Petroleum Exploration in Geologically Complex Areas: Opportunities for Geochemical and Non-Seismic Hydrocarbon-Detection Methods*

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Search and Discovery Article #80505 (2016)**
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Editor's note: Please refer to two closely related articles, Search and Discovery Article #80504 (2016) and Article #80503 (2016).

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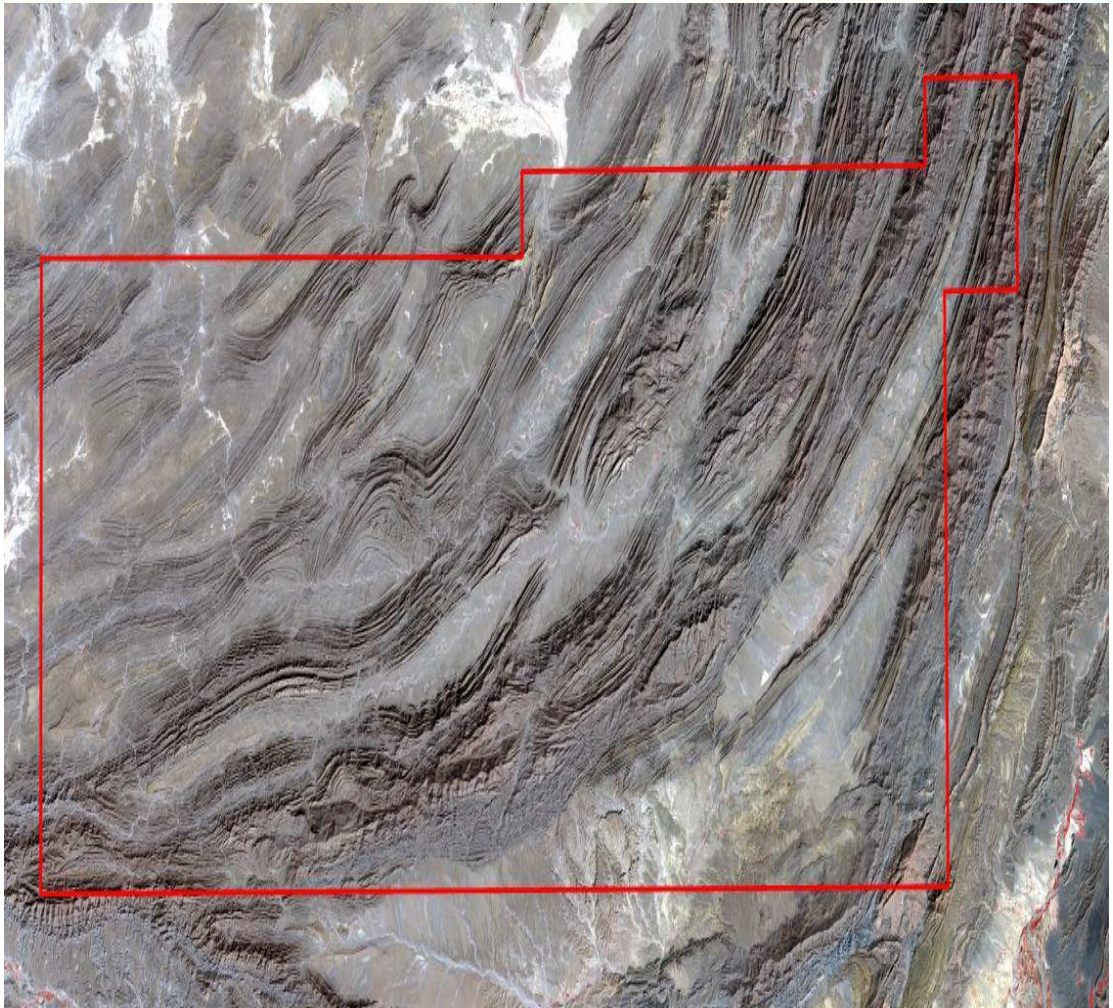
Abstract

The petroleum potential of geologically complex areas — such as highly faulted and folded terranes — 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 terranes. 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. It has long been known that (1) all petroleum basins exhibit some type of near-surface hydrocarbon leakage, (2) that petroleum accumulations are dynamic and their seals imperfect, (3) that hydrocarbon seepage can be active or passive, and that it can be visible (macroseepage) or only detectable analytically (microseepage). The surface and near-surface expressions of hydrocarbon migration and seepage can take many forms, ranging from elevated hydrocarbon concentrations in soils to complex mineralogic, microbial, and geophysical changes. While such hydrocarbon leakage does not require significant faulting and fracturing, the common presence of faults and fractures in structurally complex and tectonically active terranes provides additional migration pathways for hydrocarbon seepage and microseepage. Hydrocarbon-detection surveys in geologically complex areas require careful planning, close sample spacing, and 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. 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. The presentation illustrates examples from Asia and South America.

Reference Cited

Noble, R., D. Orange, J. Decker, P. Teas, and P. Baillie, 2009, Oil and gas seeps in deep marine sea floor cores as indicators of active petroleum systems in Indonesia. Proceedings 33rd Annual Convention, Indonesian Petroleum Association, IPA09-G-044, p. 385-394.



PETROLEUM EXPLORATION IN GEOLOGICALLY COMPLEX AREAS:

OPPORTUNITIES FOR GEOCHEMICAL AND NON-SEISMIC HYDROCARBON DETECTION METHODS

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OUTLINE

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- Characteristics of Geologically Complex Areas
- Why Hydrocarbon Detection Surveys
- Survey Methods for Geologically Complex Areas
- Survey Objectives and Design Considerations
- Selected Exploration Examples
- Conclusions

GEOLOGICALLY COMPLEX AREAS

ADVANTAGES – MORE LEAKAGE POINTS: FAULTS, FRACTURES, OUTCROPS, ACCUMULATIONS, MATURE, SOURCE ROCKS, SEEPS

LIMITATIONS – MORE LEAKAGE POINTS, MORE “ANOMALIES”; INTERPRETATION CHALLENGES; LOGISTICAL CHALLENGES, FAULT SURFACE EXPRESSIONS YIELD BIGGEST ANOMALIES

Microseepage Characteristics

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

Common and Widespread

Predominantly Vertical

Dynamic (1-3+ m/d)

HYDROCARBON DETECTION

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- REMOTE SENSING, SATELLITE IMAGERY
  - detects hydrocarbon-induced alteration, oil slicks
- AEROMAGNETICS, MICROMAGNETICS
  - detects hydrocarbon-induced alteration
- SOIL GAS, FLUORESCENCE
  - hydrocarbon concentration and composition
- MICROBIOLOGICAL
  - measures HC-oxidizing bacteria
- PASSIVE ELECTROMAGNETICS, TELLURICS
  - depth to hydrocarbon-bearing zones

