Geochemical Exploration in Deserts of North Africa and Middle East: Strategies, Methods, and Exploration Case Histories*

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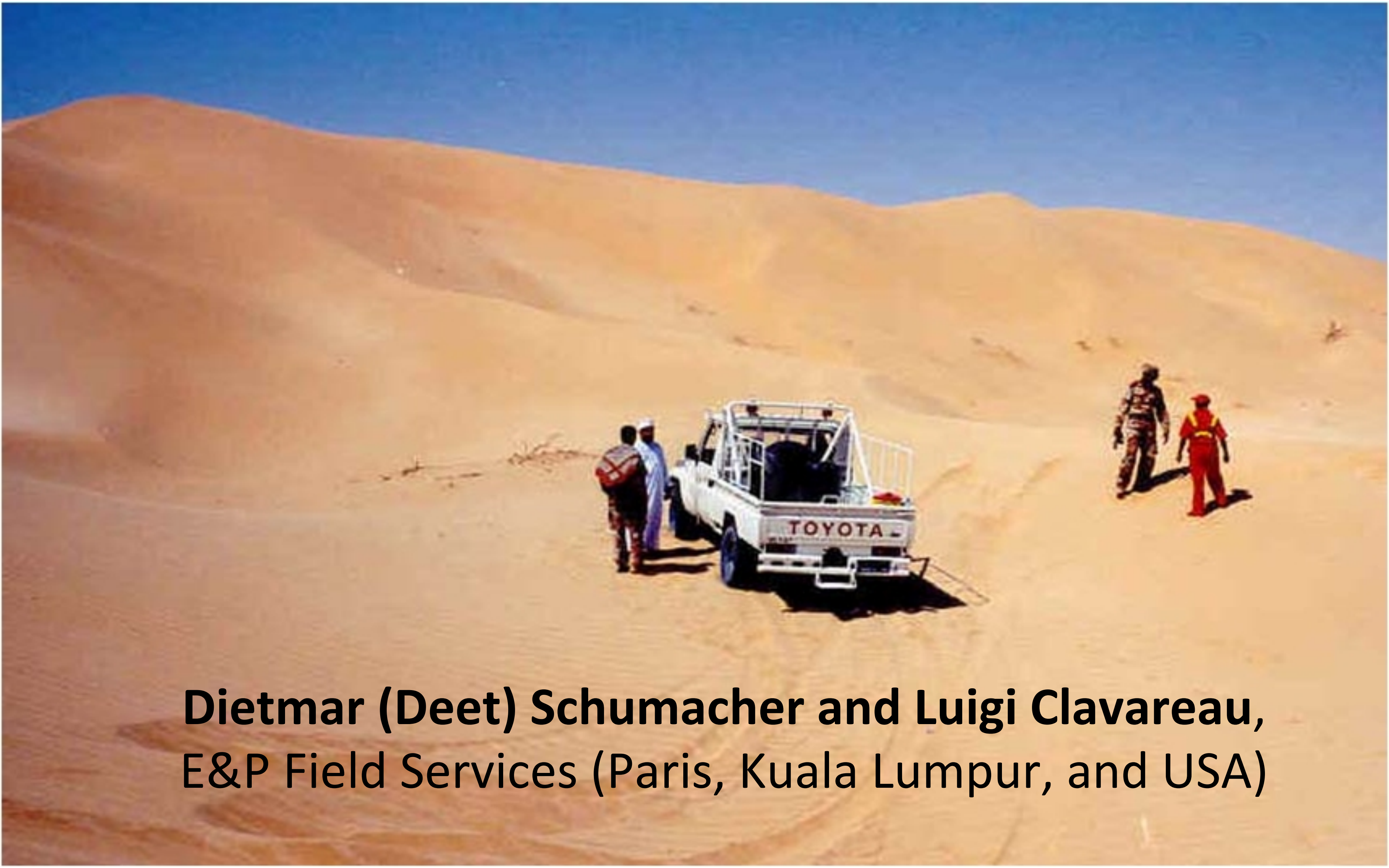
Abstract

Surface geochemical exploration for petroleum is the search for surface or near-surface occurrences of hydrocarbons and their alteration products. It has been well documented that most oil and gas accumulations leak, that this leakage is predominantly vertical (with some obvious geologic exceptions), that it is dynamic, and that this leakage can be detected and mapped using any of a number of direct and indirect methods. Hydrocarbon microseepage surveys in deserts require careful planning and implementation. Microseepage data are inherently noisy and require adequate sample density to distinguish between anomalous and background areas. To optimize the recognition of a seepage anomaly, the sampling pattern and sample density must reflect survey objectives, expected size and shape of the target, expected variation in surface measurements. Defining background values adequately is an essential part of anomaly recognition and delineation. Under-sampling and/or the use of improper analytical techniques is a major cause of ambiguity and interpretation failures. Desert environments are well suited for hydrocarbon microseepage surveys. Results of microbial and soil gas surveys in the deserts of Algeria, Tunisia, Egypt, Yemen, and Oman are presented here. These results illustrate the value of hydrocarbon microseepage data for high-grading basins, plays, and prospects. Surveys in Algeria and Tunisia document hydrocarbon microseepage to the surface in spite of the presence of 200–400 meters of halite above Triassic reservoirs, and the composition of the migrating hydrocarbons correctly predicted the composition of the reservoired hydrocarbons. In Oman, samples were collected from along more than 2900 line kilometers of seismic lines to high-grade seismic leads and prospects, and identify areas that warrant further evaluation. The Yemen survey illustrates the use of geochemical ground-truthing of possible seep-induced remote sensing anomalies. Results from surveys in Egypt, Yemen, Oman, and Algeria successfully discriminated prospects on basis of likely hydrocarbon charge. Geochemical exploration surveys, such as these, require close sample spacing and are most effective when results are integrated with subsurface data.

Reference Cited

Schumacher, D., 2010, Integrating hydrocarbon microseepage data with seismic data doubles exploration success: Proceedings, 34th Indonesian Petroleum Association Annual Convention, May 2010, IPA 10-G-104 (2011), 11 p.

