# From Satellite Images to Reservoired Hydrocarbons: The In-Depth Investigations of the Marco Polo Seeps, Green Canyon, Gulf of Mexico*

**Harry Dembicki[1]**

Search and Discovery Article #51377 (2017)**
Posted May 15, 2017

*Adapted from oral presentation given at AAPG 2017 Annual Convention and Exhibition, Houston, Texas, United States, April 2-5, 2017


[1]Consulting Petroleum Geochemist, The Woodlands, Texas, United States (hdembicki@aol.com)

## Abstract

The search for seafloor hydrocarbon seeps is frequently an integral part of deepwater exploration programs. If thermogenic hydrocarbons are found at the seafloor, exploration risk can be mitigated by the seeps providing evidence of a working petroleum system. The recovered seeped hydrocarbons can then be used to discern the contents of the subsurface reservoir and provide clues about their origin. This was the case for Anadarko Petroleum's exploration efforts in Green Canyon Blocks 607 and 608 that resulted in the discovery of the Marco Polo oil field. The initial seep study included using synthetic aperture radar (SAR) satellite imagery to look for sea surface slicks, processing the 3-D seismic data for seafloor attributes to help recognize potential seep features, sampling these features with piston coring, and geochemically analyzing the recovered core material. While most studies of seafloor seeps end at this point, many aspects of the Marco Polo seeps have been the subject of further investigations. These studies have included: gas chimney processing of the seismic data; a high resolution geophysical survey using an autonomous underwater vehicle (AUV) that acquired detailed multibeam bathymetry, side scan sonar, and sub-bottom acoustic profiling over the seep area; resampling the original seep features, as well as sampling potential seep features in adjacent areas; and in-depth geochemical analysis of the sediments and seeped hydrocarbons recovered. This presentation will review some of the results of these investigations. It will demonstrate how seafloor seep features can be more easily recognized and how this can lead to improving the sampling of the seep features. It will also show how detailed geochemical analysis, including comparisons to the background organic matter and reservoired oil, can provide better evidence for identifying the origin of the seeped hydrocarbons encountered and understanding their exploration significance. Finally, it will illustrate how examining the cores for the presence of authigenic carbonates, chemosynthetic organisms, and other features can help characterize the seep sites.

## References Cited

Abrams, M.A. and N.F. Dahdah, 2011, Surface sediment hydrocarbons as indicators of subsurface hydrocarbons: Field calibration of existing and new surface geochemistry methods in the Marco Polo area, Gulf of Mexico: AAPG Bulletin, v. 95, p. 1907–1935.

Chaouche, A., P. Gamwell, and J. Brooks, 2004, Surface geochemical evaluation of Green Canyon Block 608, Gulf of Mexico: A comparison of seafloor seeps and reservoir hydrocarbon fluids: AAPG Search and Discovery Article #90026, Web Accessed April 29, 2017, http://www.searchanddiscovery.com/abstracts/html/2004/annual/abstracts/Chaouche.htm

Dembicki, Jr., H., 2010, Recognizing and compensating for interference from the sediment's background organic matter and biodegradation during interpretation of biomarker data from seafloor hydrocarbon seeps: An example from the Marco Polo area seeps, Gulf of Mexico, USA: Marine and Petroleum Geology, v. 27, p. 1936-1951.

Dembicki, Jr., H., 2013, Interpreting Geochemical Data From Seafloor Hydrocarbons Seeps: You Can't Always Get What You Want: Offshore Technology Conference Proceedings Paper 24237, 22 p.

Dembicki, Jr., H. and D.L. Connolly, 2013, Surface and subsurface expression of hydrocarbon seepage in the Marco Polo Field Area, Green Canyon, Gulf of Mexico: Hydrocarbon Seepage: From Source to Surface, F. Aminzadeh, T.B. Berge, and D.L. Connolly, eds., SEG Geophysical Developments Series No. 16, Chapter 5, p. 83-91.

Dembicki, Jr., H. and B.M. Samuel, 2007, Identification, Characterization, And Ground-Truthing of Deepwater Thermogenic Hydrocarbon Macro-Seepage Utilizing High-Resolution AUV Geophysical Data: Offshore Technology Conference Proceedings Paper 18556, 11 p.

Dembicki, Jr., H. and B.M. Samuel, 2008, Improving the Detection and Analysis of Seafloor Macro-Seeps: An Example from the Marco Polo Field, Gulf of Mexico, USA: International Petroleum Technology Conference Proceedings Paper 12124, 18 p.

Mount, V.S., A. Rodriguez, A. Chaouche, S.G. Crews, P. Gamwell, and P. Montoya, 2006, Petroleum system observations and interpretations in the vicinity of the K2/K2-North, Genghis Khan, and Marco Polo fields, Green Canyon, Gulf of Mexico: Gulf Coast Association of Geological Societies Transactions, v. 56, p. 613-625.

# *From Satellite Images to Reservoired Hydrocarbons: The In-Depth Investigations of the Marco Polo Seeps, Green Canyon, Gulf of Mexico*

*"There is something fascinating about science. One gets such wholesale returns of conjecture out of such a trifling investment of fact."*

**- Mark Twain -**

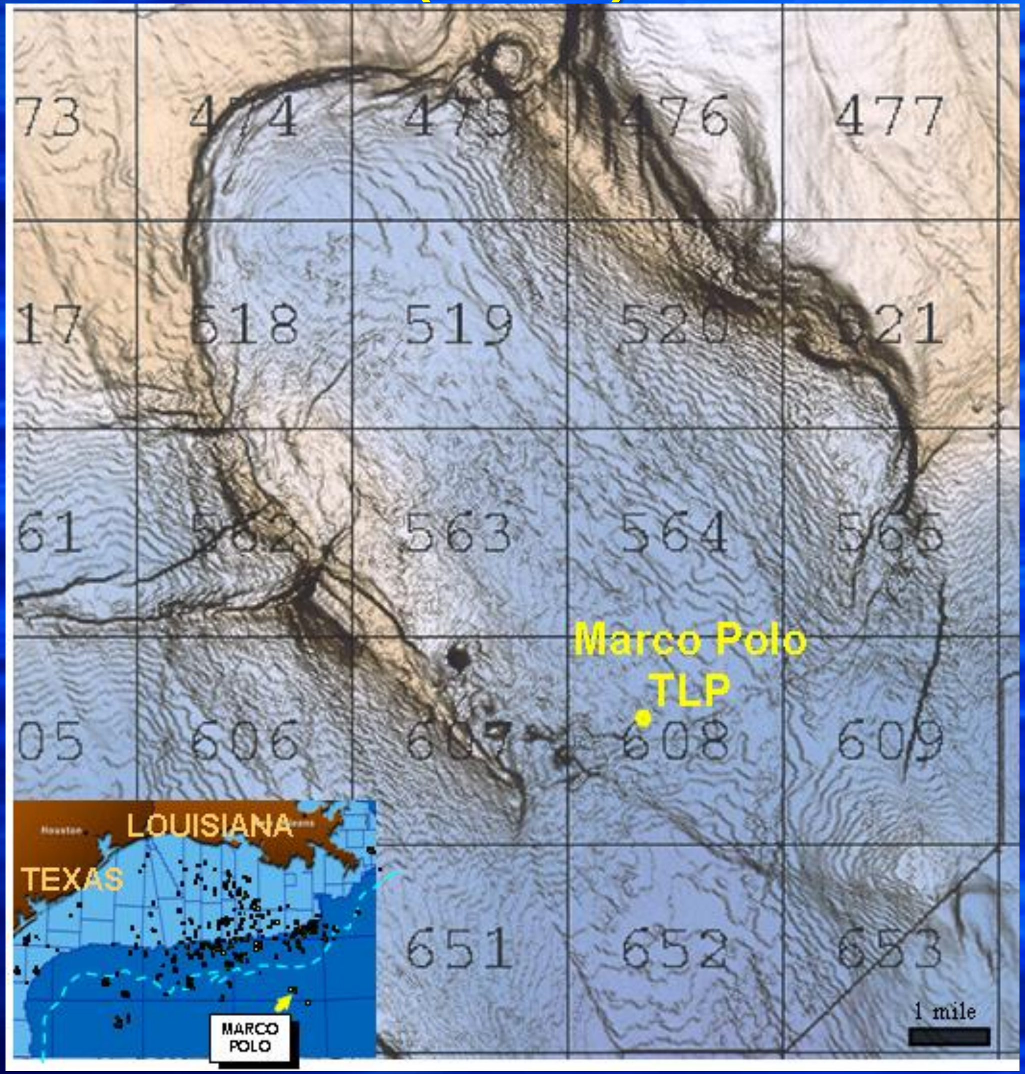
**Harry Dembicki, Jr.***
**Consulting Petroleum Geochemistry**
**The Woodlands, Texas**

**APPG Annual Convention & Exhibition**
**Houston, April 2-5, 2017**

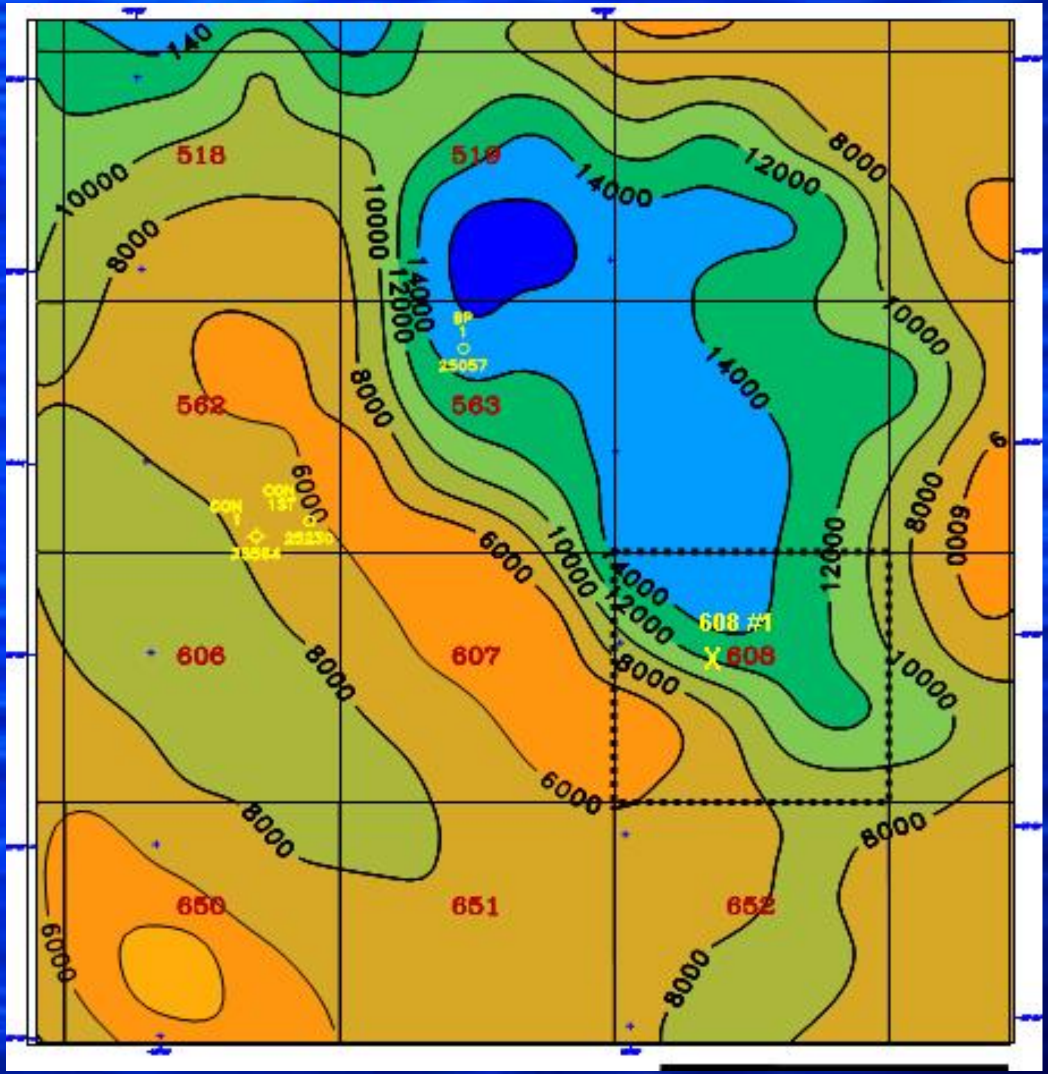
*** Previously with Anadarko Petroleum Corporation**

# The Marco Polo Field Area

**Location map with bathymetry showing the Marco Polo TLP on the continental slope 175 miles (281 km) south of New Orleans in just over 4000 feet (1219 m) of water.**

