

Geochemical Exploration Strategies for Papua New Guinea and other Geologically Complex Areas in Southeast Asia: Best Practices and Recent Exploration Case Histories*

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Search and Discovery Article #11318 (2020)**

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Abstract

The petroleum potential of geologically complex areas -- such as highly faulted and folded terrains -- is often poorly known due to technical challenges affecting seismic acquisition and imaging. When these areas occur in jungles and highlands, the logistical challenges only add to the difficulty of evaluating the petroleum potential of such regions. For such areas, surface geochemical and non-seismic hydrocarbon detection 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.

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 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) spectral and hyperspectral anomalies. These varied expressions of hydrocarbon seepage have led to the development of an equally diverse number of hydrocarbon detection methods. Some of these methods are geochemical, some are non-seismic geophysical methods, and some come under the category of remote sensing.

Hydrocarbon detection surveys in geologically complex areas require careful planning and implementation due to extreme variations in topography and surface conditions. Based on effective logistical and security considerations, geochemical surveys have proven ideal for this region's diverse exploration regions. To optimize recognition of hydrocarbon anomalies, survey patterns and sample numbers must reflect survey objectives, expected size and shape of targets, and expected variation in surface measurements. Defining background values is an essential part of anomaly recognition and delineation. Under-sampling and/or the use of improper sampling techniques represent a major cause of ambiguity which may lead to interpretation failures.

Hydrocarbon detection surveys are most effective when results are integrated with satellite remote sensing data and available geophysical data. Such surveys are ideally suited for an early stage evaluation since they can quickly identify those parts of the area possessing the highest petroleum potential, as well as determine the characteristics of petroleum in the areas of interest.

When used to high-grade exploration leads and prospects on the basis of their likely hydrocarbon charge, geochemical survey results predict 75% to 85% of subsequent discoveries, and 90% of subsequent dry holes. The inclusion of hydrocarbon detection surveys early in an exploration strategy focuses attention and resources on a relatively small number of high potential areas, thereby minimizing both risks and expenses.

This presentation is illustrated with examples of surface geochemical results evaluating drilling sites, AOIs, prospects and post drilling surveys over dry and discovery wells from PNG, Australia, Indonesia, Laos, Malaysia, Philippines, Taiwan, and Thailand. The examples from PNG and some from Indonesia and the Philippines have not been published before.

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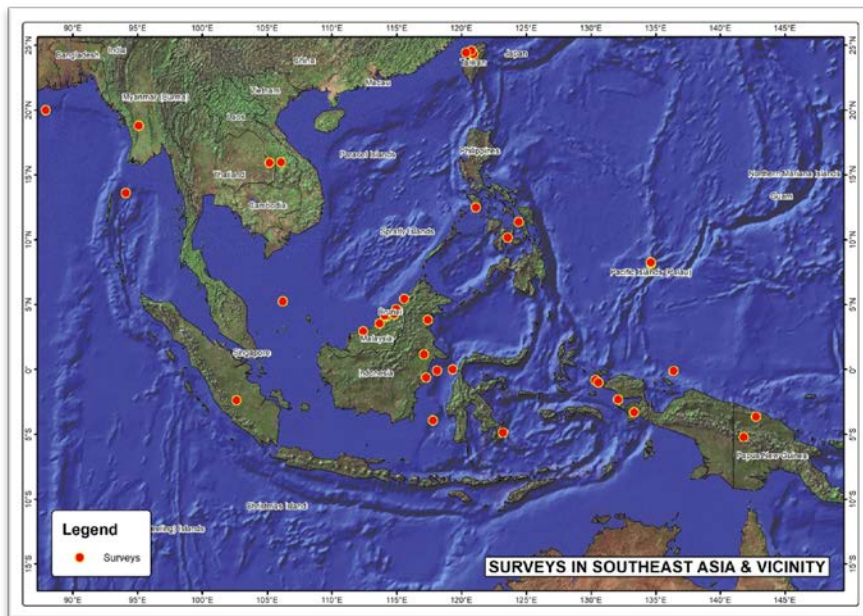
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Geochemical Exploration Strategies for Papua New Guinea and other Geologically Complex Areas in Southeast Asia Best Practices and Recent Exploration Case Histories



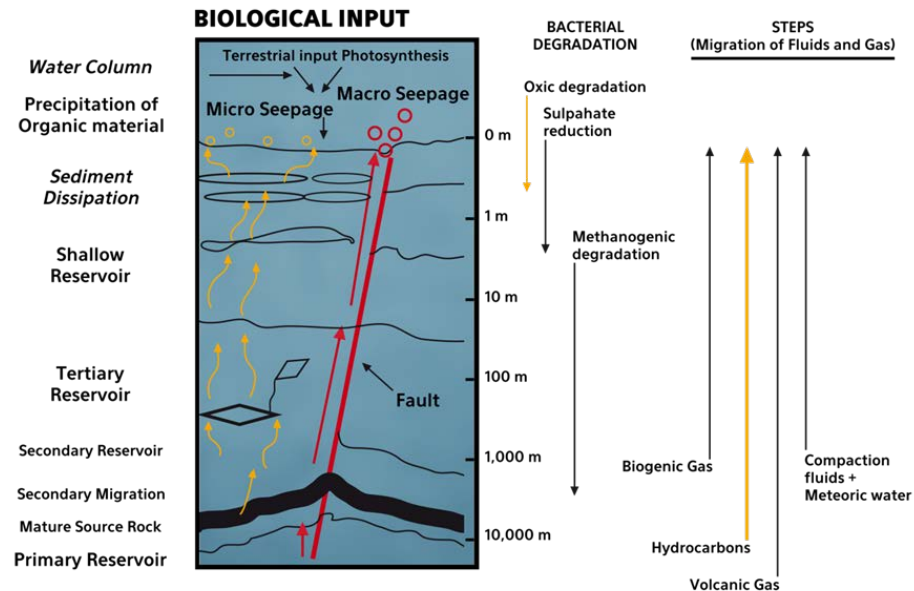
Luigi Clavareau and Dietmar Schumacher, E&P GeoField Services, Singapore

Outline

- **Why Geochemical Hydrocarbon Detection Surveys**
- **Geochemical Hydrocarbon Detection Methods/Survey Methods**
- **Survey Objectives and Design Considerations**
- **Selected Exploration Examples**
- **Measuring Success of Geochemical Surveys**
- **Summing Up**

Why Use Geochemical Hydrocarbon Detection Surveys?

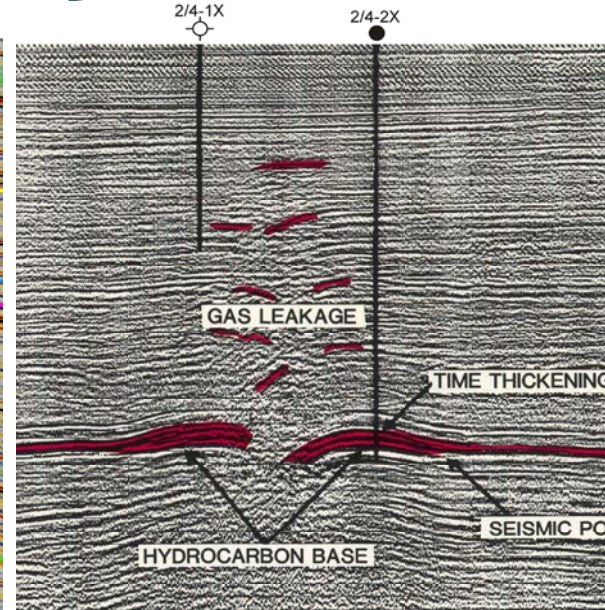
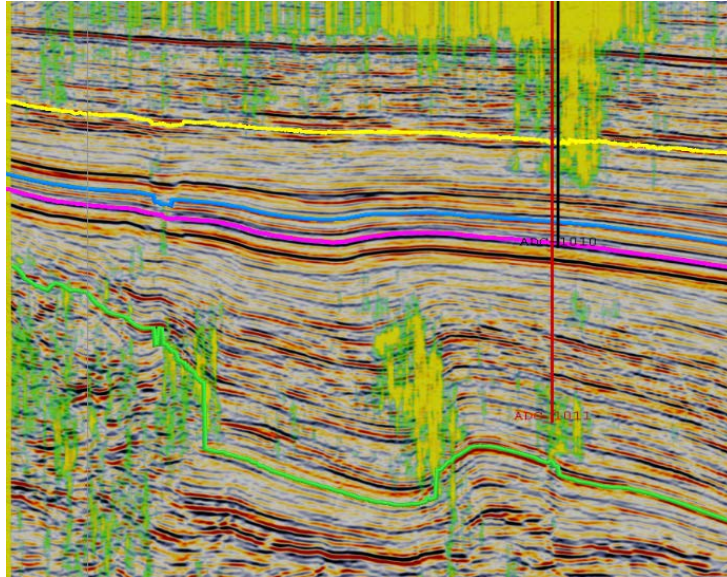
- Most productive basins leak
- Most accumulations leak
- Discriminate between oil versus gas
- Leakage is predominantly vertical
- Direct indicator of hydrocarbons
- Identify and map hc-induced alteration
- Minimal environmental impact
- Prospects with hydrocarbon anomaly
- 4-6X more likely to result in discovery



