pathway is nearly vertical
- Overlie source/reservoir

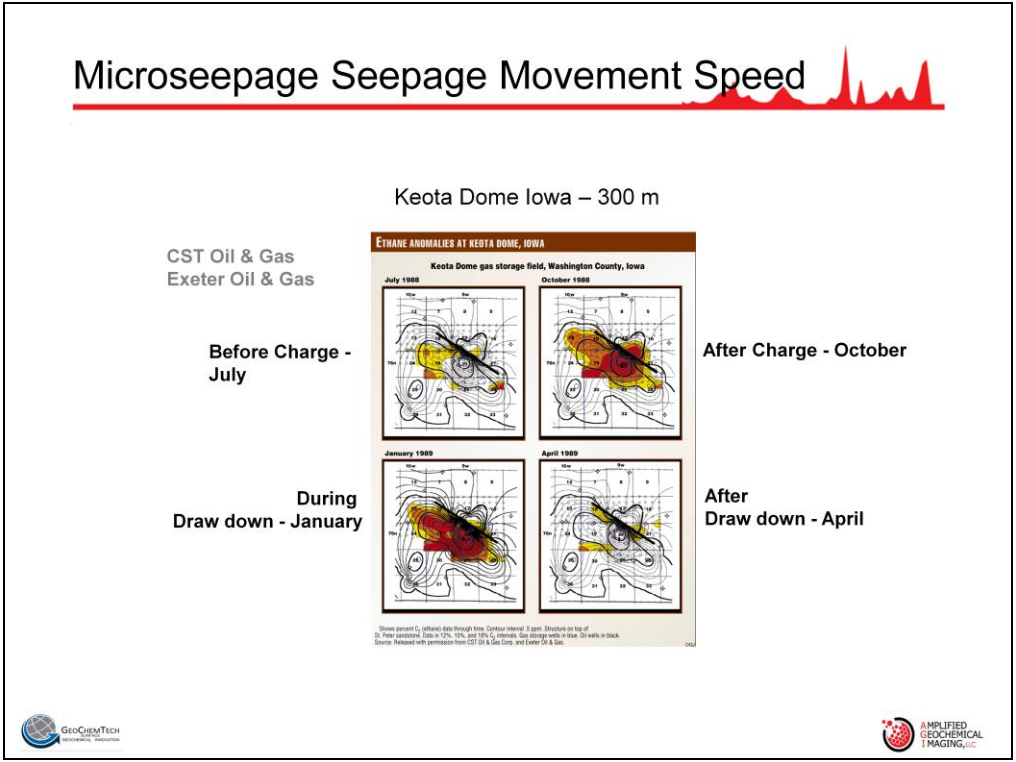
Presenter's notes: Here you see the outline of the surface geochemical survey. The red line is the boundary of the survey. The yellow dots indicate the locations of the hydrocarbon adsorbing modules. Notice around the reef complex you have tight 250-meter spacing in the grid pattern, but as you move northwest, you see the spacing increases to 500 meters. Tighter spacing was utilized over the reef section to improve resolution for this hydrocarbon bearing area. The dark blue line indicates the margin of the Dahl Reef. As you can see, the majority of the drilled wells are in and around the northern reef margin. In the exploded section in particular, you can see dry wells and producing gas wells. This is obviously a gas field with no liquids produced. In addition to grid samples, additional modules were placed around both producing gas wells and dry wells. These locations are indicated by the black arrows. The signals or fingerprints from these model wells or calibration wells were used to define both the dry well signal as well as the gas signal for the area. In addition, you see the black arrow to the north of the carbonate patch reef complex. This was used to define the background hydrocarbon signature for the area. So, let us take a minute to talk about how this technology works, why is it different from older traditional surface surveys, and why do we use calibration wells in the interpretation and modeling process.

Hydrocarbon Capturing Mechanism

Modules

- Patented, passive, sorbent-based
  - Chemically-inert, waterproof, vapor permeable
  - Direct detection of organic compounds
  - Sample integrity protected
- Engineered sorbents
  - Consistent sampling medium
  - Minimal water vapor uptake
- Time-integrated sampling
  - Minimize near-surface variability
  - Maximize sensitivity (up to C20)
  - Avoids variables inherent in instantaneous sampling
- Duplicate samples





Presenter's notes: In this diagram, the green section in the middle of the slide represents the reservoir and the horizontal blue line on top of it represents the seal. The thick gray vertical line next to the reservoir represents a fault. We are all familiar with macro seepage. Hydrocarbons from macroseepage travel along faults, find their way to the surface, and can be visually seen. Their concentrations are at percent levels and they are normally visual. Additionally, their location at the surface is normally offset from the source.

What most of us are less familiar with is microseepage. Microseepage occurs when hydrocarbon molecules in the reservoir go into the gas phase. These gas molecules are lifted-up by microbuoyancy from the pressure in the reservoir. These small gas molecules move upward, essentially vertically, along grain boundaries through the seal and through the lithology above the reservoir to the surface. Therefore, macroseepage occurs at percent levels and microseepage occurs at part per billion levels. Macroseepage travels along faults to get to the surface and microseepage moves upward due to microbuoyancy from reservoir pressure. The location of macroseepage hydrocarbons at the surface is offset from the source while hydrocarbons from microseepage are essentially directly above the source.

