Hydrocarbon Microseepage--A Significant but Underutilized Geologic Principle with Broad Applications for Oil/Gas Exploration and Production*

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Abstract

It is well documented that mature source rocks and most oil and gas accumulations leak hydrocarbons,that this leakage (or microseepage)is widespread, predominantly vertical, and is dynamic. Hydrocarbon microseepage occurs in all petroleum basins and forms the basis for most geochemical, microbiological, and non-seismic geophysical hydrocarbon detection methods.

The surface manifestations of hydrocarbon microseepage can take many forms, including:

(1) anomalous hydrocarbon concentrations in soils, sediments, waters, and atmosphere;
(2) microbiological anomalies;
(3)mineralogic changes such as formation of calcite, pyrite, uranium, elemental sulfur, and magnetic iron oxides and sulfides;
(4)bleaching of redbeds;
(5) clay-mineral changes;
(6)acoustic anomalies;
(7) radiation anomalies;
(8) electrochemical changes;
(9)biogeochemical changes and geobotanical anomalies.

Applications of hydrocarbon microseepage to petroleum exploration and production include:

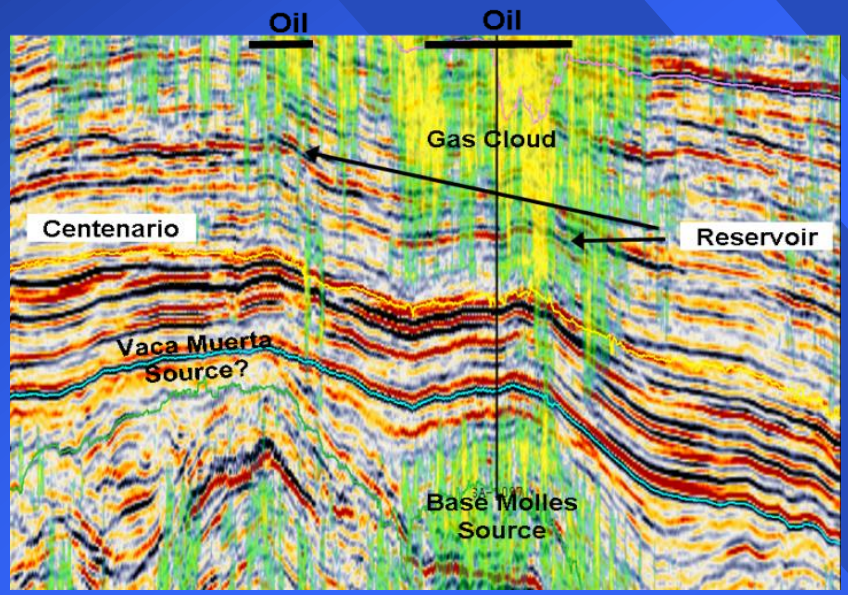
(1) documenting that oil/gas has been generated in frontier basins;
(2) high-grading leads and prospects on basis of likely hydrocarbon charge;
(3) identifying presence of by-passed pay in old or abandoned fields;
(4) monitoring hydrocarbon drainage due to production in producing fields or waterfloods;

(5) identifying sweet spots in unconventional resource plays.

Seismic data will continue to be unsurpassed for imaging trap and reservoir geometry, but in many geologic settings seismic yields no information about whether a trap is charged with hydrocarbons. A review of 2700 US and international exploration wells - all drilled after completion of microseepage surveys - documents that 82% of wells on prospects with a microseepage anomaly were completed as oil or gas discoveries; in contrast, only 11% of wells drilled on prospects with no associated seepage anomaly resulted in a discovery. When hydrocarbon microseepage data is properly acquired and interpreted, it can significantly reduce exploration risks and costs by improving success rates and shortening development time.

Hydrocarbon Microseepage --

A Significant but Underutilized Geologic Principle with Broad Applications for Oil/Gas Exploration and Production



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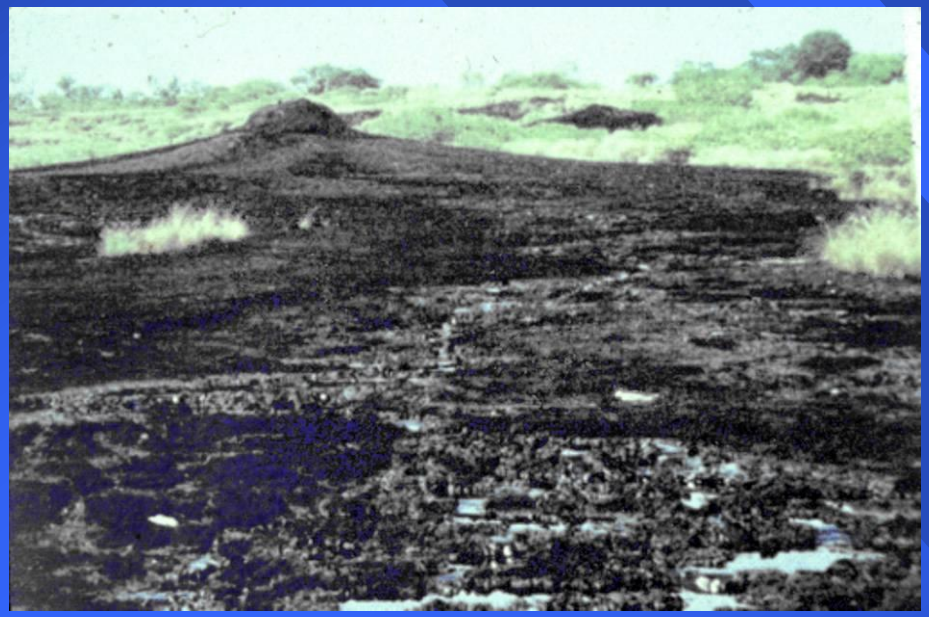
OUTLINE

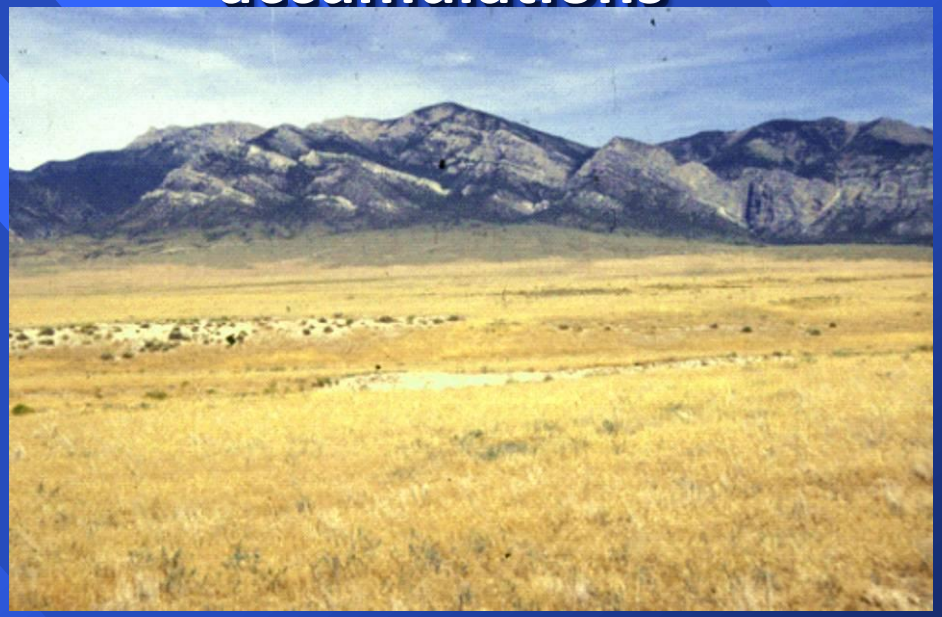
- Evidence for Microseepage
  - Geochemical, Geophysical
- Characteristics of Microseepage
- Hydrocarbon Detection Methods
- Survey Objectives, Survey Design
- Selected Exploration & Development Examples
- Measuring Success
- Summary

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



Evidence for Hydrocarbon Microseepage

Increase in non-methane hydrocarbons as reservoir is approached during drilling and mud-logging

Increase in soil-gas concentrations and soil-gas ratios (C2/C1, C3/C1, and C4/C1) over hydrocarbon reservoirs

Sharp lateral changes in soil-gas concentrations and soil-gas ratios at edge of surface projection of the reservoir

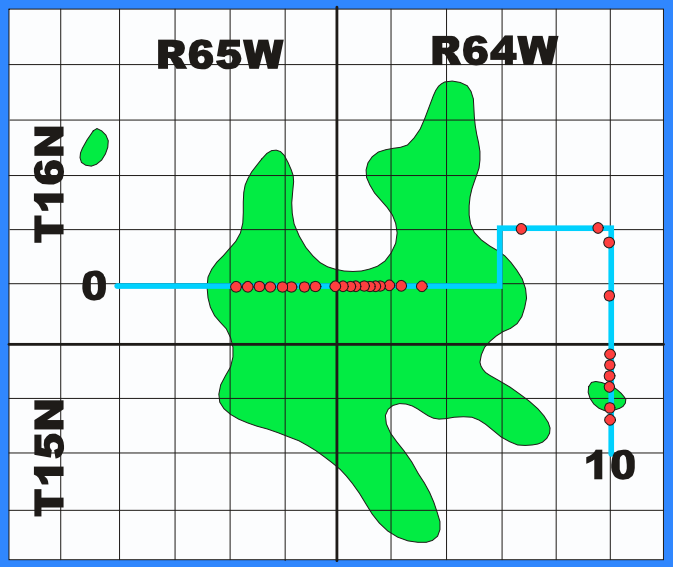
Stable carbon isotopic ratios for methane in soil gases which are similar to those found in hydrocarbon reservoirs

