Confirming the Presence of a Working Petroleum System in the Eastern Black Sea Basin Using Sea Surface Slicks*

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Abstract

As new plays emerge in deepwater settings, one of the more difficult tasks facing the exploration geologist is to find evidence confirming the presence of a working petroleum system. Geologic evaluation of the Eastern Black Sea Basin, offshore Georgia, indicates the elements of a petroleum system are likely present. Potential source rocks of Oligo-Miocene age in the Maykop Formation could charge Middle Miocene deepwater channel-levee sands in fold and thrust system traps. However, to reduce the exploration risk in this frontier area, direct evidence of hydrocarbon generation and migration is needed. To provide confirmation of charge, a diverse set of data was used. Synthetic aperture radar satellite images revealed the presence of large recurring sea surface slicks over the prospective structures. 3-D seismic data was then used to image the seafloor and found potential seep features including pockmarks, near seafloor sediments with high impedance contrast suggesting authigenic carbonates, and mud volcanoes located below the apparent origin points of the slicks. The 3-D seismic imaging also demonstrated that there are potential migration pathways from the observed traps to these seafloor features. Finally, geochemical analysis of sea surface slick samples was done. Data from these analyses showed the slicks were composed of biodegraded thermogenic hydrocarbons and their compositional characteristics were very similar to known Maykop sourced oils in the region. These highly similar compositional characteristics suggesting both the slicks and oils were generated from the same or geochemically similar sources. This combination of data provides a high level of confidence that the seismically imaged traps in the Eastern Black Sea Basin in offshore Georgia are charged. What it cannot tell us is how much petroleum may be in these structures. This question can only be answered by the drill bit.

AAPG International Convention & Exhibition 16 October 2017, London, UK

CONFIRMING THE PRESENCE OF A WORKING PETROLEUM SYSTEM IN THE EASTERN BLACK SEA BASIN USING SEA SURFACE SLICKS

"Exploring the unknown requires tolerating uncertainty."
– Brian Greene

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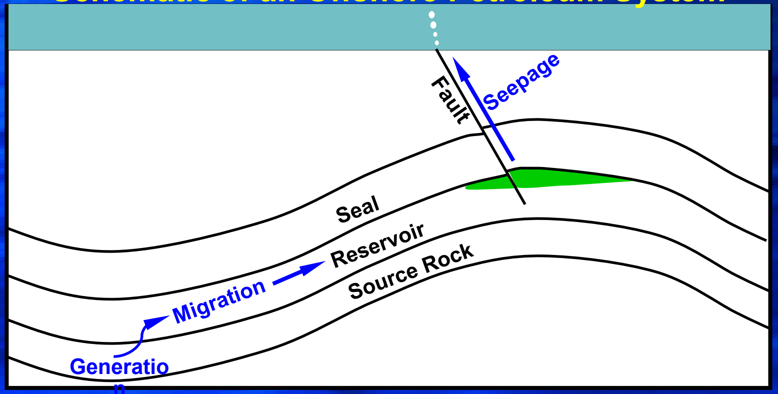
Slicks, Seafloor Seeps And Offshore Exploration

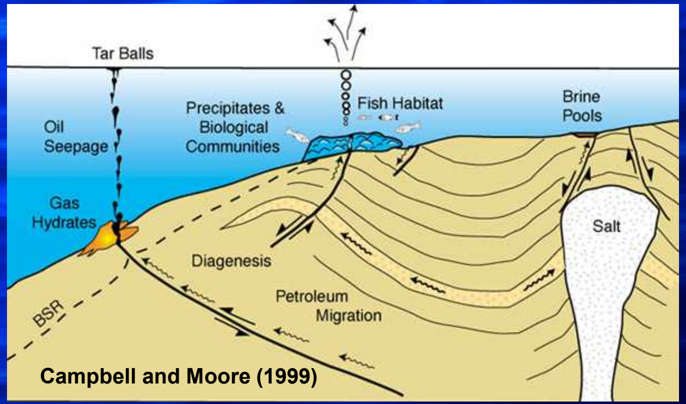
- Most sea surface slicks from naturally occurring hydrocarbon seeps are episodic and ephemeral.
- They need to be sampled to confirm the presence of thermogenic hydrocarbon.
- There also needs to be evidence that the hydrocarbons originated from the seafloor, such as…
  - …observing surfacing oil,
  - …identifying seafloor features that are consistent with seepage, and
  - …correlating the slick's hydrocarbons to oils in the area.
- The potential seafloor seep features then need to be linked to likely subsurface reservoirs by possible migration pathways to the surface.
- And ideally, the seafloor seep features should eventually be sampled for confirmation.

Schematic of an Offshore Petroleum System

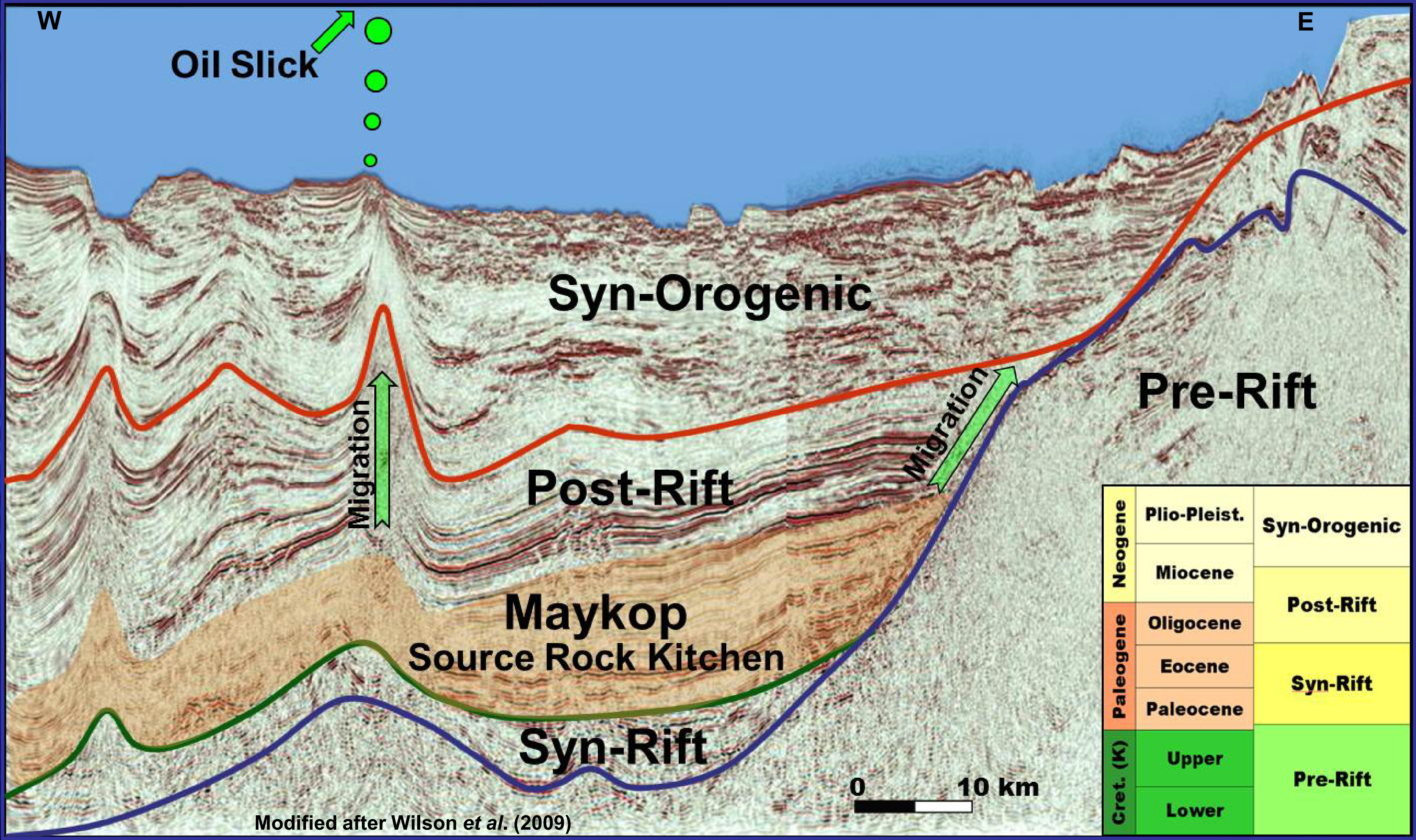


Classic "Pancake" of Surfacing Oil

Potential Seafloor Seep Targets



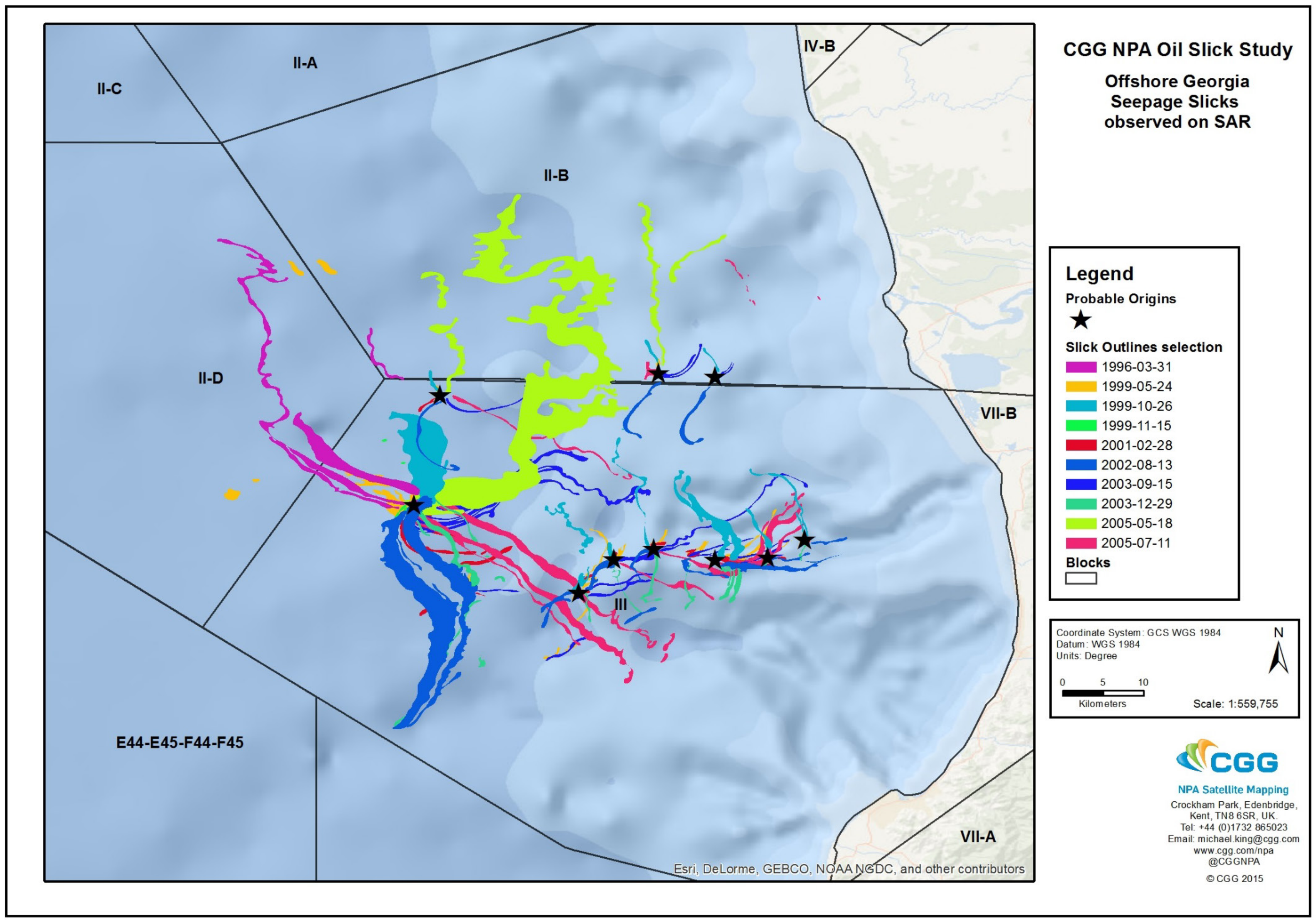
Composite Seismic Line Showing Elements Of The Potential Petroleum System



Oil generated in the Maykop source rock can migrate up into overlying deep water channel-levee sands in the fold and thrust system traps, as well as migrate up the edge of the basin to fill fault offset Cretaceous sands in traps onshore.