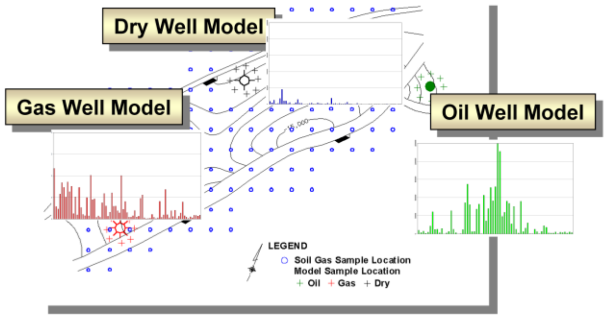
Analytical Compound List: C2 – C20

<table>
<tr><th colspan="4">Typical Petroleum Constituents
Hydrocarbon number in ( )</th></tr>
<tr><th>Normal Alkanes</th><th>Iso-alkanes</th><th>Cyclic Alkanes</th><th>Aromatics and PAH*</th></tr>
<tr>
<td>Ethane (2)
Propane (3)
Butane (4)
Pentane (5)
Hexane (6)
Heptane (7)
Octane (8)
Nonane (9)
Decane (10)
Undecane (11)
Dodecane (12)
Tridecane (13)
Tetradecane (14)
Pentadecane (15)
Hexadecane (16)
Heptadecane (17)
Octadecane (18)</td>
<td>2-Methylbutane (5)
2-Methylpentane (6)
3-Methylpentane (6)
2,4-Dimethylpentane (7)
2-Methylhexane (7)
3-Methylhexane (7)
2,5-Dimethylhexane (8)
3-Methylheptane (8)
2,6-Dimethylheptane (9)
Pristane (19)
Phytane (20)</td>
<td>Cyclopentane (5)
Methylcyclopentane (6)
Cyclohexane (6)
cis-1,3-Dimethylcyclopentane (7)
trans-1,3-Dimethylcyclopentane (7)
trans-1,2-Dimethylcyclopentane (7)
Methylcyclohexane (7)
Cycloheptane (7)
cis-1,3/1,4-Dimethylcyclohexane (8)
cis-1,2-Dimethylcyclohexane (8)
trans-1,3/1,4-Dimethylcyclohexane (8)
trans-1,2-Dimethylcyclohexane (8)
Ethylcyclohexane (8)
Cyclooctane (8)
Propylcyclohexane (9)</td>
<td>Benzene (6)
Toluene (7)
Ethylbenzene (8)
m,p-Xylenes (8)
o-Xylene (8)
Propylbenzene (9)
1-Ethyl-2/3-methylbenzene (9)
1,3,5-Trimethylbenzene (9)
1-Ethyl-4-methylbenzene (9)
1,2,4-Trimethylbenzene (9)
Indane (9)
Indene (9)
Butylbenzene (10)
1,2,4,5-Tetramethylbenzene (10)
Naphthalene (10)
2-Methylnaphthalene (11)
Acenaphthylene (12)</td>
</tr>
<tr><th colspan="4">Byproduct / Alteration and Other Compounds</th></tr>
<tr><th>Alkenes</th><th>Aldehydes</th><th>Biogenic</th><th>NSO* and Other Compounds</th></tr>
<tr>
<td>Ethene (2)
Propene (3)
1-Butene (4)
1-Pentene (5)
1-Hexene (6)
1-Heptene (7)
1-Octene (8)
1-Nonene (9)
1-Decene (10)
1-Undecene (11)</td>
<td>Octanal (8)
Nonanal (9)
Decanal (10)</td>
<td>alpha-Pinene
beta-Pinene
Camphor
Caryophyllene</td>
<td>Furan
2-Methylfuran
Carbon Disulfide
Benzofuran
Benzothiazole
Carbonyl Sulfide
Dimethylsulfide
Dimethyldisulfide</td>
</tr>
</table>

Presenter's notes: Amplified Geochemical Imaging Technology was developed. This new technology uses passive adsorbent sampling. The passive sampler contains a specially engineered hydrophobic adsorbent encased in a layer of microporous expanded polytetrafluoroethylene (ePTFE). This module is placed in the ground about 1.5 – 2.0 ft down in a small hole and then covered. It remains in the ground for approximately 3 weeks. This 3-week period is important b/c it allows a sufficient volume of hydrocarbons to migrate to the surface and adsorb onto the module.

Survey Design & Calibration Wells

Model development..

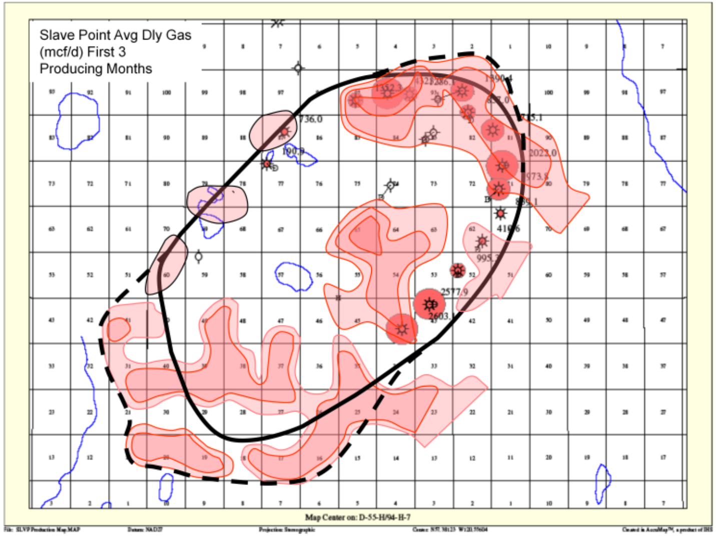


GeoChemTech

Amplified Geochemical Imaging, LLC

Presenter's notes: The Keota Natural Gas Storage Facility in Keota, Washington County, Iowa, stores gas in the St. Peter sandstone at approximately 1,000 ft defined as a northwest trending anticlinal structure. The dome or anticline produced minor amounts of oil in 1963 from the overlying Petaconica and McGregor carbonate formations before the reservoir was converted to gas storage. All three formations are Middle Ordovician in age. The gas is injected into the dome in summer through fall for winter withdrawal. The percentage of ethane at each sample location was measured on four occasions. It can be seen the yellow indicates low ethane concentrations. The Orange indicates medium concentrations while the red indicates high-level ethane concentrations. These maps demonstrate that the concentration changes can be detected and measured from quarter to quarter. This empirical data shows that microseepage rates occur at rates of meters per day through microbouyancy and that surface readings do not occur in geologic time, but essential current time.