Why Use Geochemical Hydrocarbon Detection Surveys?

1. Most oil/gas accumulations leak light hydrocarbons to the surface. Exceptions are reservoirs with heavy oil, or severely underpressured for their depth.
2. Leakage is Dynamic
3. Hydrocarbon microseepage is predominantly vertical, and buoyancy is principal force that brings gases to the surface. Migration rates average 1 – 3 m/day.
4. Provides Direct Indication of Hydrocarbons and/or of Hydrocarbon-Induced Changes
5. Prospects with Microseepage Anomaly are 4-6 times more likely to result in a discovery
6. Microseepage is the end of the migration path

Hydrocarbon Microseepage is Predominantly Vertical



North Sea (Van den Bark)

Leakage is 1000 liters/hour; approx. 1 TCF/MY

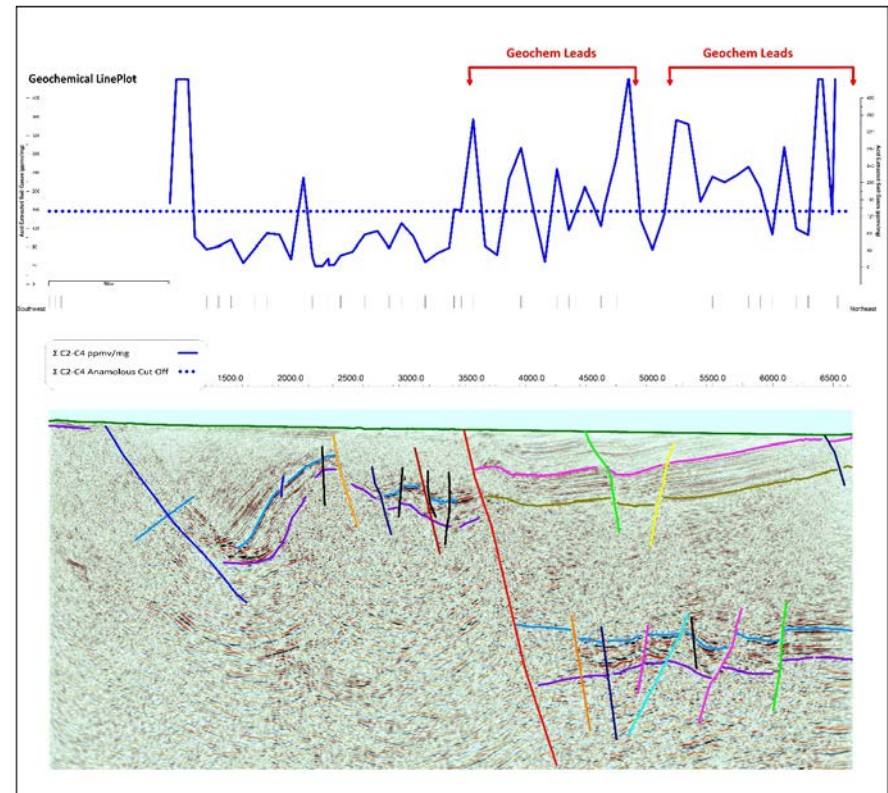
Presenter's notes:

1. Most oil/gas accumulations leak light hydrocarbons to the surface.
Exceptions are reservoirs with heavy oil, or severely underpressured for their depth.
2. Leakage is Dynamic.
3. Hydrocarbon microseepage is predominantly vertical, and buoyancy is principal force that brings gases to the surface. Migration rates average 1 – 3 m/day.
4. Provides Direct Indication of Hydrocarbons and/or of Hydrocarbon-Induced Changes.
5. Prospects with Microseepage Anomaly are 4-6 times more likely to result in a discovery.
6. Microseepage is the end of the migration path.

Why Use Geochemical Hydrocarbon Detection Surveys?

Microseepage Data - when properly acquired, analyzed, interpreted, and integrated with seismic data:

ADDS INFORMATION AND VALUE TO SEISMIC DATA BY IDENTIFYING LEADS AND PROSPECTS ASSOCIATED WITH HYDROCARBONS



Presenter's notes:

1. Early delineation of field limits.
2. Identify by-passed pay or undrained reservoir compartments.
3. Identify near-field opportunities.
4. Document hydrocarbon drainage over time with repeat surveys.

Geochemical Hydrocarbon Detection Methods - Summary

Direct Measurements/Detection of Hydrocarbon Seepage Detection

- **Soil Gas** – FID GC C1 to C5, Qualitative – Quantitative **Interstitial, Headspace, Occluded, etc.**
- **Acid Extracted Soil Gas** – FID GC C1 to C5+, Qualitative – Quantitative
- **Aromatics/Fluorescence (Liquid Hydrocarbons) C5 to C10** hydrocarbon concentration and composition
- **Passive Soil Vapor, C2-20** – GCMS – Qualitative
- **Heavy Hydrocarbons, C10+**

Indirect Measurements/Detection of Hydrocarbon Seepage Detection

- **Microbial (thermogenic C4)**
 - measures HC-oxidizing bacteriaQualitative – Quantitative
- **Helium, Radon , Iodine - Trace Elements**

Other Related Techniques

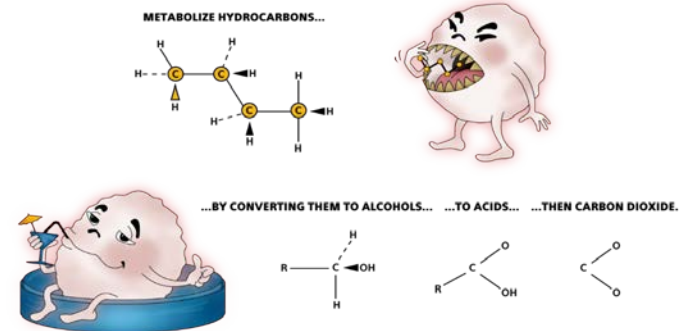
- **Thermal and Vegetation Anomaly Study**
- **Carbon Isotopes Analysis**
- **Hydrocarbon Seep Analysis**
- **Biomarkers Analysis**

Hydrocarbon Detection Methods

Microbial:

In the laboratory, a portion of the sediment sample is suspended in a sterile liquid sea salts medium with mineral and nutrients and n-butanol is employed to screen for specific microorganisms in the environment whose presence would be indicative of a population that is adaptive to a buried source of butane.