Geochemical Exploration in Deserts of North Africa and the Middle East: Strategies for Success



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Outline

- Hydrocarbon Microseepage Characteristics
- Survey Methods
- Survey Objectives, Survey Design
- Exploration Examples
- Measuring Success
- Limitations and Uncertainties
- Recommendations
- Summary

Why Microseepage Surveys?

- Most Accumulations Leak Hydrocarbons
- Leakage is Predominantly Vertical
- Leakage is Dynamic (1-3 m/day)
- **Provides Direct Detection of Hydrocarbons**
- Detection of Hydrocarbon-Induced Alterations
- Methods Have Minimal Environmental Impact
- **Prospects with Seepage Anomaly are 4-6 times more likely to result in a discovery**

MICROSEEPAGE MODEL

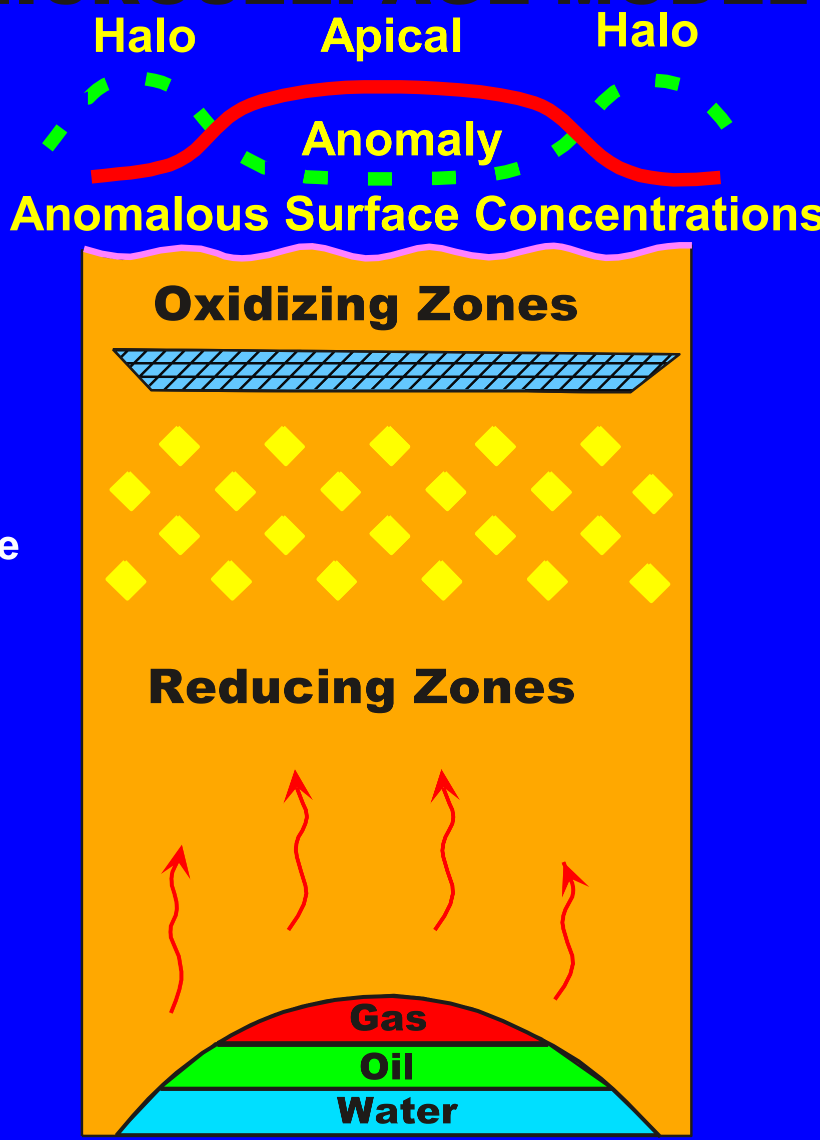
GEOCHEMICAL

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

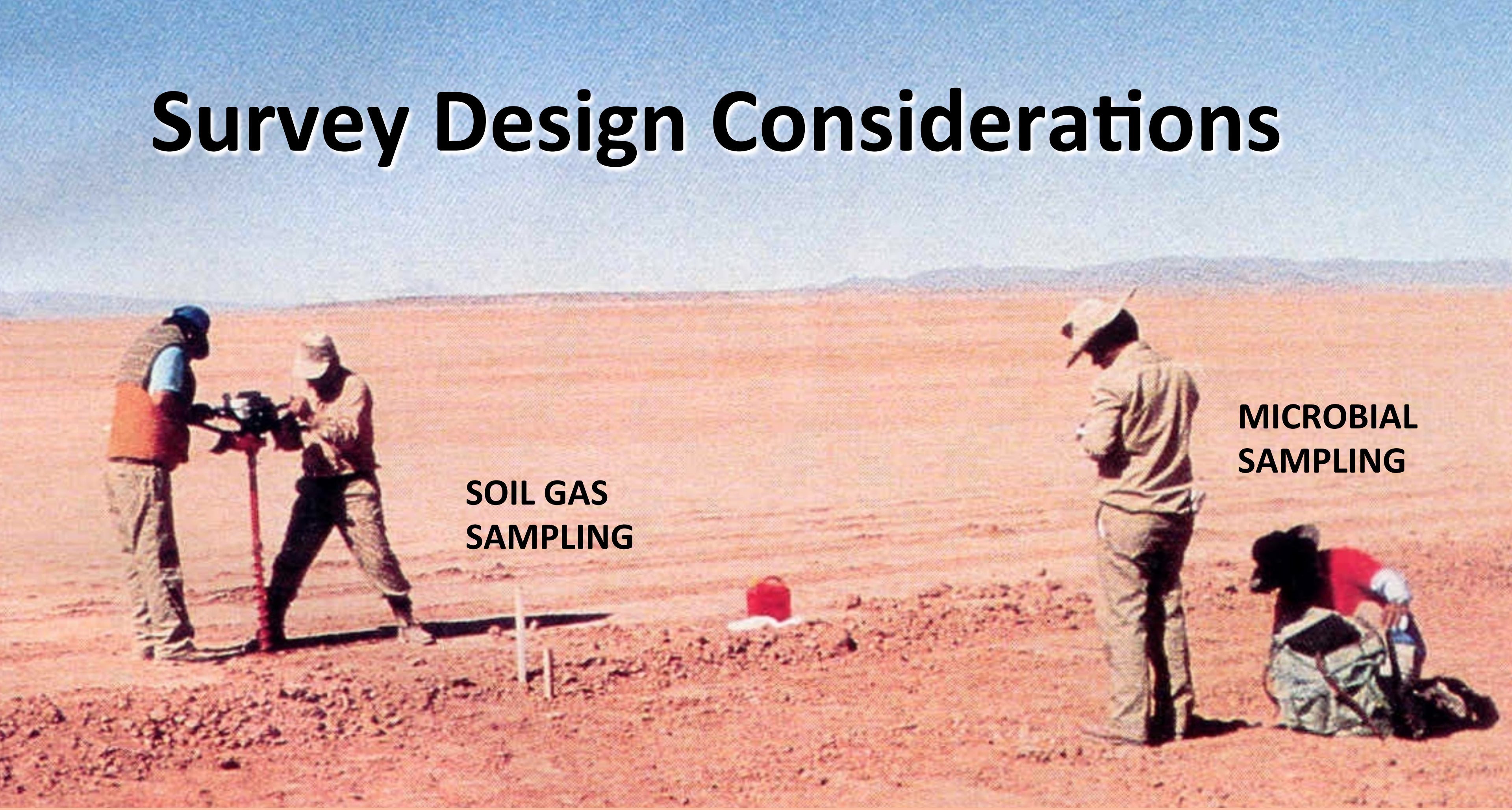
