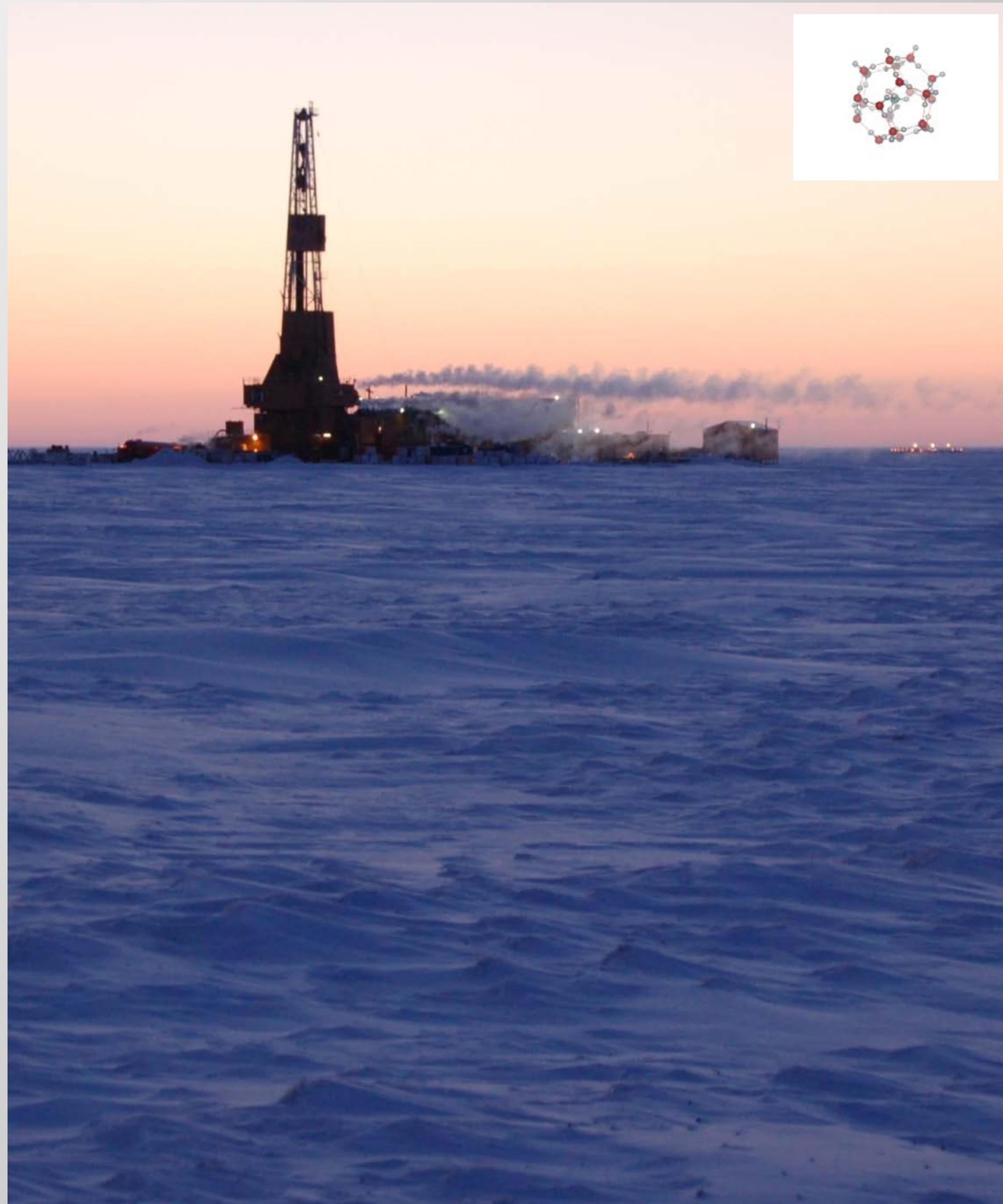
DOE'S NATURAL GAS HYDRATES PROGRAM

Ray Boswell, DOE/NETL

Methane Hydrate
Federal Advisory Committee

Galveston, TX

March 28, 2014



Mt Elbert Test Site, ANS, 2007

Program Approach

National Program Lead by DOE

Public Domain

Interagency & International

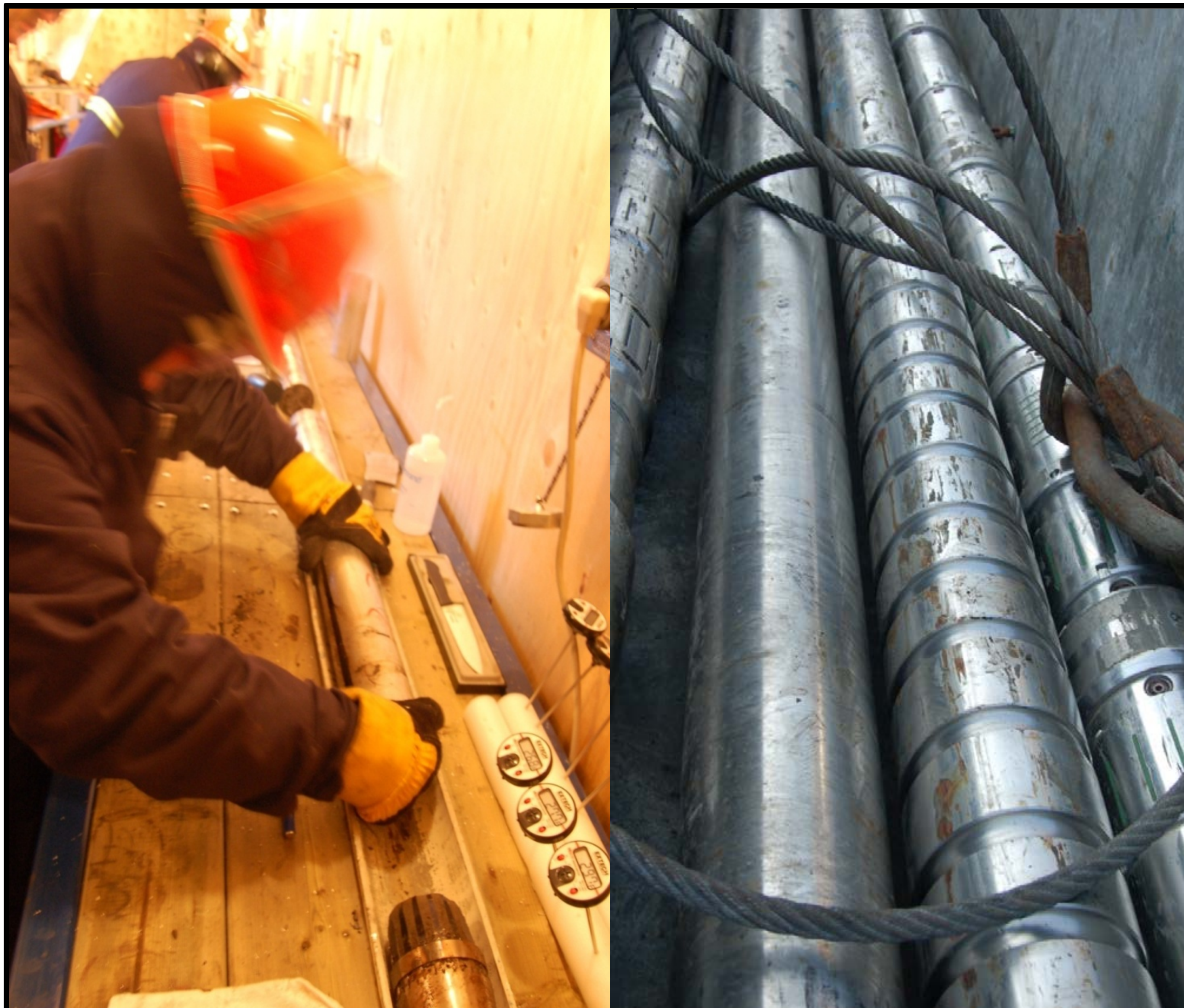
Merit-based & Transparent

Gas Hydrate in Nature

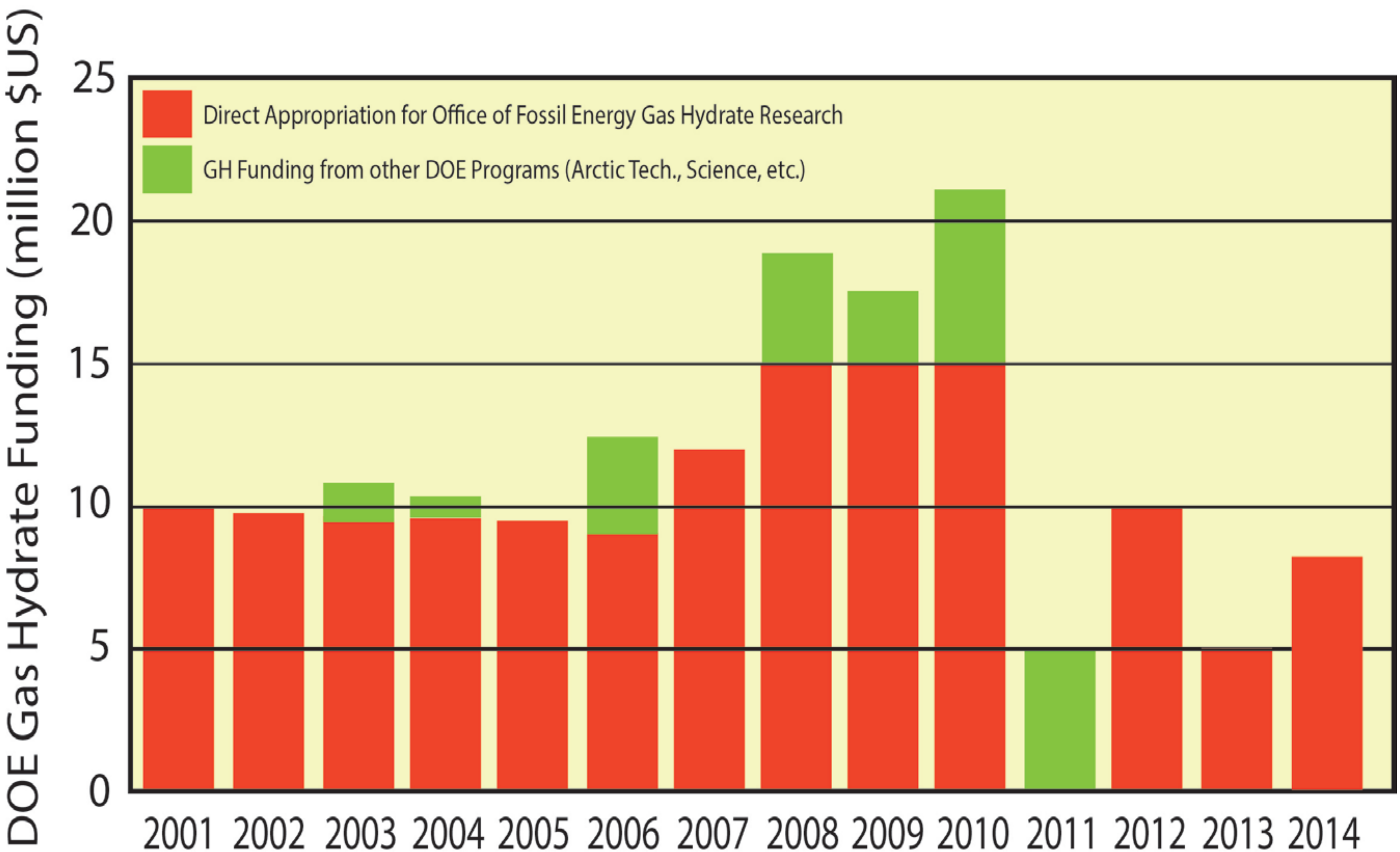
Science and Technology

Emphasis on Research *in the Field*

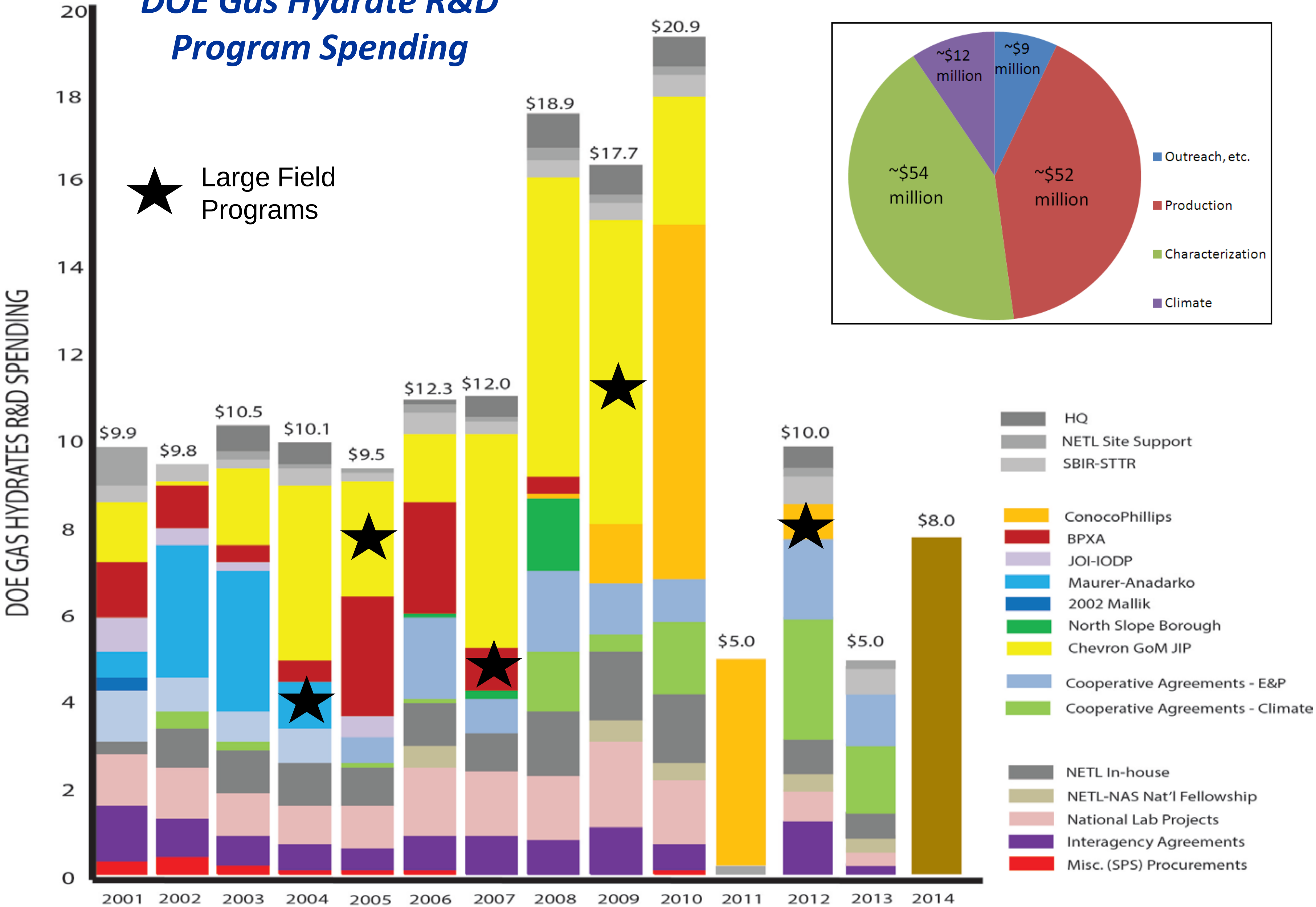
Outreach & Education



Historic DOE Budgets



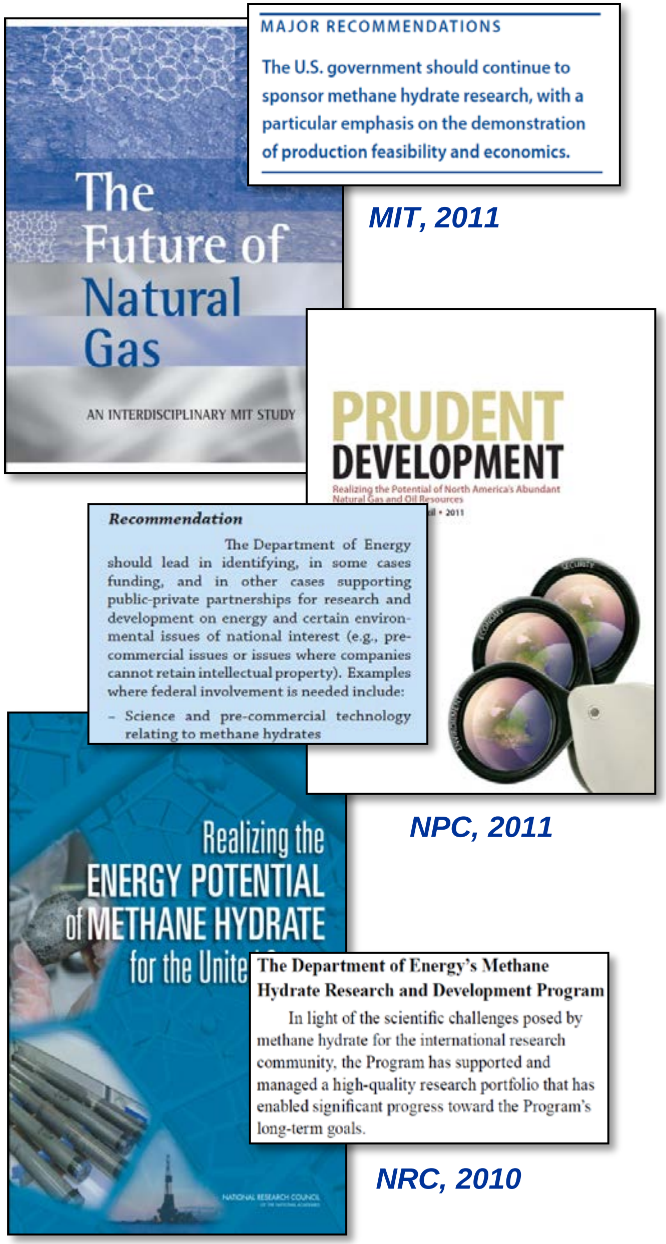
DOE Gas Hydrate R&D Program Spending



- **The federal role in gas hydrate science and technology development is widely accepted**
  - tangible, wide-ranging, public benefits.
  - consensus that DOE has managed the effort well n

