[PS]Geochemical Exploration in Northern South America: Recent Successes from Venezuela, Colombia, and Peru*

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Abstract

Detailed geochemical and research studies document that hydrocarbon microseepage from petroleum accumulations is common, is predominantly vertical (with obvious exceptions in some geologic settings), and is dynamic (responds quickly to changes in reservoir conditions). Since microseepage is nearly vertical, the extent of an anomaly at the surface can approximate the productive limits of the reservoir at depth. Furthermore, the detailed pattern of seepage can reflect reservoir heterogeneity, discriminate between charged and uncharged compartments, and identify areas of bypassed pay.

Results of recent microbial and soil gas surveys in Venezuela, Colombia, and Peru establish the value of hydrocarbon microseepage data for high-grading prospects and aiding field development projects. These surveys were conducted in the Eastern Venezuela basin, the Maracaibo-Catatumba basin in western Venezuela, the Guajira and Cesar Rancheria basins in northern Colombia, the Middle Magdalena Valley basin in central Colombia, and the Lancones basin in Peru. Results from the underexplored Lancones basin identified structures that warrant additional study due to strong hydrocarbon indications. The Guajira survey documented previously unrecognized oil potential in a basin known only for its biogenic dry gas. Results from eastern Venezuela and Cesar Rancheria successfully discriminated prospects on basis of probably hydrocarbon charge. Surveys over two old oil fields in western Venezuela and in the Middle Magdalena Valley identified bypassed pay and several new drilling opportunities.

High-resolution microseepage surveys offer a flexible, low-risk and low-cost environmentally friendly technology that not only complements traditional geologic and seismic data, but add value to such data. Properly integrated with other exploration data, their use has led to discovery of new reserves and drilling fewer dry or marginal wells.

Geochemical Exploration in Northern South America: Recent Successes From Venezuela, Colombia, and Peru

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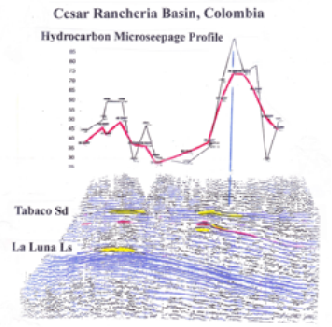
ABSTRACT

Detailed geochemical and research studies document that hydrocarbon microseepage from petroleum accumulations is common, is predominantly vertical with obvious exceptions in some geologic settings), and is dynamic (responds quickly to changes in reservoir conditions). Since microseepage is nearly vertical, the extent of an anomaly at the surface can approximate the productive limits of the reservoir at depth. Furthermore, the detailed pattern of seepage can reflect reservoir heterogeneity, discriminate between charged and uncharged compartments, and identify areas of bypassed pay.



Results of recent microbial and soil gas surveys in Venezuela, Colombia, and Peru establish the value of hydrocarbon microseepage data for high-grading prospects and aiding field development projects. These surveys were conducted in the Eastern Venezuela basin, the Maracaibo-Catatumba basin in western Venezuela, and Guajira and Cesar Rancheria basins in northern Colombia, the Middle Magdalena Valley basin in central Colombia, and the Lancones basin in Peru. Results from the under explored Lancones basin identified structures that warrant additional study due to strong hydrocarbon indications. The Guajira survey documented previously unrecognized oil potential in a basin known only for its biogenic dry gas. Results from eastern Venezuela and Cesar Rancheria successfully discriminated prospects on basis of probably hydrocarbon charge. Surveys over two old oil fields in western Venezuela and in the Middle Magdalena Valley identified bypassed pay and several new drilling opportunities.

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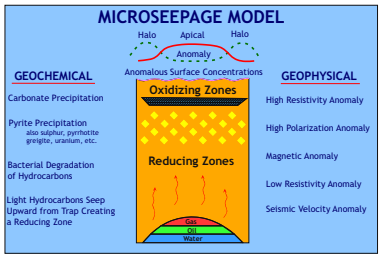
BASICS OF HYDROCARBON MICROSEEPAGE

- Most oil and gas accumulations have a surface geochemical expression, unless they are greatly underpressured or contain heavy oil (API Gravity < 15)
- 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
- Microseepage is predominantly vertical except in structurally complex areas with many faults or fracture leak points
- Prospects with an associated microseepage anomaly are 4 to 6 times more likely to result in a commercial discovery than prospects lacking such an anomaly.