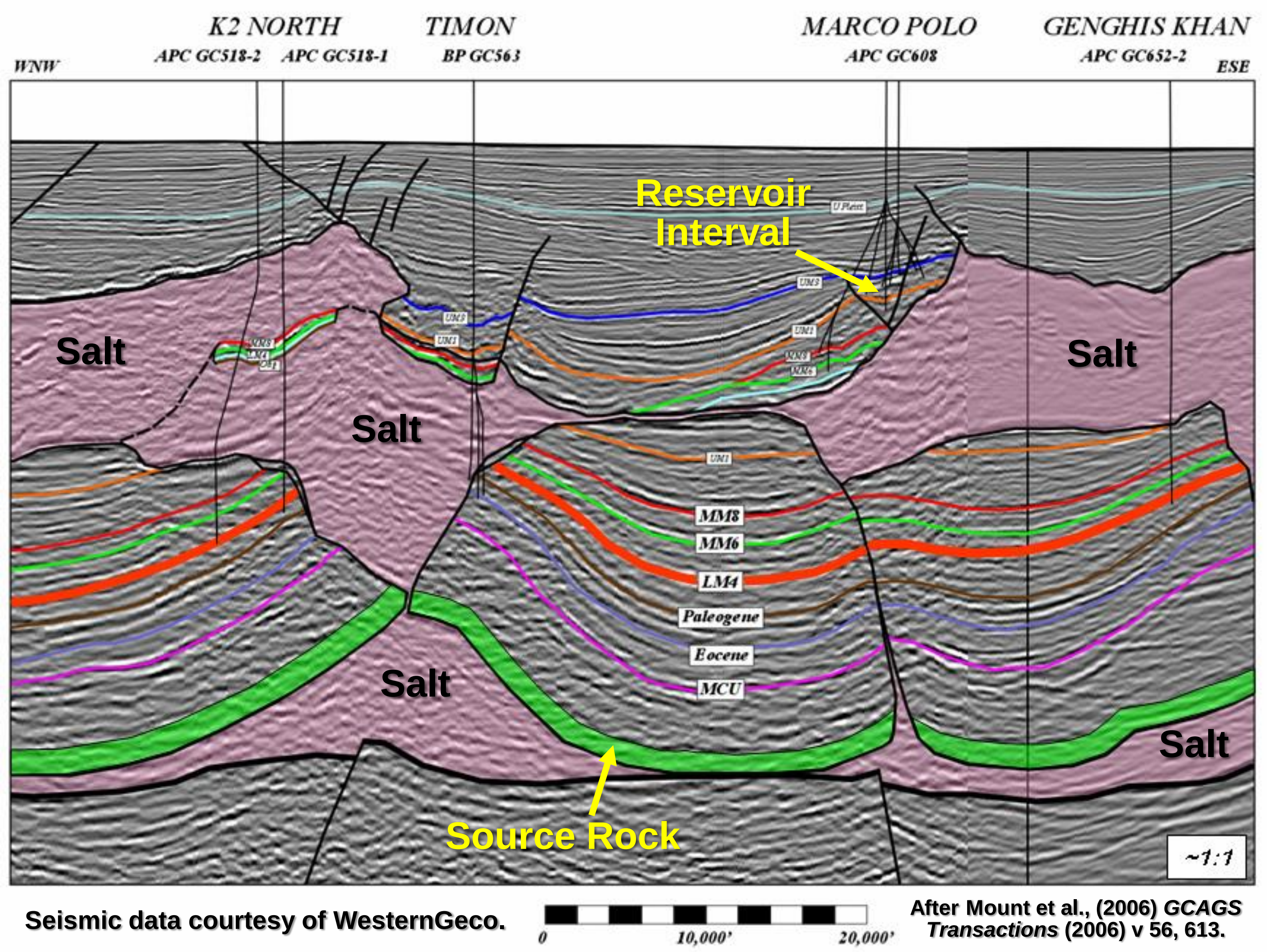



**An isopach map showing sediment thickness from mud line to top of salt in the Marco Polo area indicating the geometry of the supra-salt mini-basin.**




After Dembicki, Jr., H., and B. M. Samuel, 2008, Poster presentation , IPTC, Kuala Lumpur, Malaysia.

# A Seismic Transect In Green Canyon Showing The Complex Salt Tectonics In The Marco Polo Area




**Jurassic sourced oil migrated up to supra-salt Miocene reservoirs in the Marco Polo field through windows in the welded salt canopy.**

**Dynamic salt tectonics in this area of the Gulf of Mexico is in large part responsible for the large amount of hydrocarbon seepage observed.**

From H. Dembicki, Jr. and B. M. Samuel, 2008, IPTC Proceedings Paper 12124, 18 p.

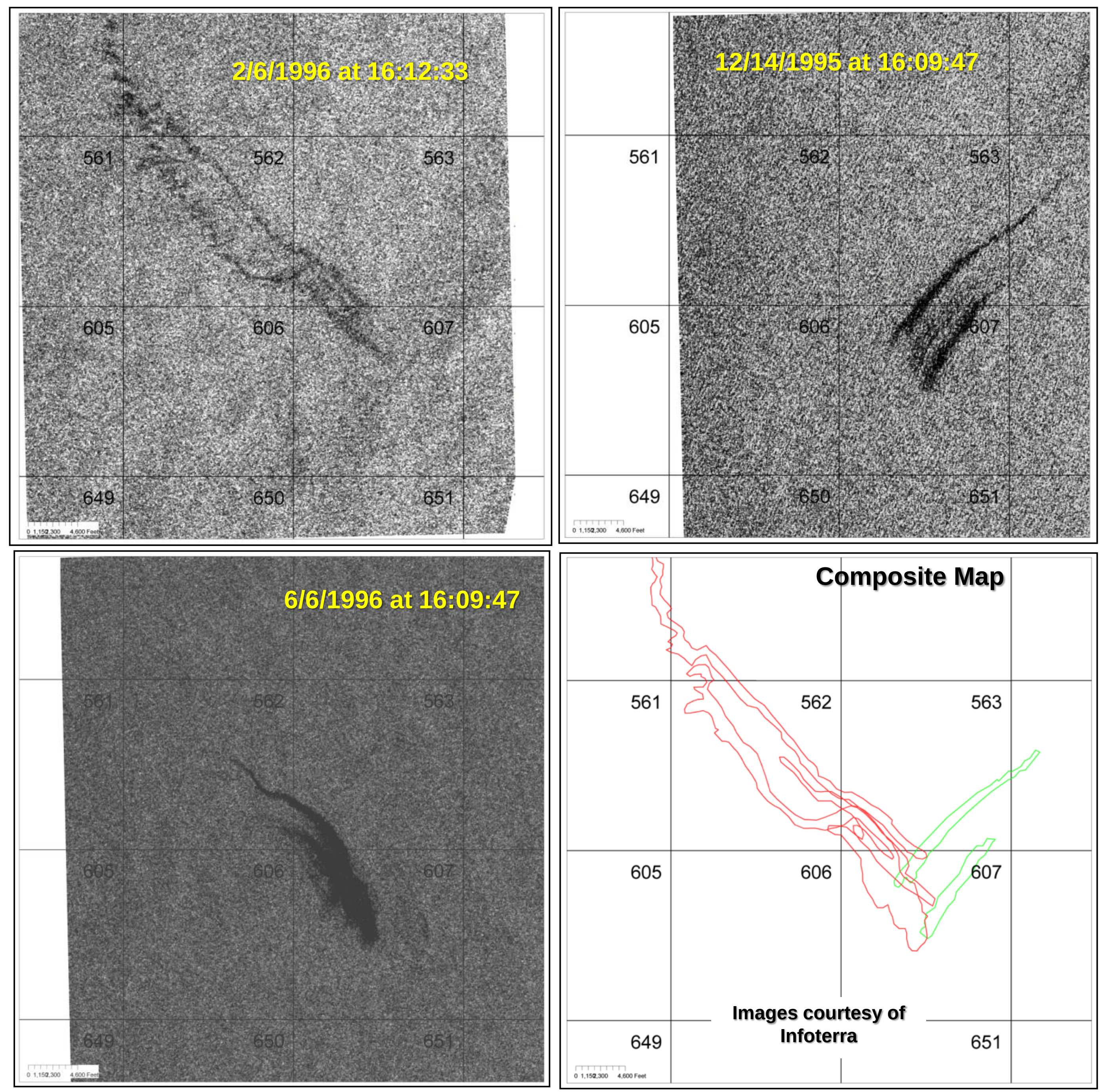
# Synthetic Aperture Radar (SAR) Images Of The Marco Polo Field Area

**In the area around the mini-basin, sea surface slicks have repeatedly formed.**

**Their size and shape suggest these slicks could be from naturally occurring hydrocarbon seepage.**

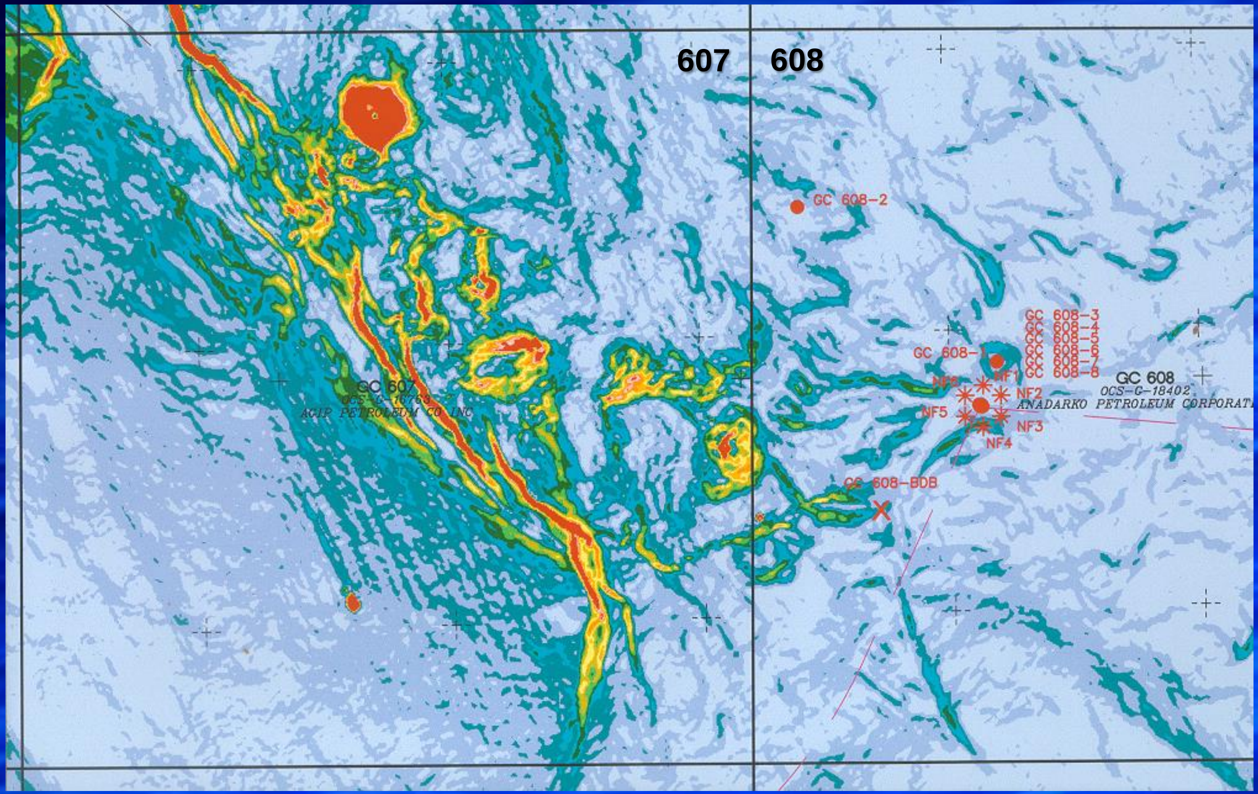
**The focal point of the slicks is in the north central part of Block 607, just west of the Marco Polo Field.**

**Sea surface slicks observed in the north central part of Block 607 during the August 2006 coring operation.**






From H. Dembicki, Jr. and B. M. Samuel, 2008 IPTC Proceedings Paper 12124, 18 p.



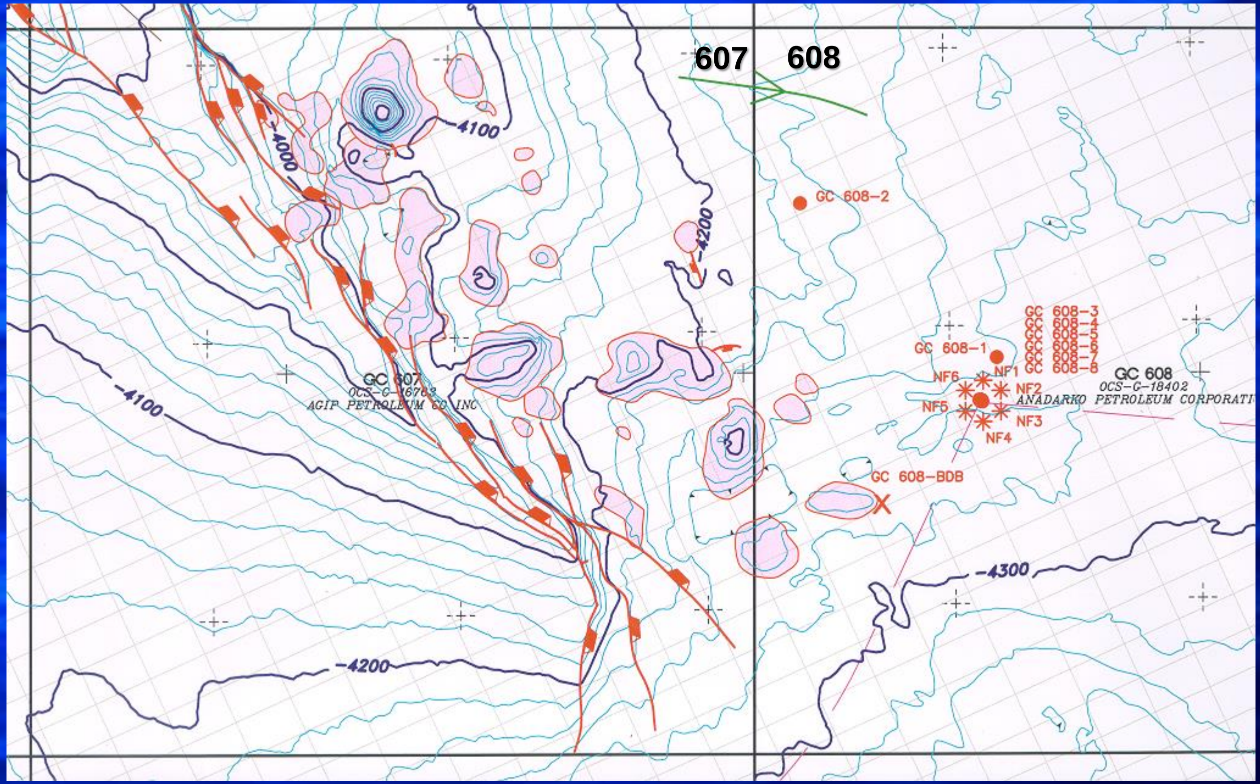

# Seafloor Amplitude Extraction From 3-D Seismic Data

**Higher amplitude may indicate the presence of authigenic carbonates, hydrates, or chemosynthetic communities developing in response to hydrocarbon seepage.**