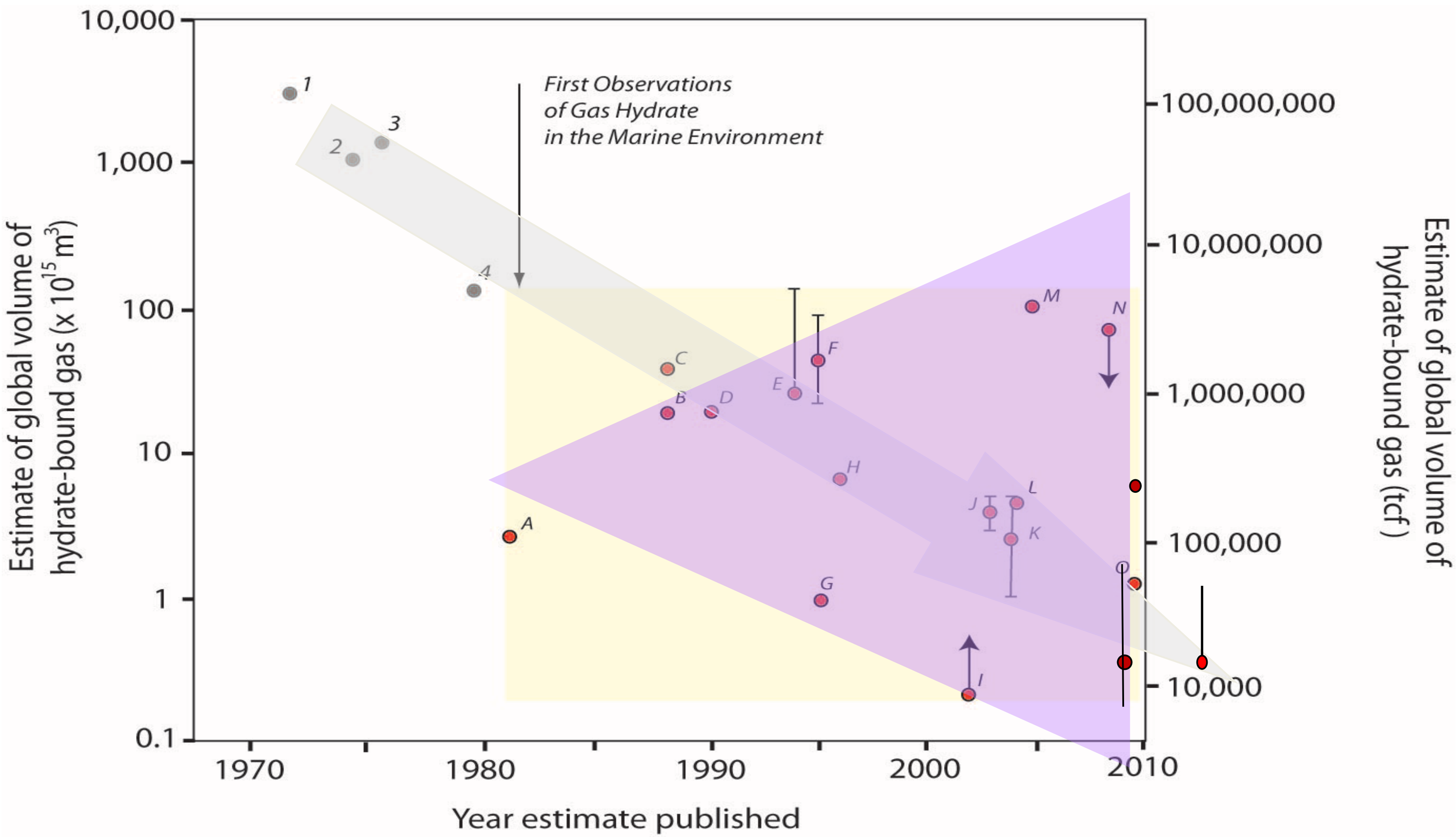
- **The primary goals and next steps are clear and the groundwork well laid**
  - monitored production tests (Alaska first, then marine)
  - sampling/analysis of marine occurrences
  - resource confirmation in other US OCS areas
  - refinement/field calibration of exploration technologies
  - integration of GH science into climate change models

- **Lab and modeling work needed as support <u>but the answers will come from the field</u>**
  - the work to be done is <u>complex and costly</u>
  - industry/int'l perspectives change rapidly. Most of the industry is increasingly disinclined to lead further projects
  - Significant international interest



Global Resource Estimates

Evolution with time



"The gas hydrate *resource* is…"

GAS-IN-PLACE (GIP)

- *f(geology)*
- *GIP = 100,000s tcf*

TECHNICALLY-RECOVERABLE (TRR)

