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

Dietmar (Deet) Schumacher[1]

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

[1]Schumacher and Associates LLC, Mora, NM, USA (deetschumacher@gmail.com)

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

Beghtel, F.W., D.O. Hitzman, and K.R. Sundberg, 1987, Microbial Oil Survey Technique (MOST) evaluation of new field wildcat wells in Kansas: Association of the Petroleum Explorationists Bulletin, v. 3, p. 1-14.

Curry III, W.H., 1984, Evaluation of surface gamma radiation surveys for petroleum exploration in the deep Powder River basin, Wyoming: in M.J. Davidson and B.M. Gottlieb, eds., Unconventional Methods in the Exploration for Petroleum and Natural Gas, 3: Dallas, Texas, Southern Methodist University Press, p. 25-39.

Foote, R.S., 1996, Relationship of near-surface magnetic anomalies to oil- and gas-producing areas: in D. Schumacher and M. A. Abrams, eds., Hydrocarbon Migration and its Near-Surface Expression: AAPG, Memoir 66, p. 111-126.

Hitzman, D.C., B.A. Rountree, J.D. Tucker, and S. Smith, 2002, Integrated microbial and 3D seismic surveys discover Park Springs (Conglomerate) field and track microseepage reduction: in D. Schumacher and L.A. LeSchack, eds., Surface Exploration Case Histories: Applications of geochemistry, magnetic, and remote sensing: AAPG Studies in Geology No. 48, and Society of Exploration Geophysicists, Geophysical Reference Series No. 11, p. 59-65.

Jones III, V.T., and R.J. LeBlanc, Jr., 2004, Moore-Johnson (Morrow) field, Greeley County, Kansas: A successful integration of surface soil gas geochemistry with subsurface geology and geophysics: AAPG, Search and Discovery, Article 20022, Web Accessed April 29, 2017, http://http://www.searchanddiscovery.com/documents/2004/leblanc/figures/leblanc.pdf.

Klusman, R.W., 1993, Soil Gas and Related Methods for Natural Resource Exploration: John Wiley and Sons, Ltd., Chichester, UK, 483 p.

Klusman, R.W., 2002, The interpretation and display of surface geochemical data: in D. Schumacher and L.A. LeSchack, eds., Surface Exploration Case Histories: Applications of geochemistry, magnetic, and remote sensing: AAPG, Studies in Geology No. 48, and Society of Exploration Geophysicists, Geophysical Reference Series No. 11, p. 1-24.

Leaver, J.L., and M.R. Thomasson, 2002, Case studies relating soil iodine geochemistry to subsequent drilling results: in D. Schumacher and L.A. LeSchack, eds., Surface Exploration Case Histories: Applications of geochemistry, magnetic, and remote sensing: AAPG, Studies in Geology No. 48, and Society of Exploration Geophysicists, Geophysical Reference Series No. 11, p. 41-57.

LeSchack, L.A., and D. Van Alstine, 2002, High-resolution ground magnetic (HRGM) and radiometric surveys for hydrocarbon exploration: Six case histories in western Canada: in D. Schumacher and L.A. LeSchack, eds., Surface Exploration Case Histories: Applications of geochemistry, magnetic, and remote sensing: AAPG, Studies in Geology No. 48, and Society of Exploration Geophysicists, Geophysical Reference Series No. 11, p. 67-15.

Lopez, J.P., D. Hitzman, and J. Tucker, 2004, Combined microbial and seismic surveys predict oil and gas occurrences in Bolivia: Oil and Gas Journal, 24 October 1994, p. 68-70.

Mello, M.R., F.T. T. Concalves, N.A. Babinski, and E.P. Miranda, 1996, Hydrocarbon prospecting in the Amazon rain forest: Application of surface geochemical, microbiological, and remote sensing methods: in D. Schumacher and A. Abrams, eds., Hydrocarbon Migration and its Near-Surface Expression: AAPG, Memoir 66, p. 401-411.

Meyer, W.T., J.S. Lovell, and M. Hale, 1983, Detection of concealed mineral and energy resources by vapor geochemistry: in I. Thornton and R. J. Howarth, eds., Applied Geochemistry in the 1980s: London, Graham and Trotman, p. 86-102.

Potter II, R.W., P.A. Harrington, A.H. Silliman, and J.H. Viellenave, 1996, Significance of geochemical anomalies in hydrocarbon exploration: one company's experience: in D. Schumacher and M.A. Abrams, eds., Hydrocarbon Migration and its Near-Surface Expression: AAPG, Memoir 66, p. 431-439.

Prelat, A., S. Gunaratne, L. Huebner, C. Freeman, A. Cook, and C. Soriano, 2013, Airborne hyperspectral detection of natural onshore and offshore hydrocarbon seeps: in F. Aminzadeh, T.B. Berge, and D.L. Connolly, eds., Hydrocarbon Seepage: From Source to Surface, AAPG, Tulsa OK, USA, p. 171-182.

Rose, P.R., 2001, Risk Analysis and Management of Petroleum Exploration Ventures: AAPG Methods in Exploration Series, Number 12, 164 p.

Rudolph, K.W., and F.J. Goulding, 2017, Benchmarking exploration predictions and performance using 20+ years of drilling results: One company's experience: AAPG, Bulletin, v. 101/2, p. 161-176.

Schumacher, D., 1996, Hydrocarbon-induced alteration of soils and sediments: in D. Schumacher and M.A. Abrams, eds., Hydrocarbon Migration and its Near-Surface Expression: AAPG, Memoir 66, p. 71-89.

Schumacher, D., 1999, Surface geochemical exploration for petroleum: in T. Beaumont and N. Foster, eds., Exploring for Oil and Gas Traps: AAPG, Treatise of Petroleum Geology Handbook, p. 18-1 to 18-27.

Schumacher, D., 2011, Pre-Drill Prediction of Hydrocarbon Charge: Microseepage-Based Prediction of Charge and Post-Survey Drilling Results: AAPG Search and Discovery Article #40841, Web Accessed April 29, 2017, http://www.searchanddiscovery.com/documents/2011/40841schumacher/ndx_schumacher.pdf.

Schumacher, D., and M.A. Abrams, eds., 1996, Hydrocarbon Migration and its Near-Surface Expression: AAPG Memoir 66, 445 p.

Schumacher, D., and R.S. Foote, 2006, Seepage-induced magnetic anomalies associated with oil and gas fields: onshore and offshore examples: AAPG Annual Convention, Program with Abstracts, Houston, Texas, p. 96.

Schumacher, D., and L.A. LeSchack, eds., 2002, Surface Exploration Case Histories: Applications of geochemistry, magnetic, and remote sensing: AAPG Studies in Geology No. 48 and SEG Geophysical Reference Series No. 11, 486 p.

Tedesco, S.A., 1995, Surface Geochemistry in Petroleum Exploration: Chapman and Hall, Inc., New York, 206 p.

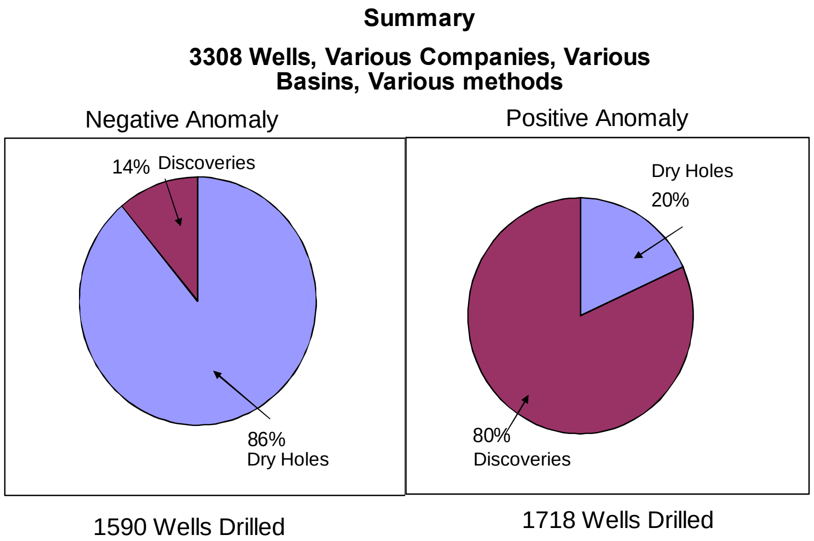
Wagner, M., M. Wagner, J. Piske, and R. Smit, 2002, Case histories for microbial prospection for oil and gas, onshore and offshore in northwest Europe: in D. Schumacher and L.A. LeSchack, eds., Surface Exploration Case Histories: Applications of geochemistry, magnetic, and remote sensing: AAPG Studies in Geology No. 48 and SEG Geophysical Reference Series No. 11, p. 453-479.

Weart, R.C., and G. Heimberg, 1981, Exploration radiometrics: post-survey drilling results: in B.M. Gottlieb, ed., Unconventional Methods in the Exploration for Petroleum and Natural Gas, 2: Dallas, Texas, Southern Methodist University Press, p. 116-123.