SURVEY DESIGN CONSIDERATIONS

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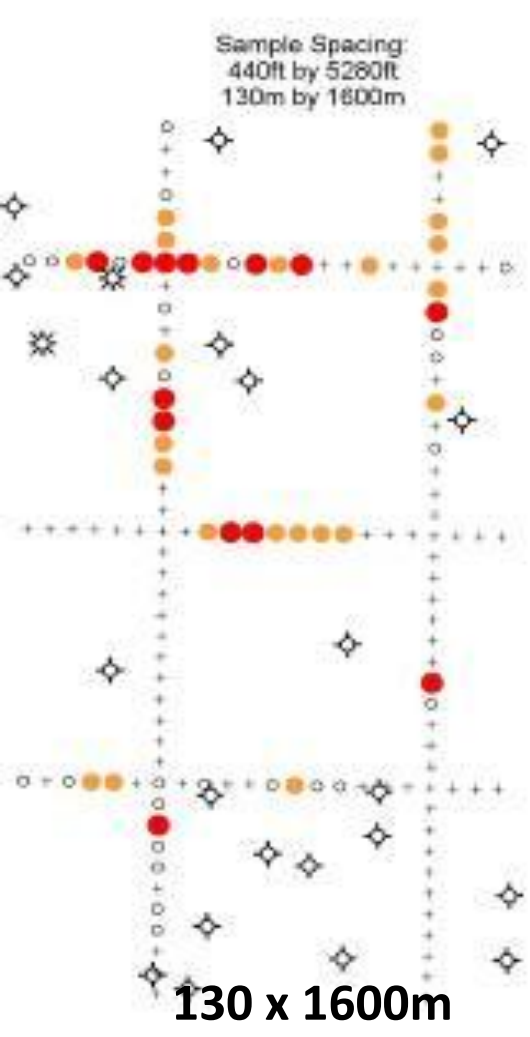
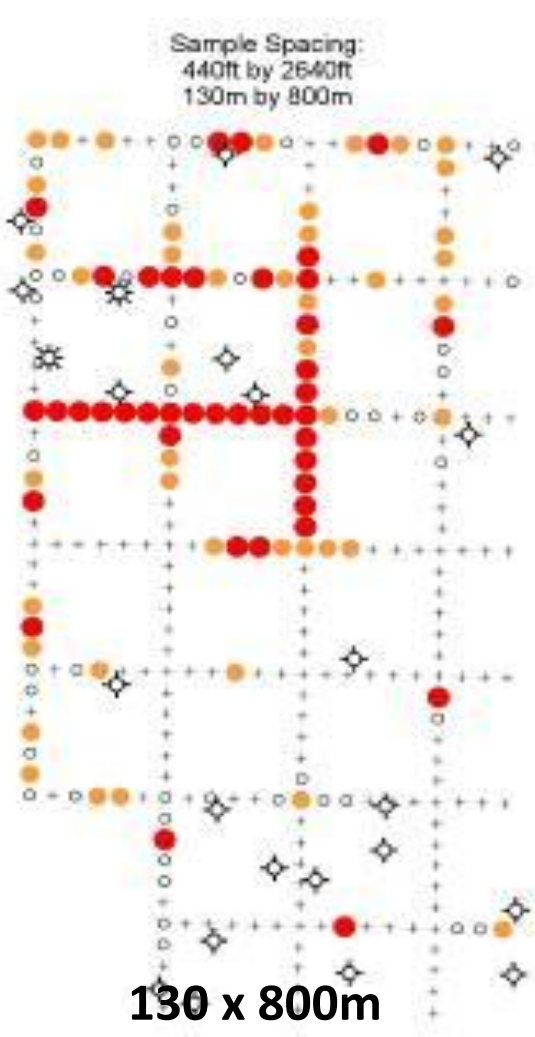
- **Survey Objectives**
- **Target Size, Shape**
- **Geologic Setting**
- Topography, Vegetation
- **Logistical Considerations**
- Data Integration
- Ability to Sample Along & Between Seismic Lines
- **Geologic Analogs for Calibration**
- Permitting
- Environmental Issues
- Security Concerns
- Prior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



130 x 1600m



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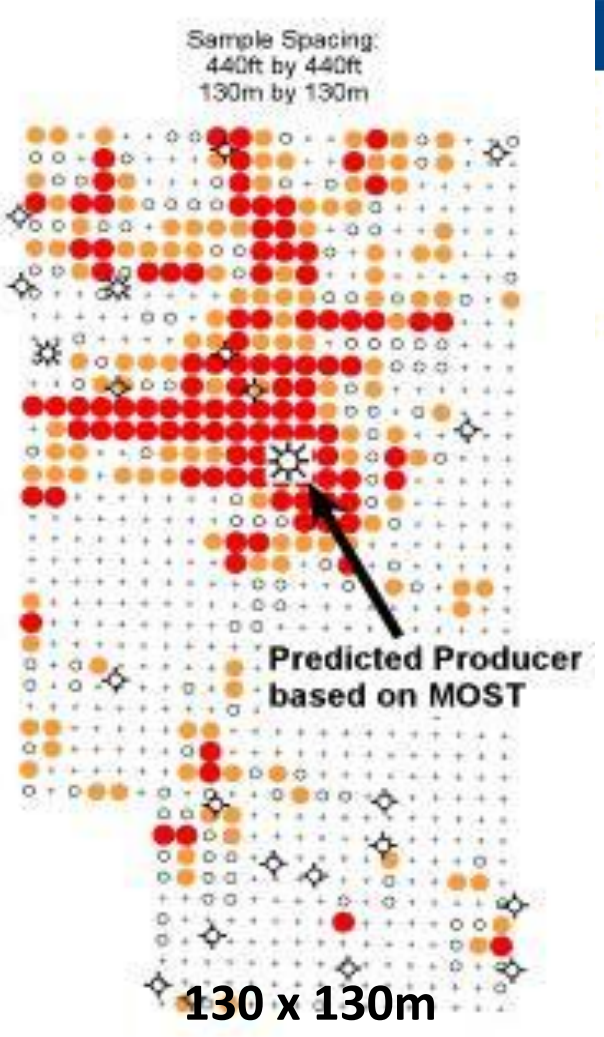

