THE LAST U.S. OIL AND GAS?

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PRELIMINARY STATEMENT

- The U.S. uses about 8 million barrels of high-cost oil per day for transportation
- Clean-burning natural gas is an energy option partly because of successful shale-gas technology (e.g. Barnett Shale)
- There may be far more producible methane energy in shale than in gas hydrate
- Research is needed on conversion of gas to liquids such as octane (catalysis)

THE LAST BUFFER

1. Our national energy policy depended on giant and super-giant oil and gas fields overseas
2. The great oil fields of Saudi Arabia and Middle East were discovered 50 to 100 years ago
3. Attempts to replace giants such as Gawahr (1948) failed
4. These giant fields now approach the point of rapid depletion

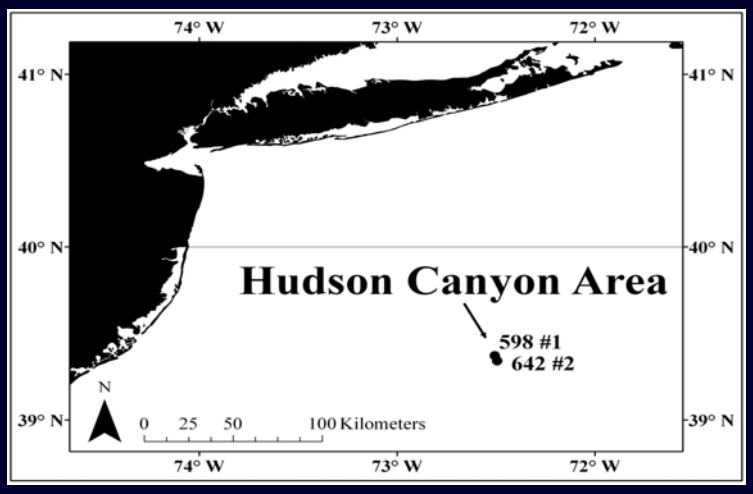
W.J. Carrigan et al., 1995

U.S. ATLANTIC OCS

Since drilling was halted in the U.S. Atlantic OCS, Canada discovered ~3 billion barrels of oil and much gas* offshore from Nova Scotia to Labrador

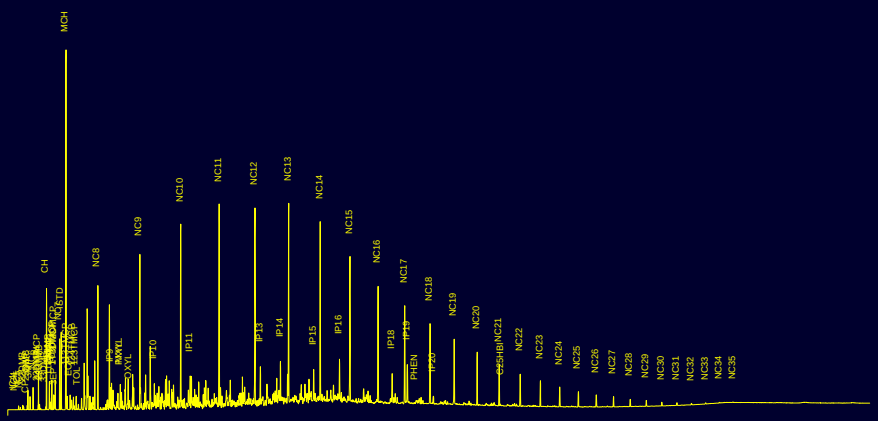
*About 1 year of Japan's energy requirements