Wyman, R.E., 2002, From skeptic to believer: in D. Schumacher and L.A. LeSchack, eds., Surface Exploration Case Histories: Applications of geochemistry, magnetic, and remote sensing: AAPG Studies in Geology No. 48 and SEG Geophysical Reference Series No. 11, Foreword, p. x-xi.

Minimizing Exploration Risk:

The Impact of Hydrocarbon Detection Surveys for Distinguishing Charged from Uncharged Traps



Dietmar (Deet) Schumacher

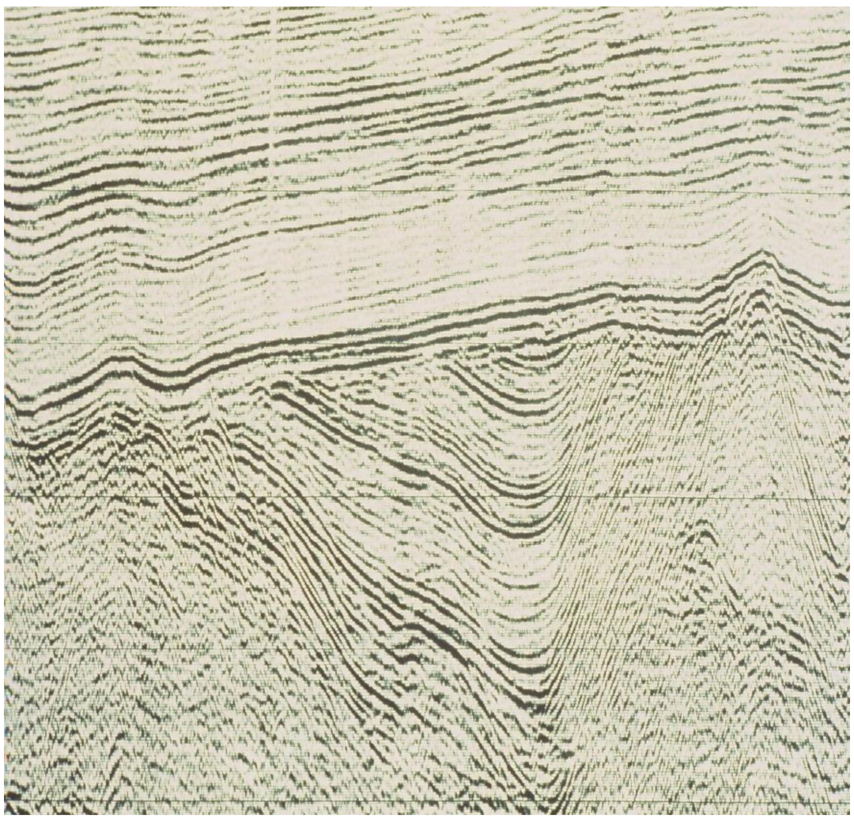
E&P Geo)(Field Services, Mora NM and Paris, France

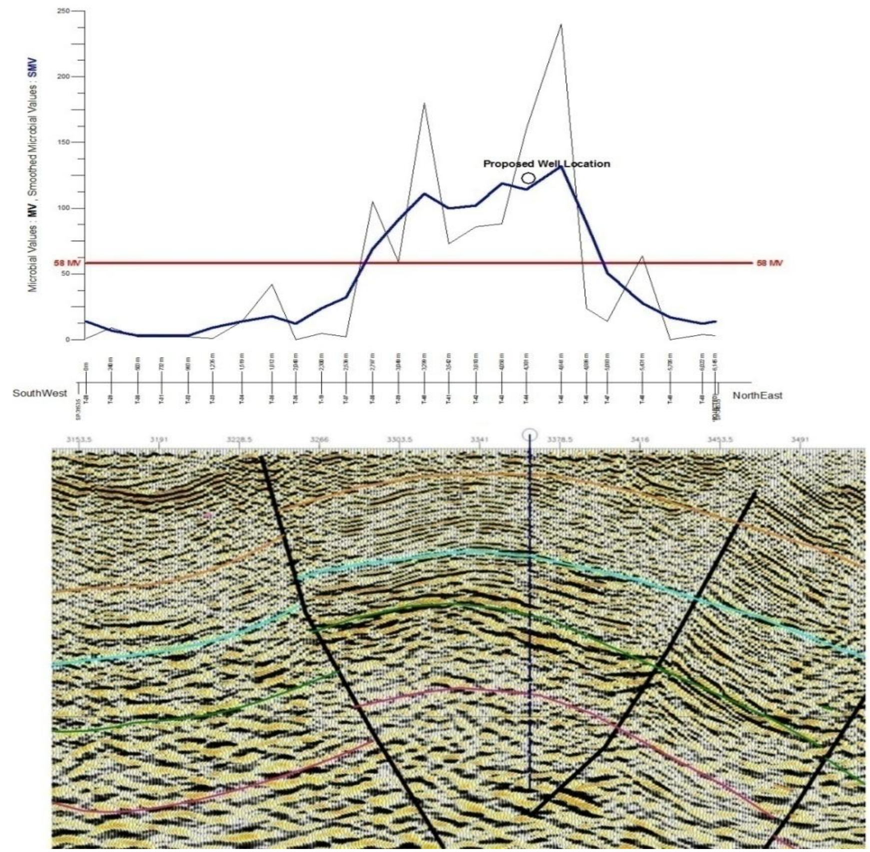
OUTLINE

- Geologic Risk Factors
- Characteristics of Hydrocarbon Microseepage
- Hydrocarbon Detection Methods
- Survey Objectives, Survey Design
- Selected Exploration Examples
- Measuring Success
- Summary

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)

When Is Seismic Not Enough ?

- ☐ When it is Important to Determine Hydrocarbon Charge
- ☐ When Hydrocarbon Composition is Important (Oil versus Gas)
- ☐ When Quality of Seismic is Poor Due to Unfavorable Geology or Surface Conditions
- ☐ When Targets are Difficult to Image Seismically

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;