130 x 130m

WHAT AND WHERE TO SAMPLE

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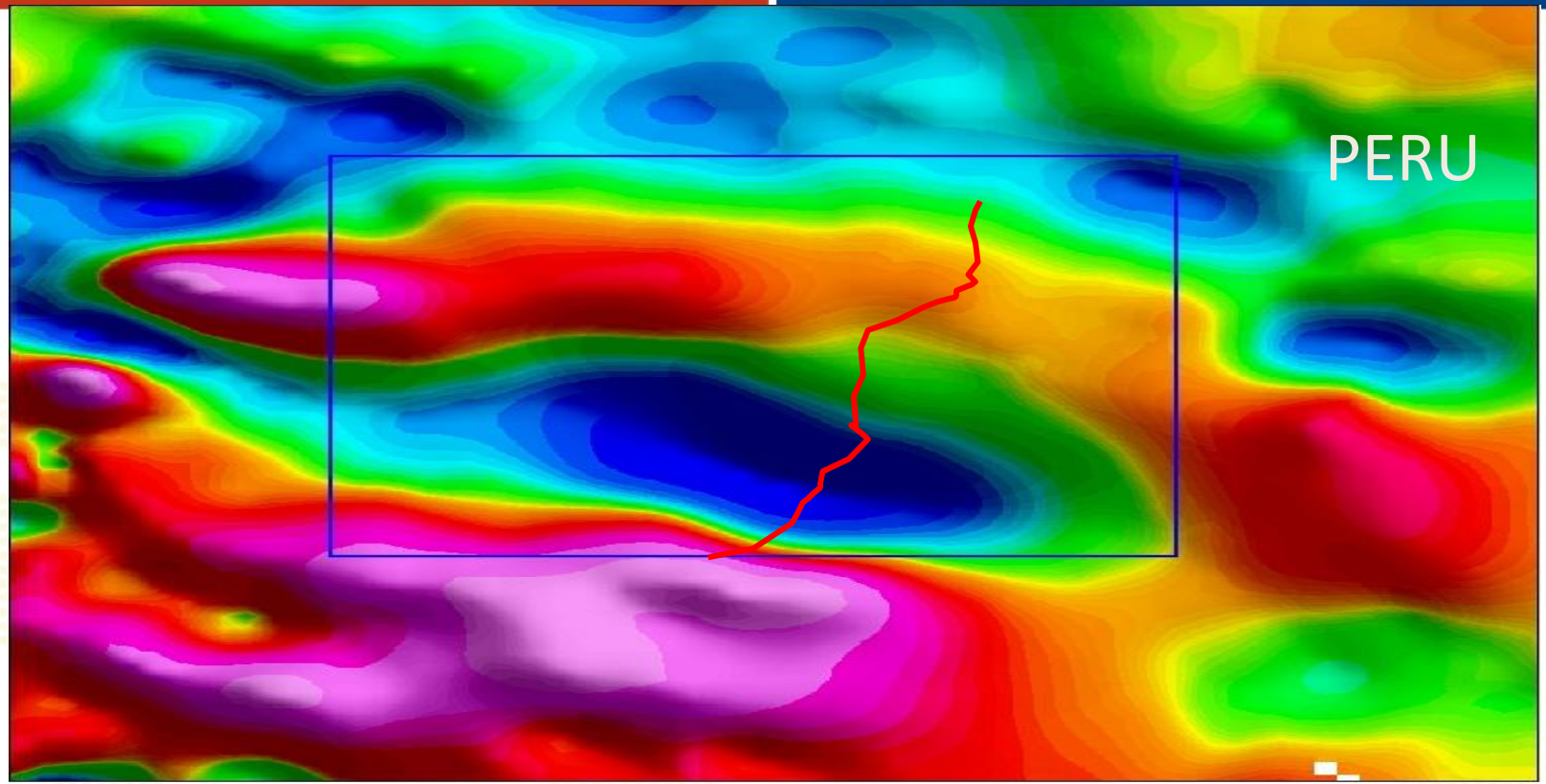
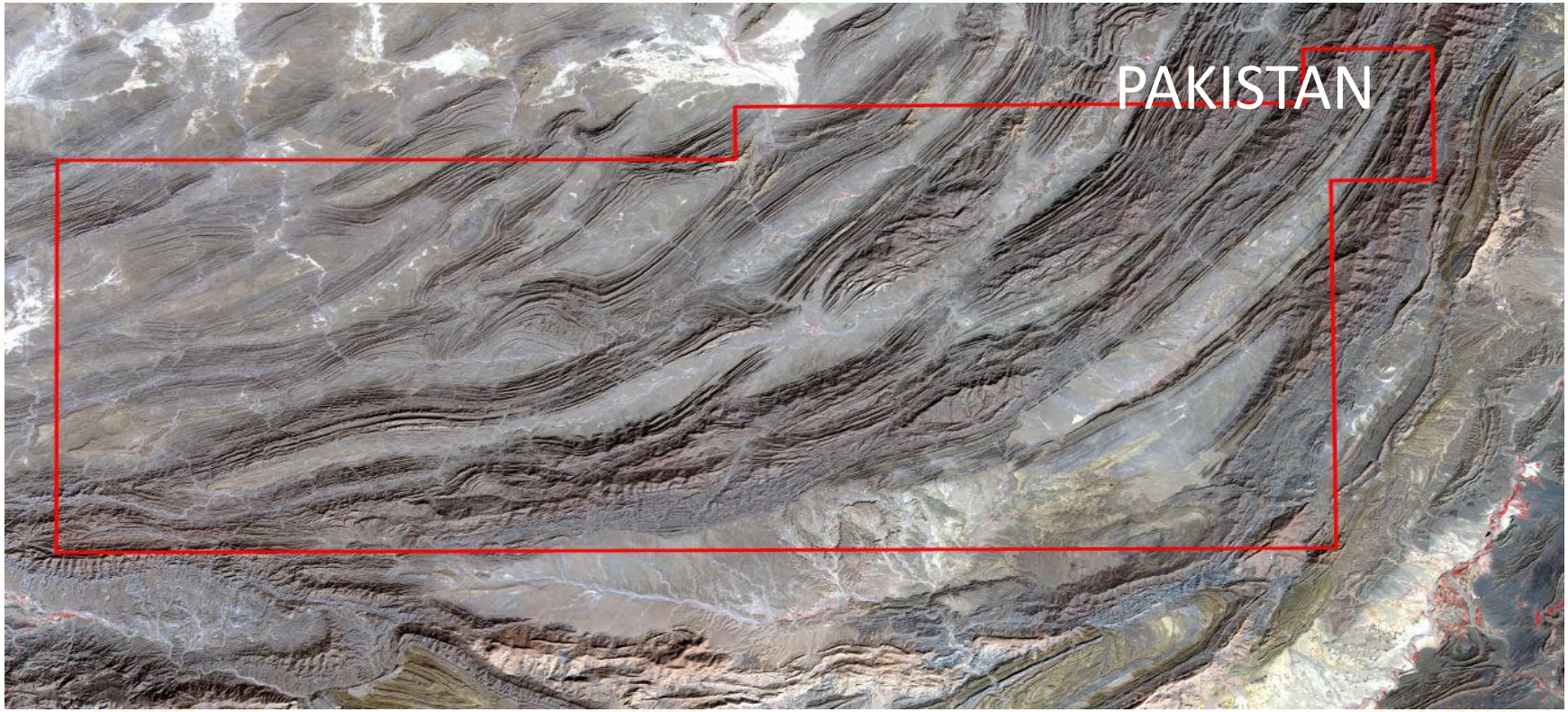
- Oil and Gas Seeps, if present
- Along & Across Faults and Fracture Zones
- Gravity Lows (Basin Depocenter?)
- Structural Highs (Possible Traps)
- Possible Seep-Induced Soil/Sediment Alteration
- Along Regional Seismic Lines, if available
- Geologic Analogs (both productive and dry)
- Regional Survey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