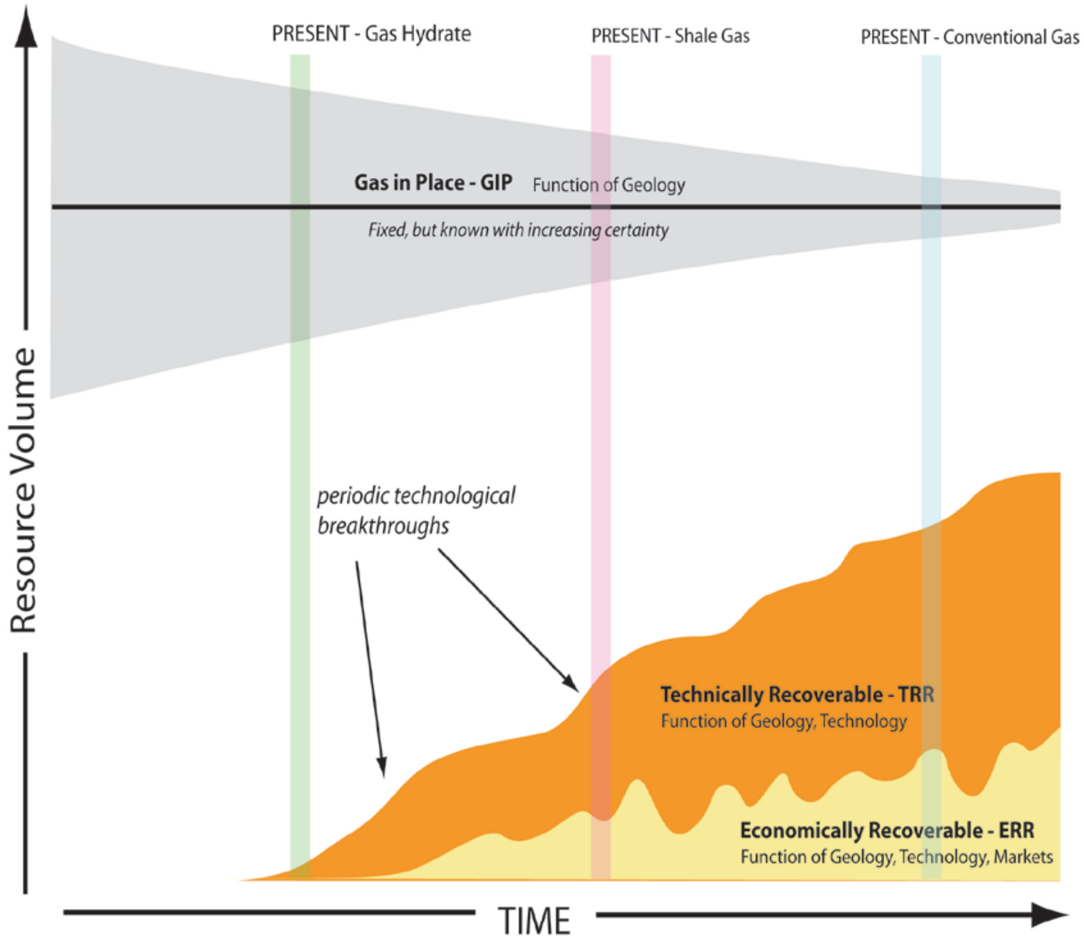
- *f(GIP, tech., timing, policy, reg.)*
- *TRR = 85 tcf (AK)*
- *Best Guess: TRR = 10,000 tcf vicinity*

ECONOMICALLY-RECOVERABLE (ERR)

- *f(TRR, market conditions)*
- *Gas Hydrate (2014) ERR = 0*
- *Best Guess: TBD*

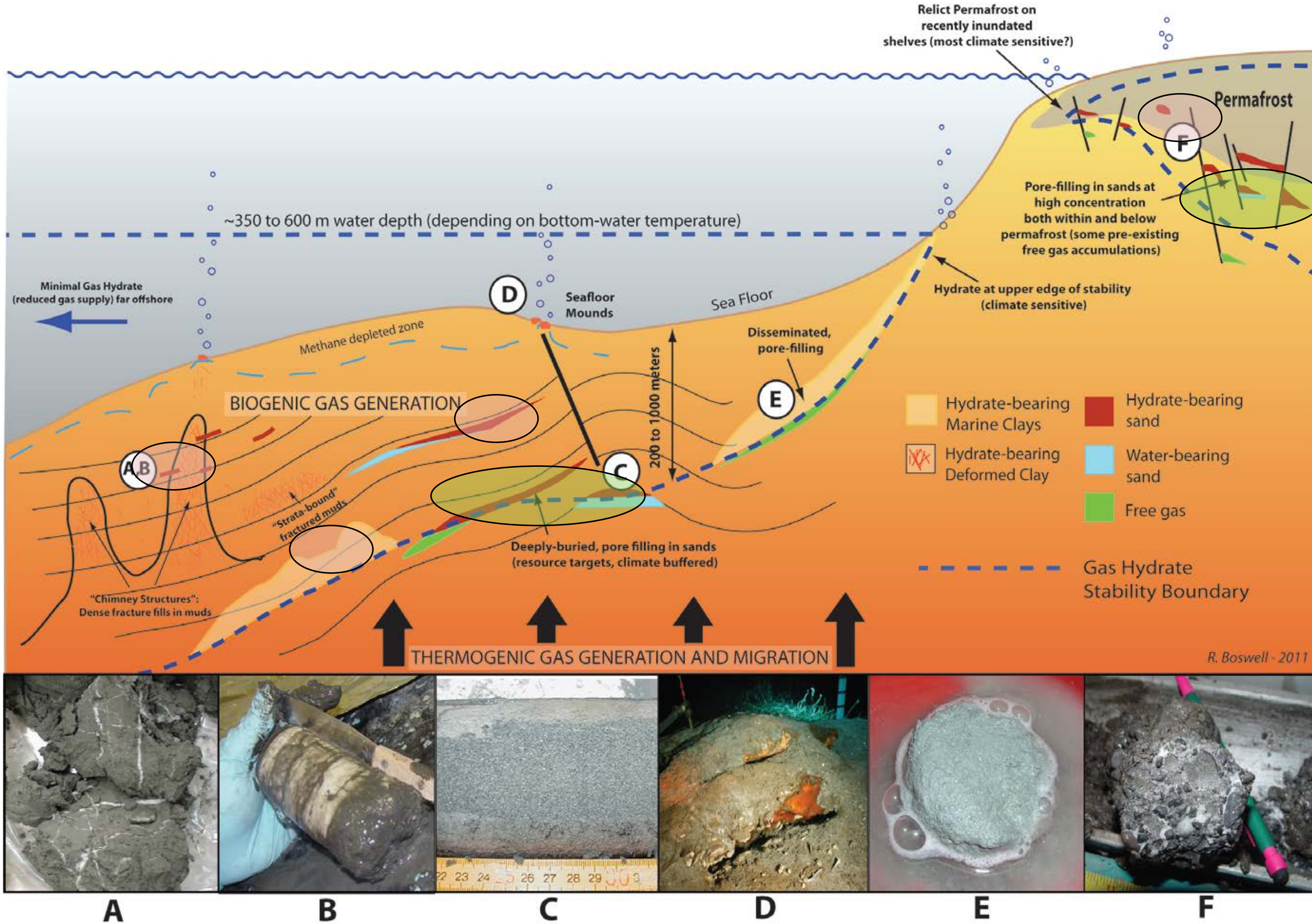
RESERVES (Various categories)

- *f(ERR*, drilling activity, data certainty)*
- *Gas Hydrate (2014) Reserves = 0*



after Boswell and Collett, 2011

Gas Hydrates Occurrences



The Most Favorable Form: Pore-Filling in Sediment with K

PORE FILLING (Sand/Silt Reservoirs)

- High saturation
- High intrinsic reservoir quality
- Better geomechanical stability
- Proven production concepts – depressurized; stimulated

GRAIN-DISPLACING

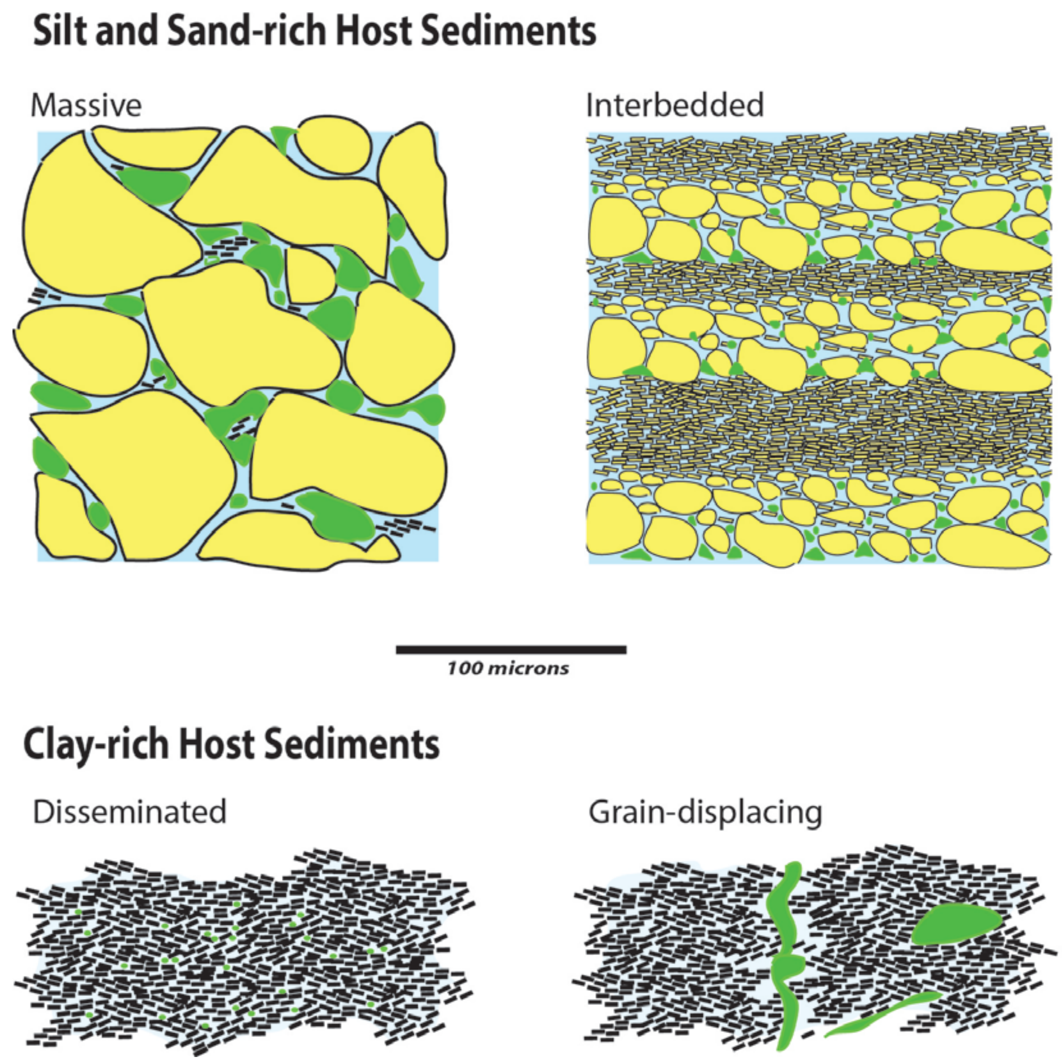
- Low-to-moderate saturation
- Very poor reservoir quality
- No geomechanical stability
- Is mining the only method?

DISSEMINATED (silty clays)

- Large in-place resources
- Very low saturations
- No reservoir quality
- No geomechanical stability