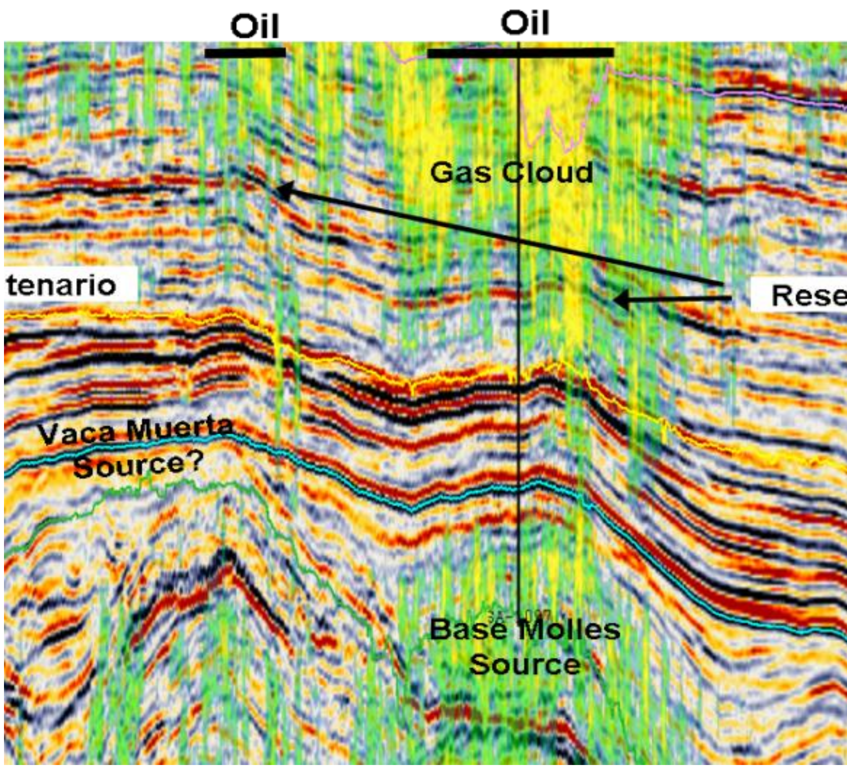
Common and Widespread

Predominantly Vertical

Dynamic

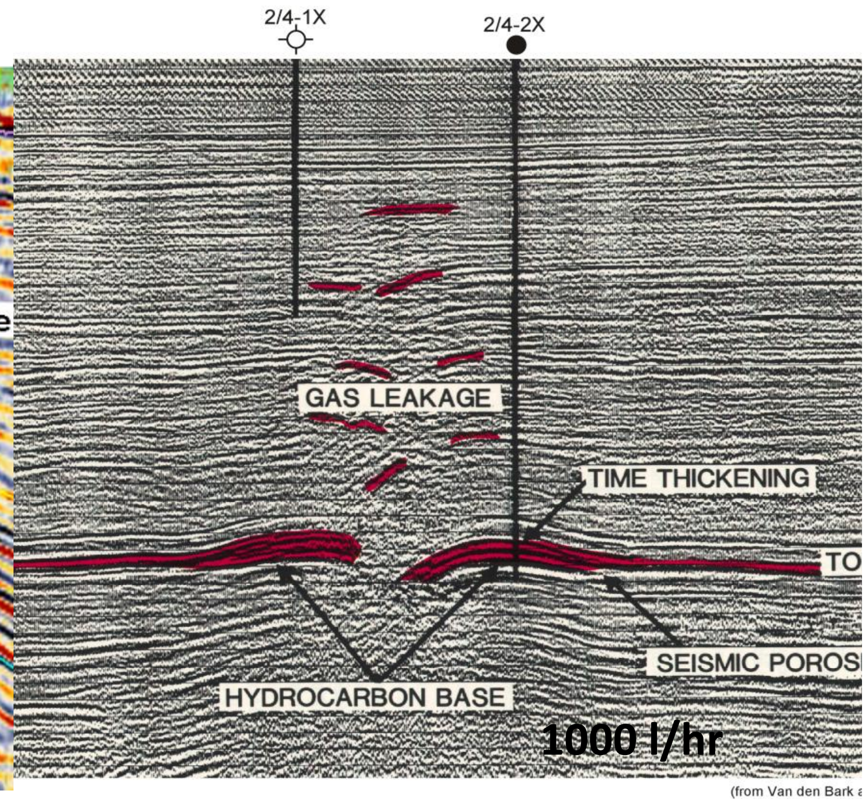
Microseepage is Predominantly Vertical

Argentina



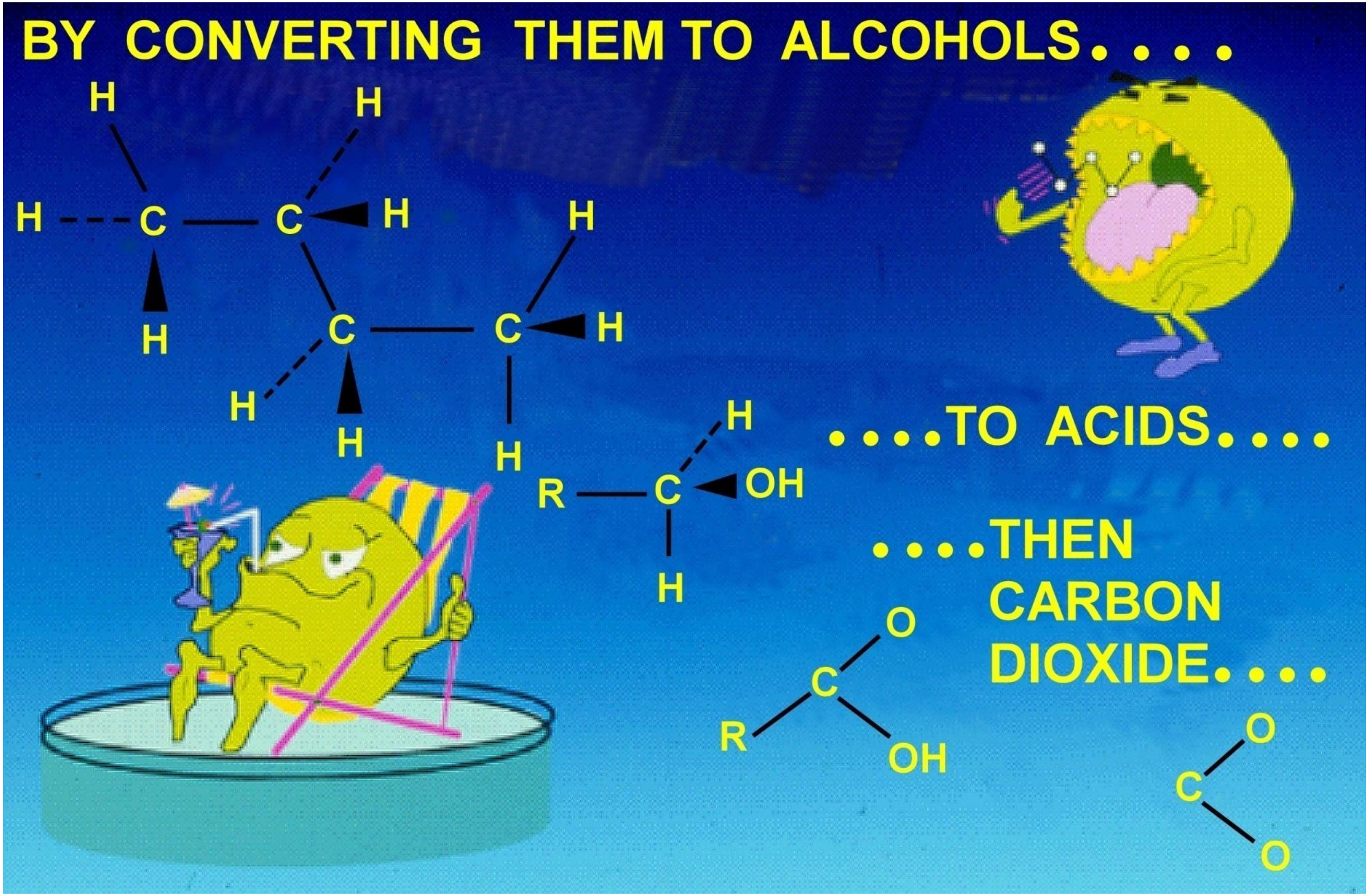
Connolly et al., 2011

North Sea

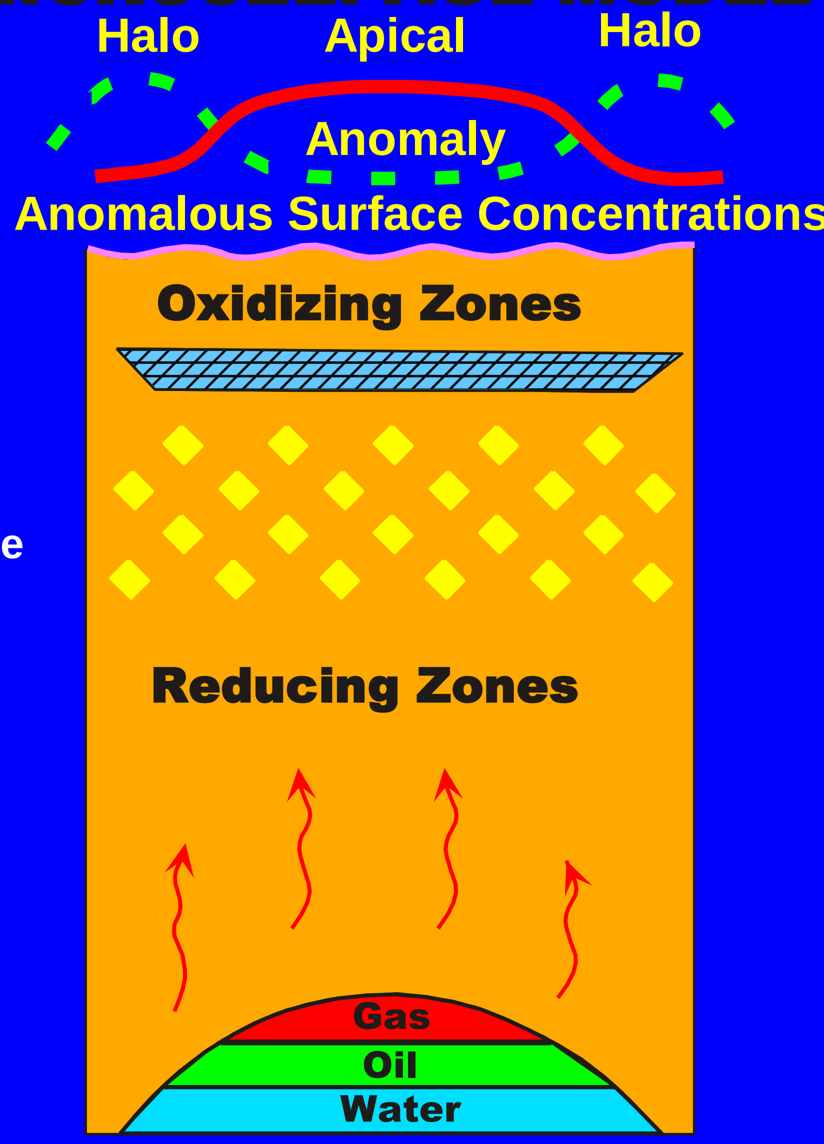


Van den Bark & Thomas, 1990

HYDROCARBON-UTILIZING BACTERIA METABOLIZE HYDROCARBONS



MICROSEEPAGE MODEL



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

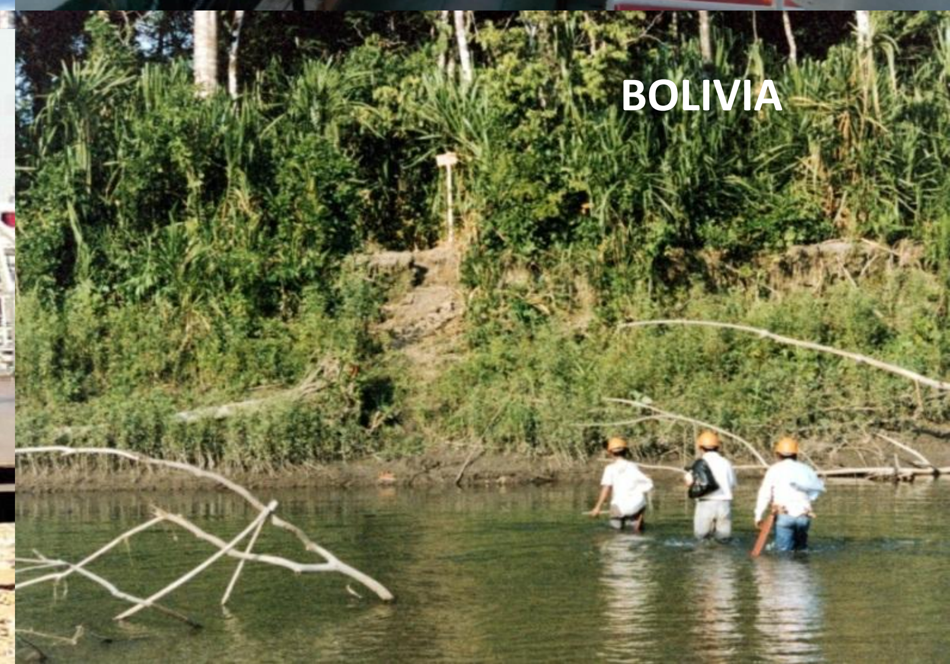
Seismic Velocity
Anomaly