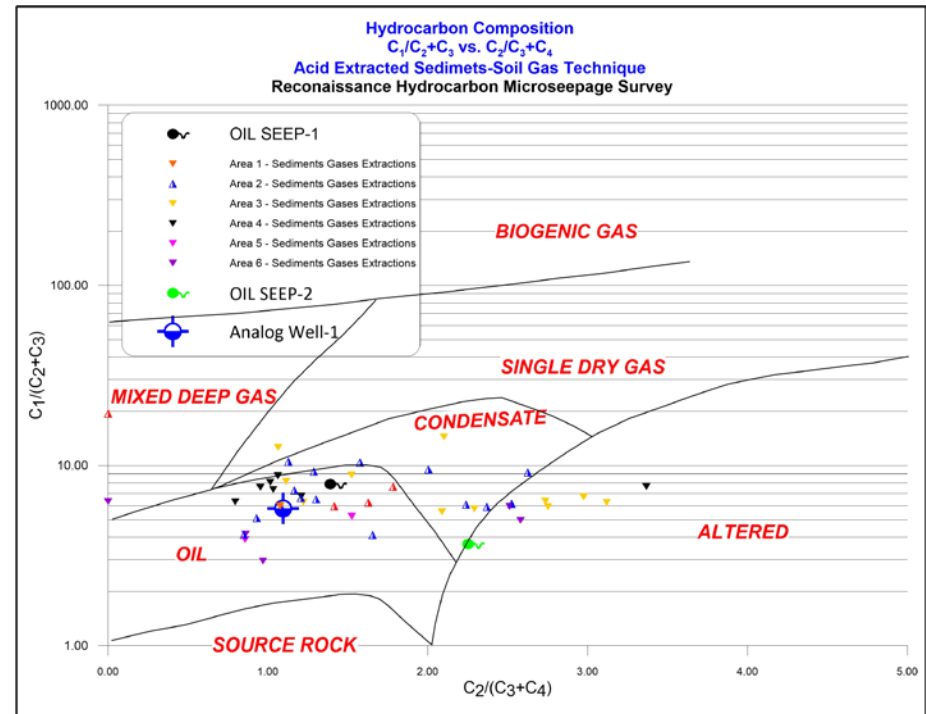
Microbial growth is monitored and measured daily by the turbidity of the liquid for approximately 15 days.



Hydrocarbon Detection Methods

**FID GC Gas Chromatography Analysis
C1 to C4 or C5+**

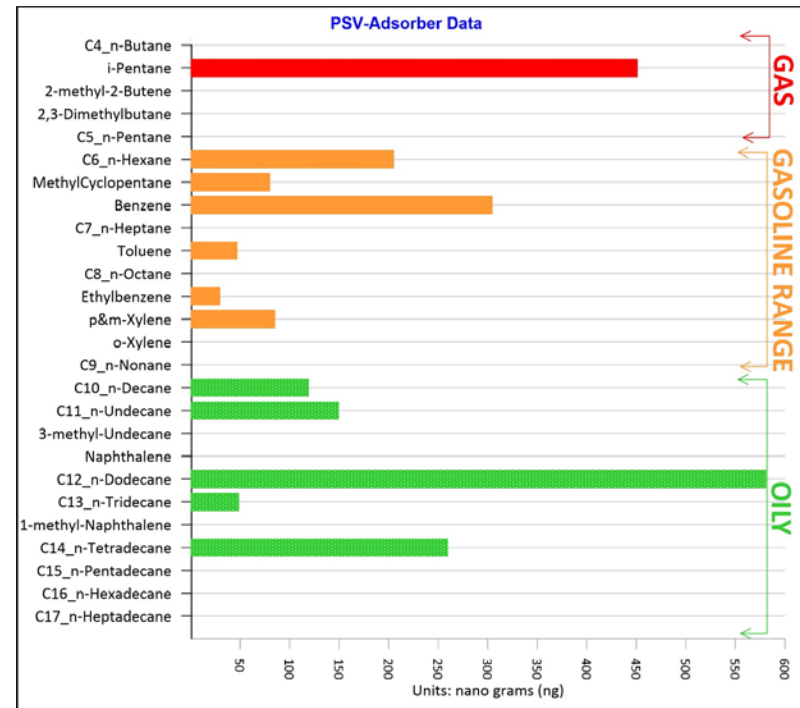
**Analyzed by GC, Quantitative and
Qualitative - Gas ratios predict if
hydrocarbon source is oil, condensate,
or gas prone.**



Hydrocarbon Detection Methods

Passive Soil Vapor: C2 to C20; integrative; uses in-can samplers; 2 - 3 week residence time – **Analyzed by GC/MS, Qualitative.**

The PSV Technique is a modification of a soil gas method which attempts to sample hydrocarbons over the range of C2 to C20 by use of a specially designed in-ground sampler and a long collection time (2 to 3 weeks).



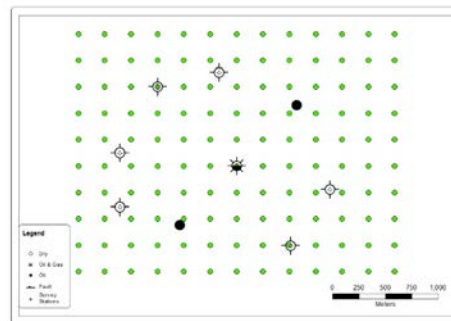
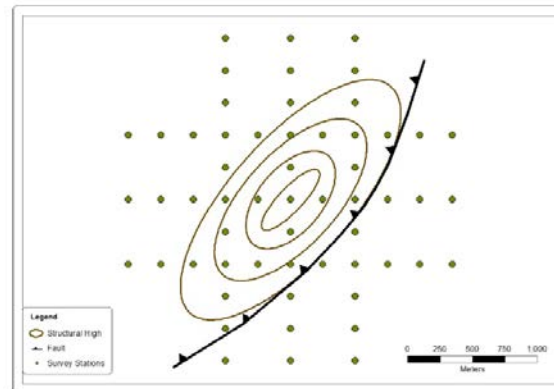
Presenter's notes: In-ground sampler and a long collection time (2 to 3 weeks).

Survey Objectives and Design Considerations

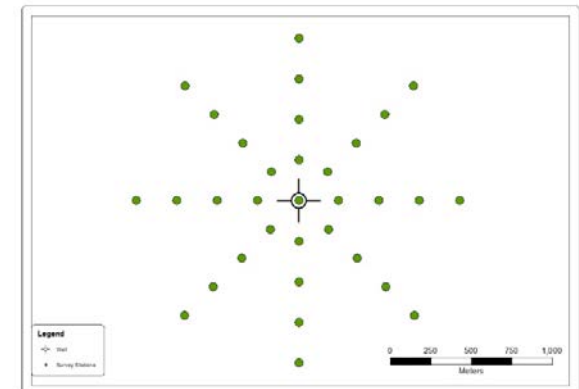
Reconnaissance



Prospect Evaluation De-Risking



High-grade Drilling Locations

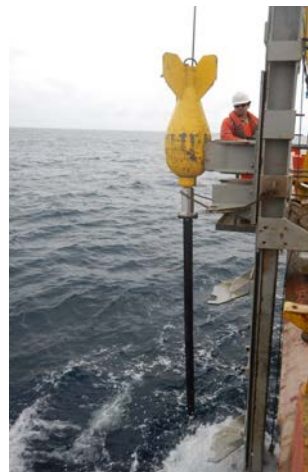


- Target Size, Shape
- Geologic Setting - Faults
- **Topography, Vegetation**
- Geologic Analogs for Calibration

Presenter's notes: Survey design and sample spacing depends on the exploration objectives and on the expected size of your exploration targets.