Low Resistivity
Anomaly

Seismic Velocity
Anomaly

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, depth, thickness

Survey Design Considerations

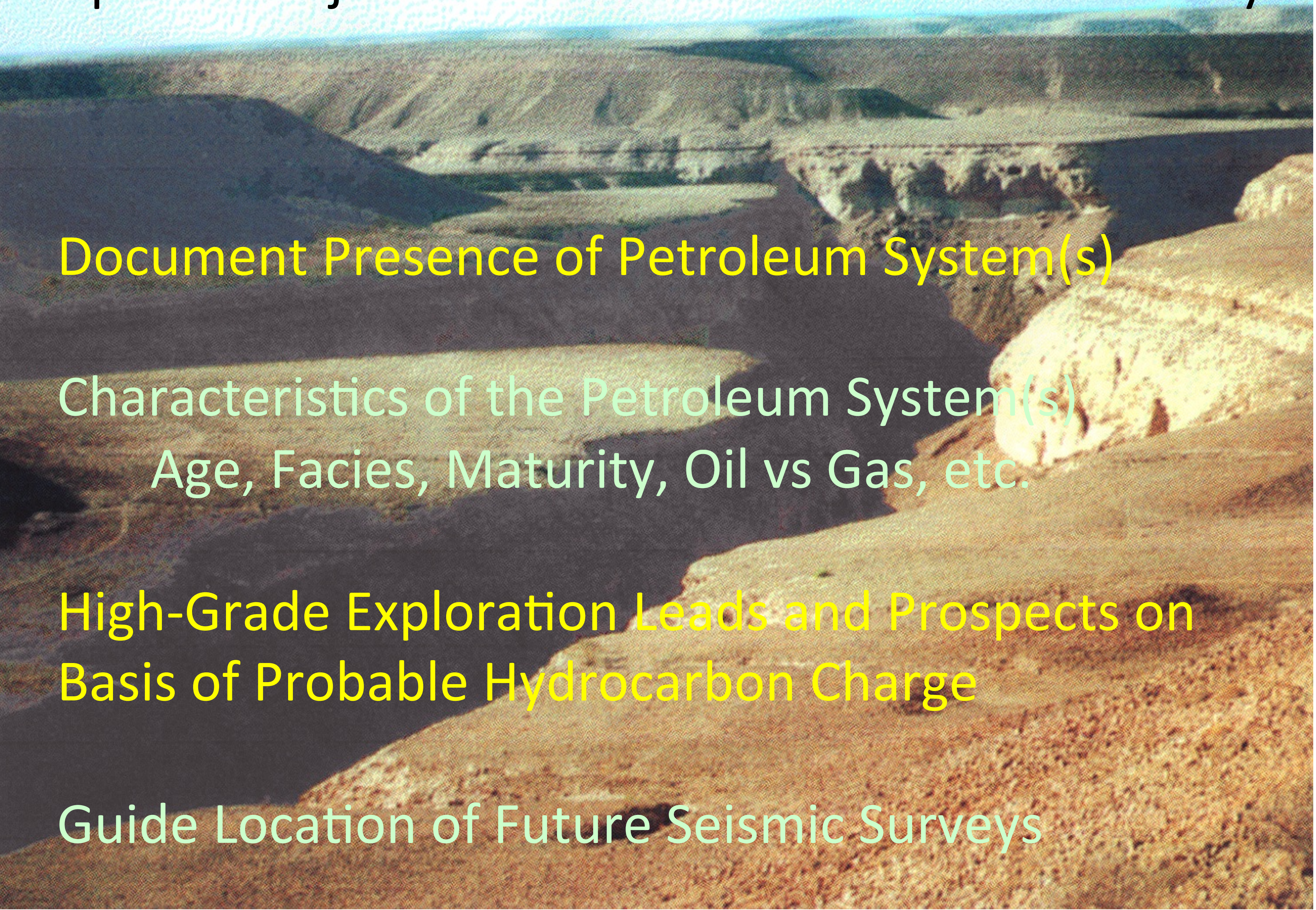


- Survey Objectives
- Target Size, Shape
- Geologic Setting
- Topography, Vegetation
- Logistical Considerations
- Ability to Sample Along, Between Seismic Lines
- Geologic Analogs for Calibration
- Permitting; Environmental Issues
- Prior Experience

Survey Objectives

- **Reconnaissance Surveys**
  Mali, Chad, Sudan, Ethiopia, Egypt, Kazakhstan
- **Prospect Generation, Prospect Evaluation**
  Algeria, Tunisia, Sudan, Oman, Yemen, Egypt
  Saudi Arabia, Iraq, Turkey

Specific Objectives of Surface Geochemical Surveys




Exploration Examples
Algeria, Sbaa Sub-basin
Tunisia, Ghadames Basin
Egypt, Western Desert
Oman, South Oman Salt Basin
Yemen, Masilah Basin
Armenia