(SCHUMACHER, 1996)

Hydrocarbon Detection Methods

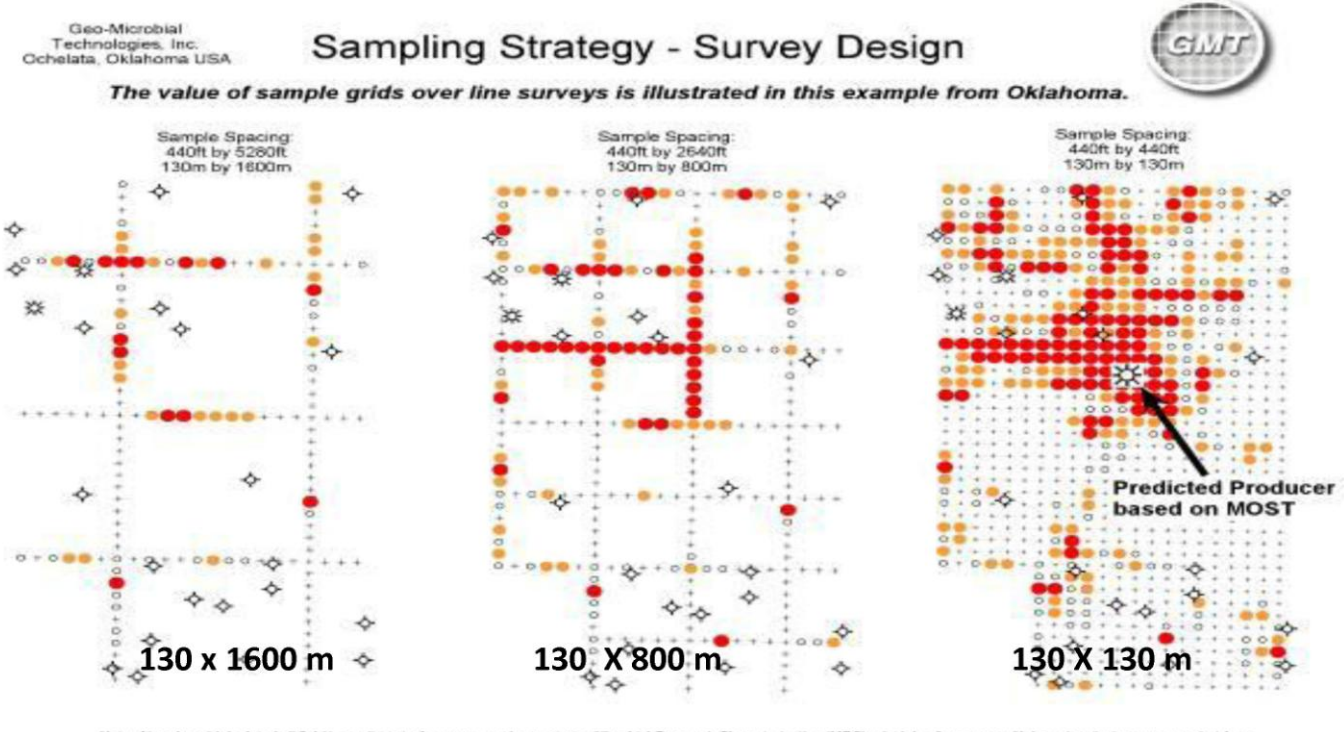
- REMOTE SENSING, SATELLITE IMAGERY
  - detects hydrocarbon-induced alteration, oil slicks
- AEROMAGNETICS, MICROMAGNETICS
  - detects hydrocarbon-induced alteration
- SOIL GAS, FLUORESCENCE, HEAVY HCS
  - measures hydrocarbon concentration
- MICROBIOLOGICAL
  - measures HC-oxidizing bacteria
- BIOGEOCHEMICAL, GEOBOTANICAL
  - trace elements, vegetation stress
- ELECTROMAGNETIC, TELLURIC
  - oil/gas presence, approx. depth and thickness

