

# **PS Finding New Pays in Old Plays: New Applications for Surface Geochemistry in Mature Basins\***

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## **Abstract**

Detailed surface geochemical surveys and research studies document that hydrocarbon microseepage from petroleum accumulations is common and widespread, is predominantly vertical, and is dynamic (responds quickly to changes in reservoir conditions). These characteristics create a new suite of applications for surface geochemical surveys; field development, reservoir characterization, identifying by-passed pay, and monitoring patterns of hydrocarbon drainage. Combined with other uses of surface geochemistry like high-grading leases, leads, and prospects, these new applications show great promise for better prospect evaluation and risk assessment in mature basins.

Because hydrocarbon microseepage is predominantly vertical, the extent of an anomaly at the surface can approximate the productive limits of the reservoir at depth. The detailed pattern of microseepage over a producing field can also reflect reservoir heterogeneity and distinguish hydrocarbon-charged compartments from drained or uncharged compartments. Additionally, since hydrocarbon microseepage is dynamic, seepage patterns change rapidly in response to production-induced changes. Evidence for such changes are identified with detailed microbial and soil gas surveys. When such surveys are repeated over the life of a producing field or waterflood project, the changes in seepage patterns can reflect patterns of hydrocarbon drainage.

These applications require close sample spacing and are most effective when results are integrated with subsurface data, especially 3-D seismic data. The need for such integration cannot be overemphasized. Seismic data, reservoir fluid geochemical data, and reservoir pressure data will remain unsurpassed for defining trap and reservoir geometry, but only detailed microseepage surveys have the potential to reliably image hydrocarbon microseepage from those same reservoirs and compartments.

# Finding New Pays in Old Plays: New Applications for Surface Geochemistry in Mature Basins

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## ABSTRACT

Detailed surface geochemical surveys and research studies document that hydrocarbon microseepage from petroleum accumulations is common and widespread, is predominantly vertical, and is dynamic (responds quickly to changes in reservoir conditions). These characteristics create a new suite of applications for surface geochemical surveys; field development, reservoir characterization, identifying by-passed pay, and monitoring patterns of hydrocarbon drainage. Combined with other uses of surface geochemistry like high-grading leases, leads, and prospects, these new applications show great promise for better prospect evaluation and risk assessment in mature basins.



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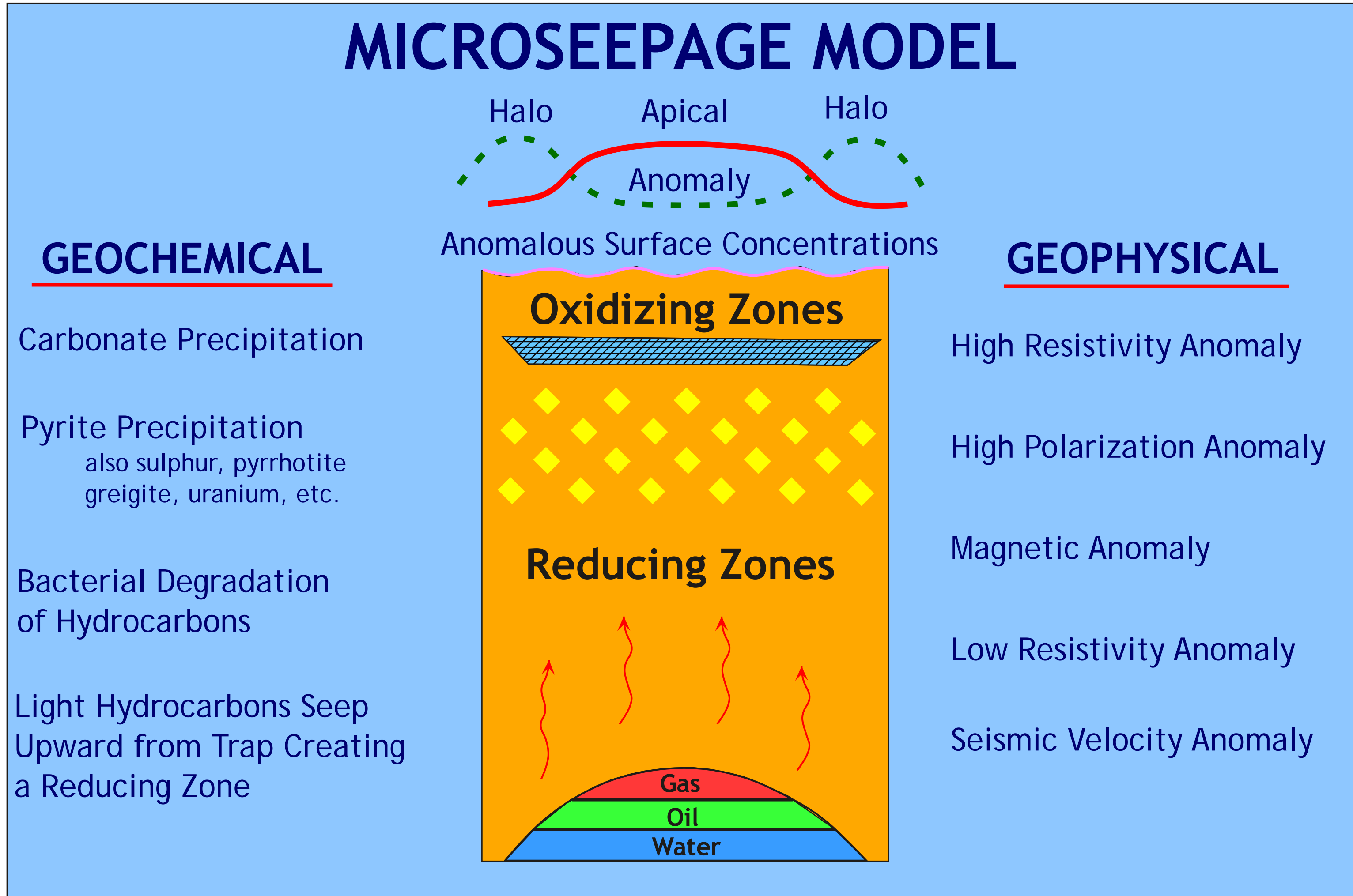
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## BASICS OF HYDROCARBON MICROSEEPAGE