**Higher amplitudes are hotter colors.**

# Bathymetry And Faults With High Amplitude Areas Highlighted

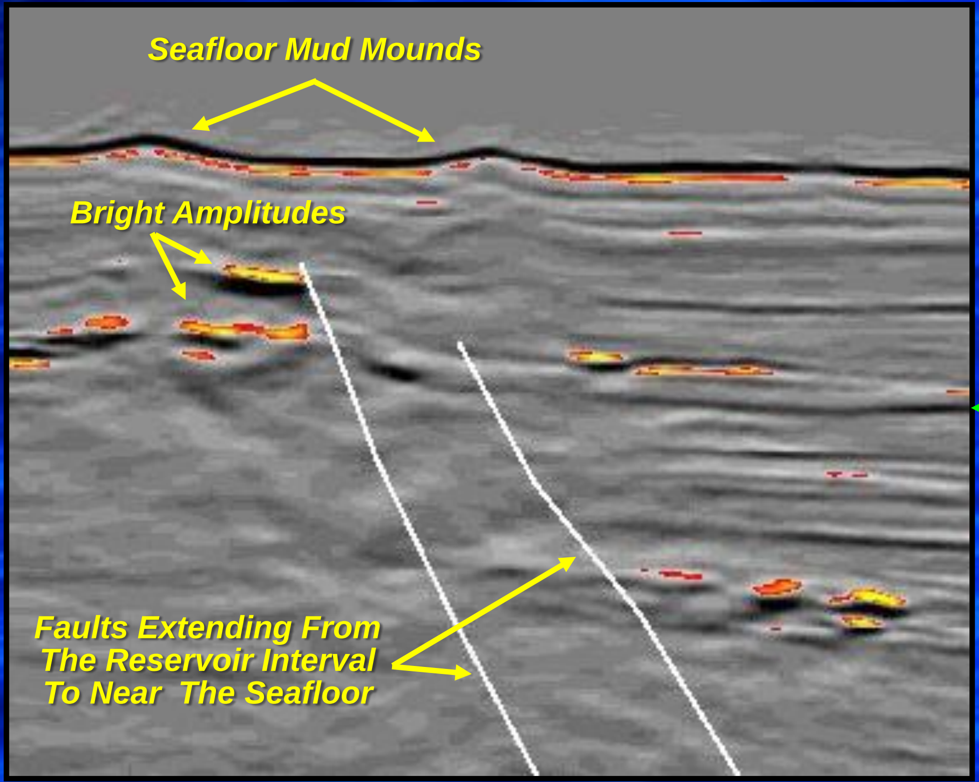
**Areas with high potential for seepage as indicated by amplitudes are coincident with bathymetric features that could also be related to seepage.**

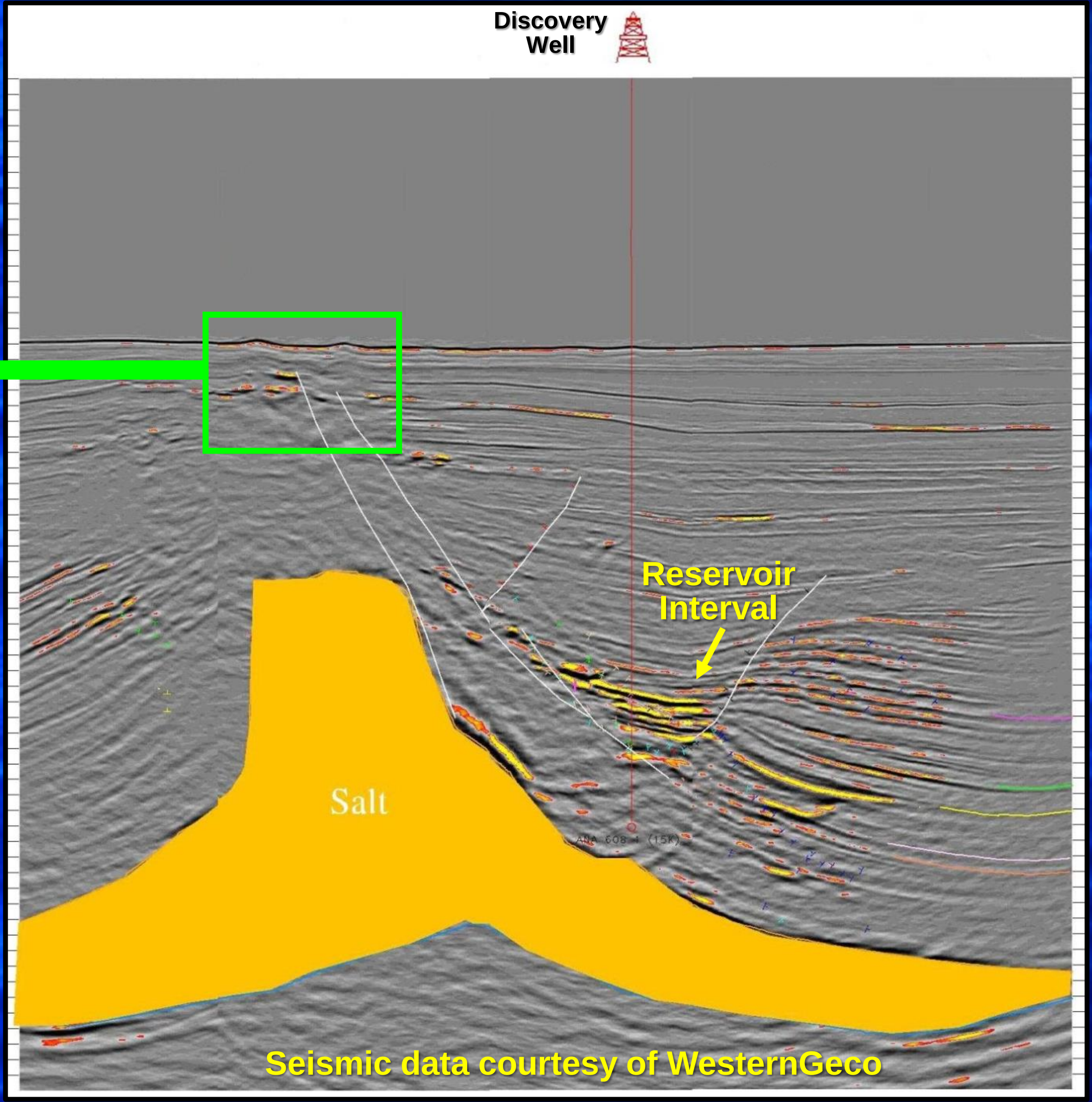



H. Dembicki, Jr.

After Chaouche, A., *et al*., 2004, Oral presentation, AAPG Annual Meeting, Dallas, TX.

# 3-D Seismic Data Showing The Marco Polo Field And Indications Of Potential Seafloor Seepage



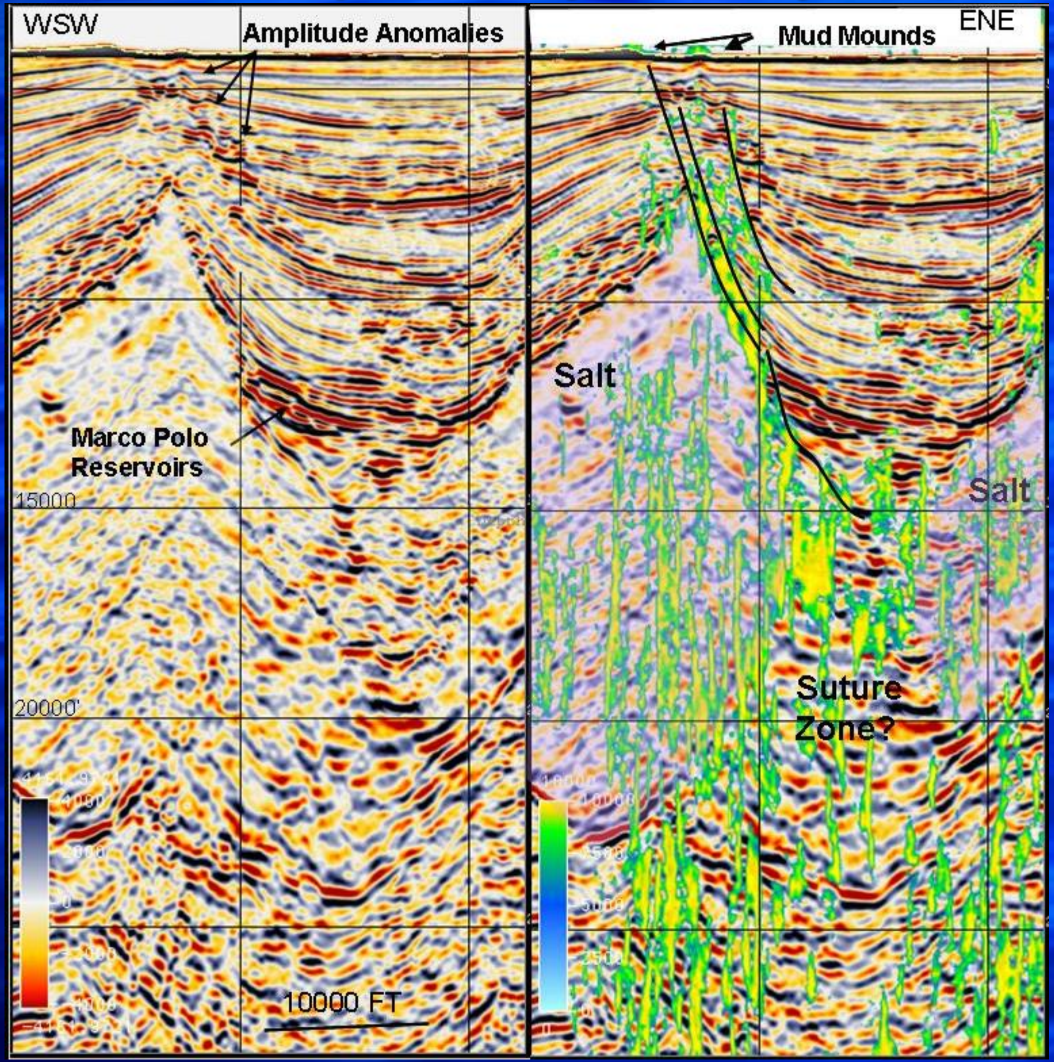




**Faults extend up from the reservoir interval to near the seafloor. Shallow bright amplitudes and seafloor mud mounding suggest the potential for hydrocarbon seepage. Together they data establish a link between subsurface reservoirs, migration pathways, and potential seafloor seeps.**

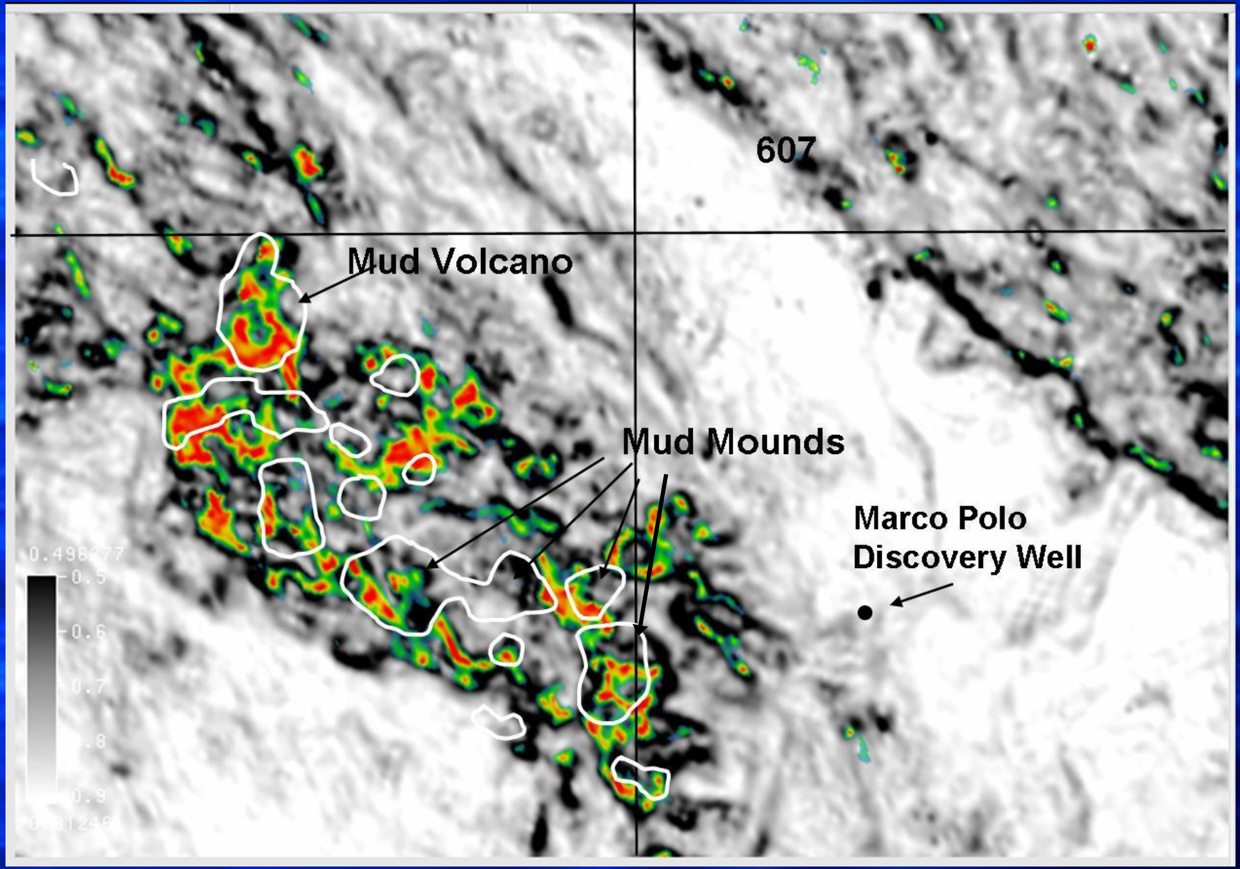
After H. Dembicki, Jr. and B. M. Samuel, 2007, OTC Proceedings Paper 18556, 11 p.