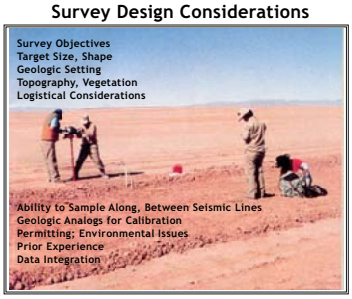
MICROSEEPAGE DETECTION METHODS

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.

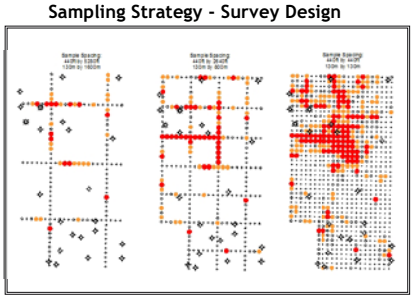


- ***Remote sensing, satellite imagery analysis.***
  Detects hydrocarbon-induced alteration of soils and sediments
- ***Aeromagnetics, micromagnetics.***
  Detects seep-induced magnetic anomalies in shallow subsurface
- ***Soil gas, acid extracted soil gas, fluorescence.***
  Measures concentration 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

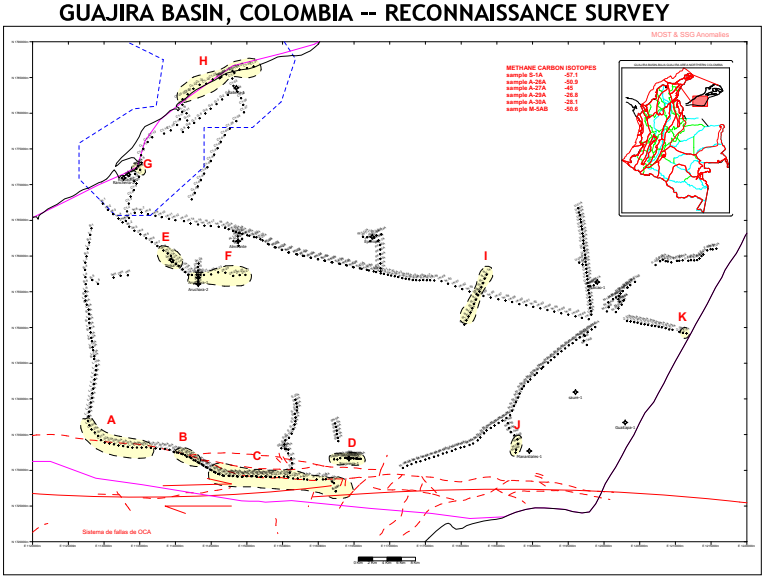
Survey Design Considerations



Sampling Strategy - Survey Design



GUAJIRA BASIN, COLOMBIA -- RECONNAISSANCE SURVEY



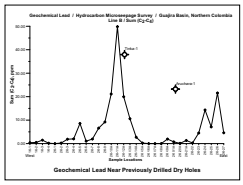
Geologic Setting

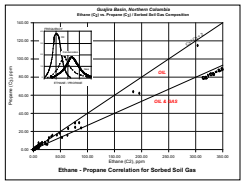
The Guajira basin occupies the southern part of the Guajira Peninsula in northern Colombia. Exploration targets are primarily of Early Miocene age, but the area may also have potential in older reservoirs (Eocene, Oligocene, Cretaceous). Existing production in the Guajira basin is biogenic dry gas. No oil or thermogenic gas has been discovered in the basin to date.

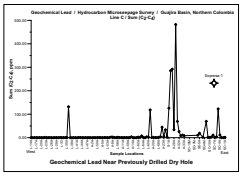
Survey Objectives

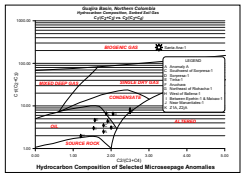
The objectives of this reconnaissance survey are:

- To determine if a petroleum system for oil and thermogenic gas exists in the basin.
- To evaluate the magnitude and extent of the microseepage anomalies.
- To establish the composition of the migrating hydrocarbons (oil, condensate, gas).