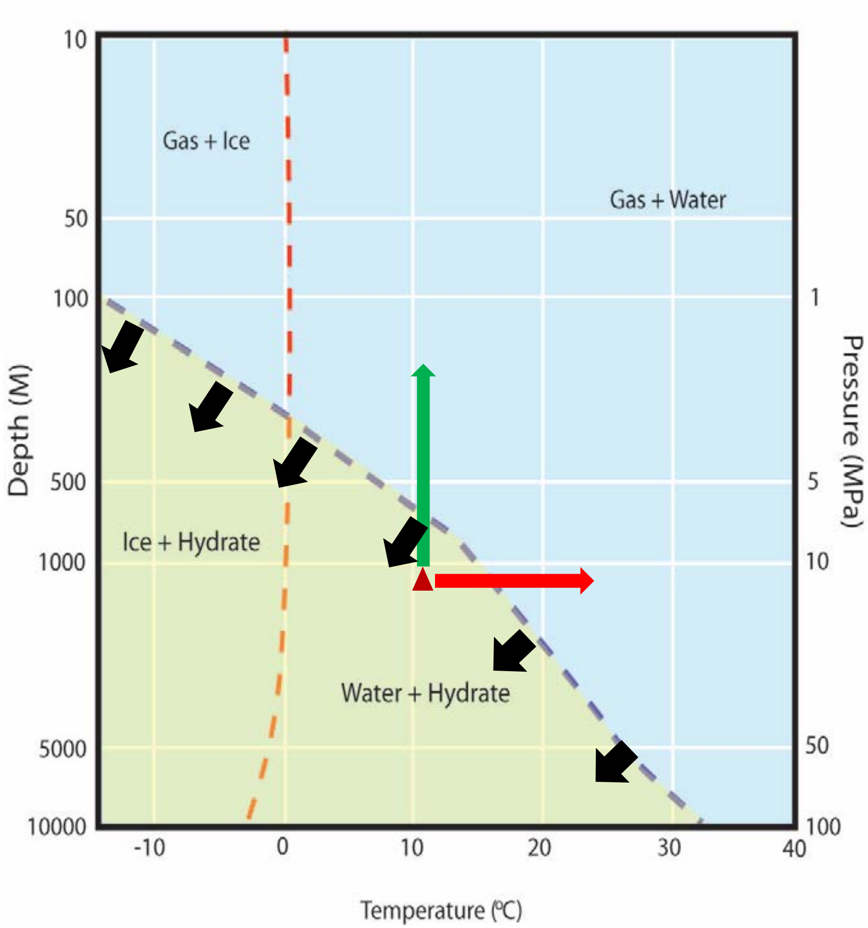
SEA-FLOOR MOUNDS

- Small size, ephemeral
- Associated unique biological communities



Production Technology

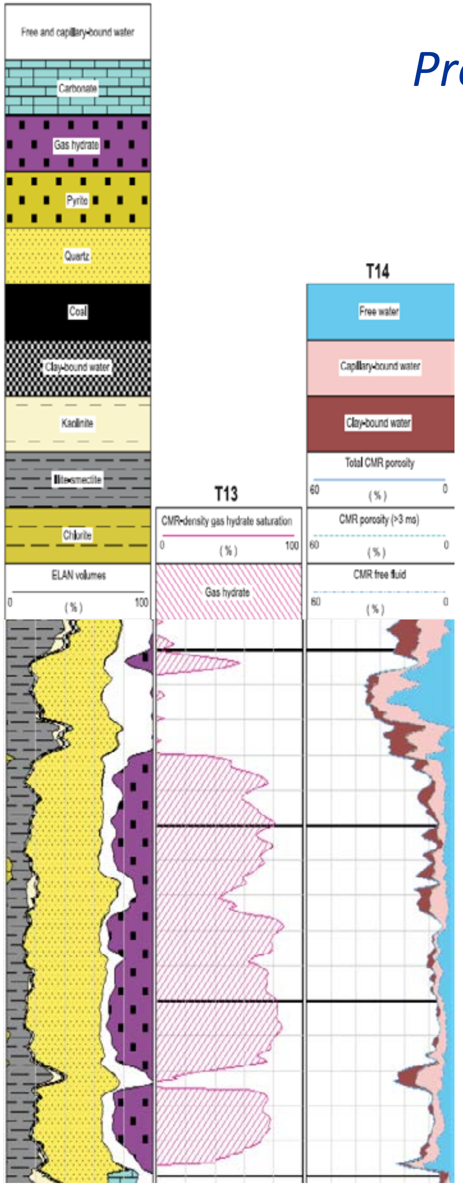
To date, only short-duration scientific field experiments



- **Thermal (Mallik, 2002)**
  - Tests and Modeling → Not feasible
  - Stimulation/Near-well bore maintenance
- **Chemical (Ignik Sikumi, 2012)**
  - Inhibitor Injection: Costly? Ineffective
  - CO_2-CH_4 Exchange
- **De-pressurization (Mallik *2007, 2008*; Nankai, *2013*)**
  - Simplest
  - Demonstrated in field tests and simulation

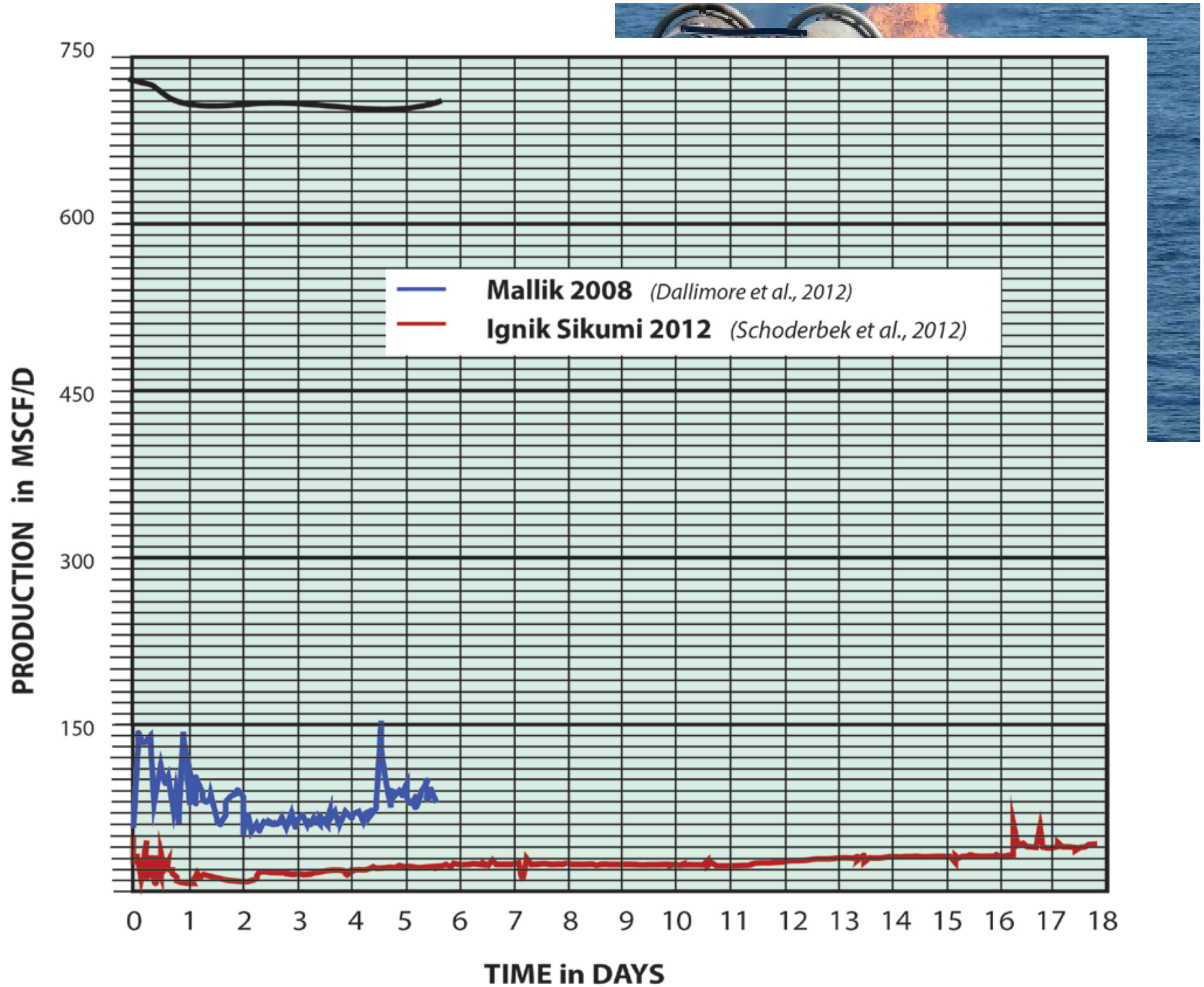
Depressurization

Production sustained over short test durations



Dallimore et al., 2005

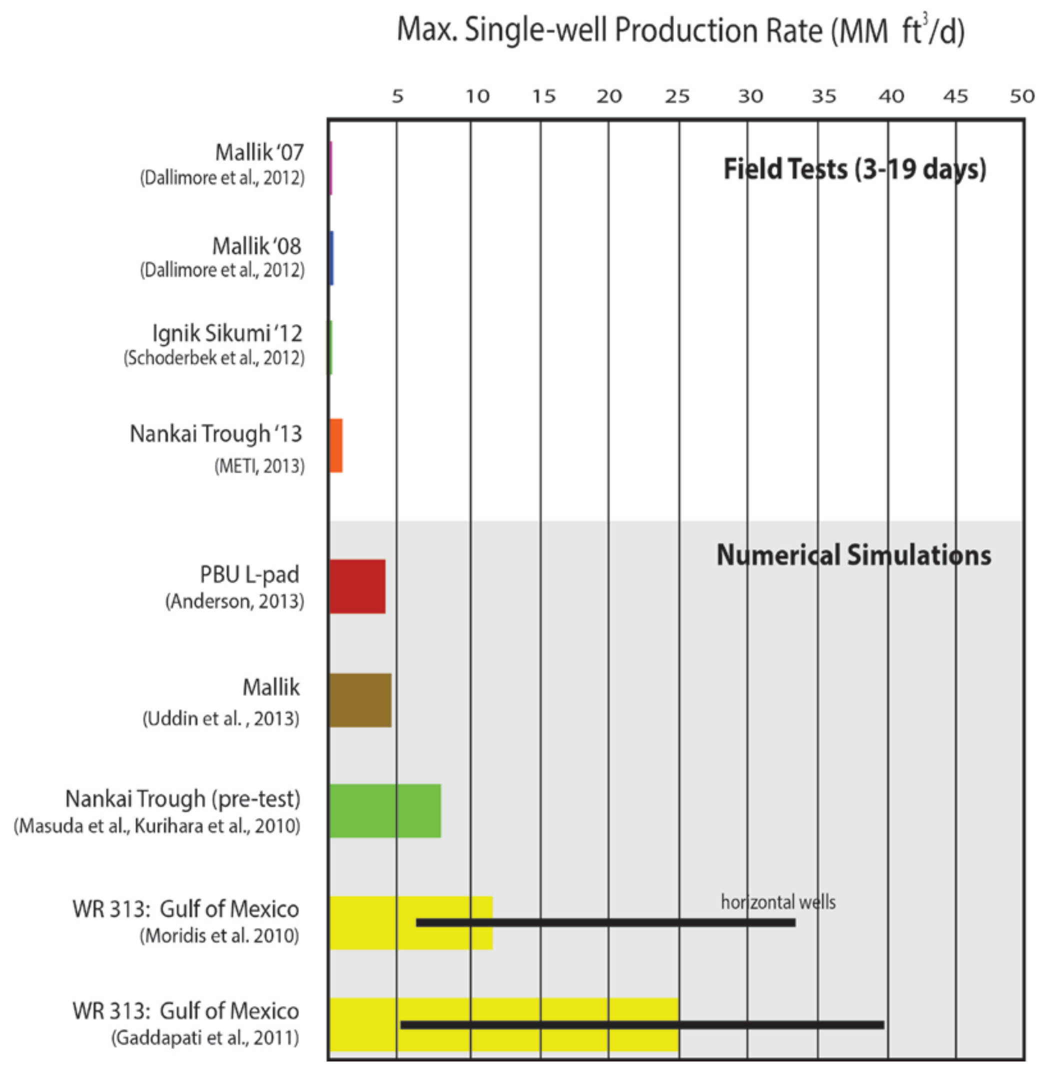
700 mcf/d



Production Rate

Numerical simulations give promising results

- Field Tests
  - Onshore 60 mscf/d
  - Offshore 700 mscf/d
- Simulation - Onshore
  - ~4,000 mscf/d
- Simulation - Offshore
  - Offshore: up to 40 mmscf/d
  - Well design, Geology, etc…
- Required for Viability
  - Varies with region, costs, etc
  - The modeled rates are favorable