What and Where To Sample

- Oil and Gas Seeps, if present
- Along & Across Faults and Fracture Zones
- Gravity Lows (Basin Depocenter?)
- Structural Highs (Possible Traps)
- Possible Seep-Induced Soil/Sediment Alteration
- Along Regional Seismic Lines, if available
- Geologic Analogs (both productive and dry)
- Regional Survey Lines or Grids, depending on terrain and logistical considerations



Survey Objectives and Design Considerations

PNG



- Sampling is fast
- Small Crews, 2-3 people per crew
- No Environmental Issues **samples are from shallow holes 20 to 100cm**
- Light hand digging tools

SABAH

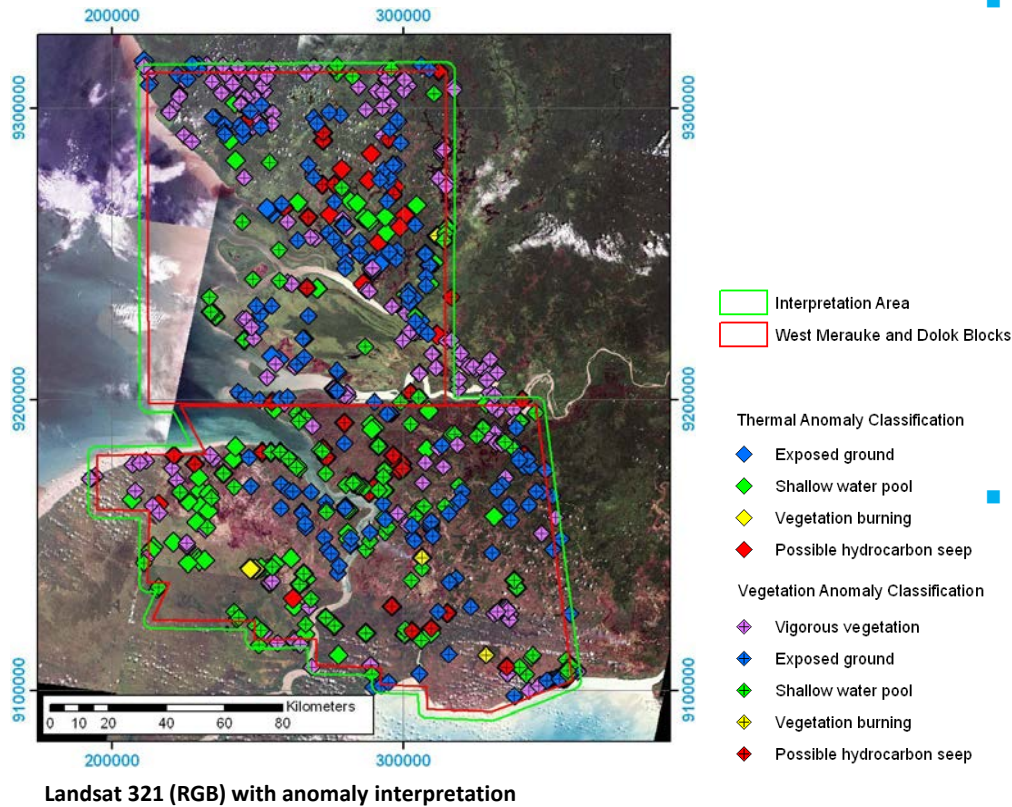


- Ability to Sample Along & Between Seismic Lines
- Ability to relocate sampling sites to better locations
- **Permitting**

Presenter's notes: Small Crews, 2-3 people per crew can access difficult remote areas to collect soil samples for Qualitative and Quantitative Hydrocarbon Detection Analysis.

Selected Exploration Examples

Thermal and Vegetation Anomaly Study



- Landsat thermal imagery processed in to a thermal band combination (652 RGB) allows the identification of thermal anomalies which may be related to hydrocarbon macro seeps

- NDVI analysis can be used as an assessment of vegetation health, in a attempted to identify any locally stressed vegetation which may indicate surface macro seeps

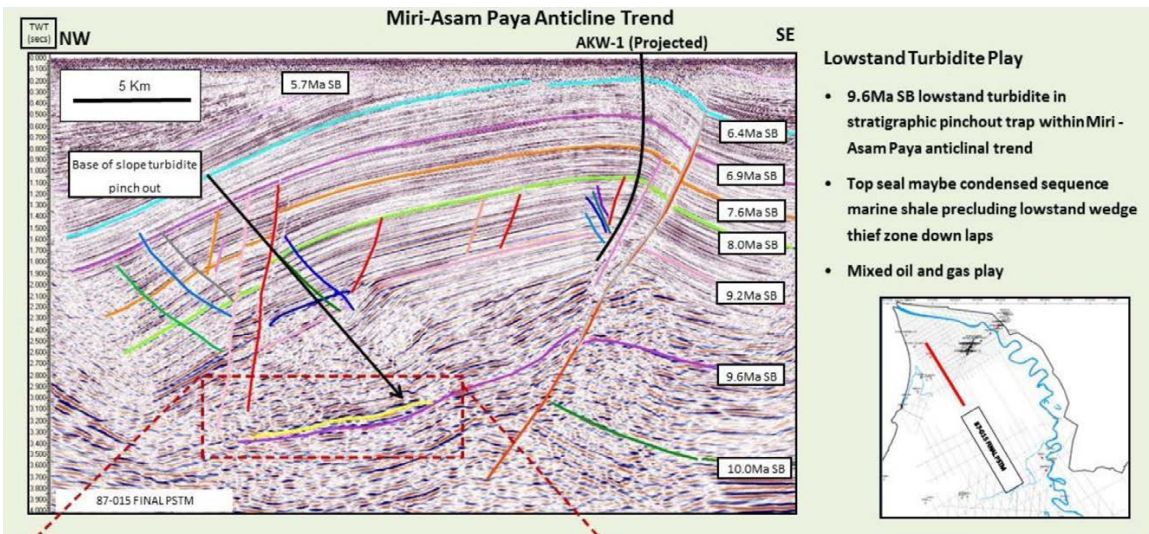
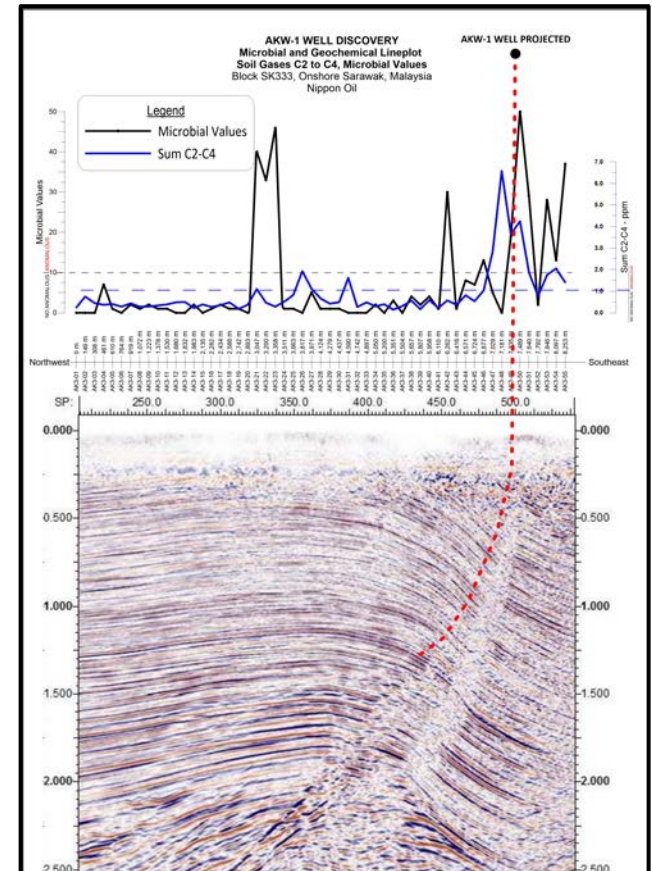
SARAWAK MALAYSIA, MIRI-ASAM PAYA ANTICLINE

AKW-1 Discovery

AKW-1 WELL DISCOVERY

Microbial and Geochemical Lineplot
Soil Gases C2 to C4, Microbial Values
Onshore Sarawak, Malaysia