Well Locations, Hudson Canyon area of Baltimore Canyon Trough



Gas-Condensate was Discovered in Hudson Canyon about 30 years ago

Gas chromatogram of Hudson Canyon Liquid Hydrocarbons



Thermal Maturity Framework

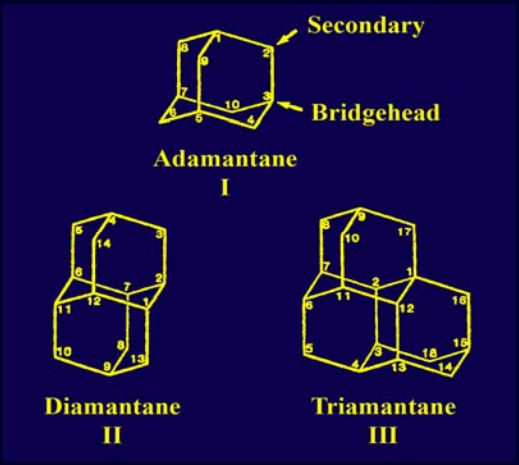
- Gas-condensate is far more thermally mature than Upper Jurassic reservoirs
- The gas-condensate was not generated by coaly shale adjacent to reservoirs; the source rock was deeper and hotter
- Gas-condensate migrated vertically from depth to the shallower and younger traps

(Miller, 1986; Sassen and Post, 2008, OG)

DIAMONDOIDS

The most thermally stable of all complex hydrocarbons in Earth's crust. They were concentrated in Hudson Canyon condensate as it was destroyed by time and temperature

CHEMICAL STRUCTURES OF DIAMONDOIDS



Diamondoids that Plugged a Gas Field

IN MORATORIUM

Of 32 wells drilled in the Baltimore Canyon area, 8 wells encountered shows and 5 tested gas, gas-condensate, or condensate. Other wells drilled in the U.S. Atlantic were dry holes… why?

Assumptions prior to Drilling

- It was *assumed* that Cretaceous source rocks for oil were deposited offshore Atlantic (black shale from oceanic anoxic events)
- Secondly, it was *assumed* that the Cretaceous shale generated oil from high heat flow as the Atlantic Ocean opened
- Drilling found low-quality, immature Cretaceous source rocks

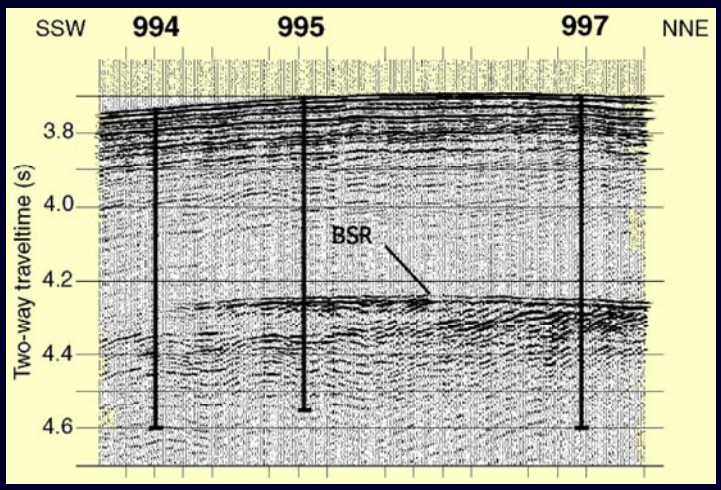
RETURN STRATEGIES

- Drill deeper in the Atlantic…
- Drill the entire sediment to igneous rock; penetrate Triassic and older sediments
- Analyze geochemistry of conventional core of Mid- to Lower Jurassic rocks
- Better predict reservoir properties at depth
- Determine the maximum depths at which methane may be preserved

MICROBIAL METHANE IN U.S. ATLANTIC

- Gas vents were identified decades ago on the Atlantic sea floor
- A shallow microbial methane system generated huge volumes of gas in sediment
- Are there large traps with microbial methane in U.S. Atlantic?
- Potential for methane hydrate production?