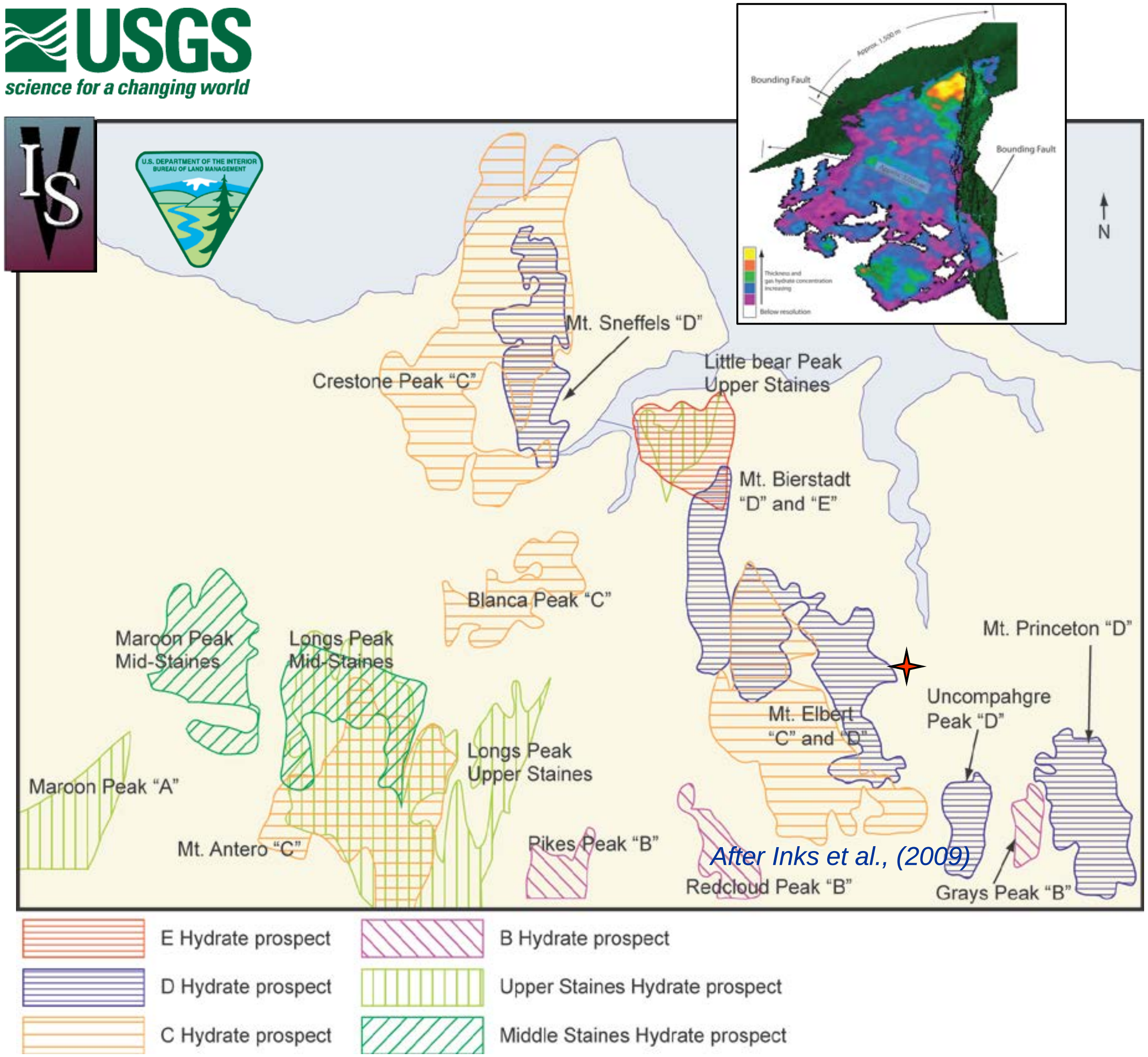
Production Challenges

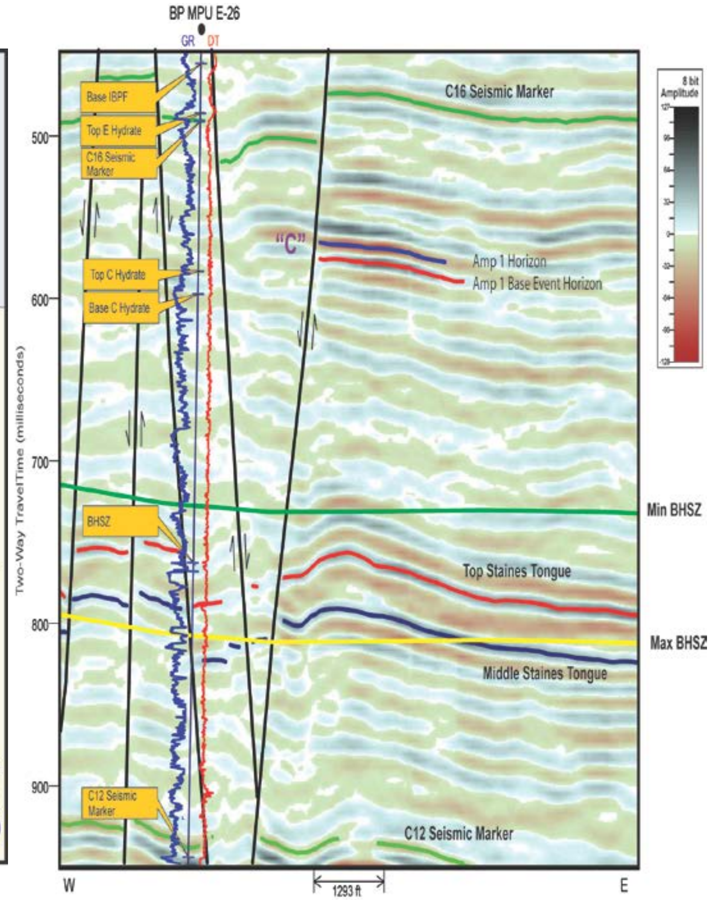
The most favorable accumulations

- **Wells will be complex**
  - Deepwater
  - Horizontal
  - Cold → flow assurance
  - Low-pressure → artificial Lift
  - Effective and immediate intervention during shut-in
  - Handling and disposal of produced water (not fresh)
  - Endothermy → periodic wellbore maintenance
- **Wells will be shallow (sub-seafloor)**
  - Unconsolidated sediments and seals
  - Likely to be fine-grained sands with substantial fines intermixed or in close proximity
  - Effective sand control -- subsidence
  - Reservoir (prior to production) has lower K than the seals

Mt Elbert Gas Hydrate Stratigraphic Test Well (2007)

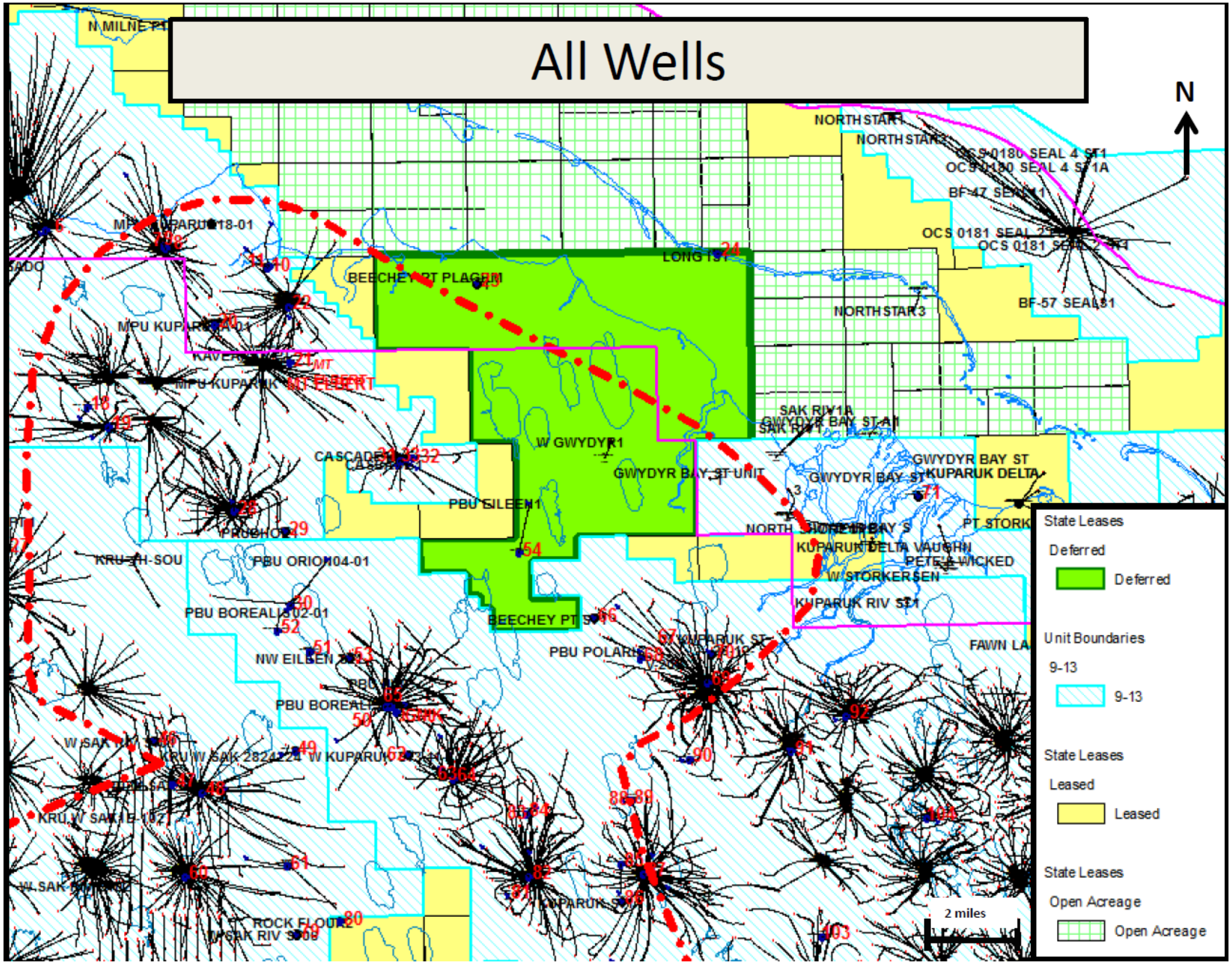
Drilling tested a previously undrilled fault-block (BPXA)





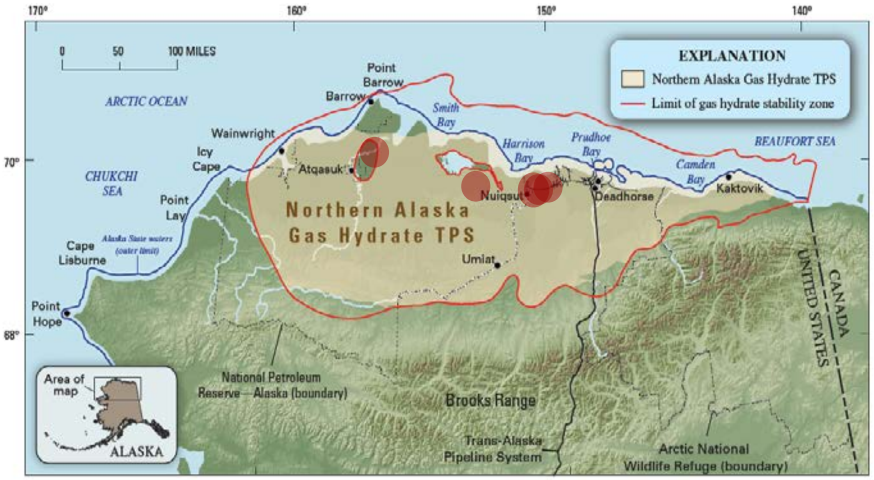
Alternative Test Site Evaluations (2014)

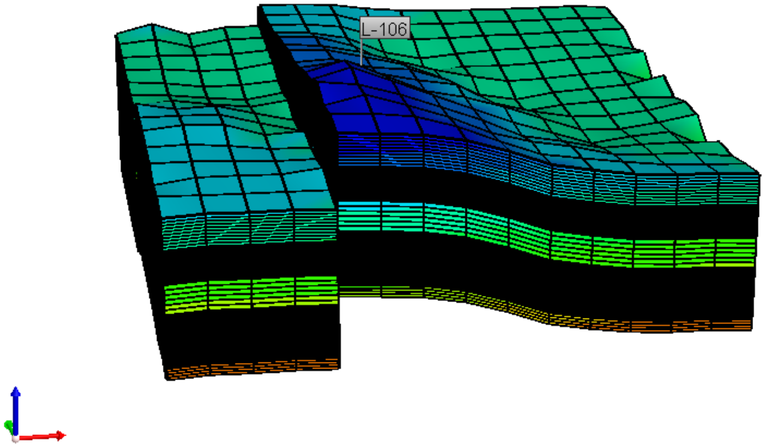
Unleased and set-aside state lands (AKDNR, USGS)



Ongoing Projects

- **IA DOE → USGS**
  - USGS contributions to effort in Alaska
- **IA USGS→DOE**
  - Part of larger USGS study funded by BLM
  - Production models for five "type" areas
  - Life Cycle Assessment
  - Subsidence/other env costs
  - Costs/Economics
- **NL FWPs**
  - LBNL,PNNL, NETL to maintain best possible simulation capability for potential ANS test sties
- **CA Texas A&M and Ga Tech**
  - Coupled geomechanical-reservoir simulation model

