Hydrocarbon Exploration Survey Strategies for Frontier Basins and Other Underexplored Areas*

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Abstract

Frontier basins and other underexplored onshore basins are well suited for hydrocarbon detection surveys using a variety of surface geochemical and non-seismic geophysical hydrocarbon detection methods. These methods can reliably detect surface or near-surface occurrences of hydrocarbons and their alteration products. The noninvasive, low-impact nature of these techniques makes them ideally suited for use in an early-stage evaluation of remote and sometimes environmentally sensitive areas in jungles, deserts, grasslands or in the Arctic. Properly designed surveys can document the presence of a petroleum system, and quickly identify those parts of the area possessing the highest petroleum potential. Use of such an exploration strategy protects the greater part of the area from more costly and more-invasive exploration methods by focusing attention and resources on a relatively small number of high- potential sites.

Geochemical exploration techniques can be direct or indirect, and measurements can be instantaneous or integrative. Direct techniques analyze small quantities of hydrocarbons that occur in the pore spaces of soil, are adsorbed onto clay minerals, or are incorporated in soil cements. Indirect methods detect seepage-induced changes to soil, sediment, or vegetation. Non-seismic geophysical methods for detection of hydrocarbons or their alteration products include satellite image analysis for seep-induced alteration, high-resolution aeromagnetic data to identify sedimentary magnetic anomalies that form in the seepage environment, radiometric surveys, radar and laser detection of hydrocarbon gases in atmosphere, and passive electromagnetic and telluric measurements.

Onshore hydrocarbon microseepage surveys in frontier basins require careful planning and implementation. Microseepage data are inherently noisy data and require adequate sample density to distinguish between anomalous and background areas. Defining background values adequately is an essential part of hydrocarbon anomaly recognition and delineation. This presentation will be illustrated with examples from North Africa, Asia, South America, USA, and Canada.

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OUTLINE

- Why Surface Geochemistry
- Survey Methods for Frontier Basins
- Survey Objectives
- Survey Design Considerations
- Exploration Examples
- Conclusions

Why Surface Geochemistry ?

- 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

SPECTRUM OF SEEPAGE STYLES

MACROSEEPAGE

MICROSEEPAGE

Exploration Methods for Frontier Basins

- **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**

EFFECTIVE IN ALL ENVIRONMENTS

GMT's Frontier Basin Surveys

Canada – NWT, Newfoundland
USA- Nevada, Washington, Oregon
South America – Guyana, Colombia, Peru, Paraguay, Bolivia, Argentina
Africa – Mali, Ethiopia, Sudan, Chad, Congo
Middle East – Yemen, Oman
Asia – Kazakhstan, Pakistan, Indonesia, PNG

Frontier Basin Survey Objectives

Document Presence of Petroleum System(s)

Characteristics of the Petroleum System(s)
Age, Facies, Maturity, Oil vs Gas, etc.