**Leakage along a fault is
indicative of a charged
trap against the fault**

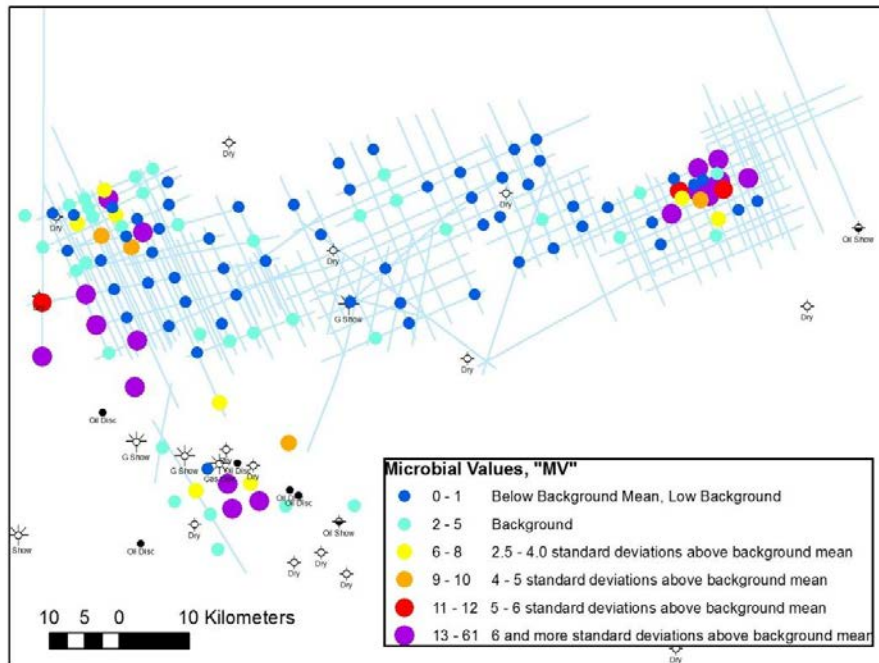


Presenter's notes: Leakage along a fault is indicative of a charged trap against the fault.

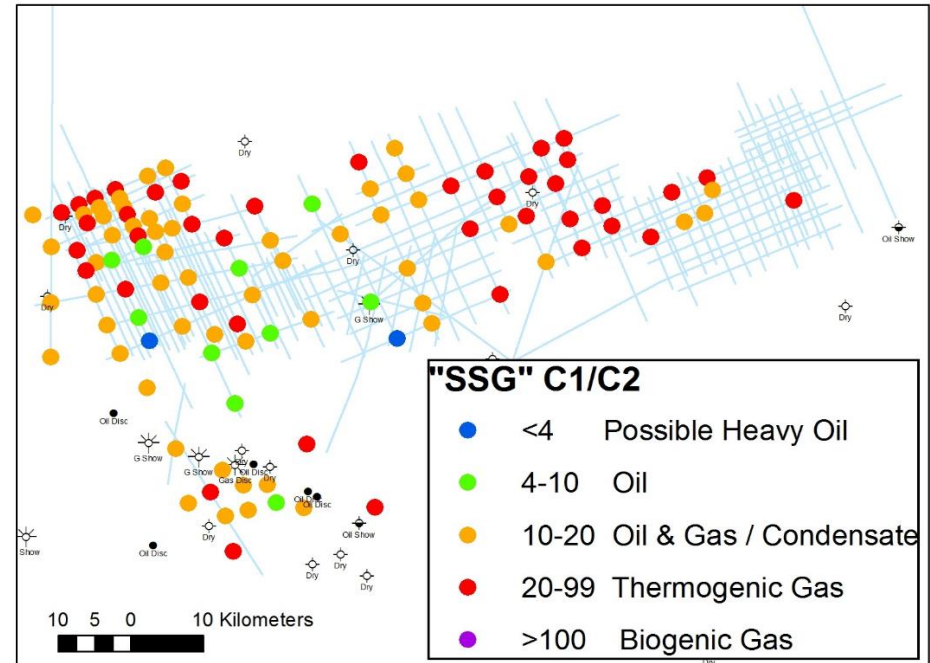
Another untested play of low stand turbidite was observed in the deeper part of the Miri-Asam Paya Anticline simply overlying over the 9.6 Ma SB. The play, which also has the potential for both oil and gas trapping, is stratigraphically contained with the condensed sequence of marine shales potentially acting as the top seal (after Jong *et al.*, 2013; 2015). *Bulletin of the Geological Society of Malaysia, Volume 63, June 2017* - Exploration history and petroleum systems of the onshore Baram Delta, northern Sarawak, Malaysia

OFFSHORE INDONESIA, Natuna Sea

Microbial Technique (MT) Anomaly Recognition



Acid Extraction Core Sediments Gases Hydrocarbon Composition

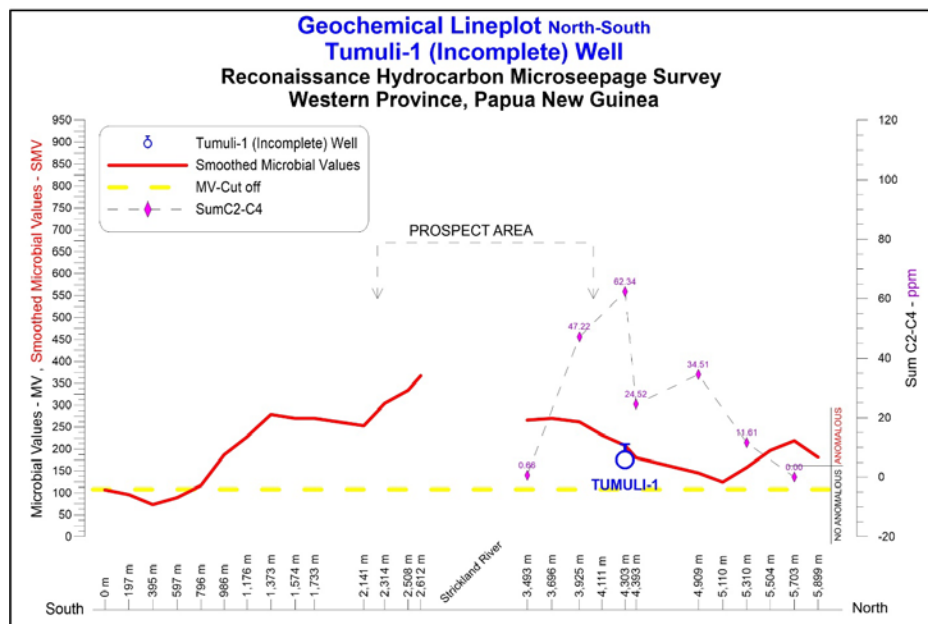


Presenter's notes: Offshore survey over Production Area as analog for prospect areas, northeast prospect shows anomalous samples high prospectivity base on MT technique and composition from the extracted gases agrees with known production, oil, condensate, gas.

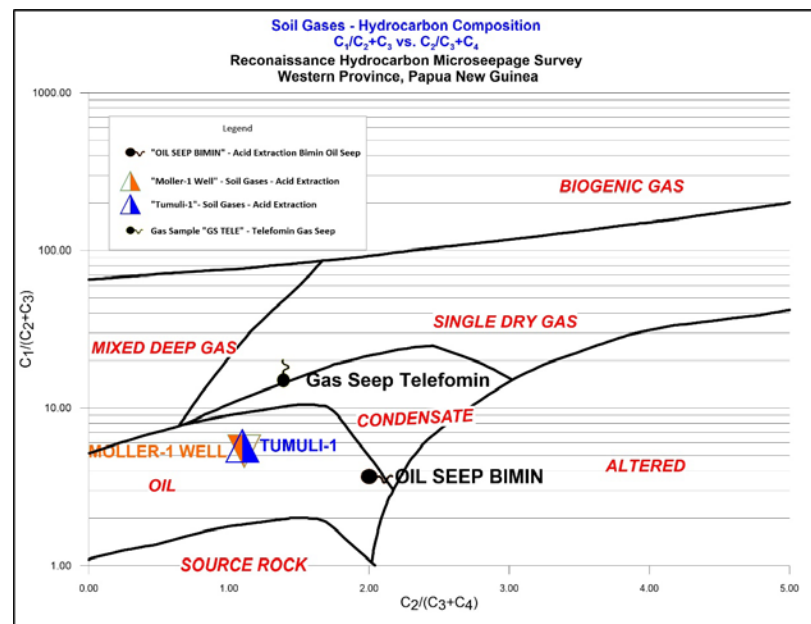
WESTERN PROVINCE, PAPUA NEW GUINEA

Tumuli-1 (Incomplete) Well

Geochemical Lineplot Over Prospect and Analog Well Microbial Technique (MT) and Soil Gases