# Results From Gas Chimney Seismic Processing

**Seismic lines extracted from the 3D survey with the interpreted gas chimney probability overlay shown on the right half of the image. High probability chimneys are in yellow.**

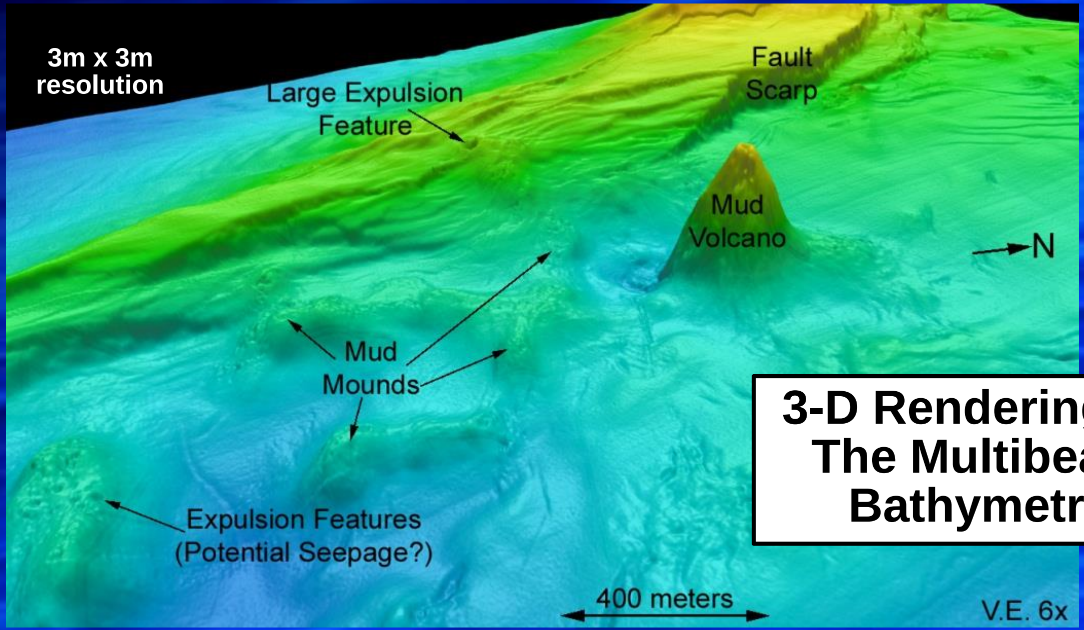



**The slice is approximately 800 Ft below sea floor and shows fault attribute in gray scales overlain by chimney probability (red: highly probable chimneys). Outlined areas indicate probable seep features based on their geomorphology and acoustic characteristics. Good correlation is noted between chimneys and seeps features.**



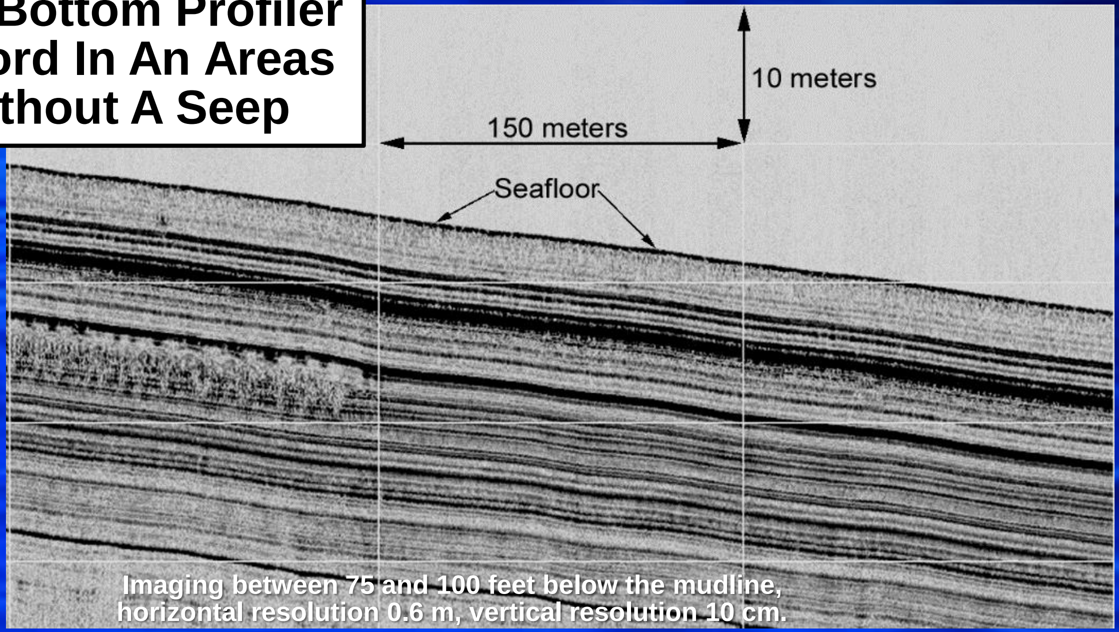

From H. Dembicki, Jr and D. L. Connolly, 2013, SEG Geophysical Developments Series No. 16, Chapter 5, p.83-91.

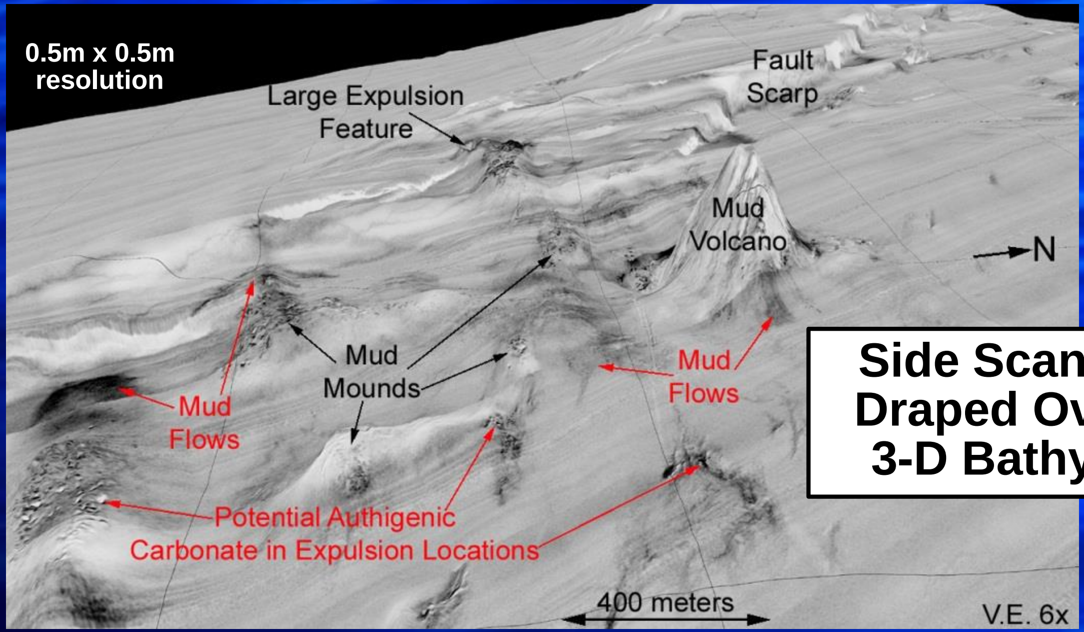
# AUV Geophysical Data Collected 40m Above The Seafloor




**3-D Rendering Of The Multibeam Bathymetry**

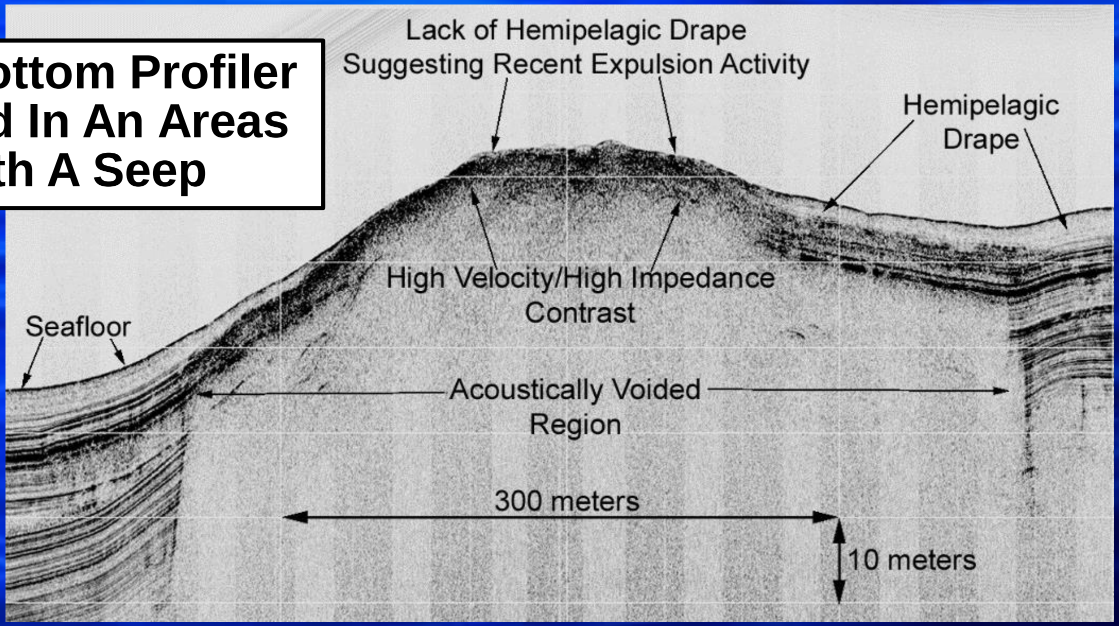
**Sub-Bottom Profiler Record In An Areas Without A Seep**



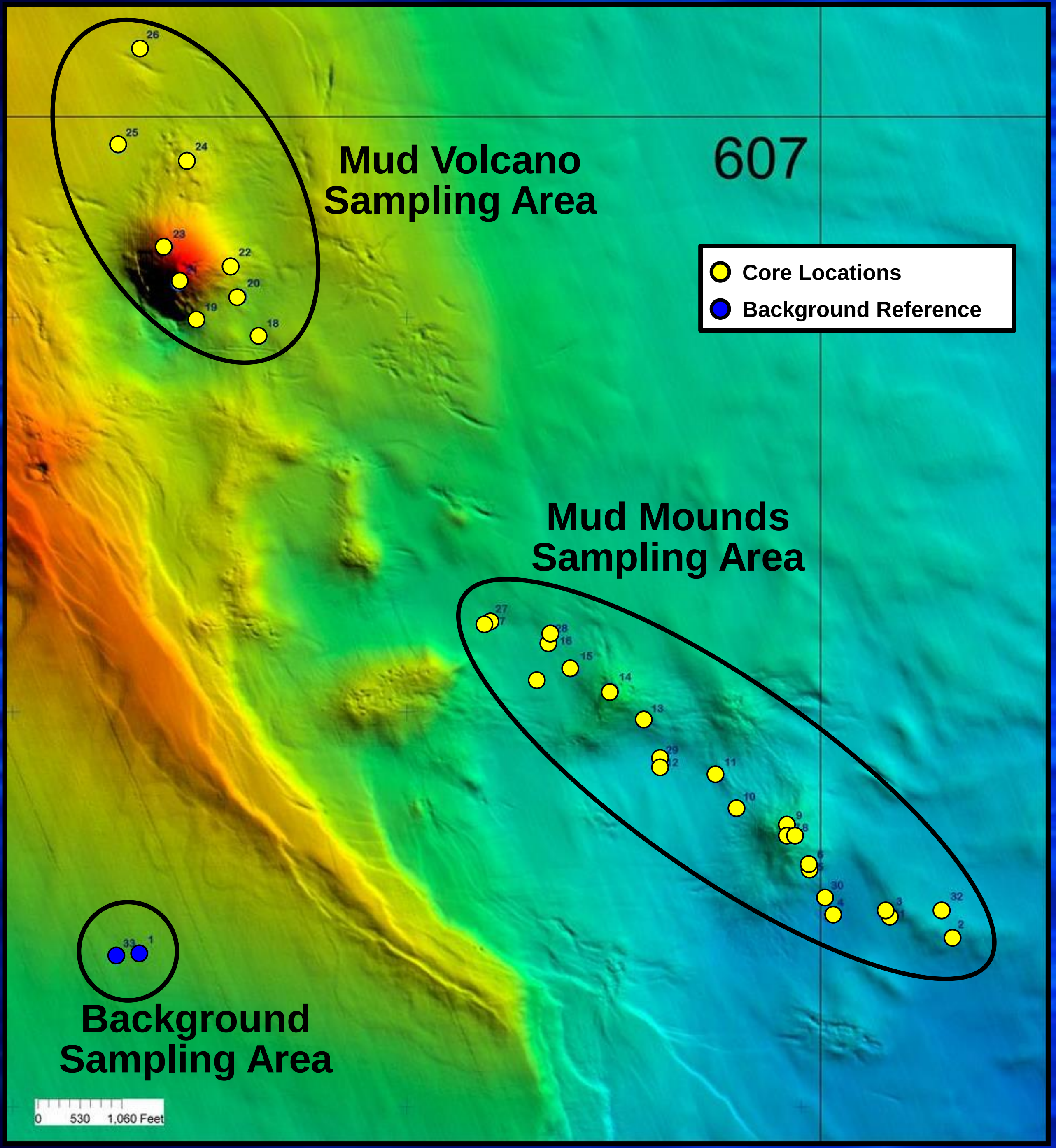

**Side Scan Sonar Draped Over The 3-D Bathymetry**

**Sub-Bottom Profiler Record In An Areas With A Seep**






After H. Dembicki, Jr. and B. M. Samuel, 2007, OTC Proceedings Paper 18556, 11 p.




# Selecting Sampling Areas

The mud volcano is a high flux seep feature. Hydrocarbon discharge from this feature is episodic.