Seismic Evidence of Gas Hydrate in Blake Ridge



After Paull and Matsumoto, 2000

Total Estimated Hydrate Resource = ~990 TCF (Dickens et al., 1997)

After Matsumoto and Borowski, 2000

Economics of Methane Hydrate Production are Variable

- Japan's Nankai Trough gas-hydrate deposits are immense, in lithified sandstone with good reservoir properties
- Alaska has lithified reservoirs but a limited volume of recoverable hydrate energy
- The vast gas hydrate resource from under-consolidated sand and mud in U.S. Atlantic may not be producible…

U.S. Atlantic Summary

- Deeper, older traps need to be tested for gas-condensate, Middle Jurassic down to the Triassic
- Reservoir properties may be preserved at great depth and high temperatures…
- Potential for shallow traps with microbial methane and gas hydrate should not be overlooked

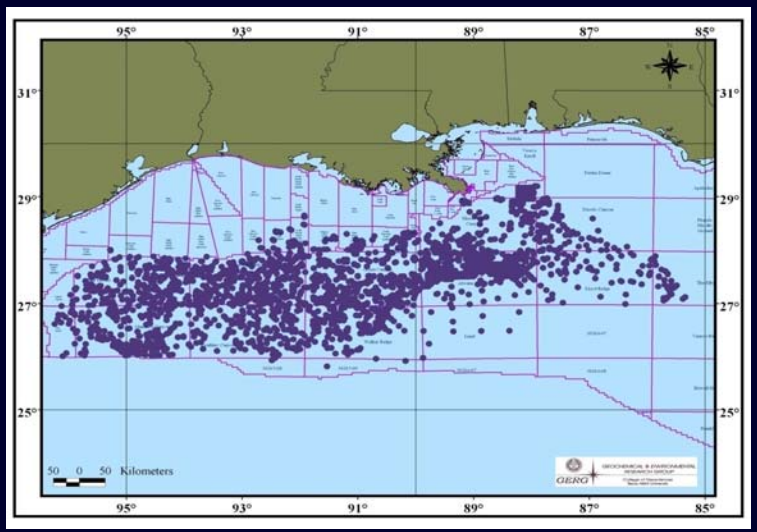
GULF OF MEXICO OCS

Drill for gas and gas condensate; focus shallow on microbial methane and future gas hydrate energy

PISTON CORING

1. Seismic identifies oil seeps and gas vents on gas floor
2. Accurate to within about 25 meters
3. Allows collection of mud, oil, gas, and gas hydrate samples to ~6 meters
4. No practical depth limit in the gulf

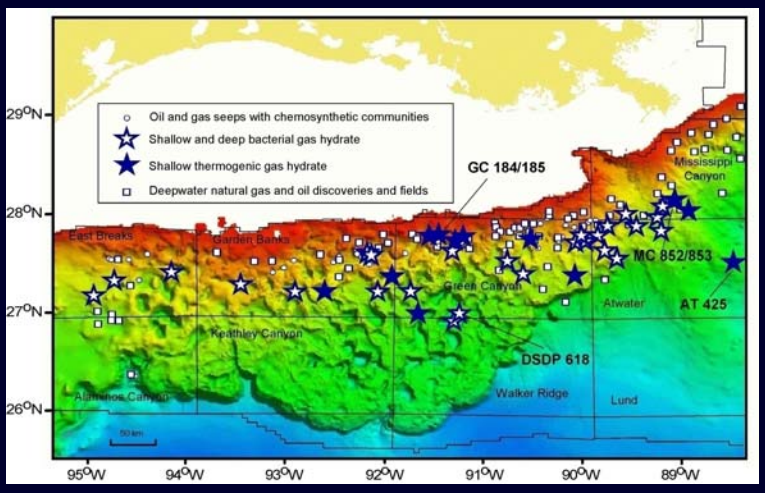
Piston Cores (~2,620) across the Gulf of Mexico Slope



UPPER JURASSIC SOURCE ROCKS OF CENTRAL GULF SLOPE

- Tithonian Shale (Bossier/Haynesville equivalent) is probably the most significant oil source rock
- Early Oxfordian Carbonates (Smackover equivalent) also important source rock
- Oil varies considerably in properties depending on burial history, mixing, and microbial alteration in reservoir