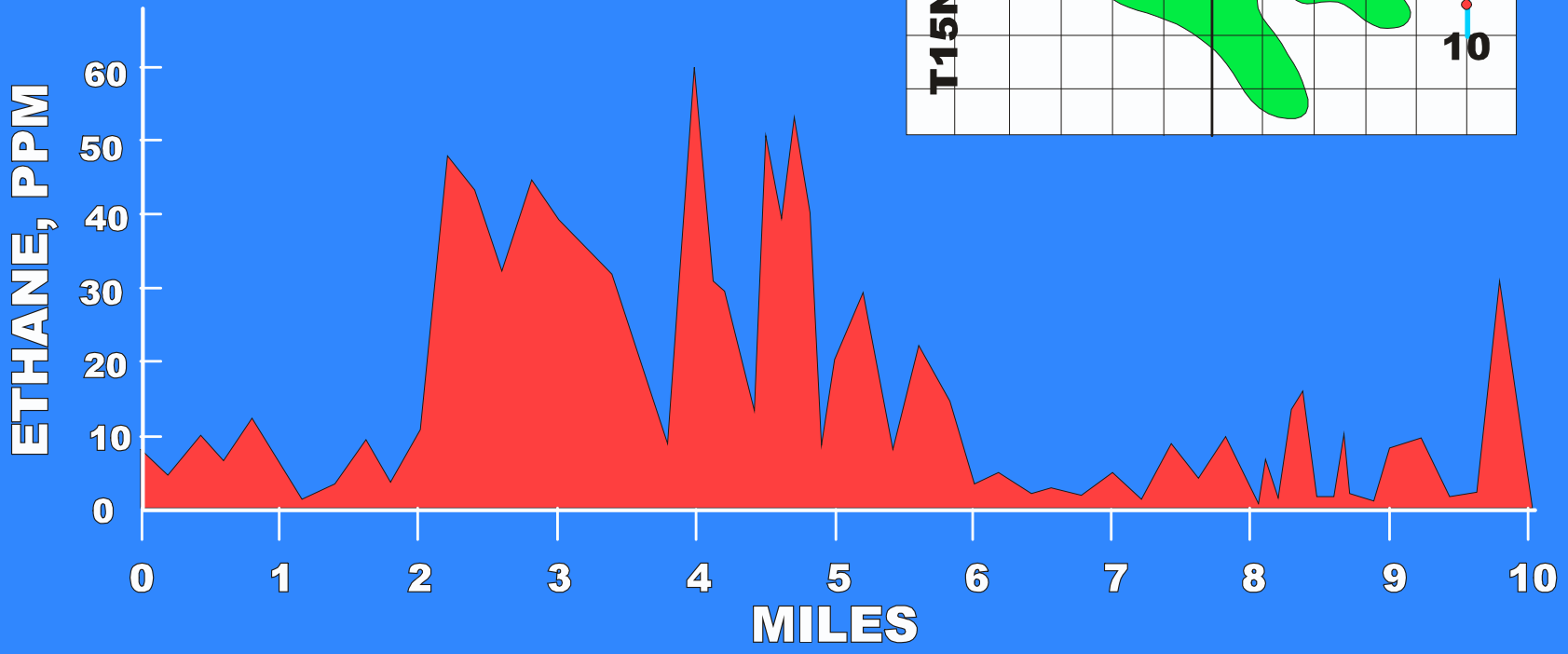
Rapid decline of surface anomaly with production, and

Re-appearance of anomaly in response to increased reservoir pressure due to waterflooding or gas injection

Soil Gas Anomaly Over Niobrara Chalk Reservoir

GEOCHEMICAL PROFILE
Across Silo Field
Laramie County, Wyoming





Why is Concept of Microseepage Controversial ?

- Since microseepage is not normally a visible process, direct observation has been difficult for geoscientists who rely heavily on direct observation.
- Also, if a hydrocarbon reservoir has held oil/gas for millions of years, by definition it must not be leaking, even at low rates. Seals are seals.
- Making repeated and reliable measurements of the microseepage process is technically challenging. Gases are by their mobile nature, difficult to sample from soils and sediments in a reliable and repeatable manner.
- Due to the heterogeneity of soils and near-surface sediments and the small sample volume collected in most surveys, there is normally considerable variability in composition and concentration. Consequently, not all samples from an area of microseepage are anomalous, and not all samples from area of background have a background-like composition.

