Minimizing Exploration Risk: The Impact of Hydrocarbon Detection Surveys for Distinguishing Charged from Uncharged Traps*

Dietmar (Deet) Schumacher¹

Search and Discovery Article #42073 (2017)**
Posted May 15 2017

*Adapted from oral presentation given at AAPG 2017 Annual Convention and Exhibition, Houston, Texas, United States, April 2-5, 2017
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Abstract

It has been well documented that most oil and gas accumulations leak hydrocarbons, that this leakage (or microseepage) is predominantly vertical, and that this leakage can be detected and mapped using any of several geochemical and non-seismic geophysical methods. While seismic data are unsurpassed for imaging trap and reservoir geometry, in many geological settings seismic data yield no information about whether a trap is charged with hydrocarbons. Hydrocarbon microseepage data can provide direct evidence for the probable hydrocarbon charge of the lead or prospect. In order to quantify the reliability of hydrocarbon microseepage data for pre-drill predictions of hydrocarbon charge, we have compiled published microseepage survey results for more than 3300 exploration wells with the results of subsequent drilling. These prospects are located in both frontier basins and mature basins, onshore and offshore, and occur in a wide variety of geologic settings. Target depths ranged from 300 meters to more than 4900 meters and covered the full spectrum of trap styles. Prospects were surveyed using a variety of microseepage survey methods including free soil gas, integrative soil gas, microbial, iodine, radiometrics, and micromagnetics. Of wells drilled on prospects associated with positive microseepage anomalies 80% were completed as commercial discoveries. In contrast, only 14% of wells drilled on prospects without an associated microseepage anomaly resulted in discoveries. These results clearly document that hydrocarbon microseepage data – when properly acquired, interpreted, and integrated with conventional exploration data – can reliably predict hydrocarbon charge in advance of drilling.
References Cited


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Summary
3308 Wells, Various Companies, Various Basins, Various methods

<table>
<thead>
<tr>
<th>Negative Anomaly</th>
<th>Positive Anomaly</th>
</tr>
</thead>
<tbody>
<tr>
<td>14% Discoveries</td>
<td>20% Dry Holes</td>
</tr>
<tr>
<td>86% Dry Holes</td>
<td>80% Discoveries</td>
</tr>
</tbody>
</table>

1590 Wells Drilled
1718 Wells Drilled

Dietmar (Deet) Schumacher
E&P Geo)(Field Services, Mora NM and Paris, France
Conventional Exploration versus Geochemical Exploration
Finding Traps versus Finding Hydrocarbons
GEOLOGIC RISK FACTORS
(after Peter Rose, 2001)

- Hydrocarbon Source Rocks
- Hydrocarbon Migration, Charge
- Reservoir Rock
- Trapping (Closure)
- Containment (Preservation)
<table>
<thead>
<tr>
<th>When Is Seismic Not Enough?</th>
</tr>
</thead>
<tbody>
<tr>
<td>☐ When it is Important to Determine Hydrocarbon Charge</td>
</tr>
<tr>
<td>☐ When Hydrocarbon Composition is Important (Oil versus Gas)</td>
</tr>
<tr>
<td>☐ When Quality of Seismic is Poor Due to Unfavorable Geology or Surface Conditions</td>
</tr>
<tr>
<td>☐ When Targets are Difficult to Image Seismically</td>
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</tbody>
</table>

Presenter’s notes: Seismic data are unsurpassed for providing stratigraphic and structural information, mapping reservoir geometry, and in some instances providing direct hydrocarbon indicators. However, in many onshore basins – especially older basins – seismic cannot provide reliable information about likely hydrocarbon charge and hydrocarbon composition.
Why Geochemical Surveys?