CENTRAL GULF SLOPE

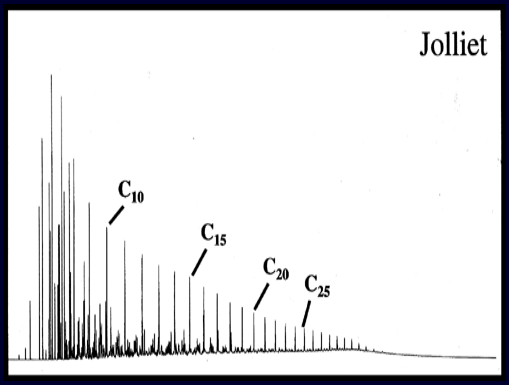


Milkov and Sassen, 2001

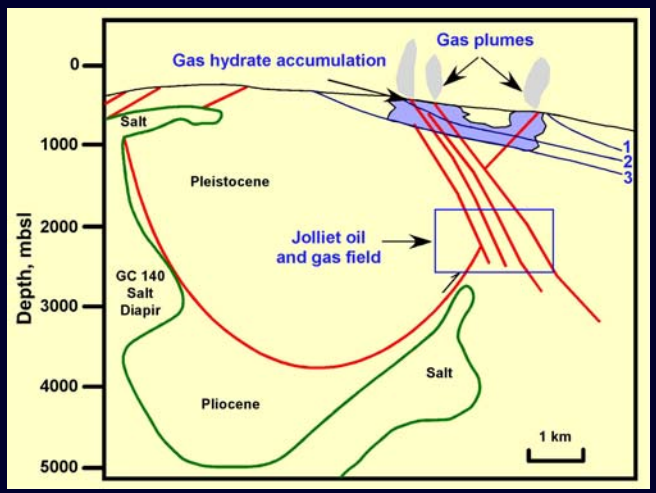
JOLLIET FIELD
Green Canyon 184/185

1. Oil and gas in sandstone reservoirs, structural traps at 2 to 3 km depth below seafloor
2. Discovered by seismic and by natural oil slicks at sea surface
3. First discovery of Type II oil-related gas hydrate at seafloor
4. First insight to chemosynthetic communities in oil-stained gassy sediment

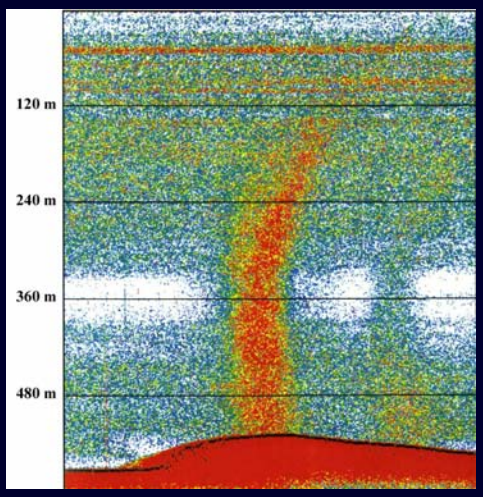
- **Petroleum System: Probable mixture from deeply-buried Tithonian and Early Oxfordian source rocks**



Cross-section of Bush Hill over Jolliet Field in Green Canyon 184/185

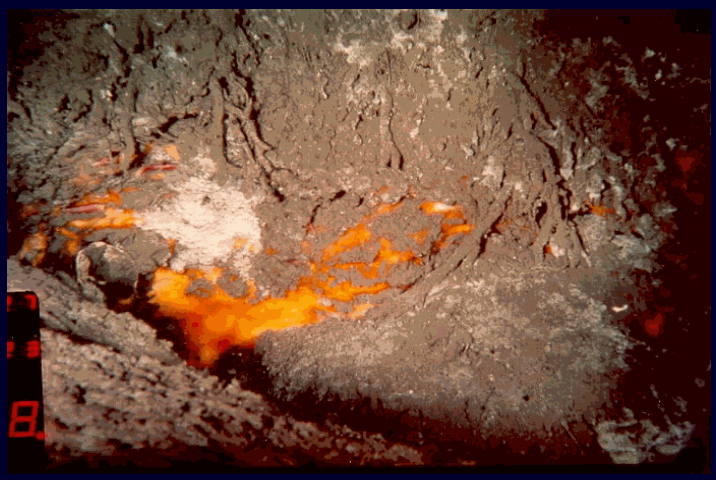


Natural Gas Seepage from 1,650 ft Water Depth near Jolliet Field (38 kHz imagery)