PLANNING THE SURVEY -- GRAVITY AND MAGNETIC DATA

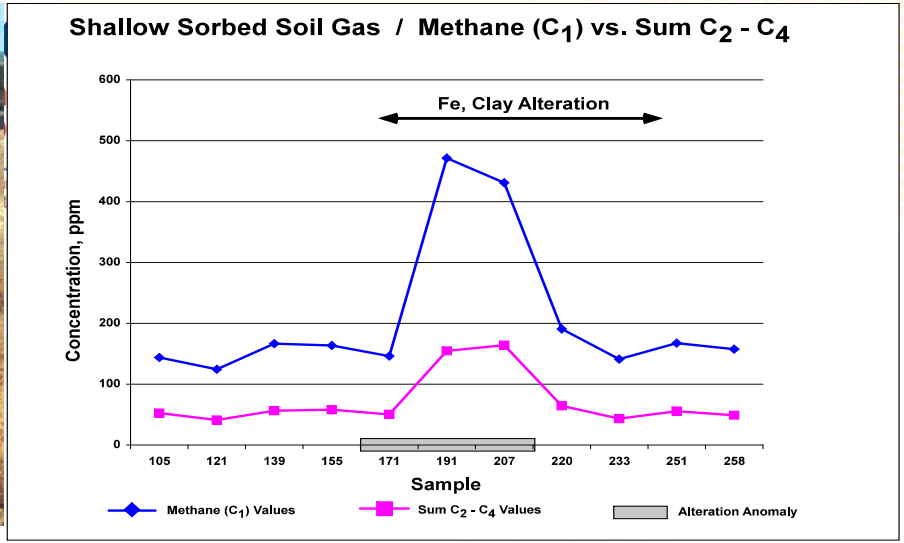
Acquire samples across both the highs and the lows

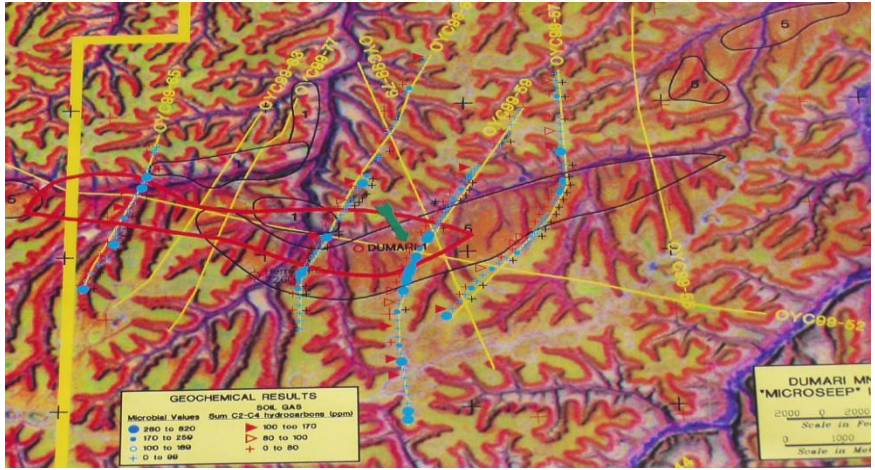


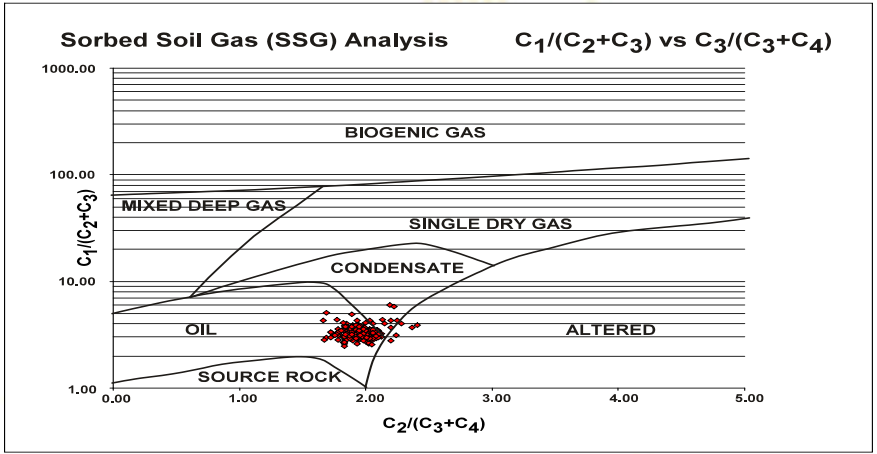
PLANNING THE SURVEY – AIR PHOTOS AND SATELLITE DATA

Hydrocarbon Survey Documented Liquid HC Potential only in SE

MASILA BASIN, YEMEN







South Oman

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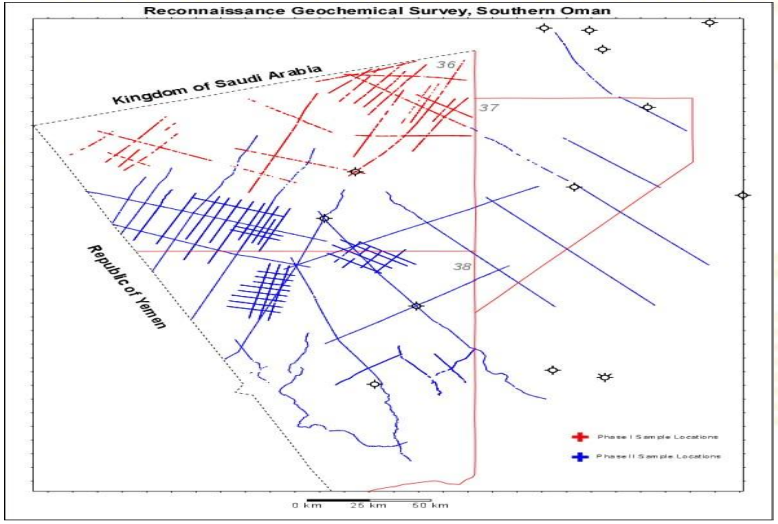
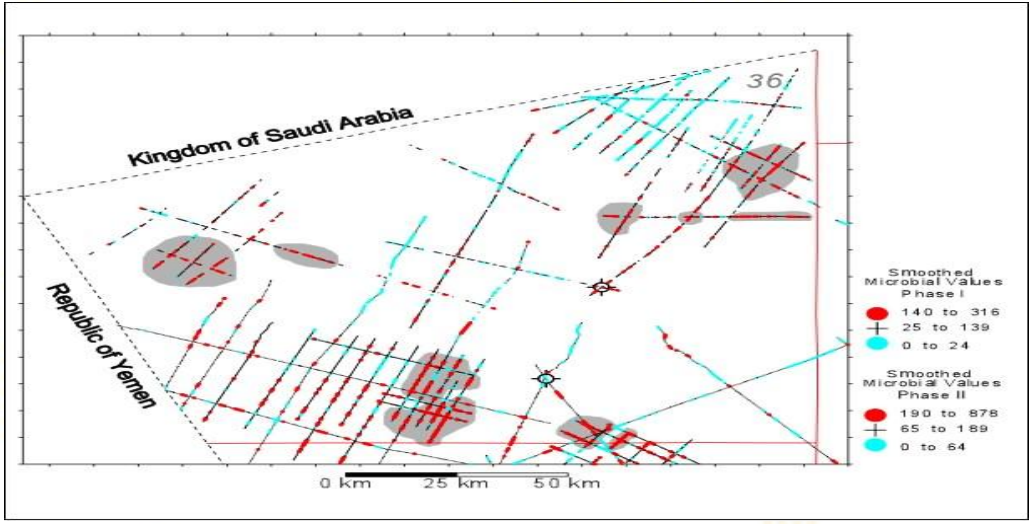
Salt Basin