Characteristics of Hydrocarbon Microseepage

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

Common and Widespread

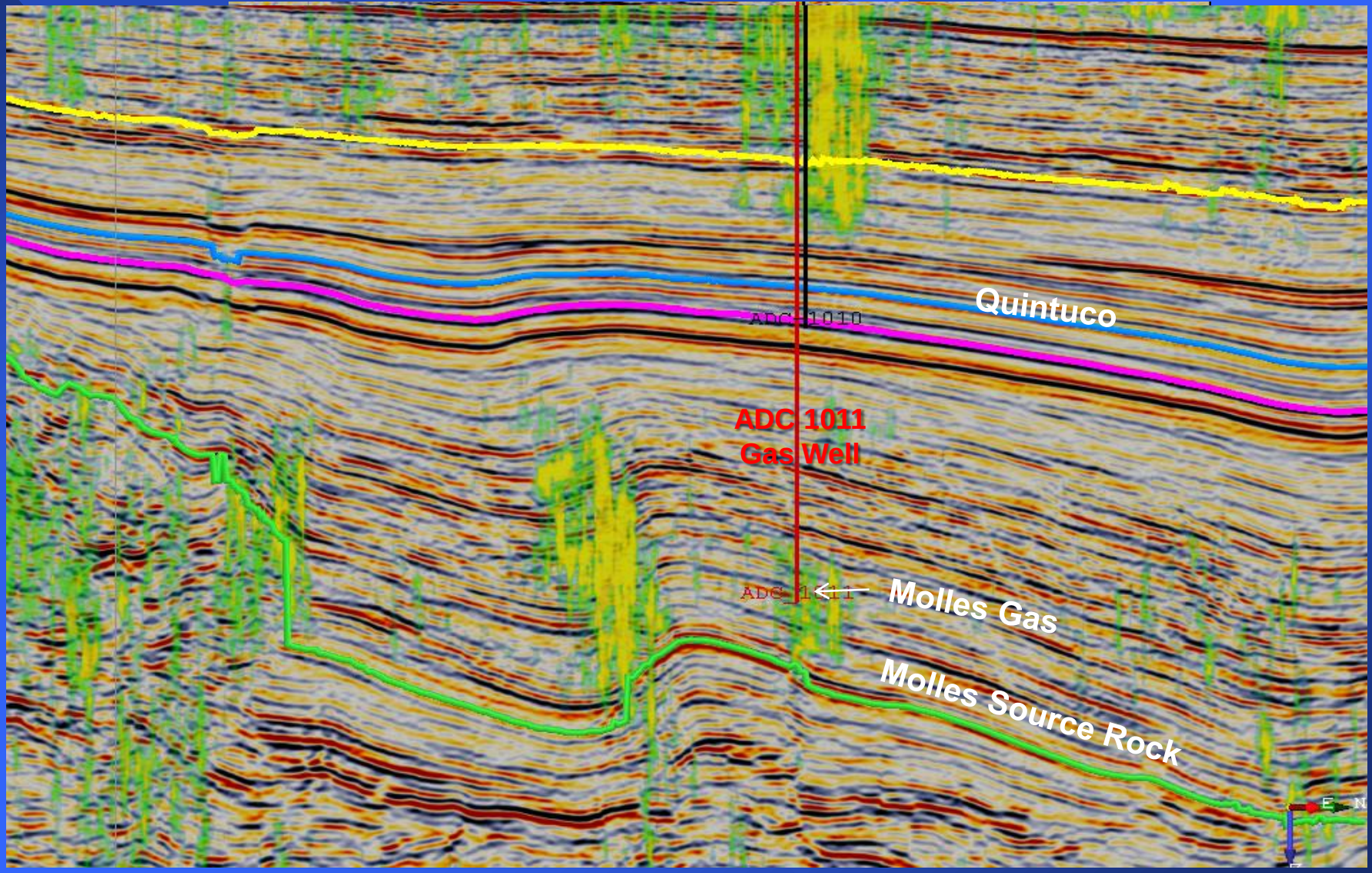
and

Predominantly Vertical

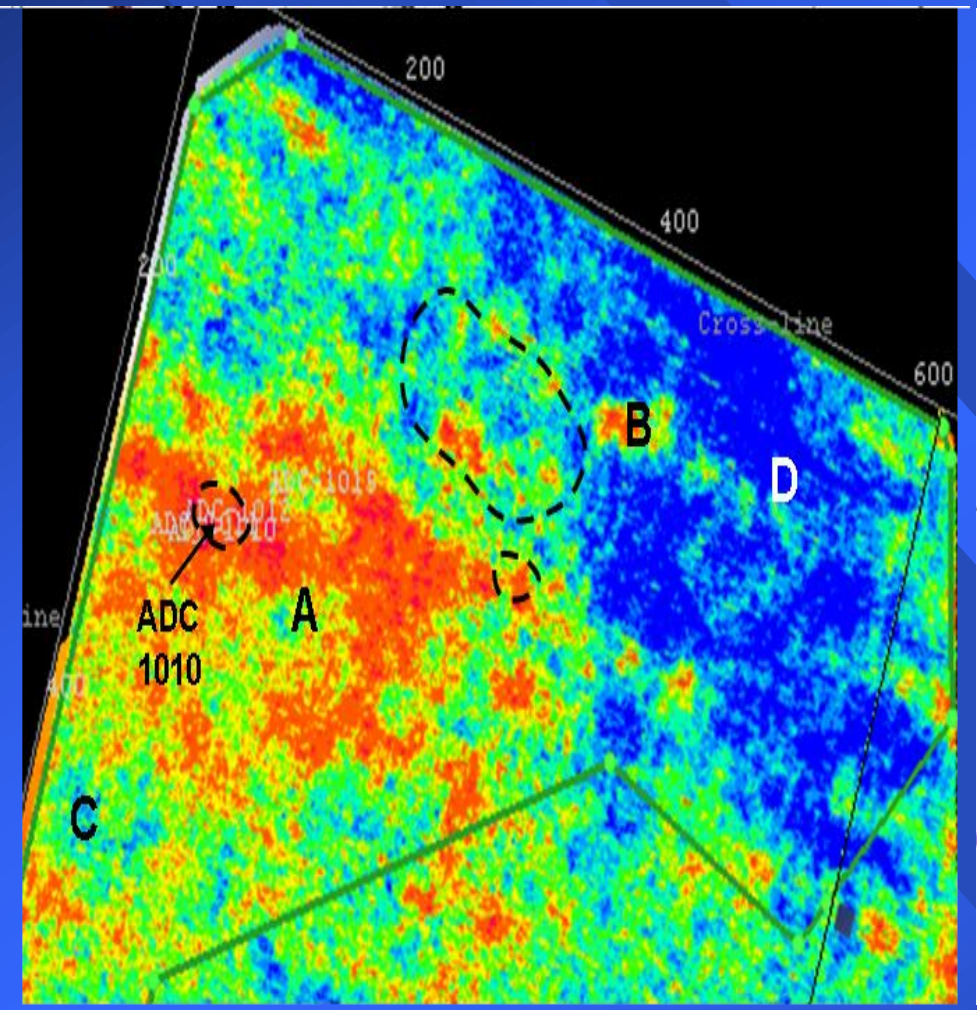
and

Dynamic

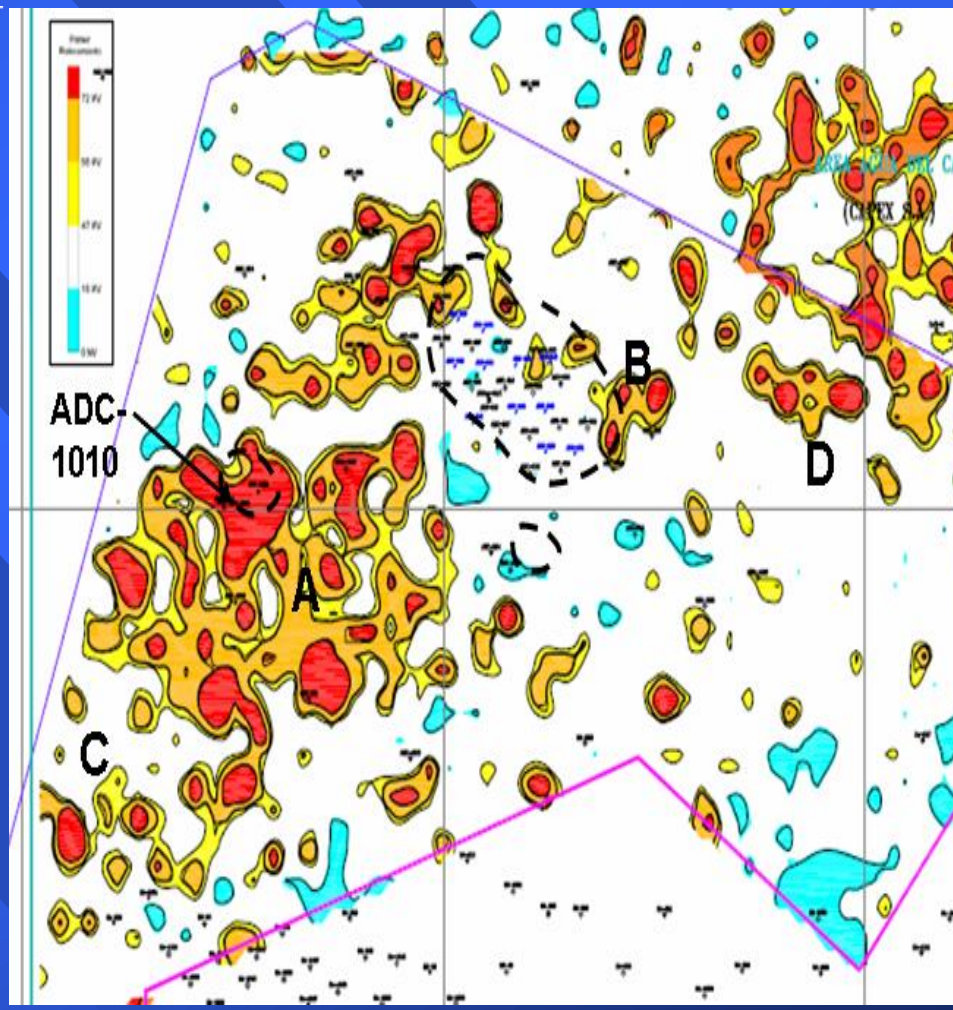
ADC-110 Well Location and Associated Microseepage Anomaly (Microbial)



Shallow Gas Chimneys and Hydrocarbon Microseepage Anomalies, Agua del Cajon Field Area, Argentina

