# Non-Seismic Detection of Hydrocarbons*

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Editor's note: This is a sequel to other Search and Discovery articles by the author: PS Recognizing Non-Seismic Detection of Hydrocarbons: An Overview, Search and Discovery article #40392 (2009); When 3-D Seismic Is Not Enough: Improving Success by Integrating Hydrocarbon Microseepage Data with 3-D Seismic Data, Search and Discovery article #40556 (2010); Petroleum Exploration in Environmentally Sensitive Areas: Opportunities for Geochemical and Non-Seismic Geophysical Models, Search and Discovery article #40681 (2011); and Hydrocarbon Exploration Survey Strategies for Frontier Basins and Other Underexplored Areas, Search and Discovery article #10292 (2011).

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## Abstract

Seismic data are unsurpassed for imaging trap and reservoir geometry; however, in many geological settings seismic data yield no information about whether a trap is charged with hydrocarbons. In other settings, the quality of seismic data is poor due to unfavorable geology or surface conditions.

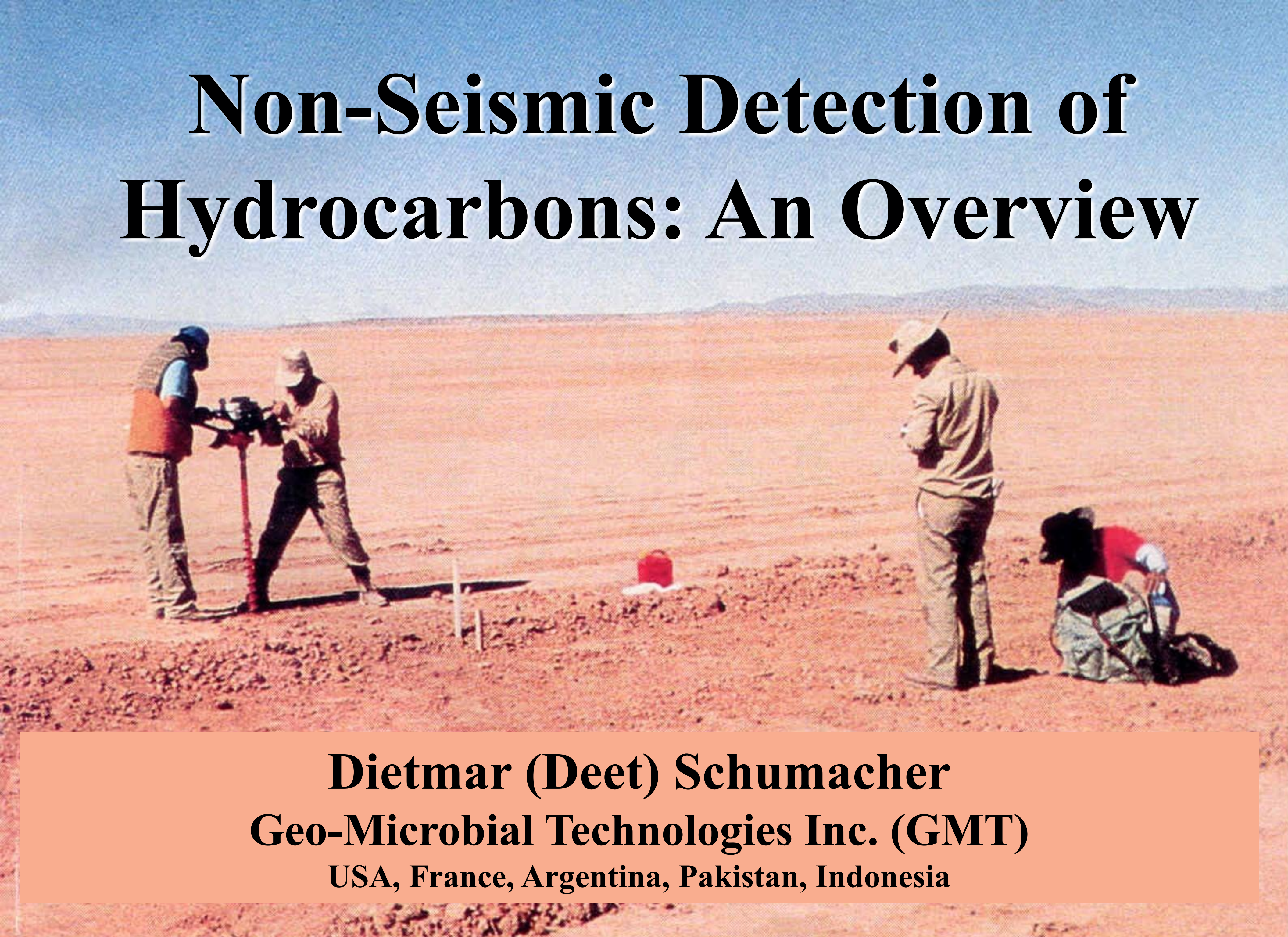
The surface manifestations of hydrocarbon seepage and microseepage can take many forms, including (1) anomalous hydrocarbon concentrations in sediments; (2) microbiological anomalies; (3) mineralogic changes such as the formation of calcite, pyrite, uranium, elemental sulfur, and certain magnetic iron oxides and sulfides; (4) bleaching of red beds; (5) clay-mineral changes; (6) acoustic anomalies; (7) electrochemical changes; (8) radiation anomalies; and (9) biogeochemical and geobotanical anomalies. These varied expressions of hydrocarbon seepage have led to the development and marketing of an equally diverse number of hydrocarbon-detection methods. These include direct and indirect surface chemical methods, magnetic and electrical methods, radioactivity-based methods, and satellite remote-sensing methods. Each has its proponents; each claims success; and all compete for the explorationists' attention and dollars. Is it any wonder explorationists are confused, or at least skeptical?

What are the benefits of using geochemical and non-seismic geophysical hydrocarbon detection methods in conjunction with conventional exploration methods? A review of more than 2600 US and International wildcat wells – all drilled after completion of geochemical or non-seismic geophysical hydrocarbon detection surveys – more than 80% of wells drilled on prospects associated with positive hydrocarbon

microseepage anomalies resulted in commercial discoveries. In contrast, only 11% of wells drilled on prospects without such anomalies resulted in oil or gas discoveries.

Clearly, the benefits of such hydrocarbon detection surveys are significant. Although these geochemical and non-seismic methods cannot replace conventional exploration methods, they can be a powerful complement to them. The need for such an integrated exploration strategy cannot be overemphasized. This presentation is illustrated with examples from surface geochemical surveys, aeromagnetics/micromagnetic surveys, passive and active electromagnetic data, and satellite remote-sensing data.

# Non-Seismic Detection of Hydrocarbons: An Overview



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**USA, France, Argentina, Pakistan, Indonesia**

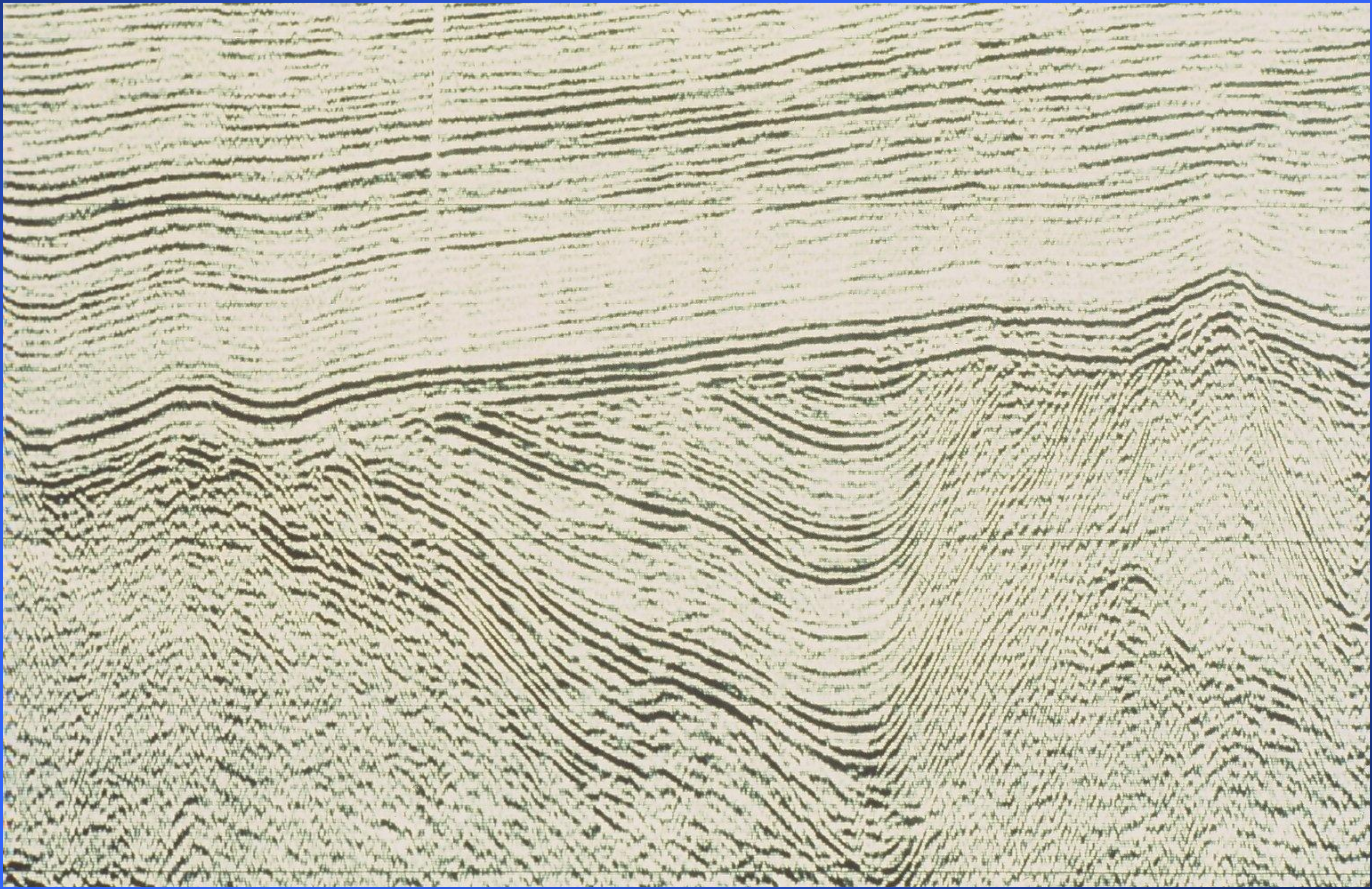
# OUTLINE

- Why Hydrocarbon Detection Methods
    - Basics and Benefits
- Microseepage Model
- Geochemical and Non-Seismic Methods
- Survey Objectives and Survey Design
- Selected Examples – Surface Geochemistry,
- Remote Sensing, Micromagnetics, EM
- Conclusions