- Most oil and gas accumulations have a surface geochemical expression, unless they are greatly underpressured or contain heavy oil (API Gravity < 16)
- Petroleum accumulations are dynamic and their seals imperfect
- Hydrocarbons can move vertically through thousands of meters of strata without observable faults or fractures in relatively short time (weeks to months)
- Microseepage is dominated by hydrocarbon gases (C1 - C5) and aromatic hydrocarbons
- Hydrocarbon microseepage is predominantly vertical except in structurally complex areas with many fault or fracture leak points

## MICROSEEPAGE DETECTION METHODS

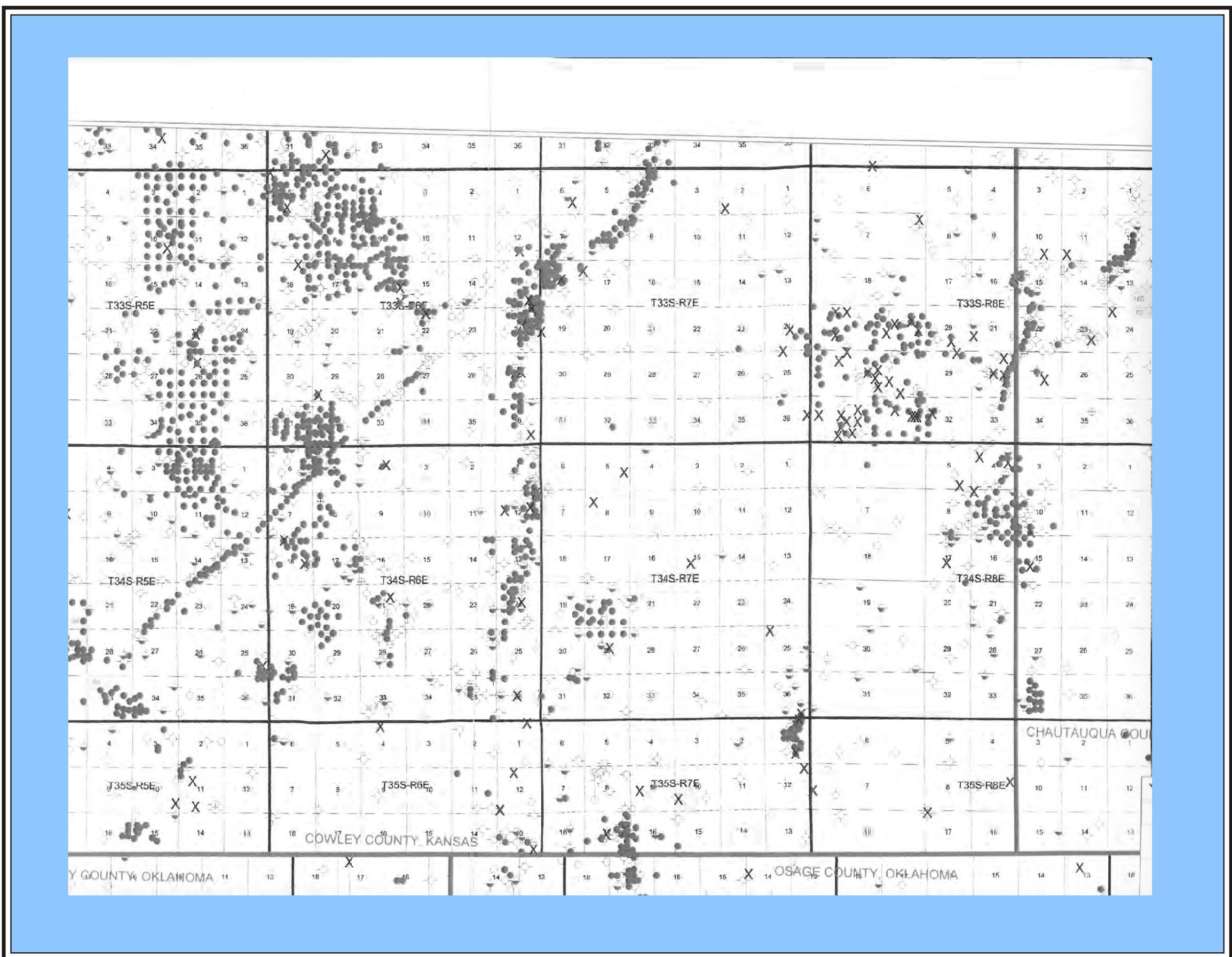
Due to the varied surface expressions of hydrocarbon microseepage, a number of different methods are available for detecting and mapping hydrocarbon microseepage. Some of these methods are surface geochemical methods, some are microbiological, and some are non-seismic geophysical methods.



- **Remote sensing, satellite imagery analysis.**  
Detects hydrocarbon-induced alteration of soils and sediments
- **Aeromagnetics, micromagnetics.**  
Detects seep-induced magnetic anomalies in shallow subsurface
- **Soil gas, acid extracted soil gas, fluorescence.**  
Measures concentration and composition of hydrocarbon gases and aromatic hydrocarbons in soils
- **Microbiological.**  
Measures concentration and distribution of hydrocarbon-utilizing bacteria
- **Biogeochemical, geobotanical.**  
Measures trace elements and vegetation stress due to hydrocarbon leakage