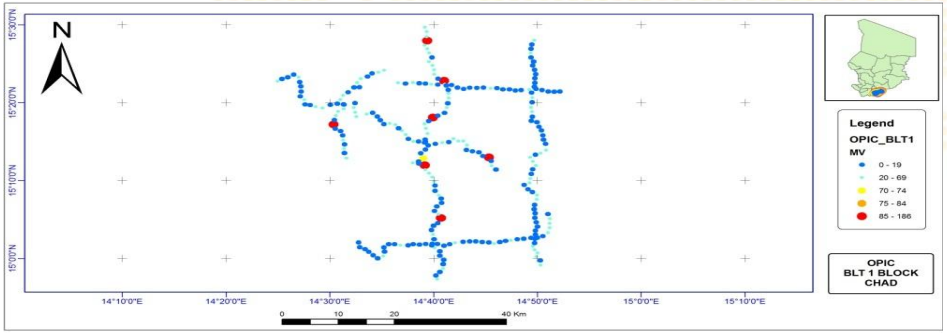
Reconnaissance geochemical survey of 70,000 km² in Blocks 6, 36, 37, and 38. Samples collected at 250m intervals along 2900 line km of pre-existing seismic lines. Results documented the presence of two petroleum systems and several geochem leads

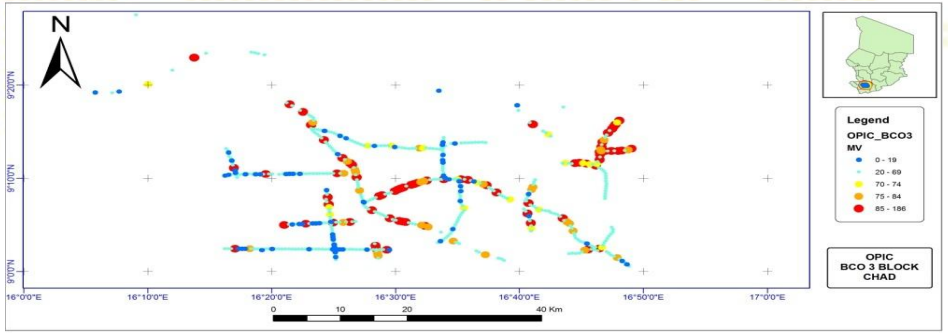




CHAD SURVEYS: EXAMPLES

Microbial Method





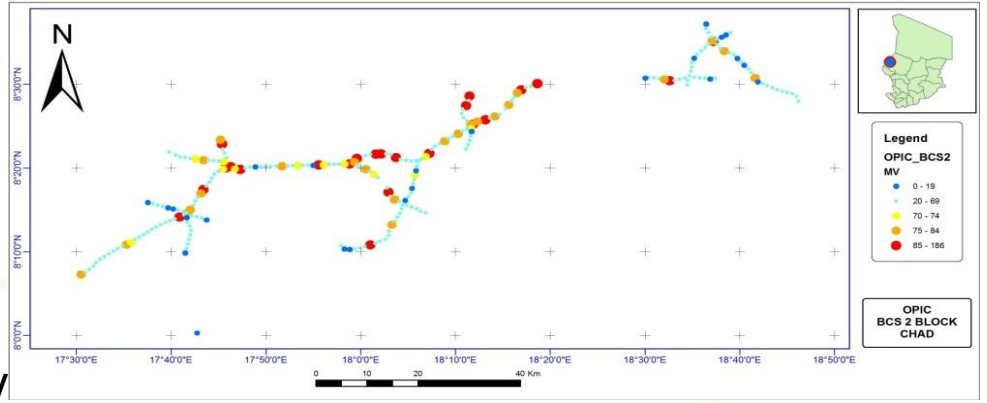
3 Blocks surveyed

Samples: +1,000

Analytical Cost: +/- 100,000 USD

Results: one block relinquished due to low prospectively

The survey results guided the client on what to do next. First well was a discovery



Eastern Venezuela Basin, QLC Block

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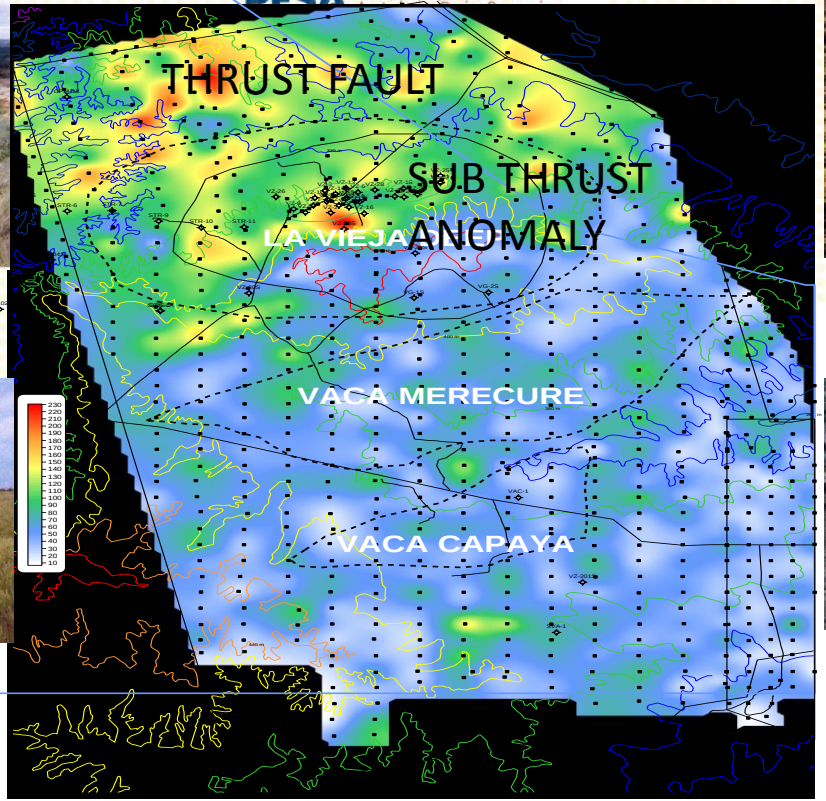
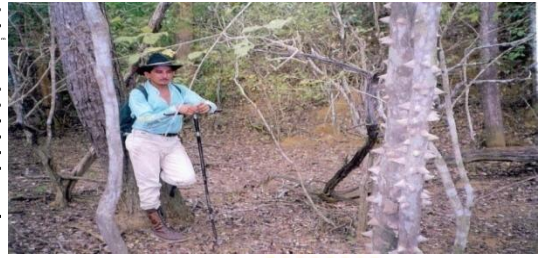
PROSPECT EVALUATION