# 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.

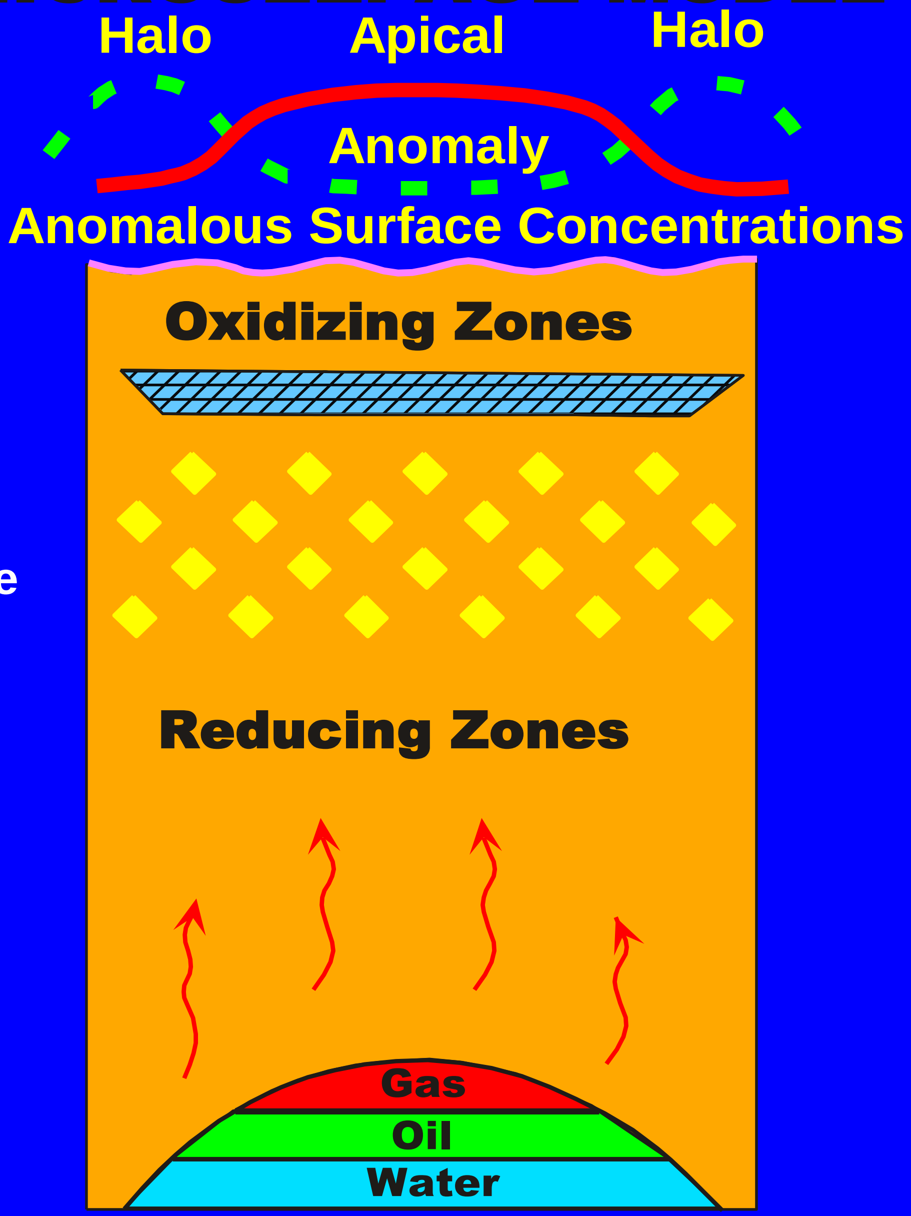
# Conventional vs Unconventional
# Finding Traps vs Finding Hydrocarbons



# Why Use Hydrocarbon Microseepage Exploration Methods

- Most Productive Basins Leak Hydrocarbons
- Most Accumulations Leak Hydrocarbons
- Leakage is Predominantly Vertical, Dynamic
- Provides Direct Detection of Hydrocarbons
- Detect Hydrocarbon-Induced Alterations
- Minimal Environmental Impact
- Prospects with Seepage Anomaly are 4-6 times more likely to result in a commercial 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

# Microseepage-Based Exploration Methods

## Direct Detection

Soil Gas

- Interstitial, Headspace

Adsorbed Soil Gas

Aromatics/Fluorescence

Heavy Hydrocarbons, C10+

"Sniffers" and Lasers

Oil Slick Detection

## Indirect Detection

Microbial

Radiometrics

Helium, Radon

Iodine

Trace Elements

Remote Sensing

Electrical

Magnetic

# EFFECTIVE IN ALL ENVIRONMENTS


# Survey Objectives

Document Presence of Petroleum System(s)

Characteristics of the Petroleum System(s)
Age, Facies, Maturity, Oil vs Gas, etc.

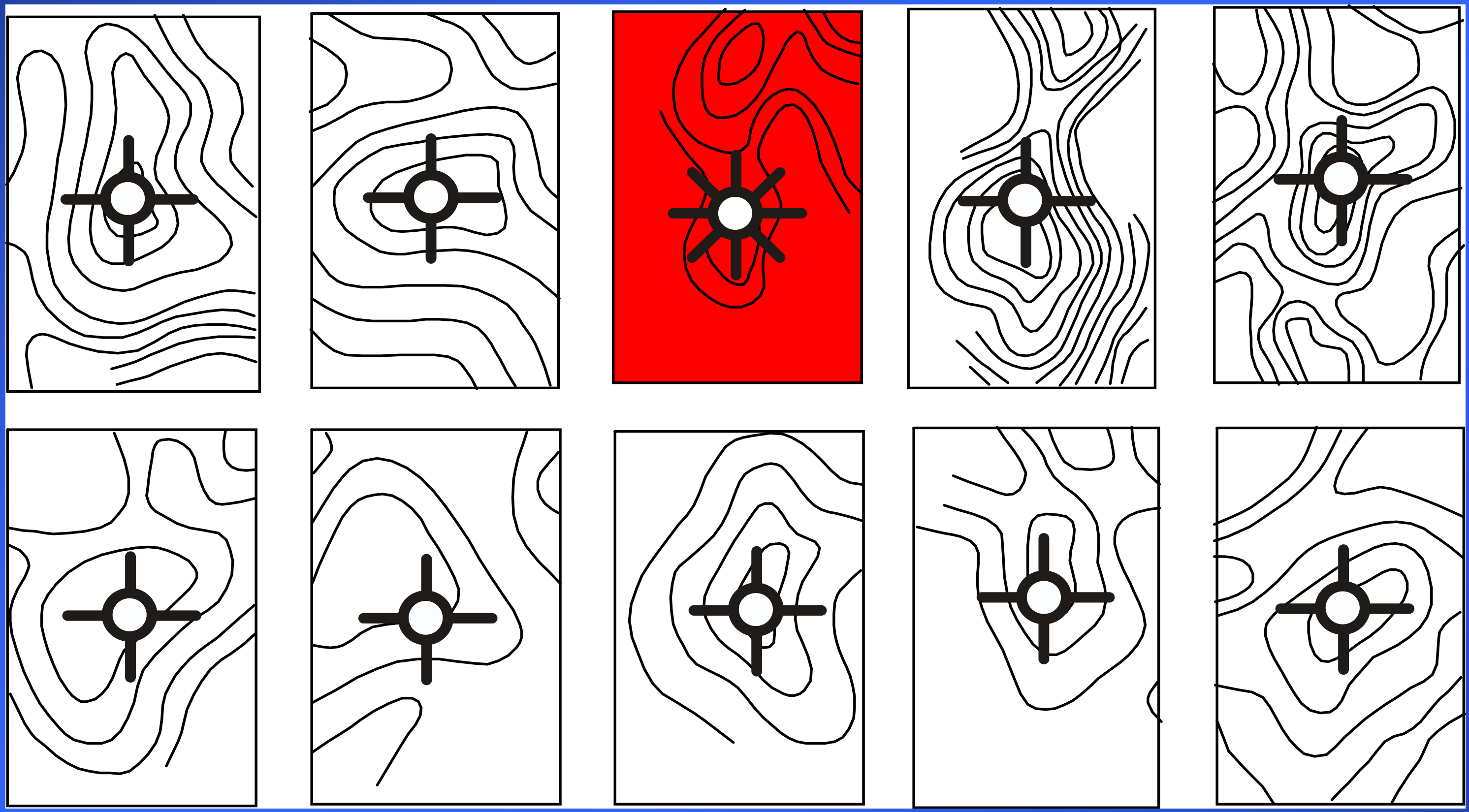
High-Grade Leads and Prospects on Basis of
Likely Hydrocarbon Charge

Guide Location of Future Seismic Surveys

# Survey Design Considerations

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

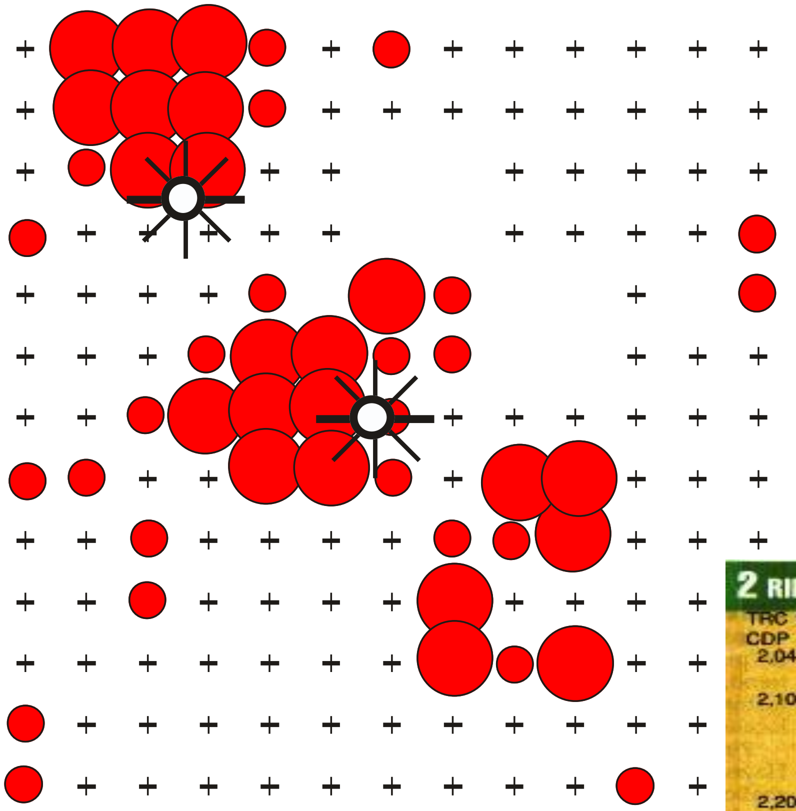
# Surface Geochemical Survey using Microbial Method, Denver Basin, USA