## Why Explore Mature Basins?

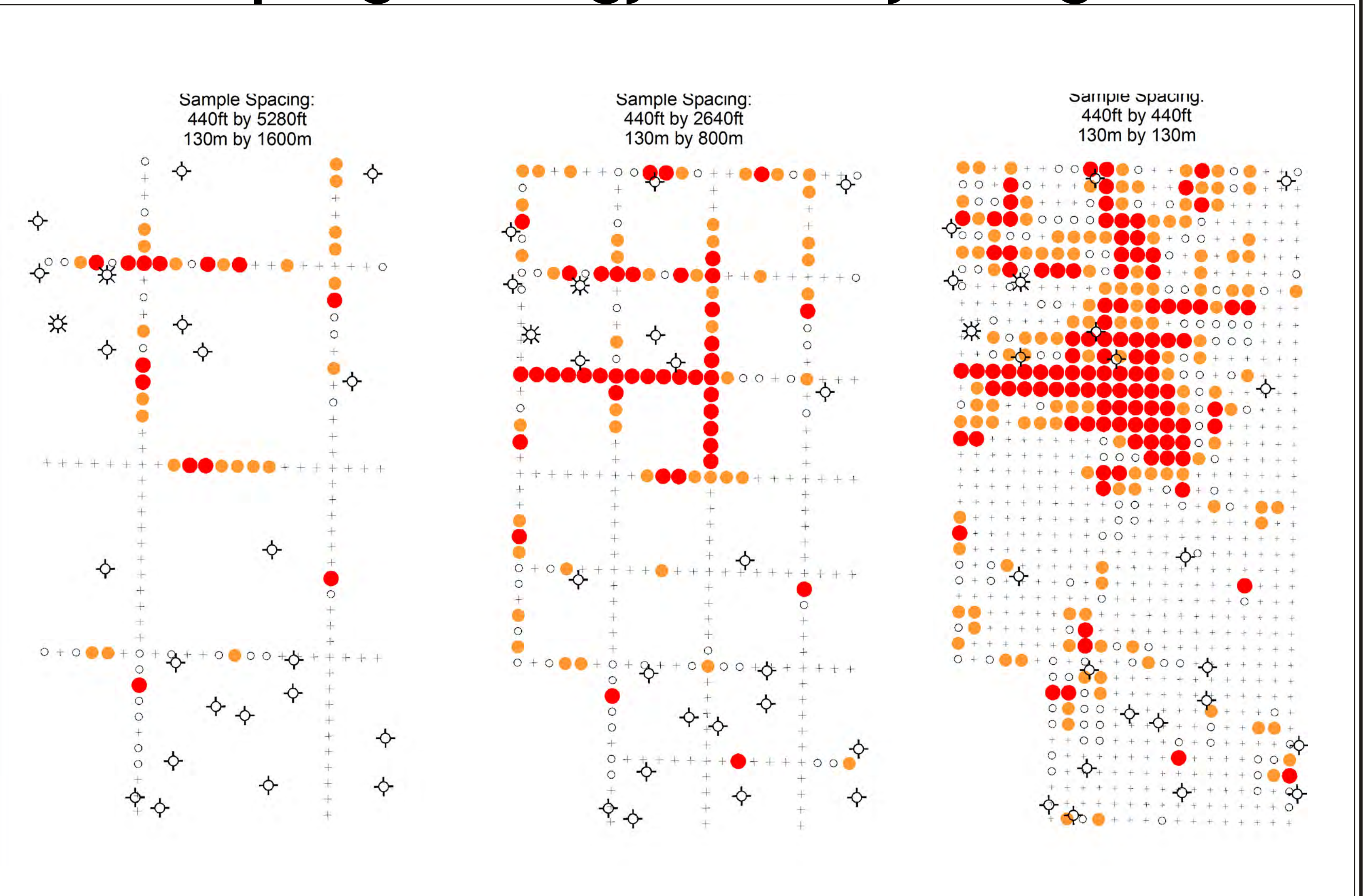
- Known Source Rocks
- Proven Reserves
- Abundance of Data
- Infrastructure
- Markets
- Significant Remaining Potential



## Survey Design Considerations



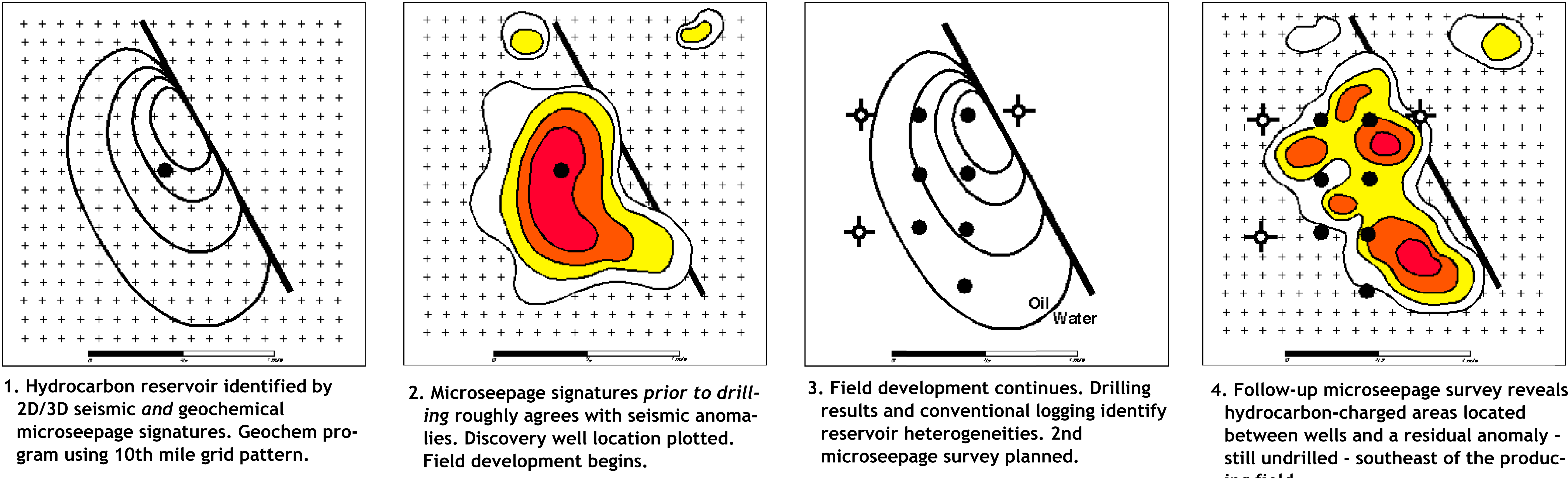
## Sampling Strategy - Survey Design



Microseepage Survey Applications for Field Development and Production

Because hydrocarbon microseepage is predominantly vertical, the extent of a microseepage anomaly at the surface can approximate the productive limits of the oil or gas pool at depth. Detailed microseepage surveys can help evaluate hydrocarbon charge at infill or step-out locations, delineate the productive limits of undeveloped fields, and identify by-passed pay and/or undrained reservoir compartments. Hydrocarbon microseepage surveys add value to 2D and 3D seismic data by identifying those features or reservoir compartments that are most likely to be hydrocarbon charged. Repeat microseepage surveys over the life of a field or waterflood project can document the pattern of hydrocarbon drainage over time.