Seismic data shown with permission of the State Agency for Oil and Gas, Republic of Georgia

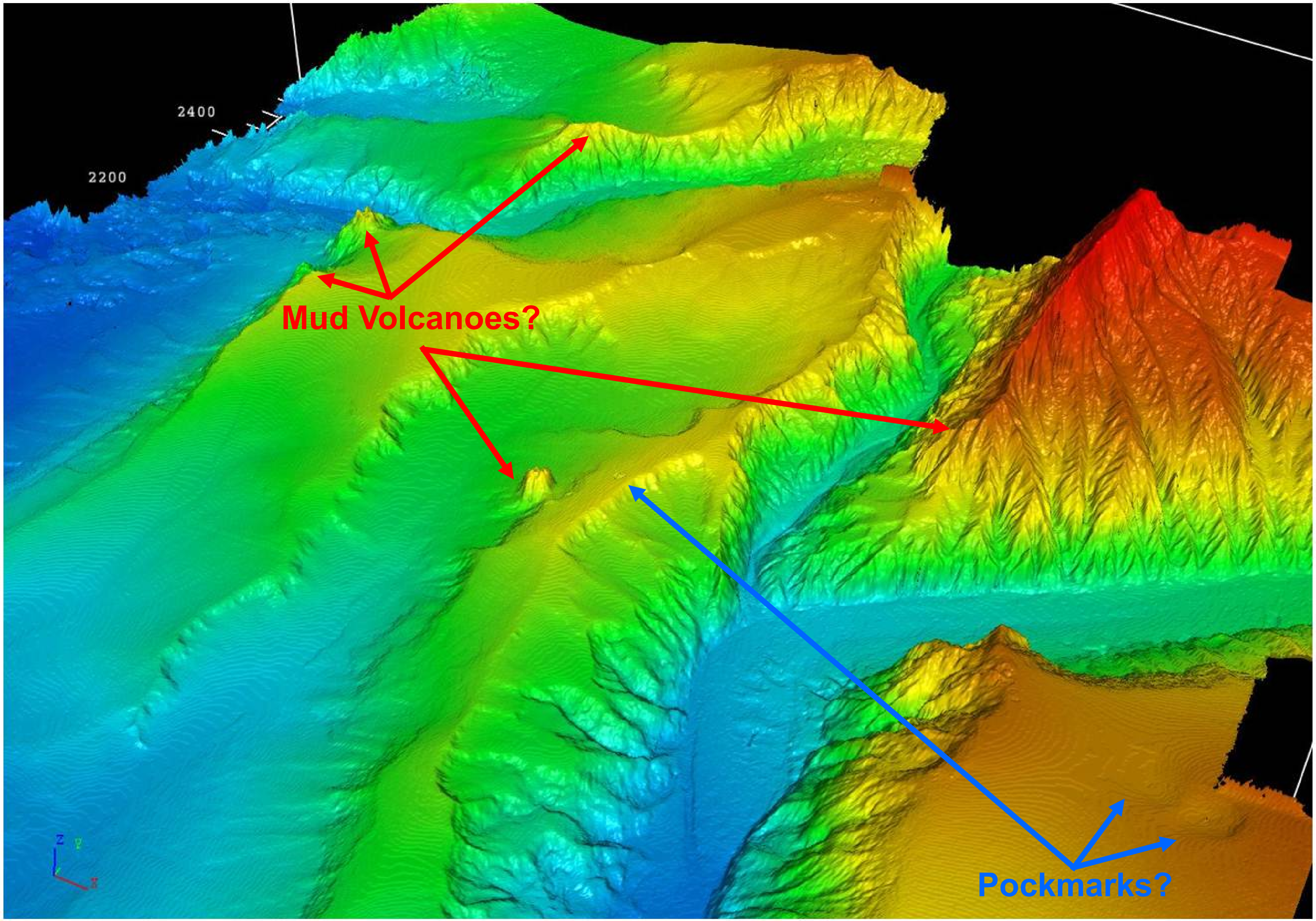
Composite Map Of Slicks Detected With Synthetic Aperture Radar



SRA data courtesy of CGG NPA Satellite Mapping Limited

Shipboard Observations Of Sea Surface Slicks

When observed from a distance, the slicks were often described as "marks on the water" or "flatter sea surface". When closely observed, the slicks appear as iridescence surface films, having a fuel-like smell.

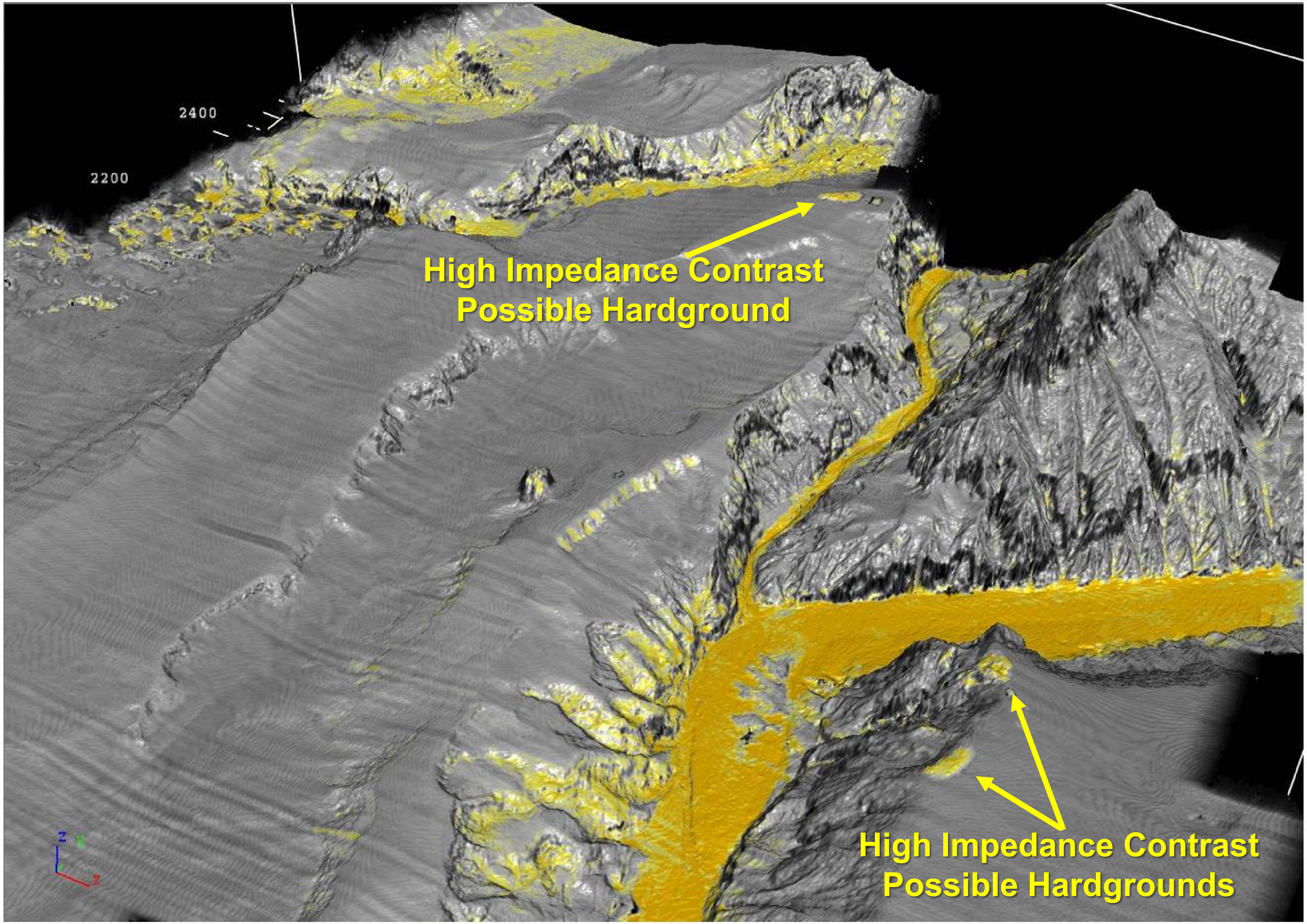


Potential Seep Features Recognized From The Bathymetry Extracted From The 3-D Seismic

Possible mud volcanoes and pockmarks could be identified as potential fluid expulsion features.