Survey Results



GeoChemTech

Amplified Geochemical Imaging, LLC

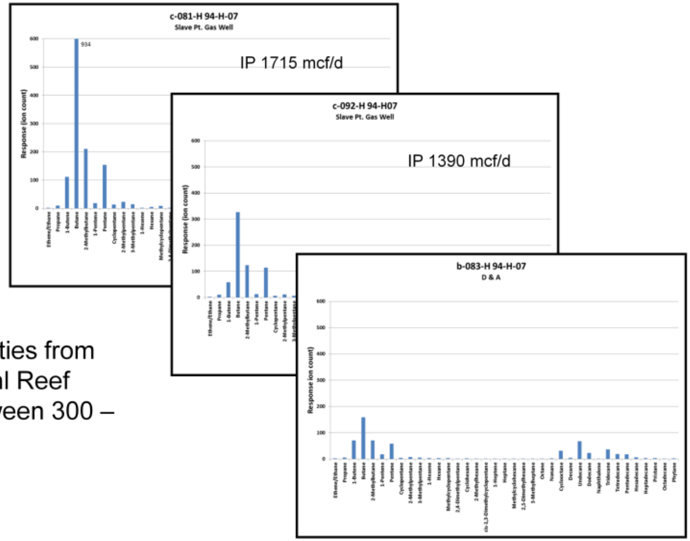
Presenter's notes: Amplified Geochemical Imaging monitors between 80 – 90 compounds as opposed to eight compounds from traditional methods. These additional compounds result in a powerful analytical tool for several reasons:

1.) The use of 80 – 90 compounds provides a rich set of organic compounds for each sample that can be interrogated with various statistical techniques like cluster analysis and canonical plots.

2.) The wealth of compounds provide the ability to generate a variety of geochemical interpretive plots that indicate factors such as depositional environment, biodegradation, thermal maturity, and several other factors.

3.) Since the compounds range from C2 – C20 it not only allows for clear distinction between gas, condensate, and oil, but also allows for differentiation between differing gas or oil signatures.

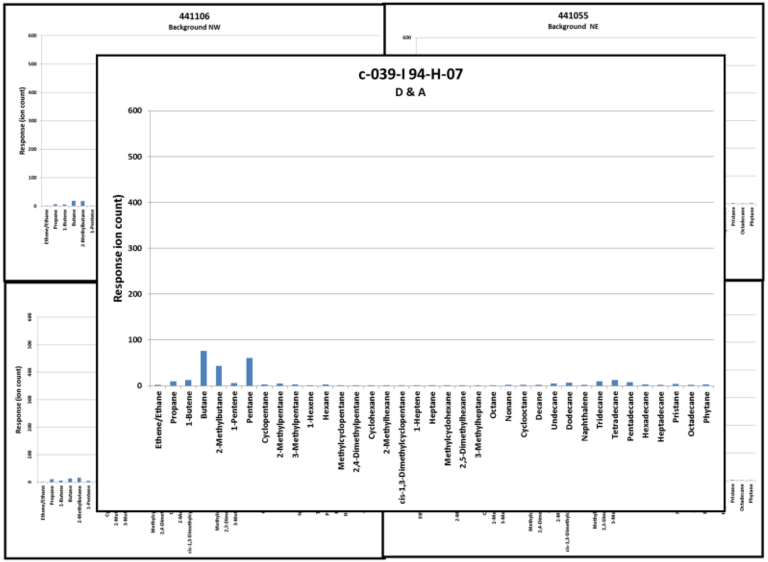
Dahl Reef Margin Hydrocarbon Intensities



Most butane intensities from samples on the Dahl Reef Margin ranged between 300 – 600 ion counts.

Presenter's notes: Deployment plans differ based on the project objective (i.e. frontier areas, prospect ranking, acreage relinquishment, field development, or phase identification for unconventional plays). The most common scenario is a grid pattern over the area of interest. The blue circles represent the location of each module. The spacing between the modules can range from 250 m to 2 km depending on the size of the field and the project objectives. Note the crosses around the dry well, gas well, and the oil well. Normally 15 modules are placed around such calibration wells. Calibration wells are used as hydrocarbon signal end-members for comparison during the evaluation and statistical analysis of the data. So, for example, if an oil signature is detected in the survey, that oil signature can be compared against the oil calibration signature. In addition, note, that there are distinct differences between the dry well, gas well, and oil well signatures. This ability is unique to Amplified Geochemical Imaging technology because this is the only surface geochemical technology that can measure the full range out to C20, thus providing a clear hydrocarbon signature – not just compound ratios.

Background Hydrocarbon Intensities

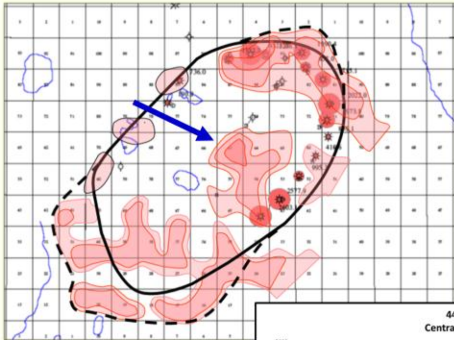


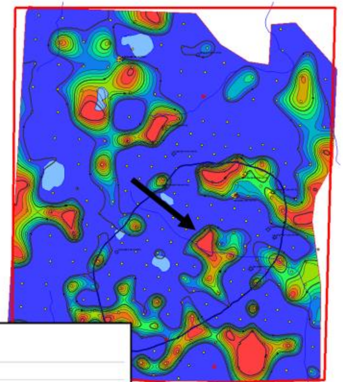
GeoChemTech

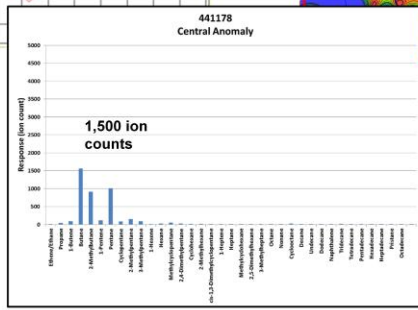
Amplified Geochemical Imaging, LLC

Presenter's notes: The solid black line indicates the boundaries of the Dahl Reef. The rose-colored shading indicates the probability map for the presence of gas, as compared to the gas well signatures obtained during the modeling process. The darker the shading the higher the probability factor for finding gas in that area. Therefore, the shading goes from darker rose coloration to white, where white indicates a very low probability of finding gas. Also, notice that production of each well is indicated by the size of the dark rose-colored symbol. So, it appears the Amplified Geochemical Imaging probability map contours fairly well with the known production after the survey. Notice that predominantly the larger circles (i.e. the stronger producing wells) are found in the darker shaded probability areas and the smaller producing wells are found in the lighter shaded areas. It should be noted that this map, with the production figures, was generated four years after the surface survey. Therefore, that really is a good match. What was less clear was why were there strong gas anomalies outside the Dahl Reef complex and margin. Geologically you would expect the gas accumulations to be bounded by the reef margin, but it appears that is not the case.