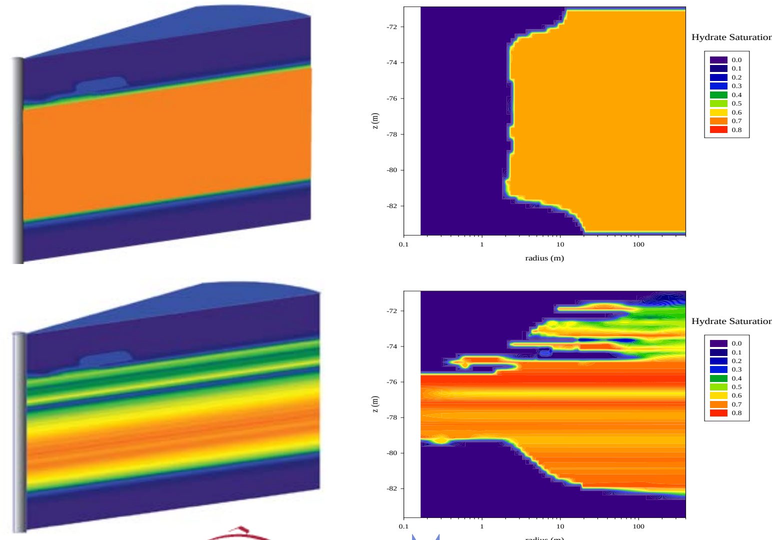


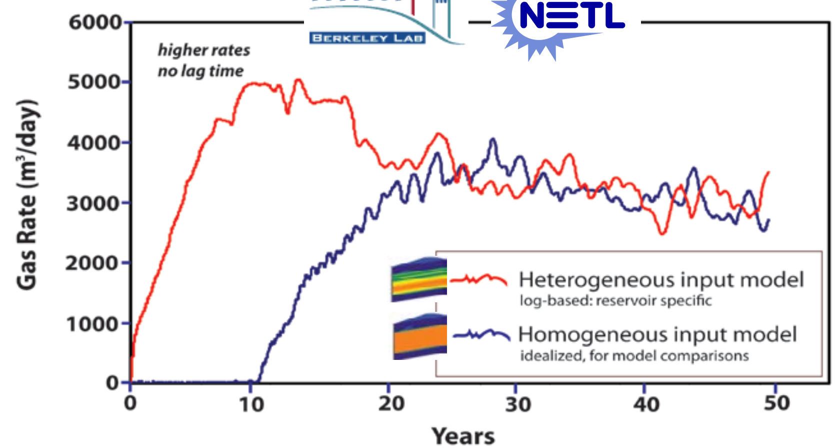


GH Production Modeling

Field data enables more complex models

- Early 2000s
  - Low rates, long lag times, large cumulatives but very long production profiles
- Today
  - High sensitivity to reservoir quality, heterogeneity, temperature
  - Intriguing rates obtainable in certain settings: 1s to 10s MMcf/d with minimal lag times, short production profiles
  - Recoverability theoretically high (60-85%)





Marine Resource Characterization

Began with focus on Gulf of Mexico drilling hazards, JIP Leg I (2005)

- First hydrate drilling and sampling in the Gulf of Mexico
- First measurement of physical properties of core while retained under natural pressures
- Confirmed ability to characterize low-saturation hydrates pre-drill
- Confirmed ability to safely drill low-saturation, deep-water, gas hydrates
- With goals achieved, NETL successfully transitioned the JIP to resource evaluation


U.S. Department of Energy • Office of Fossil Energy • National Energy Technology Laboratory

Fire in the Ice

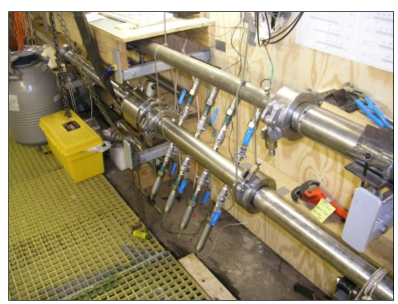
Vol. 8, Iss. 1 — Methane Hydrate Newsletter

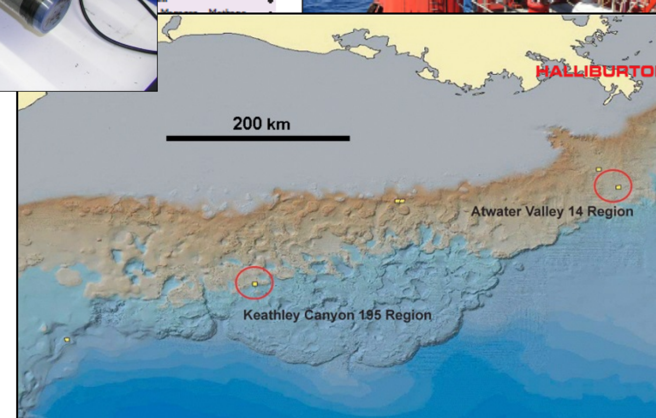
NETL

Safe Drilling in Gas-Hydrate Prone Sediments: Findings from the 2005 Drilling Campaign of the Gulf of Mexico Gas Hydrates Joint Industry Project (JIP)

By Richard Birchwood, Sheila Noeth (DCS Geomechanics Group, Schlumberger), & Emrys Jones (Chevron)

In 2005, the DOE-Chevron Gas Hydates JIP conducted a drilling, logging, and coring expedition designed to address concerns related to the safe drilling of deepwater oil and gas wells through gas-hydrate bearing strata.





BOEM Gulf of Mexico Assessment: (2008)

Mean estimate ~6,700 tcf GIP in Sand Reservoirs

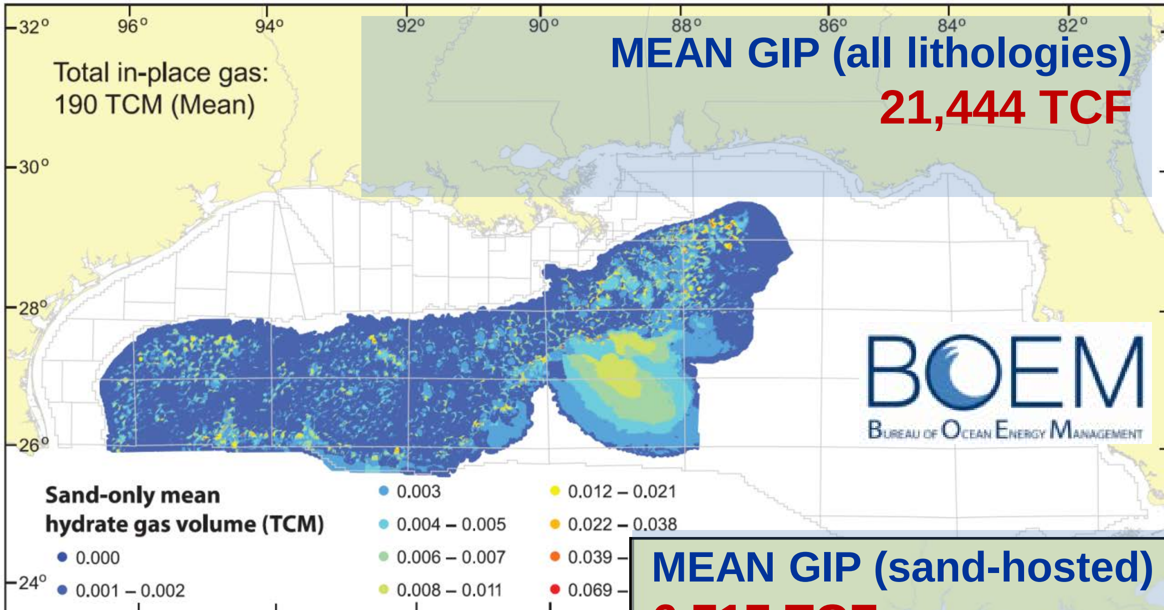
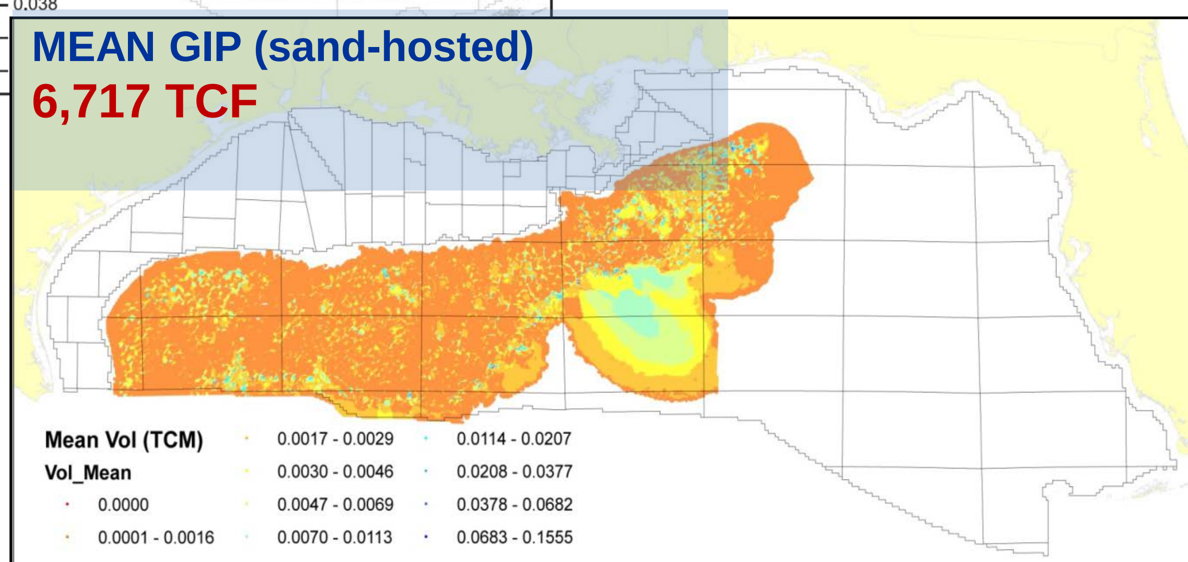
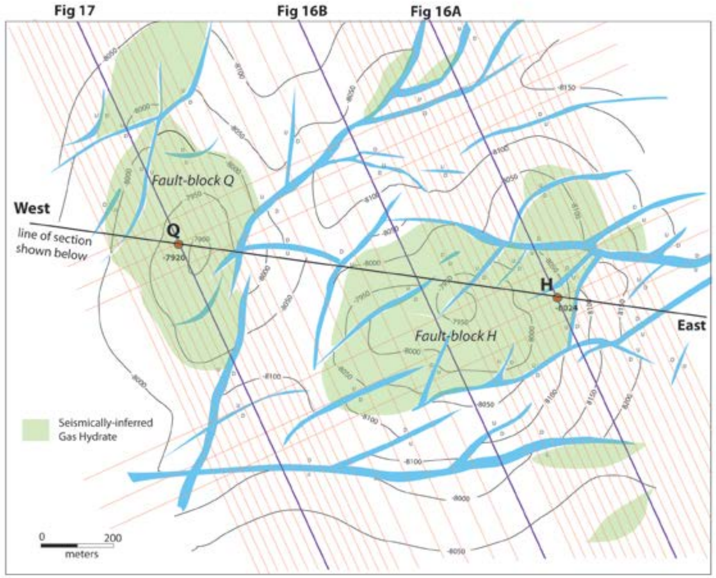


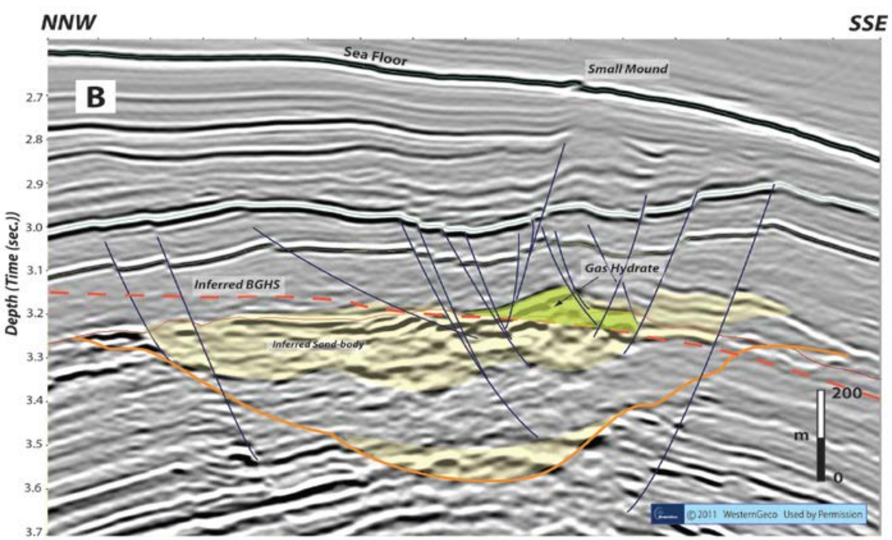
Table 1. BOEM in-place gas hydrate resource volumes for the Atlantic, Pacific, and Gulf of Mexico Outer Continental Shelf. Units are trillion cubic feet; 1 x 10^{12} ft^3. Resource volumes have not been subject to geologic risk.