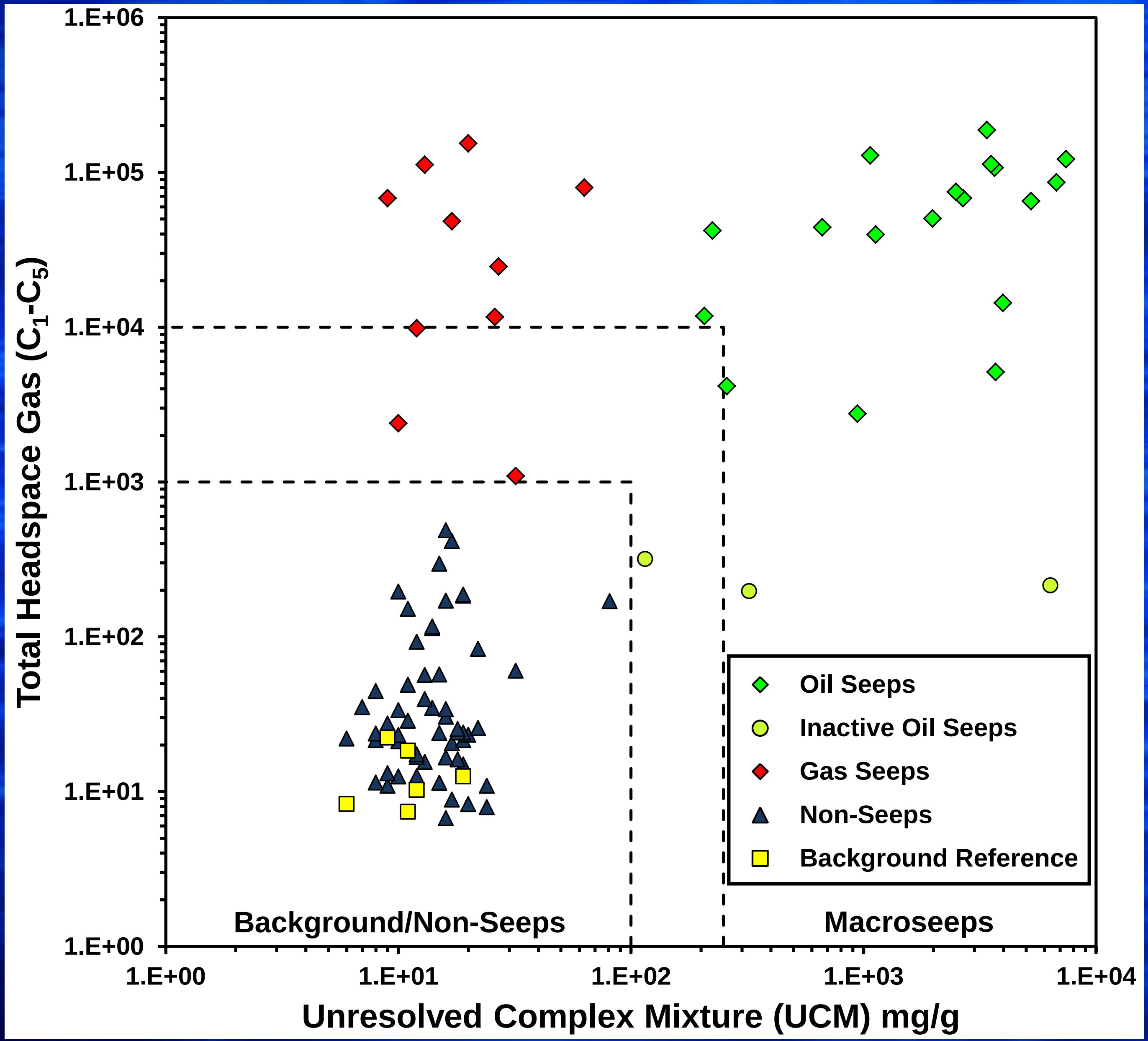
The mud mounds are slow flux seep features. The mud mounds appear to be receiving seeped hydrocarbons more continuously.

Background samples were collected outside the mini-basin.

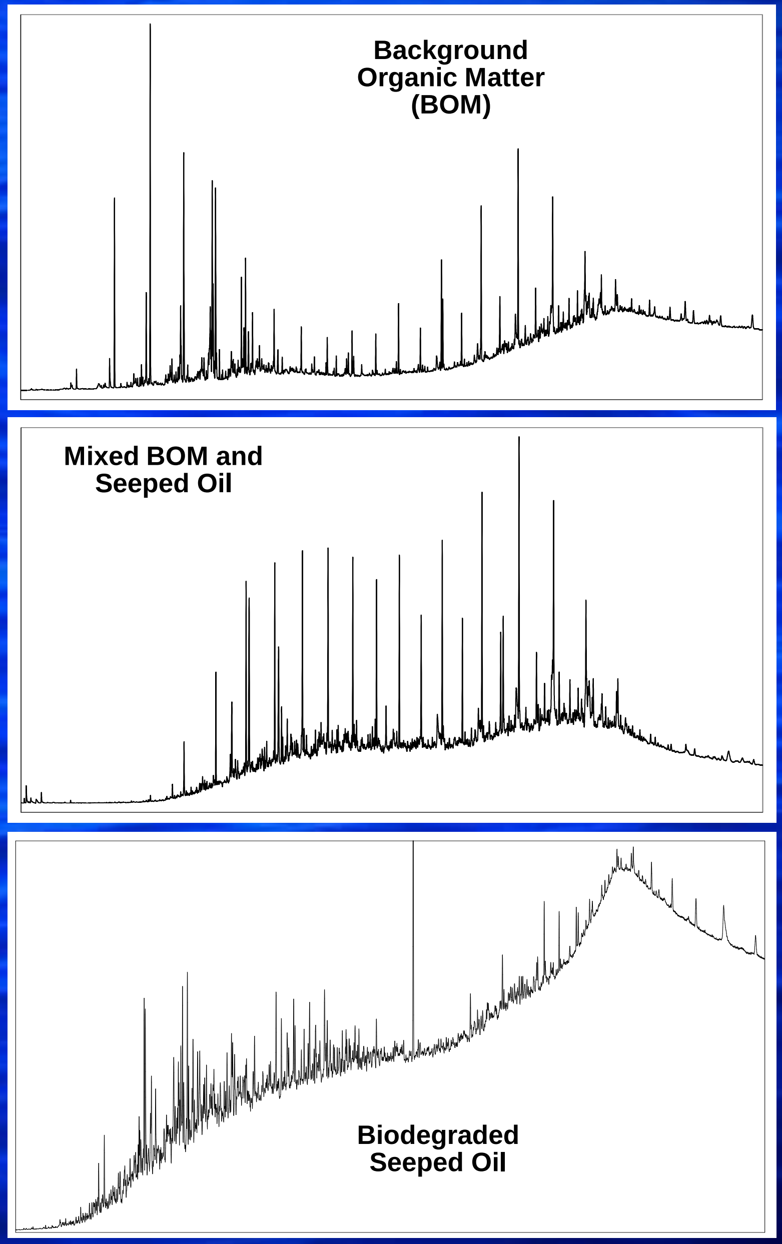
Modified after H. Dembicki, Jr. and B. M. Samuel, 2007, OTC Proceedings Paper 18556, 11 p.

# Screening Results From The Piston Core Samples

## Comparing the Total Headspace Gas to the Unresolved Complex Mixture (UCM) in the Extract Gas Chromatograms

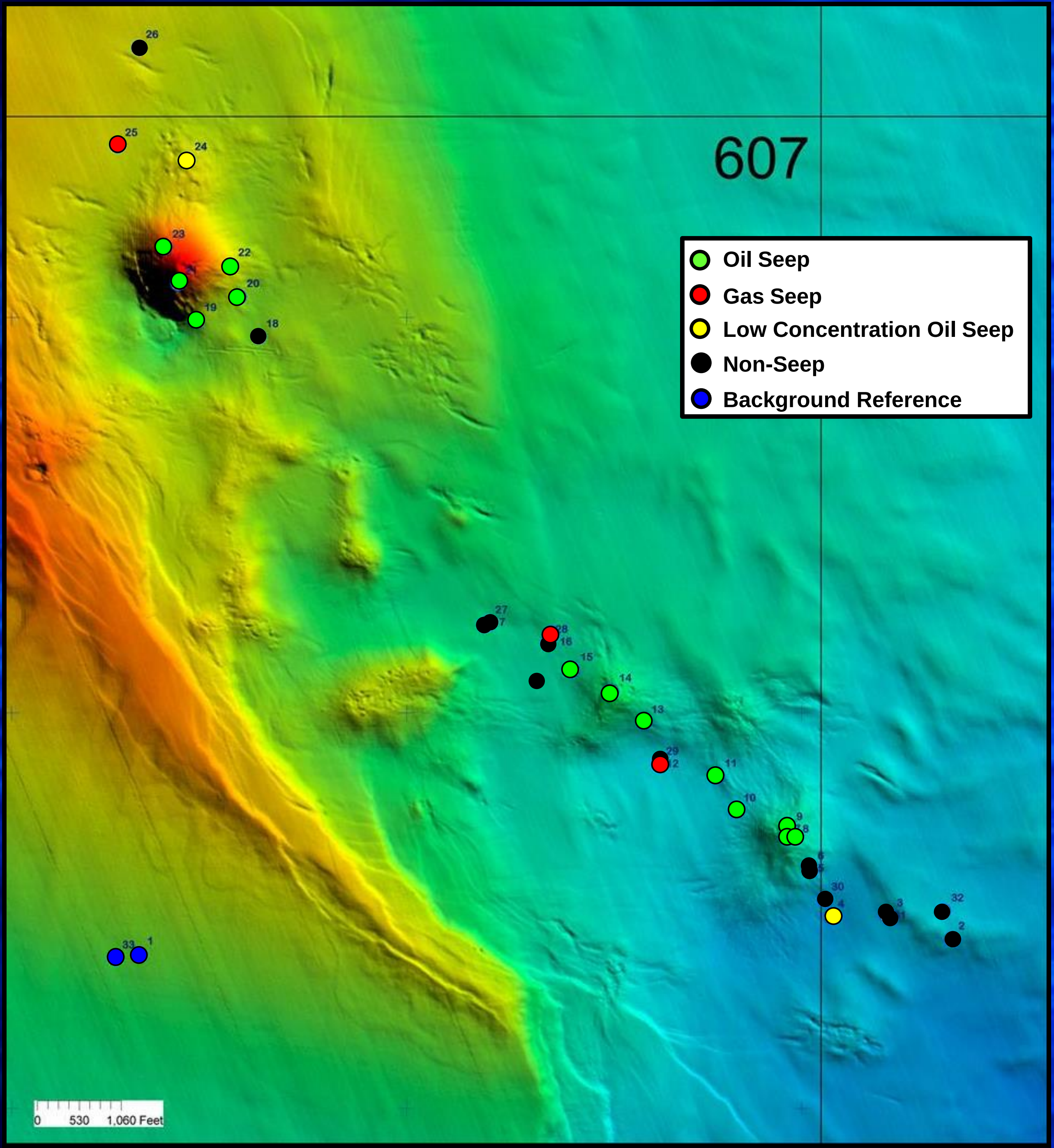



## Examining The Extract Gas Chromatograms




Data from M.A. Abrams and N.F. Dahdah, 2011, AAPG Bulletin, v. 95, p. 1907-1935.

Dembicki




Dembicki

# Interpretation Of Screening Data Results

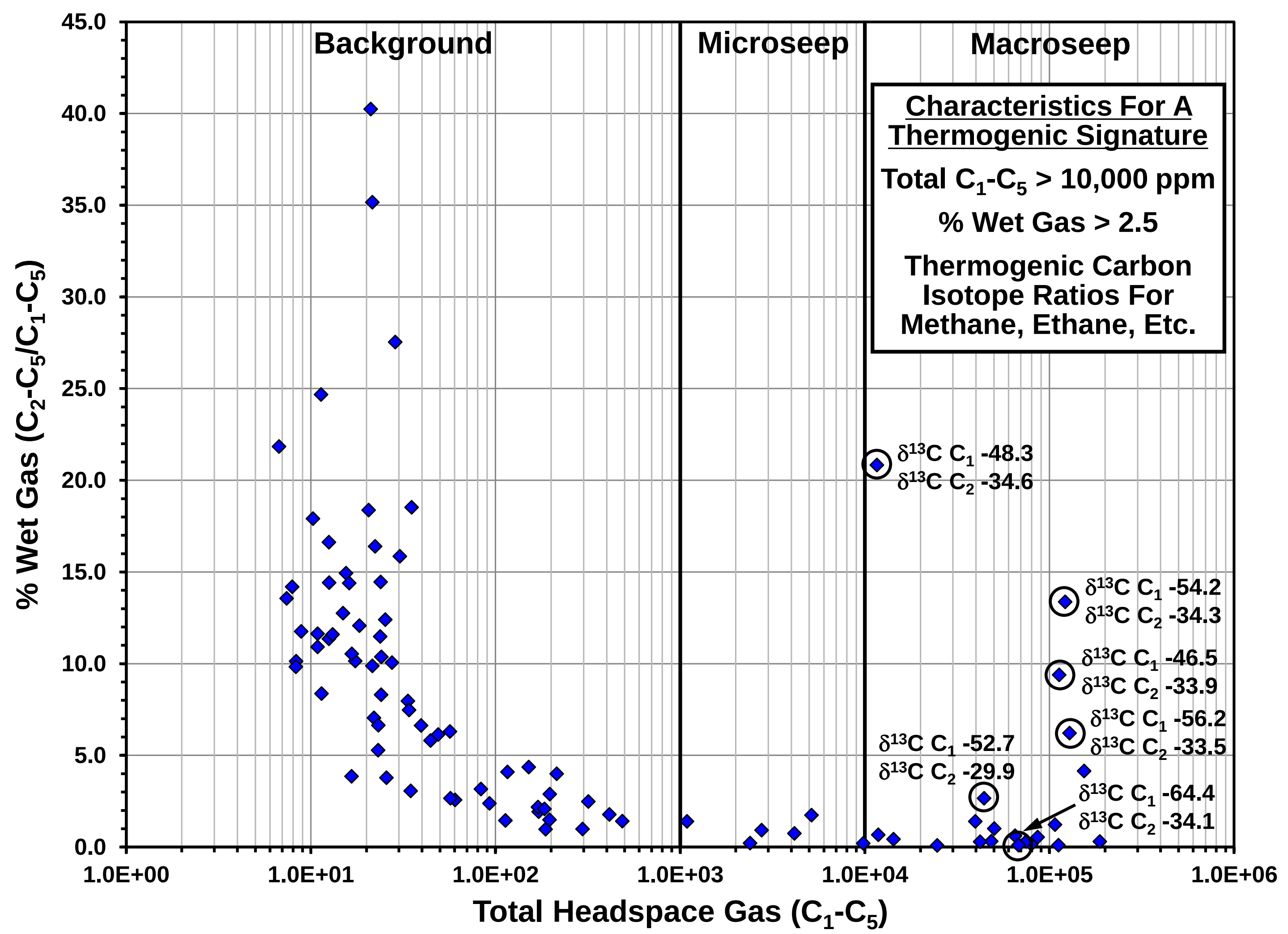
After comparing the headspace gas and $C_{10}$+ extract gas chromatogram data (both the UCM and whole extract GC characteristics), for all three section of each piston core, an overall assessment of whether thermogenic hydrocarbons are present is made along with the concentration of those hydrocarbon and their primary phase.