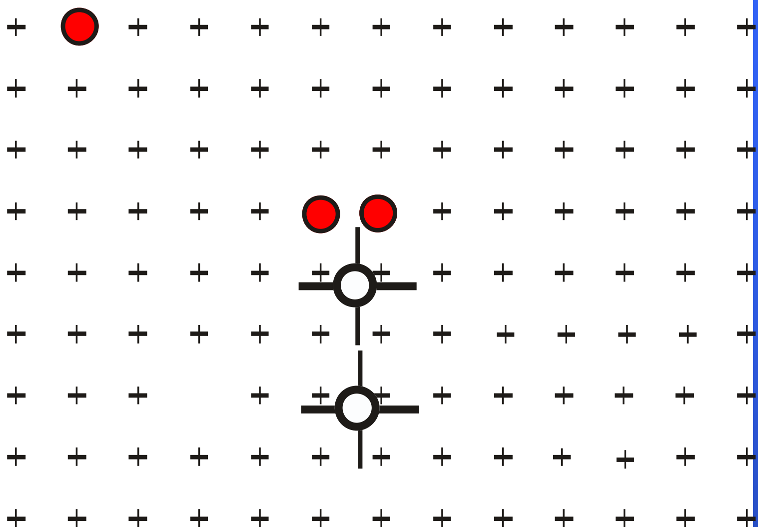
**Only One of These 10 Seismic Prospects Resulted in a Producer. It was the Only Prospect with a Surface Geochemical Anomaly.**

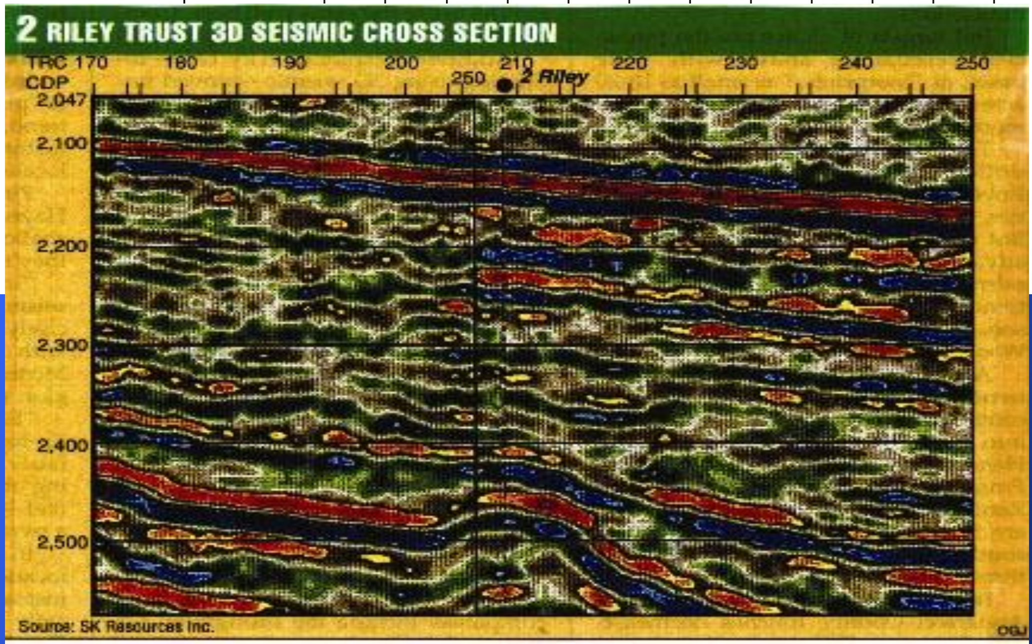
# Jurassic Pinnacle Reefs, East Texas, Depth 5000 m, Microbial Method