Central Reef Hydrocarbon Intensities



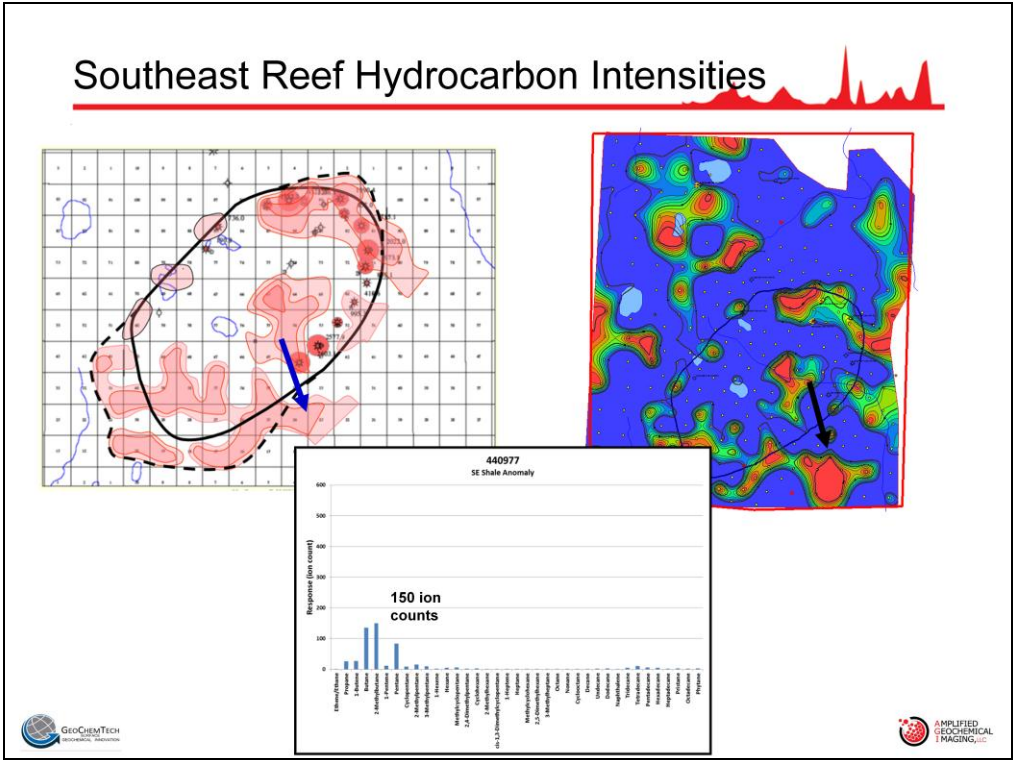




The central reef is not carbonate, but rather a dolomitized core with small natural fractures.

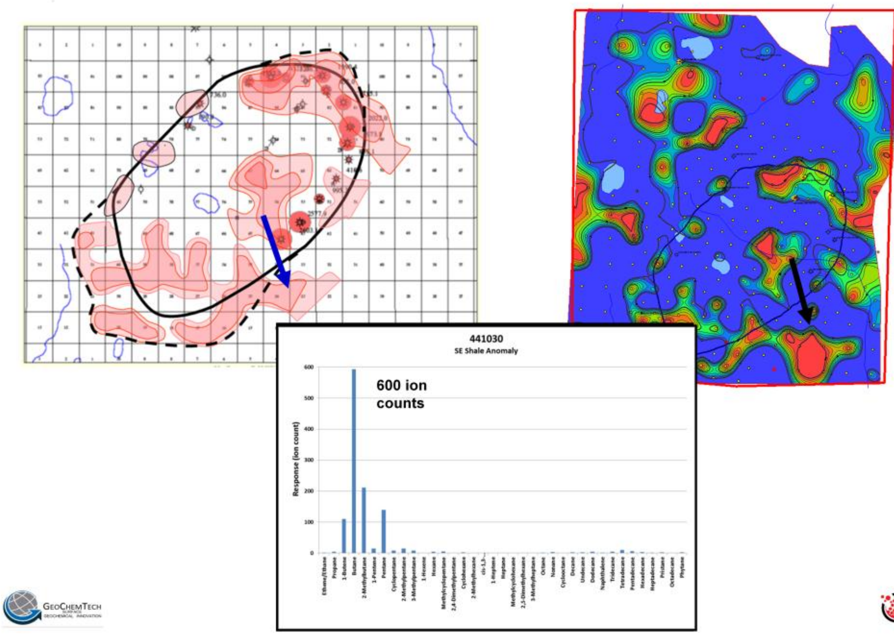
Presenter's notes: In an attempt to explain this curiosity, the people at GeoChem Tech began to look at not only the probability maps, but they also looked at the components of the gas signatures and their intensities. It is important to realize these hydrocarbon profiles are from the surface geochemical survey and have nothing to do with produced gas signatures.

You can see from the hydrocarbon profiles that the gas was primarily comprised of a handful of compounds from C3 (propane) – C5 (pentane) and a few later eluting compounds from C8 (cyclooctane) – C15 (pentadecane). The principal compounds were Butene, Butane, 2-Methylbutane, Pentene, and Pentane, with Butane typically being the predominant compound. The scales for these hydrocarbon profiles are set to 0 – 600 ion counts. Well C-081 was one of the model wells and had one of the highest butane intensities of 934 and had one of the highest Initial Productions (IPs) of 1715 mcf/d. Well C-081 was up-dip and located on the northern reef margin. Well C-092 was also an up-dip well, but displayed a lower butane intensity of 325 ion counts and had a lower IP of 1390 mcf/d. Well b-083 was interesting in that during the survey it was used as a dry well model, but later it was determined that this was not a dry well, but the well actually had gas shows, but was Plugged & Abandoned (P&A'd). The data from the survey supports the findings of the well not being dry as you see a butane intensity of 175 ion counts. Therefore, when you combine the probability map and the hydrocarbon intensity data you get a consistent picture that the probability map corresponded fairly well with production from the field and that butane intensities seemed to correlate to some degree with production for this conventional carbonate reef complex.