A strong indication of thermogenic hydrocarbons in a single section of a piston core is adequate to confirm the presence of seeped oil and/or gas at the location.

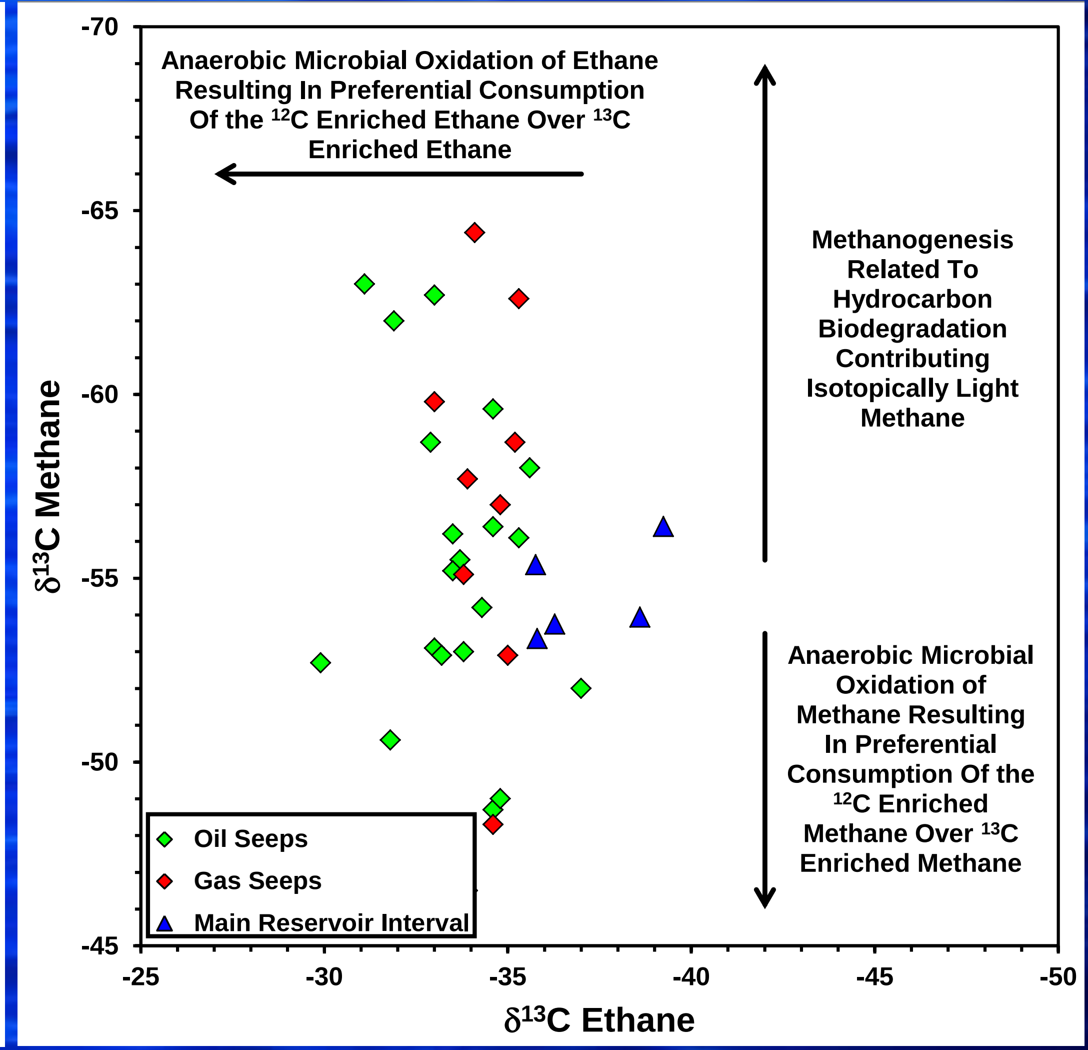
Modified after H. Dembicki, Jr. and B. M. Samuel, 2007, OTC Proceedings Paper 18556, 11 p.

# Headspace Gas Data

**While *Anaerobic Microbial Oxidation* of short chained hydrocarbons can deplete wet gas and preferential consume the $^{12}C$ enriched hydrocarbons over $^{13}C$ enriched hydrocarbons to make the remaining hydrocarbons isotopically heavier, *Methanogenesis* related to biodegradation can produce isotopically light methane and carbon dioxide. Hydrates can also contribute further complicating interpretation.**

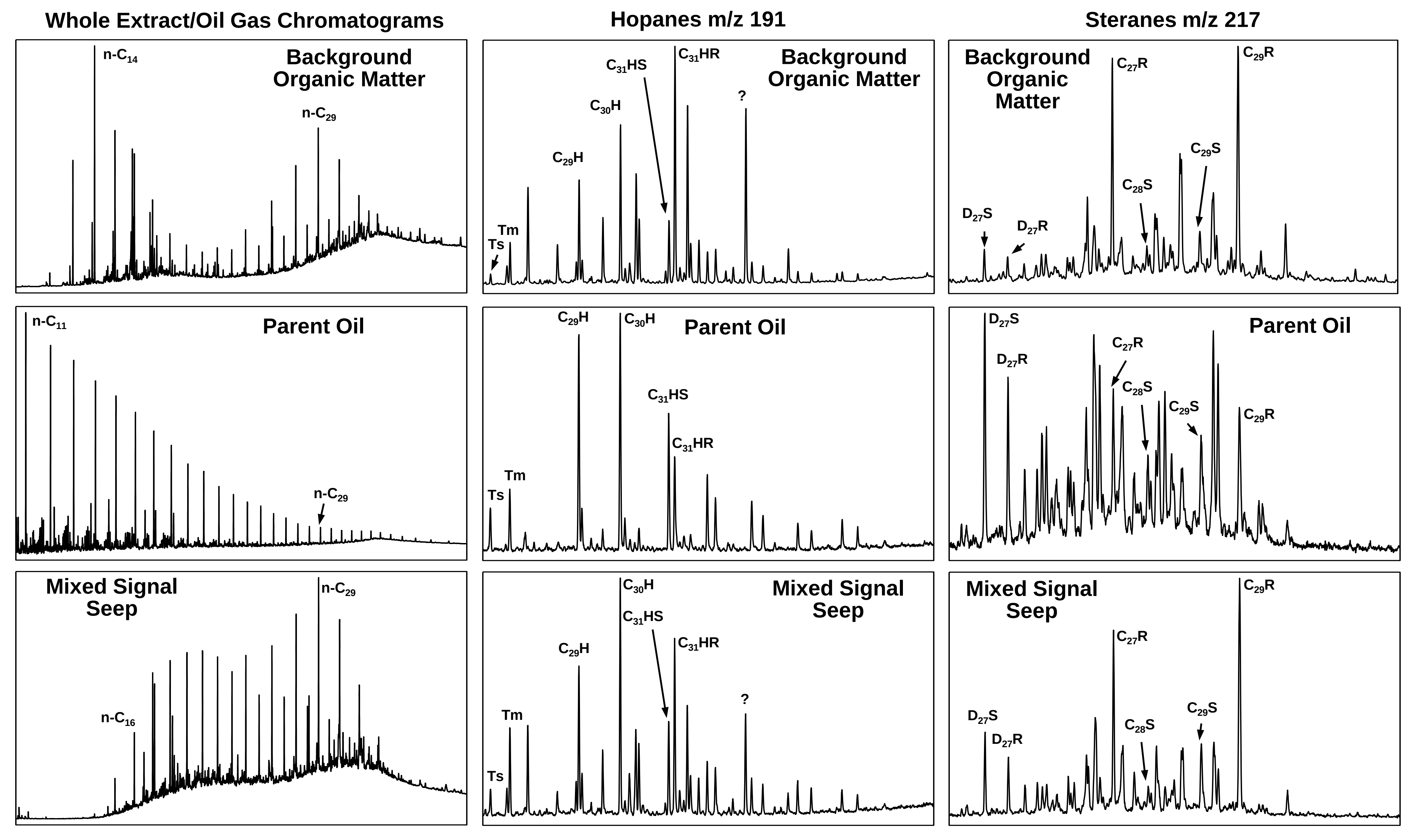



After H. Dembicki, Jr. , 2013, OTC Proceedings Paper 24237, 22 p. Data from M.A. Abrams and N.F. Dahdah, 2011, AAPG Bulletin, v. 95, p. 1907–1935.




After H. Dembicki, Jr. , 2013, OTC Proceedings Paper 24237, 22 p.

# Whole Extract/Oil GC And Biomarkers From The BOM, Parent Oil, And A Low Concentration Mixed Signal Seep



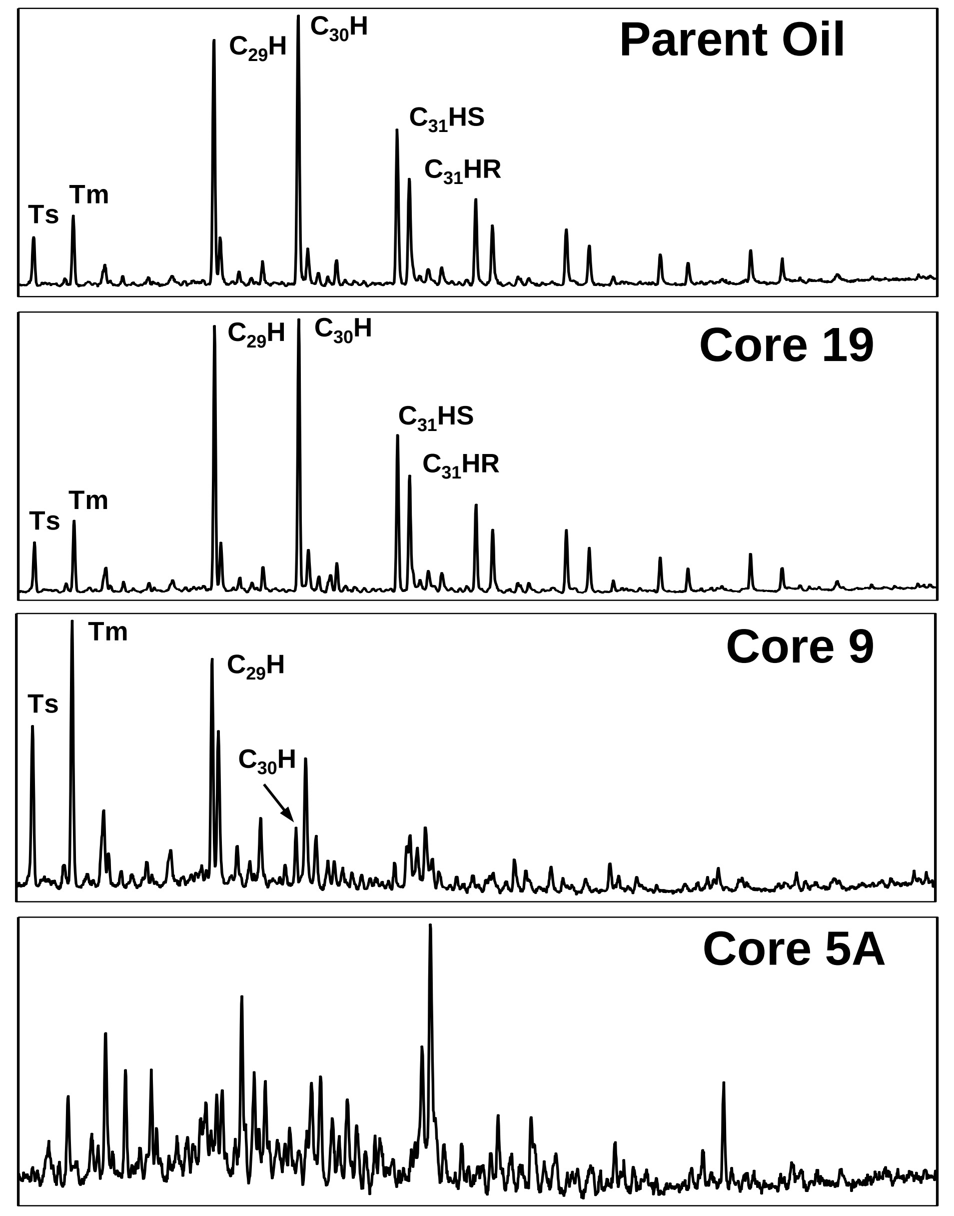

**Mixing of the thermogenic hydrocarbon signal from the seeped oil as well as the recent organic matter and reworked thermogenic signal from the background organic matter makes it difficult to interpret.**



After H. Dembicki, Jr. , 2013, OTC Proceedings Paper 24237, 22 p.

