Petroleum Exploration in Environmentally Sensitive Areas: Opportunities for Geochemical and Non-Seismic Geophysical Methods*

Dietmar Schumacher[1]

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[1]Geo-Microbial Technologies, Inc, Ochelata, OK. (deet@gmtgeochem.com)

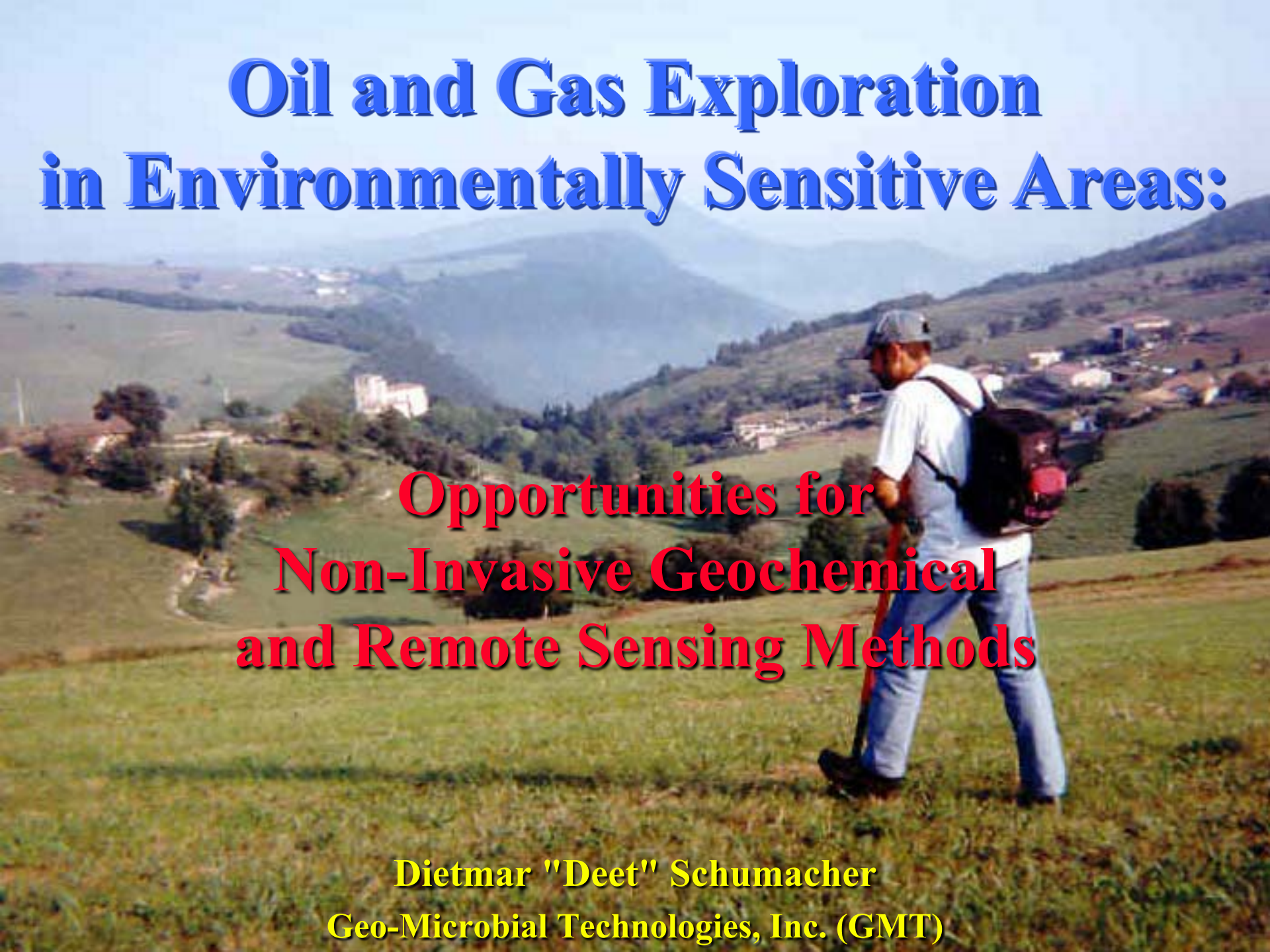
Abstract

The petroleum potential of environmentally sensitive areas, such as forests, wetlands and arctic environments, is often poorly known due to restrictions limiting conventional exploration methods like seismic surveys and exploratory drilling. For such areas, surface geochemical and non-seismic methods provide an opportunity to reliably detect and map the elevated hydrocarbon concentrations and hydrocarbon-induced changes commonly associated with undiscovered oil and gas accumulations, while having minimal impact on the surface environment.

There is now a general consensus that (1) all petroleum basins exhibit some type of near-surface hydrocarbon leakage, (2) that petroleum accumulations are dynamic and their seals imperfect, (3) that hydrocarbon seepage can be active or passive, and that it can be visible (macroseepage) or only detectable analytically (microseepage). The surface and near-surface expressions of hydrocarbon migration and seepage can take many forms ranging from elevated hydrocarbon concentrations in soils to complex mineralogical, microbial, and botanical changes.

Advances in geochemical and non-seismic hydrocarbon detection methods, coupled with an improved understanding of hydrocarbon migration processes, have led to an increased usage of various remote sensing, surface geochemical, and non-seismic methods to detect and map the small but significant concentrations of hydrocarbons that occur above oil and gas accumulations. The non-invasive, low impact nature of these techniques makes them ideally suited for use in an early stage evaluation of environmentally sensitive areas. The results of such surveys can quickly identify those parts of the area possessing the highest petroleum potential. Use of such an exploration strategy protects the greater part of the area from more invasive exploration methods by focusing attention and resources on a relatively small number of high potential sites.