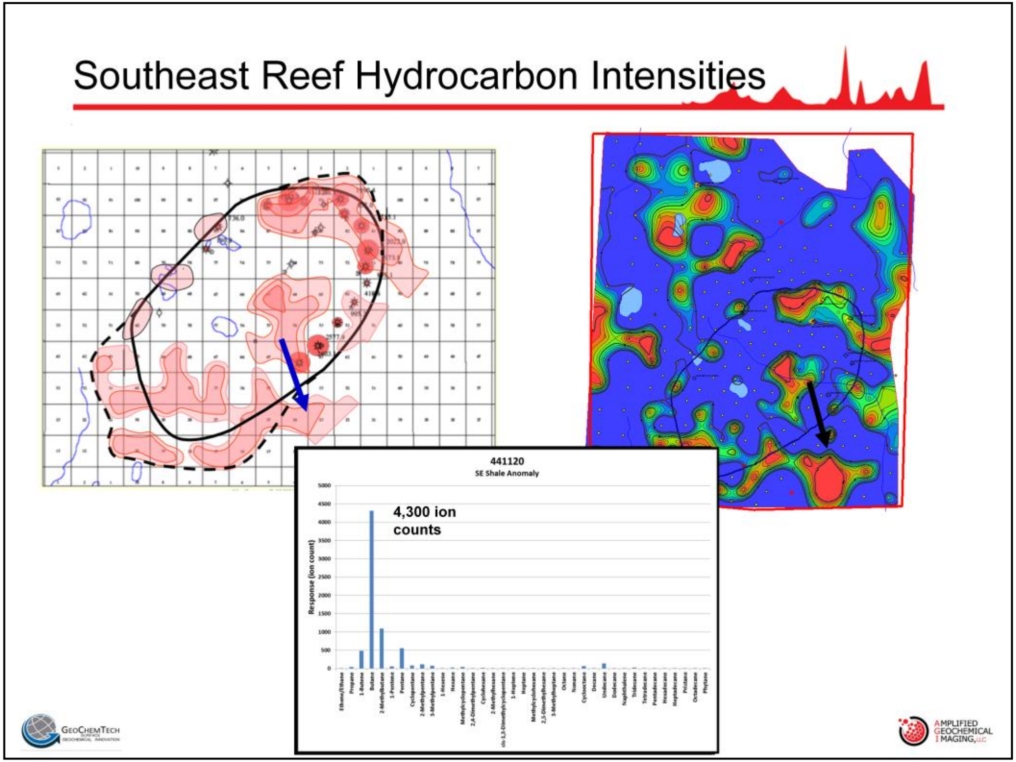


Presenter's notes: So, one of the questions that arises from the previous slide is, was the low intensity on the b-083 P&A'd well the same as background or above background. Because according to the probability map there should be a difference. Therefore, the hydrocarbon signatures of four background samples were reviewed and all of the butane intensities ranged around 25 – 35 ion counts. The review of another P&A'd well, c-039 showed a butane value of about 75 ion counts. In addition, remember, the butane concentration for the previous P&A'd well, b-083 was 175. Therefore, it does appear that the probability map and the butane intensities can differentiate between background gas concentrations and non-economic gas shows in this field.

Southeast Reef Hydrocarbon Intensities

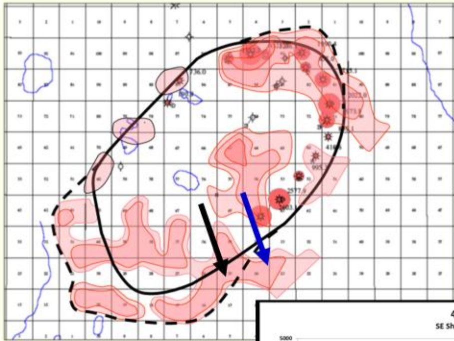


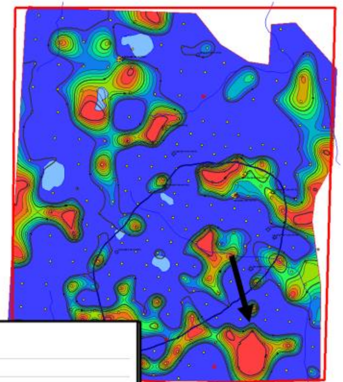
Presenter's notes: Interestingly, in the Center of the Dahl Reef complex, we see a strong red anomaly, but in this case, the butane ion counts reach levels of 1500, a level not seen in any of the reef margin samples. By definition, we know this is an indicator of better pressure, porosity, or net pay. What could be the explanation for this increased butane intensity. Remember the geologic model represents the central area of the reef to actually be a dolomitized core. We know that dolomitization can provide enhanced porosity and sometimes even potential natural fractures. Thus, it is believed the increased butane intensities are an expression of that increased porosity and small natural fractures.

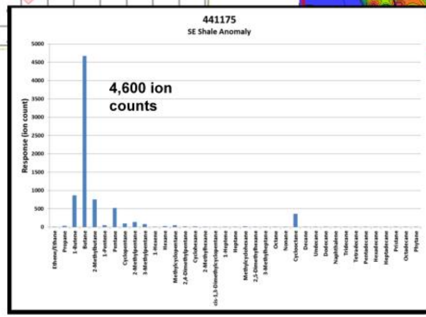


Presenter's notes: As you move to the southern down-dip portion of the reef margin, you notice a strong positive anomaly outside the reef margin. Even if you extend the reef margin to include most of the southern anomalies, there is still a portion of the red anomaly to the southeast that is not included in that. Therefore, the people at Geo ChemTech began to look at the butane intensities and noticed some very interesting correlations. If you looked at butane intensities just outside the reef margin, the intensities looked much like the previous reef margin samples with intensities of 75 and 600 ion counts. However, if you moved away from the reef margin to the area indicated by the blue and white arrows there was a dramatic difference. The butane intensities now increased levels between 4,000 – 5,000. That is eight times the previous levels.