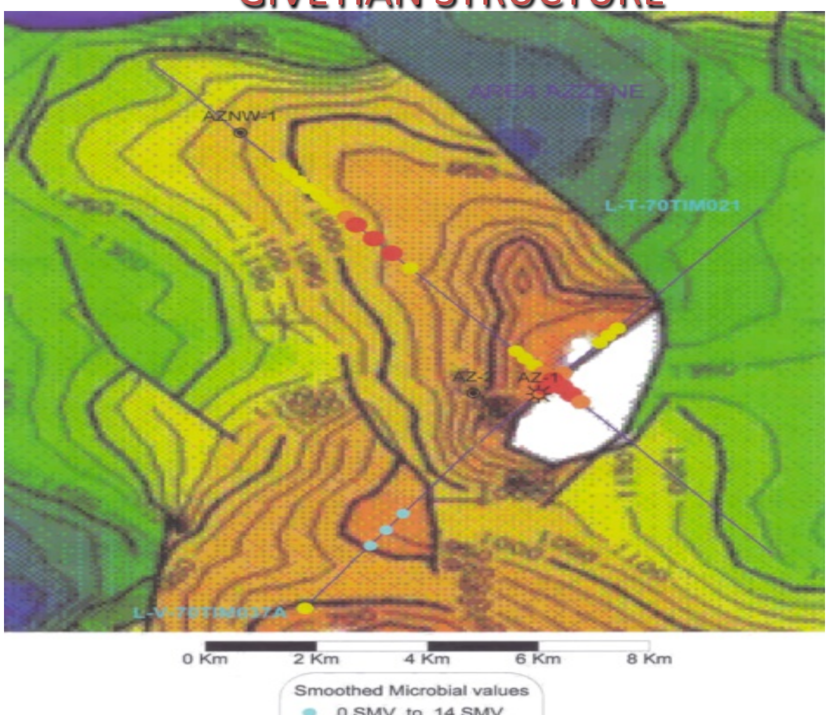
ALGERIA, SBAA SUB-BASIN

Survey Objective

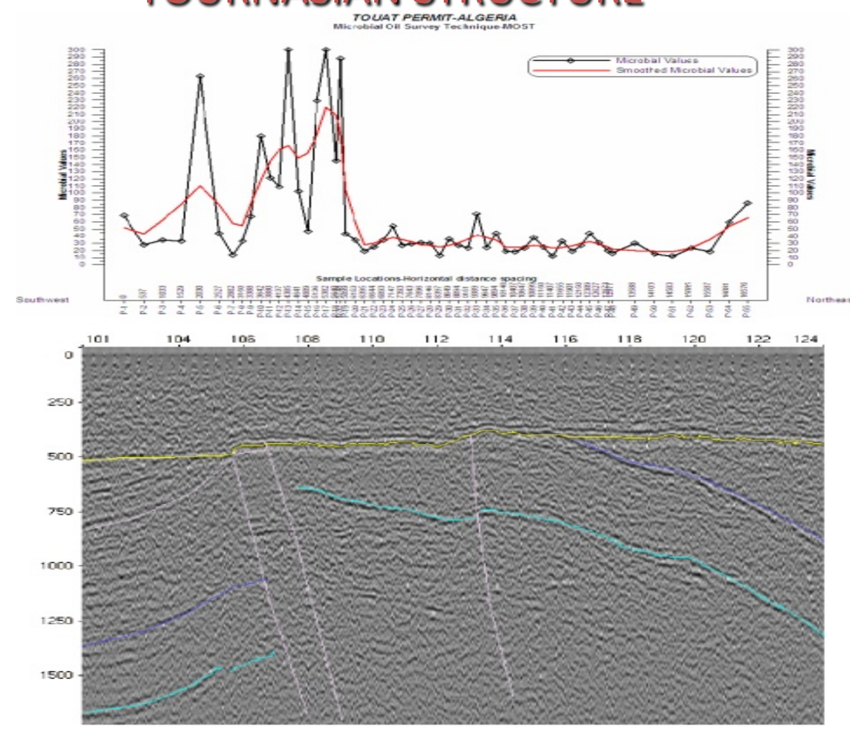
High-grade seismic prospects on basis of probable hydrocarbon charge.

Samples collected at 250-500 m intervals along seismic lines using the Microbial and Soil Gas methods.