Oil-Lined Bubbles transport Greenhouse CH_4 Directly to Atmosphere from Depth

Gas-Hydrate in Mound at Seafloor at Bush Hill



Pure Gas Hydrate Recovered from Green Canyon 232

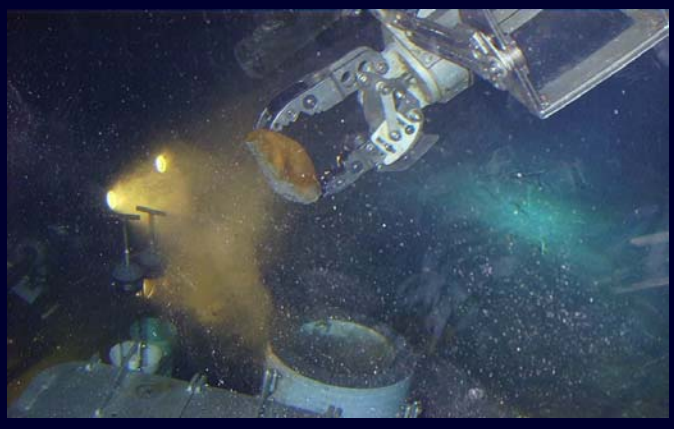


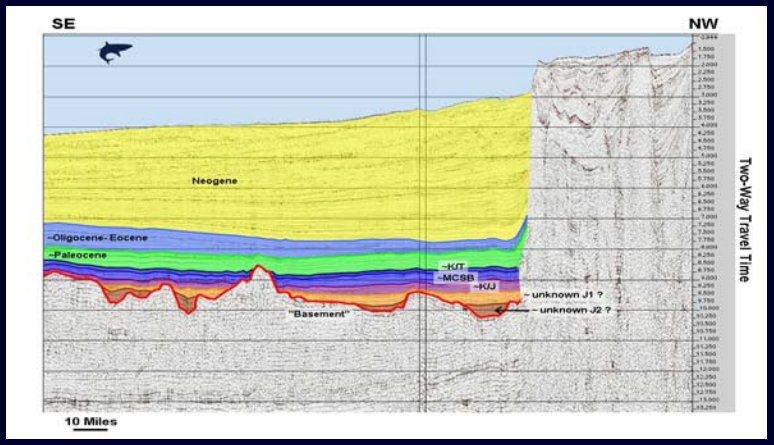
Photo by Alexei Milkov

Gas Hydrate Crystallizes from natural vent gas in seconds

UPPER JURASSIC SOURCE ROCKS OF EASTERN GULF

- Shell drilled its Shiloh discovery (oil and gas) in deep water of DeSoto Canyon
- Company reported Early Oxfordian source rock plus oil and gas in the Norphlet Sandstone, an extension of the Eastern Smackover Trend from onshore
- Tithonian source potential is also likely in Eastern Gulf of Mexico slope
- The Eastern Gulf of Mexico has potential

Seismic line across the Florida Escarpment area, Eastern Gulf



TGS-
NOPEC

Deep Submergence Vehicle ALVIN

Chemosynthetic Communities of Florida Escarpment fueled by gas seepage

Microbes Sequester Gas into Geologically Stable Carbonate Rock

Calcite from Microbial Oxidation of CH_4 fills Ooze from The Elbow 711

BASIC CONCLUSIONS

- Renew careful drilling and motivate energy research at universities
- The 2010 discovery at >28,000 ft of CH_4 in the shallow Gulf shows ultra-deep drilling is viable
- U.S. already produces abundant shale gas
- We can find deep gas and shallow gas hydrate in OCS but there are technology issues
- The United States needs fuel for transportation, lubricants, medicines, and chemicals
- Research on conversion of gas to liquid hydrocarbons is consistent with national survival

U.S. Navy NR 1 nuclear submarine leaving Pensacola on one its final cruises…

THE END