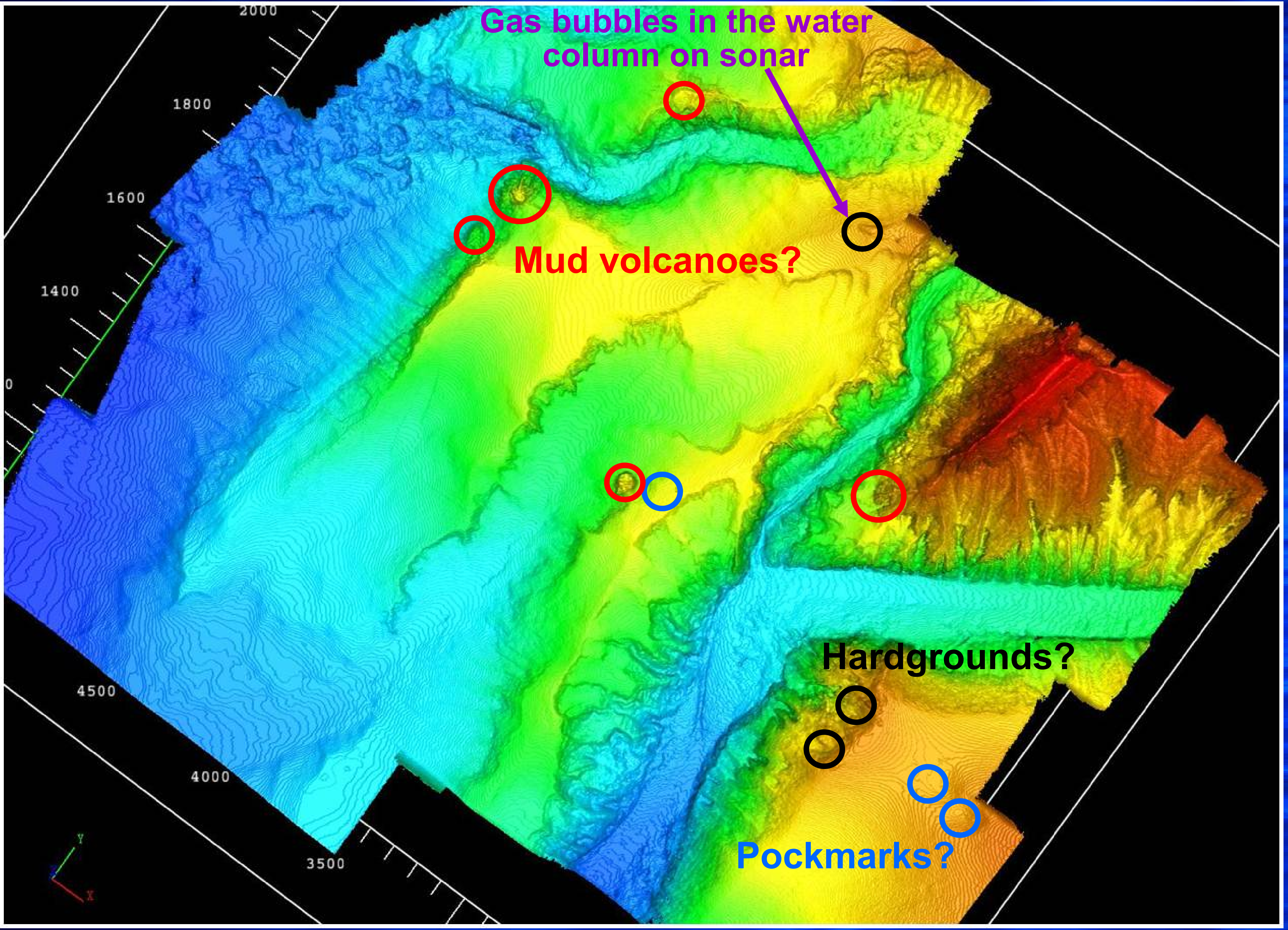
Seismic data shown with permission of the State Agency for Oil and Gas, Republic of Georgia

Potential Seep Features Recognized From Near Surface Amplitudes Extracted From The 3-D Seismic



High impedance contrast outside of channel and slump features could represent hardgrounds from authigenic carbonates and/or chemosynthetic communities.

Seismic data shown with permission of the State Agency for Oil and Gas, Republic of Georgia



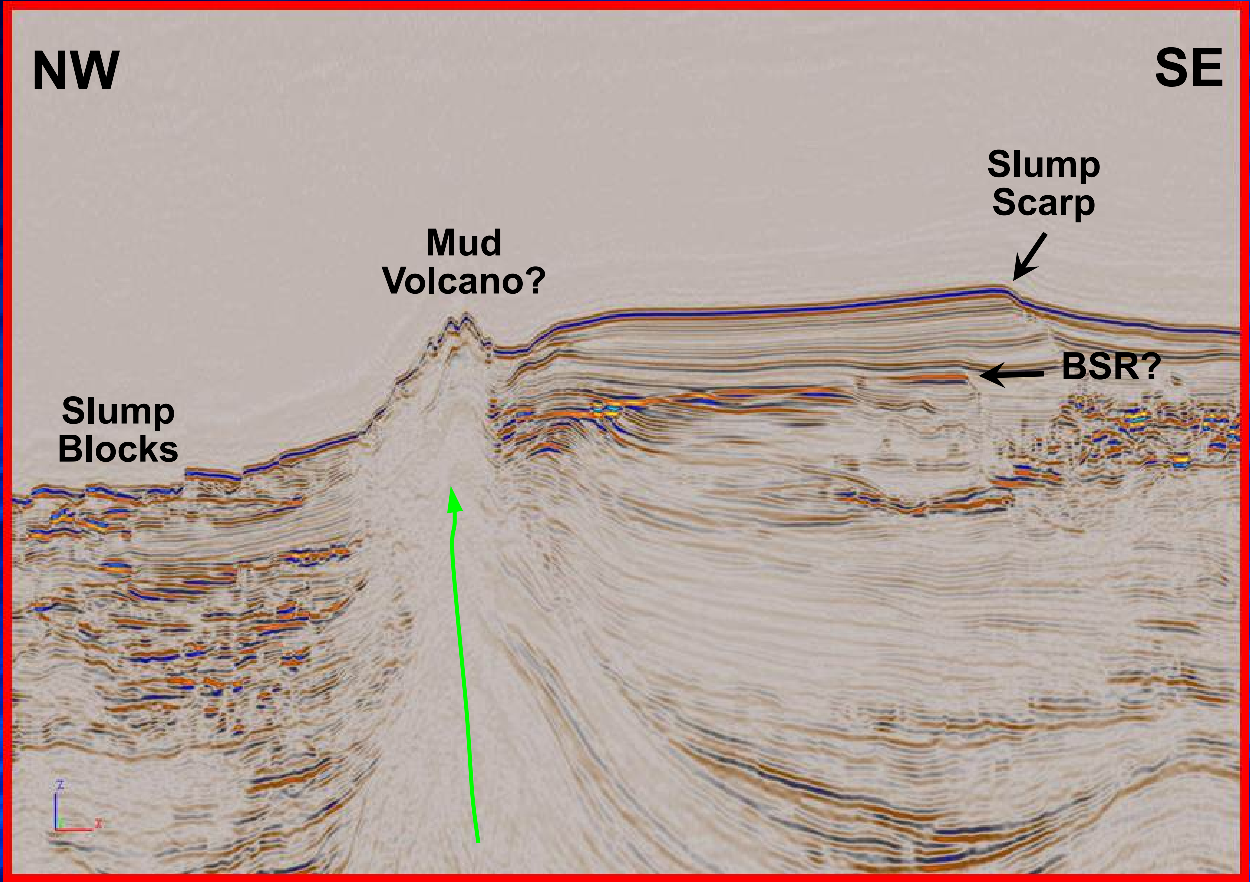
Seismic data shown with permission of the State Agency for Oil and Gas, Republic of Georgia

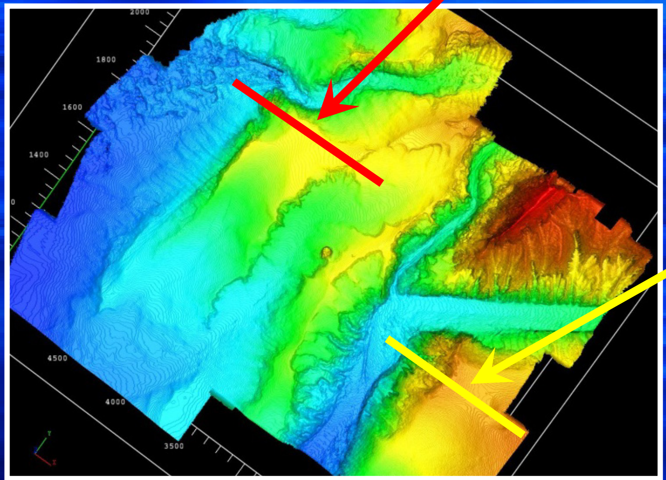
Summary Of Potential Seep Related Features

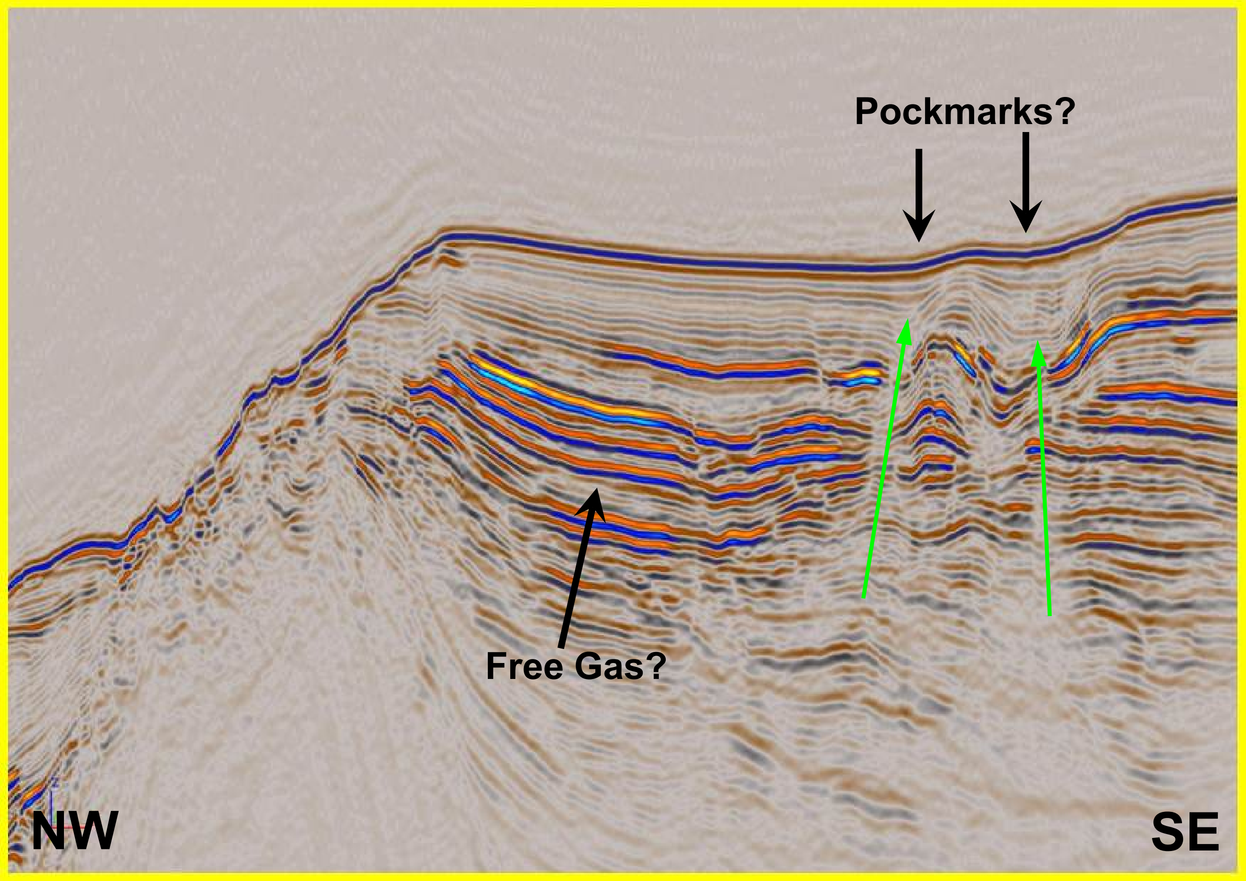
The presence of sea surface hydrocarbon slicks combined with the possible mud volcanoes, pockmarks, and hardgrounds, as well as gas bubbles in the water column suggests hydrocarbon seepage is likely.

Deep Looking Seismic

These seismic lines show potential migration pathways from depth, such acoustic wipeout and disruption of reflectors, that could direct seeping hydrocarbon to the seafloor. Green arrows indicate general migration pathways.