EFFECTIVE IN ALL ENVIRONMENTS

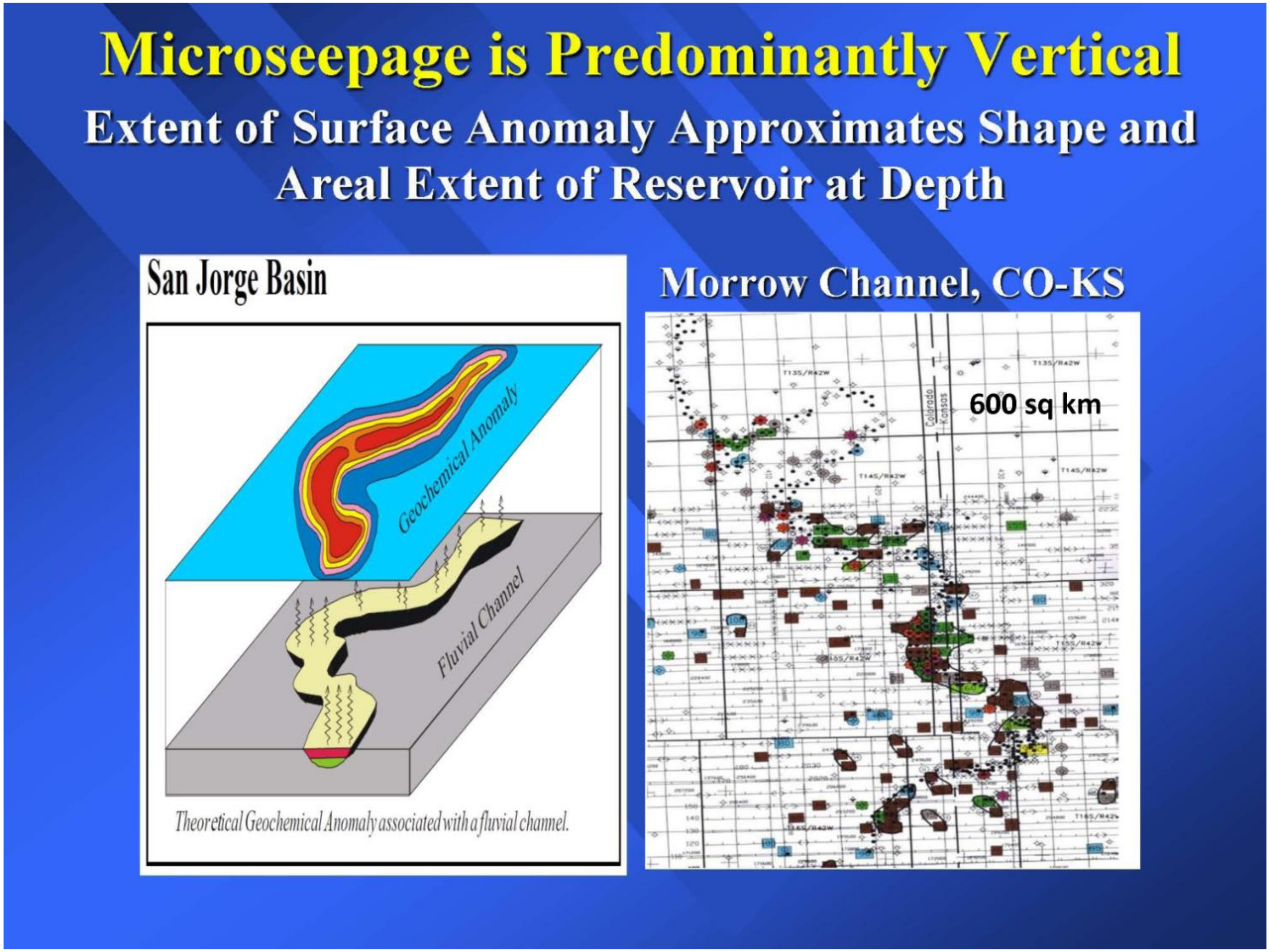


Survey Objective

High-Grade Prospects on Basis of Probable Hydrocarbon Charge

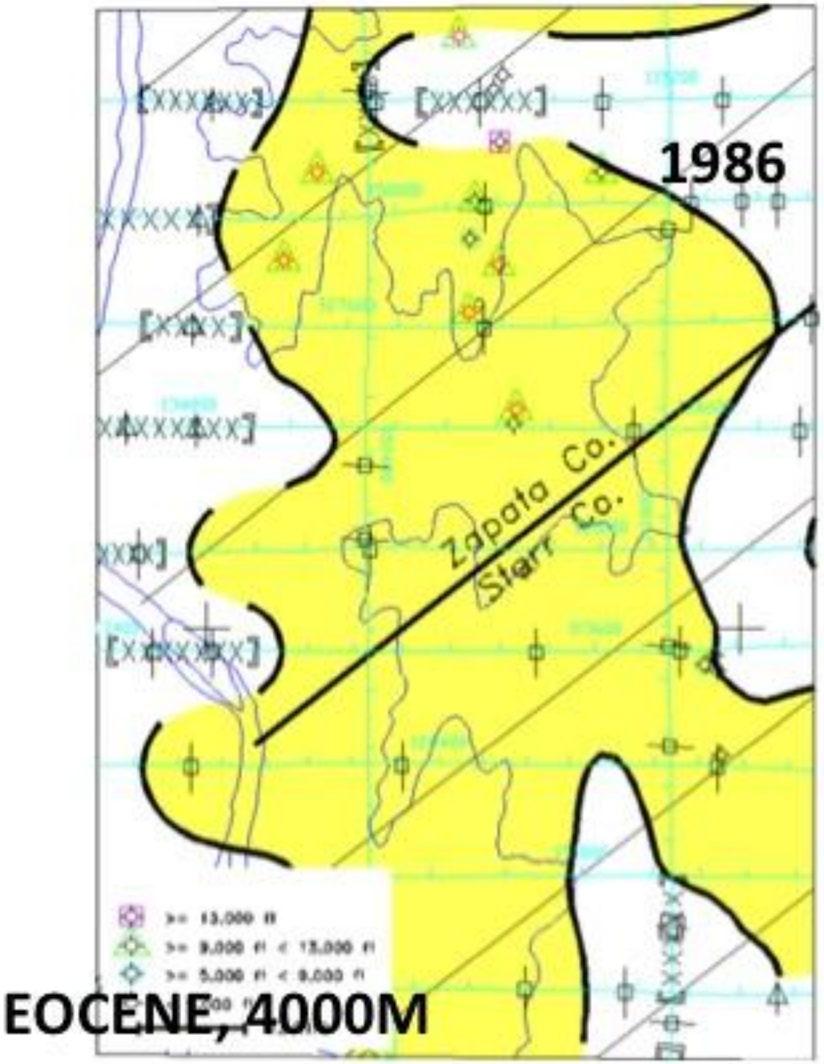


Presenter’s notes: As important as it is to select the proper hydrocarbon detection method, it is equally important – sometimes more important – to select the proper survey design and sample spacing to most effectively “image” the hydrocarbon leakage from the target traps and reservoirs. The figure above is from Osage County, OK, and illustrates the value of a grid sample pattern.



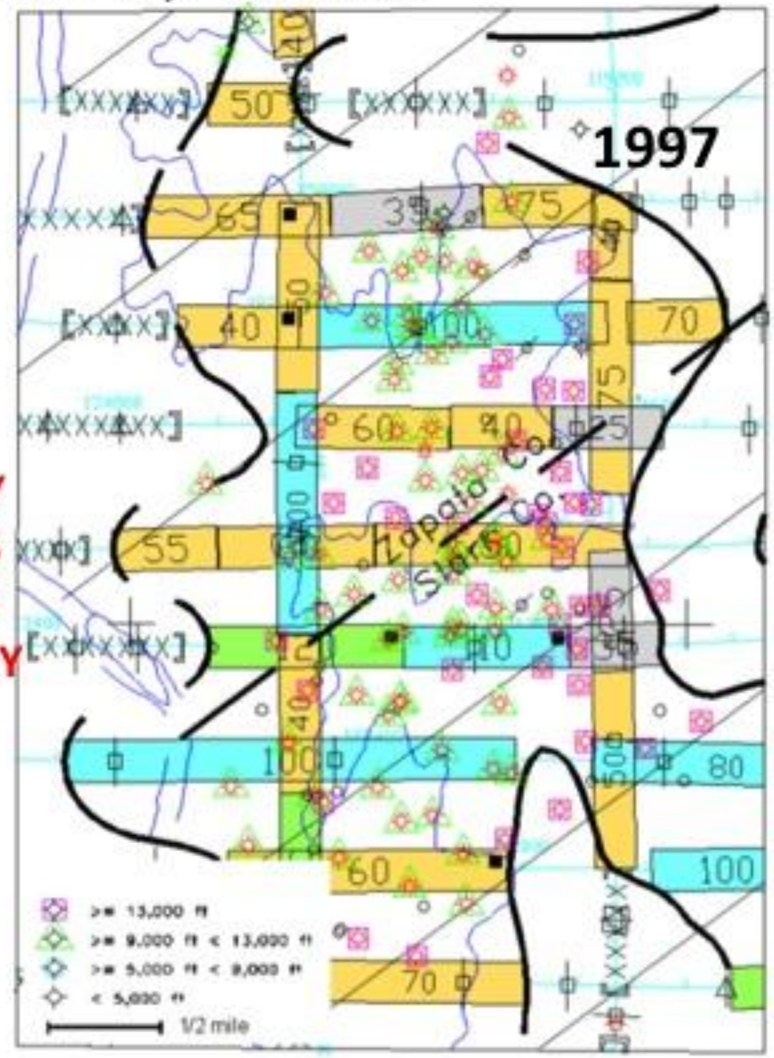
Presenter's notes: The basic premise behind all hydrocarbon microseepage survey methods is that microseepage is predominantly vertical (with obvious exceptions in geologically and structurally complex areas). Consequently, the anomaly at the surface will closely approximate the size and shape of the accumulation at depth.

Bob West Field Area, Texas



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

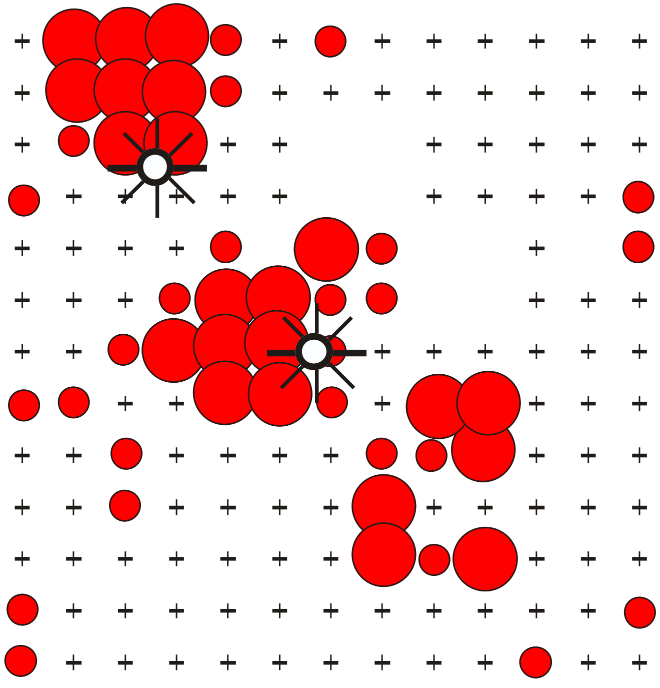
ANOMALY PREDATES GAS FIELD DISCOVERY



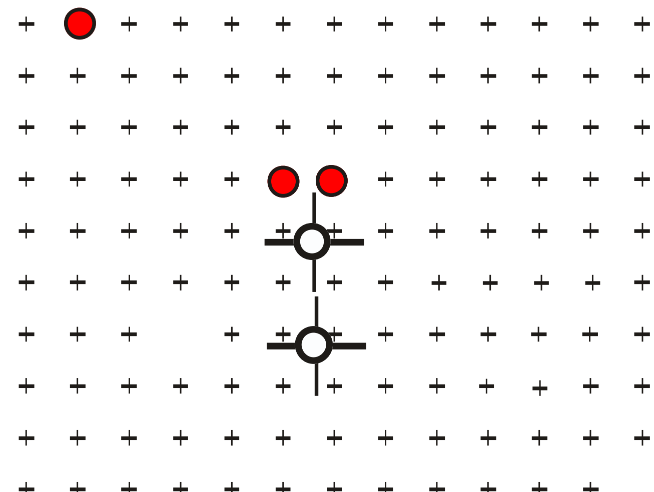
Bob West Deep Wilcox Gas Field (1990), December 1986 to April 1997 showing SRM and MBS anomalies from 1985 Aeromagnetic Data