*Area A -- Producing Reef Prospects*

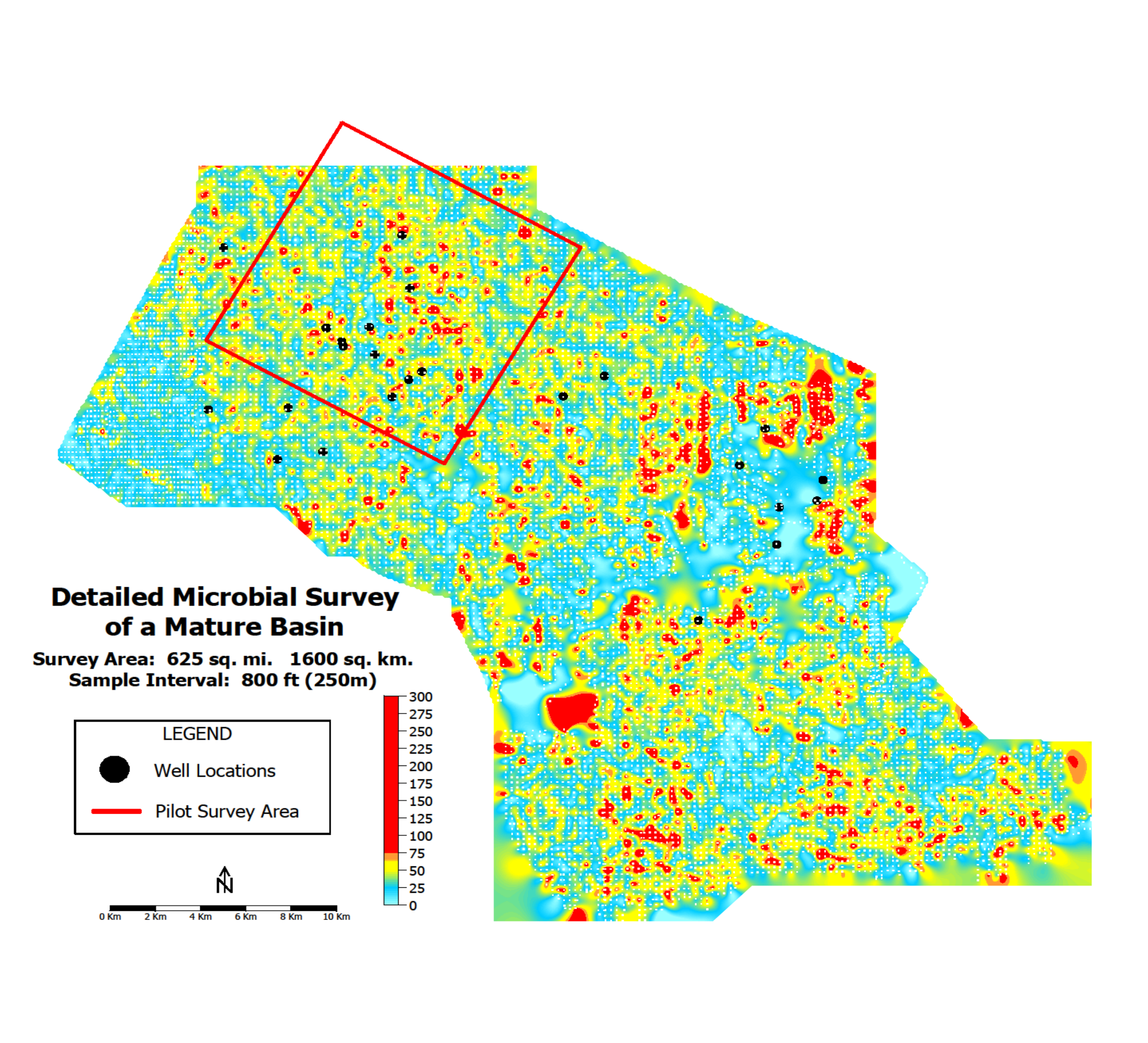


*Area C -- Dry Hole Reef*



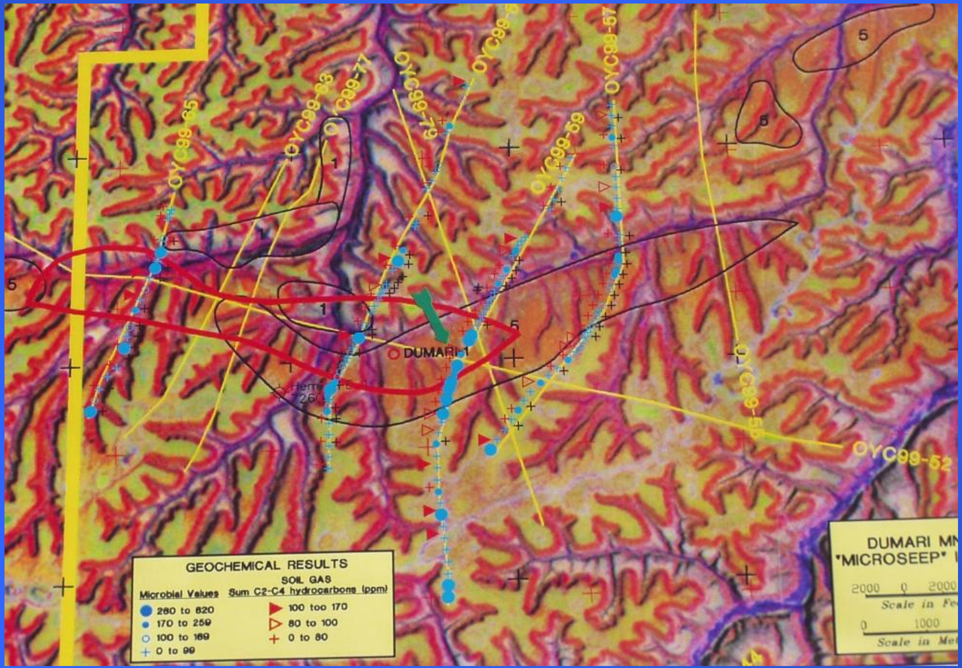


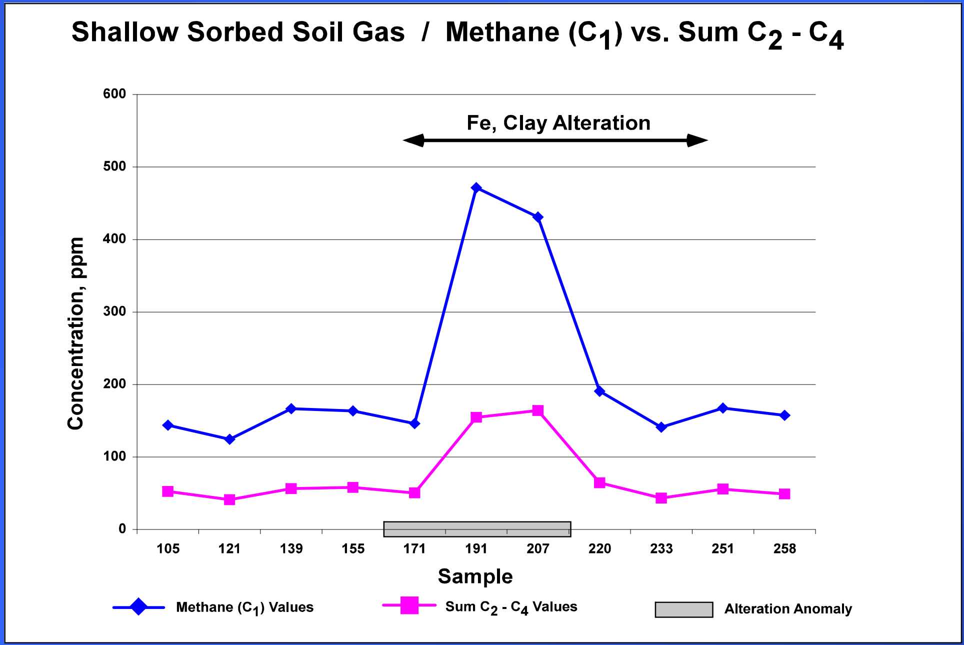
# Eastern Slovak Basin, Microbial Survey

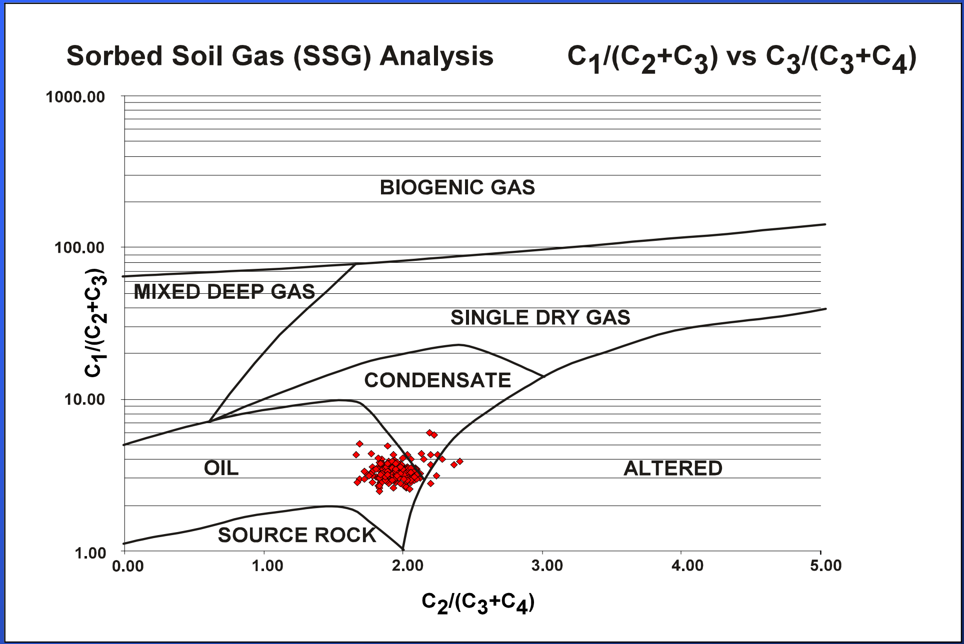


# Yemen, Masila Basin

## Remote Sensing and Surface Geochemistry

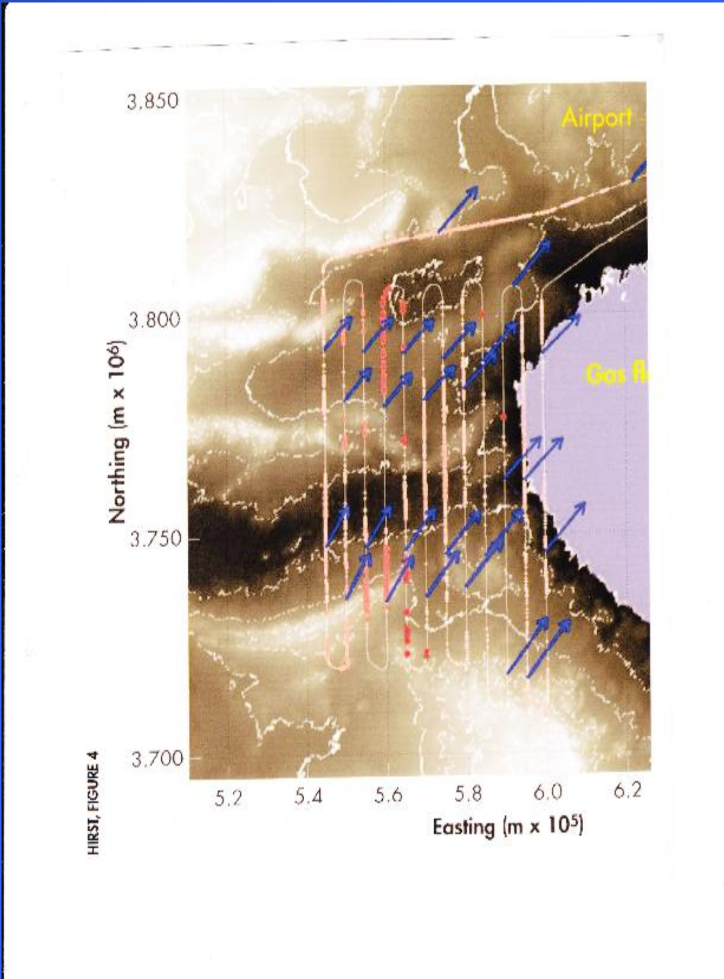


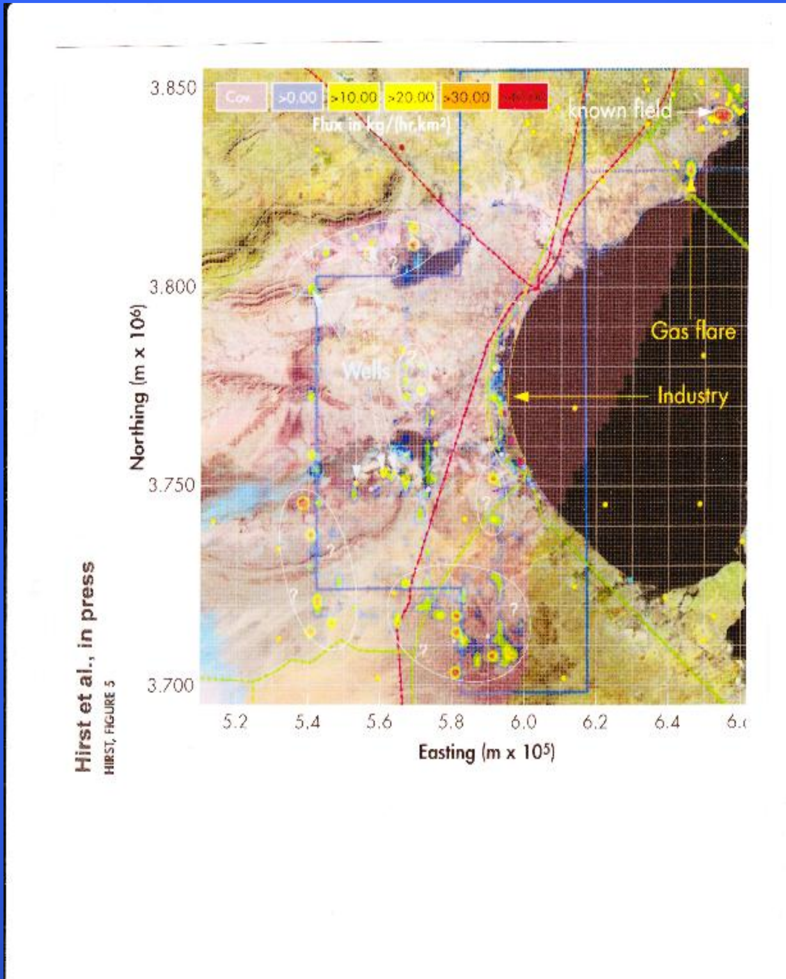



# Remote Sensing
## Airborne Hydrocarbon Detection
## Shell's "Light Touch" Methane Laser

### Tunisia, Flight Lines



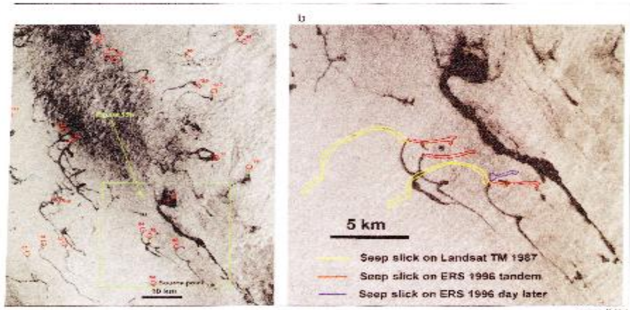

### Tunisia, Methane Flux



# Remote Sensing

## Satellite Detection of Oil Slicks

### South Caspian Basin, Azerbaijan




South Caspian Basin, typical seepage slicks (rank 1). (a) Multiple, repeating seeps; (b) multitemporal re