Republic of Congo

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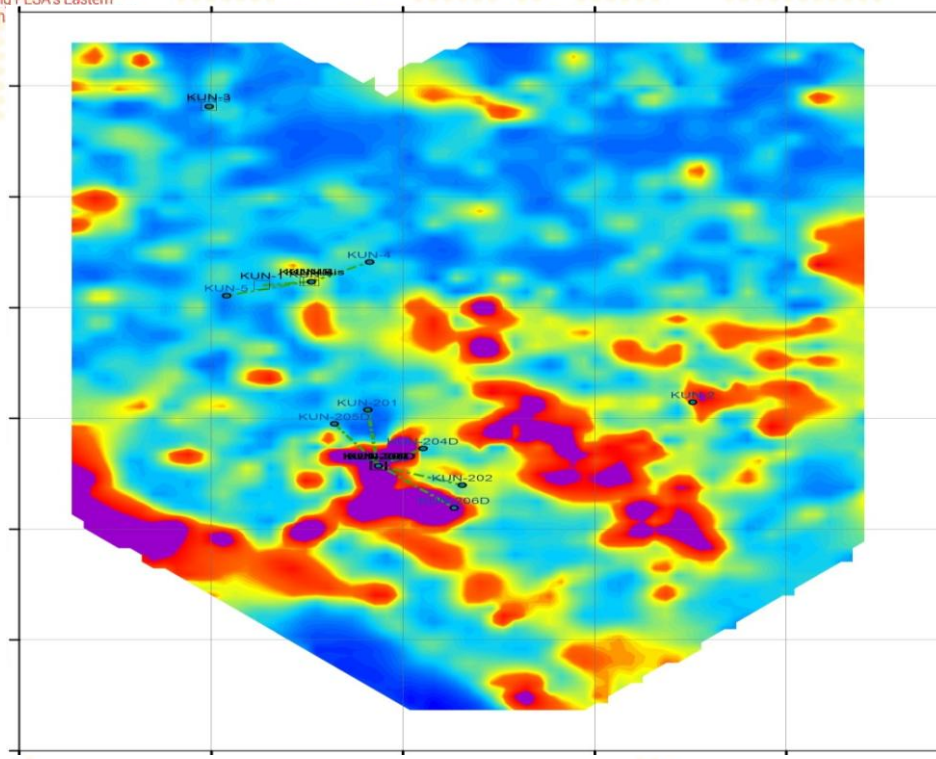
Microbial and Soil Gas analysis

- Identified 4 major anomalous areas
- Good Correlation with wells
- Kundji 202, 203, 204 & 206

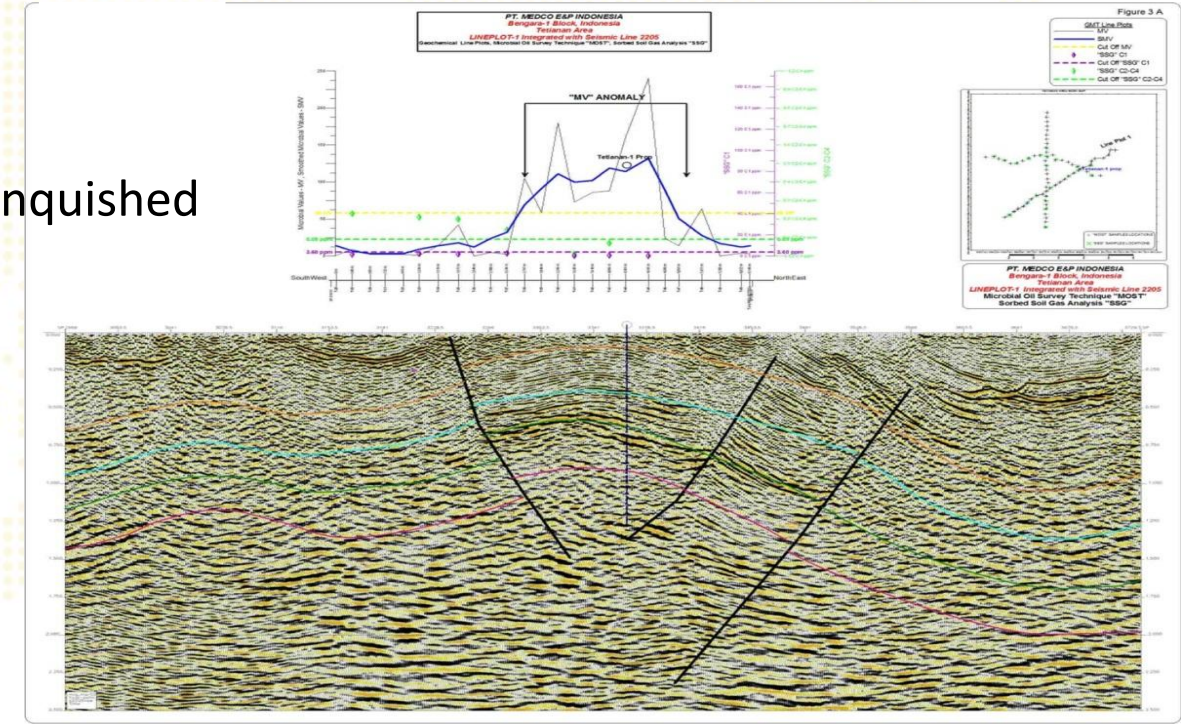
Samples: +2200
Analytical Cost: +/- 250,000 USD
Results: PRODUCTION LIMITS DEFINED, Several drilling prospects cancelled due to low prospectively
Results guided the design of a 3D seismic program; new wells planned for sites favorable on both 3D and geochemistry