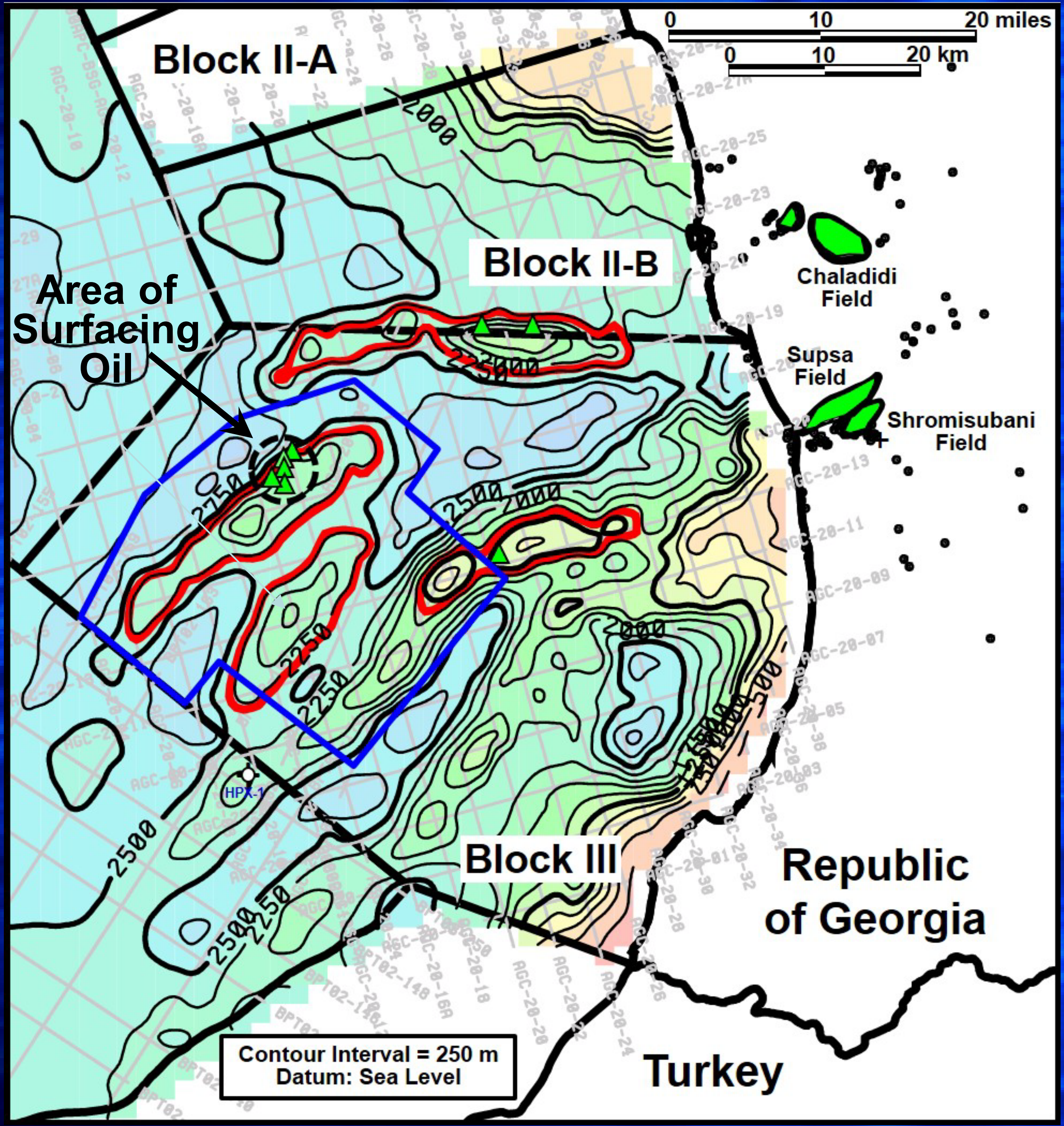






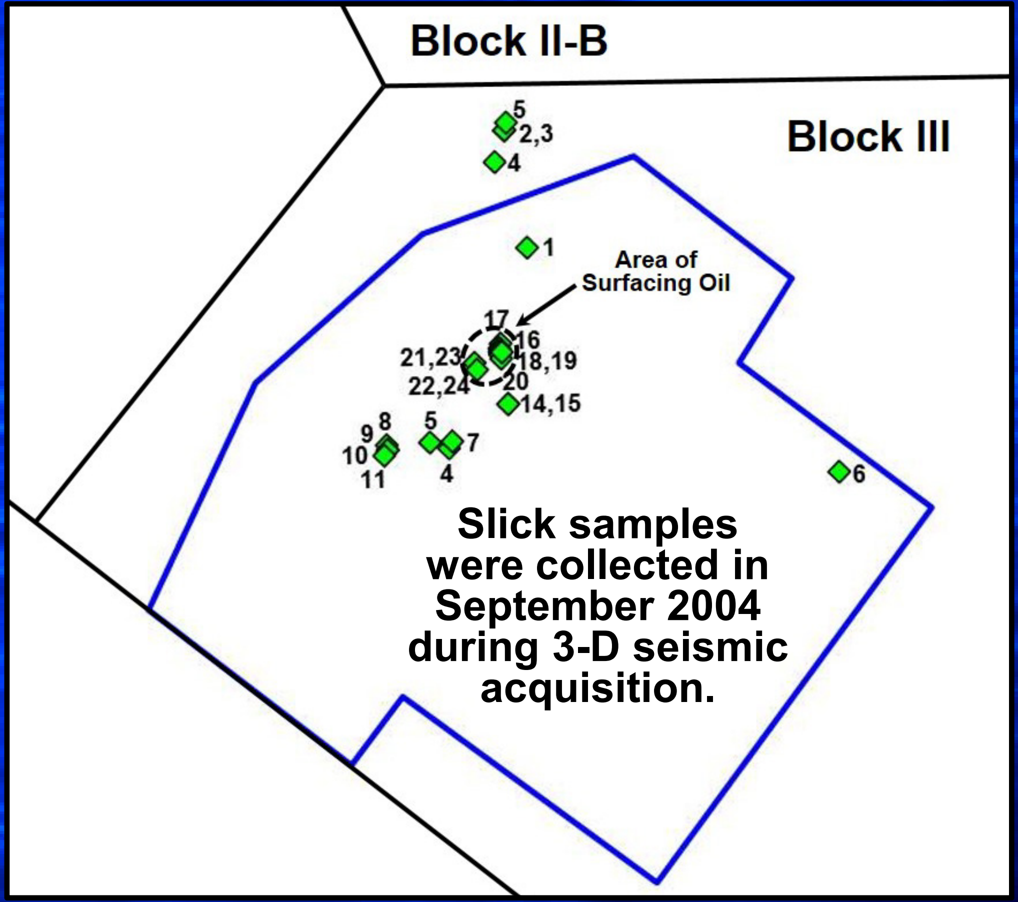
 Seismic data shown with permission of the State Agency for Oil and Gas, Republic of Georgia

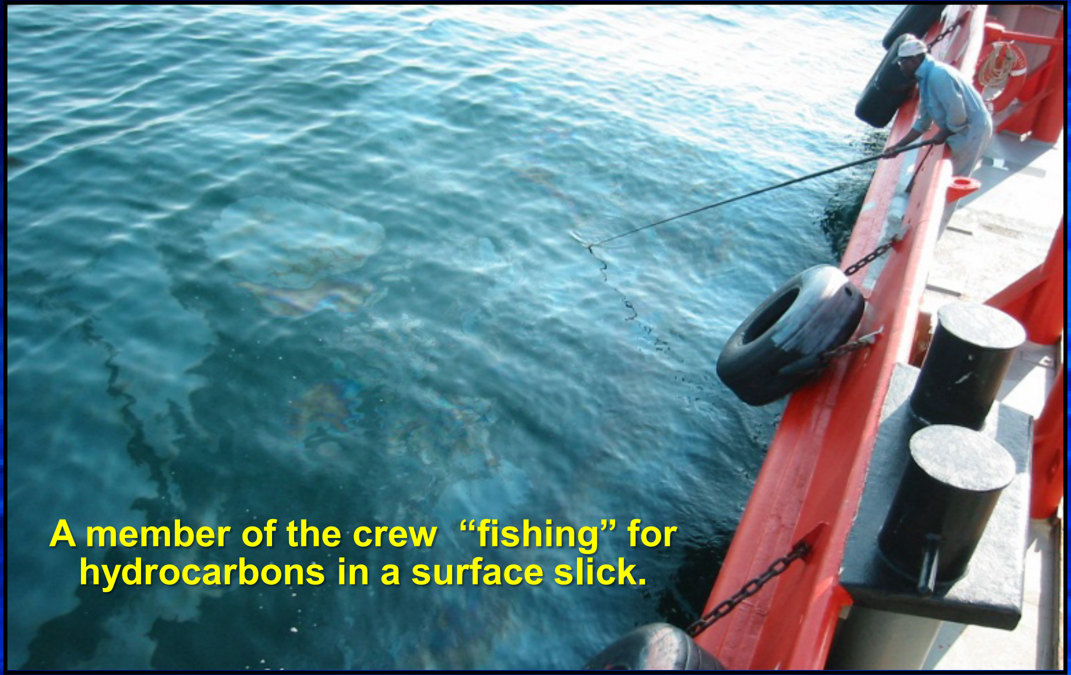
Prospects, Slick Observation And Sample Locations

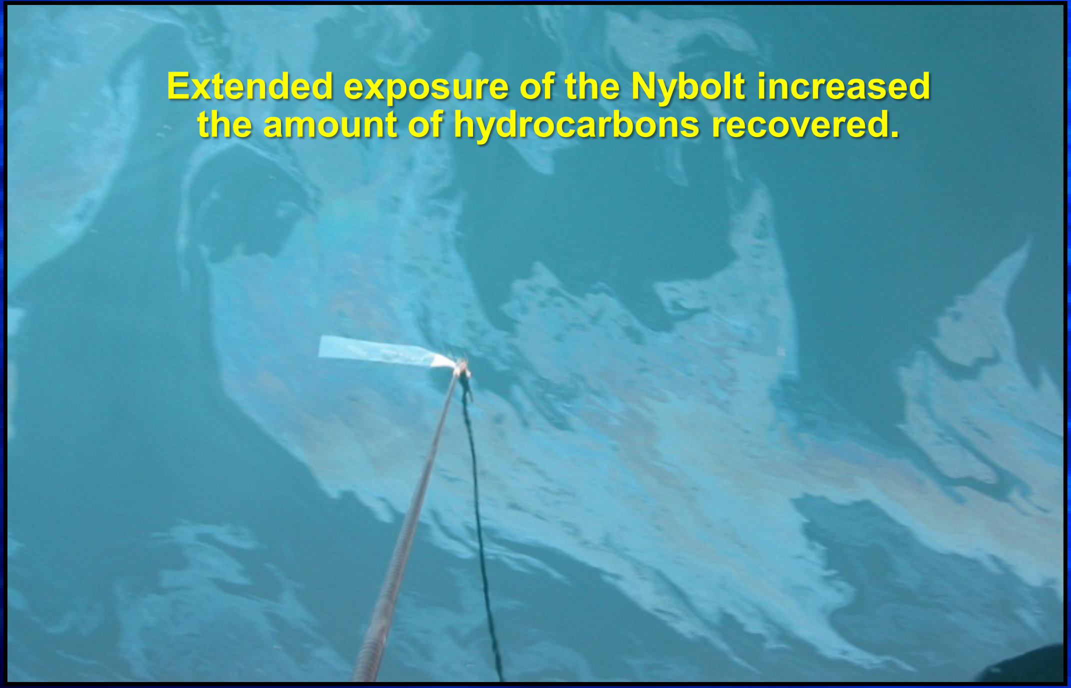


The 3-D seismic area outlined in blue, and the satellite observed sea surface slick origin points shown as green triangles. The area where surfacing oil was observed is indicated by the dashed black circle.