SURVEY LOGISTICS

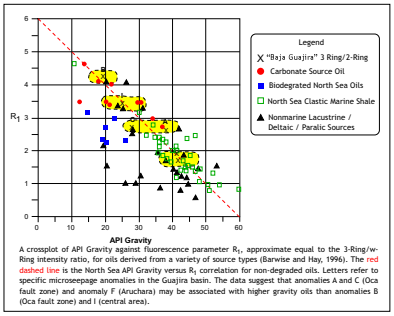
The surface geochemical reconnaissance survey was conducted along roads and trails across an area of 5400 square kilometers. Samples were collected at 250-1000 meter intervals. Four 2-man crews collected samples from 598 locations in 12 days. Microbial samples were collected at 20 cm depth; sorbed soil gas samples were collected at a depth of one meter.

Guajira Basin, Colombia: Isotopic Composition of Sorbed Soil Gas

Guajira Samples

1. S-1A
2. A-26A
3. A-27A
4. A-29A
5. A-30A
6. M-54B

Genetic characterization of natural gases by compositional and isotopic variations (Schoell, 1983). Figure shows relative concentrations of C2+ hydrocarbons in relation to carbon isotopic composition of methane. Arrows Mt and Md indicate expected compositional changes due to shallow and deep migration, respectively. B represents biogenic gas, M is mixed thermal and biogenic gas. To represents oil-associated gas, Tc is gas associated with condensate, and TT represents thermal dry gas derived from oil-prone (m) or humic (h) source rocks. Numbers 1-6 identify Guajira basin sorbed soil gas samples. Four of the samples represent oil-assiciated methane, however, samples 4 and 5 may represent coal-derived gases.



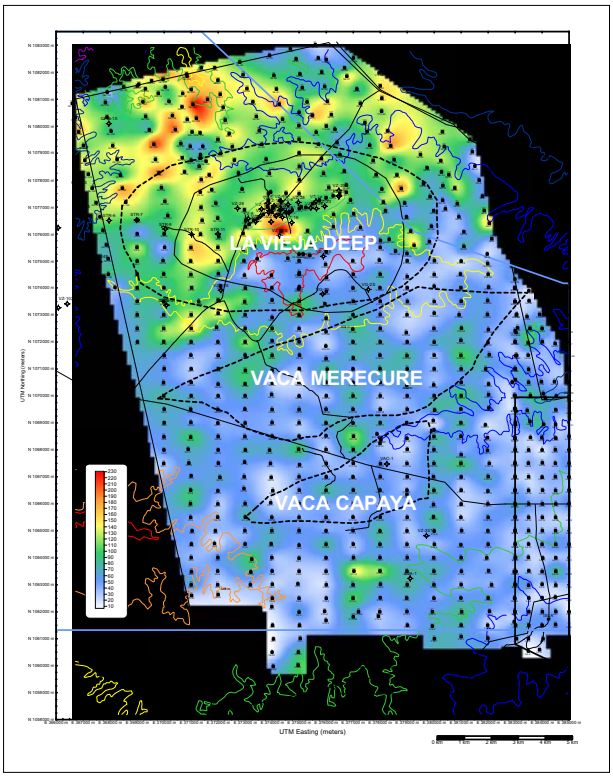
A crossplot of API Gravity against fluorescence parameter R_1, approximate equal to the 3-Ring/w-Ring intensity ratio, for oils derived from a variety of source types (Barwise and Hay, 1996). The red dashed line is the North Sea API Gravity versus R_1 correlation for non-degraded oils. Letters refer to specific microseepage anomalies in the Guajira basin. The data suggest that anomalies A and C (Oca fault zone) and anomaly F (Aruchara) may be associated with higher gravity oils than anomalies B (Oca fault zone) and I (central area).