# Which biomarkers are most likely to be preserved?

## Hopanes m/z 191



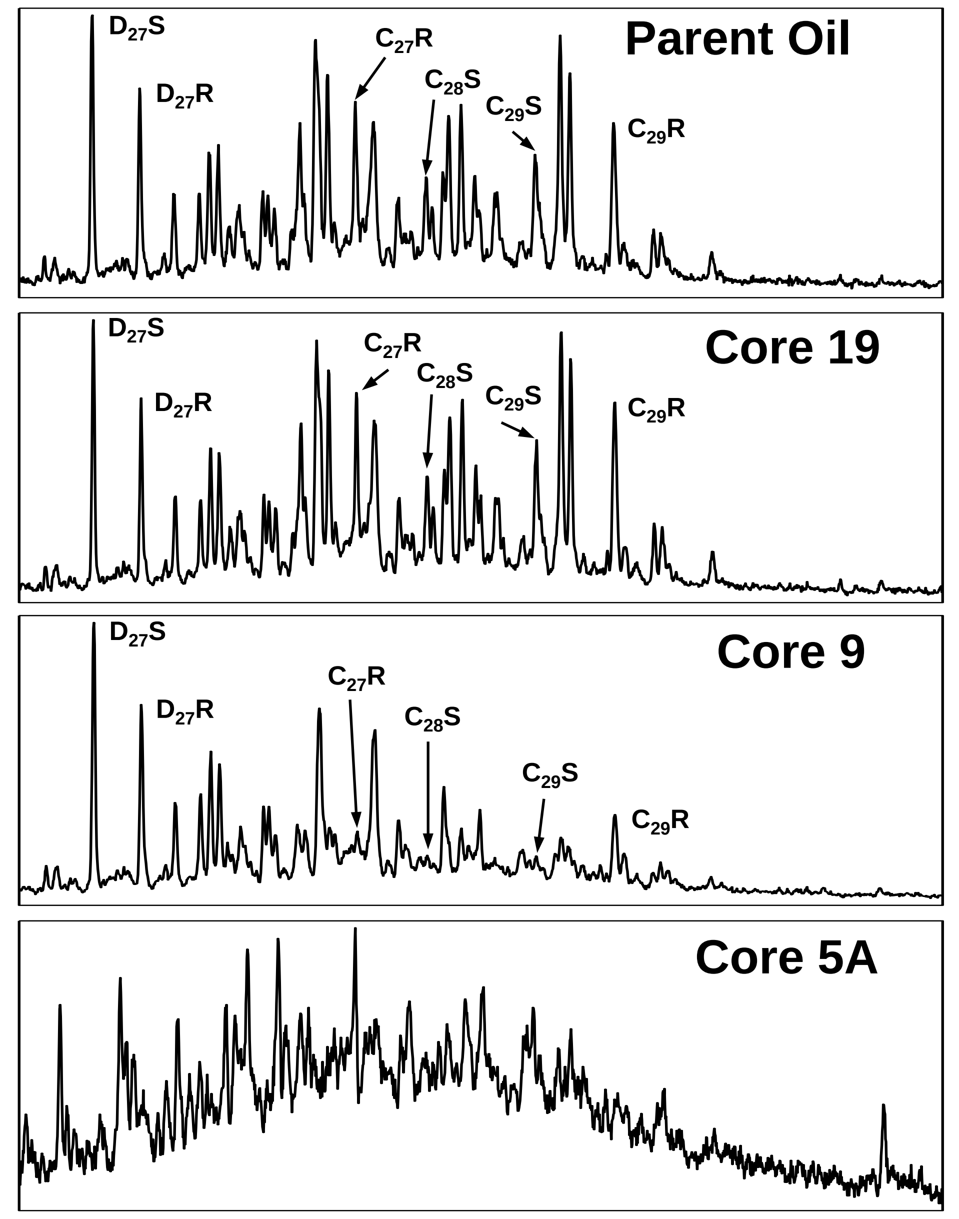

**Reservoired Oil**

**Unaltered Hopanes And Steranes**

**Altered Hopanes And Loss Of Regular Steranes**

**Loss Of Hopanes And Steranes**

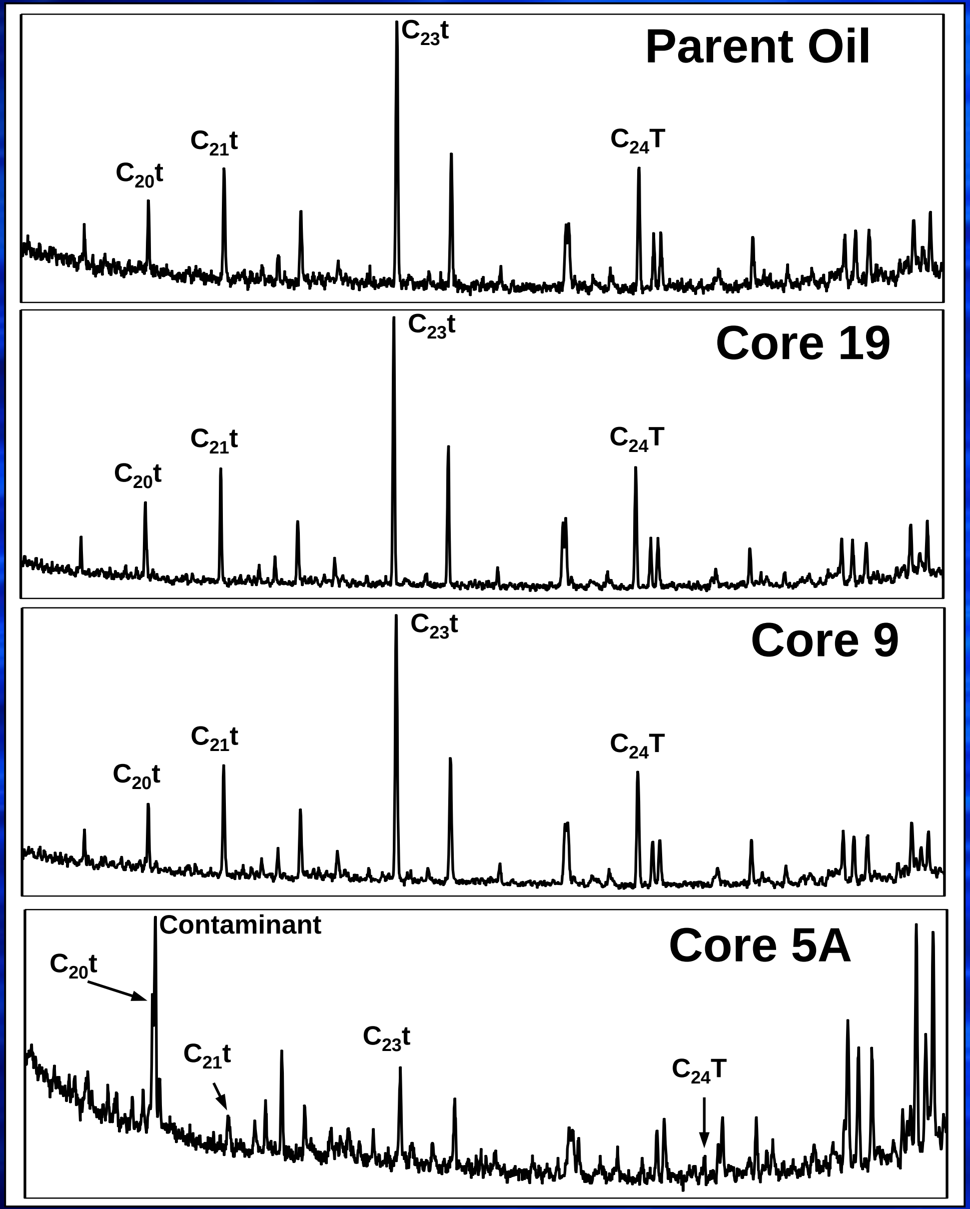
## Steranes m/z 217




After H. Dembicki, Jr., 2010, Marine and Petroleum Geology, v. 27, pp.1936-1951.

# Which biomarkers are most likely to be preserved?

Tricyclic Terpanes, m/z 191



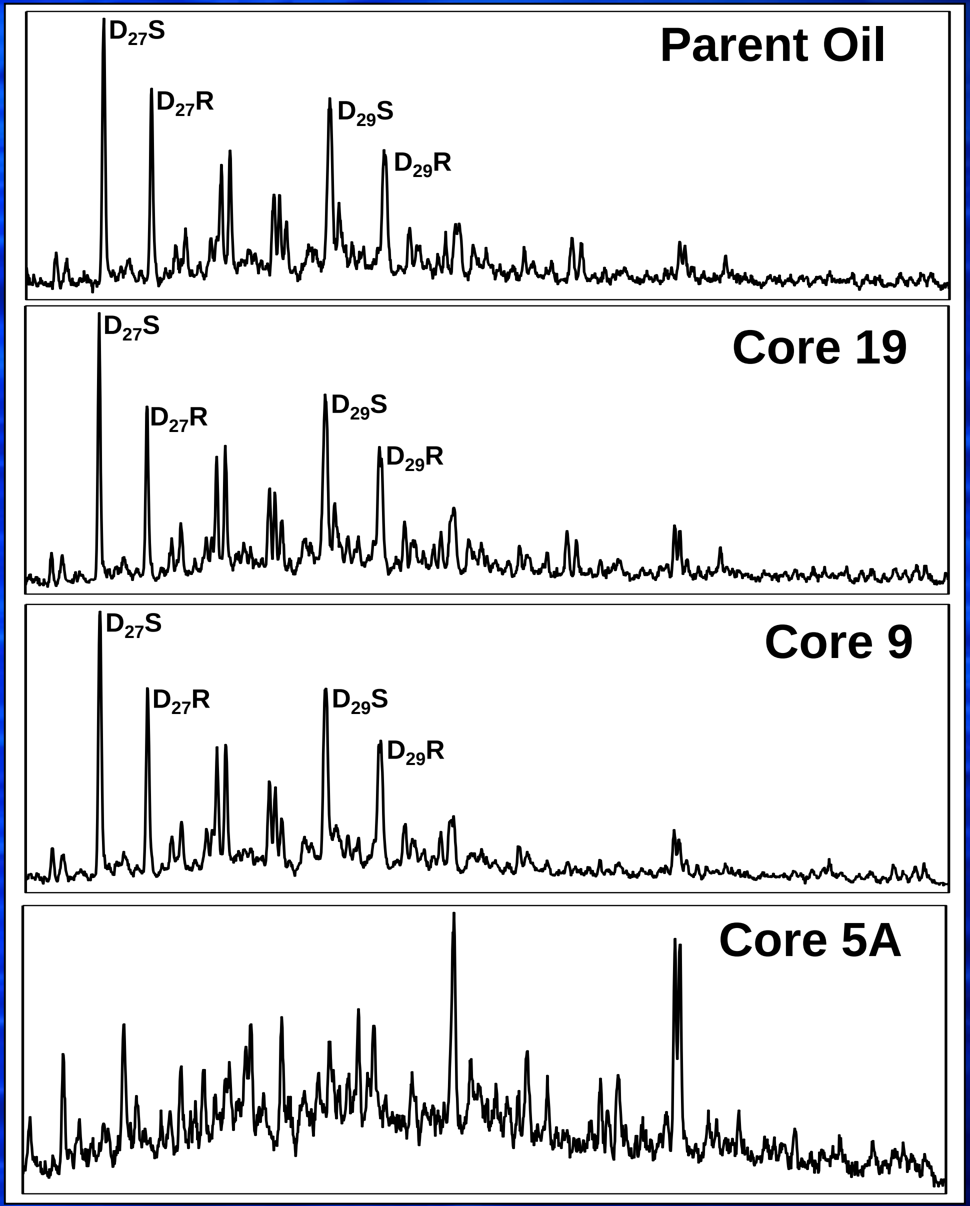

Reservoired Oil

Unaltered Tricyclic Terpanes And Diasteranes

Unaltered Tricyclic Terpanes And Diasteranes

Altered Tricyclic Terpanes And Loss Of Diasteranes

Diasteranes, m/z 259

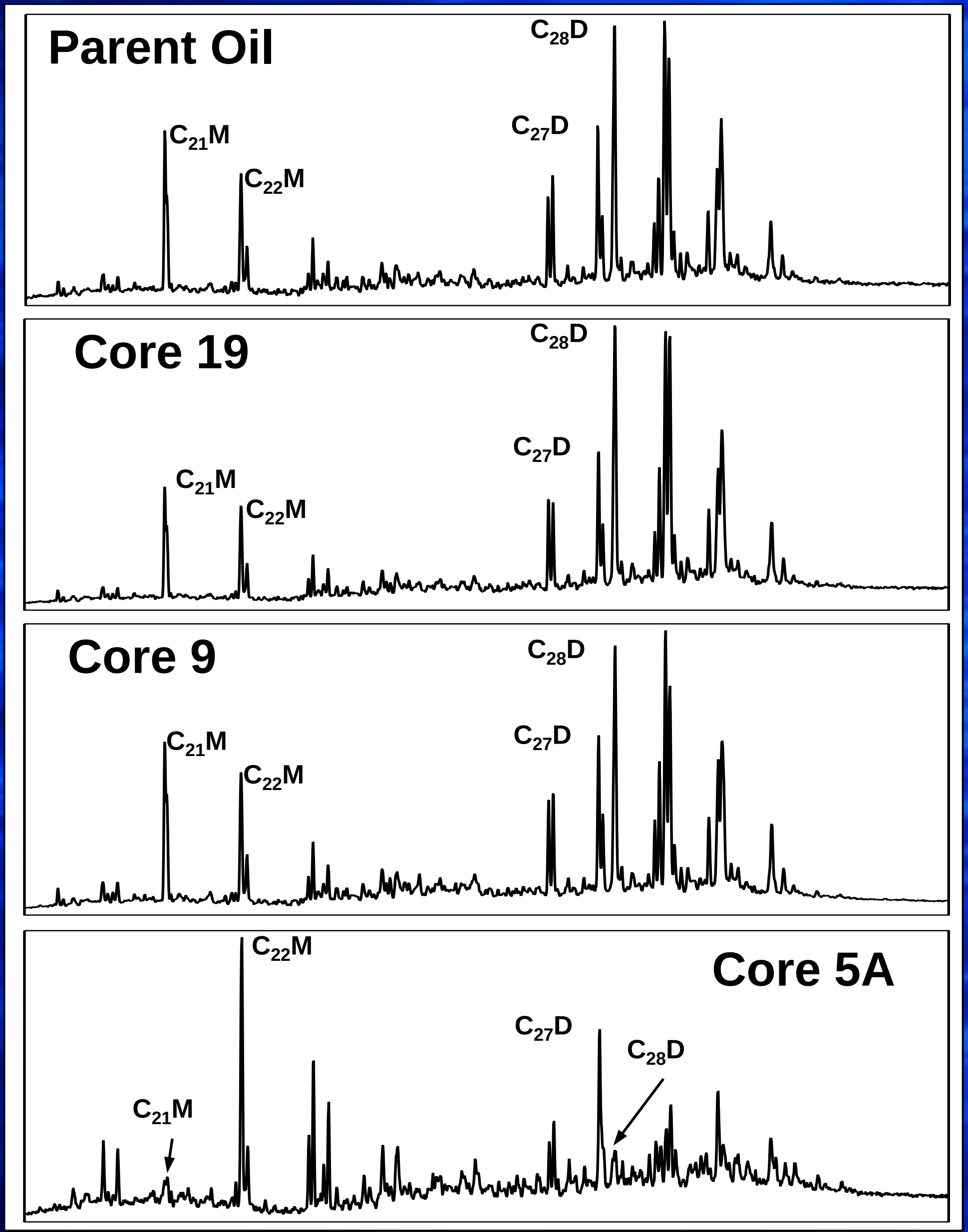



Dembicki

After H. Dembicki, Jr., 2010, Marine and Petroleum Geology, v. 27, pp.1936-1951.