High-Grade Basin on Basis of Hydrocarbons

Guide Location of Future Seismic Surveys

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

WHAT AND WHERE TO SAMPLE

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



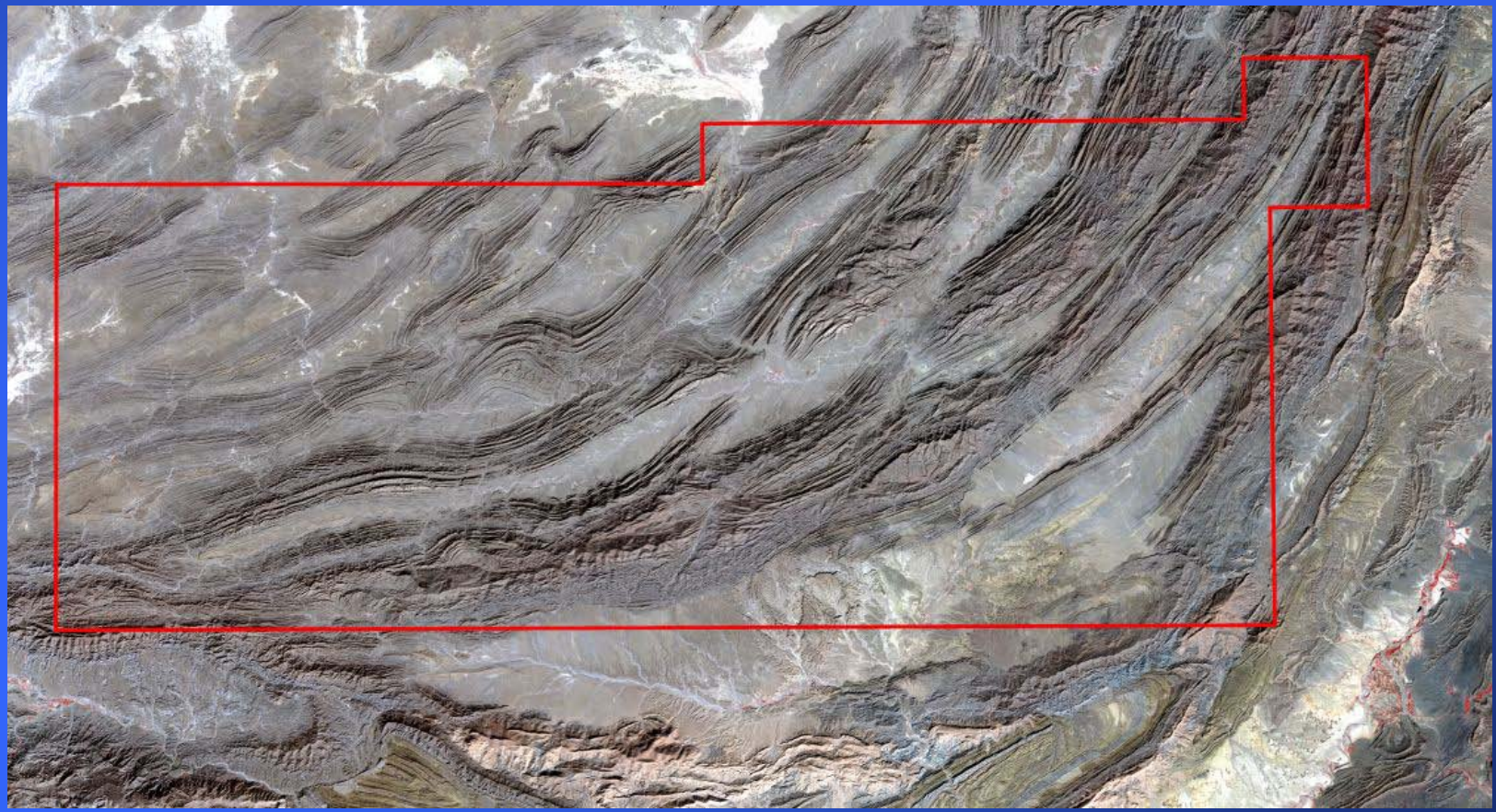



EXPLORATION EXAMPLES

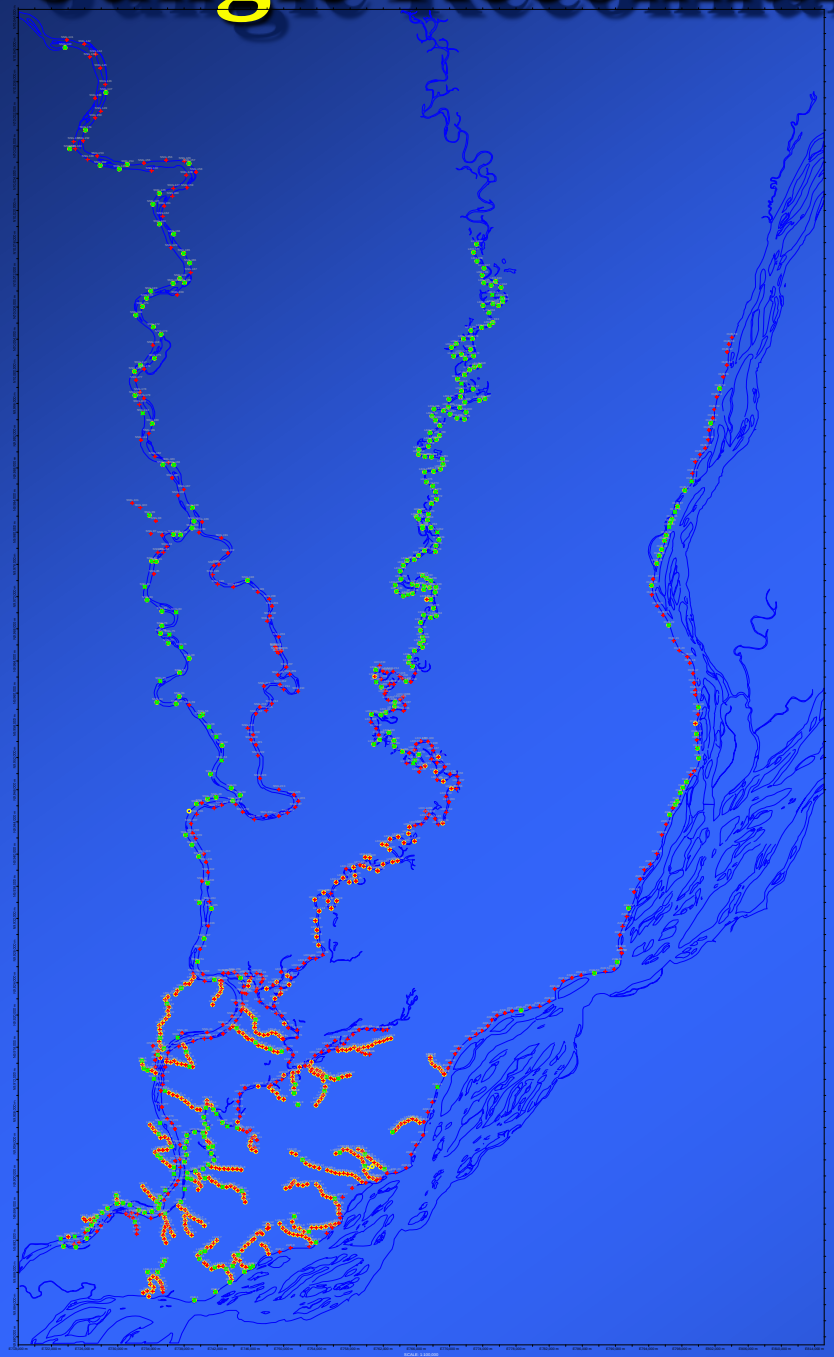
- Pakistan, Pishin Basin
- Congo, Jungle Reconnaissance
- Yemen, Masila Basin
- Oman, South Oman Salt Basin
- Canada, NWT
- USA, Washington, volcanics
- Indonesia, Offshore Deep Water
- Gulf of Mexico, Offshore Deep Water

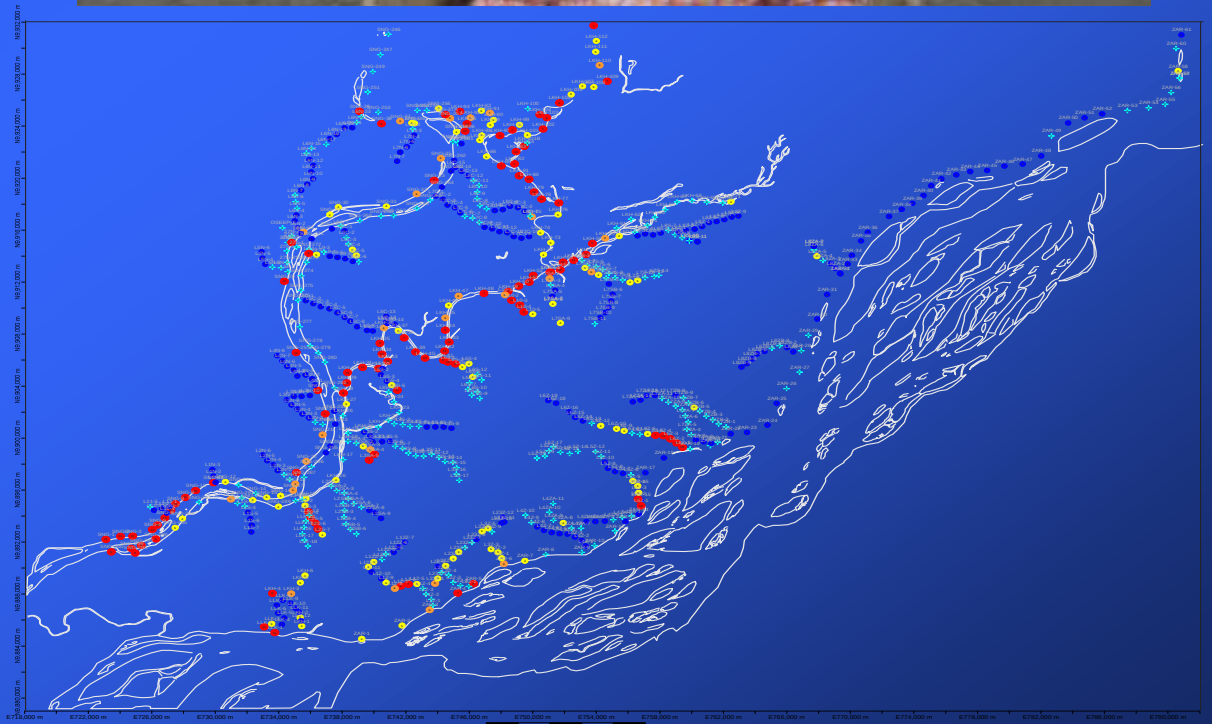
Pakistan, Pishin Basin

- Document presence of petroleum system.
- High-grade basin and concession on basis of hydrocarbons
- Guide geophysical surveys to minimize seismic costs.
- Determine if area is oil-prone, gas-prone, or both.