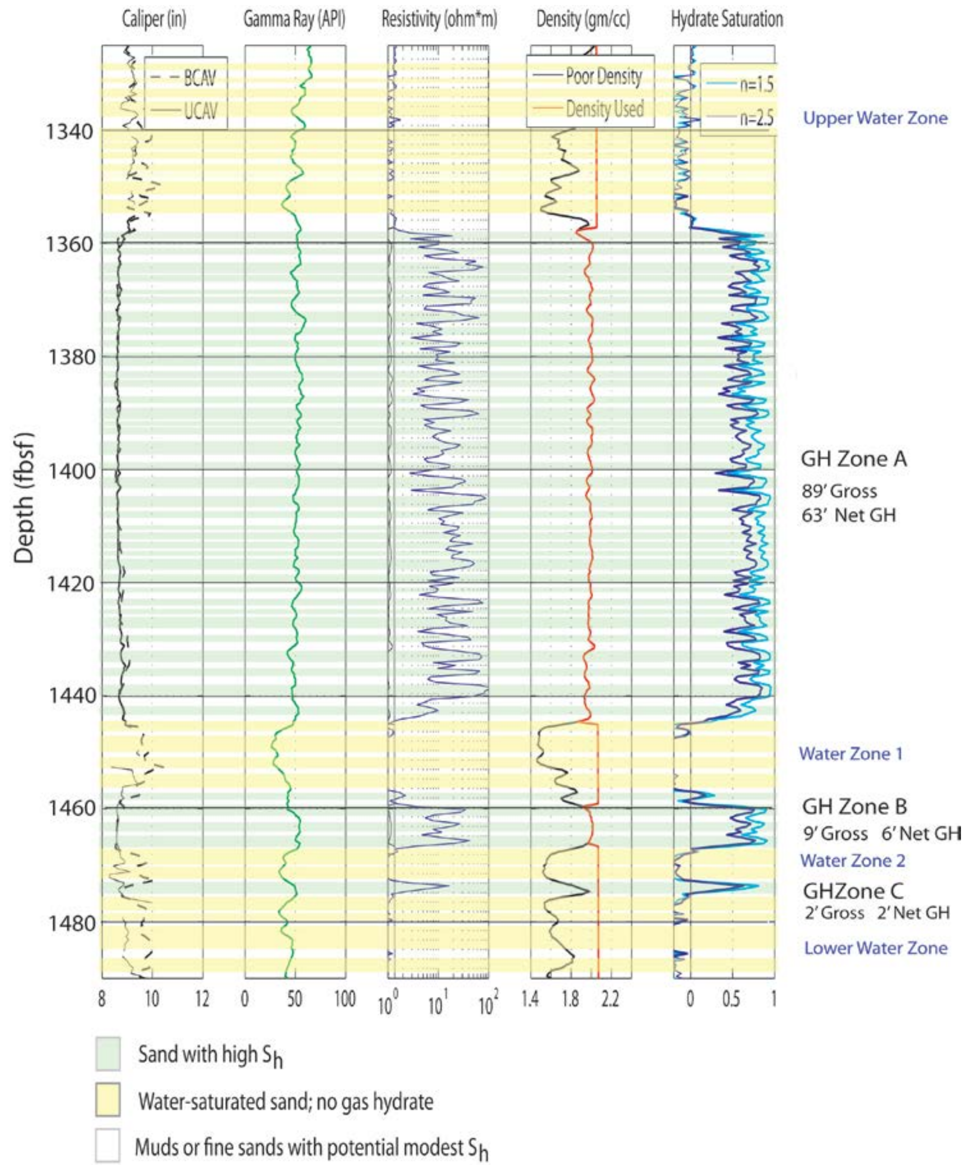
Region	In-Place Gas Hydrate Resources Gas (Tcfg)		
	95%	Mean	5%
Atlantic OCS	2,056	21,702	52,401
Pacific OCS	2,209	8,192	16,846
Gulf of Mexico OCS	11,112	21,444	34,423



Gulf of Mexico: GC955

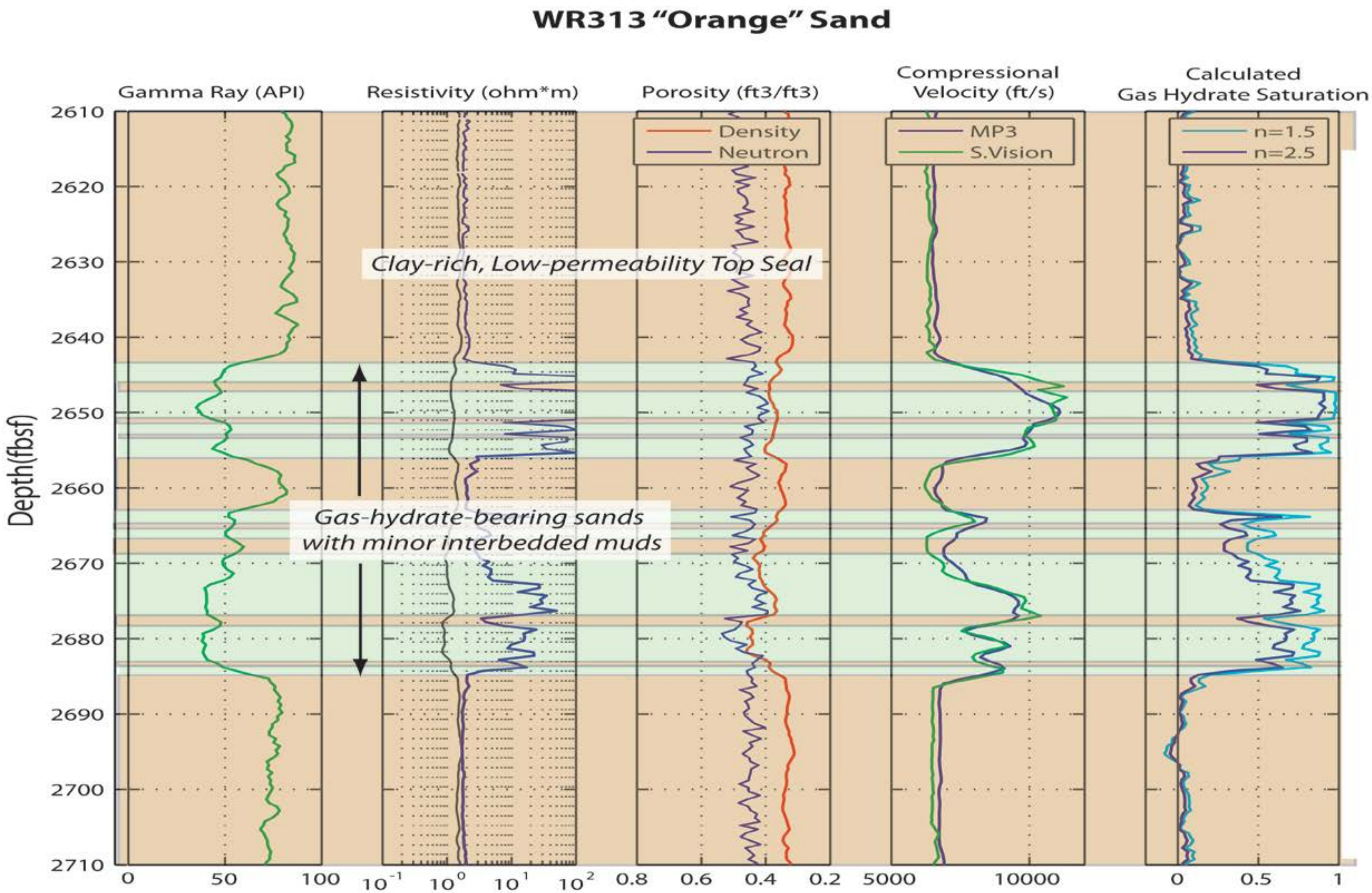






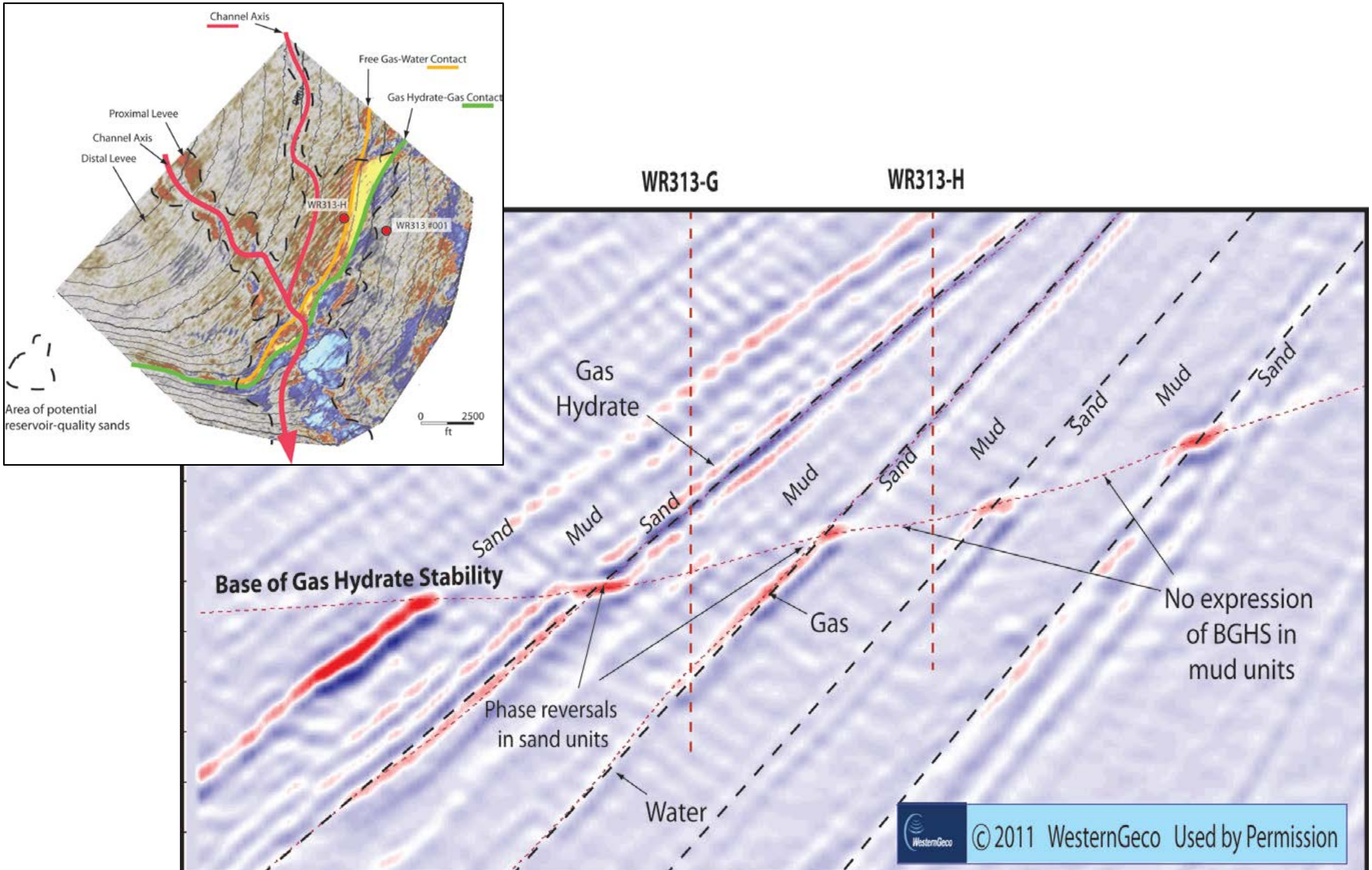
DOE/CVX JIP: GOM Gas Hydrates Exploration (2007-2009)