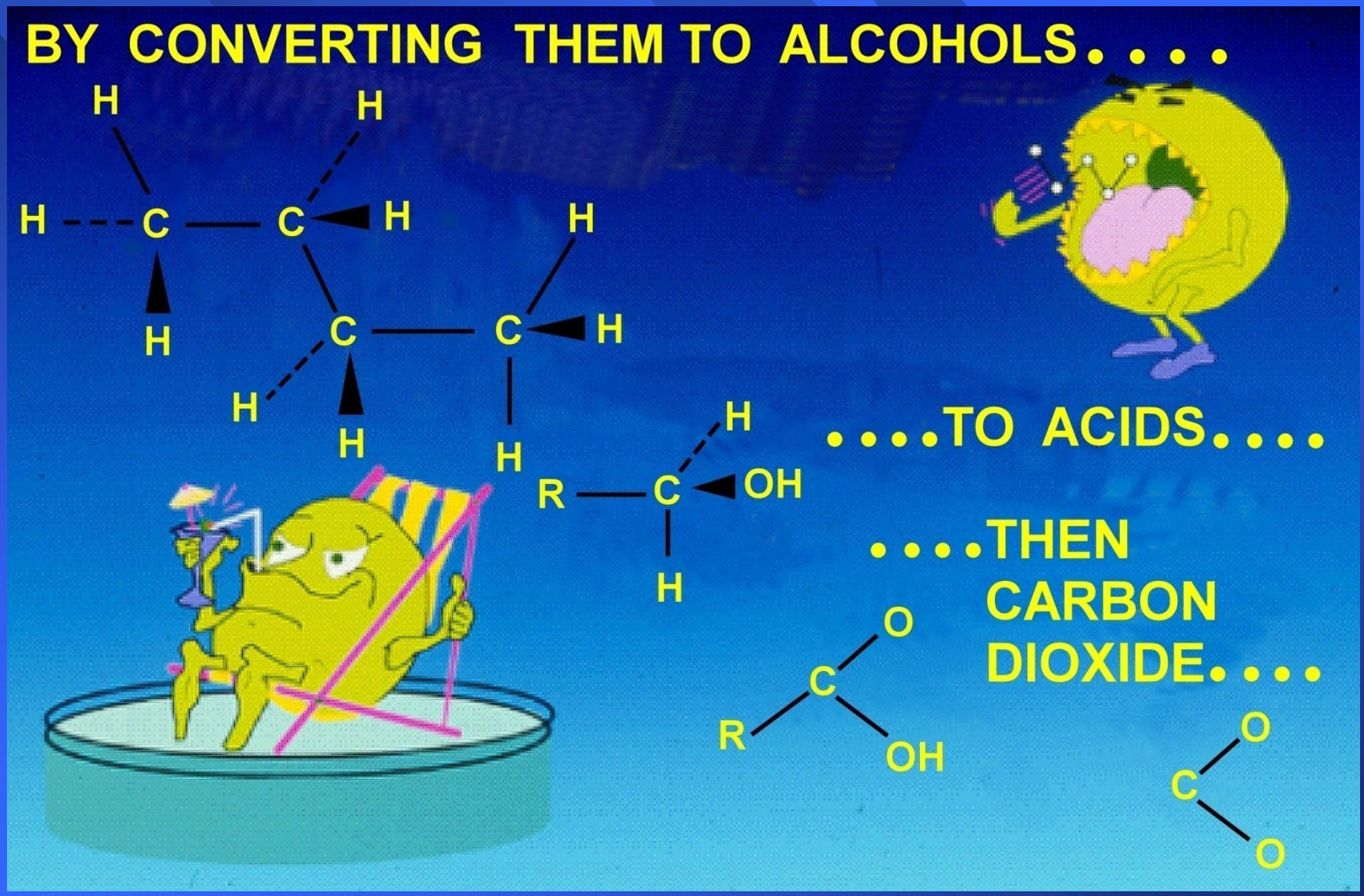


dGB

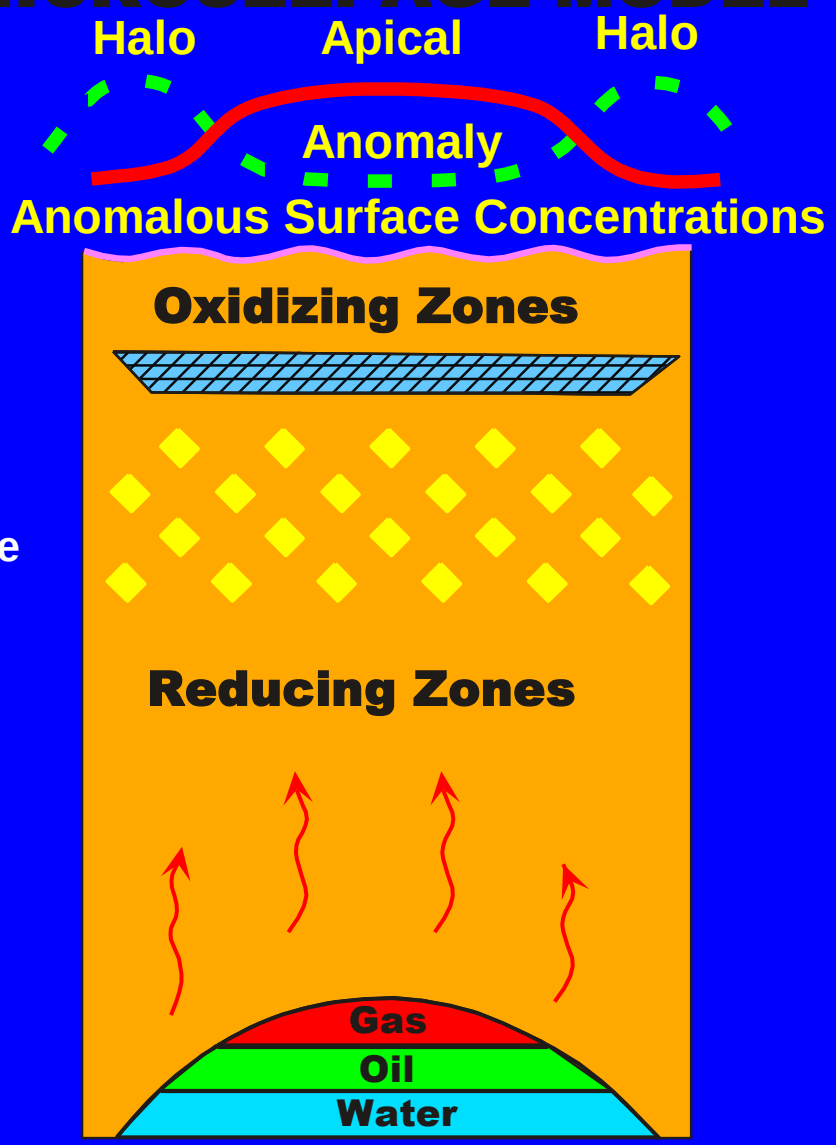


GMT

HYDROCARBON-OXIDIZING 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

Geochemical Exploration Methods

Direct Detection

- Soil Gas
  - Interstitial, Headspace
- Adsorbed Soil Gas
- Aromatics/Fluorescence
- Heavy Hydrocarbons, C10+
- “Sniffers” and Lasers
- Remote Sensing of Slicks

Indirect Detection

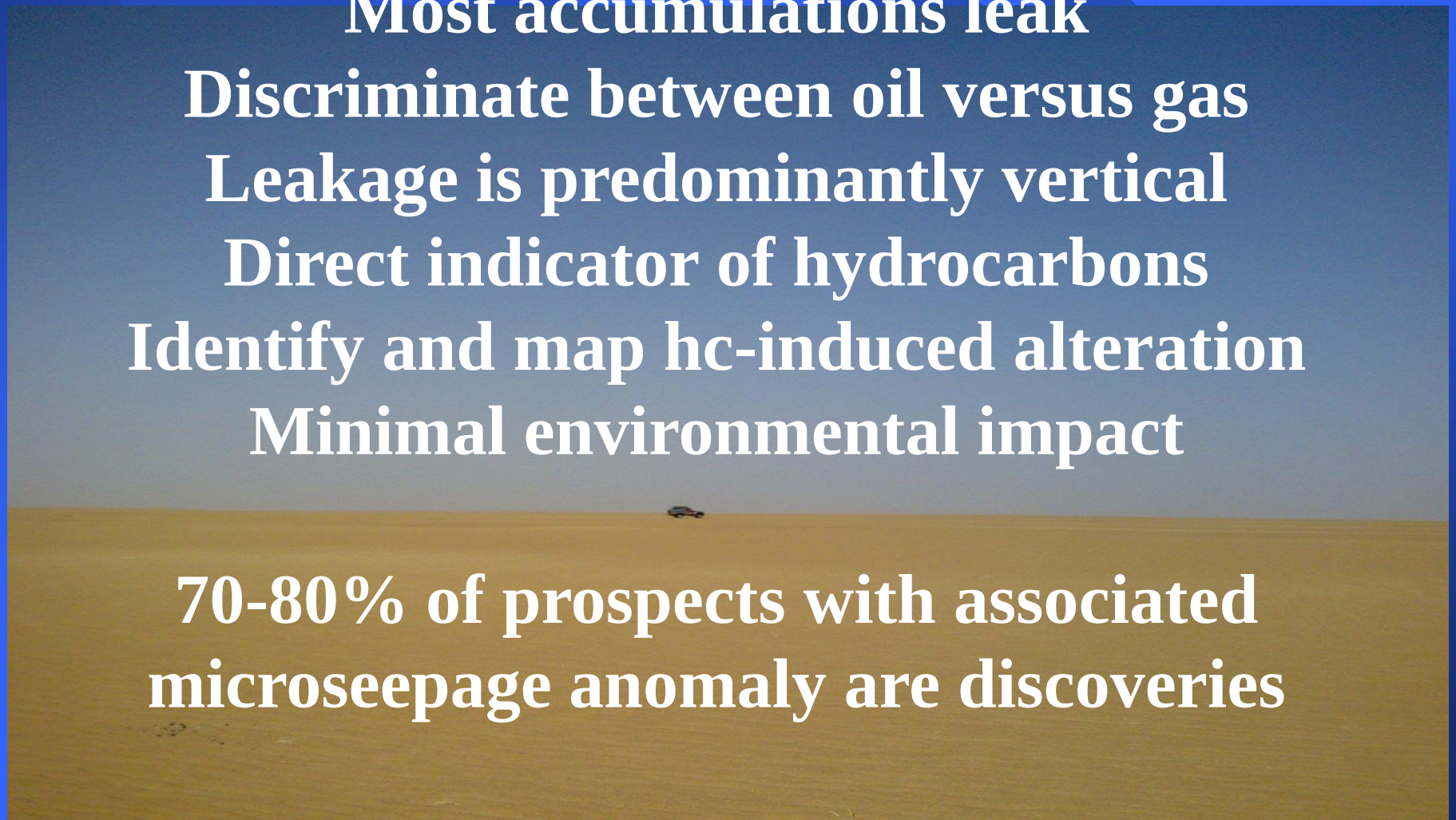
- Microbial
- Radiometrics
- Helium, Radon
- Iodine
- Trace Elements
- Remote Sensing
- Electrical
- Magnetic

EFFECTIVE IN ALL ENVIRONMENTS

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

Why Use Hydrocarbon Microseepage Data?