Slick Sample Locations







Slick Sampling And Analysis

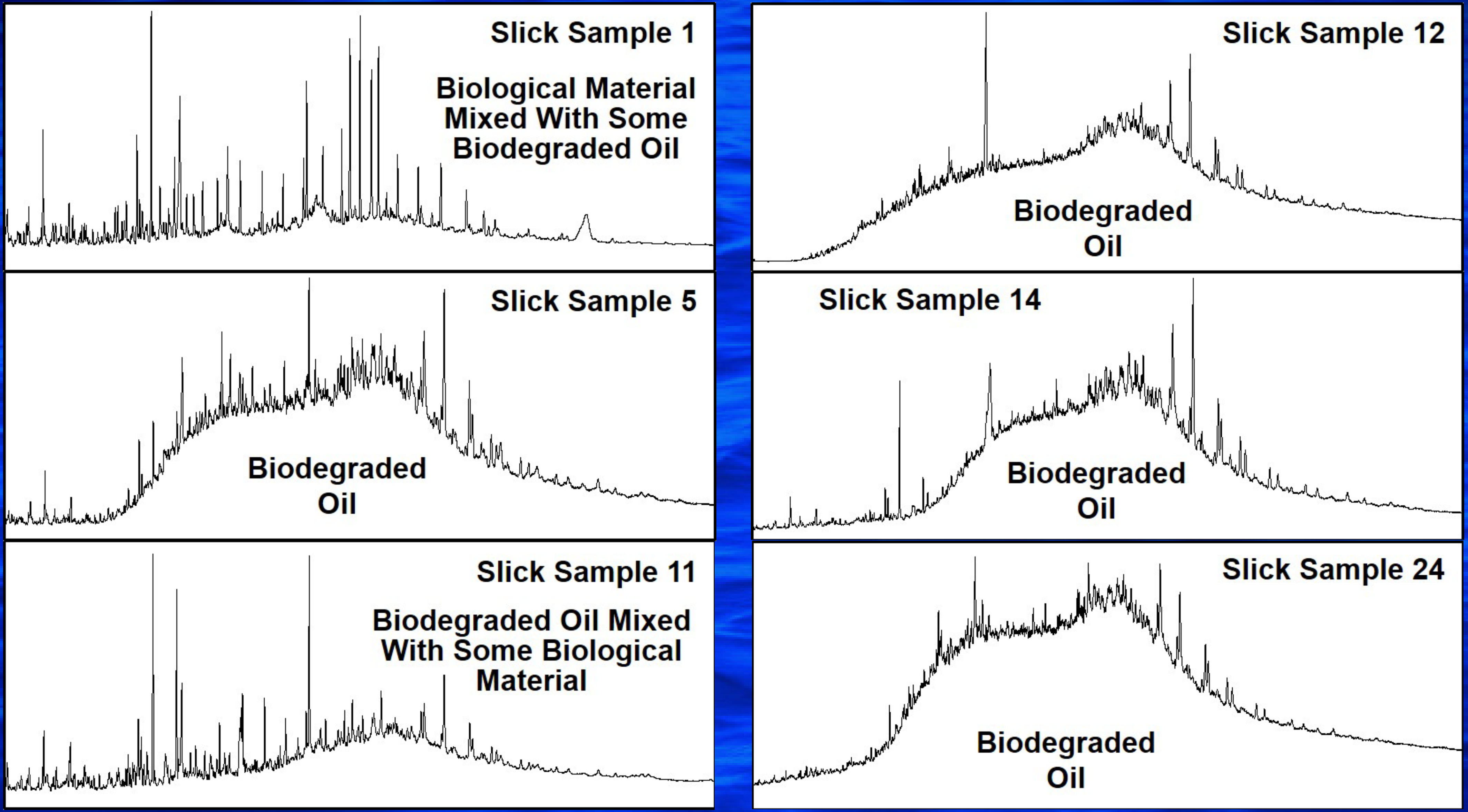
Sample Collection

- The hydrocarbons in the slicks were sampled by repeatedly dragging strips of Nybolt (a polyamide bolting cloth) through the organic film at the sea surface (MacDonald *et al*., 1993).
- The strips of Nybolt were then placed in glass jars with Teflon lined cap for storage and transport.

Sample Analysis

- Once in the lab, the Nybolt strips were extracted with dichloromethane.
- Only 13 of the 24 samples collected yielded enough extract for analysis.
- These 13 samples were analyzed by gas chromatography of the whole solvent extracts followed by high resolution GC-MS for biomarkers analysis.
- Samples of 11 Maykop sourced oils from onshore Georgia were also obtained and analyzed in a similar fashion for comparison.

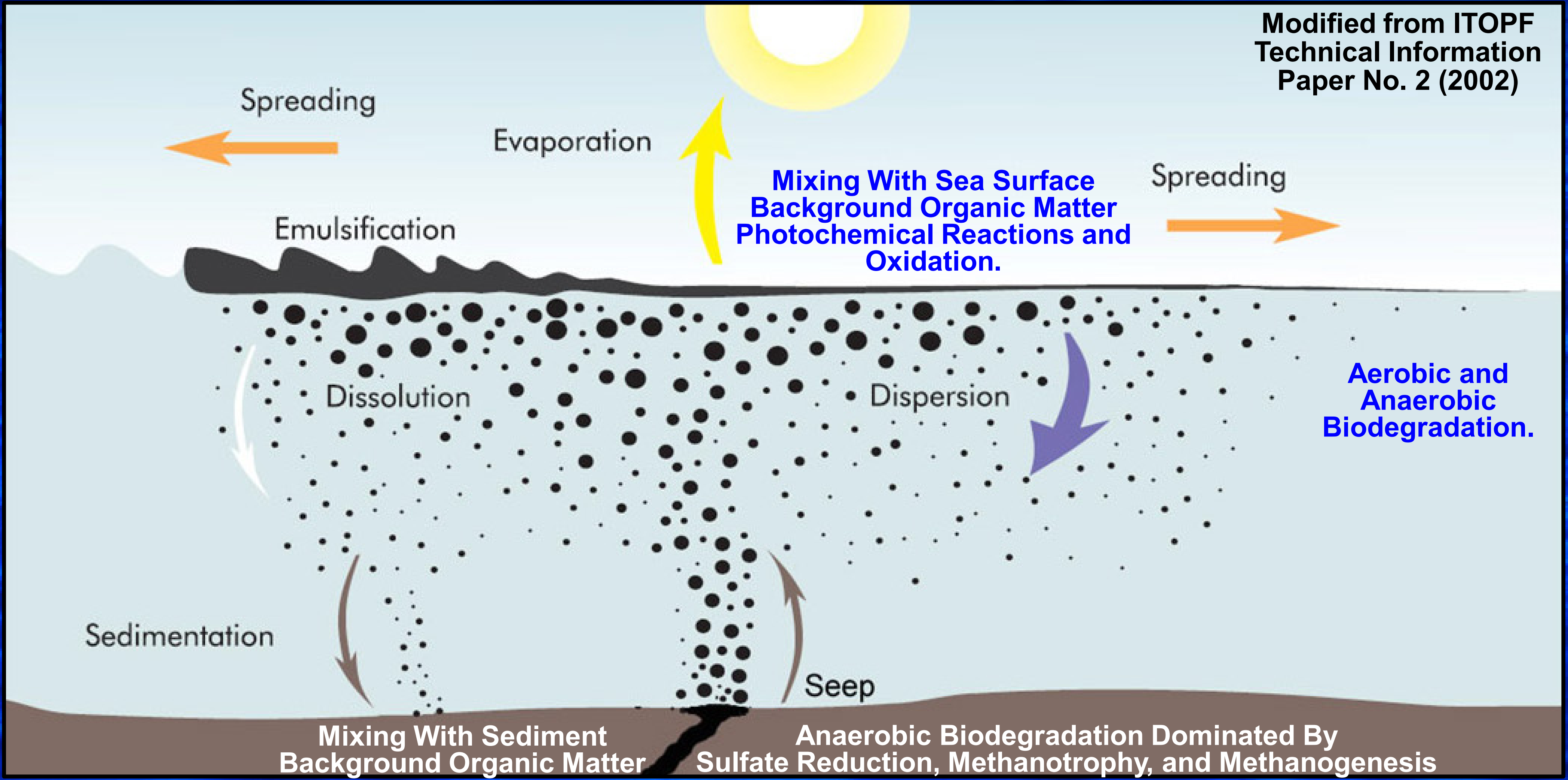
Whole Extract Gas Chromatograms From n-C_{14} – n-C_{40}



No reliable peak identifications could be made based on retention times for any of the slick samples.