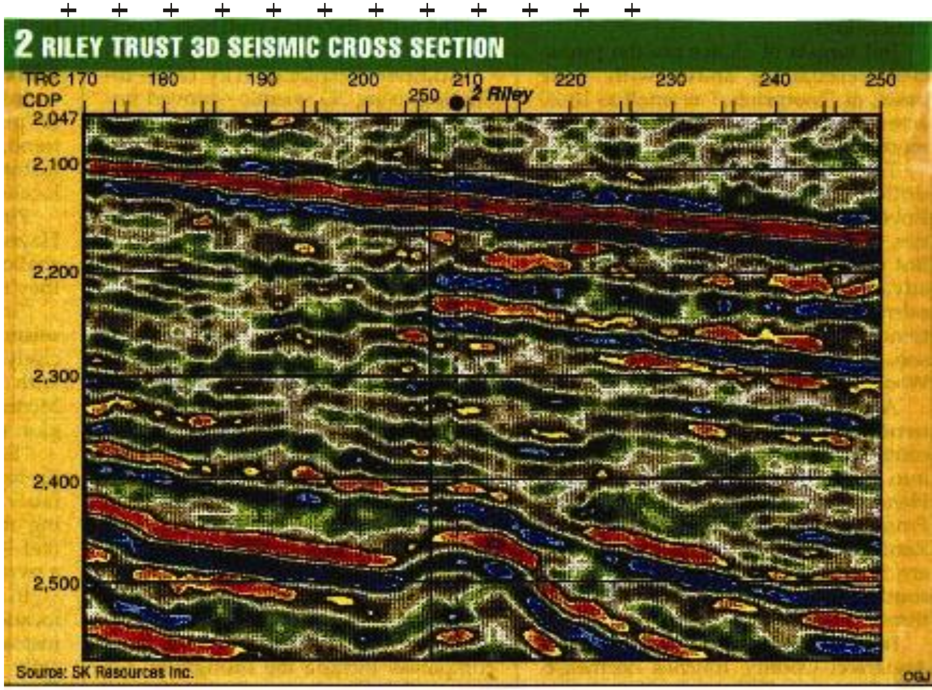
Jurassic Cotton Valley Pinnacle Reefs, East Texas

Area A -- Producing Reef Prospects



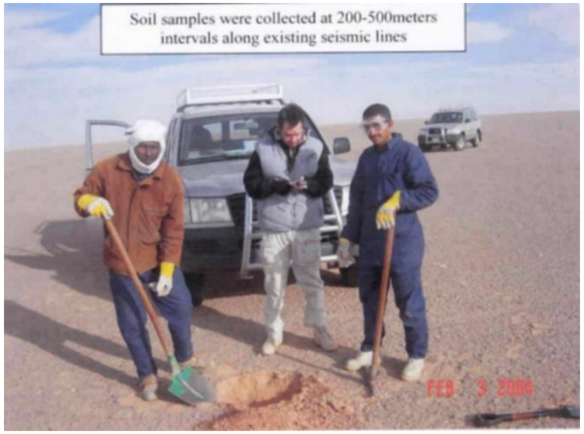
Area C -- Dry Hole Reef





Reefs are 300m wide and 4500-5000 m deep

Algeria, Sbaa Sub-Basin

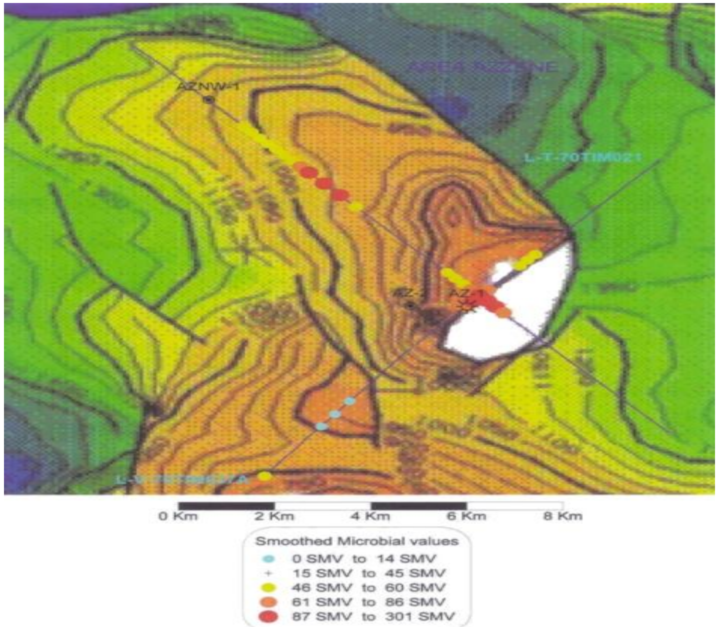


Survey Objective

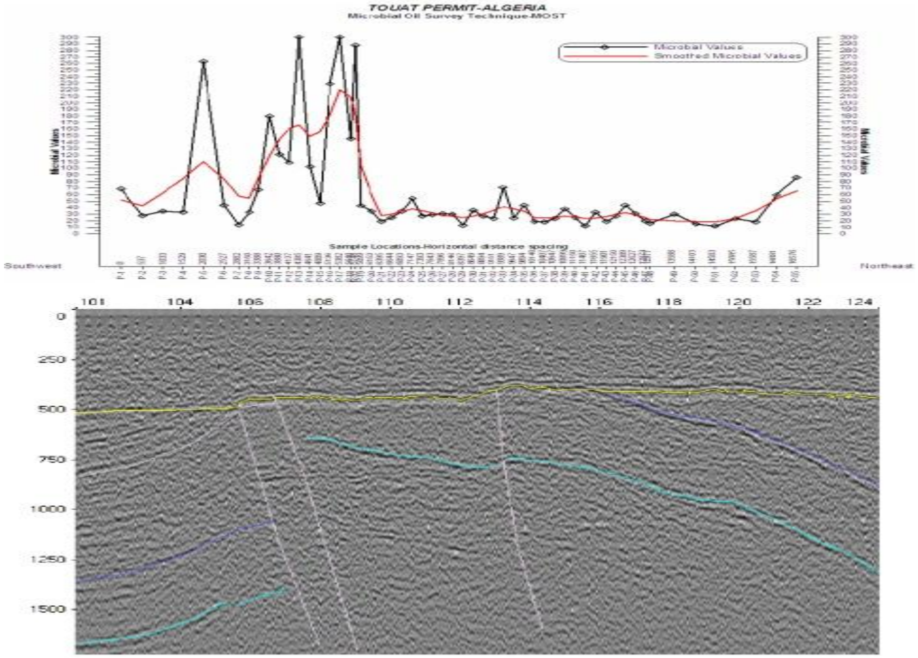
High-grade seismic prospects on basis of probable hydrocarbon charge.