Most productive basins leak

Most accumulations leak

Discriminate between oil versus gas

Leakage is predominantly vertical

Direct indicator of hydrocarbons

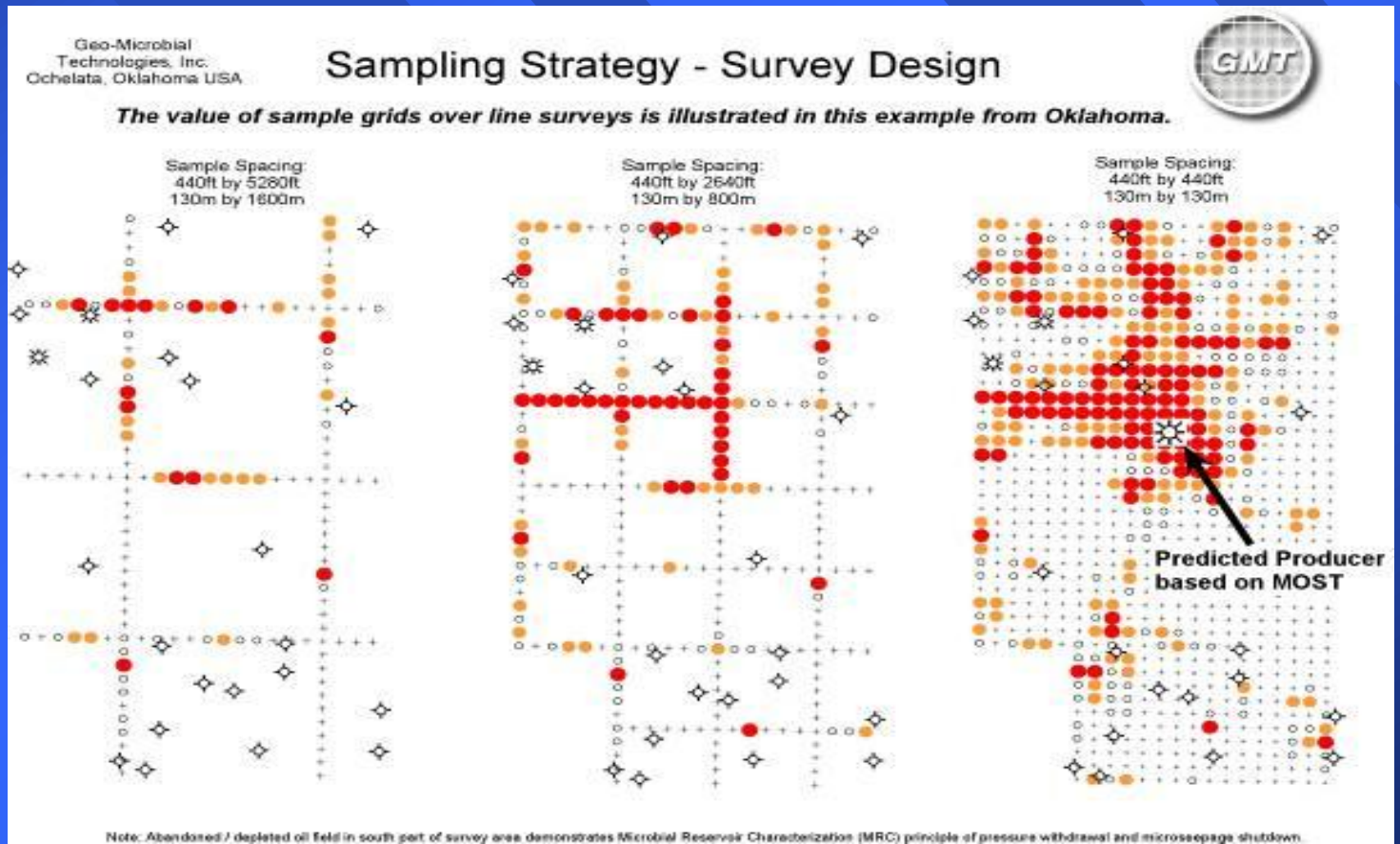
Identify and map hc-induced alteration

Minimal environmental impact

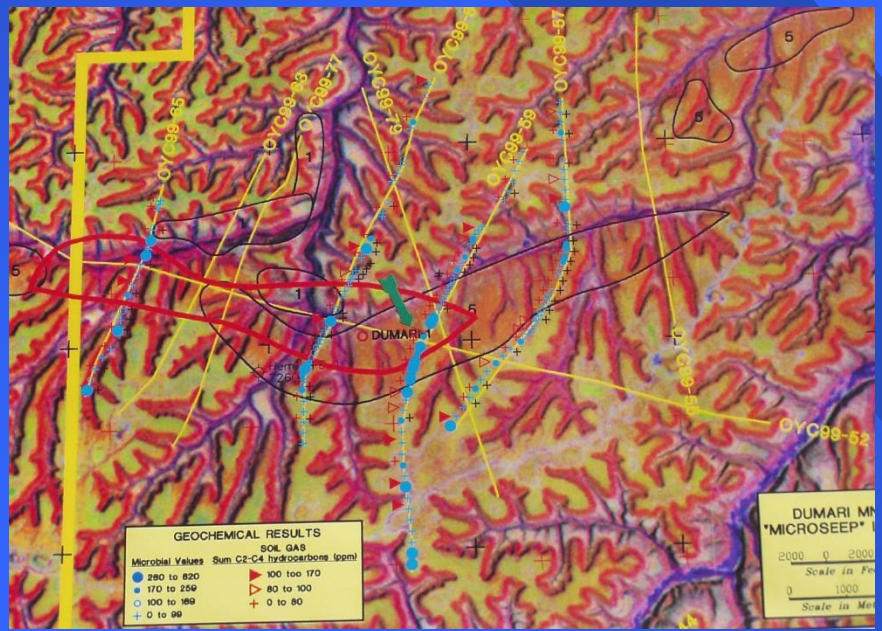
70-80% of prospects with associated microseepage anomaly are discoveries

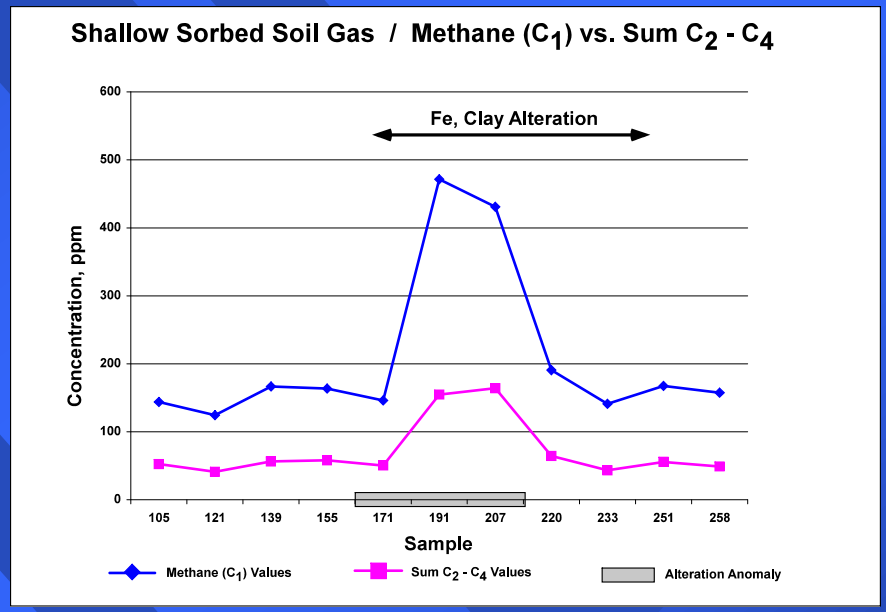
Survey Objectives

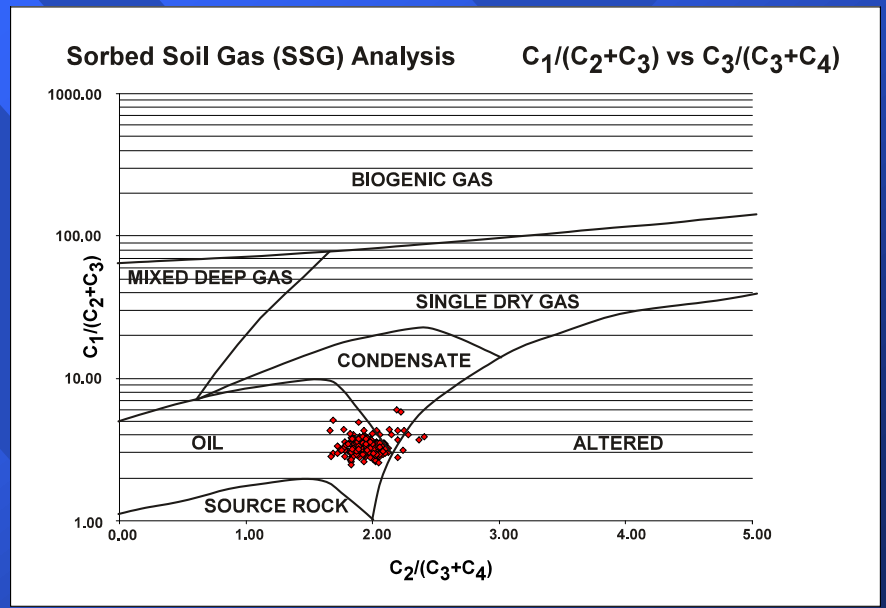
- Reconnaissance Surveys
- Prospect Generation, Prospect Evaluation
- Field Development
- Production Monitoring



Yemen, Masila Basin
Remote Sensing and Surface Geochemistry



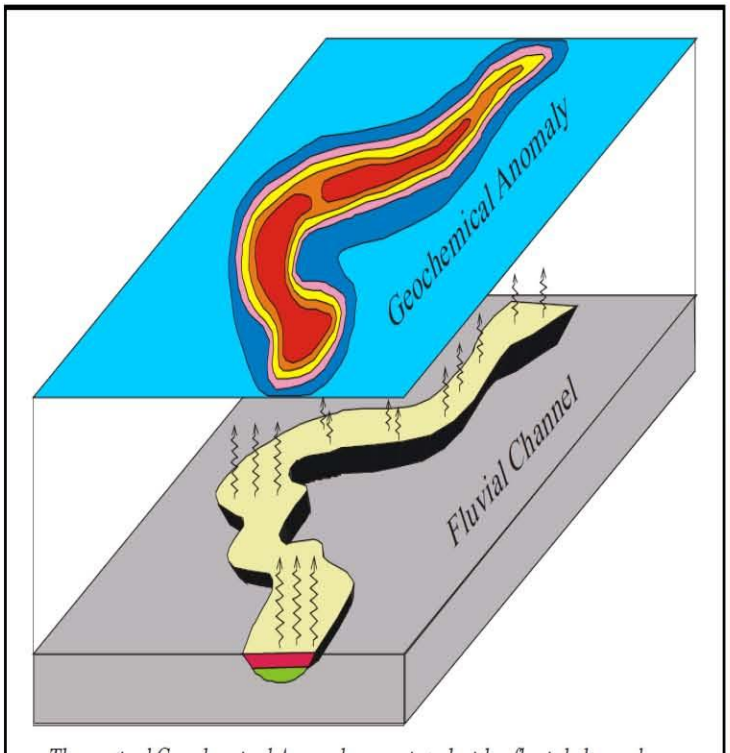




Microseepage is Predominantly Vertical

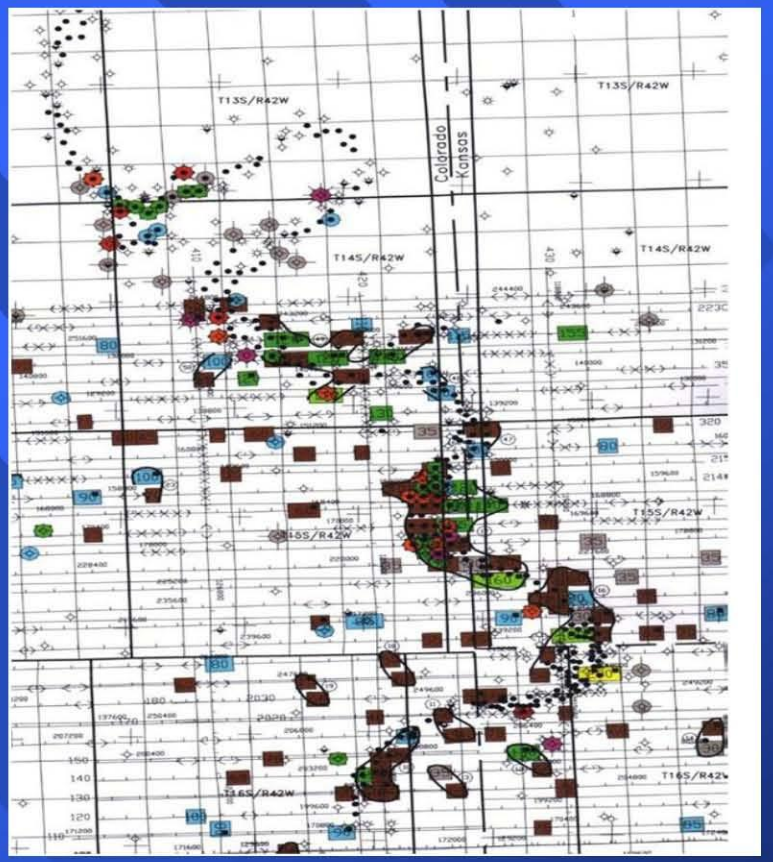
Extent of Surface Anomaly Approximates Shape and Areal Extent of Reservoir at Depth