CONCLUSIONS

The results of this reconnaissance surface geochemical survey of the Guajira basin support the following conclusions:

- One, possibly two, petroleum systems exist in addition to the previously known biogenic gas hydrocarbon system.
- Oil and oil-associated gas generation and migration have occurred in the basin. The presence of oil and associated thermogenic gas is documented by sorbed soil gas data, carbon isotopic composition of methane and ethane, fluorescence analysis of soil extracts, and gas chromatography of selected solvent extracts.
- The principal microbial and soil gas anomalies occur in the southwestern and south-central parts of the basin. Seepage is especially strong near the Oca fault zone.
- The survey identified a number of geochemical leads that warrant additional geological, geophysical, and geochemical evaluation.

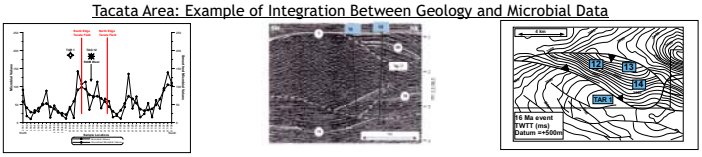
QLC BLOCK, EASTERN VENEZUELA BASIN - PROSPECT EVALUATION



Geologic Setting

The Quiamare La Ceiba (QLC) block in the Eastern Venezuela basin lies within a structurally complex zone just beyond the western edge of the prolific petroleum province known as the El Furial trend. The QLC concession is located in the Santa Rosa structural block and includes the Quiamare, La Vieja, La Ceiba, and Tacata oil fields. Production is primarily from the Milocene Oficina and Eocene Merecure formations. Heavy oil is present in the shallow reservoirs of the old La Vieja field; light oil and condensate characterize deeper reservoirs.

Tacata Area: Example of Integration Between Geology and Microbial Data



North to South microbial profile across Tacata field illustrating the strong microseepage anomaly associated with the field. The accompanying seismic section and structure map illustrate the structural complexity of the Tacata area.

Survey Objectives

The objectives of the QLC geochemical survey are:

- Determine the magnitude and lateral extent of hydrocarbon microseepage anomalies associated with the various exploration prospects, and with the La Vieja and Tacata fields.
- High-grade the major prospects based on their probable hydrocarbon charge.
- Determine the composition of the migrating and/or reservoired hydrocarbons.
- Identify geochemical leads that warrant further geologic and seismic study.

Survey Logistics

A geochemical survey was conducted over a 575 square kilometer area in the eastern half of the QLC block. Surface conditions ranged from open grassland in the eastern part of the ara to dense, almost impenetrable jungle in the west. Samples were collected at 500-1000 meter intervals in a grid pattern. Sample sites were located with hand held 12 channel Garmin GPS units. Two to three 3-man crews collected 1587 microbial samples and 200 sorbed soil gas samples in 60 days. Microbial samples were collected at 20 cm depth; sorbed soil gas samples were collected from a depth of one meter.

CONCLUSIONS

The results of microbial and sorbed soil gas analyses support the following conclusions:

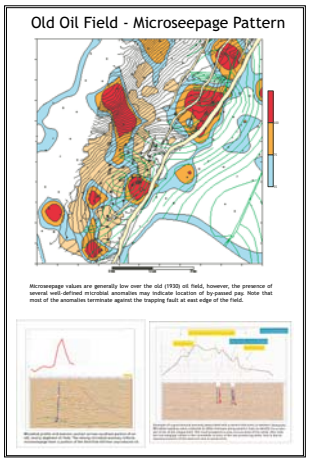
- The most intense microseepage is associated with the surface expressions of the Urica fault near Urica and extending west to just north of La Vieja field.
- Significant microseepage anomalies are associated with the La Vieja Deep prospect and the central part of the Vaca Merecure prospect. There is no geochemical anomaly associated with the Vaca Capaya prospect.
- A cluster of microseepage anomalies extends E-W along the acial portion of Tacata field. The absence of a single large anomaly -- one coincident with the mapped closure -- suggests that the trap is either not fully charged, or more compartmentalized than seismic data suggest.