Geochemical data courtesy of Anadarko Petroleum Corporation

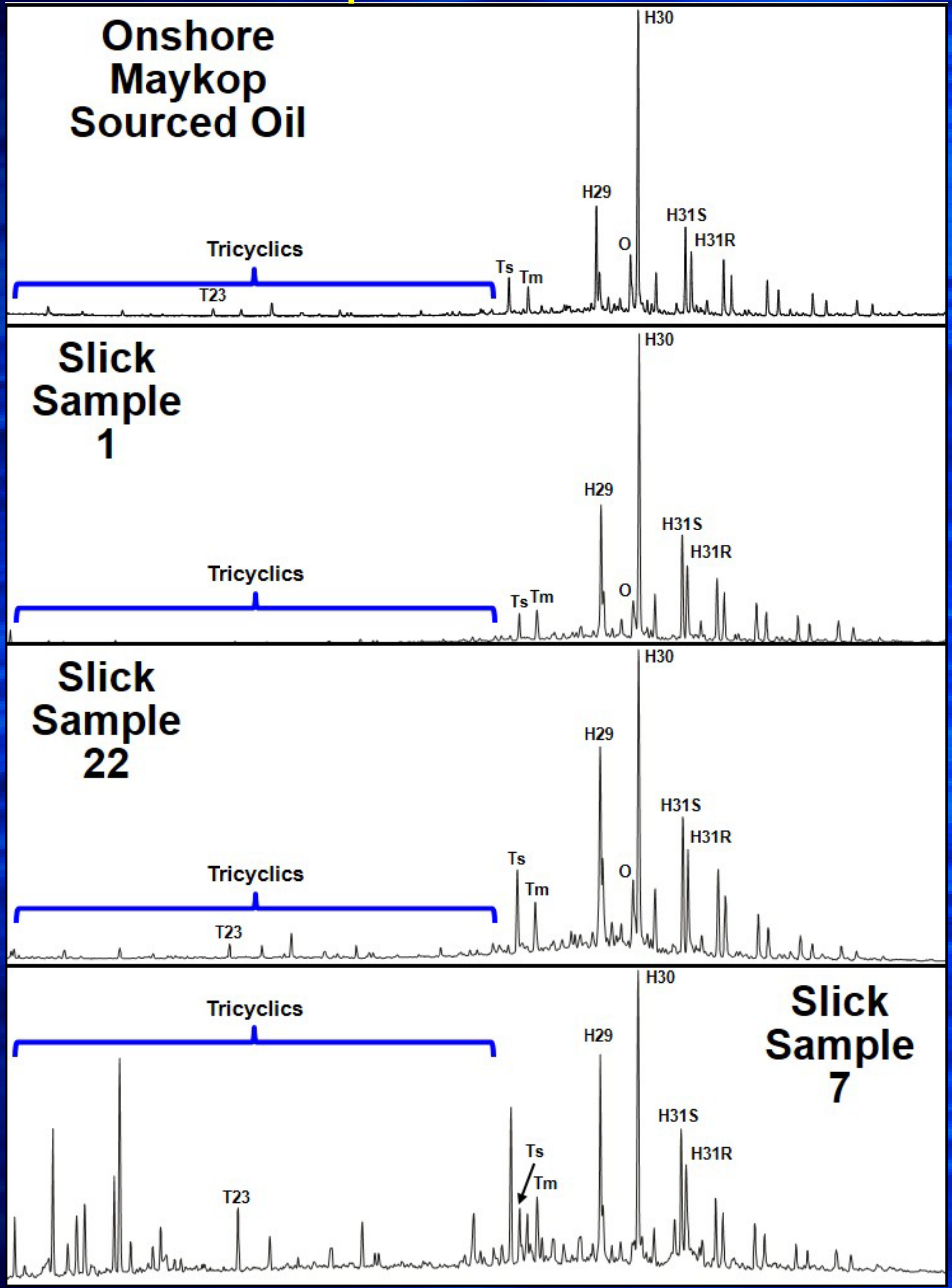
Possible Fates For Sea Surface Slick Hydrocarbons From Seafloor Seeps



Sea surface slicks from naturally occurring hydrocarbon seeps can have numerous biological, chemical, and physical processes act on the seeping oil at the sea floor, in the water column and at the sea surface to alter its composition and physical state.