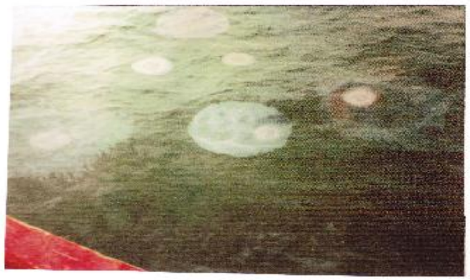
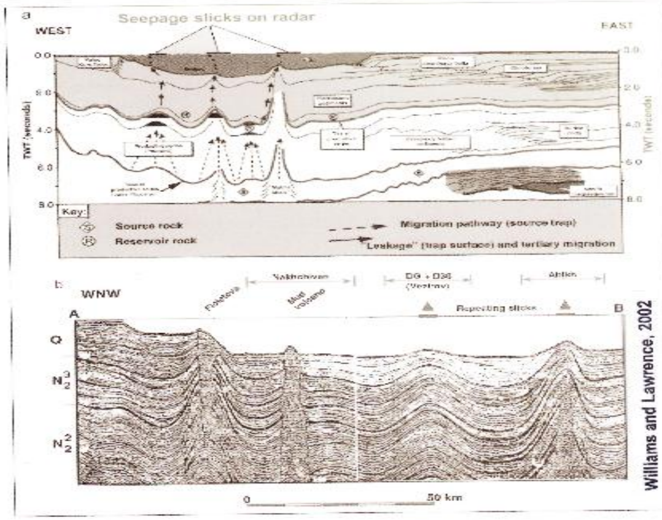


**FIGURE 16.** Surfacing oil bubbles, South Caspian Sea.

Williams and Lawrence, 2002




Williams and Lawrence, 2002

# Seep-Induced Magnetic Anomalies

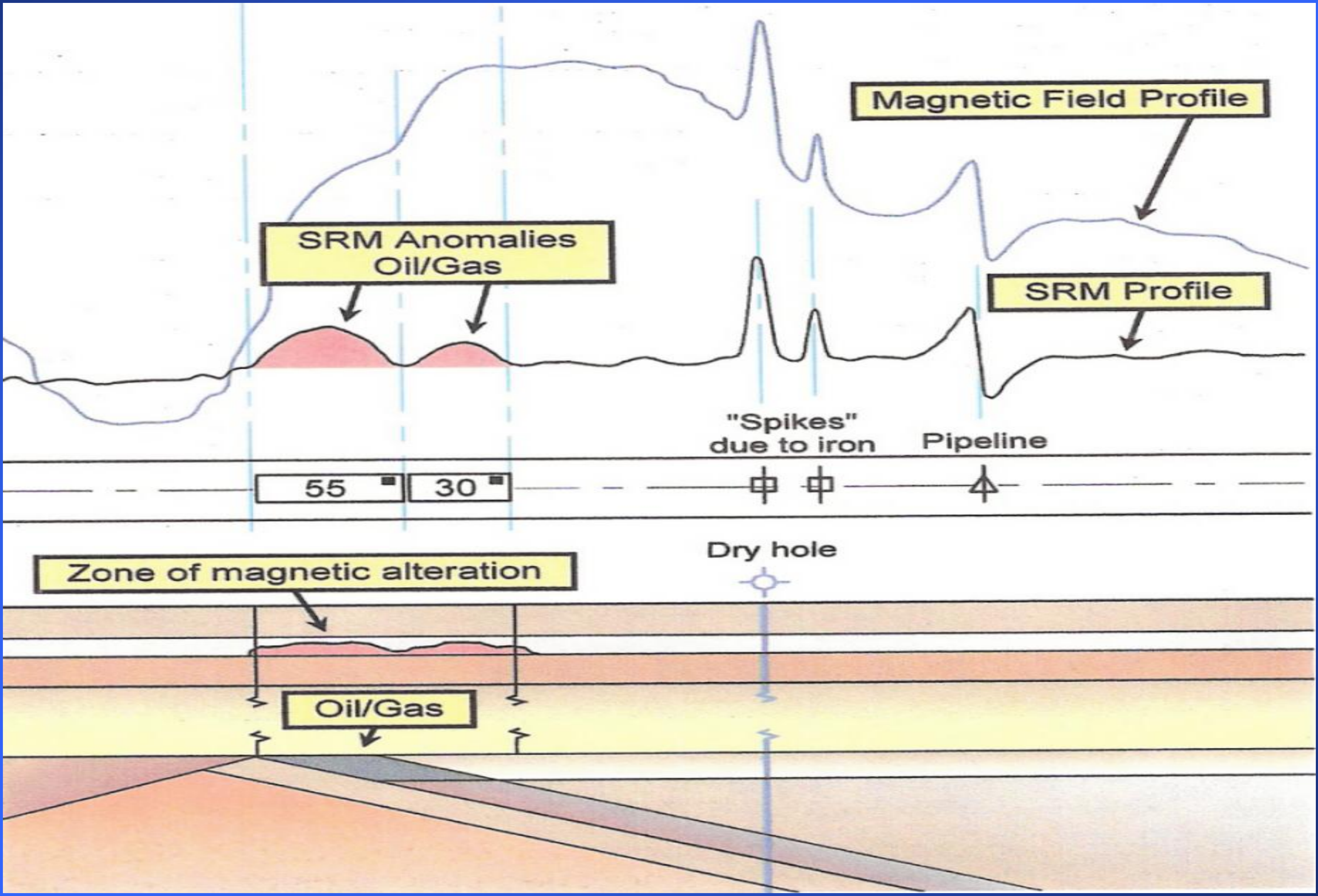
## Conventional Magnetics

Analysis of long wavelength anomalies due to crystalline (magnetic) basement

## Micromagnetics

Analysis of short wavelength, small amplitude magnetic anomalies associated with near-surface magnetic sources

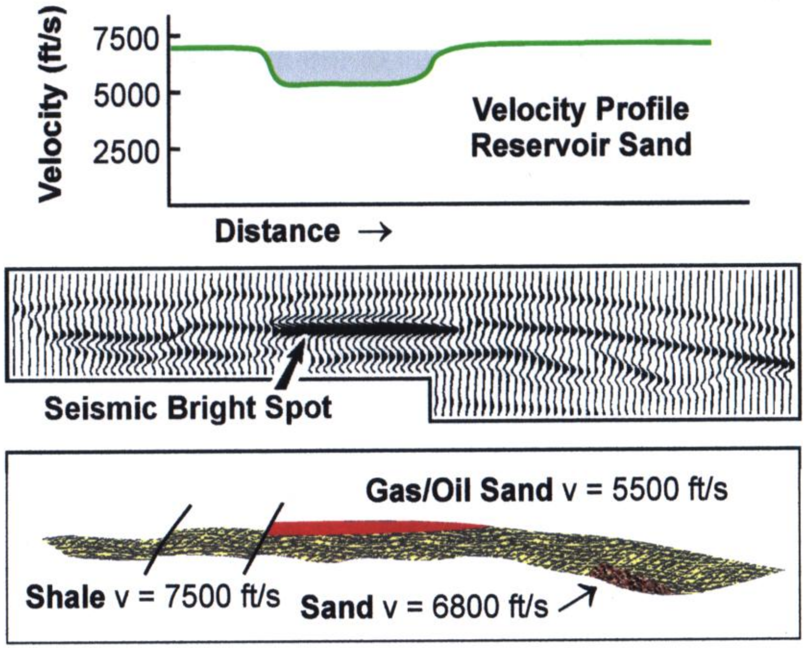
# Aeromagnetic SRM Data Interpretation



# Magnetic Bright Spot (MBS)

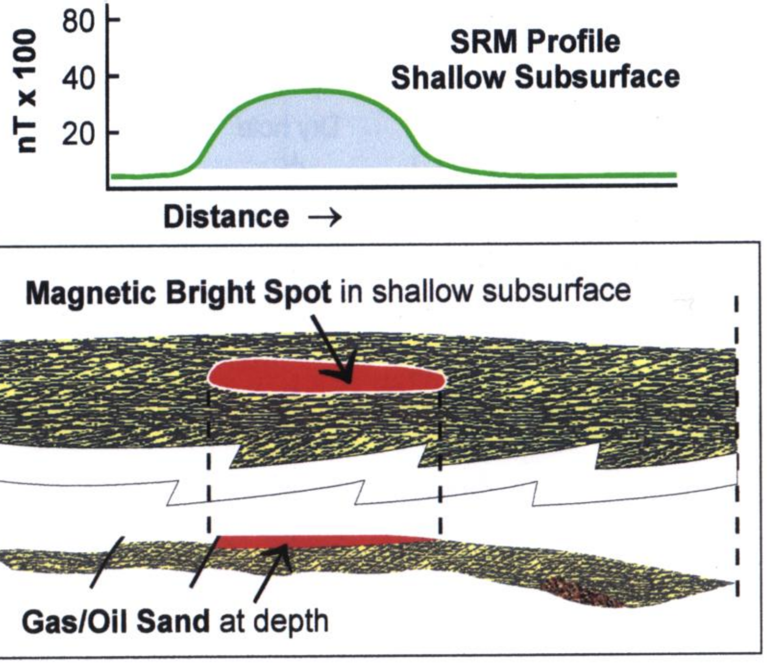
## Seismic Bright Spot Origin

A regional gas-saturated sand body slows the seismic wave front to create a seismic bright spot, and processing determines the depth to the sands. Seismic bright spots do not indicate presence of oil.