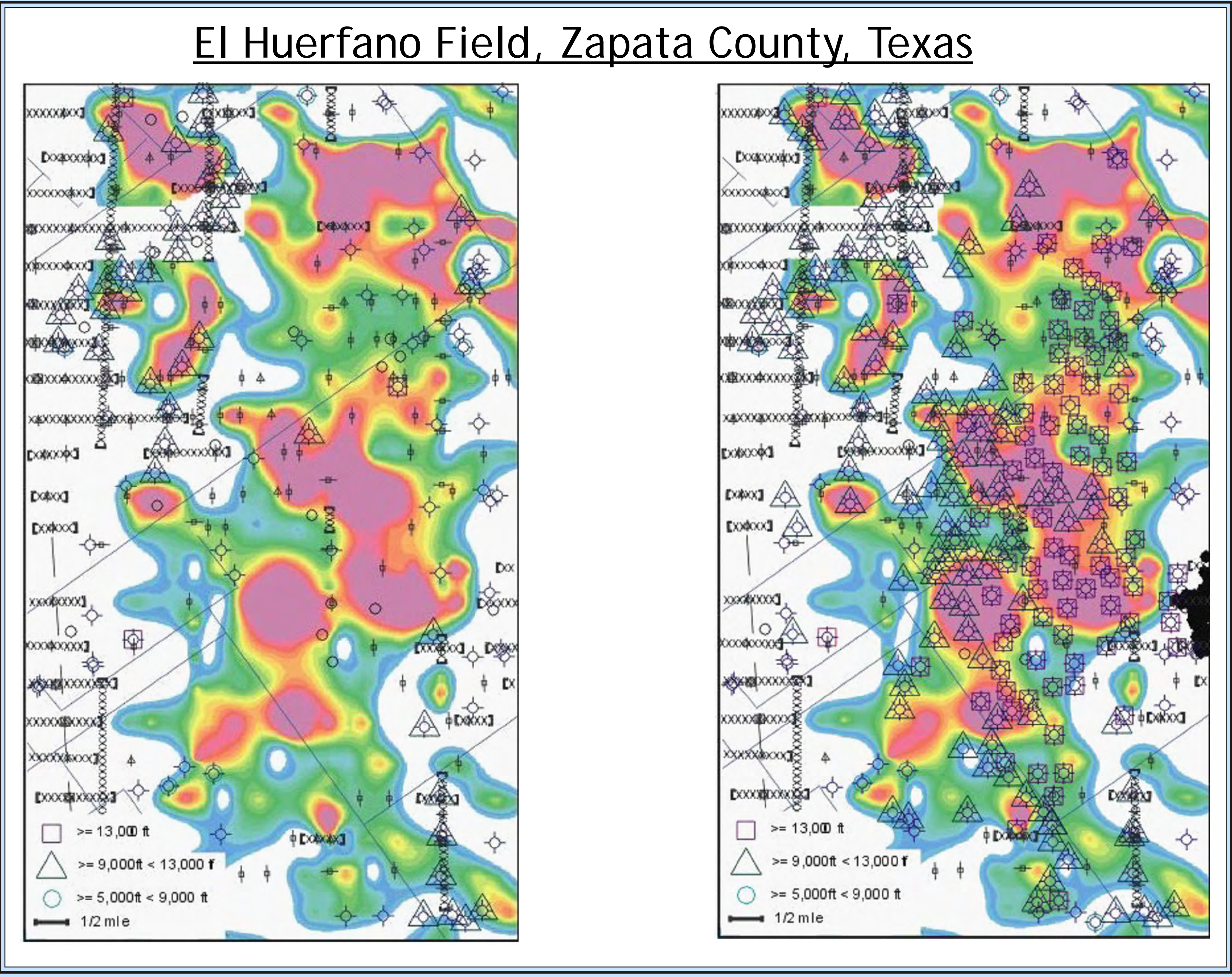
4-Part Model of Dynamic Hydrocarbon Microseepage Signatures



Proper survey design and detailed sampling is necessary for these applications. Sample intervals for such field development surveys typically range from 50m to 250m, and almost always use a grid sample pattern.