Southeast Reef Hydrocarbon Intensities



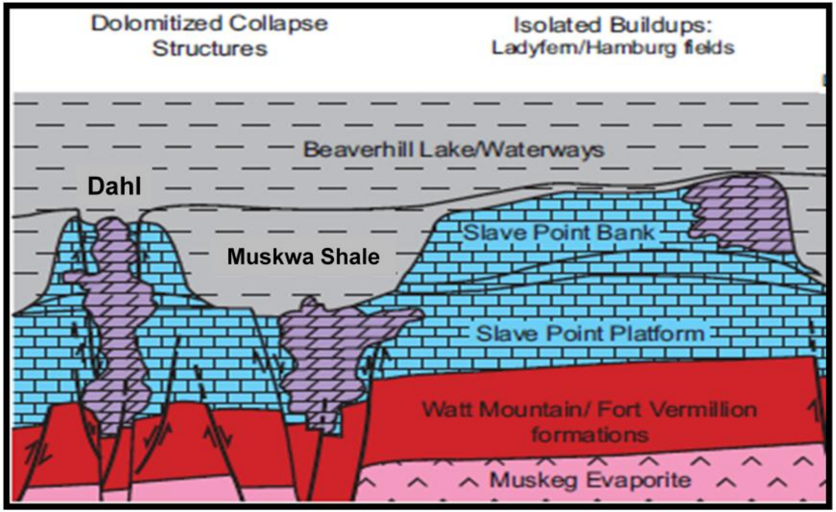




GeoChemTech Surface Geochemical Innovation

Amplified Geochemical Imaging, LLC

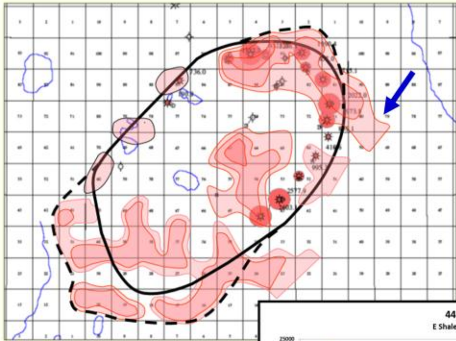
Slave Point Geological Model

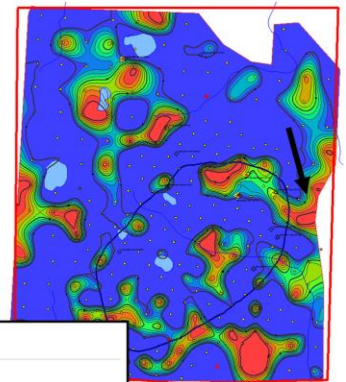


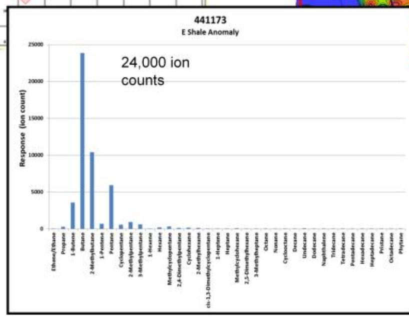
GeoChemTech Surface Geochemical Innovation

Amplified Geochemical Imaging, LLC

Northeast Reef Hydrocarbon Intensities





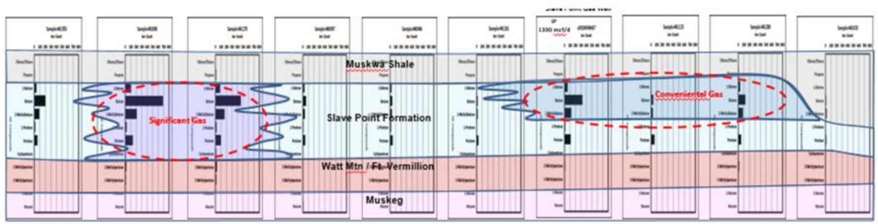


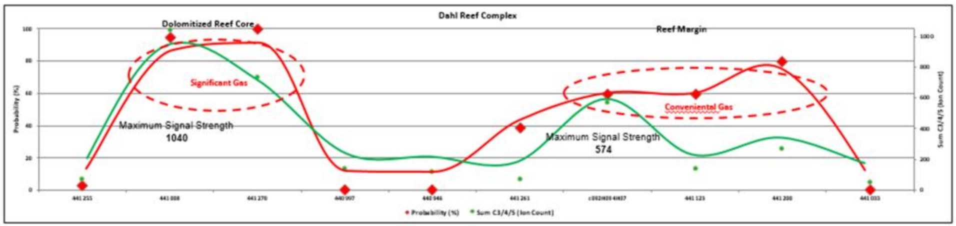
The northeastern section may be the result of hydrothermal dolomitization of a carbonate reef patch.