Oil and Gas Exploration in Environmentally Sensitive Areas:



Opportunities for Non-Invasive Geochemical and Remote Sensing Methods

Dietmar "Deet" Schumacher

Geo-Microbial Technologies, Inc. (GMT)

Outline

- Environmentally Sensitive Areas
- Hydrocarbon Microseepage Characteristics
- Benefits and Assumptions
- Survey Methods
- Survey Design Considerations
- Examples
- Conclusions

Environmentally Sensitive Areas and Culturally Sensitive Areas

- National Forests, Grasslands
- Arctic Regions
- Jungles, Rainforests
- Coral Reefs, Atolls
- Coastal Environments
- Wetlands
- Deserts
- Culturally Significant Areas
- Archeological Sites

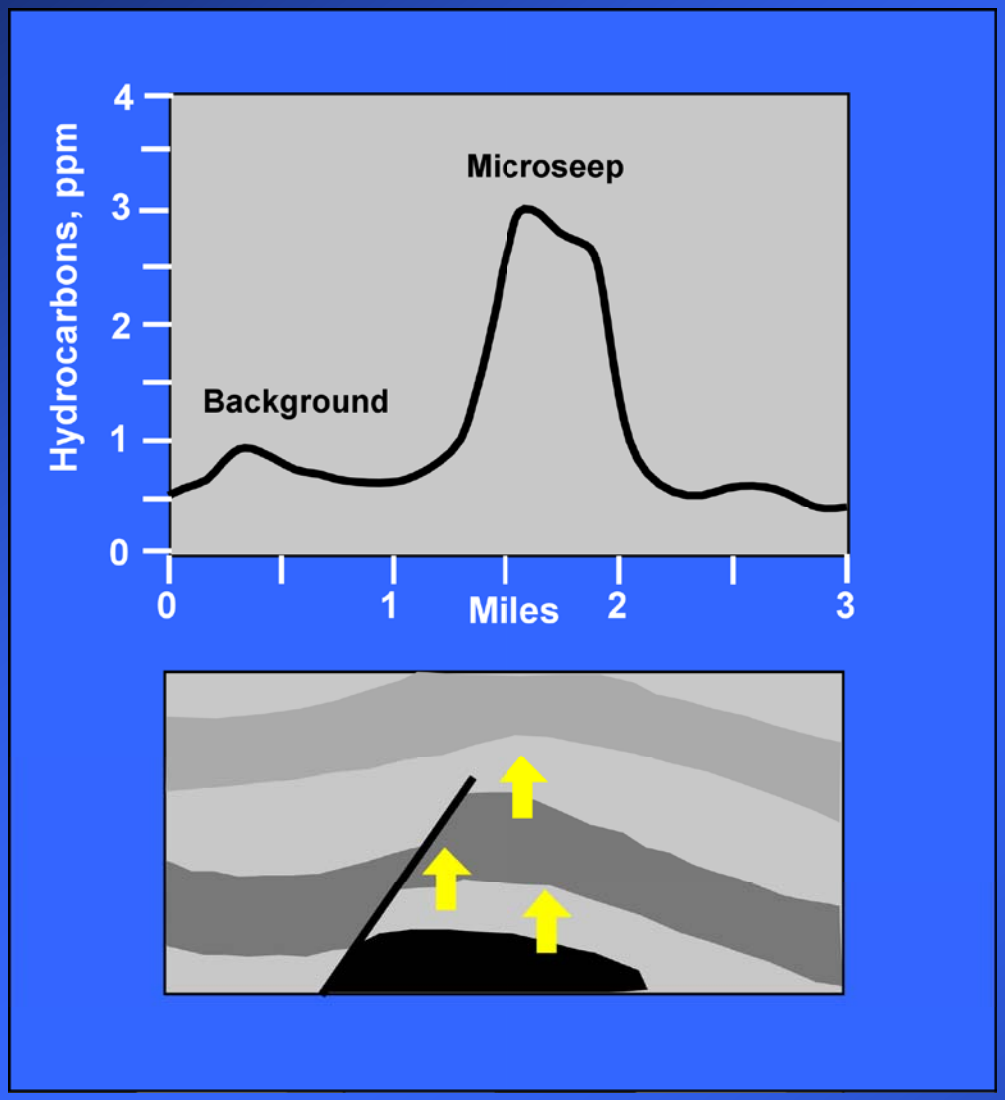
Geochemical and Non-Seismic Exploration for Oil and Gas

Geochemical and non-seismic detection of hydrocarbons is the search for chemically identifiable surface or near-surface occurrences of hydrocarbons and their alteration products, which serve as clues to the location of undiscovered oil and gas accumulations.

Benefits

- Direct detection of hydrocarbons and/or hydrocarbon-induced changes.
- Document an active petroleum system in the area of interest.
- High-grade basins, plays, or prospects prior to acquiring leases and/or before conducting detailed seismic surveys.
- High-grade leads and prospects after seismic evaluation.
- Generate unique geochemical leads for further geological and geophysical evaluation.