San Jorge Basin

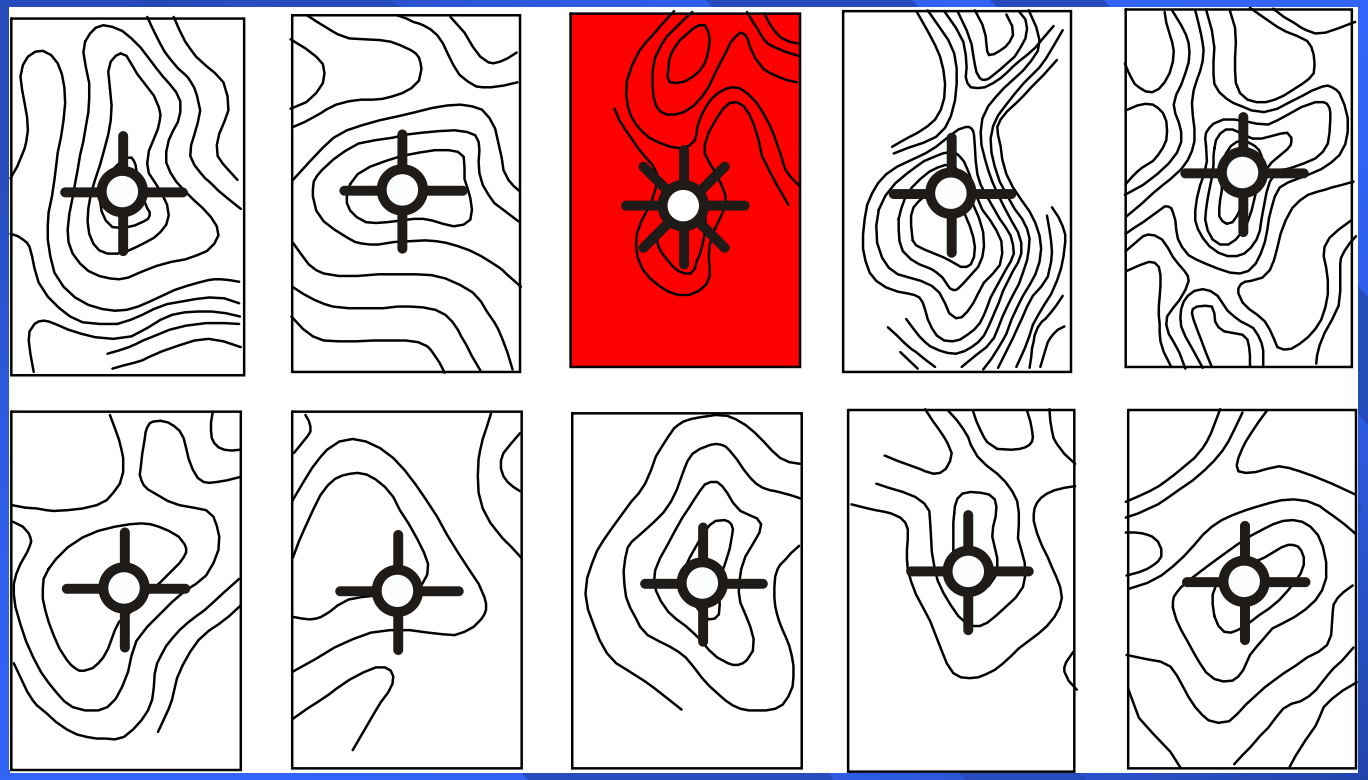


Theoretical Geochemical Anomaly associated with a fluvial channel.

Morrow Channel, CO-KS

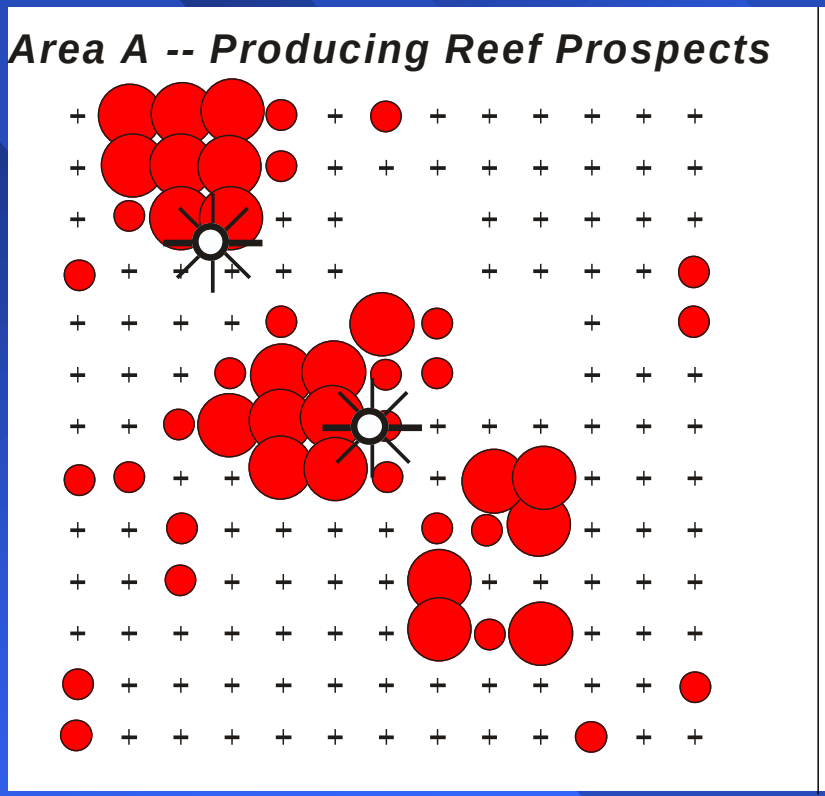


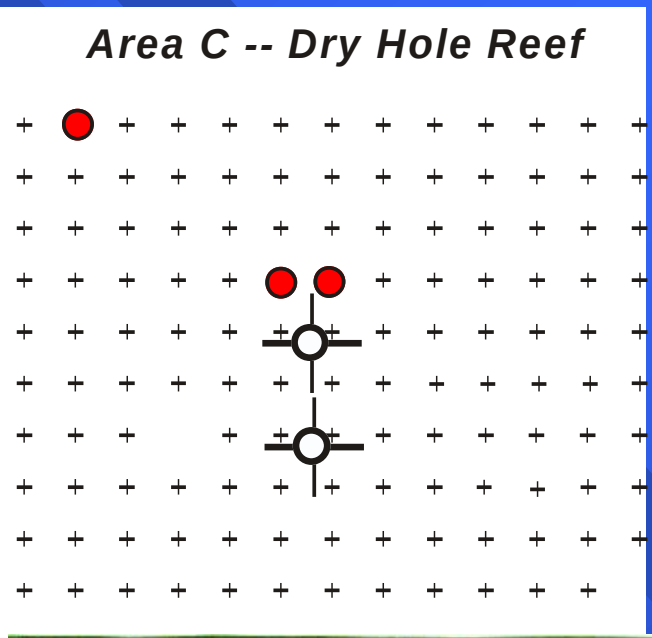
Denver Basin, USA

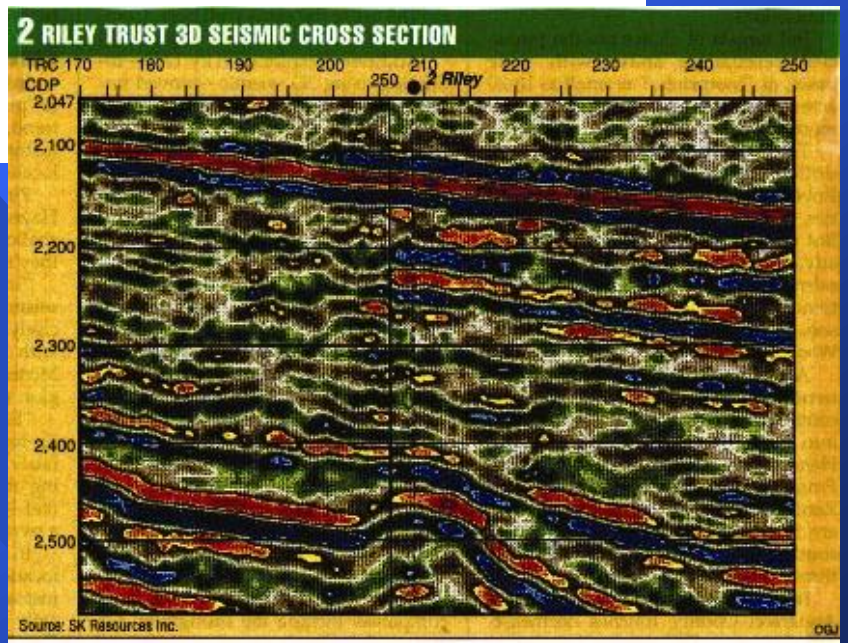


Only One of These Ten Seismic Prospects Resulted in a Producer. It was the Only Prospect with a Surface Geochemical Anomaly.