MICROSEEPAGE DEFINED FIELD OUTLINE: PRE-DISCOVERY VERSUS POST-DEVELOPMENT

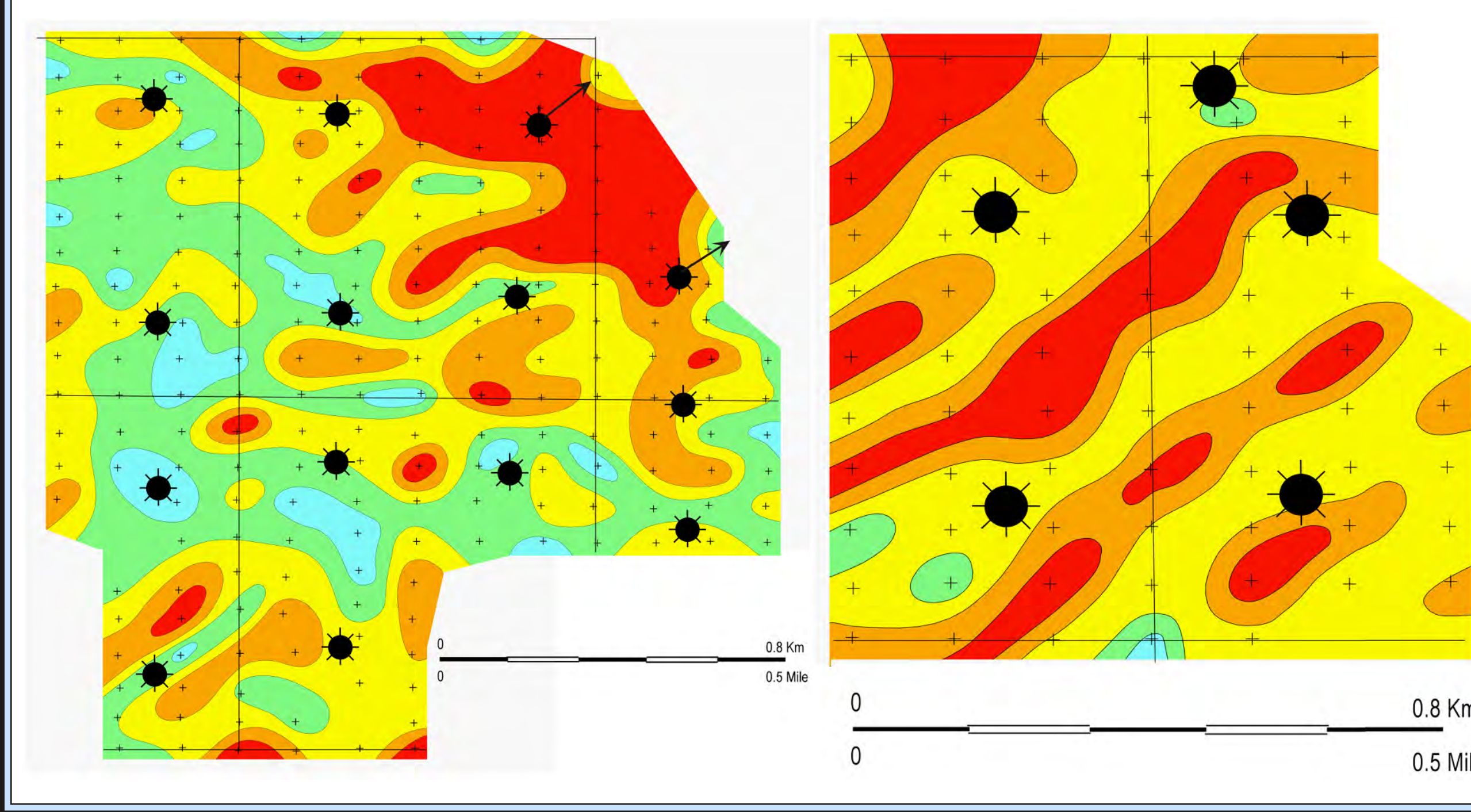
The El Huerfano gas field is located in Zapata County, south Texas, and produces from the Cretaceous Edwards Formation. The field was discovered in 1977, however, the main phase of drilling and field development occurred between 1985 and 1997. The figure on the left shows the drilling status as of 1985, and the location of a large, seep-induced magnetic microseepage anomaly based on 1985 aeromagnetic data. The warmer colors indicate the areas with higher levels of microseepage, and higher petroleum potential. The figure on the right shows the striking correlation between the 1985 outline of the microseepage anomaly and the 1997 gas field boundary (Schumacher and Foote, 2006).



MICROSEEPAGE PATTERNS OVER PRODUCING FIELDS REFLECT HYDROCARBON DRAINAGE

Example 1: Grimes Field, Sacramento Basin, California

Low levels of microseepage are shown in blue, green and yellow colors. These low levels generally occur in the immediate vicinity of producing wells and may reflect pressure depletion due to production. High levels of microseepage are indicated by orange and red colors, and tend to occur between wells and over unproduced or undrained portions of the reservoir. In the left figure, the large microseepage anomaly in the northeast portion of the map overlies an undrained portion of the reservoir. The two wells within the anomaly are directional wells that produce from a portion of the reservoir located several hundred meters to the northeast.