APPLICATIONS FOR FIELD DEVELOPMENT AND PRODUCTION

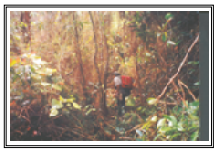
Because hydrocarbon microseepage is predominantly vertical, the extent of the anomaly at the surface can approximate the productive limit of the reservoir at depth. The detailed pattern of microseepage over a producing field can also reflect reservoir heterogeneity and distinguish hydrocarbon-charged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

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.



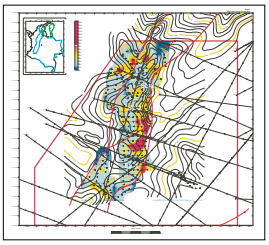
Santa Lucia Field, Middle Magdalena Valley Basin, Colombia

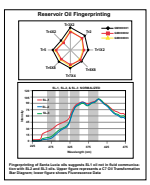
The Santa Lucia field is a small 3-well field situated on a faulted anticline in the Middle Magdalena Valley basin, central Colombia. The field produces 19-21 API Gravity oil and some associated gas from Lower Tertiary fluvial sands in the Esmeraldes-La Paz formations. At the time of the microseepage 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:

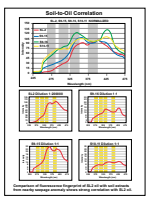
- Determine magnitude and areal extent of hydrocarbon microseepage anomalies associated with the oil field.
- Identify areas that may represent by-passed pay or leakage from an undrained reservoir compartment.
- Determine the composition of the migrating and/or reservoired hydrocarbons.
- Determine if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

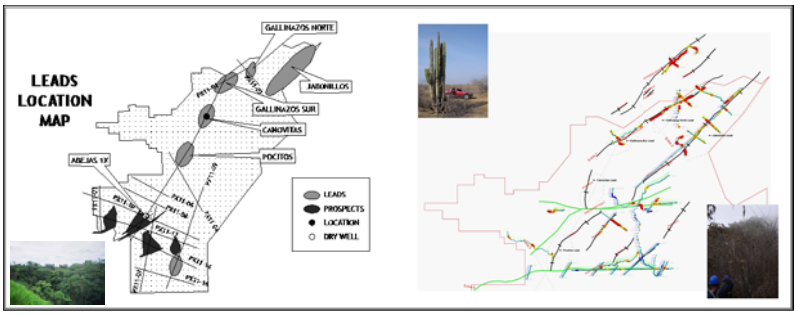
Gas chromatographic and fluorescence analysis of crude oil from the producing well were correlated with results of similar analyses performed on solvent extracts of soil from the microseepage anomaly. Chromatographic data support the conclusion that SL-1 oil is not in communication with oil from the 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.







LANCONES BASIN, PERU - RECONNAISSANCE SURVEY



Geologic Setting

The Cretaceous Lancones basin is one of a number of rift-related marginal basins in western South America. It is located in northwestern Peru and is bordered by the Amotape-Tahuin Massif (La Brea Mountains) on the west and volcanic arc strata on the east. Sediments in the basin are primarily of Upper Cretaceous and Cenozoic age, however Paleozoic rocks are present in the Paito area. Surface anticlines in the northern part of the basin represent potential exploration leads and prospects.

Survey Objectives

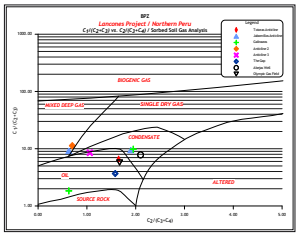
The objectives of this reconnaissance survey are:

- to determine the presence of a petroleum system for oil and/or thermogenic gas.
- to high-grade the major anticlines and other exploration leads on the basis of likely hydrocarbon charge.
- to document the composition of the migrating hydrocarbons (oil, condensate, or dry gas).
- to identify geochemical leads that warrant geologic and seismic evaluation.

Survey Results

The results of this reconnaissance geochemical survey:

- document the presence of at least one, possibly two, petroleum systems in the basin.
- identified several anticlines or portions of anticlines with strong hydrocarbon microseepage anomalies.
- the composition of the migrating hydrocarbons ranges from thermogenic dry gas to gas associated with light oil and/or condensate.



SUMMARY AND CONCLUSIONS

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