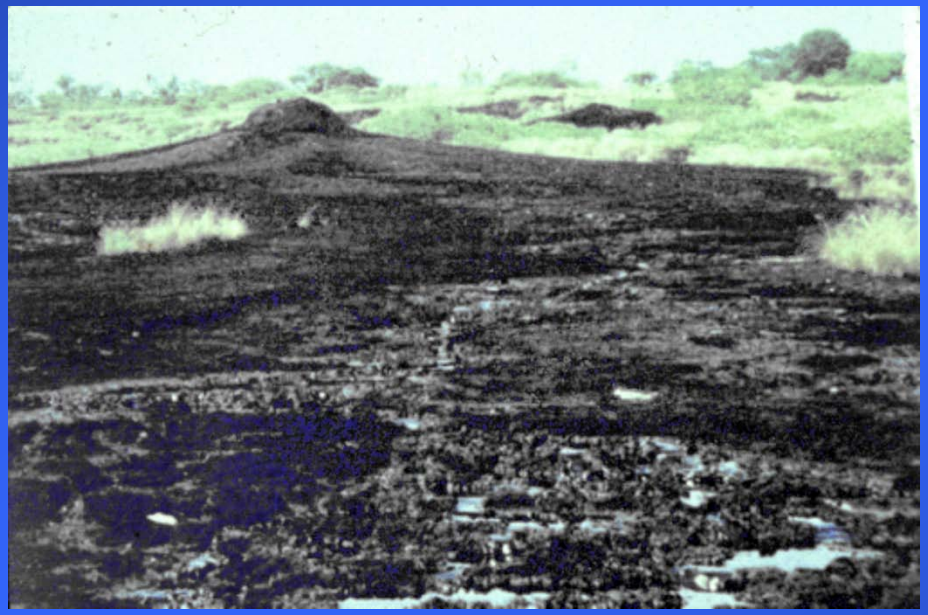
ASSUMPTIONS



- Hydrocarbon microseepage occurs
- Seepage produces changes in near-surface environment
- These changes can be detected and mapped
- Near-surface anomalies can be related to hydrocarbons at depth

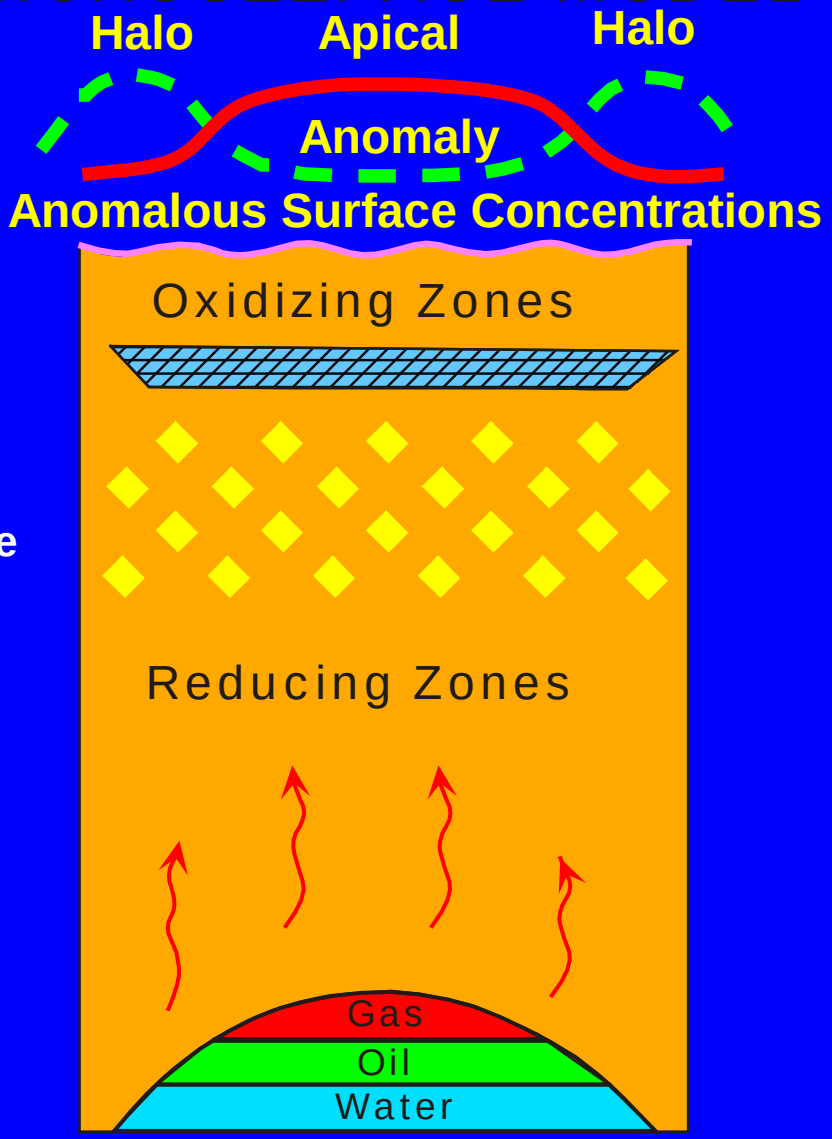
Spectrum of Seepage Styles

MACROSEEPAGE



MICROSEEPAGE

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

Exploration Methods for Environmentally Sensitive Areas

- **REMOTE SENSING, SATELLITE IMAGERY**
  - detects hydrocarbon-induced alteration, oil slicks
- **AEROMAGNETICS, MICROMAGNETICS**
  - detects hydrocarbon-induced alteration
- **SOIL GAS, ADSORBED SOIL GAS**
  - measures hydrocarbon concentration
- **MICROBIOLOGICAL**
  - measures HC-oxidizing bacteria
- **BIOGEOCHEMICAL, GEOBOTANICAL**
  - trace elements, vegetation stress

Effective in All Environments

Minimal Impact

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
- Prospect Generation, Prospect Evaluation
- Field Development
- Production Monitoring