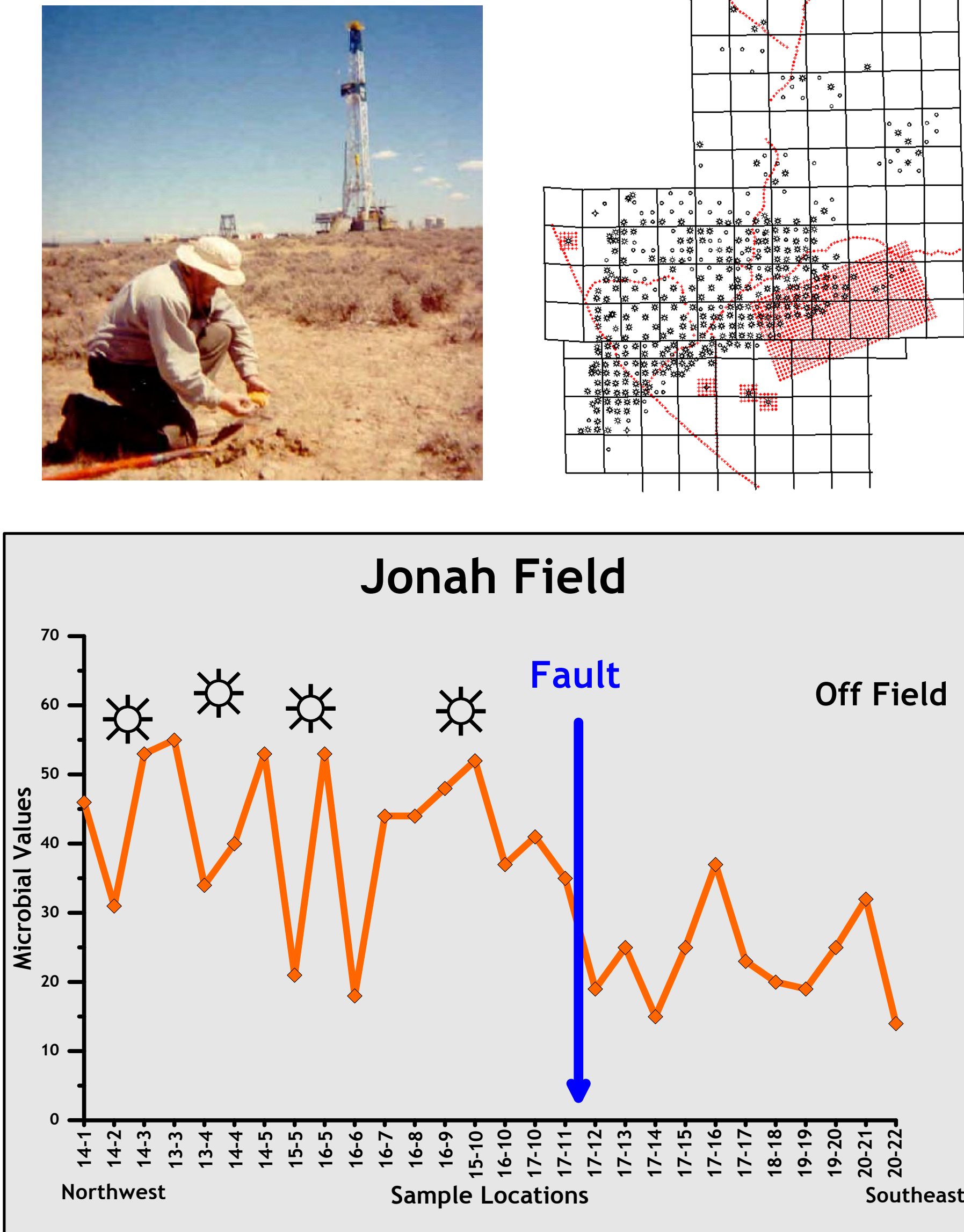
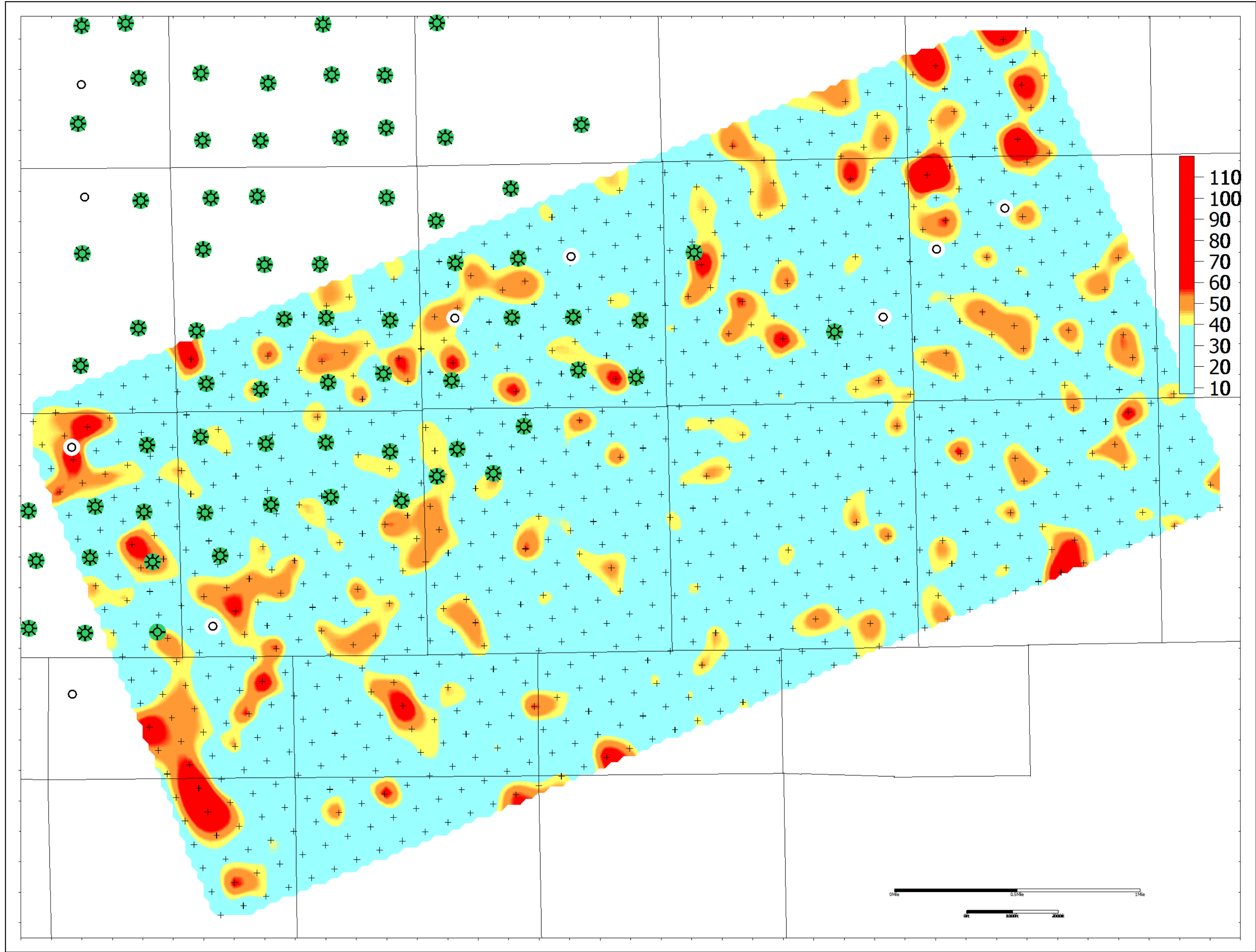


The pattern of circular to semicircular microseepage “lows” associated with producing wells is characteristic of producing fields. Over time, and in the absence of pressure maintenance, these lows tend to expand in areal extent, presumably in response to continuing hydrocarbon drainage and pressure decline. The presence of large microseepage anomalies within an old field may indicate areas or reservoir compartments not effectively drained by existing wells, or possibly reflect seepage from a different reservoir horizon (Tucker and Hitzman, 1994).