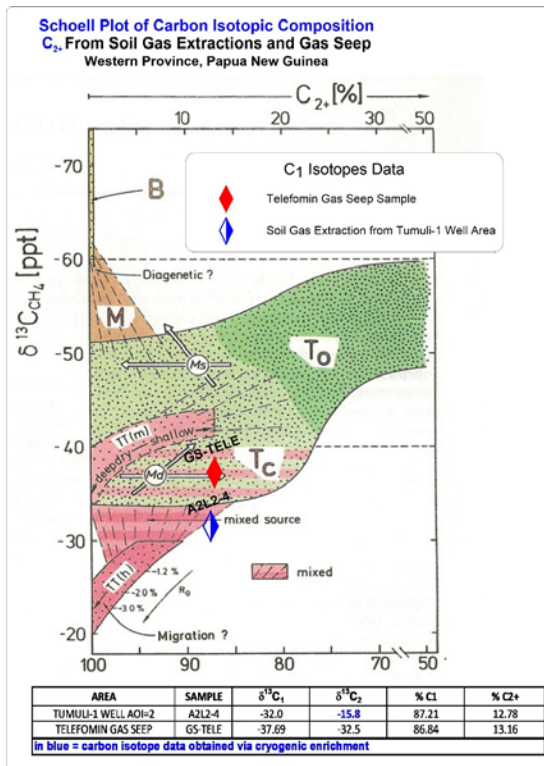


Hydrocarbon Composition Plot Soil Gases and Gas & Oil Seeps



WESTERN PROVINCE, PAPUA NEW GUINEA

Telefomin Gas Seep & Tumuli-1 (Incomplete) Well



The TELEFOMIN gas seep sample Has a composition characteristic of gases associated with condensate or very light oil.

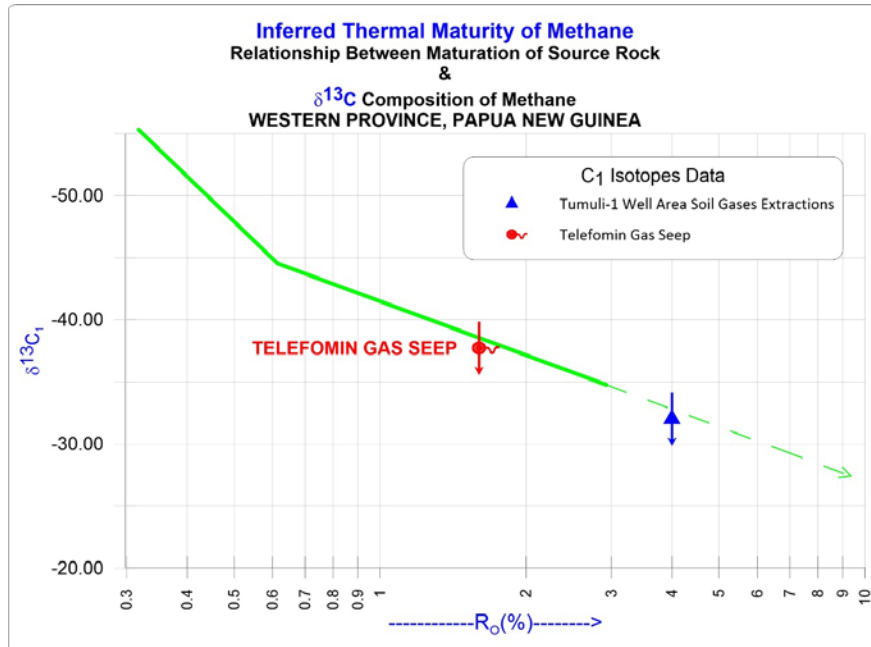
The Carbon Isotopes from the Tumuli-1 (Incomplete) Well area Soil Gases Extractions indicate a mixed source.

Presenter's notes: The Carbon Isotopes from the Tumuli-1 (Incomplete) Well area Soil Gases Extractions indicate a mixed source.

WESTERN PROVINCE, PAPUA NEW GUINEA

Telefomin Gas Seep & Tumuli-1 (Incomplete) Well

Inferred Thermal Maturity of Methane from Carbon Isotopes Analysis



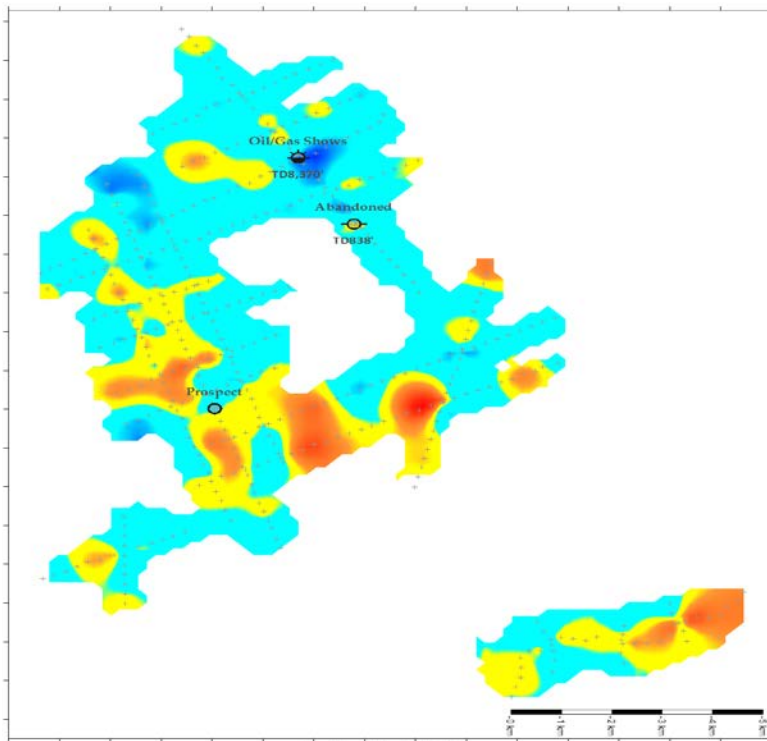
The relationship shown in this figure suggests that METHANE from the Telefomin Gas Seep was generated at thermal maturity approximating a vitrinite reflectance equivalents of 1.5 to 1.6%.

This inferred source rock maturity is significantly higher than the maturity inferred from the isotopic composition of ethane and propane, and suggests that some of the methane is from a different and perhaps deeper source rock.

The carbon isotopic composition of methane in natural gas is dependent on both source rock type and source rock thermal maturity. Relationship between the thermal maturity of a Type II source rock and the carbon isotopic composition of methane in reservoir or migrated gases derived from that source rock. Figure after: Stahl et al., 1977

PHILIPPINES – LEYTE ISLAND Prospect Evaluation Survey

Microbial Technique (MT) Anomaly Recognition



The purpose of the microseepage survey of this 70 square kilometer area was to evaluate several seismically defined prospects, and to acquire hydrocarbon seepage data from three nearby dry holes.

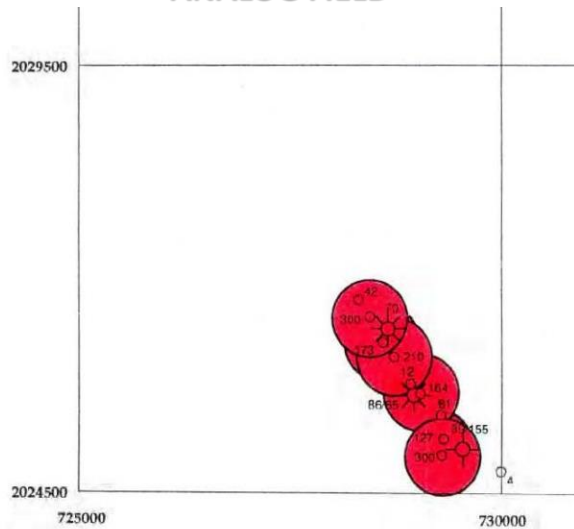
The figure is a microbial value image map of the survey in which the areas of maximum hydrocarbon seepage are highlighted in red, orange and yellow colors, and background areas are shown in blue.

The two eastern dry holes are clearly within non-anomalous microseepage areas, and the proposed Prospect drilling location located in the western part of the survey is situated between two strong seepage anomalies.