GIVETIAN STRUCTURE



TOURNASIAN STRUCTURE

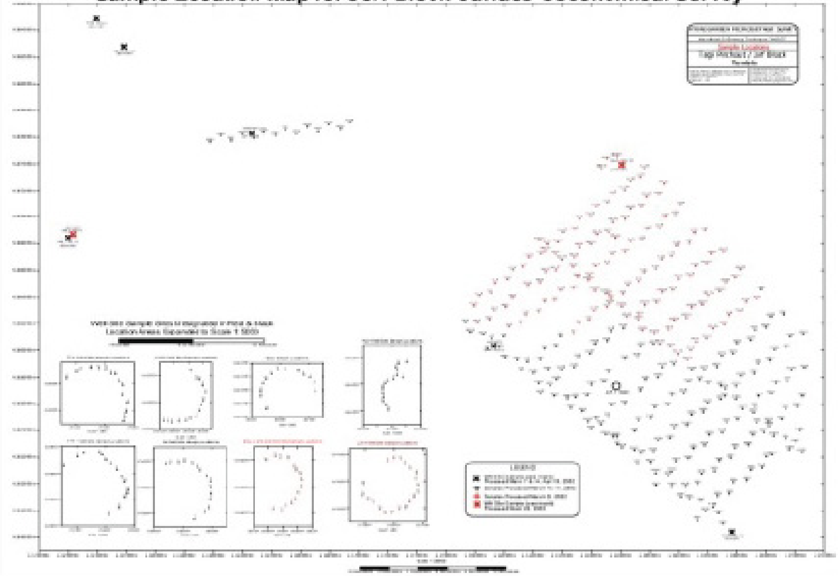


TUNISIA, Ghadames Basin

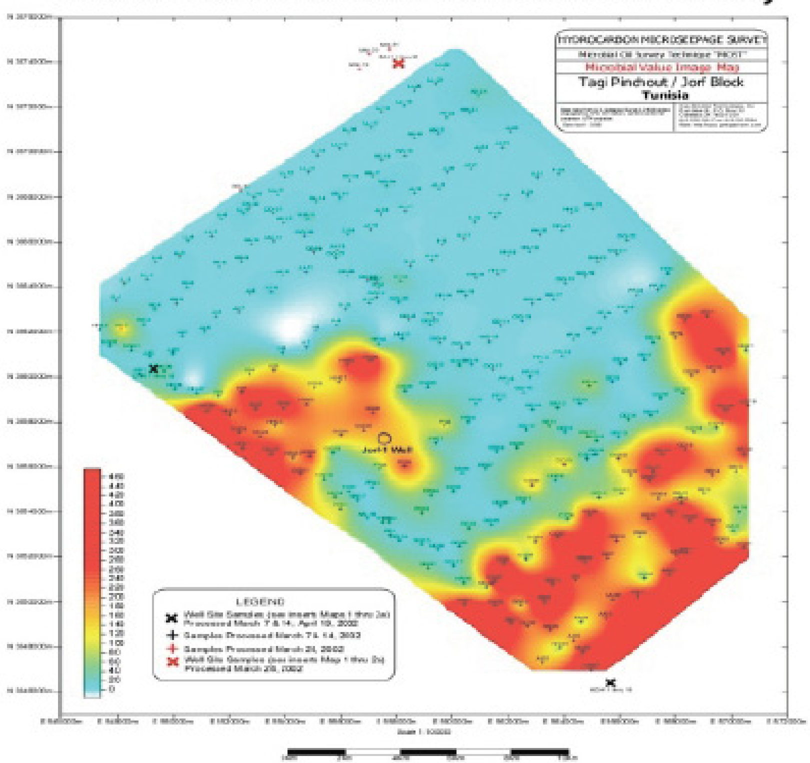
Survey Objective

To evaluate a possible stratigraphic pinch-out of TAGI sands. Both the GMT microbial survey and the GORE survey identified the same seepage anomalies; however, the Jorf-1 well was drilled several km from the nearest anomaly.

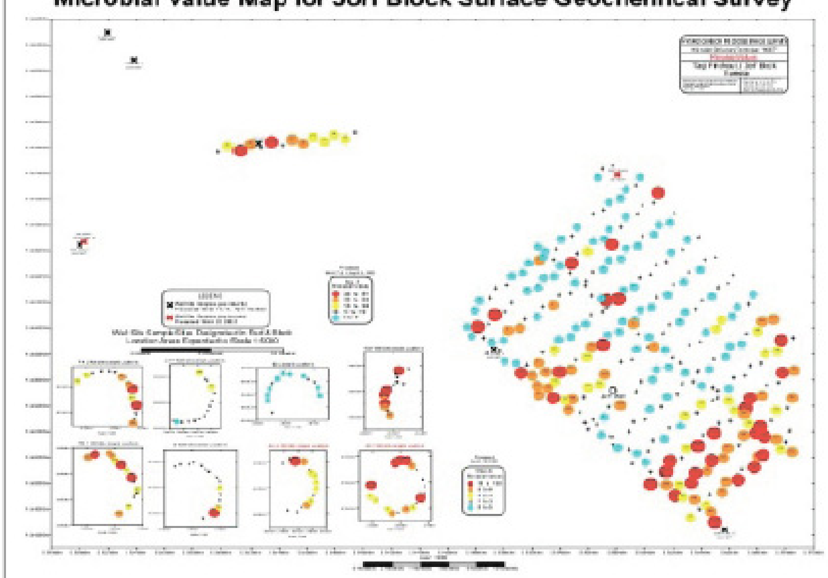
Sample Location Map for Jorf Block Surface Geochemical Survey



Microbial Value Image Map for Jorf Block Surface Geochemical Survey



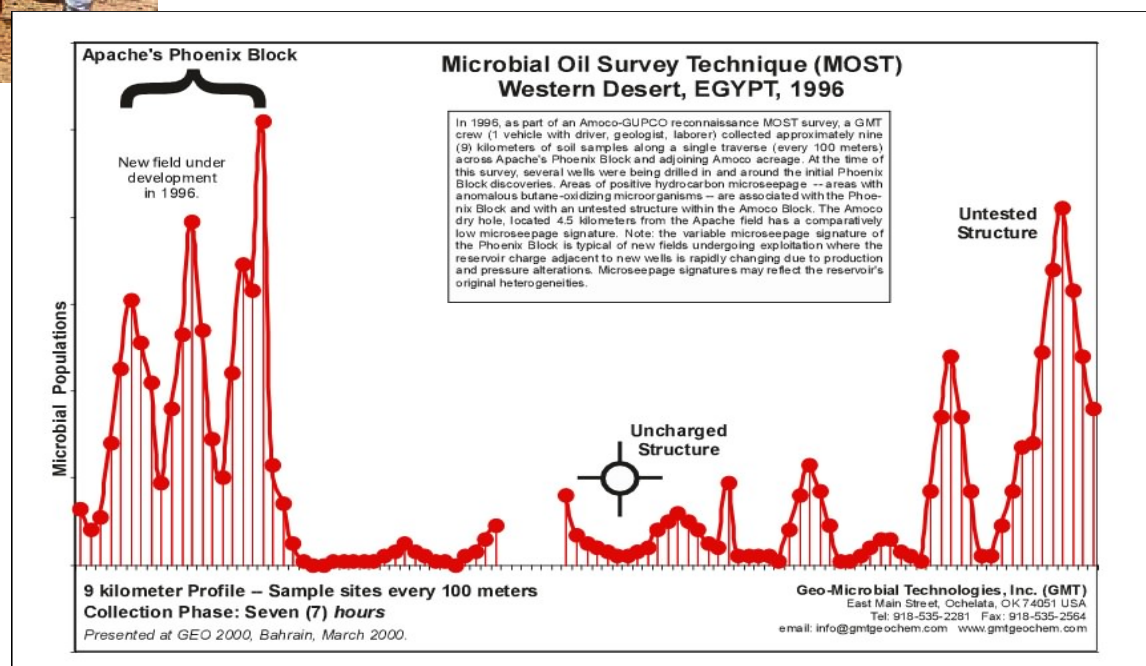
Microbial Value Map for Jorf Block Surface Geochemical Survey



EGYPT, WESTERN DESERT

A 9 km long microseepage profile across a developing oil field, a geologic analog with recent dry hole, and an undrilled prospect.