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

GIVETIAN STRUCTURE

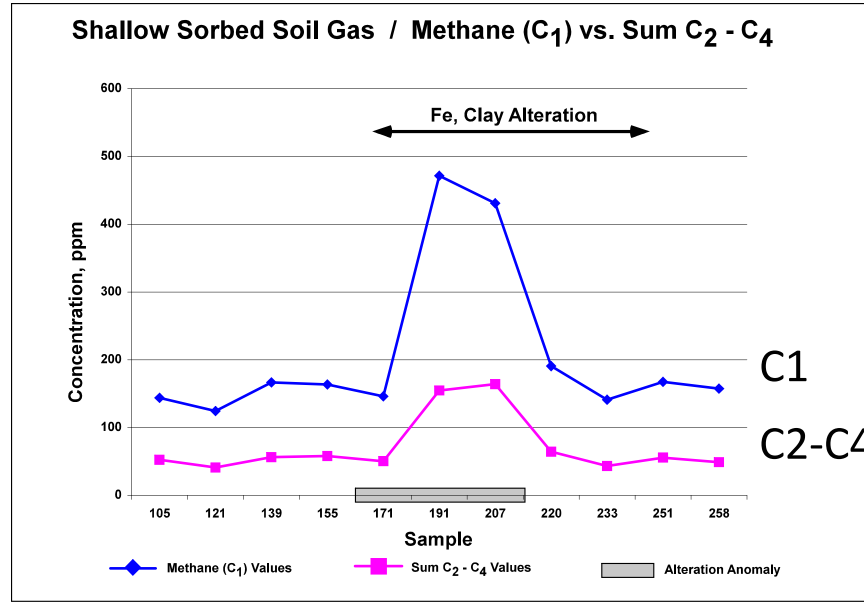


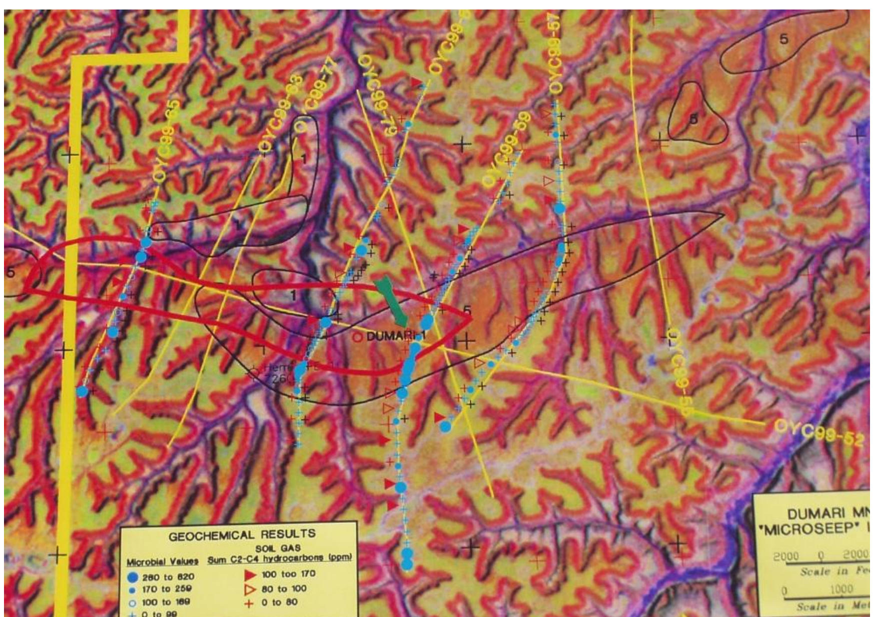
TOURNASIAN STRUCTURE

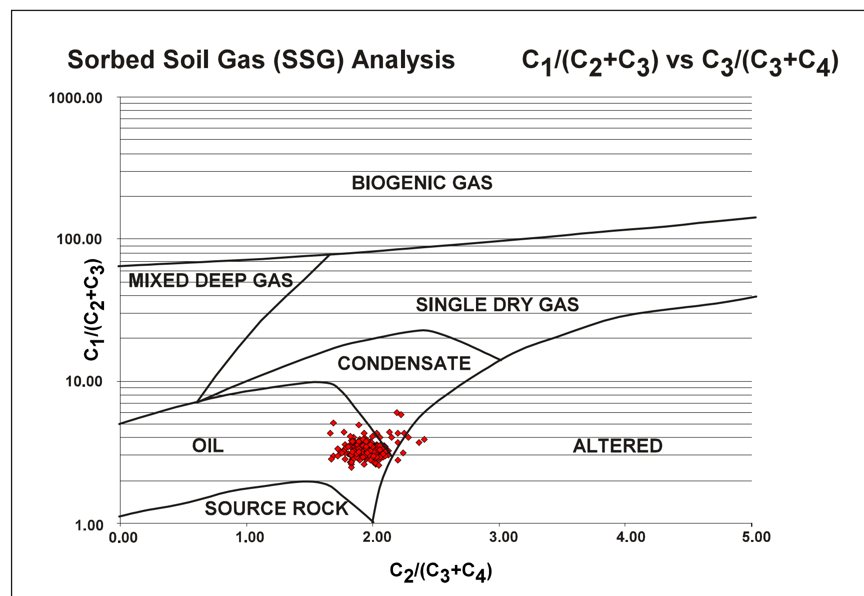


Masila Basin, Yemen

Remote Sensing and Surface Geochemistry







Determining the Depth of Origin of the Hydrocarbon Anomaly

Data from Analogs (Geol/Geochem)

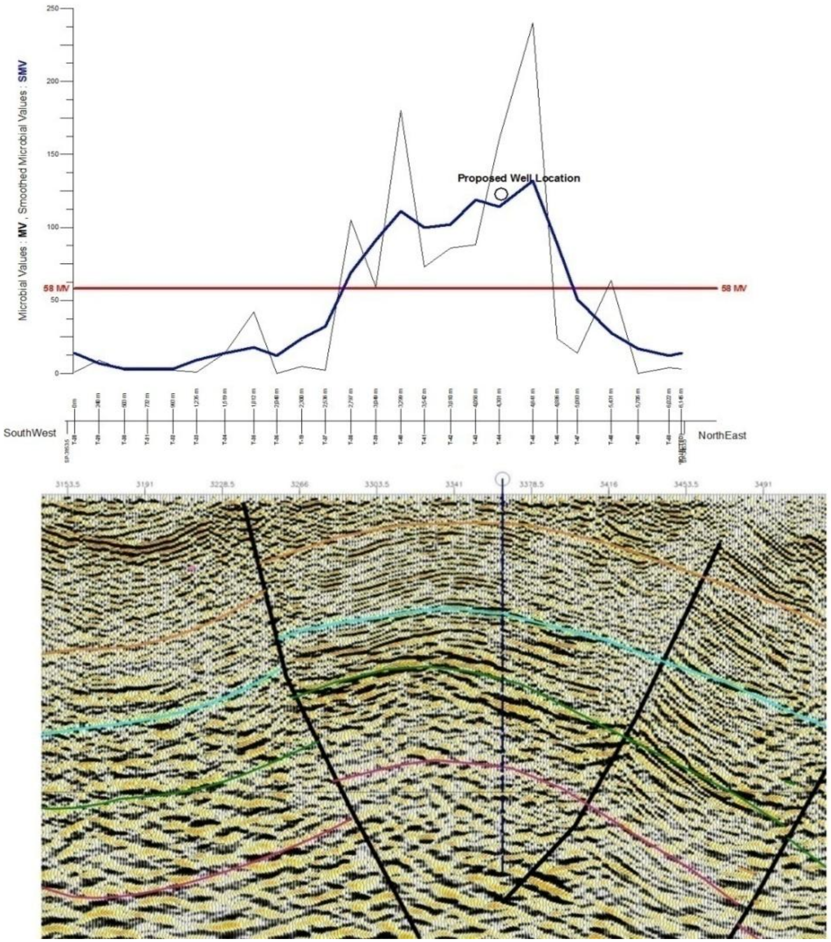
Hydrocarbon Composition

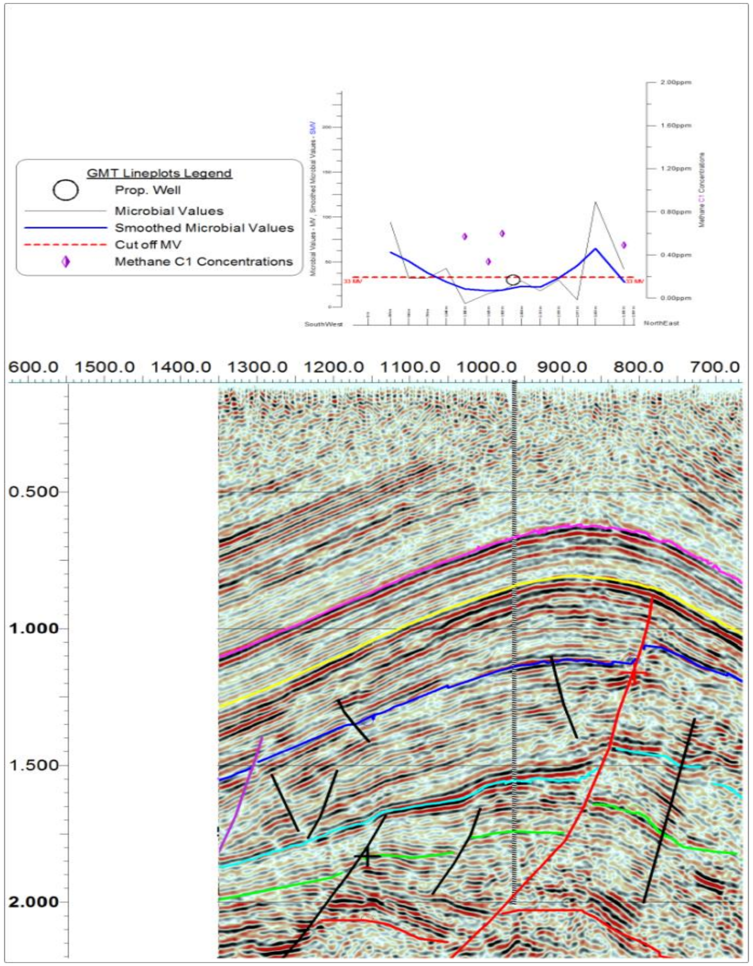
Anomaly Shape vs Trap Shape

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?