GeoChemTech Surface Geochemical Innovation

Amplified Geochemical Imaging, LLC

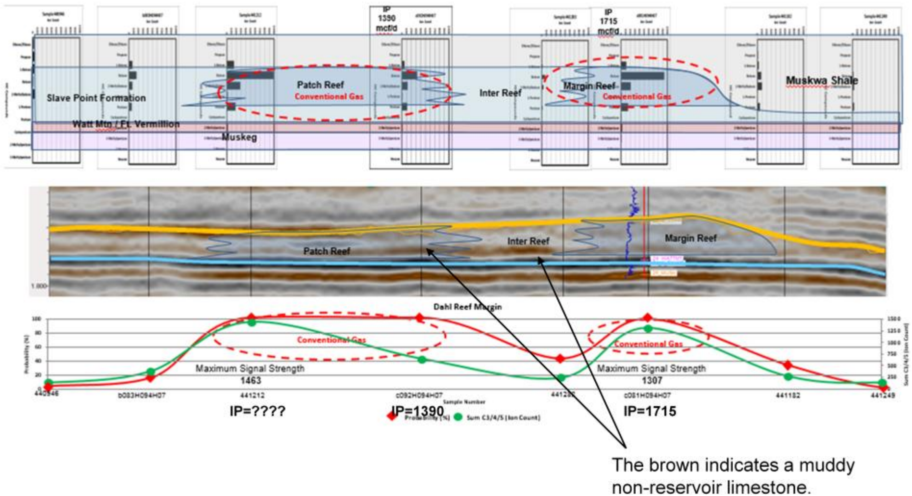
Dahl Reef Complex



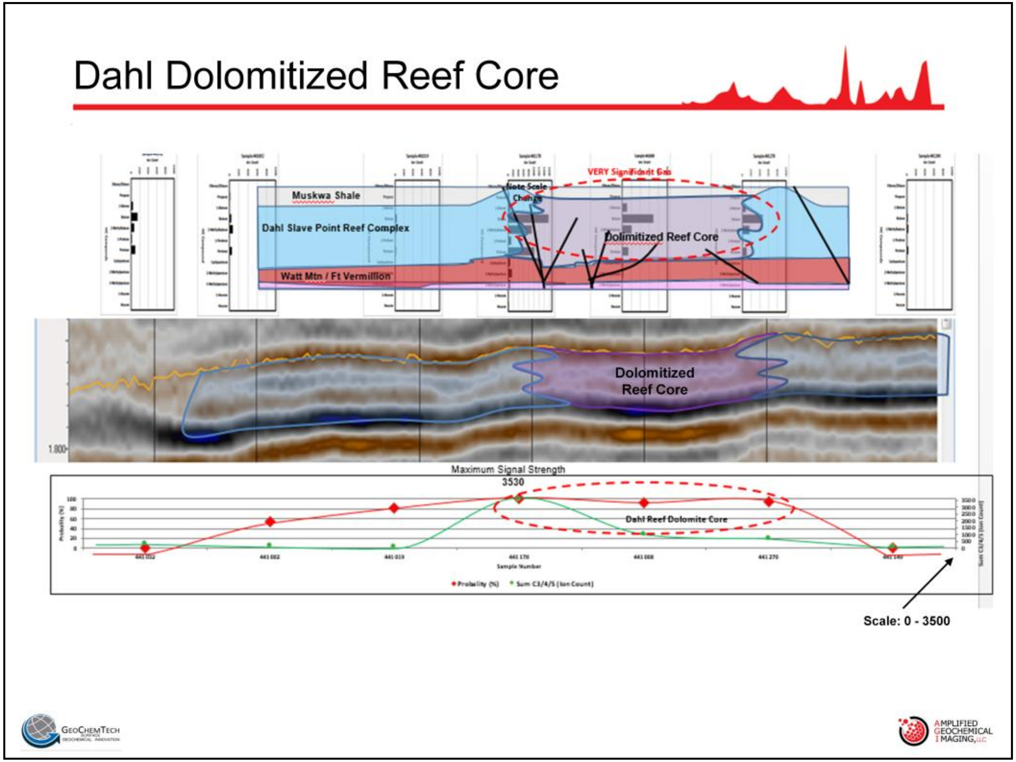


Presenter's notes: Therefore, what could account for that dramatic difference? Another review of the geology of the area revealed a shale sequence adjacent to the barrier reef. The shale platform the Muskwa Shale section had not been noticed before because the original survey had been done prior to the big North American shale boom and at the time of the survey, people were only interested in the conventional carbonate reef structure. With that in mind, things began to fall in place. If you assume the Muskwa shale is the source charging the area then that explains why all the anomalies were showing 85% - 95% probabilities because it was the same hydrocarbon everywhere. That also explained why much higher butane intensities were found over the southeast anomaly, because this was the shale kitchen that exhibited some combination of higher pressure and porosity.

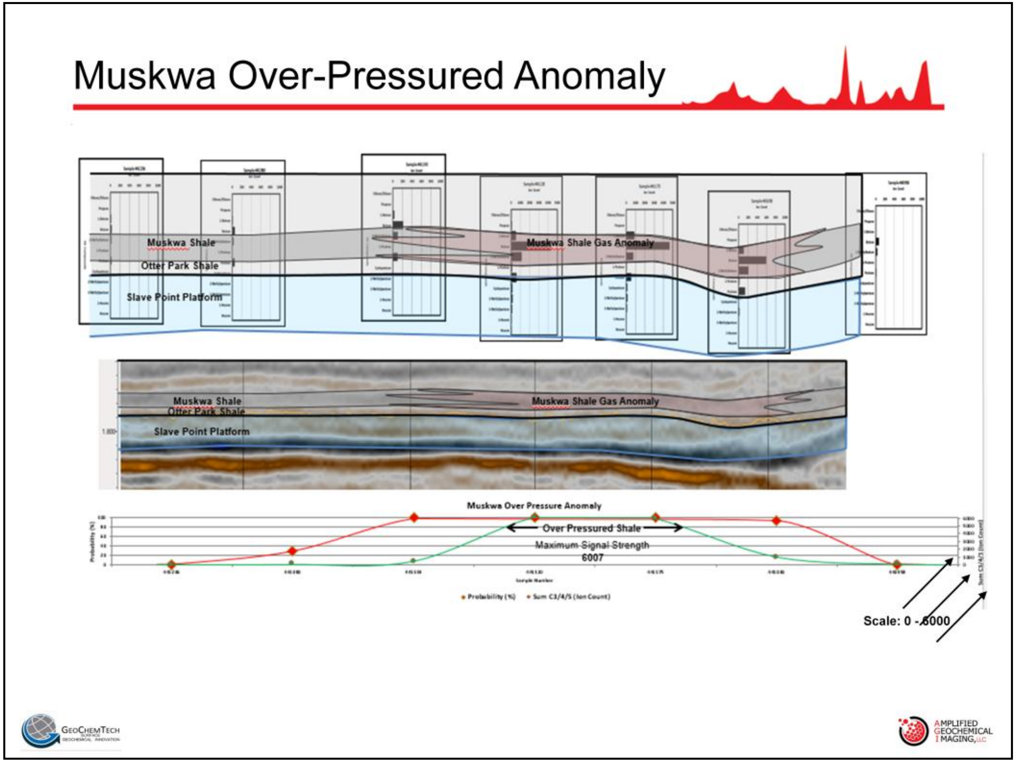
Dahl Reef Margin



Presenter's notes: Once it was theorized that the southeastern anomaly was Muskwa shale. However, Geo ChemTech wondered if the northeastern anomaly was also shale. Therefore, they looked at the butane values for this section and the values were even higher than the southeastern section. Therefore, while the butane intensity in the Muskwa Shale area was 4,000 – 5,000, the values in the northeastern section were 25,000. That is five times higher than the shale section and 50 times higher than the carbonate reef margin. When they began to look at other G&G data, they began to believe the northeastern section was actually an area of hydrothermal dolomitization. Therefore, as these hot waters flooded the carbonate section the carbonate dissolution occurred resulting in much larger pore volumes than originally found in the structure. Those larger pore volumes were then filled with more hydrocarbons, which resulted in a much higher butane signal than found anywhere else in the survey area. Therefore, if you were looking for the sweet spot in this field, it would not be on the margins of the reef, or in the center of the reef, or even in the Muskwa Shale section. According to the Amplified Geochemical Survey, it would be in the northeastern section that had the most oil and the best reservoir conditions.