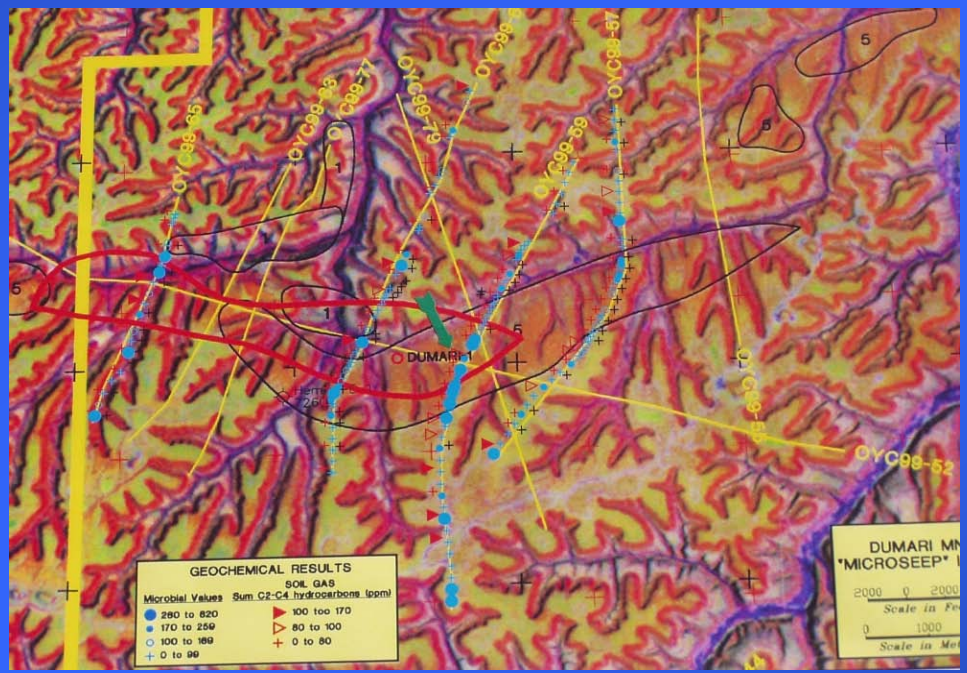


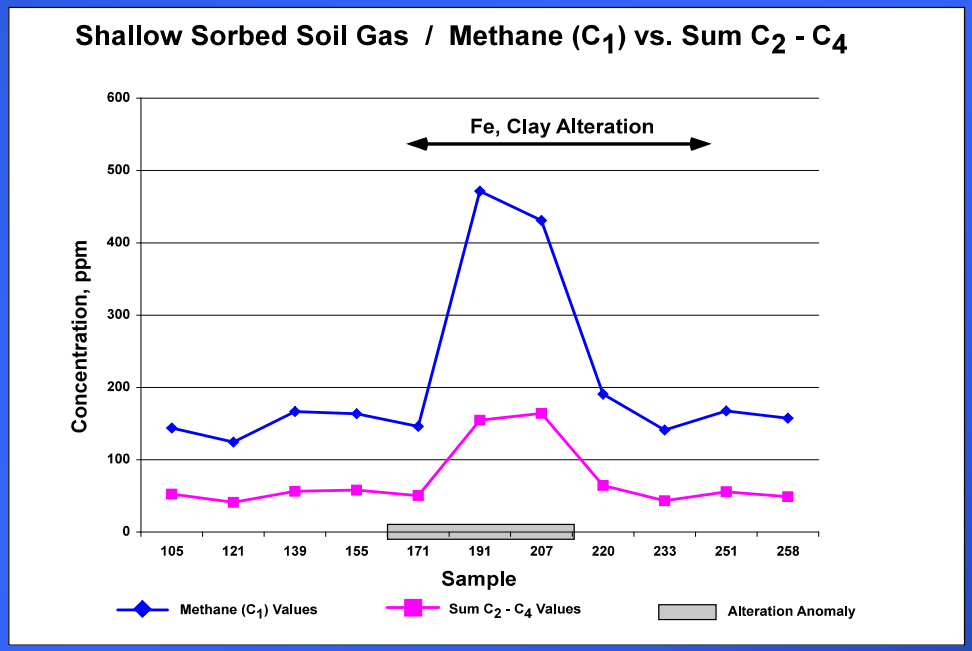
Jungle Reconnaissance Survey, Congo

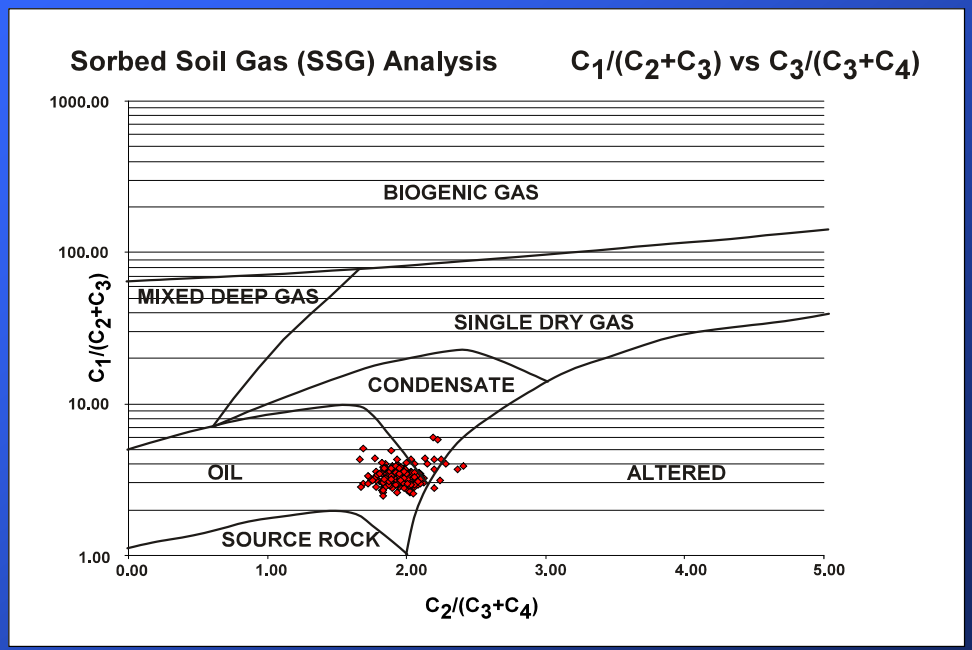




Yemen, Masila Basin
Remote Sensing and Surface Geochemistry