# Which biomarkers are most likely to be preserved?

## Monoaromatic Steranes, m/z 253



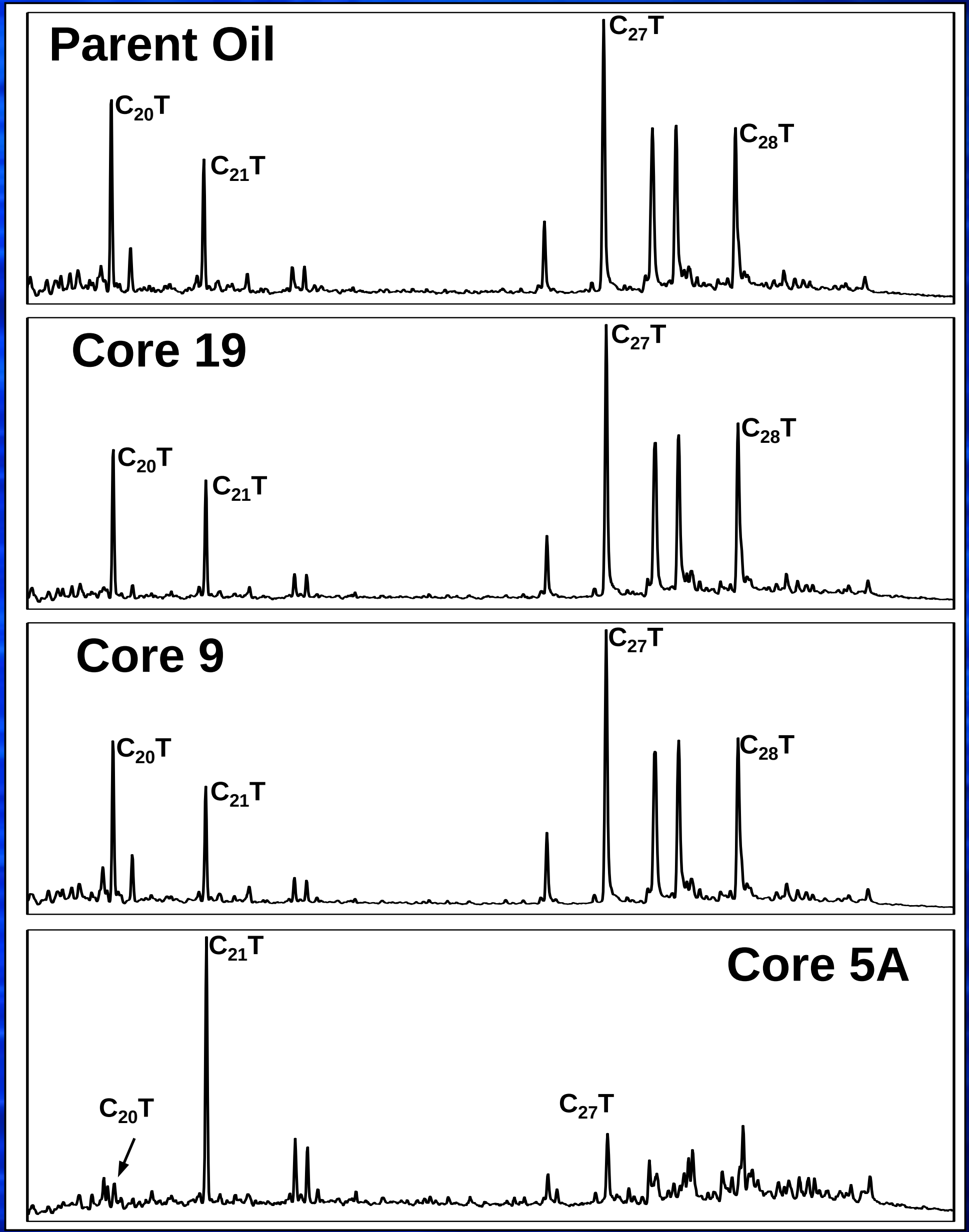

Reservoired Oil

Unaltered Aromatic Steroids

Unaltered Aromatic Steroids

Altered Aromatic Steroids

## Triaromatic Steranes, m/z 231

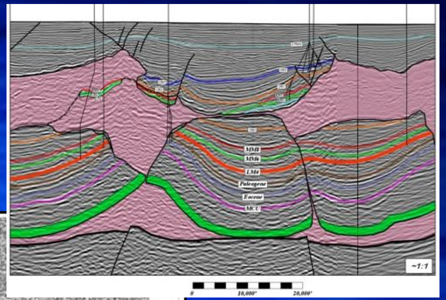


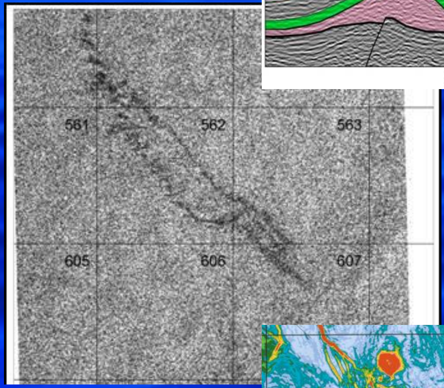

Dembicki

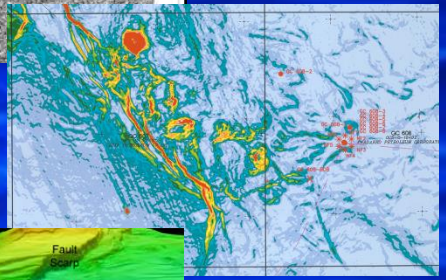
After H. Dembicki, Jr., 2010, Marine and Petroleum Geology, v. 27, pp.1936-1951.

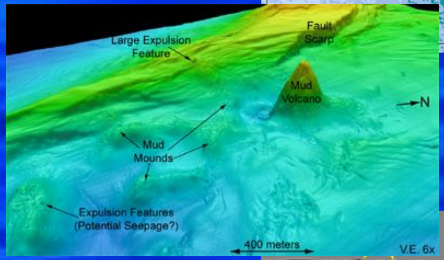
# Observations: Seep Detection

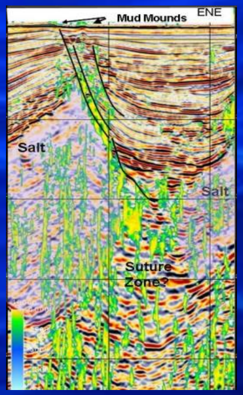
- An initial assessment of the depositional systems and tectonic regime needs to be done to determine if the geologic setting has potential for seepage.
- Start with sea surface slick reconnaissance.
  - Satellite based synthetic aperture radar (SAR)
  - Aerial photography
  - Ship board observations
- Extract the seafloor data from conventional seismic, especially 3-D data, to get bathymetry and amplitude information and to look for potential seep features and near surface migration pathways.
- When possible use high resolution geophysical imaging, such as multibeam bathymetry with backscatter and/or side scan sonar, and sub-bottom profiler data to obtain the best imaging of the seafloor and near surface sediments possible to identify potential seep related features.
- Integrated the seafloor observations with conventional deeper imaging seismic to link the potential seep features to possible conduits and subsurface structures.
- Gas chimney processing of the seismic data can provide additional insight into migration pathways, but is not an essential part of the seep detection workflow.

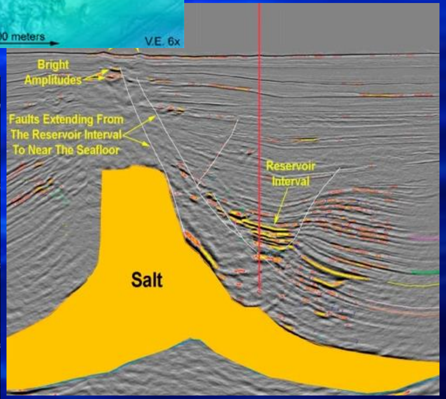






# Observations: Sediment Analysis

- **Headspace gas:**
  **Both composition and isotopic signature can be changed by**
  - **microbial anaerobic oxidation of short chained hydrocarbons,**
  - **biodegradation related methanogenesis, and**
  - **decomposition of pre-existing indigenous hydrates.**

  **This limits the use of the $C_1$-$C_5$ hydrocarbons in correlating seeped gases with their source reservoir and estimating maturity.**

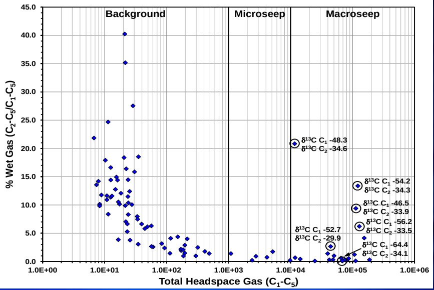
- **High molecular weight samples with low concentration seepage:**
  **Seeped thermogenic component is often obscured by the background organic matter (BOM) signal.**
  - **It is critical to have the biomarker data on the BOM to assess data from suspected low concentration seeps.**

- **High molecular weight samples with high concentration seepage:**
  **Biodegradation can be a significant problem with the biomarkers.**
  - **Hopanes and regular steranes are less resistant to alteration.**
  - **Tricylic/tetracyclic terpanes, diasteranes, and the aromatic steroids are more resistant to alteration.**
  - **If biodegradation is severe enough, all compounds are susceptible to alteration.**

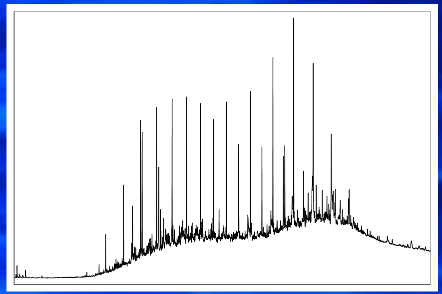
- **Because these interferences can vary within a seep feature, collecting and analyzing multiple samples from a single seep feature provides the best chance of obtaining useful biomarker data.**

- **The geochemistry can be supplement by examining the remaining sediments for indicators of seepage such as hydrates, degraded oil, evidence of chemosynthetic communities, and authigenic carbonates.**

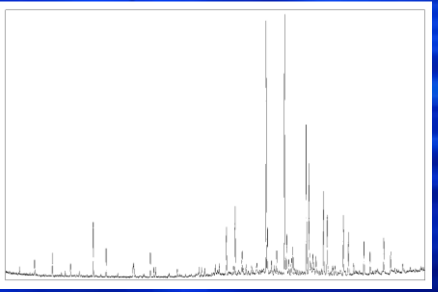
**$C_1$-$C_5$ Headspace Gas**



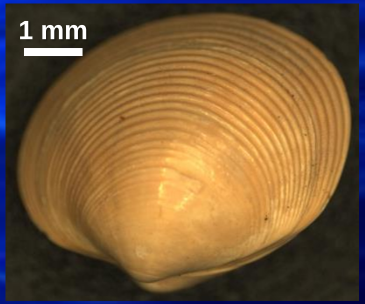

**Whole Extract GC**



**Terpanes, m/z 191**



**Lucinid Bivalve**



# Thank You For Your Attention,  Questions?

Seafloor coring operation within sight of the Marco Polo TLP.

## From Satellite Images to Reservoired Hydrocarbons: The In-Depth Investigations of the Marco Polo Seeps, Green Canyon, Gulf of Mexico

*"To find a fault is easy, to do better may be difficult."* - Plutarch


**Harry Dembicki, Jr.**
Consulting Petroleum Geochemistry
The Woodlands, Texas
email: hdembicki@aol.com


**APPG Annual Convention & Exhibition**

Houston, April 3, 2017


Thanks to Anadarko Petroleum Corporation for permission to present this paper and the technical committee for the opportunity to share these ideas.

# Marco Polo Studies Cited


Abrams. M.A. and N.F. Dahdah, 2011, *Surface sediment hydrocarbons as indicators of subsurface hydrocarbons: Field calibration of existing and new surface geochemistry methods in the Marco Polo area, Gulf of Mexico*. AAPG Bulletin, v. 95, p. 1907–1935.

Chaouche, A., P. Gamwell, and J. Brooks, 2004. *Surface geochemical evaluation of Green Canyon Block 608, Gulf of Mexico: A comparison of seafloor seeps and reservoir hydrocarbon fluids.* Oral presentation at the AAPG Annual Meeting, Dallas.

Dembicki, Jr., H., 2010, *Recognizing and compensating for interference from the sediment's background organic matter and biodegradation during interpretation of biomarker data from seafloor hydrocarbon seeps: An example from the Marco Polo area seeps, Gulf of Mexico, USA.* Marine and Petroleum Geology, v. 27, pp.1936-1951.

Dembicki, Jr., H., 2013, *Interpreting Geochemical Data From Seafloor Hydrocarbons Seeps: You Can't Always Get What You Want*. Offshore Technology Conference Proceedings Paper 24237, 22 p.

Dembicki, Jr., H. and D. L. Connolly, 2013, *Surface and subsurface expression of hydrocarbon seepage in the Marco Polo Field Area, Green Canyon, Gulf of Mexico.* "Hydrocarbon Seepage: From Source to Surface" (F. Aminzadeh, T. B. Berge, and D.L. Connolly, eds.) SEG Geophysical Developments Series No. 16, Chapter 5, p.83-91.

Dembicki, Jr., H. and B. M. Samuel, 2007, *Identification, Characterization, And Ground-Truthing of Deepwater Thermogenic Hydrocarbon Macro-Seepage Utilizing High-Resolution AUV Geophysical Data. Offshore* Technology Conference Proceedings Paper 18556, 11 p.

Dembicki, Jr., H. and B. M. Samuel, 2008, *Improving the Detection and Analysis of Seafloor Macro-Seeps: An Example from the Marco Polo Field, Gulf of Mexico, USA.* International Petroleum Technology Conference Proceedings Paper 12124, 18 p.

Mount, V.S., A. Rodriguez, A. Chaouche, S.G. Crews, P. Gamwell, and P. Montoya, 2006, *Petroleum system observations and interpretations in the vicinity of the K2/K2-North,Genghis Khan, and Marco Polo fields, Green Canyon, Gulf of Mexico.* Gulf Coast Association of Geological Societies Transactions, v. 56, p. 613-625.