Jurassic Cotton Valley Pinnacle Reefs, East Texas



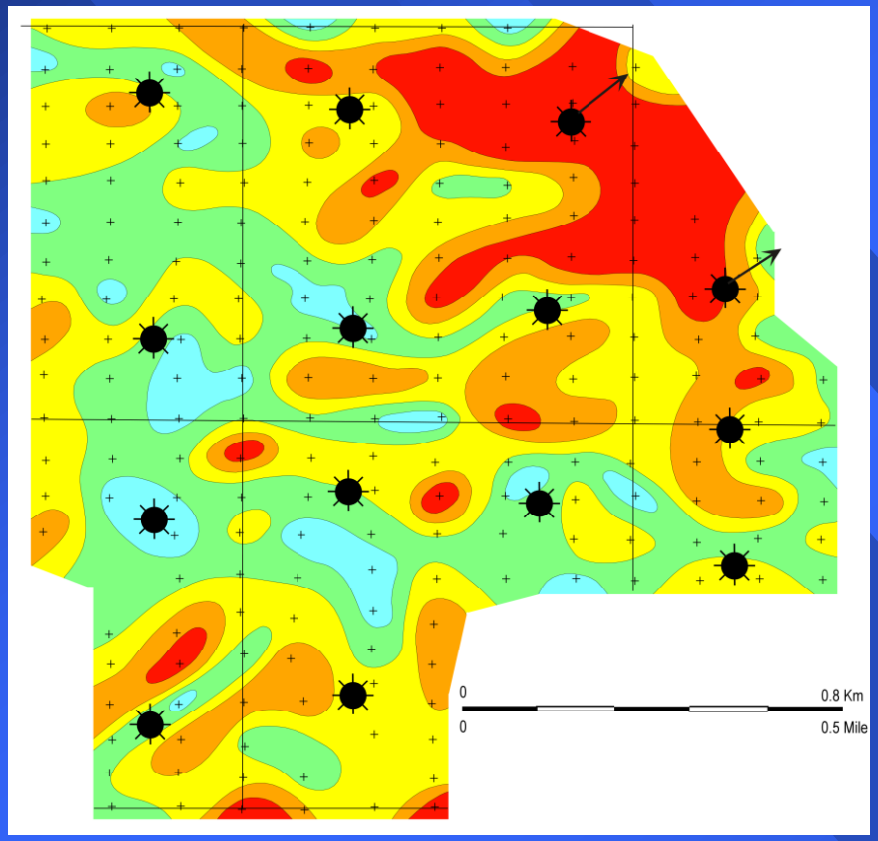


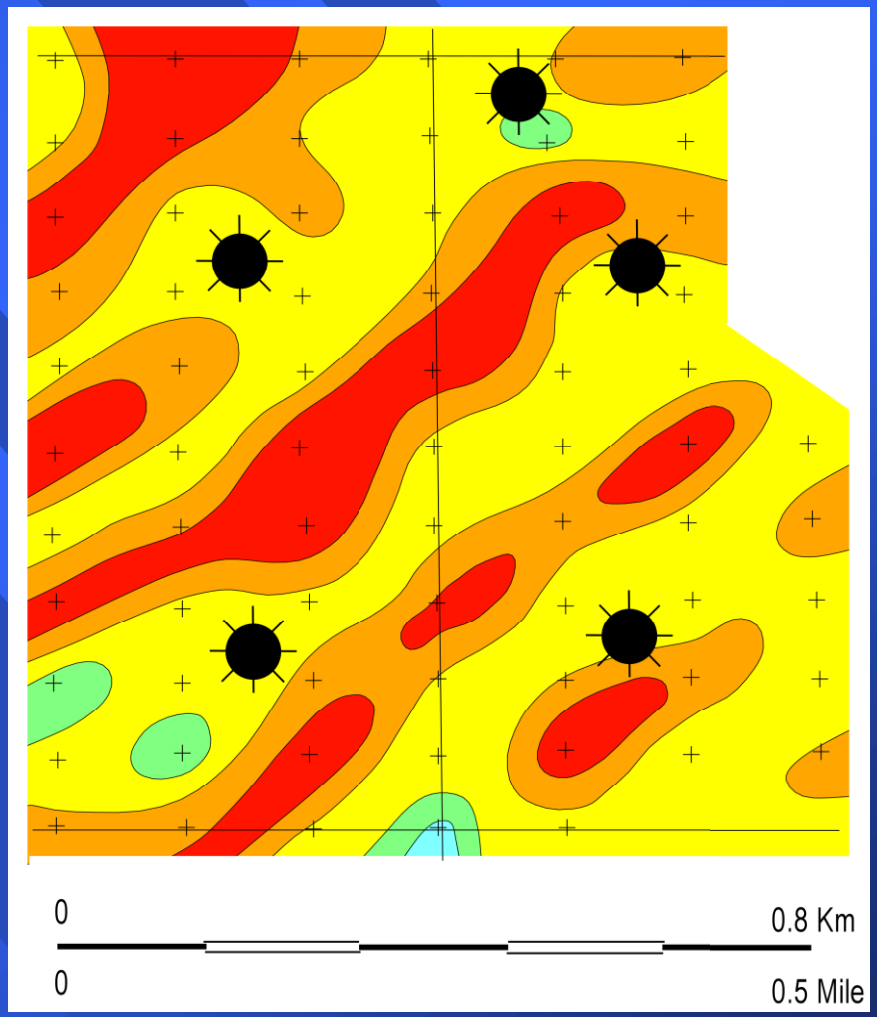


Reefs are 300m wide and 4500-5000 m deep

Geochemical Expression of Bypassed Pay

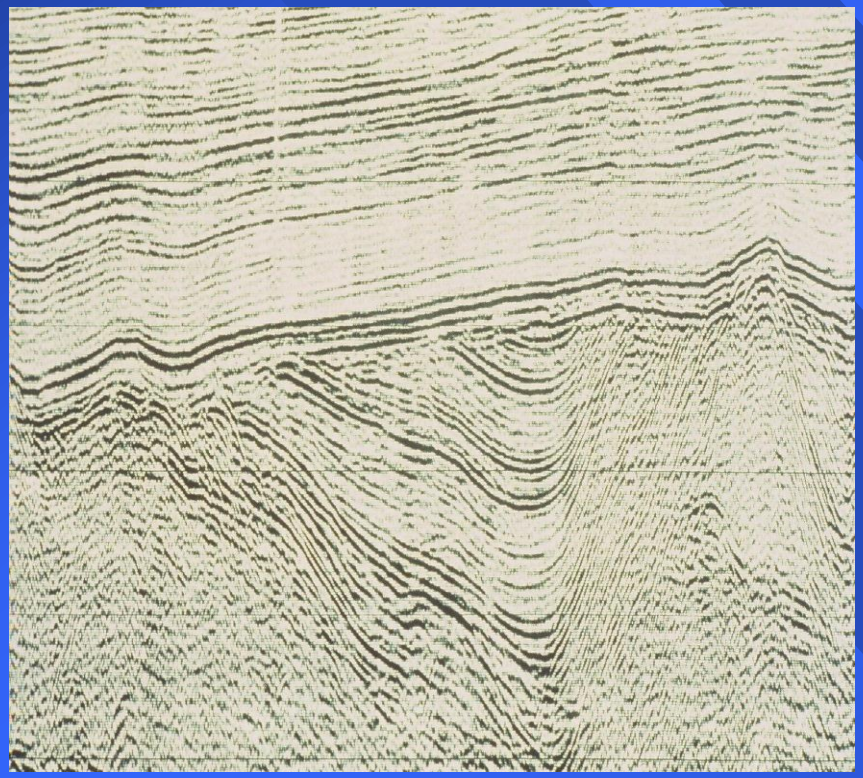
Grimes Field, Sacramento Basin, California