Example 2: Jonah Field, Green River Basin, Wyoming

Jonah Field is a tight gas reservoir producing from the Cretaceous Lance Formation at depths of 3000-3500 meters. The survey area was sampled with an 160 meter grid spacing. Low levels of hydrocarbon microseepage are indicated by blue color and the highest levels of microseepage by yellow, orange, and red colors. Low levels of seepage characterize the immediate vicinity of wells that have been on production for 3-6 months, or more. It is tempting to believe that the 200-300 meter geochemical “lows” surrounding the producing wells are a reflection of the well’s drainage radius for this tight gas sand, but we have no independent confirmation of that at this time.

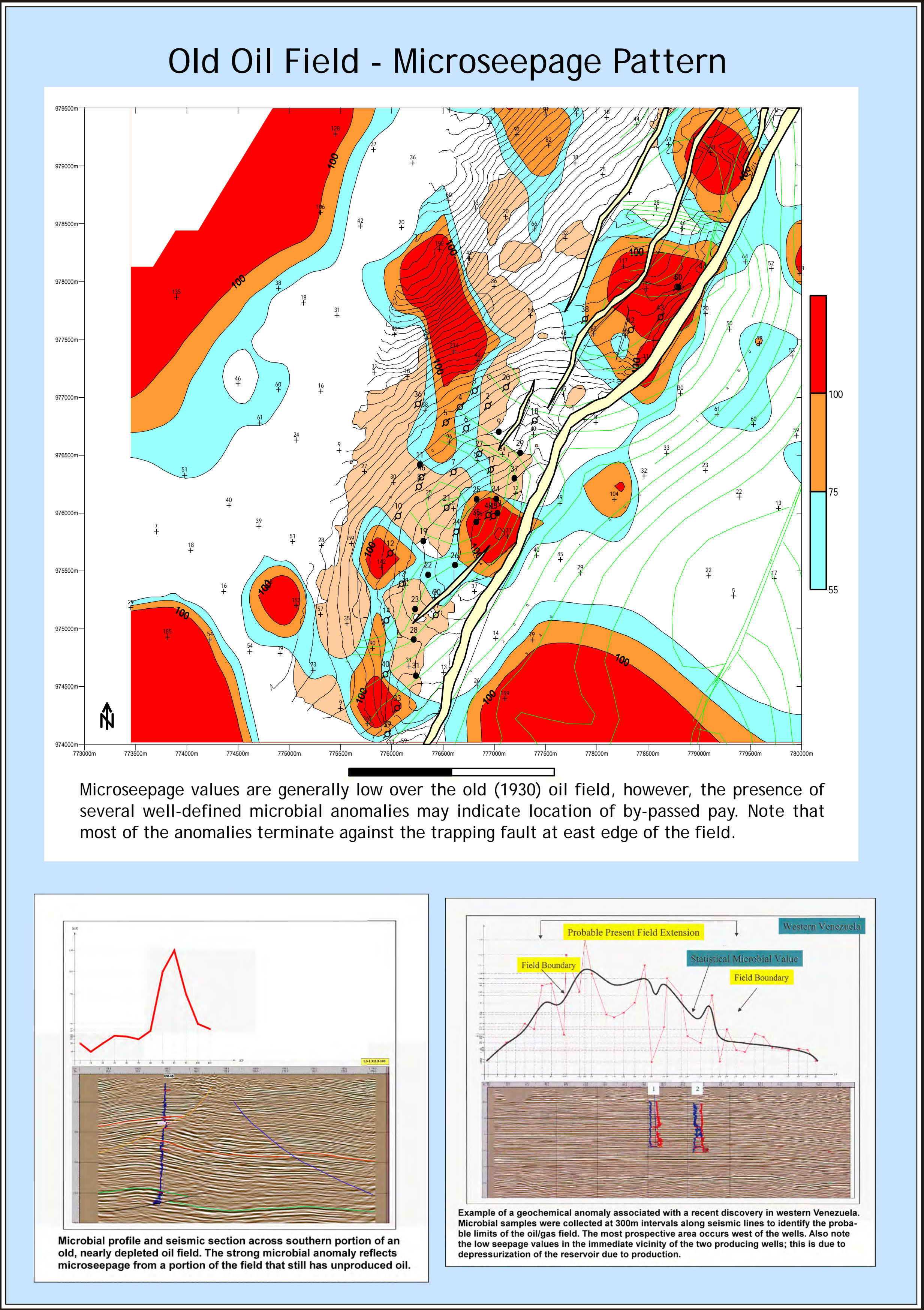
Near the left edge of the map, one well is located within a strong, circular seepage anomaly; the well had been drilled at the time of the survey, but had not yet been placed into production. In the northwest corner of the map is another strong seepage anomaly with a well locations indicated, but that well had not yet been drilled at the time of the survey.



Example 3: Los Manuelas Field, Western Venezuela

The Los Manuelas Field is located in the southwestern Maracaibo-Catatumbo basin, and occurs on the crest of a tightly folded anticline bounded on the east side by a west-dipping reverse fault. The principal reservoirs occur in the Eocene Mirador, but other reservoirs occur in the Oligocene, Paleocene, and Cretaceous. The field was discovered in 1930 and is now largely depleted. The principal objective of the microseepage survey was to determine (1) if the field has a surface geochemical expression, and (2) to document the geochemical evidence for the likely presence of bypassed pay in the old field, and (3) and the possible field extension to the north beyond the present productive limits. For comparison with the old oil field, we also acquired samples across a recently discovered and as yet undeveloped field (La Palma) nearby.

The results of the microbial and sorbed soil gas analyses form document very strong hydrocarbon microseepage over the new field, and lower but still significant microseepage over portions of the Los Manuelas field. The relatively low microseepage values over the old field are believed to reflect its long production history and lower reservoir pressures. High seepage values from over the northeast portion of Los Manuelas may reflect its shorter production history and greater remaining potential. New productive wells have been drilled within several of these microseepage anomalies, one of which is illustrated on the seismic section to the right.