Saturate Biomarkers

Terpanes m/z 191



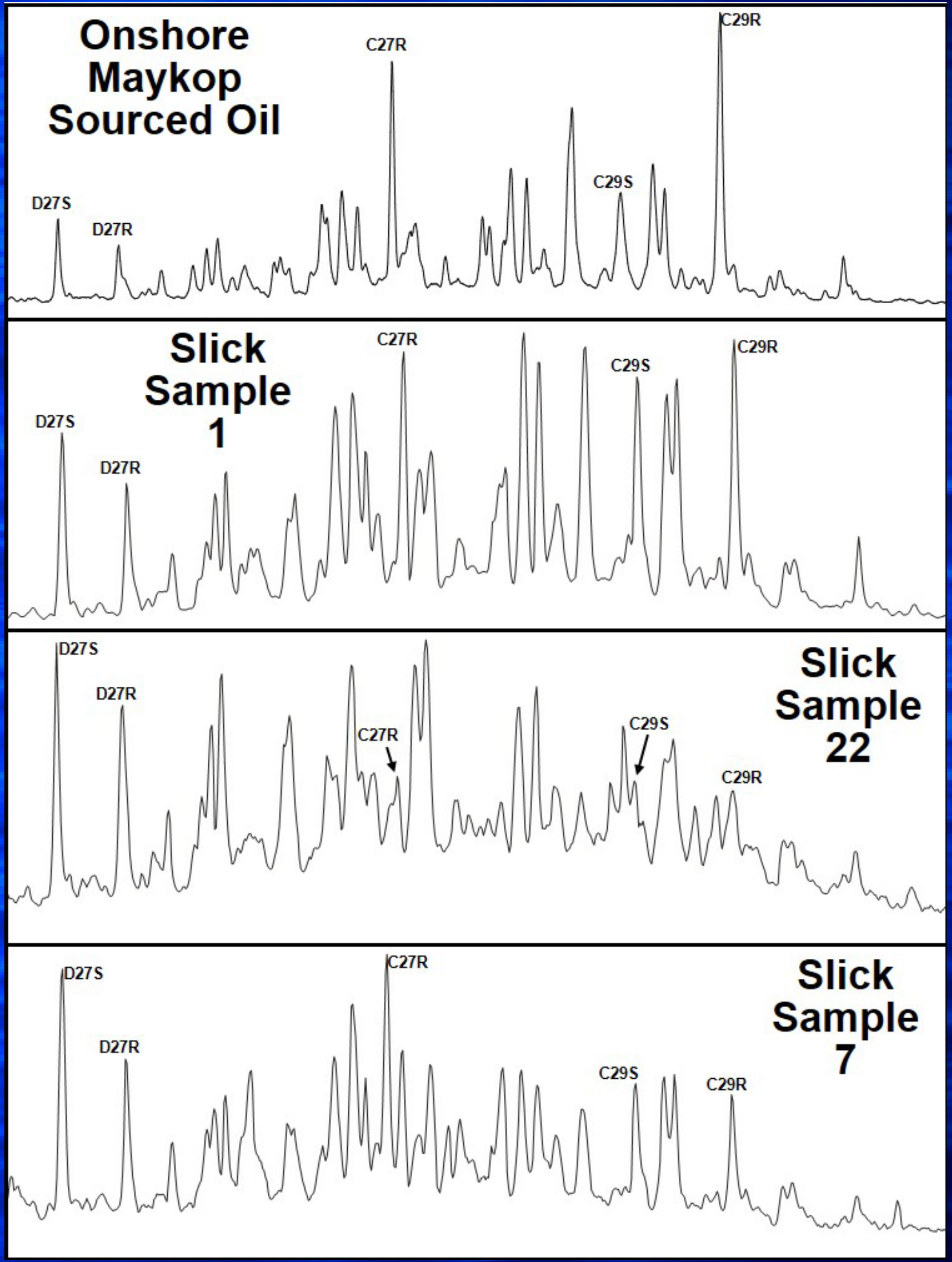
Onshore Maykop Sourced Oil

Minimal Alteration Observed

Some Alteration Of Regular Steranes, Reduction In C_{30} Hopane

Alteration Of Regular Steranes, Enhanced Tricyclics, Loss Of Oleanane

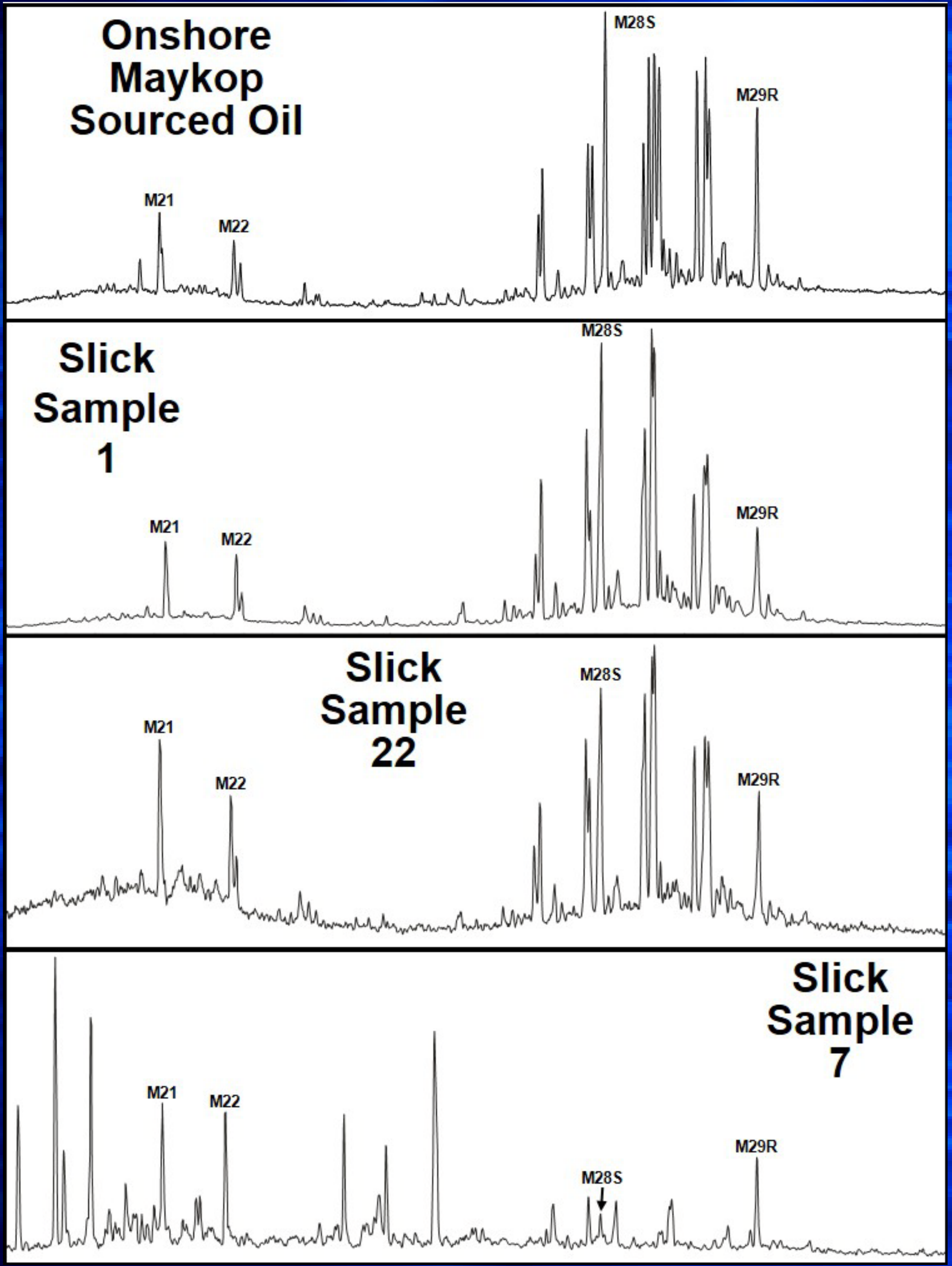
Steranes m/z 217



Geochemical data courtesy of Anadarko Petroleum Corporation

Aromatic Biomarkers

Monoaromatic Steroids m/z 253



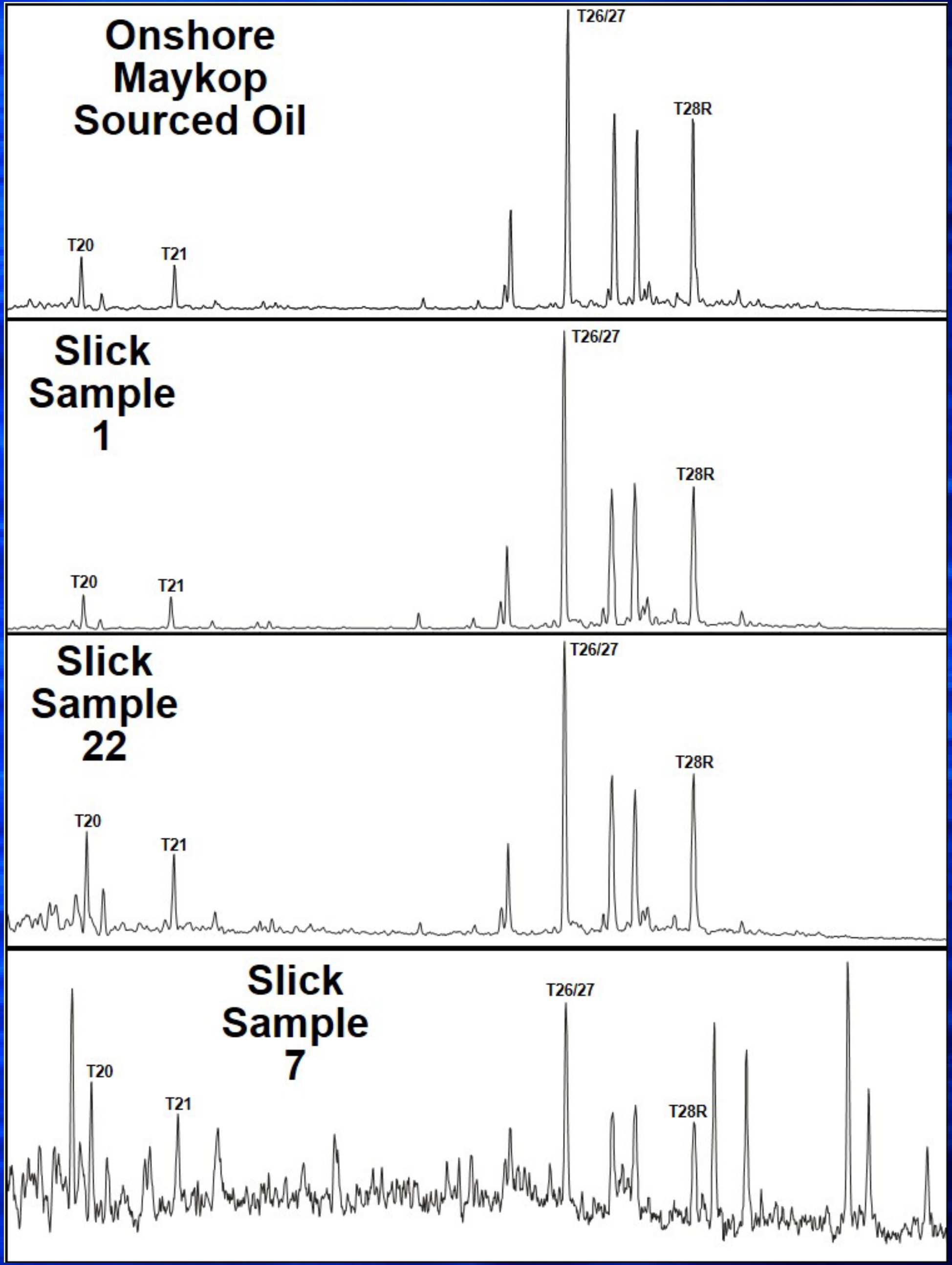
Onshore Maykop Sourced Oil

Minimal Alteration Observed

Slightly More Alteration Observed

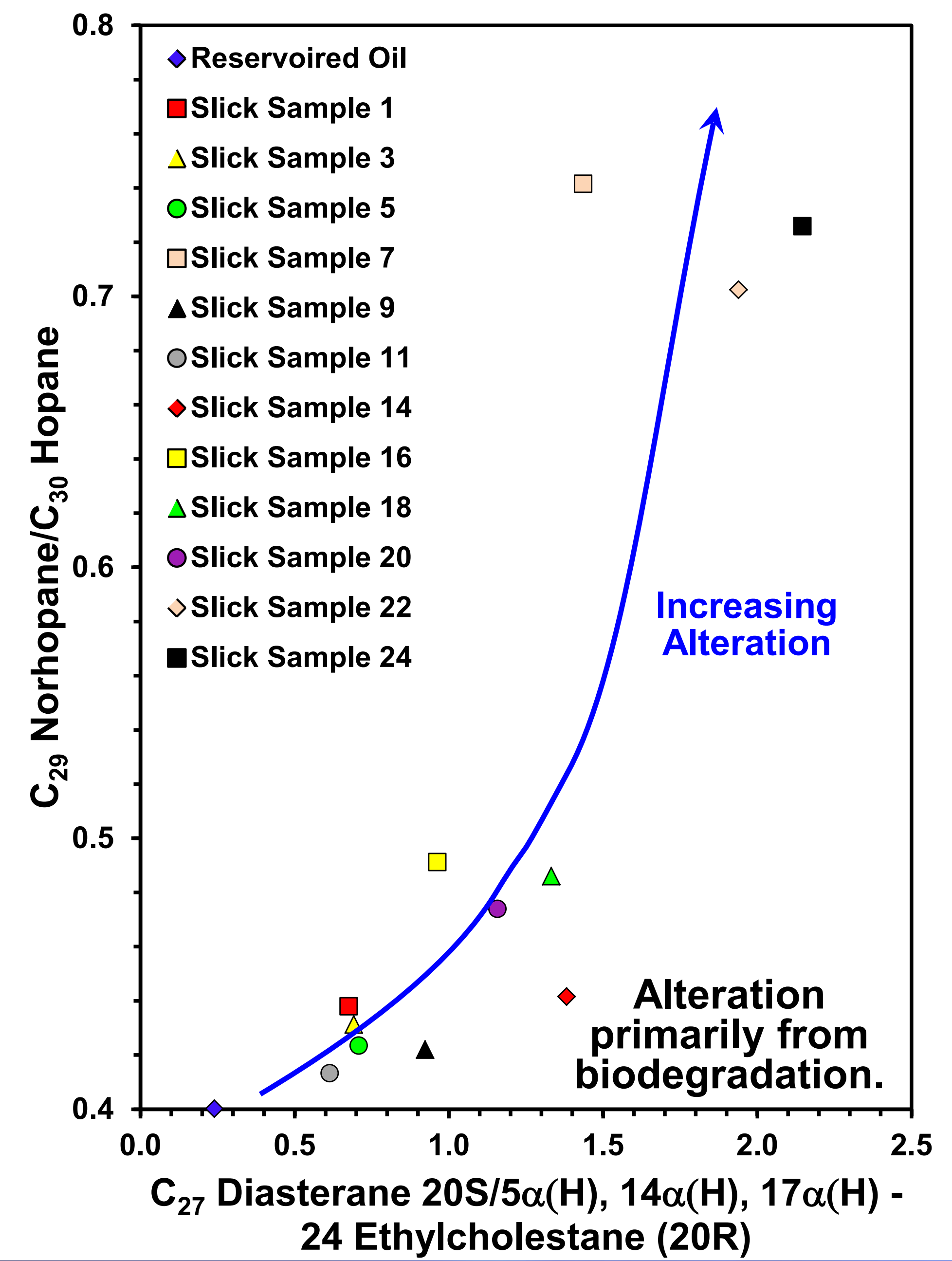
Significant Alteration Of Both Mono- And Triaromatic Steroids

Triaromatic Steroids m/z 231



Geochemical data courtesy of Anadarko Petroleum Corporation

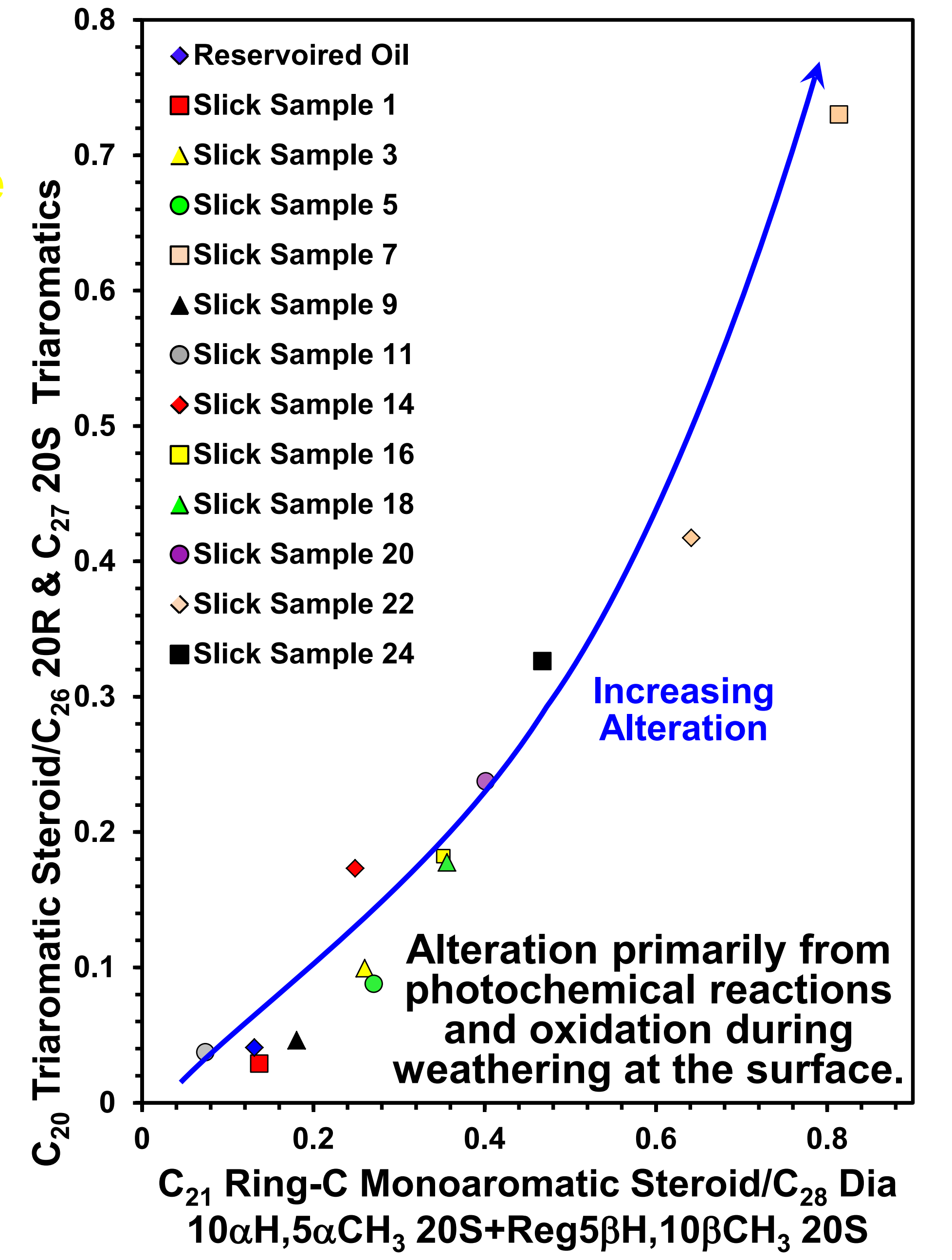
Assessing Alteration In The Slick Samples



By observing the changes in key biomarker peaks, the relative alteration experienced by the slick oils can be assessed.

A series of biomarker ratios were developed as indicators.

It is important to select the least altered samples to be used to attempt a slick-to-oil correlation with the onshore Maykop oils.