- Most Productive Basins Leak
- Most Accumulations Leak
- Leakage is Predominantly Vertical
- Leakage is Dynamic
- Provides Direct Indication of Hydrocarbons and of Hydrocarbon-Induced Changes
- Minimal Environmental Impact
- Prospects with Microseepage Anomaly are 4-6 times more likely to result in a discovery
SPECTRUM OF HYDROCARBON SEEPAGE STYLES

MACROSEEPAGE --
visible oil and gas seeps;
located at faults, fractures,
and outcrops

MICROSEEPAGE --
not visible but detectible;
occurs above mature source rocks and over accumulations
Characteristics of Hydrocarbon Microseepage

Detailed geochemical surveys and research document that hydrocarbon microseepage from oil and gas accumulations is:

- **Common and Widespread**
- **Predominantly Vertical**
- **Dynamic**
Microseepage is Predominantly Vertical

Argentina

North Sea

Connolly et al., 2011

Van den Bark & Thomas, 1990
HYDROCARBON-UTILIZING BACTERIA METABOLIZE HYDROCARBONS

BY CONVERTING THEM TO ALCOHOLS

TO ACIDS

THEN CARBON DIOXIDE
**GEOCHEMICAL**
- Carbonate Precipitation
- Pyrite Precipitation also sulphur, pyrrhotite, greigite, uranium, etc.
- Bacterial Degradation of Hydrocarbons
- Light Hydrocarbons Seep Upward from Trap Creating a Reducing Zone

**GEOPHYSICAL**
- High Resistivity Anomaly
- High Polarization Anomaly
- Magnetic Anomaly
- Low Resistivity Anomaly
- Seismic Velocity Anomaly

(SCHUMACHER, 1996)
Hydrocarbon Detection Methods

- **REMOTE SENSING, SATELLITE IMAGERY**
  - detects hydrocarbon-induced alteration, oil slicks

- **AEROMAGNETICS, MICROMAGNETICS**
  - detects hydrocarbon-induced alteration

- **SOIL GAS, FLUORESCENCE, HEAVY HCS**
  - measures hydrocarbon concentration

- **MICROBIOLOGICAL**
  - measures HC-oxidizing bacteria

- **BIOGEOCHEMICAL, GEOBOTANICAL**
  - trace elements, vegetation stress

- **ELECTROMAGNETIC, TELLURIC**
  - oil/gas presence, approx. depth and thickness
Presenter’s notes: As important as it is to select the proper hydrocarbon detection method, it is equally important – sometimes more important – to select the proper survey design and sample spacing to most effectively “image” the hydrocarbon leakage from the target traps and reservoirs. The figure above is from Osage County, OK, and illustrates the value of a grid sample pattern.
The basic premise behind all hydrocarbon microseepage survey methods is that microseepage is predominantly vertical (with obvious exceptions in geologically and structurally complex areas). Consequently, the anomaly at the surface will closely approximate the size and shape of the accumulation at depth.
Bob West Field Area, Texas

Bob West Field Area, December 1985, Showing Drilling Status and Magnetic Bright Spot Outline

Bob West Deep Wilcox Gas Field (1990), December 1986 to April 1997 showing SRM and MBS anomalies from 1985 Aeromagnetic Data
Jurassic Cotton Valley Pinnacle Reefs, East Texas

Area A -- Producing Reef Prospects

Area C -- Dry Hole Reef

Reefs are 300m wide
and 4500-5000 m deep

Source: SK Resources Inc.
Algeria, Sbaa Sub-Basin

Survey Objective

High-grade seismic prospects on basis of probable hydrocarbon charge.

Samples collected at 250-500 m intervals along seismic lines using the Microbial Technique & Acid Extracted Soil Gas

Givetian Structure

Tournasian Structure
Masila Basin, Yemen
Remote Sensing and Surface Geochemistry

Shallow Sorbed Soil Gas / Methane (C₁) vs. Sum C₂ - C₄

Sorbed Soil Gas (SSG) Analysis  C₁/(C₂+C₃) vs C₃/(C₃+C₄)
Determining the Depth of Origin of the Hydrocarbon Anomaly

Data from Analogs (Geol/Geochem)

Hydrocarbon Composition

Anomaly Shape vs Trap Shape

Passive Electromagnetics

Presenter’s notes: While surface geochemical data can reliably identify likely hydrocarbon charge to specific prospects, these methods cannot determine the depth to the source of the hydrocarbon anomaly. HOWEVER, sometimes one can infer the source and depth of the anomaly from the hydrocarbon composition, or by comparing the shape and extent of the anomaly to the shape and areal extent of potential traps and reservoirs. One can also use a recently developed passive electromagnetic method (“Power Imaging”) to determine the depth to potential oil/gas zones and/or mature source rocks.
How Do We Measure Success of Hydrocarbon Microseepage Surveys?