Example 4: Santa Lucia Field, Middle Magdalena Valley Basin, Colombia

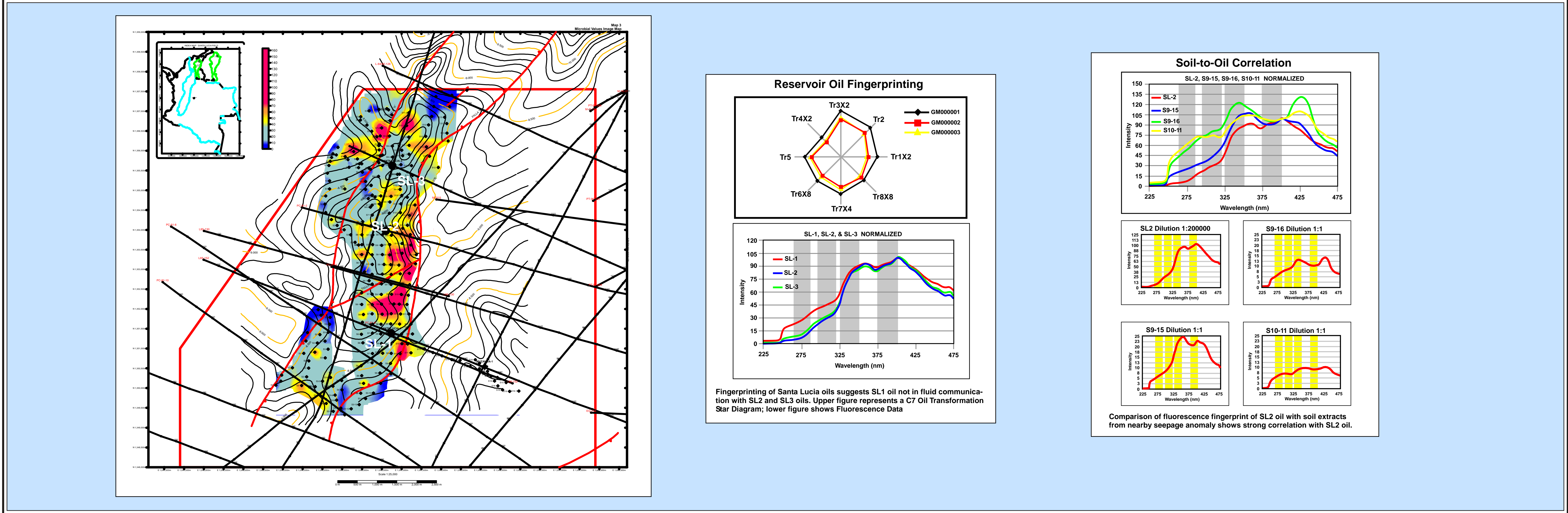
The Santa Lucia field is a small 3-well field situated on a faulted anticline in the Middle Magdalena Valley basin, central Colombia. The field produces 19-21 API Gravity oil and some associated gas from Lower Tertiary fluvial sands in the Esmeraldes-La Paz formations. At the time of the microseepage survey, 3 wells were producing 150-300 BOPD from depths of 2500-2600 meters. The survey area encompassed approximately 16km2, and consisted of low-lying farm and pasture land. Soil samples were collected at 250 meter intervals in a grid pattern. The objectives of the Santa Lucia microseepage survey were:

- Determine magnitude and areal extent of hydrocarbon microseepage anomalies associated with the oil field.
- Identify areas that may represent by-passed pay or leakage from an undrained reservoir compartment.
- Determine the composition of the migrating and/or reservoir hydrocarbons.
- Determine if the fault between wells SL-1 and SL-2 is a sealing fault.
- Correlate hydrocarbons from surface microseepage anomaly with the reservoir hydrocarbons.



The results of the microbial and adsorbed soil gas analysis documented the presence of strong microseepage at a number of locations north and east of the producing wells. The most prospective microseepage anomaly occurs as a 500-800m wide zone along the eastern edge of the field, between wells SL-1 and SL-2. The data suggest that this represents by-passed oil, or possibly oil from an untested reservoir compartment.

Gas chromatographic and fluorescence analysis of crude oil from the producing well were correlated with results of similar analyses performed on solvent extracts of soil from the microseepage anomaly. Chromatographic data support the conclusion that SL-1 oil is not in communication with oil from the SL-2 reservoir, and that the intervening fault is a sealing fault. Fluorescence characteristics of the crude oils independently support this conclusion and show a high degree of correlation with the soil extract data.



Summary and Conclusions

It has been well documented that hydrocarbon microseepage from petroleum accumulations is common and widespread, is predominantly vertical, and is dynamic (responds quickly to changes in reservoir conditions). These characteristics create a new suite of applications for surface geochemical surveys: field development, reservoir characterization, identifying by-passed pay, and monitoring patterns of hydrocarbon drainage.

Because hydrocarbon microseepage is predominantly vertical, the extent of an anomaly at the surface can approximate the productive limits of the reservoir at depth. The detailed pattern of microseepage over a producing field can also reflect reservoir heterogeneity and distinguish hydrocarbon-charged compartments from drained or uncharged compartments. Additionally, since hydrocarbon microseepage is dynamic, seepage patterns change rapidly in response to production-induced changes. Evidence for such changes are identified with detailed microbial and soil gas surveys. When such surveys are repeated over the life of a producing field or waterflood project, the changes in seepage patterns can reflect patterns of hydrocarbon drainage over a time frame of months to years.

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Development geologists and engineers may be skeptical about the conclusions and suggested implications that have been presented here, particularly since these interpretations are almost solely based on surface microseepage observations. That is understandable. As a service provider, we have limited access to such subsurface geological, geophysical, geochemical, or engineering data.

We would welcome the opportunity to work with a company to critically investigate the relationship between reservoir compartmentalization and reservoir fluid geochemistry, and their possible relationship with hydrocarbon microseepage at the surface above the field.

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