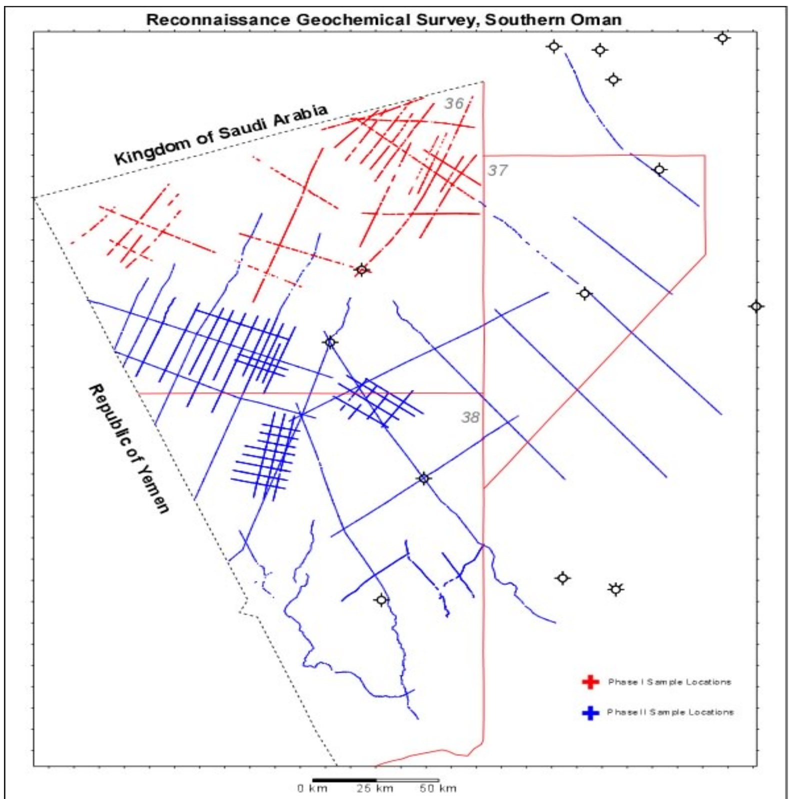
Samples collected at 100m intervals from depth of 20cm; soil gas and microbial methods.