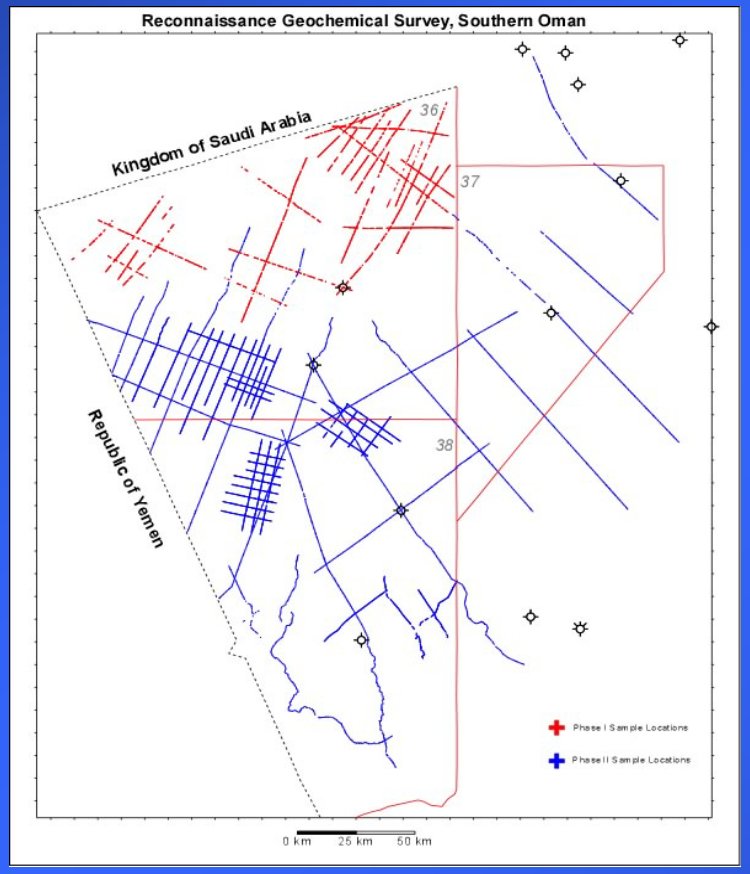


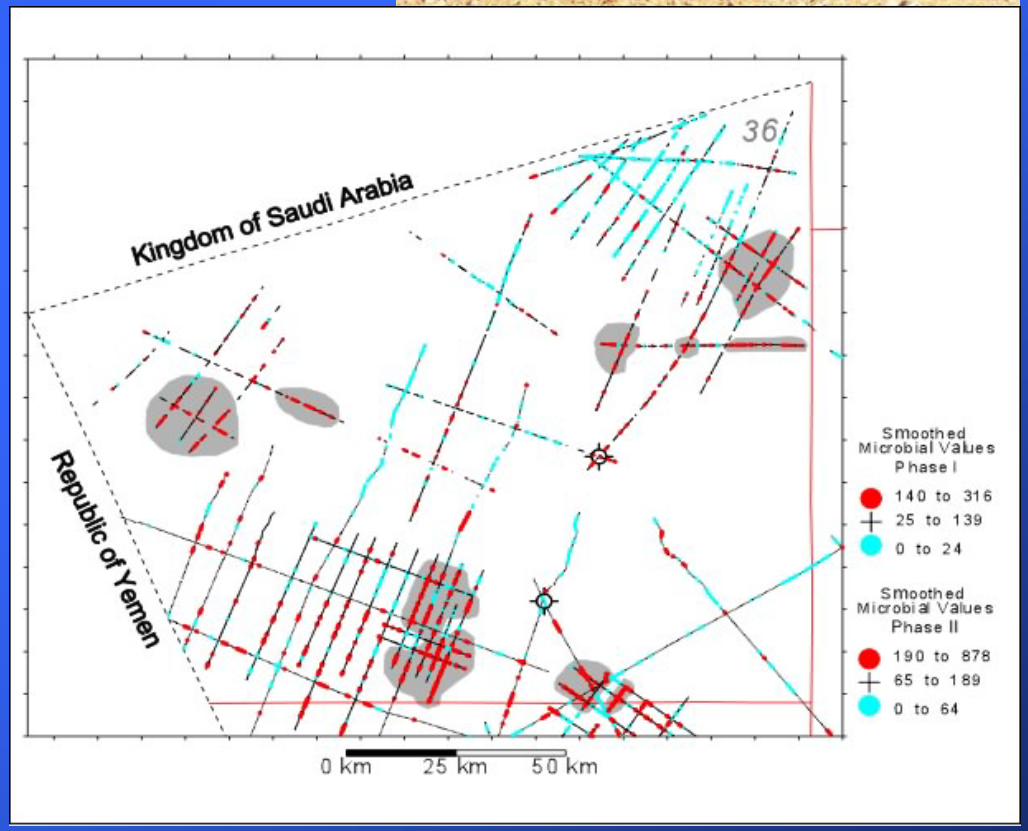


OMAN South Oman Salt Basin

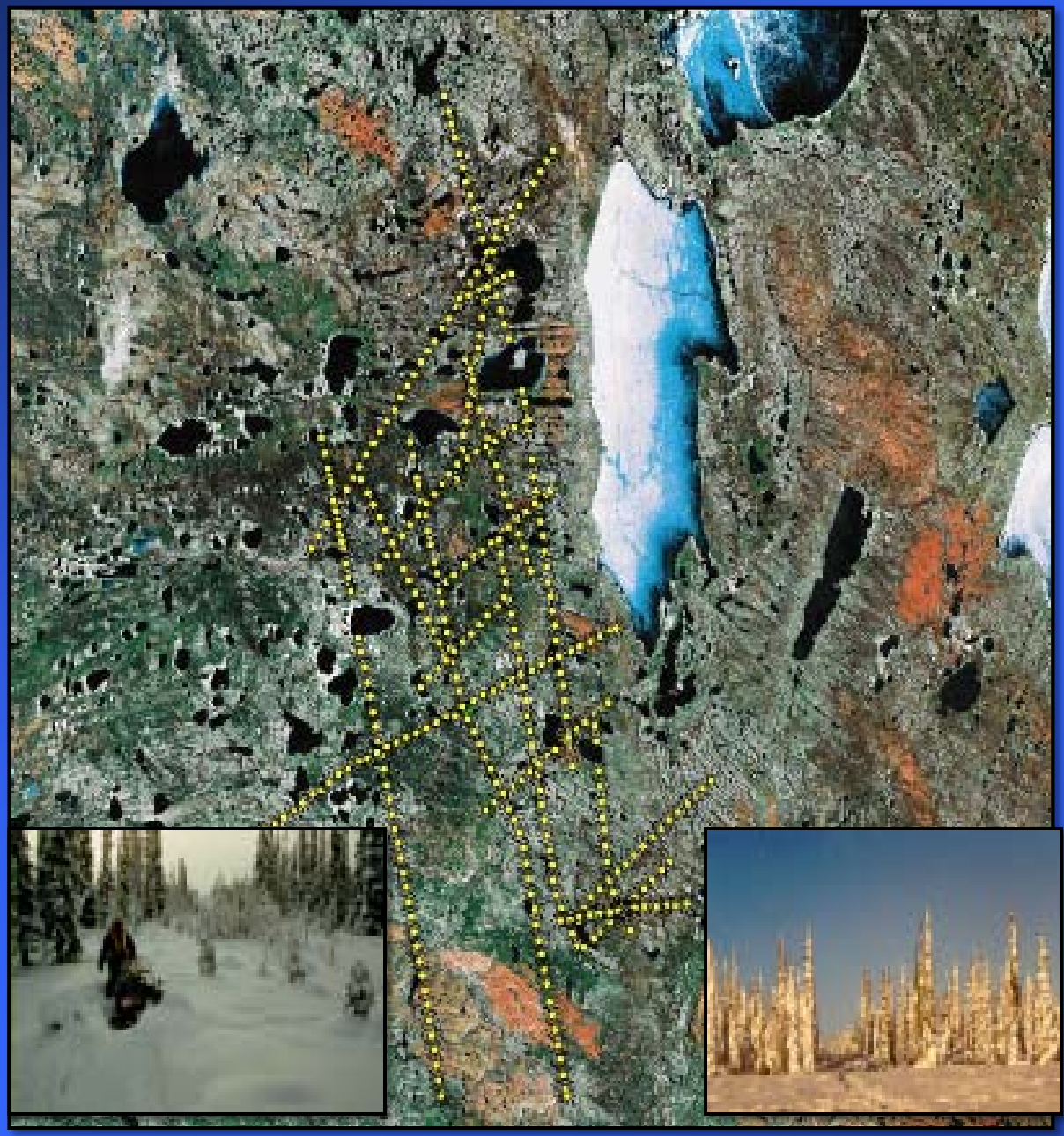
Survey Objective

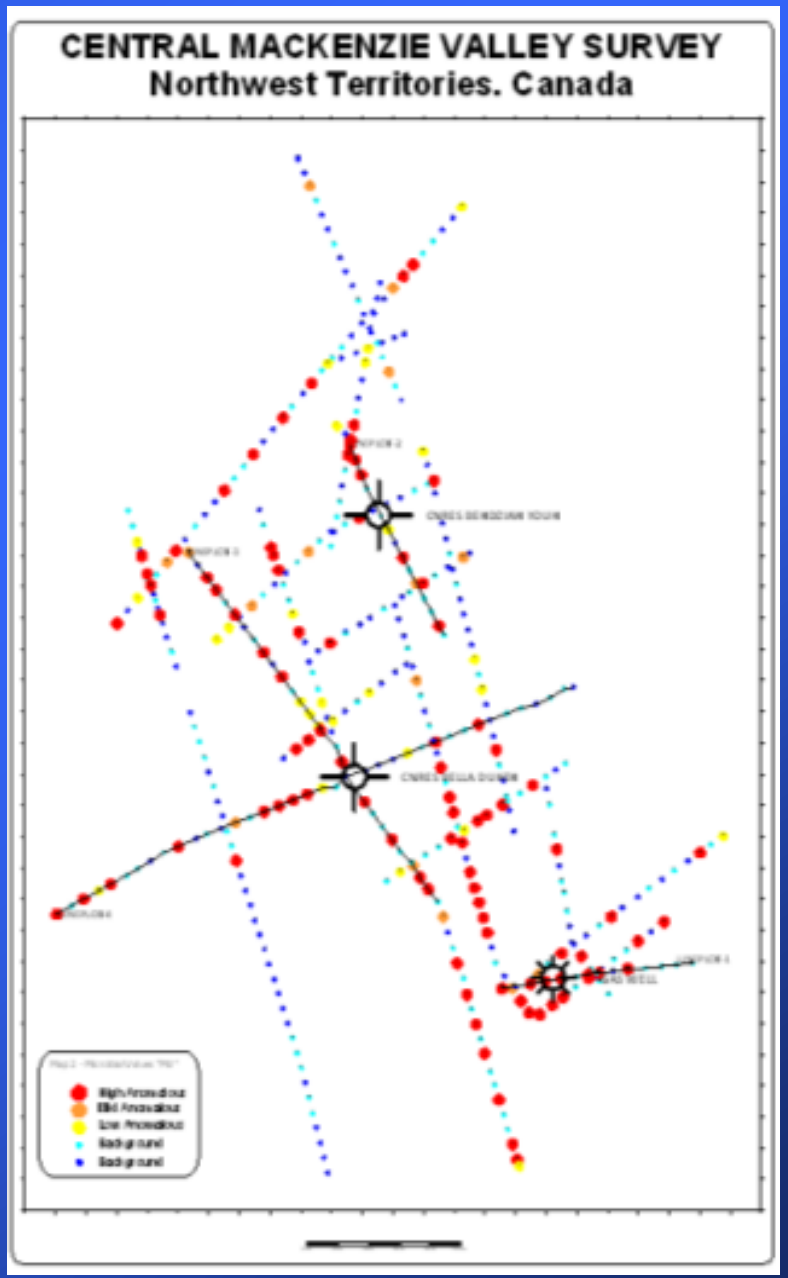
Reconnaissance geochemical survey of 70,000 km^2 in Blocks 6, 36, 37, and 38. Samples collected at 250m intervals along 2900 line km of pre-existing seismic lines. Results documented the presence of 2 distinct petroleum systems.



