Seismic Evidence for *Subsurface* Gas Hydrate in the Northern Gulf of Mexico

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The Dilemma

Well known surficial hydrate mounds
Well known leaky petroleum system
Where are the subsurface hydrates?

Photo: I. Macdonald, TAMU
USGS Gas Hydrate Studies

Field + Subsurface
Seismics + Coring

The Elusive BSR in the Gulf of Mexico

1998 and 1999 cruises: HRZ’s Free Gas?

Cooper and Hart, 2002
Insight into Complexity

Results from 2002 Giant Piston Coring in the Gulf of Mexico

(1) Heat Flow
Geothermal Gradients are elevated and variable.
(2) Geochemistry is not simple.

Recall the general case which is conceptually simple.

Examples from the MD Cores

The phase diagram boundaries are not simple.
Understanding Gas Hydrate Occurrence in the Northern Gulf of Mexico

Requires at a minimum:

• Seismics - to understand the geology
• Heat Flow - to understand the thermal regime
• Geochemistry - to understand the chemical complexities

And to integrate the results
To understand the fluxes

USGS High-Resolution Multichannel Seismics Site Survey

1-14 May, 2003
R/V Gyre

From TAMU web page
2 Sites:
Keathley Canyon 195
Atwater Valley 14

**Acquisition**

- 240-m Streamer, 24 channels, 10-m groups
- 13/13 GI Gun, 20-m shots, 3000 psi
- 1/2 ms sampling rate
Atwater Valley - Preliminary Results

Floor of the Mississippi Canyon

General Morphology - Mounds
AV94 - Regional Stratigraphy

Multiple Unconformities

Salt

Dipping Layers

Mound F

B

D

AV94

F

USGS
### Mound F

<table>
<thead>
<tr>
<th>AV69</th>
<th>AV71</th>
<th>AV68</th>
<th>AV70</th>
<th>AV67</th>
</tr>
</thead>
<tbody>
<tr>
<td>West</td>
<td>500-600 m across</td>
<td>6-20 m high</td>
<td>East</td>
<td></td>
</tr>
</tbody>
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- 500-600 m across
- 6-20 m high

**Note how shape is not of a diffraction**

Is this a BSR upwarped by warm fluid flux?
Roughness on the apex of this surface

Differential Velocity Pulldown Effect

Is this evidence of free gas?

AV68

AV71

40 msec
Bathymetry (msec)     TWTT to PD horizon (msec)

The pull-down has asymmetry.

Isopach:
Sea Floor to Pulldown

Effect is greatest on the east side
Shallow structure on edge of mound d

AV75

AV76

AV65
Atwater Valley Summary

Mounds
BSR??
Free Gas ??
Different sizes and seismic character

Keathley Canyon  Preliminary Results

700 km data
BSR
Mounds
Geologic Framework

MiniBasin
Faults
Structural High

USGS Seismic Grid

Very Different from Atwater Valley
BSR is beneath a major unconformity that may represent a change to coarser material.

Younger Bypass Assemblage is siltier, disrupted, and more chaotic.

Older Ponded Assemblage is more sand rich and layered; i.e., a better lithology for concentrating hydrate.

Bathymetry

Winker and Booth, 2000

USGS

Bathymetry

Mounds

USGS

WG-3D bathy courtesy of Western Geico
KC01 - Mound (Vent??)

High-amplitude anomalies - free gas??
Summary

The evidence for subsurface gas hydrate is subtle.

Some of the indicators are:
(1) A "normal" BSR at KC 195
(2) Possible free gas to the east of a large fault.
(3) A mound/vent system in AV14 that may indicate the presence of a BSR perturbed upwards by warm fluids.
(4) In AV14, velocity pulldown indicating deeper free gas that might be feeding shallower hydrate.

Understanding hydrate formation in the Gulf of Mexico requires knowledge of the geologic framework, the heat flow, and the geochemistry.

Where to from here?

Integrate seismics with heat flow and geochemistry.
Refine proposed drill-sites
Develop better understanding of the geologic framework.
Develop a conceptual model for the interactions between surface hydrate and deeper petroleum system that is likely to be feeding it.