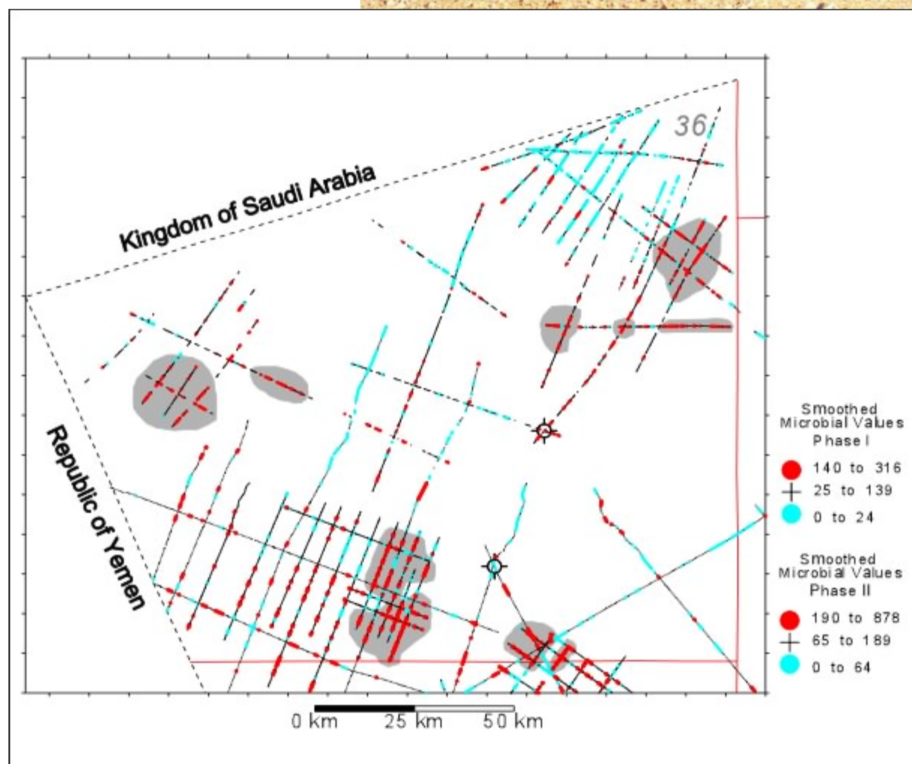


OMAN South Oman Salt Basin

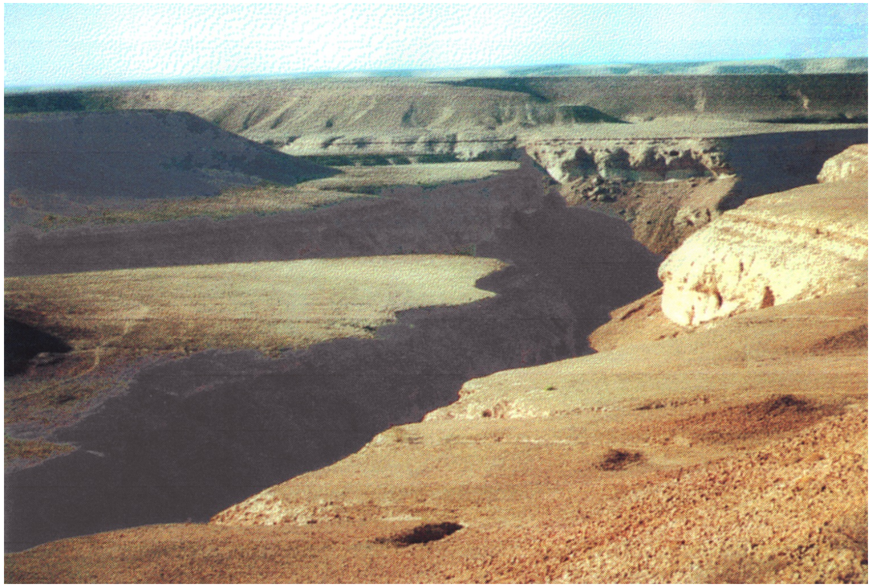
Survey Objective

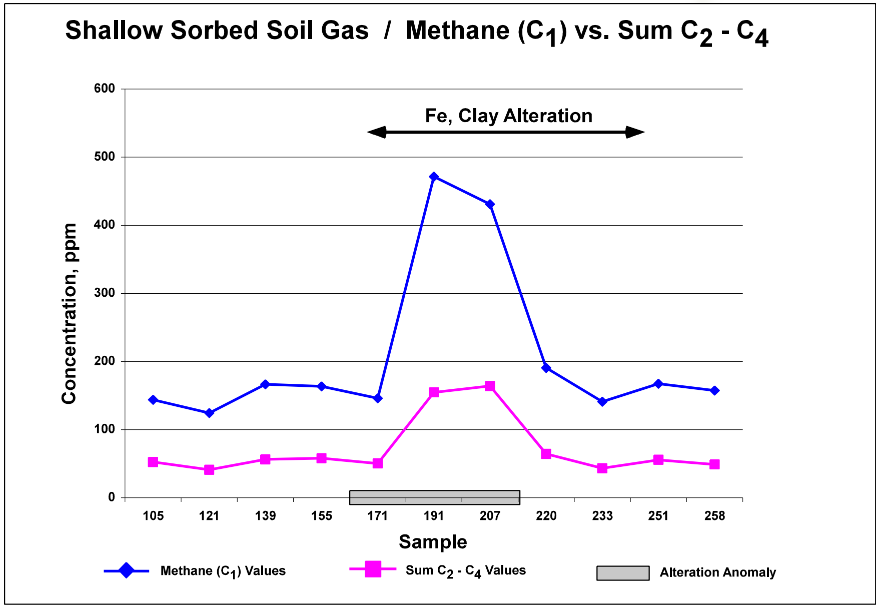
Reconnaissance geochemical survey of 70,000 km^2 in Blocks 6, 36, 37, and 38. Samples collected at 250m intervals along 2900 line km of pre-existing seismic lines. Results documented the presence of 2 distinct petroleum systems.