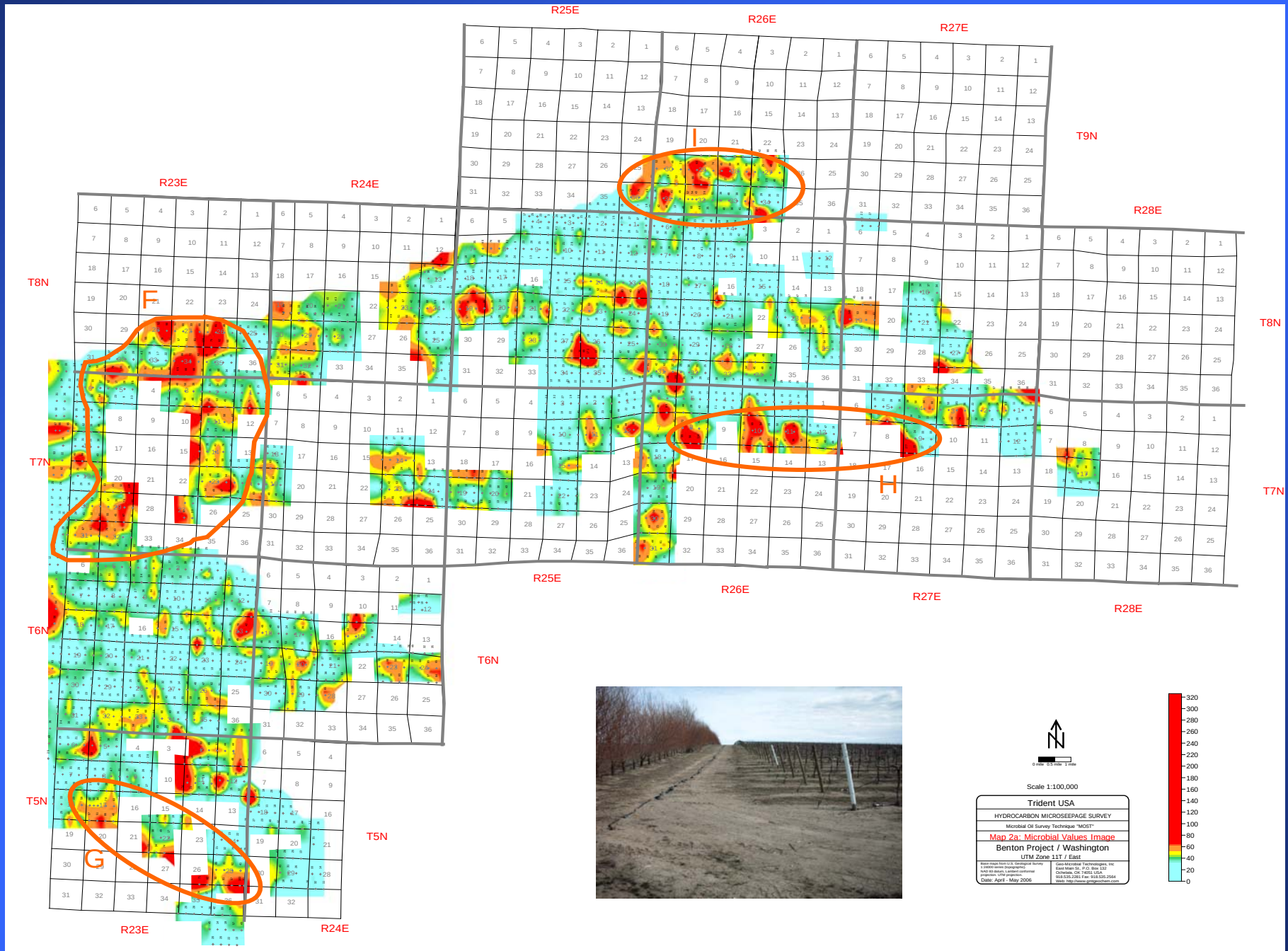


CANADIAN ARCTIC SURVEY



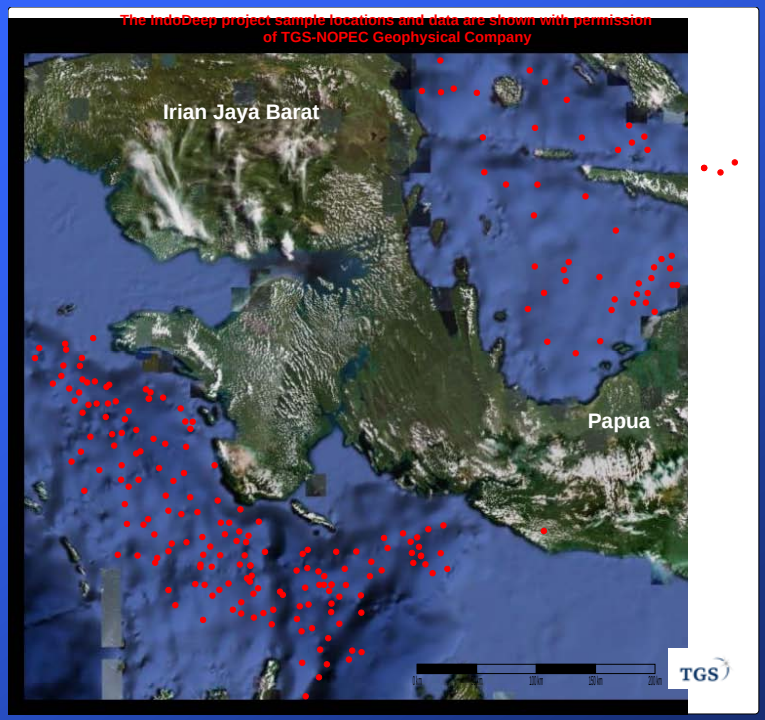


USA, Washington, Columbia Basin, Volcanics

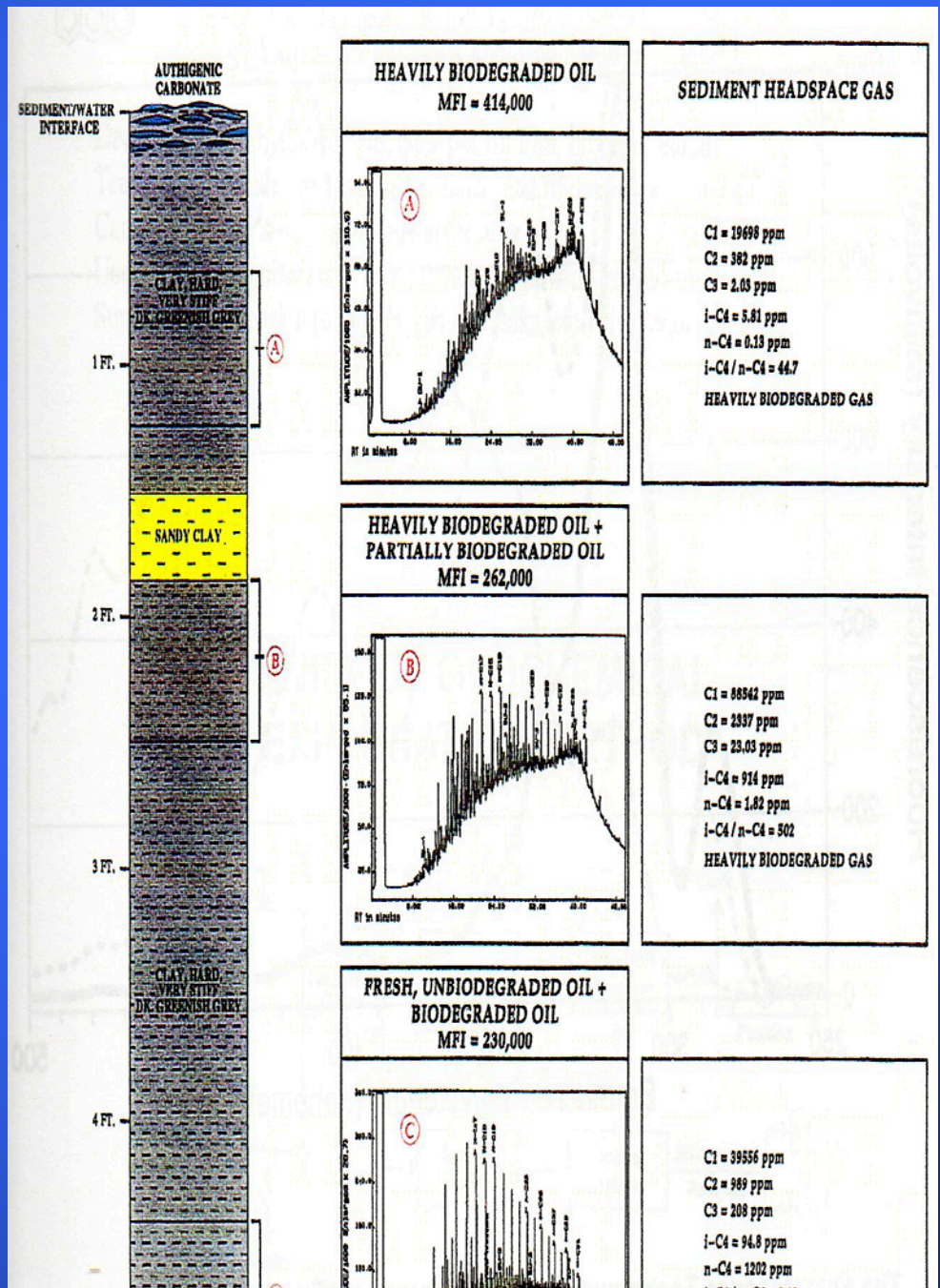


RECONAISSANCE SURVEY OF DEEP WATER FRONTIER BASINS, INDONESIA