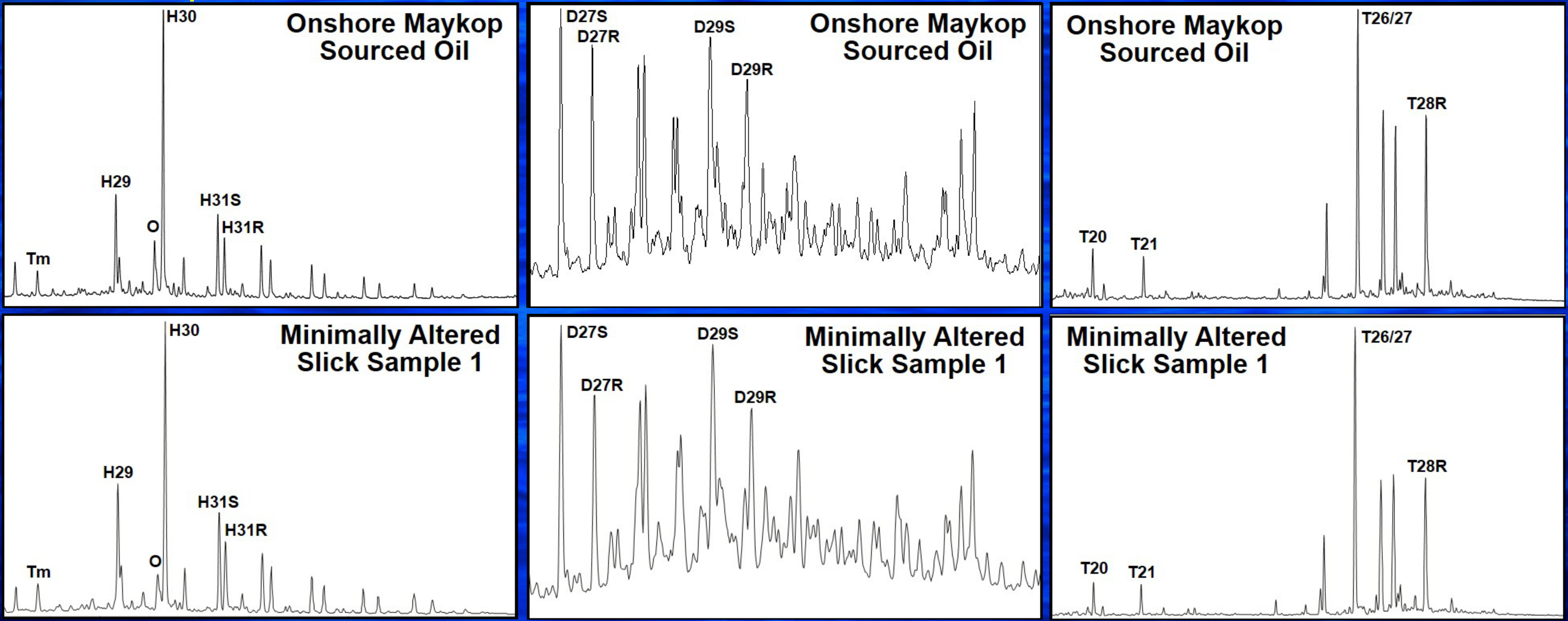


Geochemical data courtesy of Anadarko Petroleum Corporation

Correlation Of Onshore Maykop Oil To Minimally Altered Oil Slicks

Allowing for differences in maturity, the onshore oil and the minimally altered slick exhibit a high degree of similarity suggesting the same source for both.

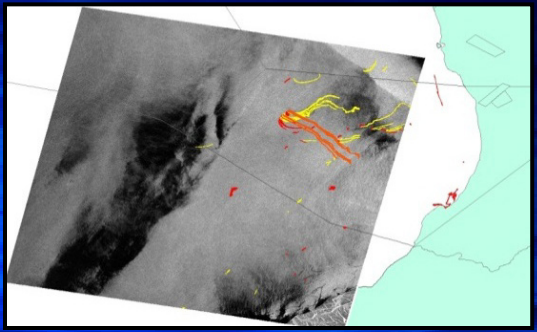
Hopanes m/z 191 | Diasteranes m/z 259 | Triaromatic Steroids m/z 231

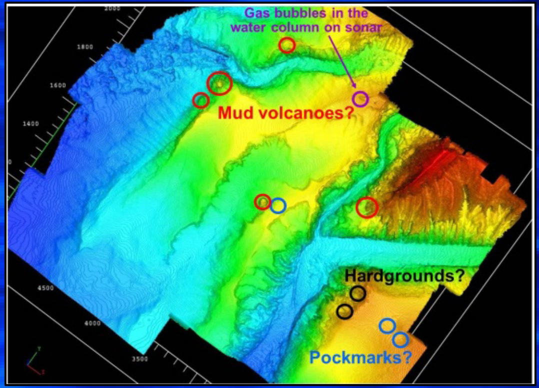


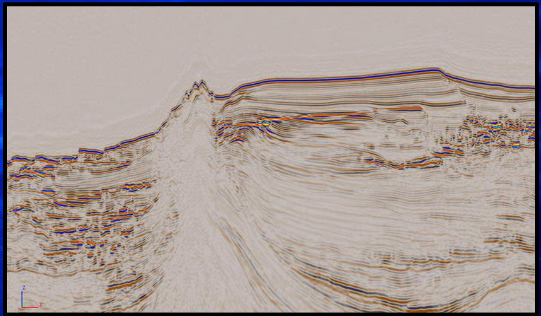
Geochemical data courtesy of Anadarko Petroleum Corporation

Observations And Conclusions, Part 1

- Sea surface slicks that were observed in the SAR satellite images and were also encountered in the same areas during seismic data acquisition.
- Bathymetric and amplitude data extracted from the 3D seismic survey revealed a series of seafloor features including mud volcanoes, pockmarks, and hardgrounds that are suggestive of hydrocarbon seepage.
- Deep-looking seismic data was able to tied these seafloor features to subsurface prospects and migration pathways.
- Hydrocarbons were witnessed to be surfacing at locations nearly directly above some of the seafloor features suggestive of hydrocarbon seepage.





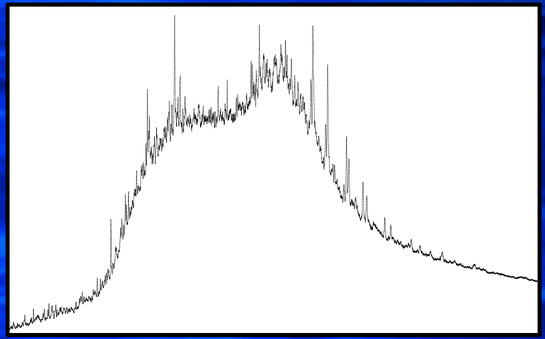


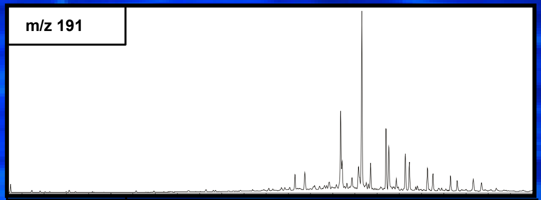
Observations And Conclusions, Part 2

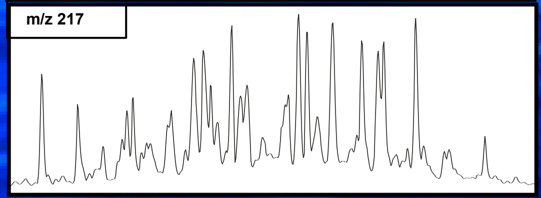
- These slicks were sampled and confirmed to be composed of naturally occurring thermogenic hydrocarbons.

- The biomarkers in these thermogenic hydrocarbons from the least altered slick samples are consistent with nearby onshore Maykop sourced oils, the same source that is expected to be contributing to the offshore traps.

- From these observations, we concluded there was a working petroleum system present, thereby reducing the charge risk to this exploration play.

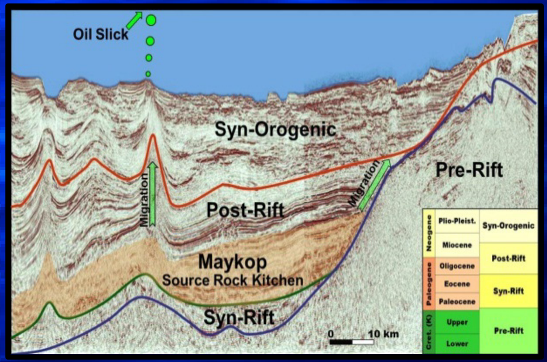






Post Script

The seafloor seep features responsible for the slicks were subsequently sampled in 2005 and 2007 by UNESCO Training Through Research cruises. Geochemical analyses were reported by Dmitry Nadezhkin in 2011 in his Ph.D. dissertation (Moscow State University) and a publication. These data confirm the observations and conclusions made using the seismic and sea surface slicks data.



Thank You For Your Attention.
Questions?

CONFIRMING THE PRESENCE OF A WORKING PETROLEUM SYSTEM IN THE EASTERN BLACK SEA BASIN USING SEA SURFACE SLICKS

"Information is the resolution of uncertainty." – Claude Shannon

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Thanks to the Republic of Georgia for permission to show the seismic data; to CGG NPA Satellite Mapping Limited for permission to show the SAR data map; to Anadarko Petroleum Corporation for permission to show the geochemical data; to Anadarko colleagues Kevin Stacy, Ryan Wilson, and Richard Hedley for sharing their insight into the geology and geophysics of the area; and to the selection committee for the opportunity to share these ideas.

And a special thanks to Jamshid Gharib who presented the paper for the author when he was unable to attend the meeting.

An earlier version of this presentation is available at AAPG Search and Discovery Article #10610.

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Peak Labels

Terpane peak labels:

T23 = C_{23} Tricyclic terpane
Ts = 18α, 21β trisnorhopane
Tm = 17α, 21β trisnorhopane
H29 = 17α, 21β norhopane
O = oleanane
H30 = 17α, 21β hopane
H31S = 17α, 21β, 22S homohopane
H31R = 17α, 21β , 22R homohopane

Monoaromatic Steroids peak labels :

M21 = C_{21} Ring-C Monoaromatic Steroid
M22 = C_{22} Monoaromatic steroid
M28S = C_{28} Dia 10αH, 5αCH_3 20S+Reg5βH, 10βCH_3 20S Monoaromatic Steroid
M29R = C_{29} Dia 10βH,5βCH3 20R+Reg5βH, 10βCH3 20R Monoaromatic Steroid

Triaromatic Steroids peak labels :

T20 = C_{20} Triaromatic Steroid
T21 = C_{21} Triaromatic steroid
T26/27 = C_{27} 20S + C_{26} 20R Triaromatic steroid
T28R = C_{28} 20R Triaromatic steroid

Sterane peak labels:

C27R = 5α, 14α, 17α cholestane (20R)
C28S = 5α, 14α, 17α ergostane (20S)
C29S = 5α, 14α, 17α stigmastane (20S)
C29R = 5α, 14α, 17α stigmastane (20R)

Diasterane peak labels:

D27S = 13β, 17α diacholestane (20S)
D27R = 13β, 17α diacholestane (20R)
D29S = 13β, 17α diastigmastane (20S)
D29R = 13β, 17α diastigmastane (20R)