Compare pre-drill prediction with post-survey drilling results

KALIMANTAN

LAOS
Presenter’s notes: Thirty-nine individual seismic prospects were surveyed before drilling using a microbial method. Each prospect has a 4-way dip closure, and each targets one of the main producing Cretaceous reservoirs in the basin. Ten of these prospects are illustrated in the above figure. Thirty-three of these 39 prospects had no associated microseepage anomalies, and all resulted in dry holes. Six prospects did have associated microseepage anomalies, and three of these were completed as commercial discoveries.
Reducing Exploration Risk
Post-Survey Drilling Results

52 Wells, Western Canada
Canadian Hunter, Soil Gas

In Negative Anomalies
38 Wells Drilled
30 Wells Dry (79%)
8 Discoveries (21%)

In Positive Anomalies
14 Wells Drilled
4 Wells Dry (29%)
10 Discoveries (71%)

Wyman, 2002
Reducing Exploration Risk
Post-Survey Drilling Results

141 Wells, USA and International
Santa Fe Minerals, Soil Gas

In Negative Anomalies
43 Wells Drilled
42 Wells Dry (98%)
1 Discovery (2%)

In Positive Anomalies
98 Wells Drilled
24 Wells Dry (24%)
74 Discoveries (76%)

Potter, 1996
Reducing Exploration Risk
Post-Survey Drilling Results

534 Wells, USA and International
ExxonMobil, Geochem & DHI

In Negative Anomalies
160 Wells Drilled
104 Wells Dry (65%)
56 Discoveries (35%)

In Positive Anomalies
374 Wells Drilled
105 Wells Dry (28%)
269 Discoveries (72%)

Rudolph & Goulding, 2017
Reducing Exploration Risk
Post-Survey Drilling Results

SUMMARY

3308 Wells, Various Companies, Various Methods, Various Basins

In Negative Anomalies
- 1590 Wells Drilled
- 1374 Wells Dry (86%)
- 216 Discoveries (14%)

In Positive Anomalies
- 1718 Wells Drilled
- 349 Wells Dry (20%)
- 1369 Discoveries (80%)

For all wells drilled, the success rate based only on geology and seismic was 48%

(Schumacher, 2010, 2017)
Summary

3308 Wells, Various Companies, Various Basins, Various methods

1718 Wells Drilled
Positive Anomaly
Dry Holes
Discoveries

1590 Wells Drilled
Negative Anomaly
86% Dry Holes
14% Discoveries

Dry Holes

20%

80%
Discoveries
## Comparison of Exploration Success Rates

<table>
<thead>
<tr>
<th>METHOD</th>
<th>GEOL/GEOPH ONLY</th>
<th>PROSPECTS W/ HC INDIC</th>
<th>PROSPECTS NO HC INDIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOIL GAS</td>
<td>49% (227)</td>
<td>76% (122)</td>
<td>18% (105)</td>
</tr>
<tr>
<td>MICROBIAL</td>
<td>44% (531)</td>
<td>79% (271)</td>
<td>8% (260)</td>
</tr>
<tr>
<td>RADIOMETRIC</td>
<td>57% (284)</td>
<td>79% (99)</td>
<td>28% (185)</td>
</tr>
<tr>
<td>MICROMAGN</td>
<td>39% (1579)</td>
<td>81% (658)</td>
<td>10% (921)</td>
</tr>
<tr>
<td>TOTALS</td>
<td>46% (2321)</td>
<td>80% (1150)</td>
<td>11% (1371)</td>
</tr>
</tbody>
</table>
For a Successful Survey -

Select the right method(s)

Use proper survey design

Calibrate with analog field or recent discovery

Integrate surface and subsurface data
NO MORE DRY HOLES ? !
Thank you!

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