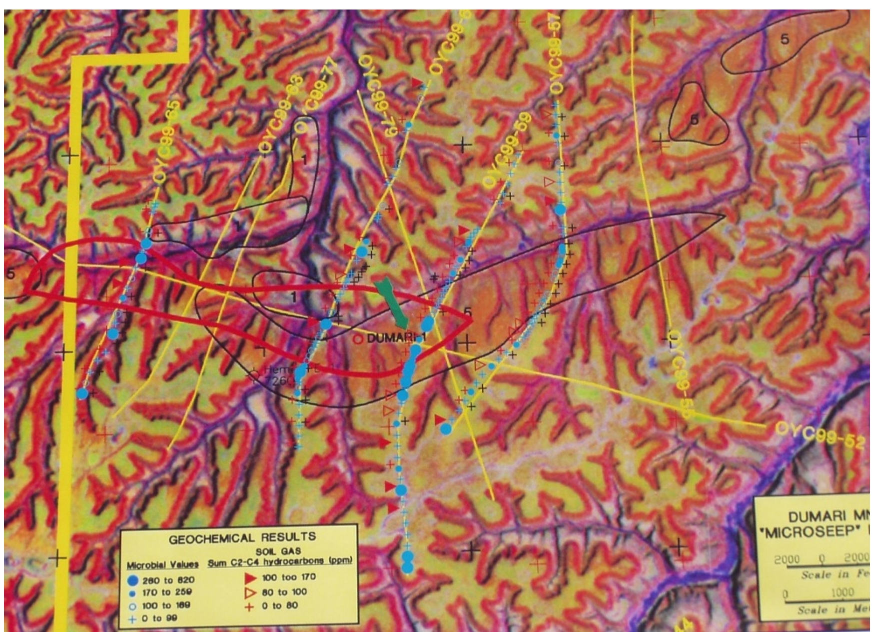


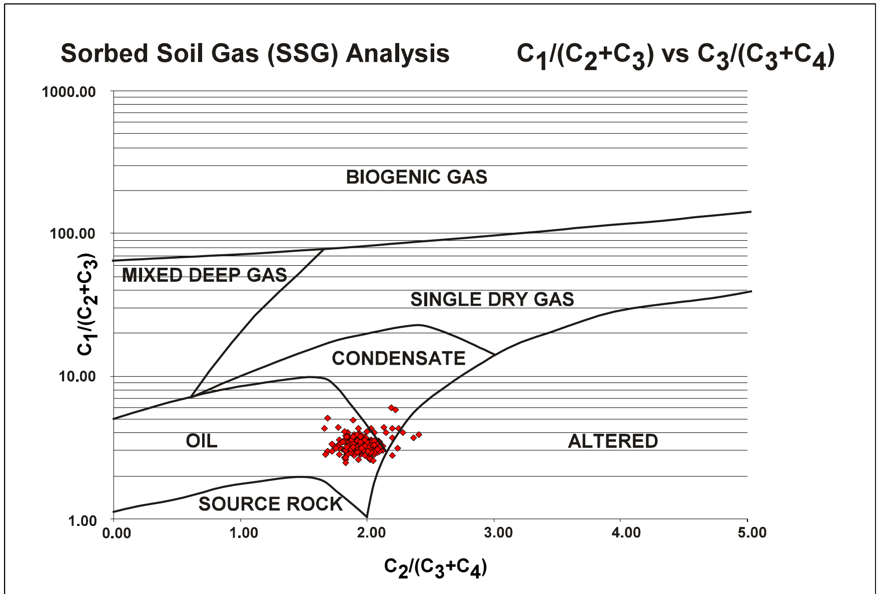


Yemen
Remote Sensing and Surface Geochemistry

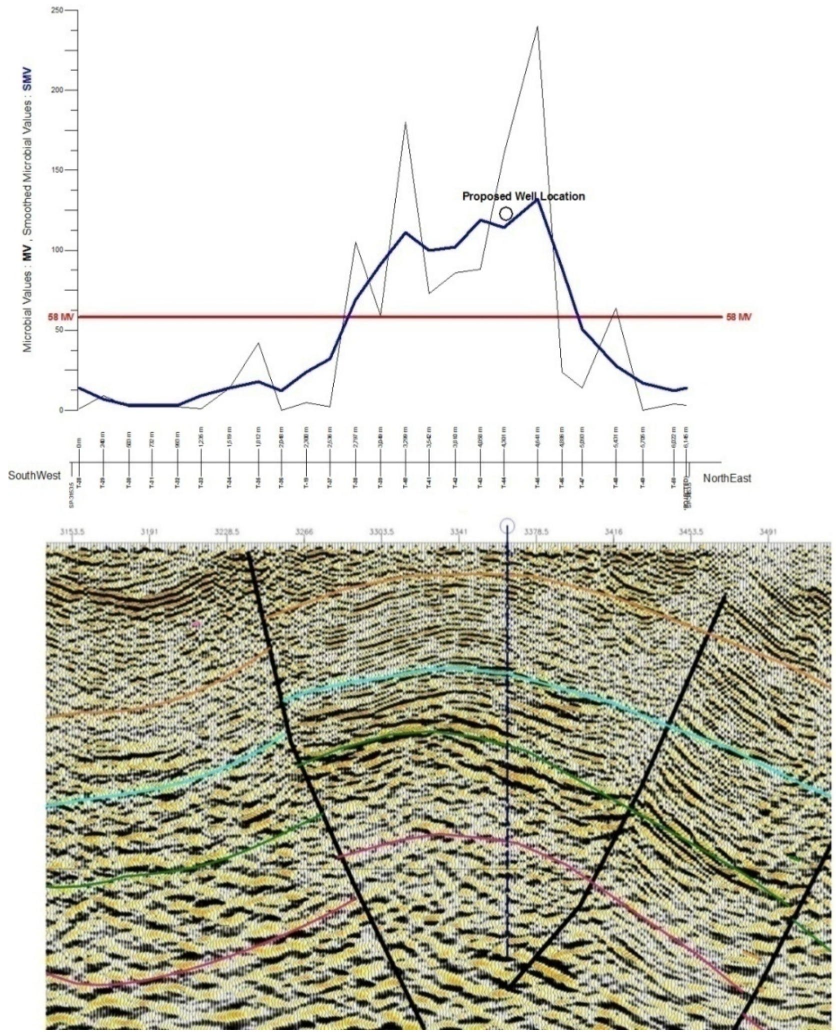




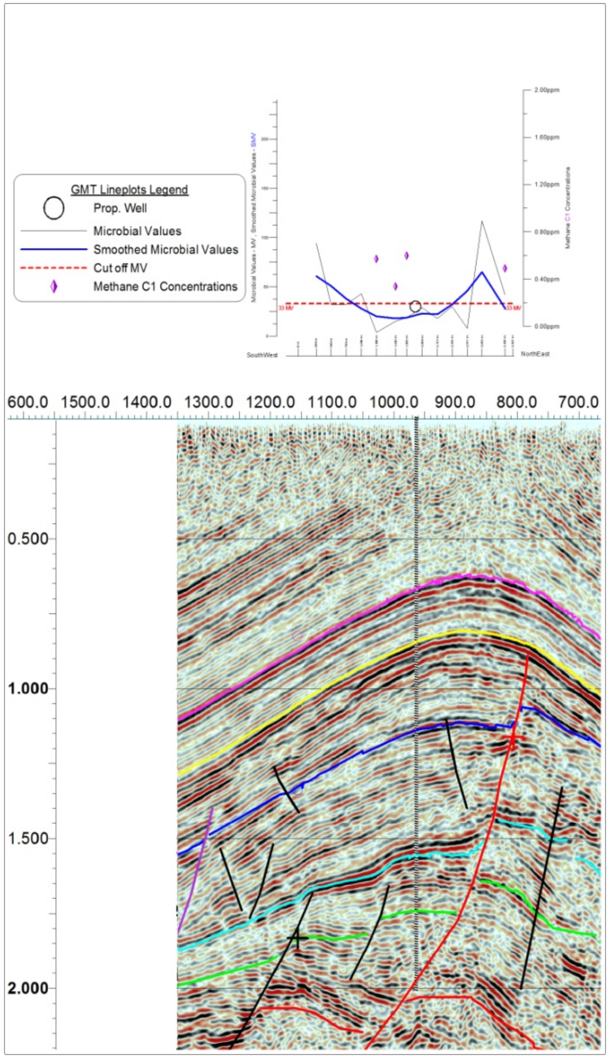




How do we measure success? Compare pre-drill prediction with post-drill results.



Kalimantan, Indonesia



Laos

Reducing Exploration Risk
Post-Survey Drilling Results

2774 Wells, Various Companies,
Various Methods, Various Basins

In Negative Anomalies

- **1430 Wells Drilled**
- **1267 Wells Dry (89%)**
- **163 Discoveries (11%)**

In Positive Anomalies

1344 Wells Drilled

247 Wells Dry (18%)

1097 Discoveries (82%)

(From Schumacher, 2010)

Summary

Most oil/gas accumulations leak hydrocarbons

This leakage can be detected and mapped with any of several geochemical and non-seismic hydrocarbon detection methods

Prospects with an associated hydrocarbon anomaly are 4 to 6 times more likely to result in a commercial discovery than prospects without such an anomaly

Limitations and Uncertainties

- Geochemical expression of seepage is complex and varied
- Many methods to choose from; no single method works everywhere
- Under-pressured reservoirs, heavy oil accumulations, and/or old fields may not be detectable by some methods
- Under-sampling and/or use of improper sampling techniques is probably major cause of ambiguity and interpretation failures
- A surface anomaly generally cannot be related to a specific source reservoir or depth, but anomaly shape and hydrocarbon composition may help identify the likely source and depth

Recommendations

- Research the method(s)
- Check out contractors, past clients
- When possible, use more than one geochemical method
- Be guided by past experience in the basin or exploration trend
- Conduct calibration survey(s) over new field or recent discovery
- Under-sampling and/or use of improper sampling techniques causes ambiguity that leads to interpretation failures
- Survey results are most meaningful when integrated with available geological and geophysical data

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