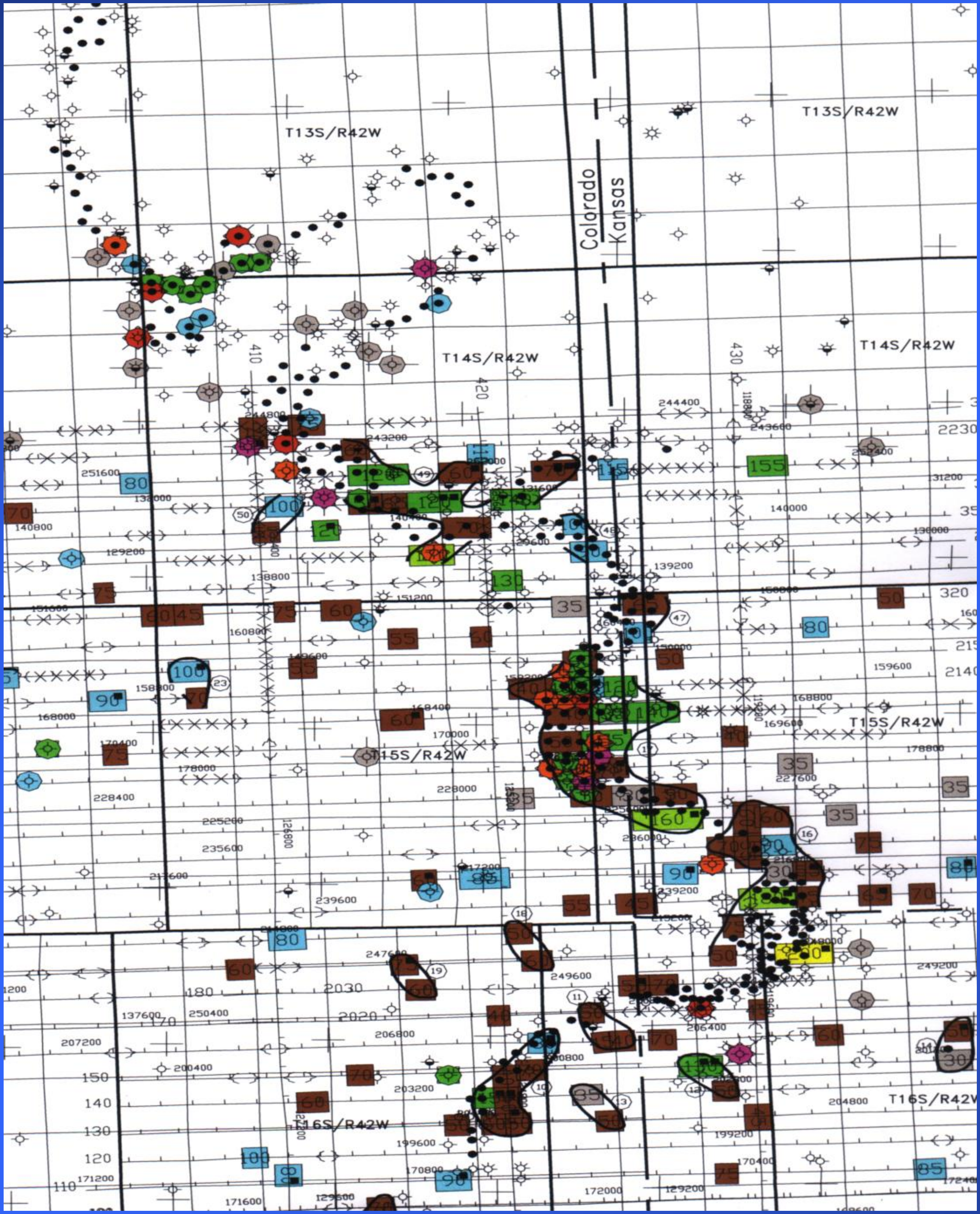



## Magnetic Bright Spot Origin

A zone of magnetically-altered minerals directly above a regional hydrocarbon deposit (whether oil or gas) is detectable from the air as a magnetic bright spot. A surface map of the MBS reveals the location of the oil or gas deposit, although its depth is not indicated.