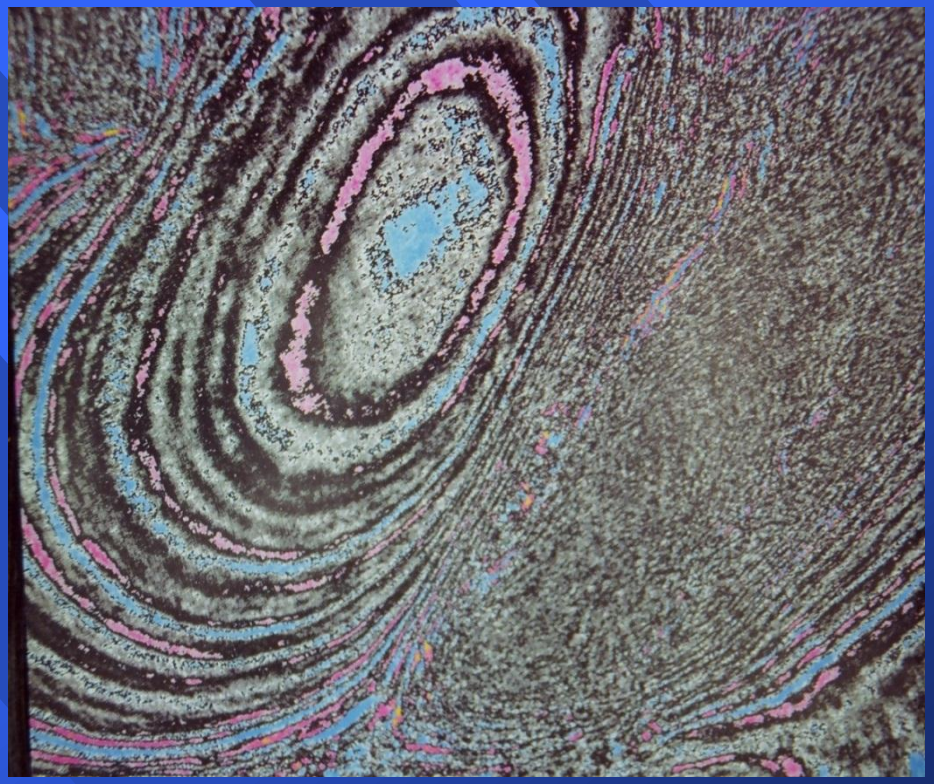




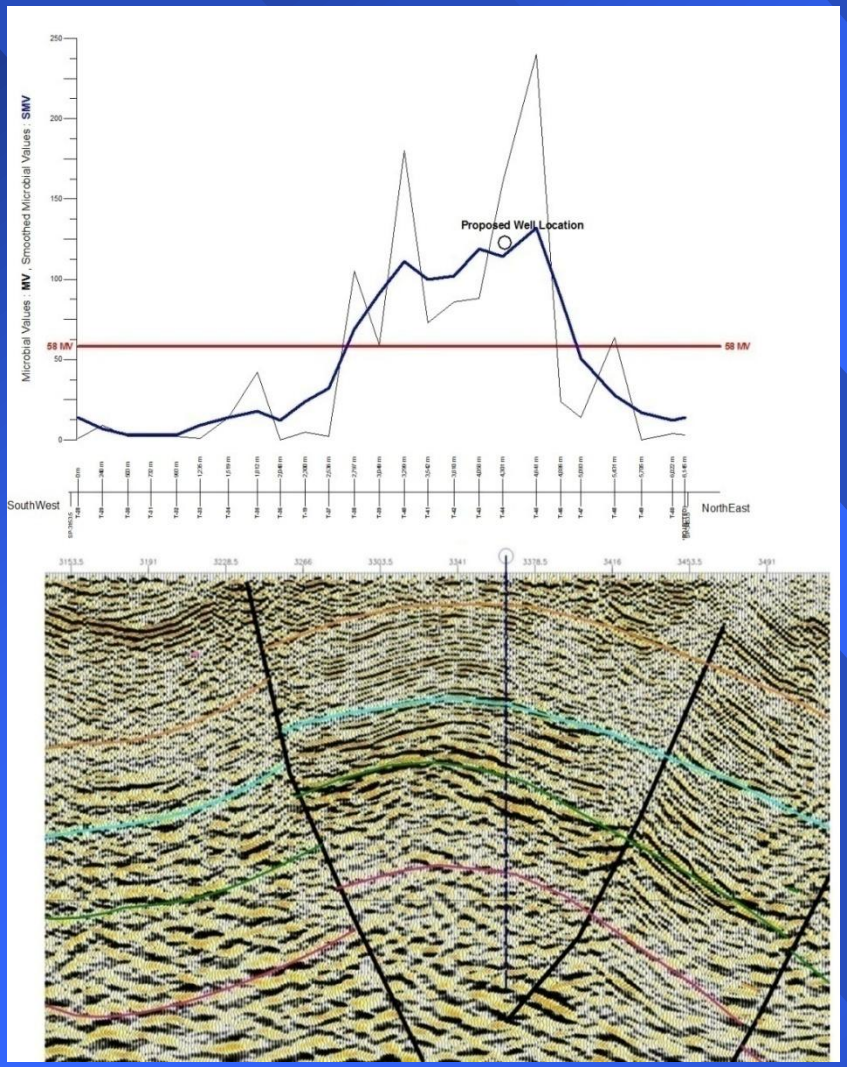
Conventional vs Unconventional Exploration Methods

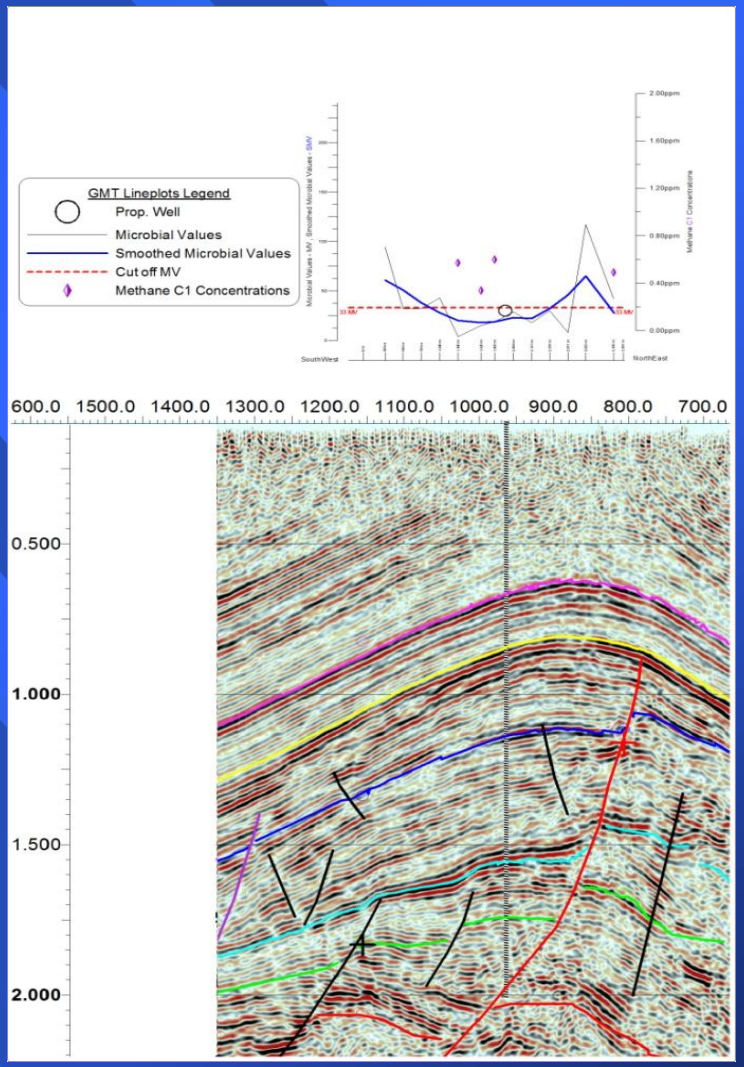
Finding Traps vs Finding Hydrocarbons





How do we Measure Success?
Compare pre-drill prediction with drilling results

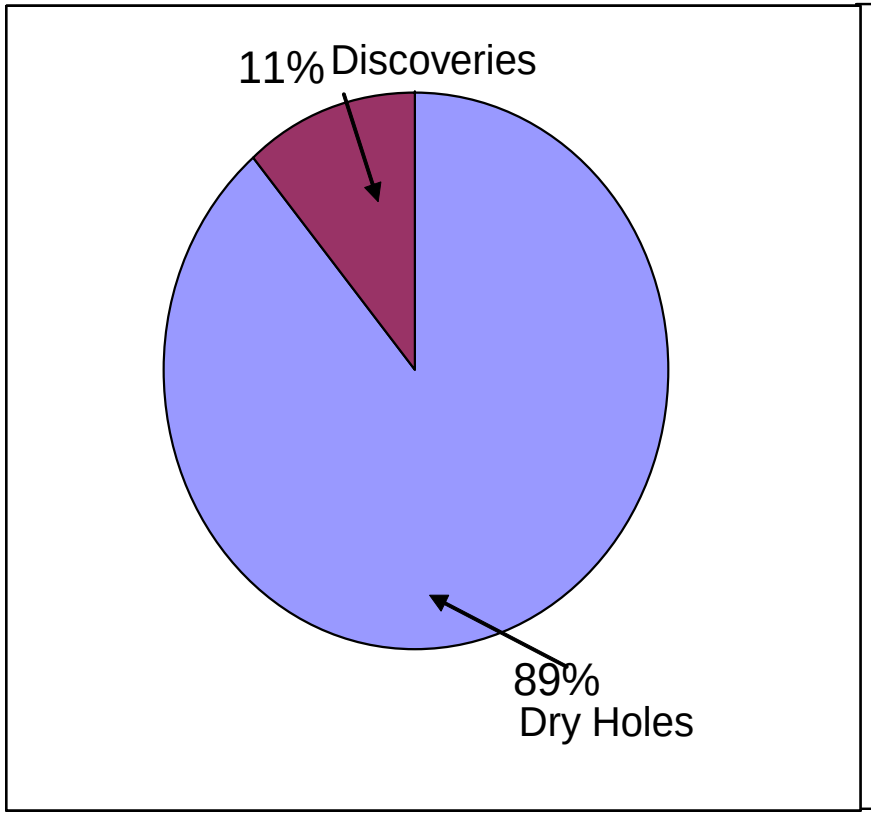




Summary

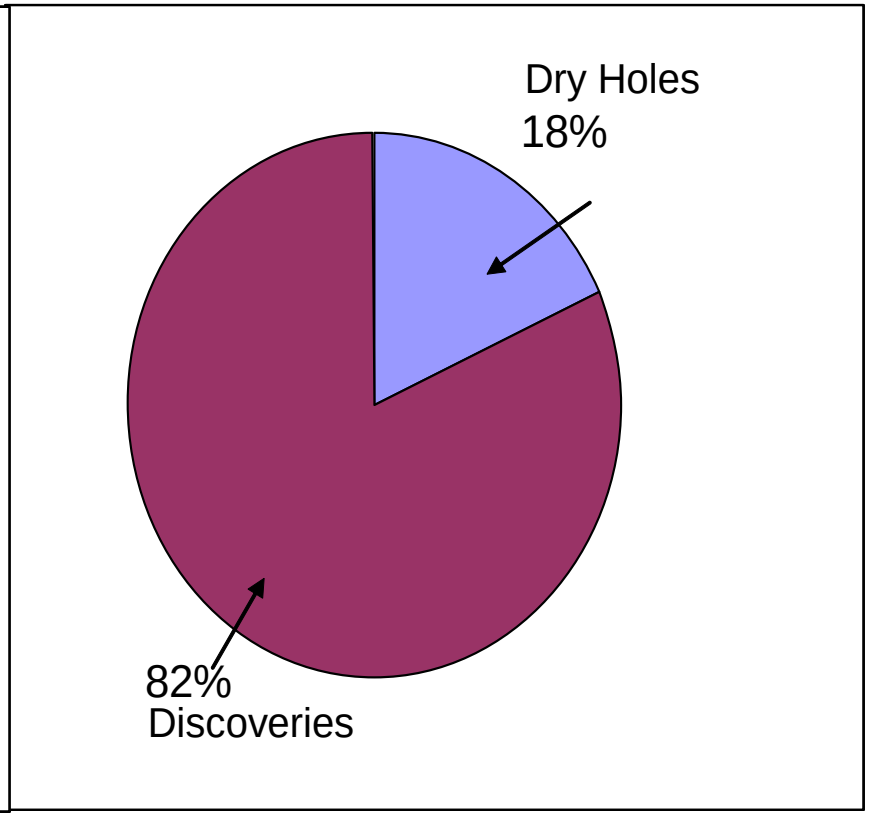
2774 Wells, Various Companies, Various Basins, Various methods

Negative Anomaly



1430 Wells Drilled

Positive Anomaly



1344 Wells Drilled

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