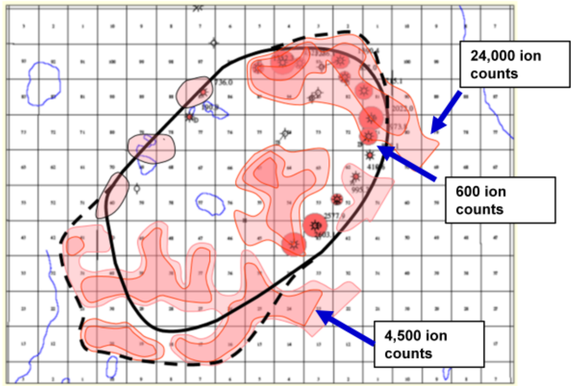


Presenter's notes: On the top portion, you see the various stratigraphic sections with the Muskwa Shale at the top. From left to right you see the various wells drilled across the field with the hydrocarbon profiles placed on their sides. Therefore, the black bars going from left to right indicate the various gases measured for each well. The red dashed line on the right indicates the wells drilled over the conventional carbonate play on the reef margin while the dashed line on the left indicates the wells drilled over the dolomitized core area. Notice the butane concentrations in the dolomitized core section are higher than the reef margin, as we discussed previously. Below, the red line, with the scale on the left, indicates the geochemical survey probability factor and the green line, with the scale on the right, indicates the butane intensity. Remember, the probability factor reflects a match to the model gas signature, but is also a reflection of the intensity of pressure, porosity, & net pay. The green line is only a reflection of gas intensity and is the sum of C3+C4+C5. The gas scale on the right goes from 0 – 1,000 ion counts. So, notice in the dolomitized reef section both the probability factor ranges between 90% - 100% and the butane intensity are high indicating a potential sweet spot with high productivity implied. Over the reef margin, the probability factors fall between 60% - 80% while all the gas intensities are below 600, indicating an area that is probably only moderately productive.



Presenter's notes: Here you see a seismic image with the yellow line indicating the top of the patch reef and reef margin while the blue line indicates the bottom. Notice in this area when you are over the patch reef or the reef margin you consistently get high probability factors and, for the most part, high gas intensity readings. However, notice in the inter-reef area in between the patch reef and the reef margin you get low readings for both the probability and the gas intensity readings. This indicates either you do not have much hydrocarbon here or you have minimal hydrocarbons with poor reservoir characteristics. In fact, the seismic data corroborates the geochem data. If you look at the seismic at the inter-reef area you see a brown coloration indicating a muddy non-reservoir limestone. Notice that muddy non-reservoir limestone carries over slightly into well C092, resulting in a poor gas intensity. Notice both the geochem and seismic data indicated well c092 should not be as productive as c081 and indeed it was not. The IP for well c081 was 1,715 mcf/day while the IP for c092 was 1,390 mcf/day. Additionally, a look at the data would indicate that had a well been drilled where sample 441212 had been placed, that well would have had beet production than either c092 or c081.

Drilling Experiences & Problems



Wells drilled in areas with butane values of **600** experienced **no drilling problems**.

Wells drilled in areas with butane values of **4,500 would kick** and circulated gas out of the hole.

Wells drilled in areas with butane values of **24,000** experienced serious drilling problems and even had some **blowouts** occur.

Presenter's notes: The black lines are interpreted faults in the collapsed reef structure. You can see a slight bowing in the seismic data indicating the collapse. The red probability line shows the best probabilities (i.e. 80% - 100%) are found across the dolomitized reef core, the sweet spot is actually around sample 441178. Notice the gas intensity scale is different than previous slides. Here the scale goes to 3,550. Therefore, the two samples to the right of 441178 have intensities more consistent with the reef margin.

Summary

- This project started out as a traditional carbonate reef complex.
- The initial Amplified Geochemical Imaging survey was used to guide drilling decisions for optimum production.
- However, as the drilling program progressed drilling operation became more complex and more difficult and could not be explained within the framework of previous geologic models.
- The surface geochem data was later used in conjunction with other G&G data to:
  - elucidate unknown geologic features (e.g. shale sequence and a hydrothermal dolomitized carbonate area)
  - Identify field sweet spots and add understanding to production rates

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Presenter's notes: This is the seismic over the Muskwa Shale. The seismic data shows nothing special here, but we see and increase in hydrocarbon probability in all four samples across the shale with the two center samples showing the highest gas intensities.

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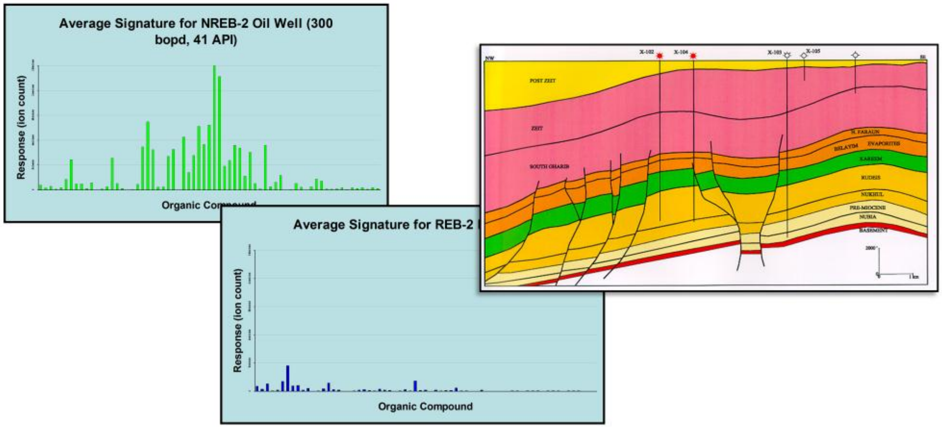
Red Sea Sub-salt Case Study



Presenter's notes: So, how do we know that the previous data and assumptions are correct? The Amplified Geochemical Imaging survey map began to explain that. The drilling results confirmed that the survey results were directly related to reservoir pressures. Areas with low butane intensity experienced low pressures and no drilling problems. Areas with high butane values showed increased pressure at the wells with kicking during drilling and gas being circulated out of the hole. In addition, the area of the survey that displayed dramatic butane values had dramatic drilling problems. Therefore, the drilling data supported the suppositions from the surface geochemical data.

Thank You!

We would like to give special thanks to Mr. Bob Potter of Geo ChemTech for his help and contributions to this presentation

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