# Stateline Morrow Trend, Colorado-Kansas

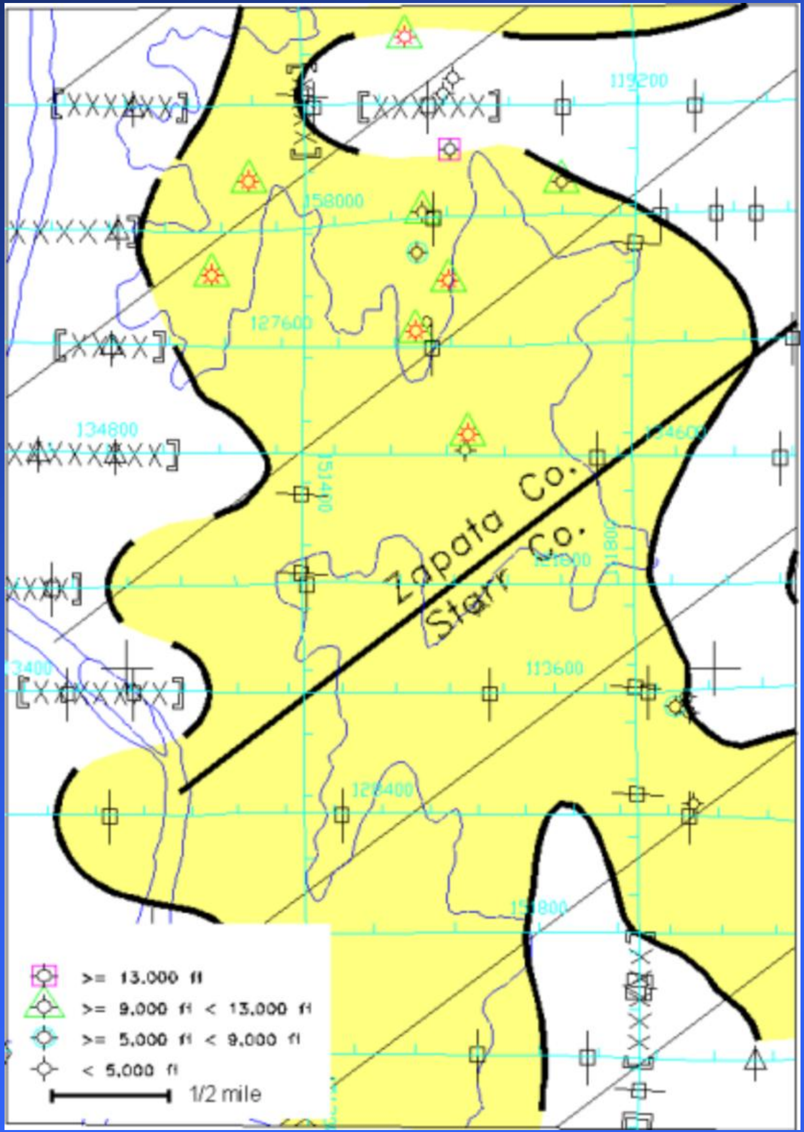



**Seep-Induced MagneticAnomalies**

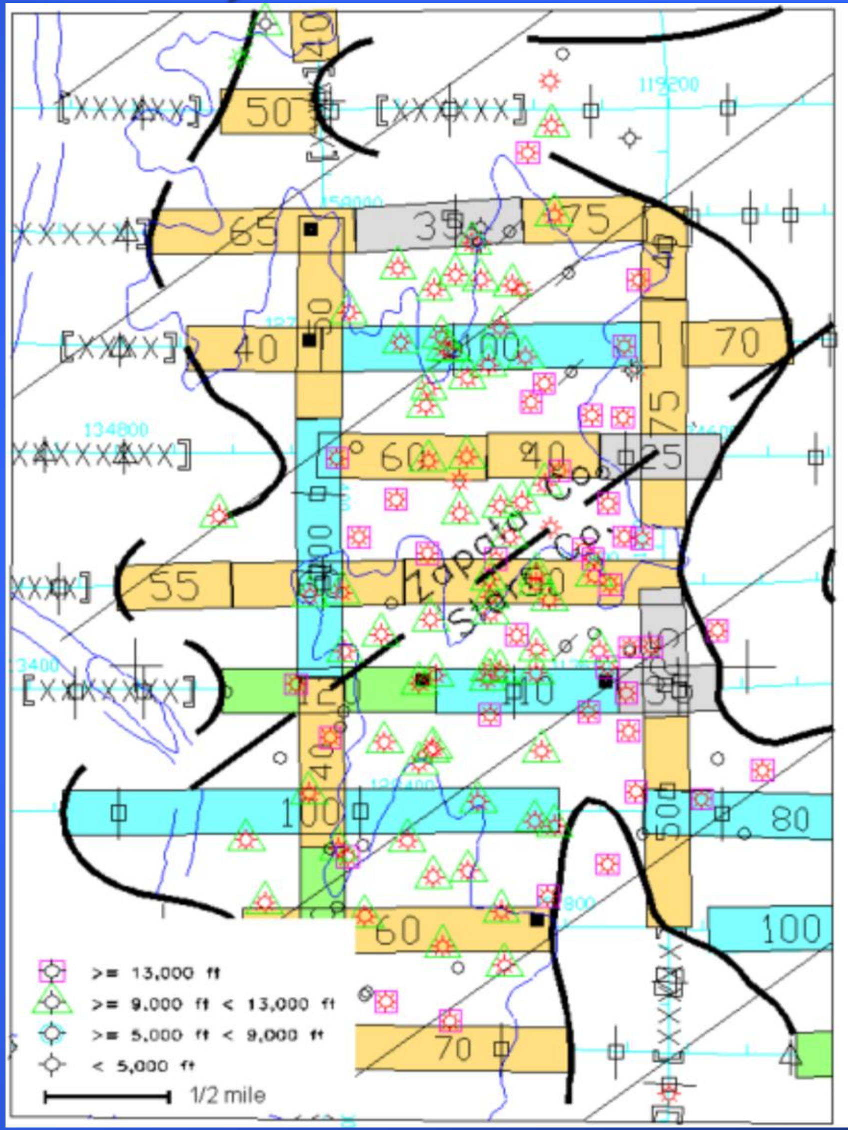
**Area, 600 sq km**

**Carboniferous Fluvial Sandstone**

# Bob West Field Area, Texas



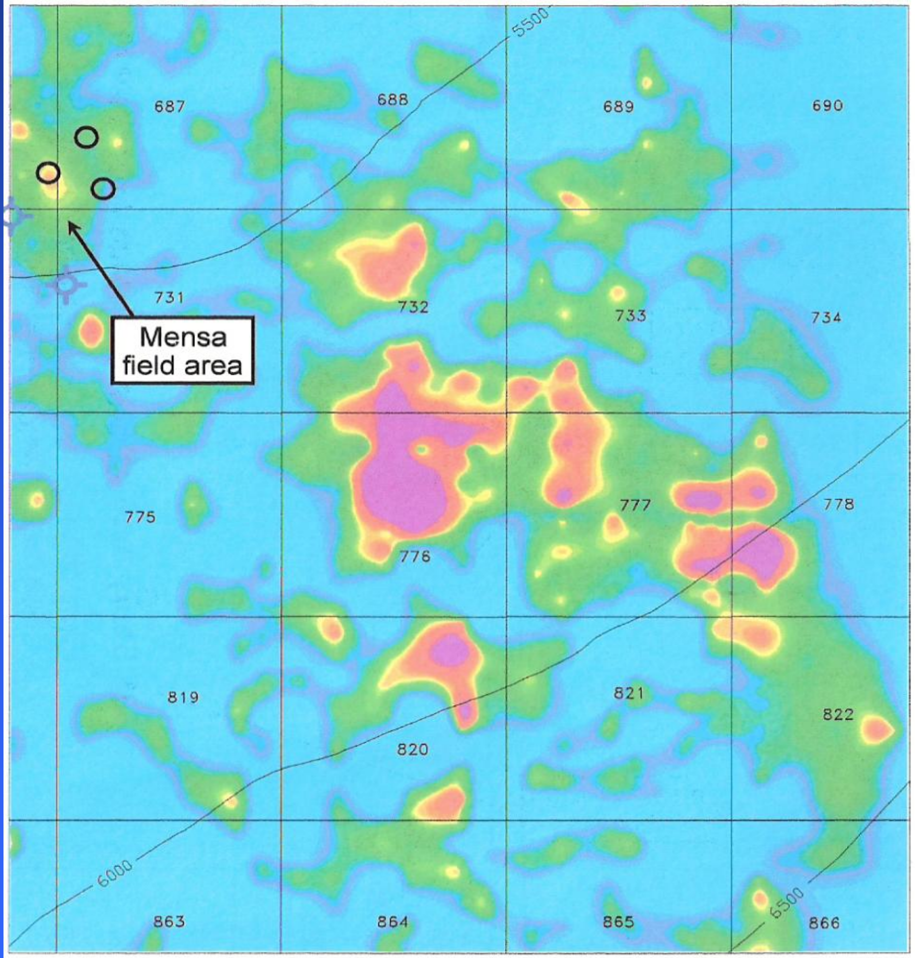

Bob West Field Area, December 1985, Showing Drilling Status and Magnetic Bright Spot Outline



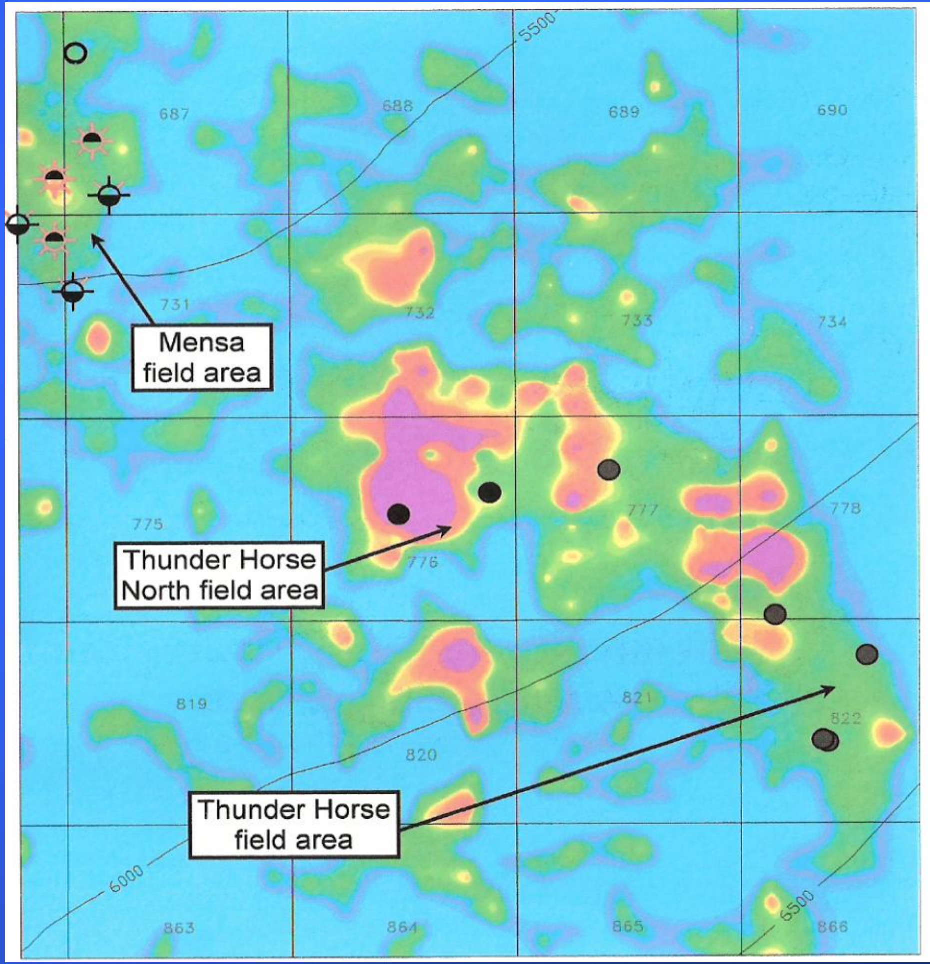

Bob West Deep Wilcox Gas Field (1990), December 1986 to April 1997 showing SRM and MBS anomalies from 1985 Aeromagnetic Data

# Seep-Induced Magnetic Anomalies

## Mensa and Thunder Horse Fields
## Mississippi Canyon Area, Gulf of Mexico
## Water Depth: 1675 – 1980 m (5500 – 6500 ft)




1990




2003

# Electrical and Electromagnetic Methods

**To Detect Seep-Induced Alteration and/or Resistive Reservoirs**

**IP, Induced Potential**
**CSAMT, Controlled Source Audiomagnetotellurics**
**CSEM, Marine Controlled Source Electromagnetics**
**MTEM, Multitransient Electromagnetics**
**AEM, Airborne Electromagnetics**

**Passive Electromagnetics**
**Passive Tellurics**
**Passive Airborne Transient Pulse Surveys**

# Passive Electromagnetics
# "Power Imaging"

--Uses EM field generated by the power grid (50 or 60 cycles).

--EM waves propagate as plane waves and encounter the various geologic boundaries.

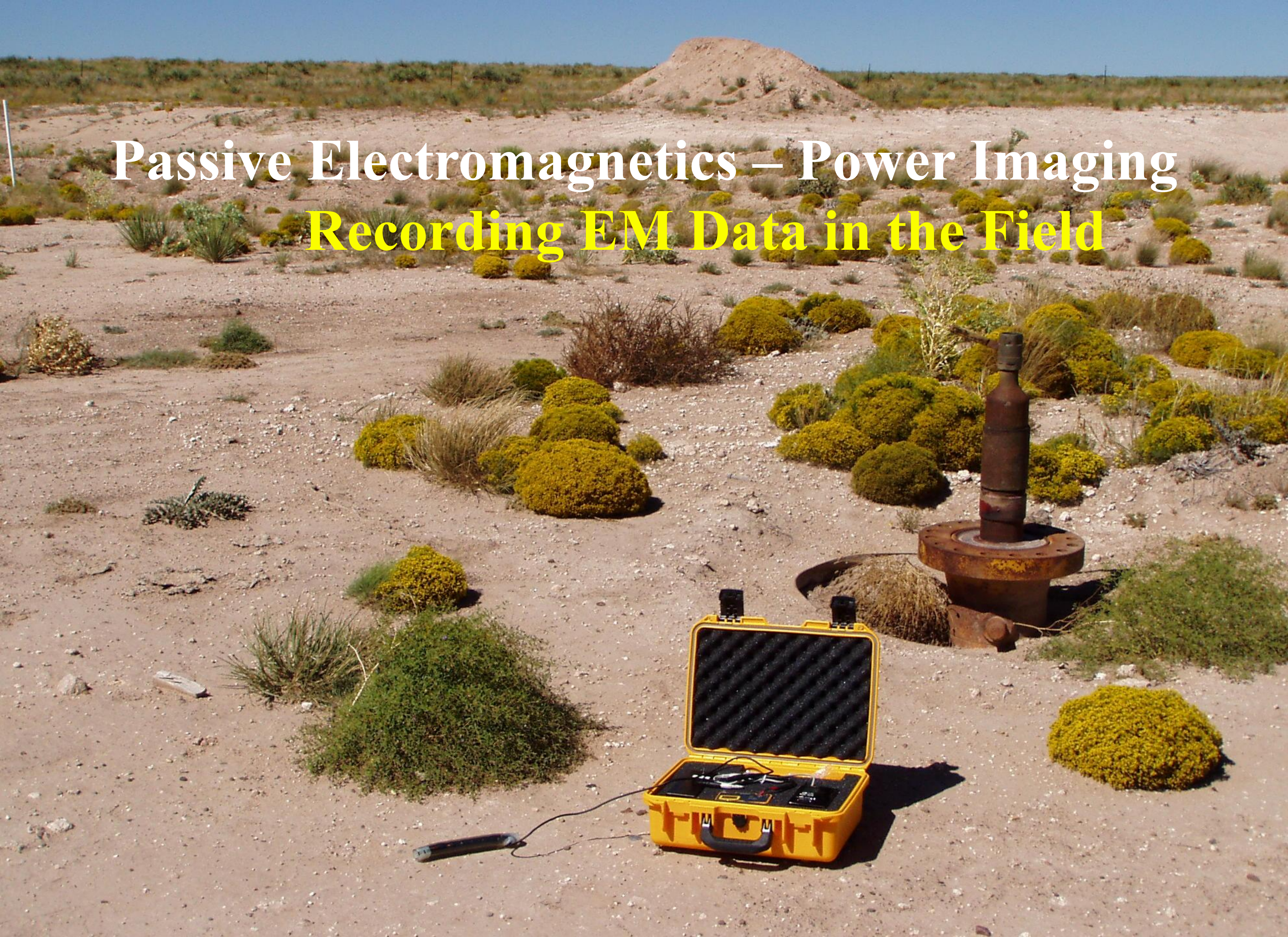
--Boundaries with distinct dielectric or conductivity contrast reflect a portion of the waves back to surface.