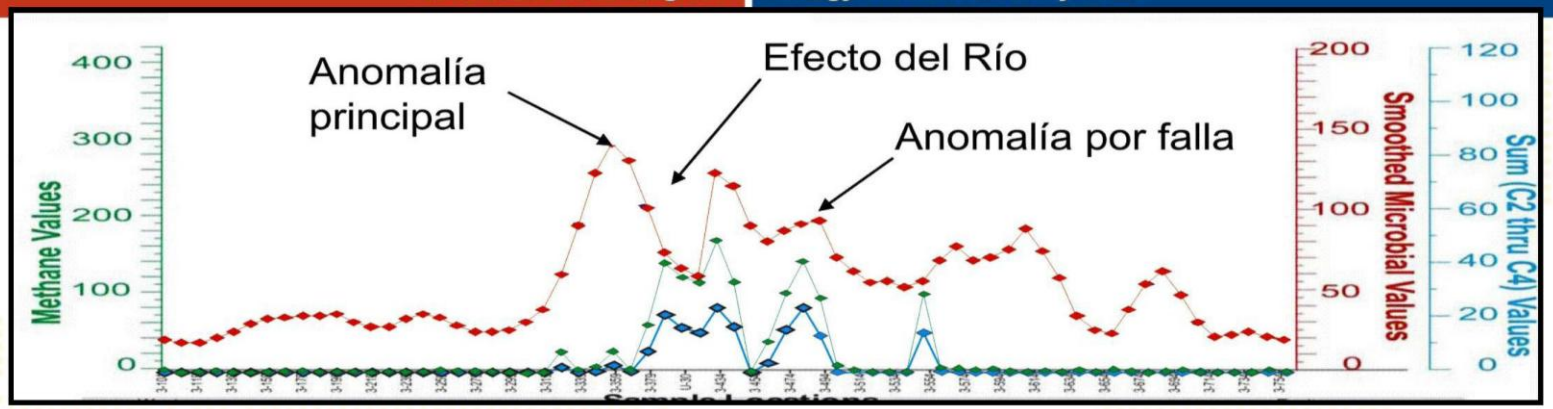


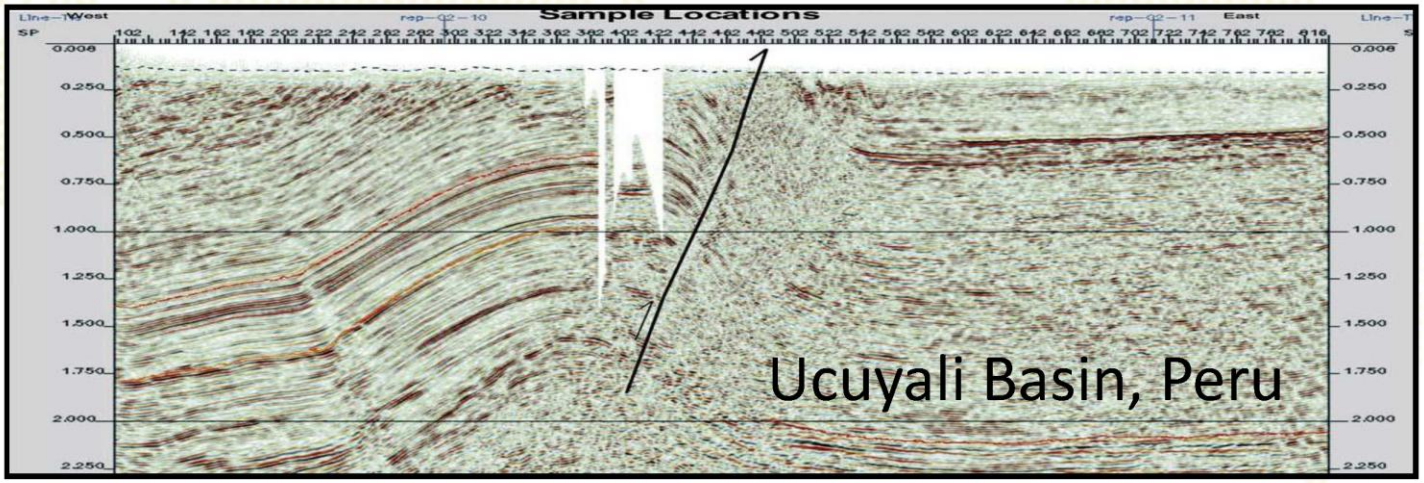
INDONESIA EXAMPLE KALIMANTAN

2 Prospects surveyed
Samples: +700
Analytical Cost: +/- 80,000 USD
Results: one drilling prospect relinquished due to low prospectively
One prospect selected for drilling

UPDATE: Oil Discovery on the remaining prospect







Presenter's Note: Profile of microbial values, in particular, shows the main anomaly, the effect of the river, and the anomaly due to the fault.

DEEP WATER BASINS. INDONESIA

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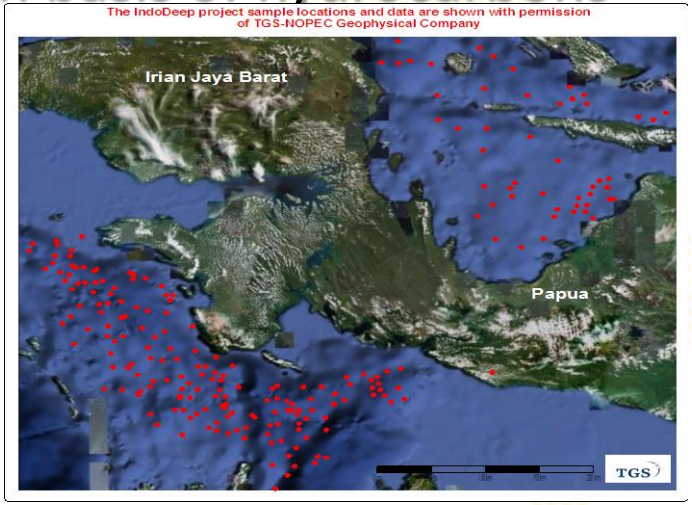
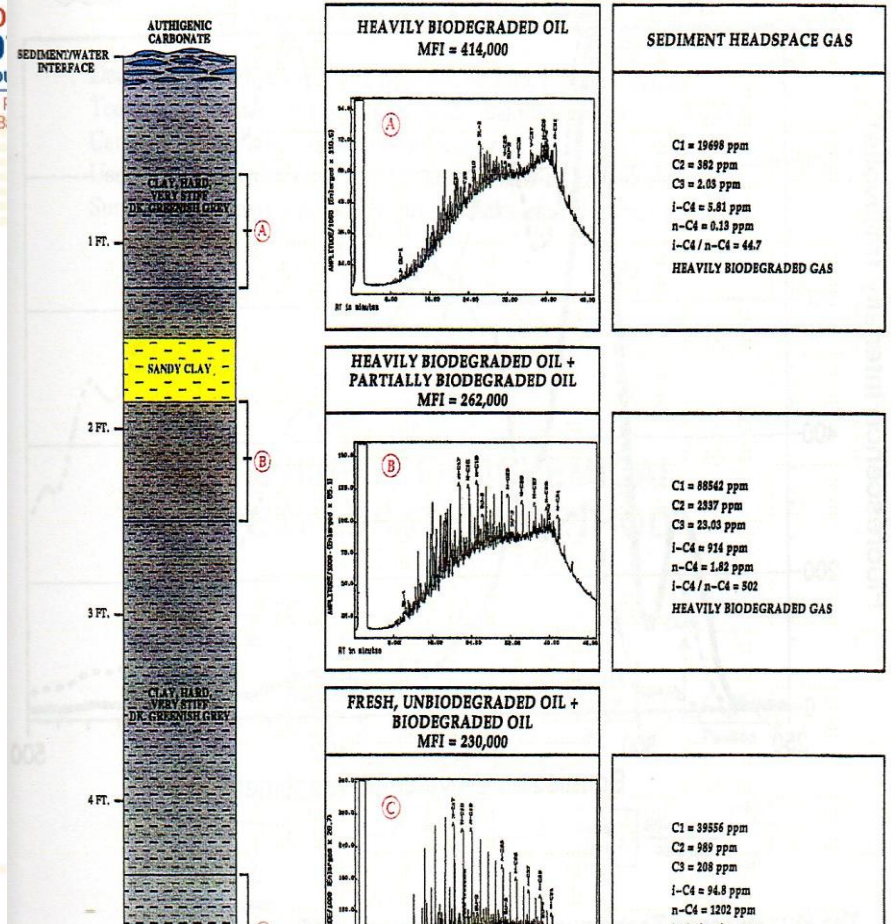
- Survey large area to document presence of petroleum system and characterize it geochemically
- High-grade basin, play, concession on basis of hydrocarbons
- Guide geophysical surveys to minimize seismic costs
- Determine if area is oil-prone, gas-prone, or both




AUTHIGENIC CARBONATE
SEDIMENT/WATER INTERFACE
1 FT.
CLAY, HARD, VERY STIFF, DK. GREENISH GREY
SANDY CLAY
2 FT.
3 FT.
CLAY, HARD, VERY STIFF, DK. GREENISH GREY
4 FT.
A
B
HEAVILY BIODEGRADED OIL
MFI = 414,000
SEDIMENT HEADSPACE GAS
C1 = 19698 ppm
C2 = 382 ppm
C3 = 2.03 ppm
i-C4 = 5.81 ppm
n-C4 = 0.13 ppm
i-C4 / n-C4 = 44.7
HEAVILY BIODEGRADED GAS
HEAVILY BIODEGRADED OIL + PARTIALLY BIODEGRADED OIL
MFI = 262,000
C1 = 88542 ppm
C2 = 2337 ppm
C3 = 23.03 ppm
i-C4 = 914 ppm
n-C4 = 1.82 ppm
i-C4 / n-C4 = 502
HEAVILY BIODEGRADED GAS
FRESH, UNBIODEGRADED OIL + BIODEGRADED OIL
MFI = 230,000
C1 = 39556 ppm
C2 = 989 ppm
C3 = 208 ppm
i-C4 = 94.8 ppm
n-C4 = 1202 ppm