Presenter's notes: The dry wells were drilled before the geochem survey - the prospect is outside the geochem anomalous areas. Areas of maximum microseepage are shown in red, orange and yellow colors.

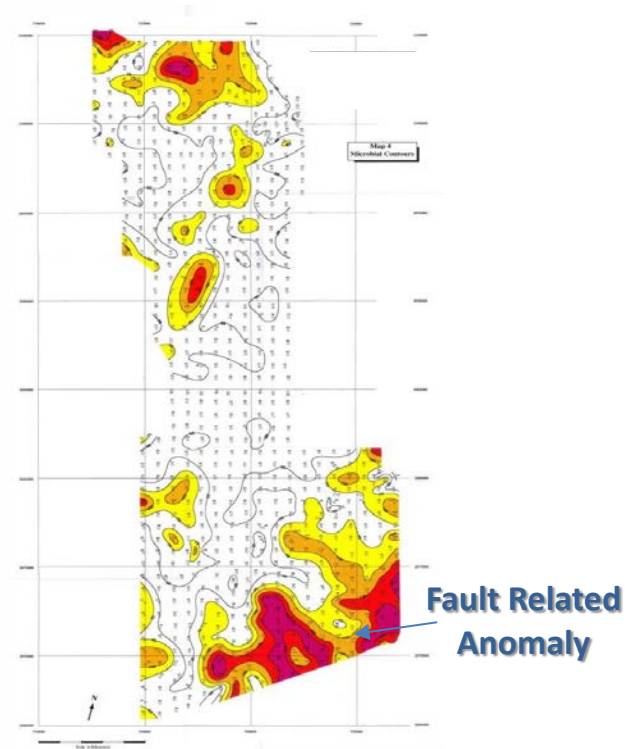
MYANMA, RPROSPECT EVALUATION

ANALOG FIELD



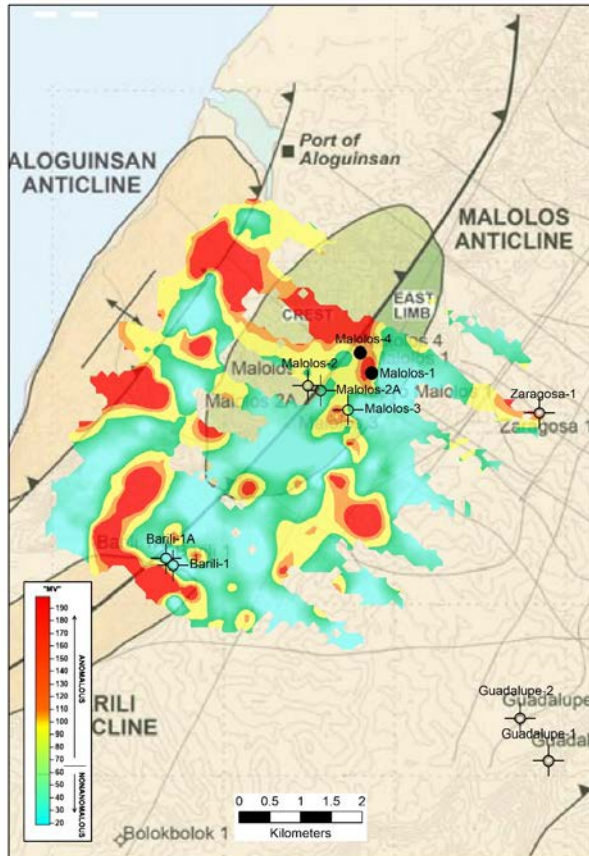
Areas of Difficult Access can be surveyed at a much lower cost than seismic, and the results can guide a seismic campaign

HTANTABIN FIELD



Presenter's notes: Large Areas of difficult access can be surveyed at a much lower cost than seismic, and the results can guide a seismic campaign.

PHILIPPINES – CEBU ISLAND, Post-Survey Malolos Discovery



MICROBIAL SURVEY

The purpose of the microseepage survey was

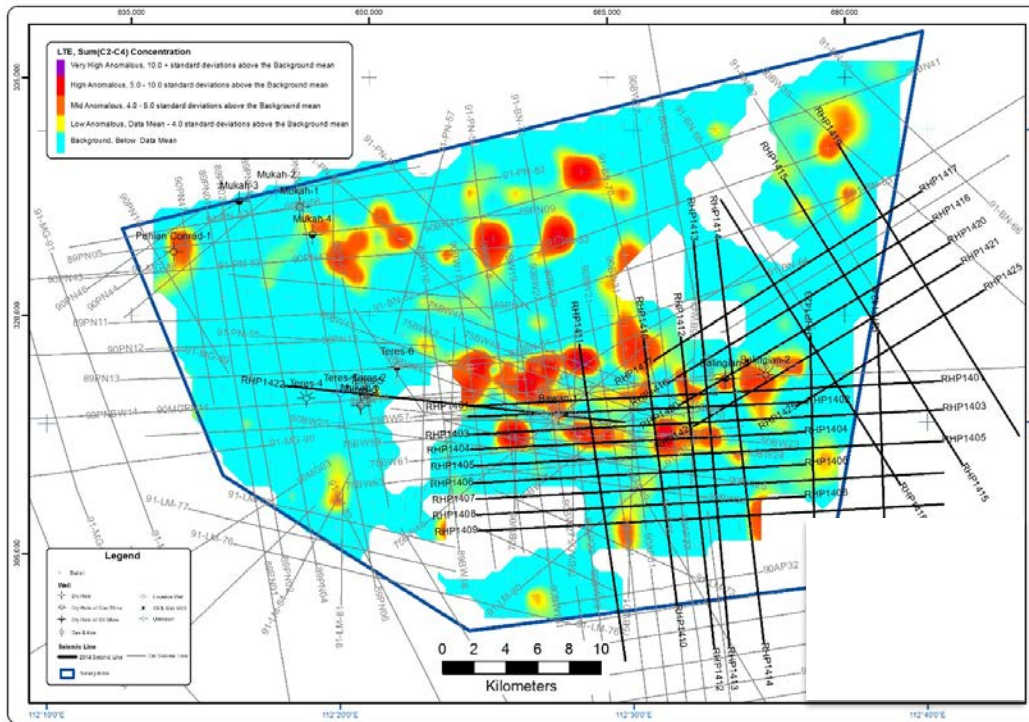
- to evaluate several dry wells areas with seismically defined deeper prospects
- and to acquire hydrocarbon seepage data from prospects

The results indicated potential over the locations of Los Malolos 1 & 4.

Reentry and drilling to the deeper targets resulted in 2 discoveries.

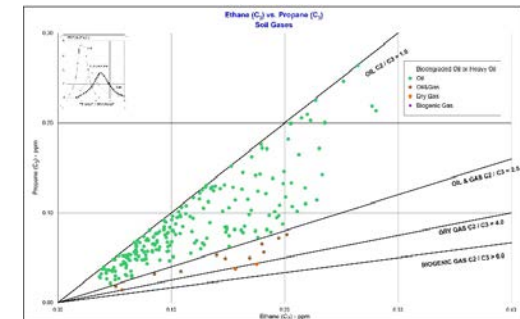
Presenter's notes: The objective was to evaluate if there were deeper charged targets to drill from the dry wells. Discovery of deeper reservoirs at Malolos 1 and 4 areas of maximum microseepage are shown in red, orange and yellow colors.