--Contrast between hc-bearing strata and surrounding rocks yield a distinctive response, the Electromagnetic Hydrocarbon Indicator (EHI)

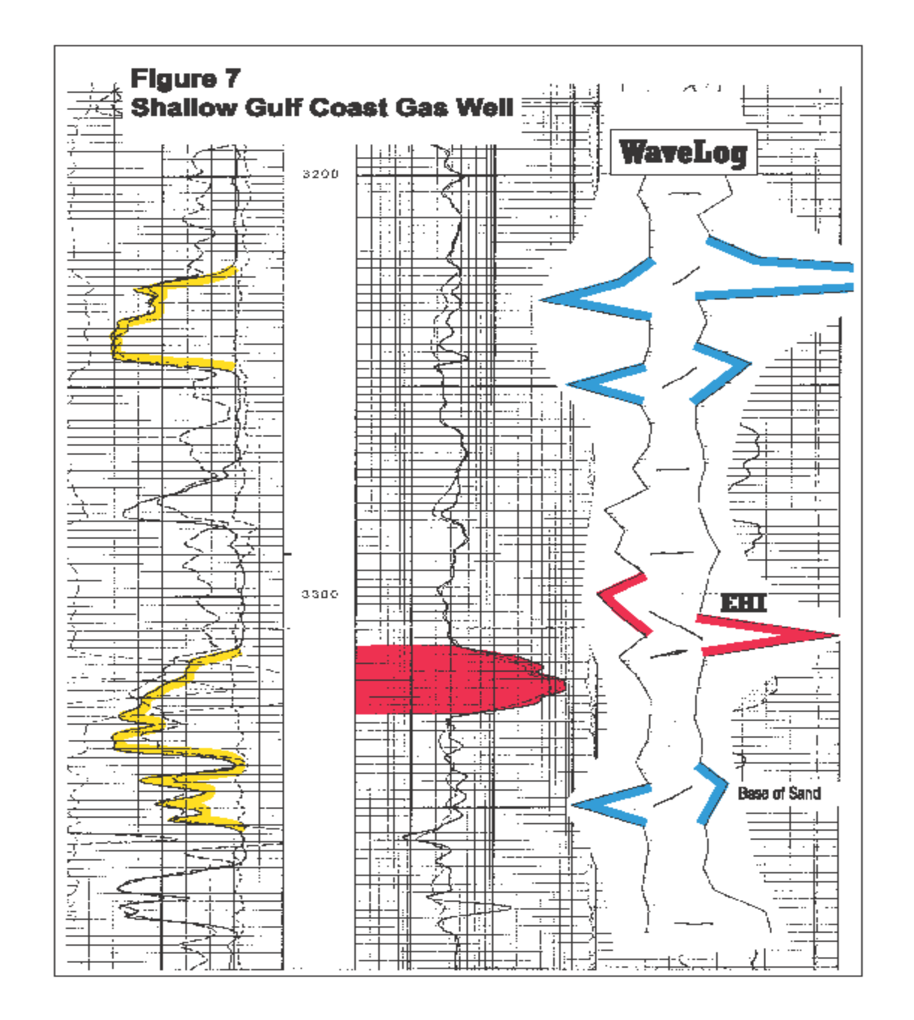
--Depth of investigation is 300m to 5000m

--Depth resolution claimed to be +/- 7 to 10 meters

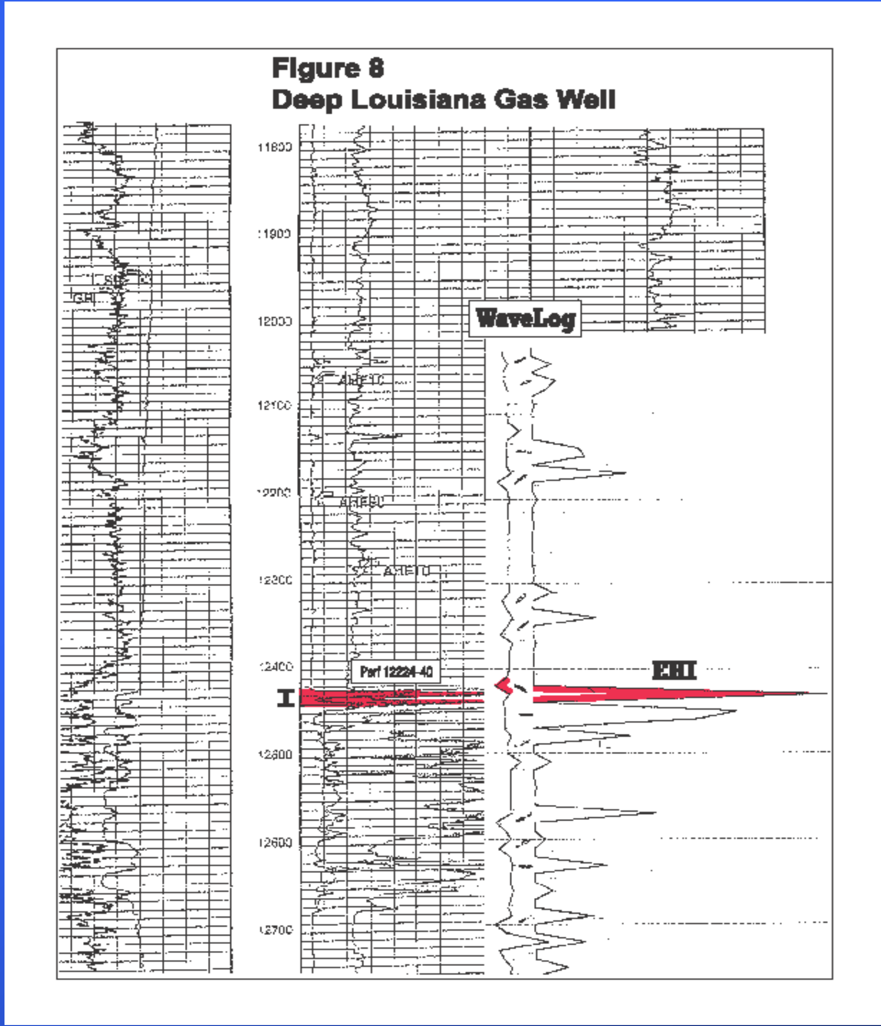
--Developed by Wave Technology Group, Houston TX


Passive Electromagnetics – Power Imaging
Recording EM Data in the Field

# Passive Electromagnetics "Power Imaging"




Shallow Oil, 1012 m




Deep Gas, 3788 m

# Conclusions

Variety of remote sensing, geochemical, and non-seismic geophysical methods available

Document presence of petroleum system(s)

High-grade basin or concession based on its hydrocarbon potential

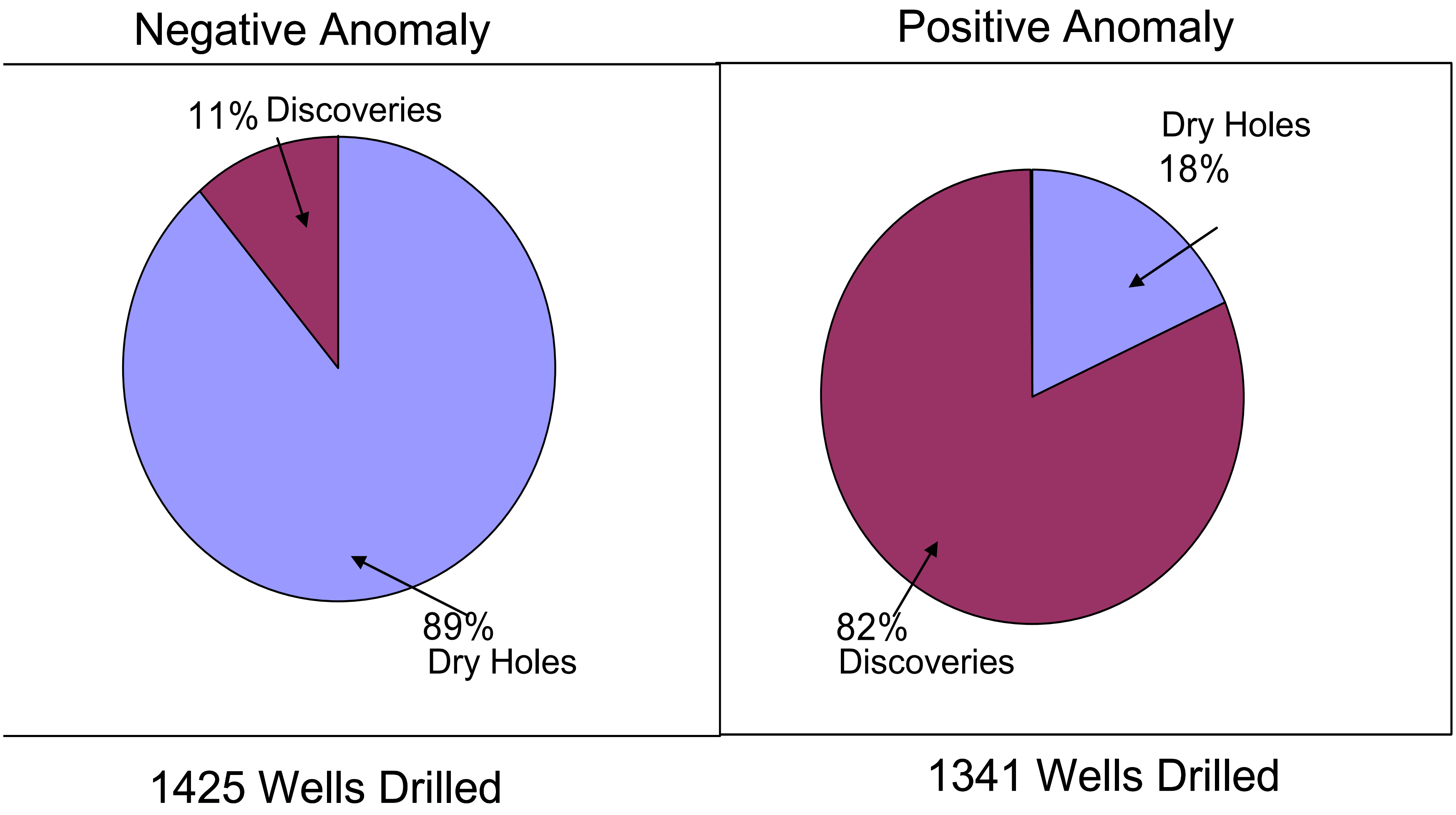
Identify priority targets for future seismic surveys

Prospects with associated seepage anomaly 4-6 times more likely to result in an oil/gas discovery

# Improving Exploration Success

**Summary**

**2766 Wells, Various Companies, Various Basins, Various methods**



# NO MORE DRY HOLES ? !