Deep-Water Petroleum Systems of Indonesia

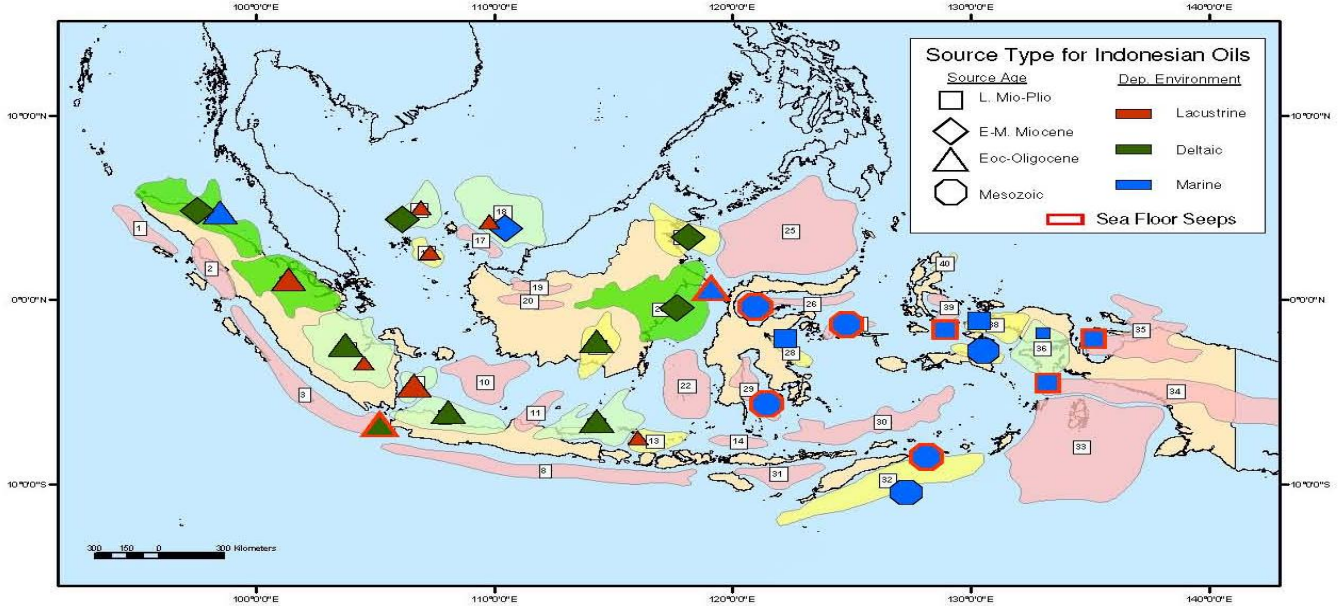
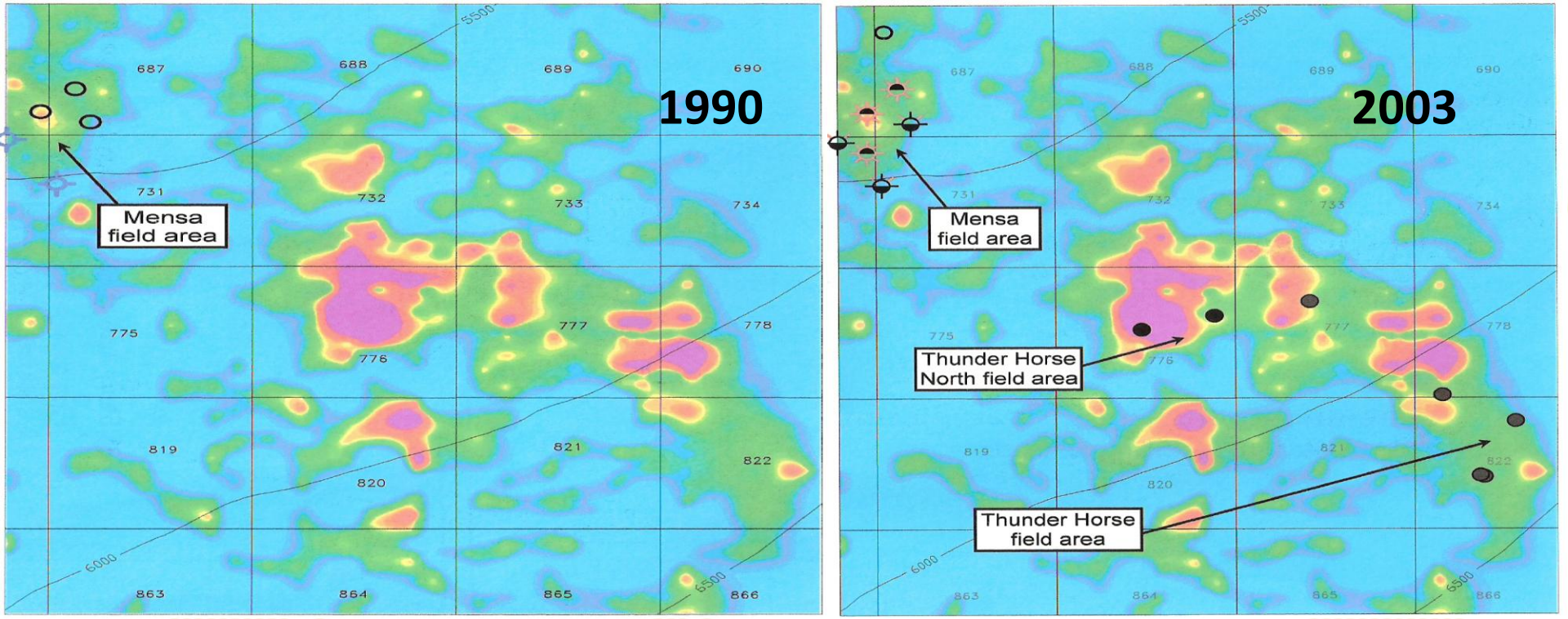


Figure 5 - Map of Indonesian crude oil families and sea-floor seeps

From Noble et al., 2009, IPA Proceedings



SEEP-INDUCED MAGNETIC ANOMALIES

Mensa and Thunder Horse Fields; Mississippi Canyon Area, Gulf of Mexico; Water Depth: 1675 – 1980 m

CONCLUSIONS

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GEOLOGICALLY COMPLEX AREAS

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

Document presence of petroleum system(s) and/or hydrocarbon charge to specific prospects

High-grade basin or concession based on its hydrocarbon potential

Identify priority targets or areas for seismic surveys

Geologically complex areas have more hydrocarbon leakage points and are more challenging to interpret

Thank You

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