Exploration Examples

Reconnaissance Surveys

- Yemen, Masila Basin
- Canada, NWT

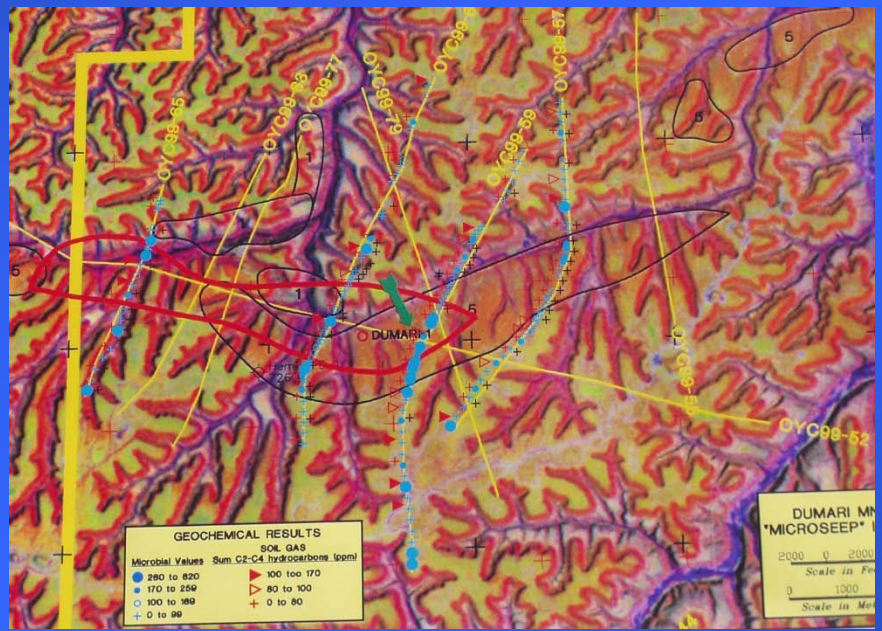
Prospect Evaluation Survey

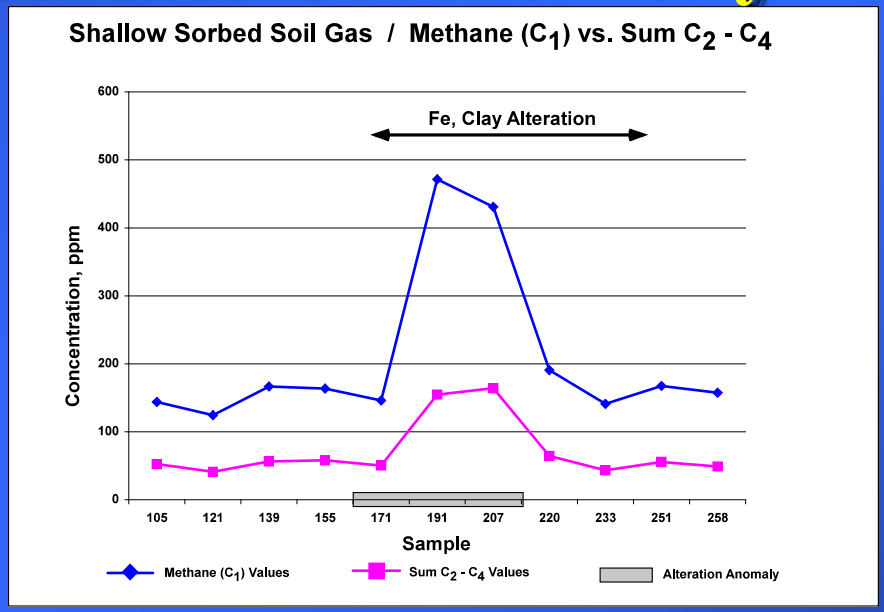
- USA, Morrow Trend
- USA, Deep Water GMX
- Eastern Venezuela