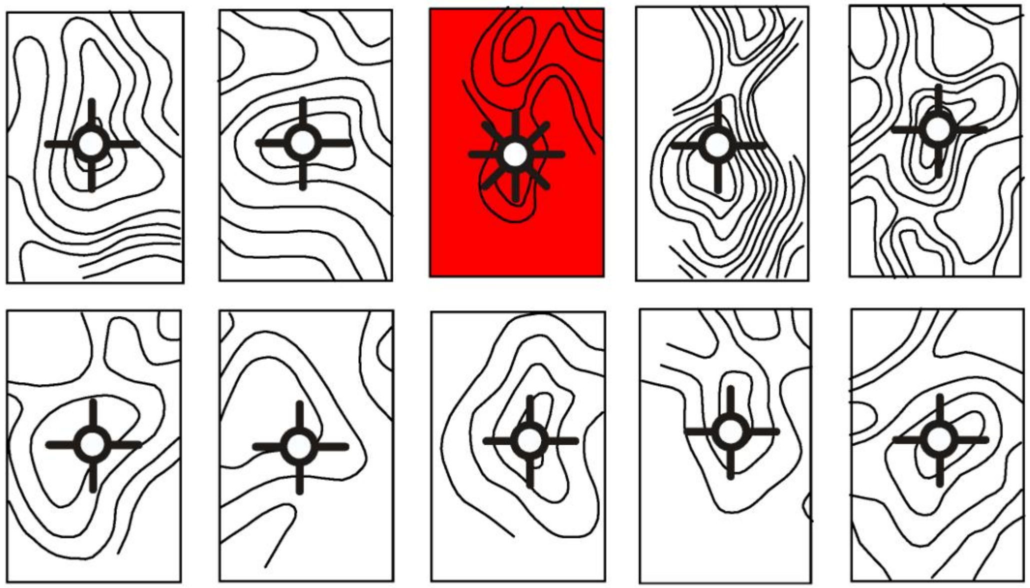


KALIMANTAN

LAOS

Compare pre-drill prediction with post-survey drilling results

Denver Basin, USA



Only One of these Ten Seismic Prospects Resulted in a Producer. It was the Only Prospect with a Surface Geochemical Anomaly. (Meyer et al., 1983)

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

<u>In Negative Anomalies</u>

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

<u>In Positive Anomalies</u>

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

<u>In Negative Anomalies</u>

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

<u>In Positive Anomalies</u>

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%)**

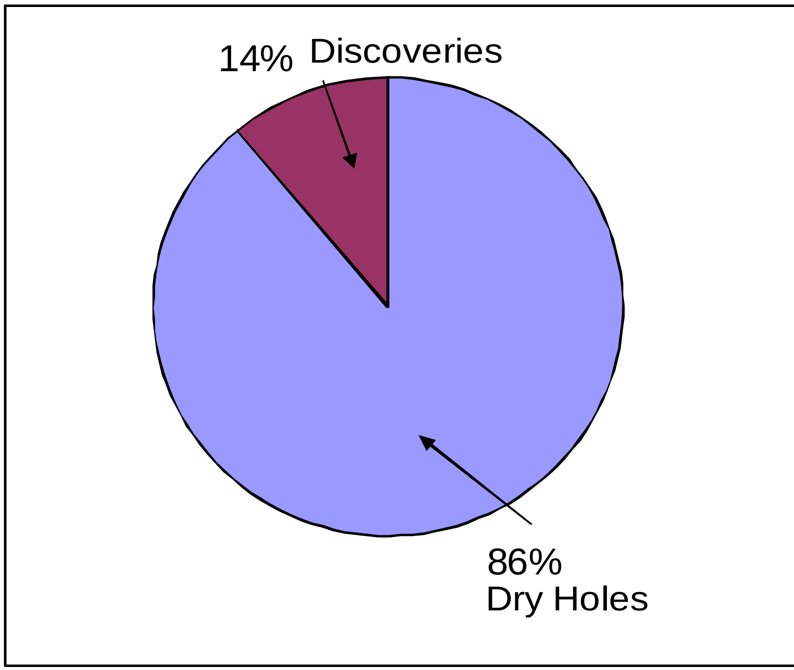
For all wells drilled, the success rate based only on geology and seismic was 48%

(Schumacher, 2010, 2017)

Summary

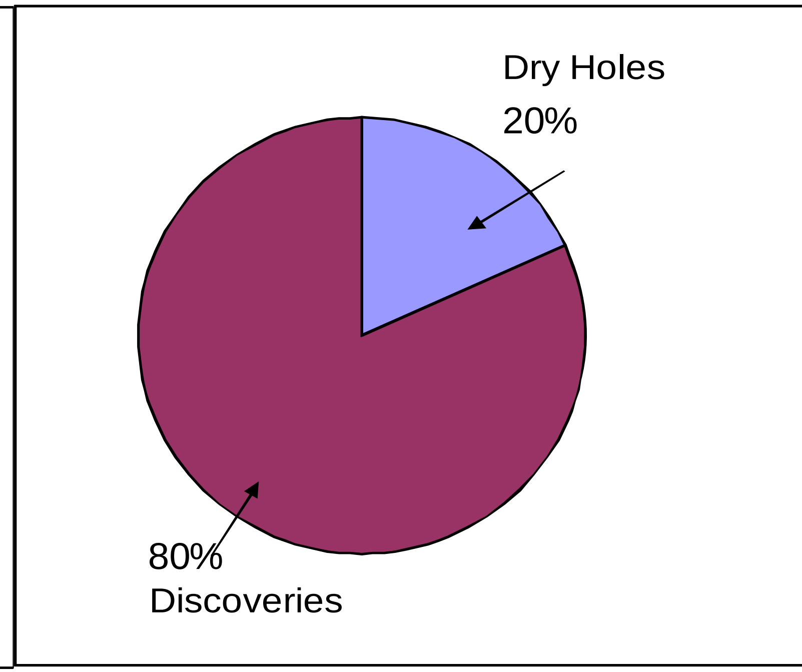
3308 Wells, Various Companies, Various Basins, Various methods

Negative Anomaly



1590 Wells Drilled

Positive Anomaly



1718 Wells Drilled

Comparison of Exploration Success Rates

METHOD	GEOL/GEOPH ONLY	PROSPECTS W/ HC INDIC	PROSPECTS NO HC INDIC
SOIL GAS	**49%** *(227)*	**76%** *(122)*	**18%** *(105)*
MICROBIAL	**44%** (531)	**79%** *(271)*	**8%** *(260)*
RADIOMETRIC	**57%** *(284)*	**79%** *(99)*	**28%** *(185)*
MICROMAGN	**39%** *(1579)*	**81%** *(658)*	**10%** *(921)*
TOTALS	**46%** *(2321)*	**80%** (1150)	**11%** *(1371)*

For a Successful Survey -

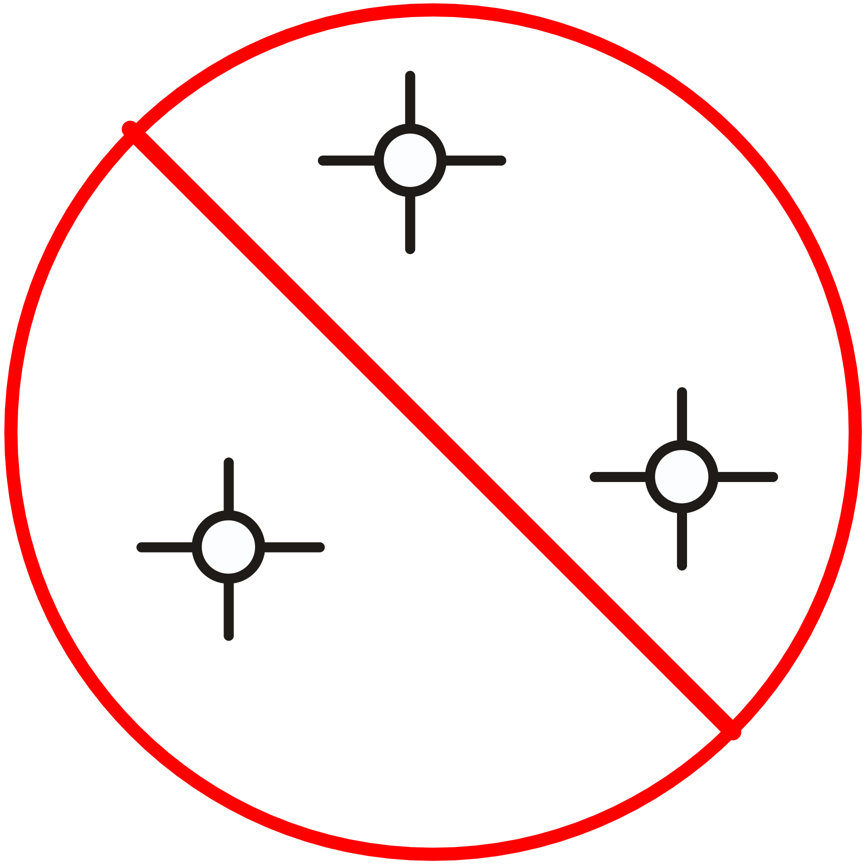
Select the right method(s)

Use proper survey design

Calibrate with analog field or recent discovery

Integrate surface and subsurface data

NO MORE DRY HOLES ? !



Thank you !

Deet Schumacher
deetschumacher@gmail.com