- 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



Offshore Sampling, Analysis



Deep-Water Petroleum Systems of Indonesia

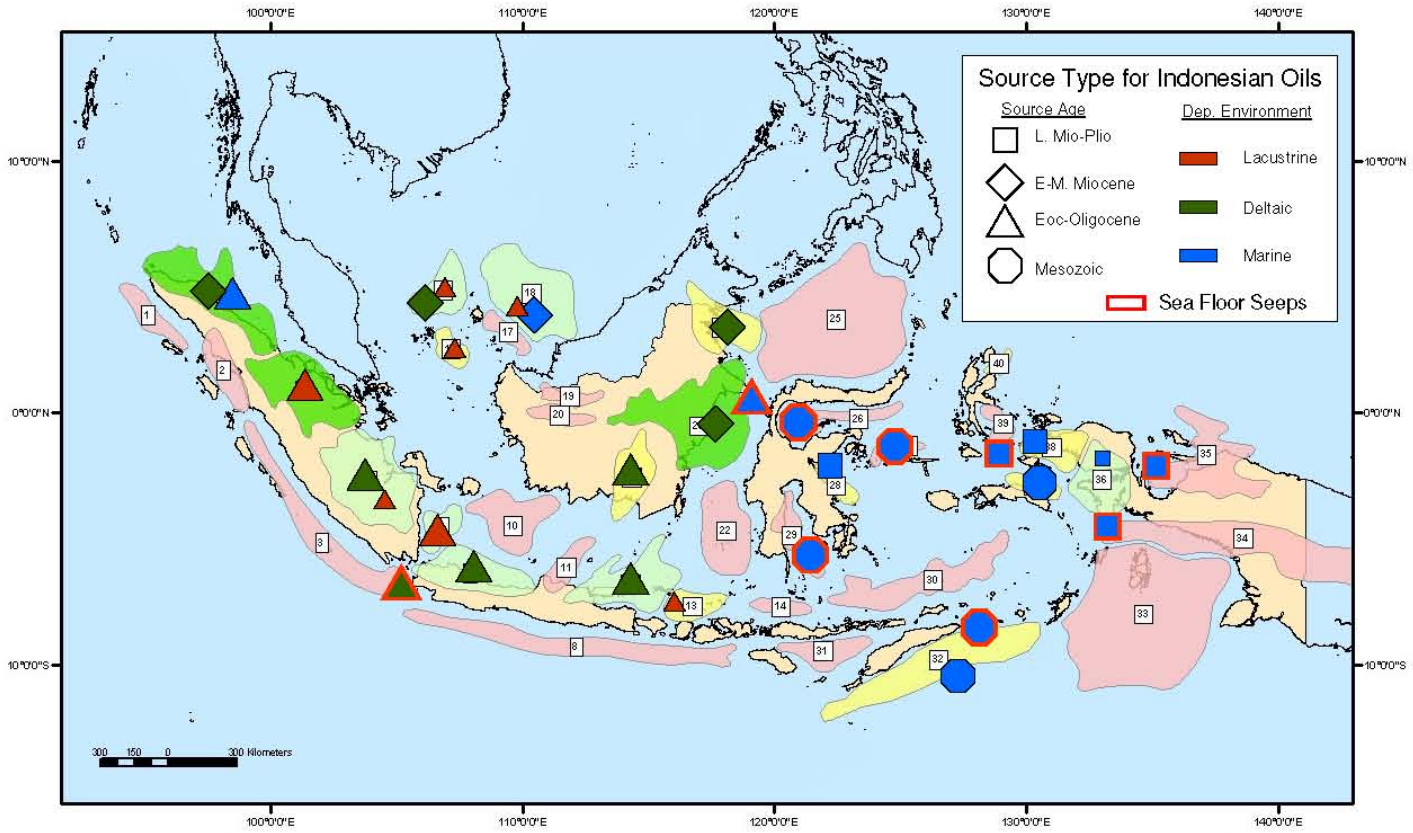
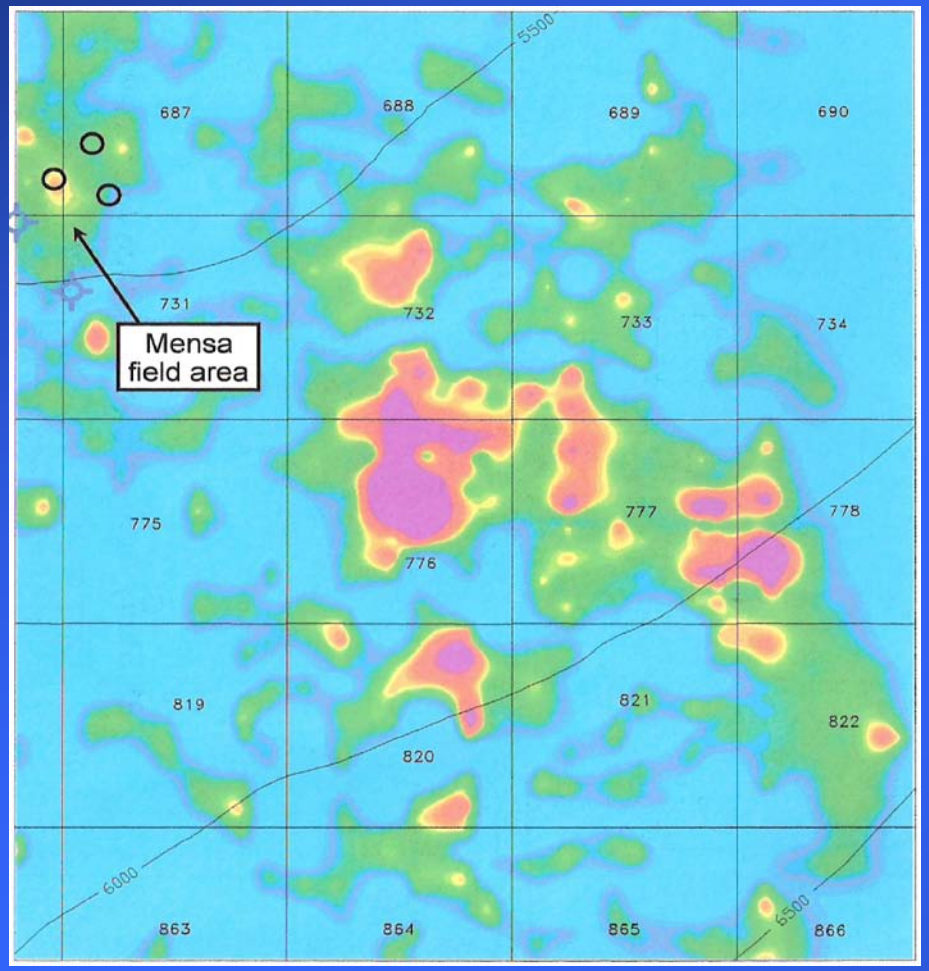