ONSHORE SARAWAK - Soil Gases Concentration and Hydrocarbon Composition



In the map areas of maximum microseepage (Soil Gases Sun C2toC4) are shown in red, orange and yellow colors

The Hydrocarbon Composition Crossplot "Soil Gases C₂/C₃" indicates that the source of the microseepage is trapped oil



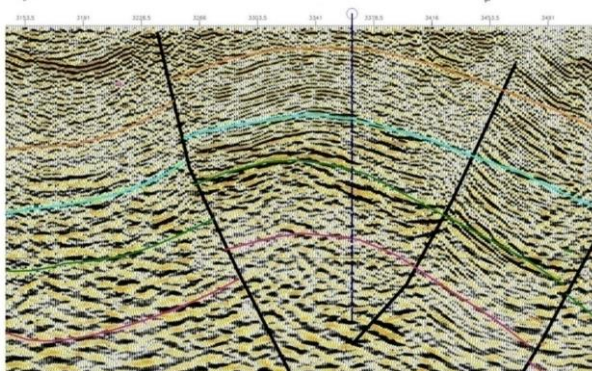
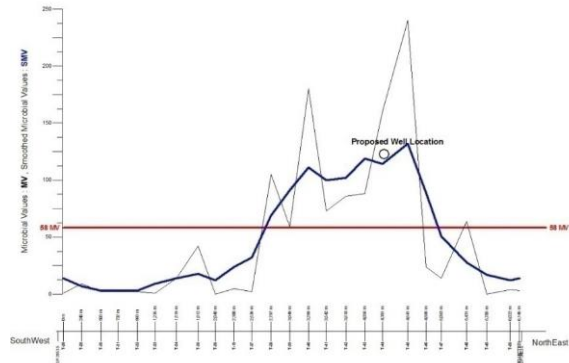
Presenter's notes: Map showing the high concentrations of C₂-C₄, and plot showing the composition of the microseepage soil gases – results indicate oil and associated gas the sources.

Measuring Success of Geochemical Surveys

How do we measure success? Compare pre-drill prediction with post-drill results.

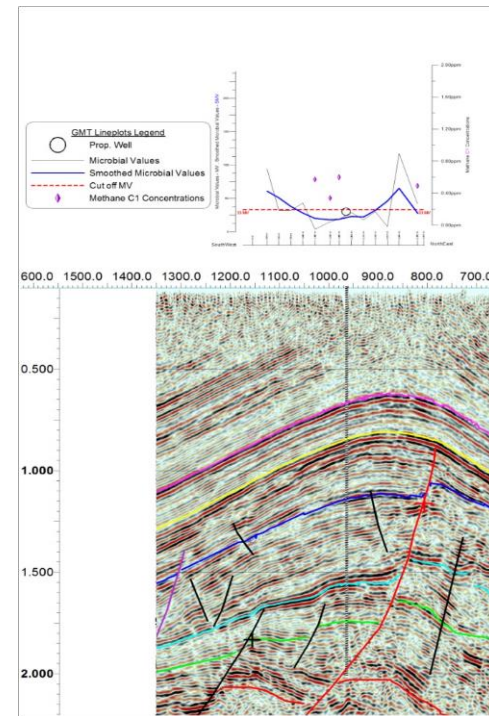
DISCOVERY KALIMANTAN INDONESIA

Prospect with a strong associated microseepage anomaly



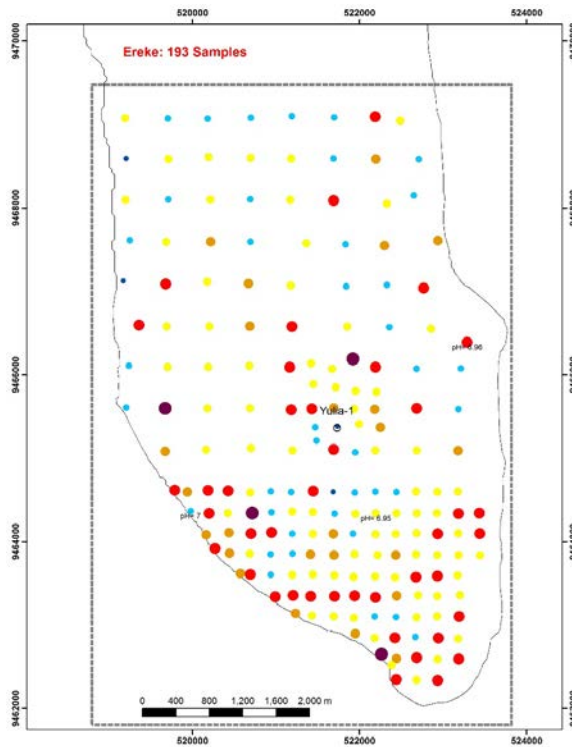
DRY WELL, LAOS

Prospect with non-anomalous microseepage signal

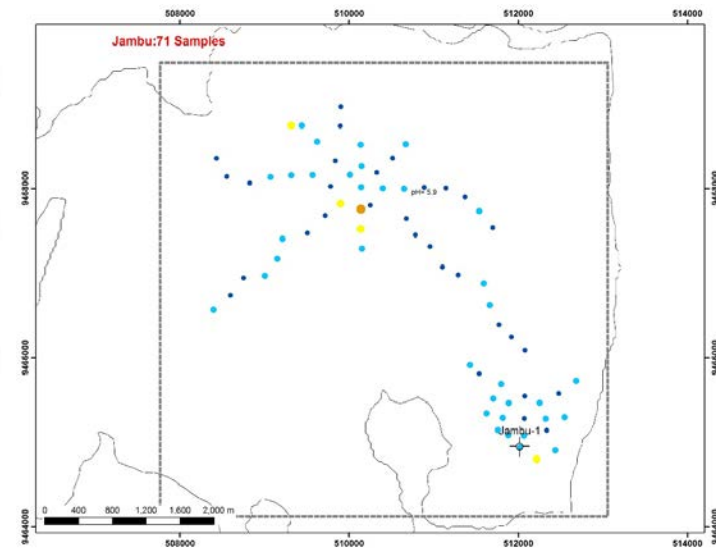
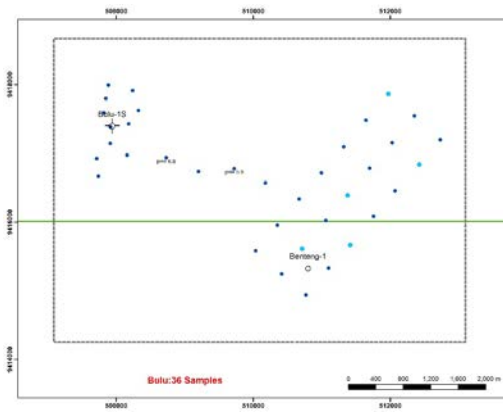


Survey Objectives - Design - Results

Grid Over A Prospect and Selected Drilling Location



Comparing selected Drilling Locations with a nearby Dry Wells



Presenter's notes: Survey design and sample spacing depends on the exploration objectives and on the expected size of your exploration targets.

Measuring Success of Geochemical Surveys

3308 Wells, Various Companies,
Various Methods, Various Basins

In Negative Anomalies

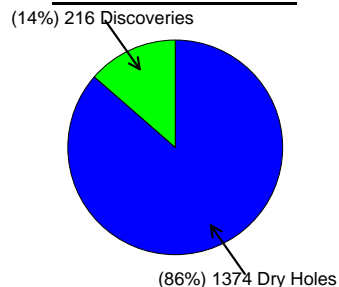
- 1590 Wells Drilled
- 1374 Wells Dry (86%)
- 216 Discoveries **(14%)**

In Positive Anomalies

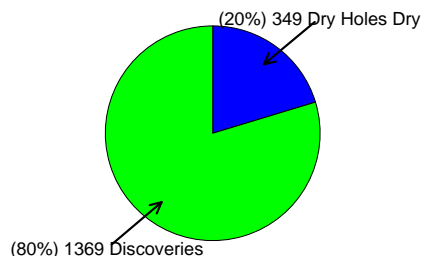
- 1718 Wells Drilled
- 349 Wells Dry (20%)
- 1369 Discoveries **(80%)**

Reducing Exploration Risk Post-Survey Drilling Results SUMMARY

Negative Anomalies 1590 Wells Drilled



Positive Anomalies 1718 Wells Drilled



For all wells drilled, the success rate based only on geology and seismic was 48%
(Schumacher, 2010, 2017)

Summing Up

Summing Up

When these areas with technical challenges occur in jungles and highlands, the logistical challenges only add to the difficulty of evaluating the petroleum potential of such regions.

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

**Prospects with Microseepage Anomaly
are 4-6 times more likely to result in a discovery**

Thank you !!