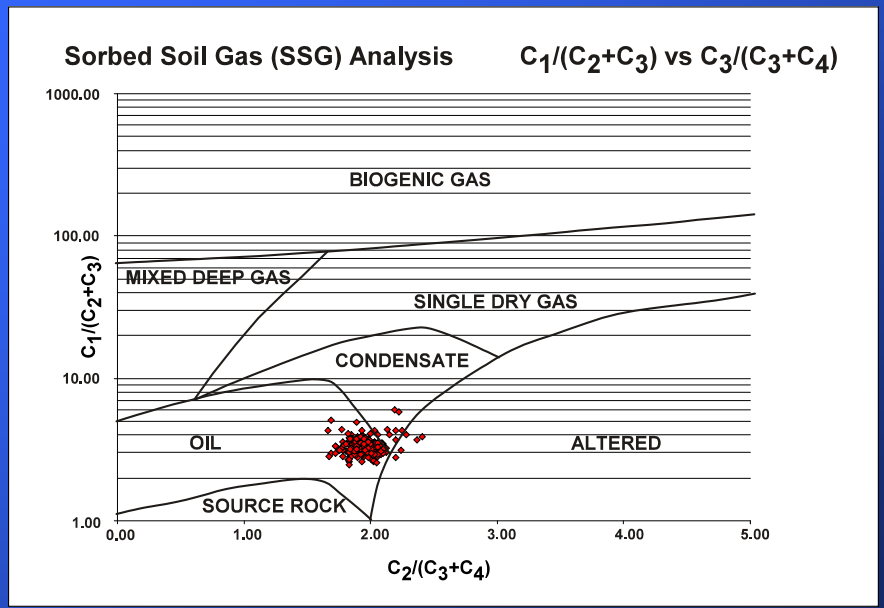
Field Development Survey

- Western Venezuela

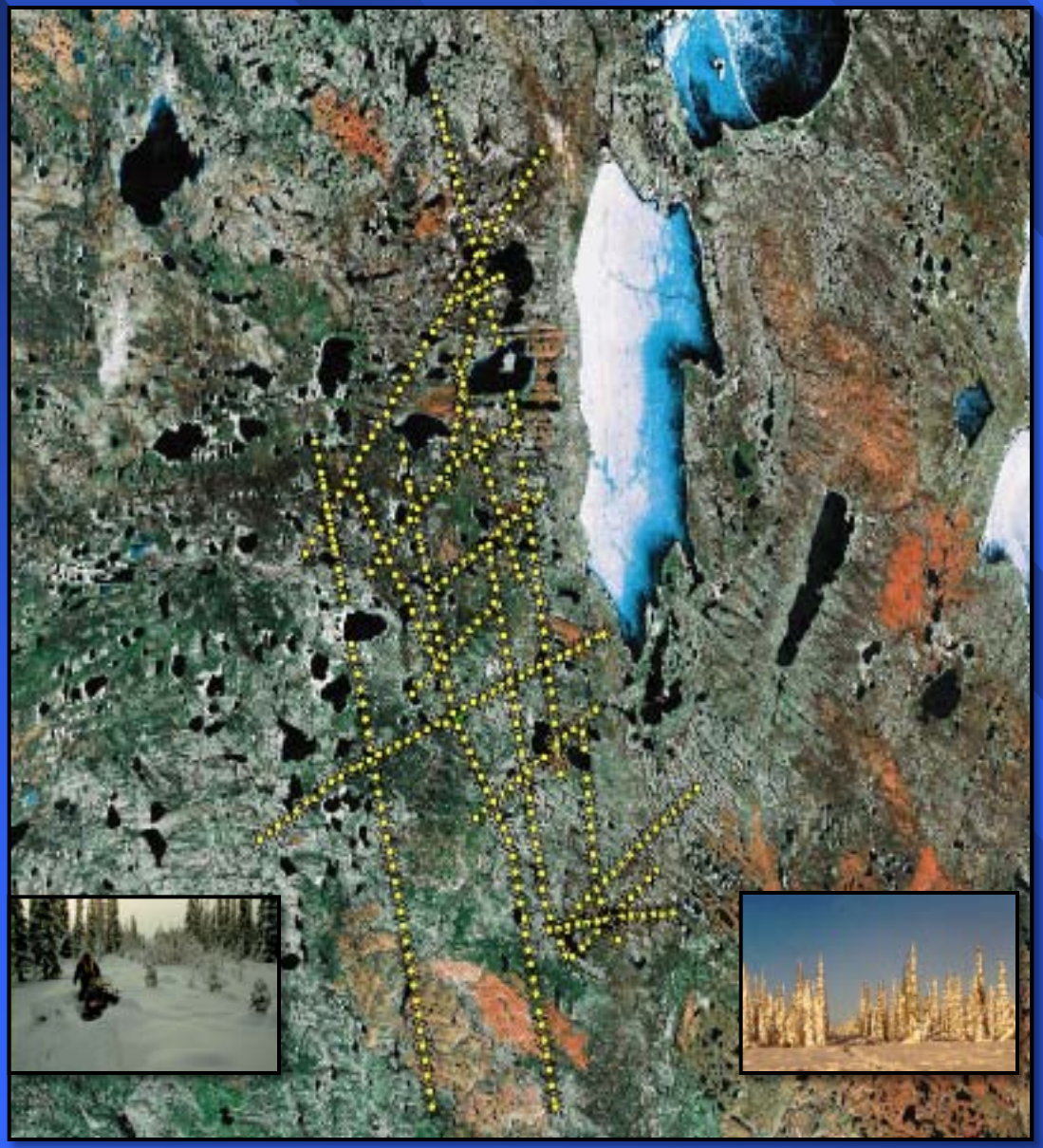
Yemen
Remote Sensing and Surface Geochemistry