Figure 5 - Map of Indonesian crude oil families and sea-floor seeps

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 (5500 – 6500 ft)



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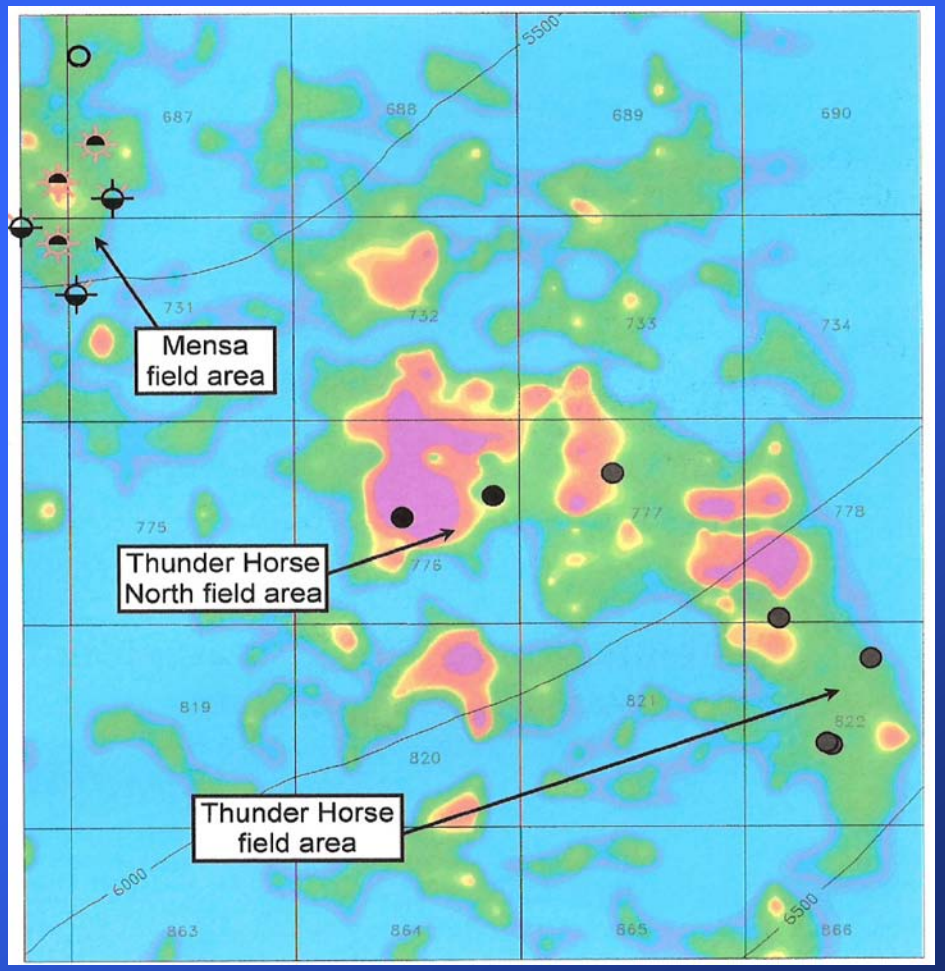

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Conclusions

Variety of remote sensing and surface methods

Document presence of petroleum system(s)

High-grade basin or concession based on its hydrocarbon potential

Identify priority targets or areas for future seismic surveys

Focus exploration resources on areas with greatest petroleum potential

HYDROCARBON SNIFFER SURVEYS

COMPARISON OF SIX NORTH AMERICAN BASINS