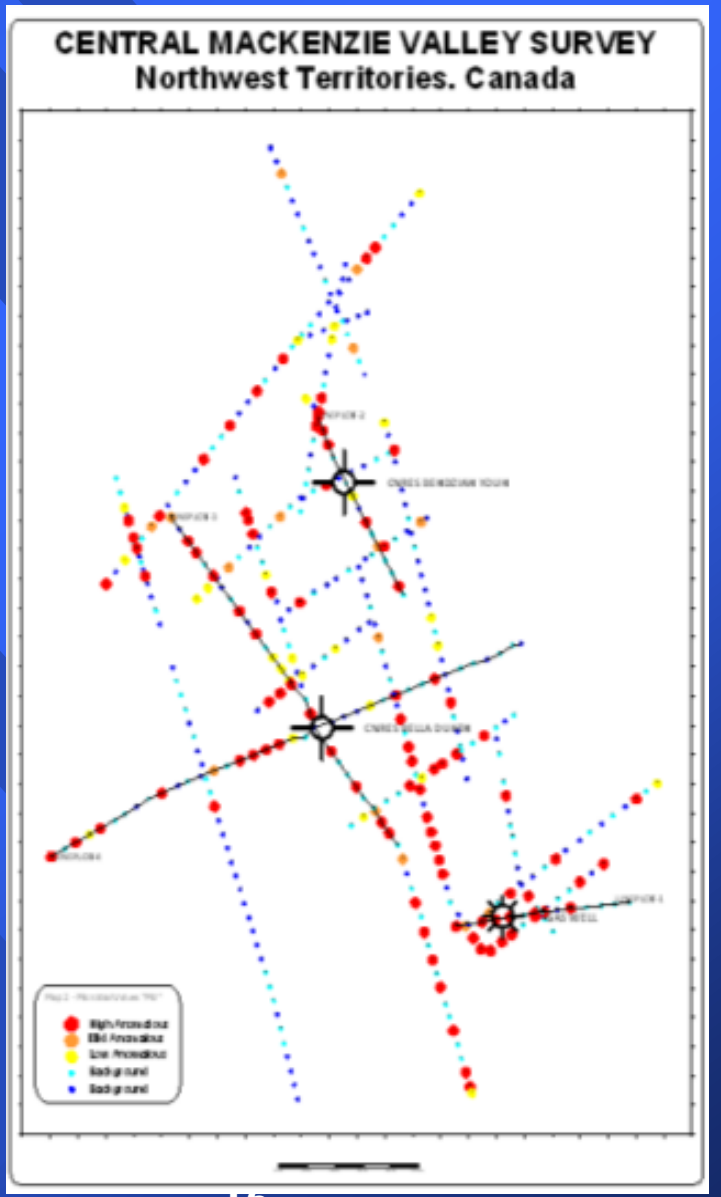






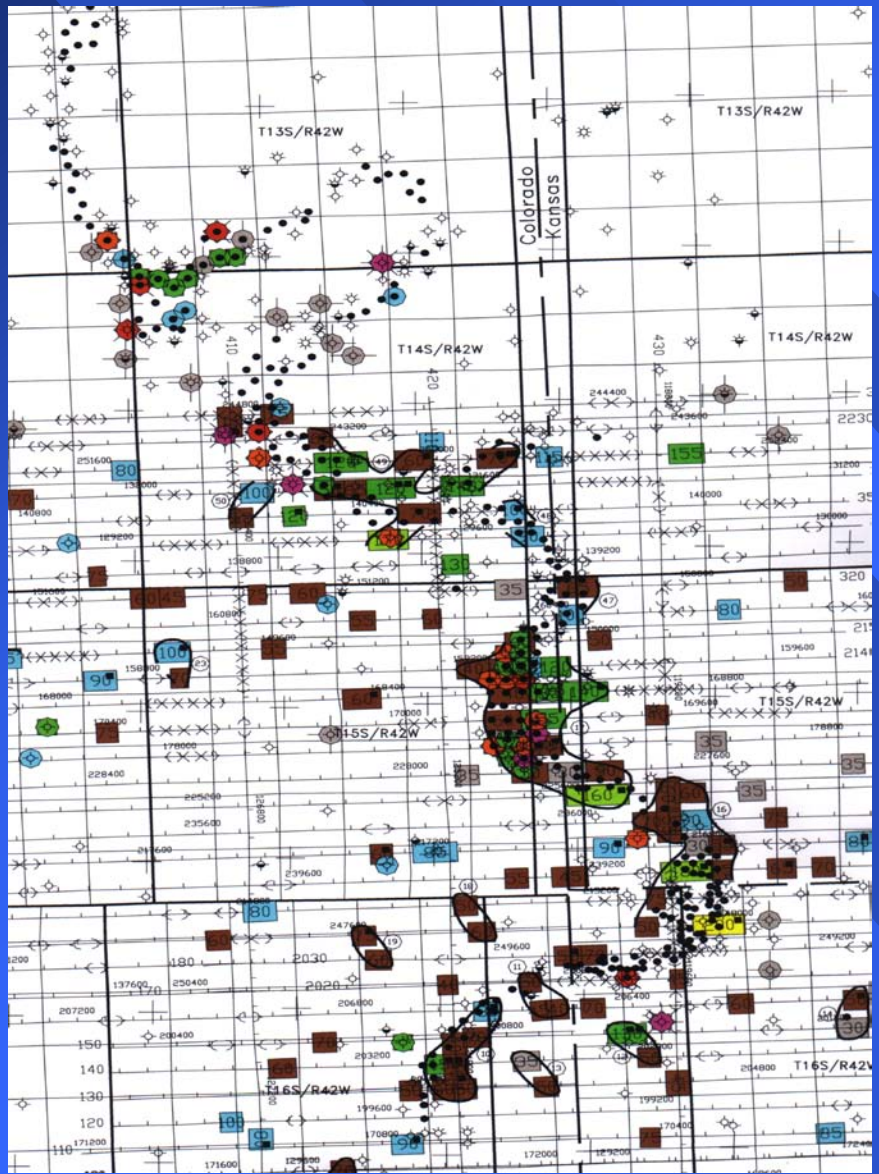
CANADIAN ARCTIC SURVEY



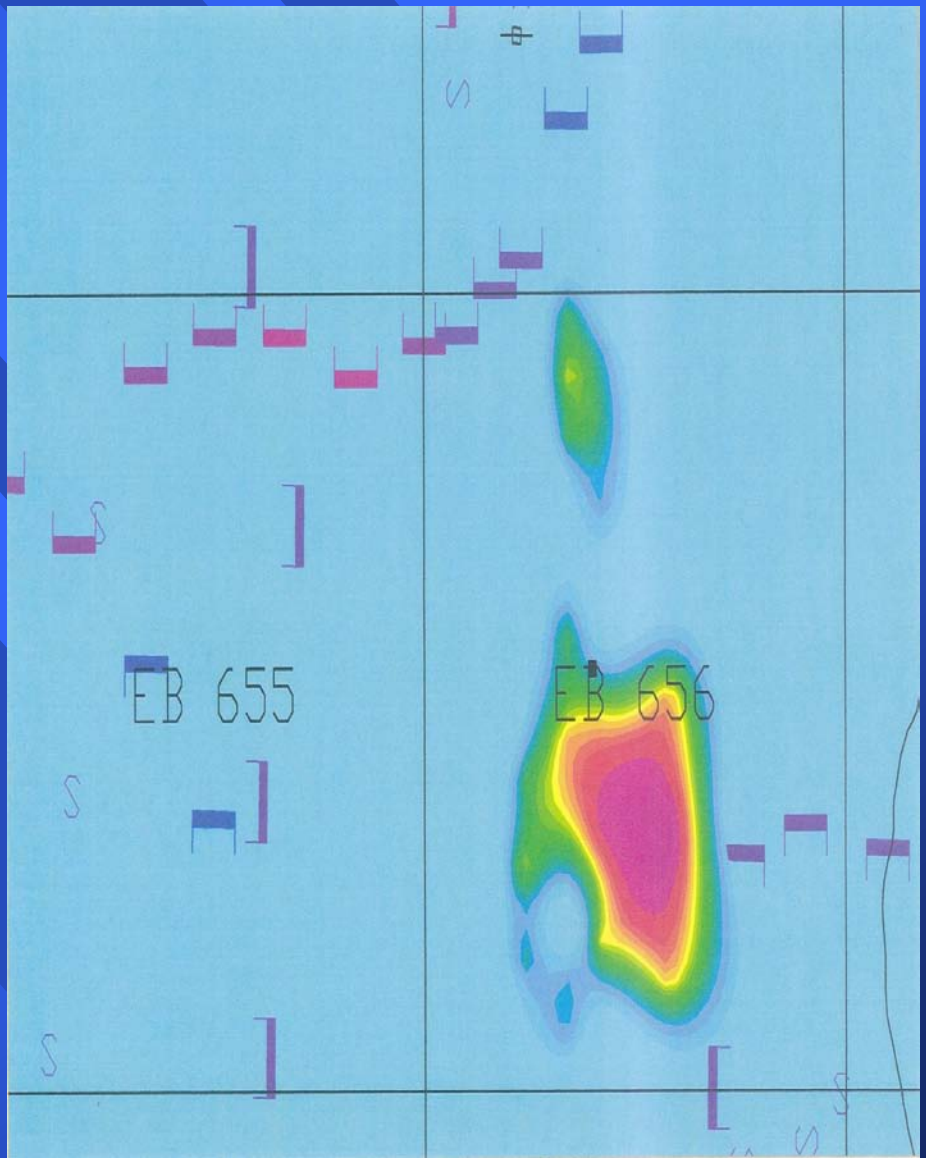


Seep-Induced Magnetic Anomalies

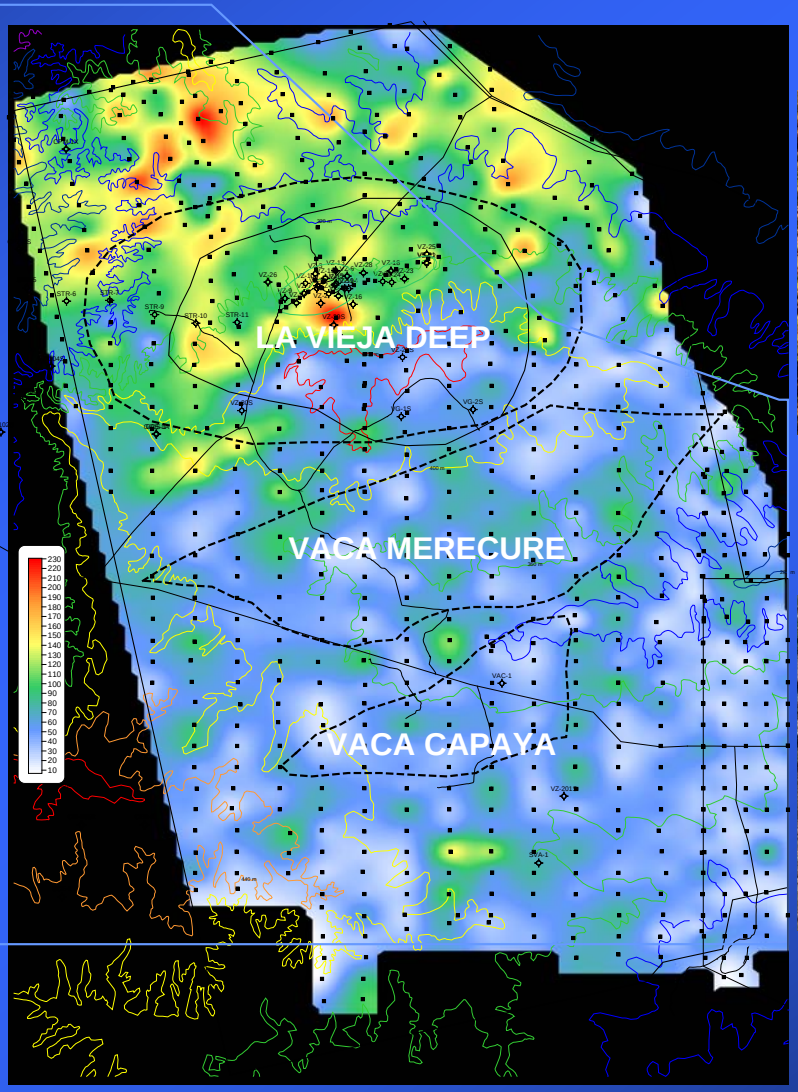
Onshore Morrow Trend, KS-CO



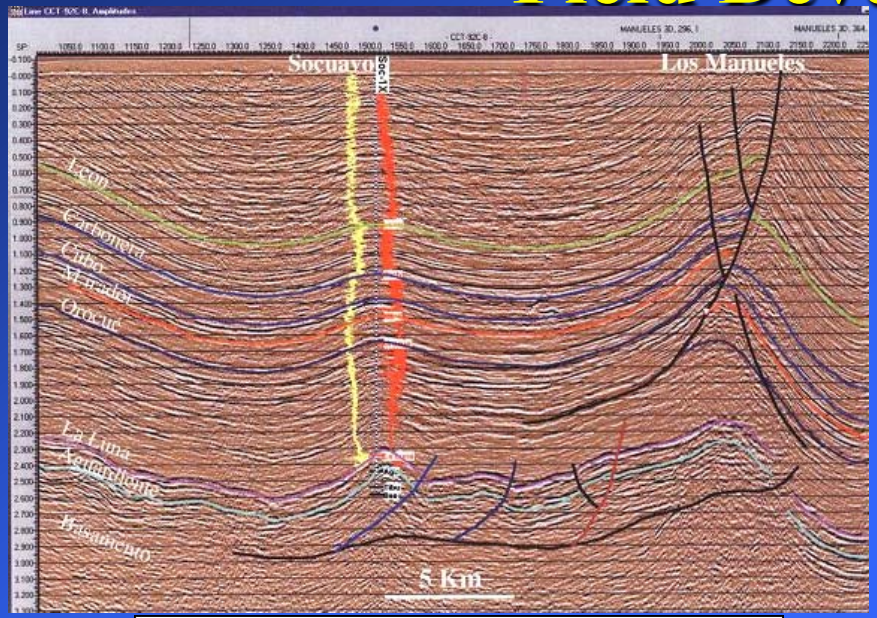
Offshore, Gulf of Mexico

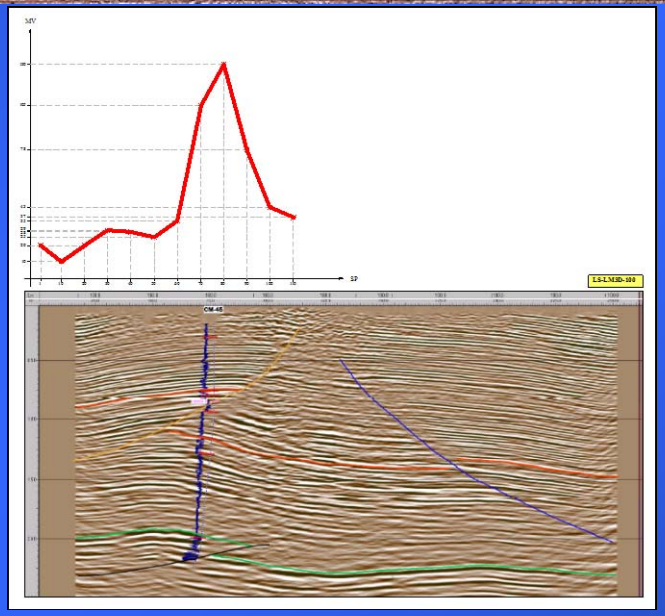


Eastern Venezuela Basin
Prospect Evaluation



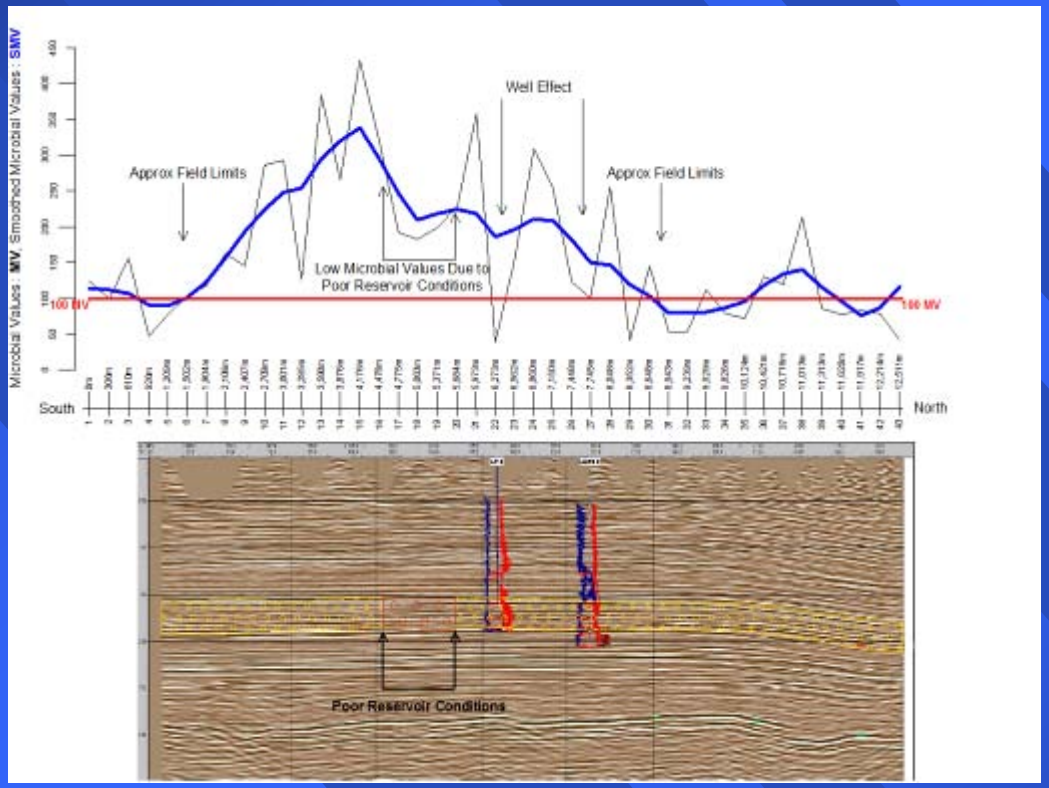
Western Venezuela
Field Development





Field Development and Production

Early delineation of field limits



Hydrocarbon microseepage profile and seismic section across a recent discovery in western Venezuela. This is an example of a surface geochemical anomaly associated with an oil field that is just beginning to be developed. Geochemical samples were collected at 300m intervals along seismic lines to identify the probable limits of the productive reservoir. The most prospective area for future drilling occurs left of the wells. Also note the low seepage values in the immediate vicinity of the 2 producing wells, This is due to depressurization of the reservoir due to production

CONCLUSIONS

- Remote sensing methods enable rapid screening of very large areas for presence of hydrocarbon-induced alteration of soils and sediments.
- Non-invasive surface geochemical methods (soil gas and microbial) can provide direct evidence of hydrocarbon generation and migration, and can discriminate between charged and uncharged traps. These methods should also be used to "ground-truth" remote sensing anomalies.

CONCLUSIONS

- **Proper use of remote sensing and surface geochemical methods in environmentally sensitive areas can identify those areas with the highest petroleum potential.**
- **Such an exploration strategy will protect the greater part of such areas from more invasive exploration methods by focusing exploration on a smaller number of high potential areas.**