4 of 7 GOM exploration wells discover gas-hydrate bearing sands

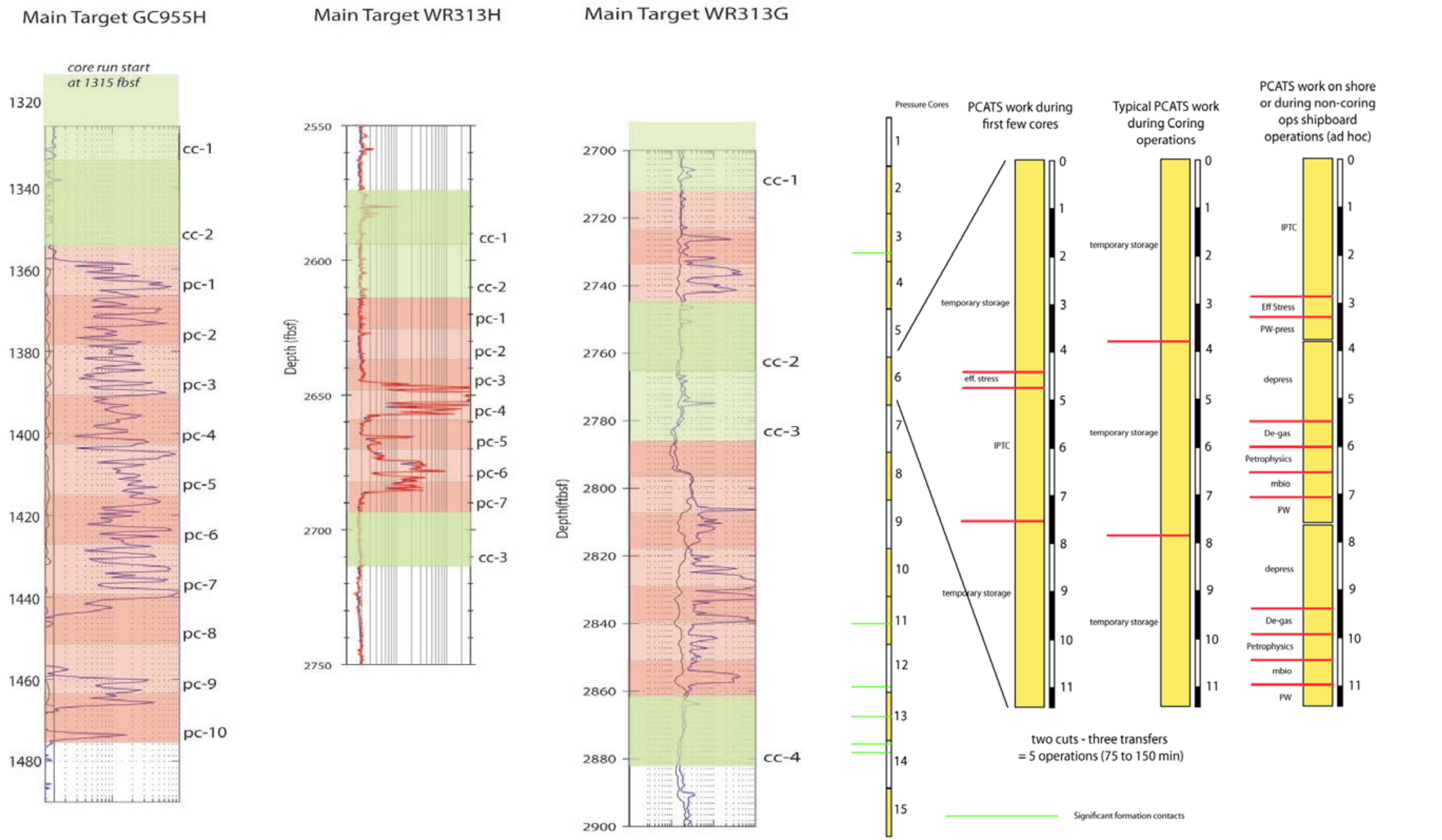


Chevron NETL USGS BOEM AOA Geophysics Inc. Reliance Statoil Halliburton Total ConocoPhillips Korea National Oil Corporation JOGMEC Schlumberger Lamont-Doherty Earth Observatory

Walker Ridge 313 Geophysical Prospecting



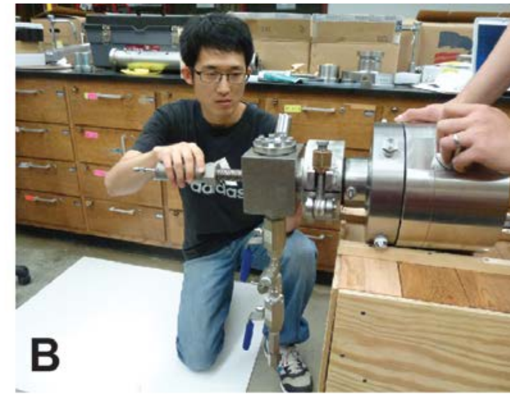
Nominal Gulf of Mexico Coring Plan (2010-11)

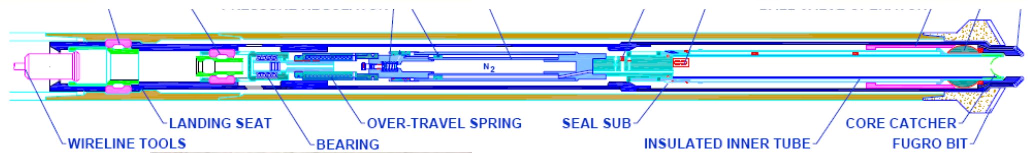


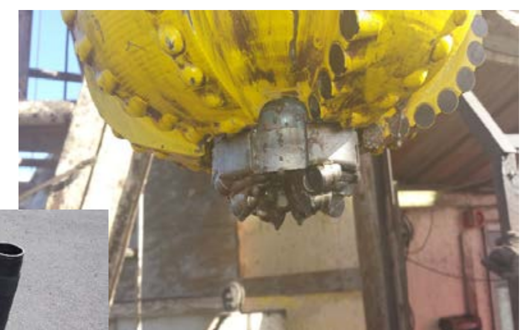
Gulf of Mexico JIP: Advance Pressure Coring Capabilities

Current Activities

- Synthesized Laboratory samples not sufficient to understand the nature of marine gas hydrate. In situ data collection is limited
- Off-the-shelf coring equipment can not deliver analyzable samples to the surface
- JIP is develop coring and core analyses equipment to enable future field data collection in resource-quality settings
- 2006 collaborations with India
- 2013 collaborations with Japan in design and field testing of components
- Pressure core tool failed several field tests at Catoosa site, November 2013. Expert group assembled to develop plan to repair
- Chevron has determined to end contract at end March, 2014.







Plans for Marine GH Characterization

- Ongoing G&G projects with Ohio St., Ok St., Fugro, UT
- New (FY13) project with Ga. Tech to develop borehole tool for in situ measurement of sediment geomechanical properties
- Conduct marine coring+ program planning workshop with Fugro, USGS, AAI, Geotek, etc…
- Opportunities
  - *East Coast LWD Exploration - further inform BOEM assessment*
  - *Core sample acquisition/analysis from confirmed GOM reservoirs*
- Expand model to include geotechnical/academic drill ships.

US Atlantic Margin

Mean Estimate of ~15,785 tcf in Sand Reservoirs

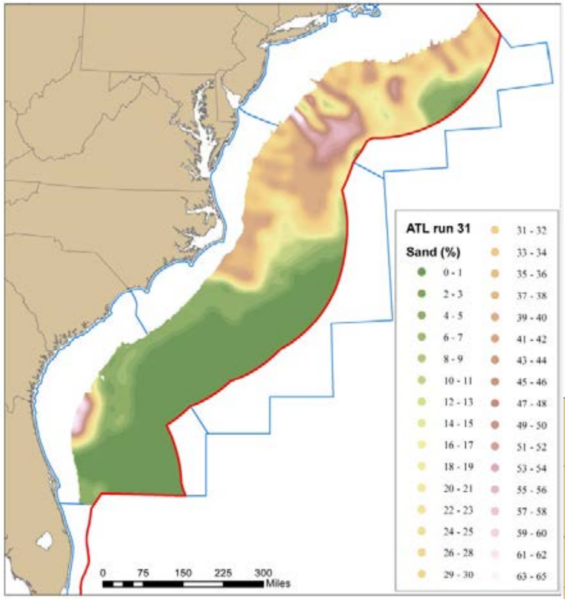


Figure 8. *Sand distribution map spatial input, reported as a percent of the upper 2000 ft of stratigraphic section.*

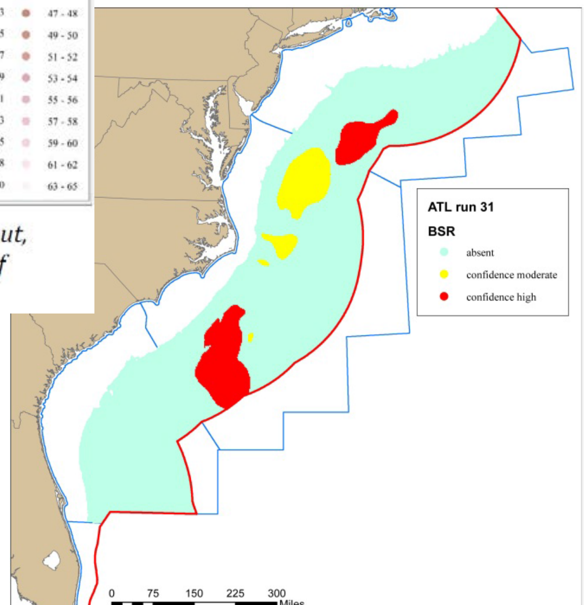
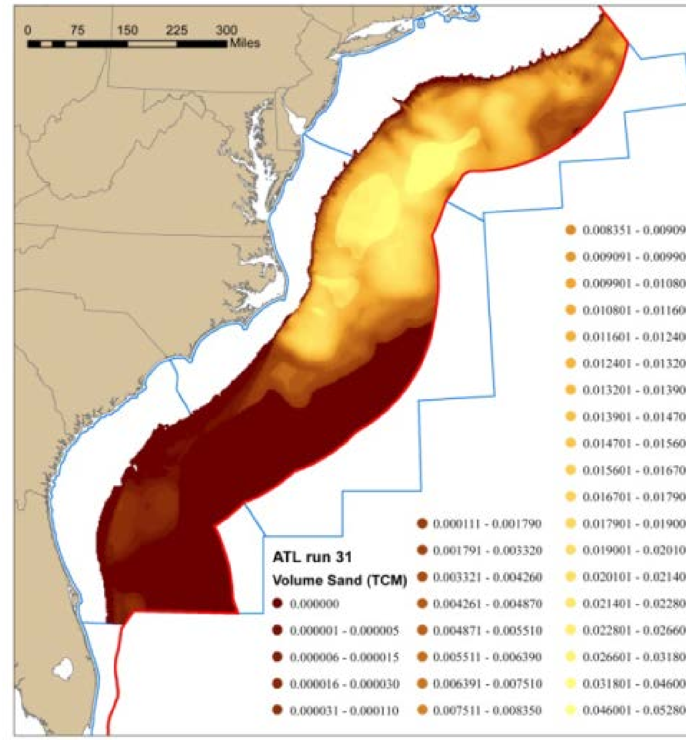


Figure 9. *Bottom Simulating Reflector (BSR) distribution spatial input.*



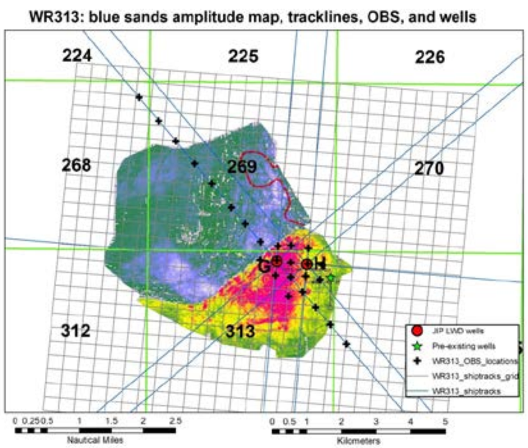
MEAN GIP (all lithologies) 21,702 TCF

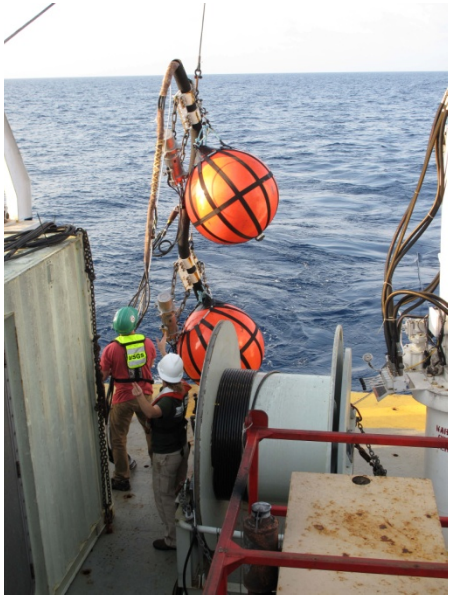
GIP (sand) 15,785 TCF

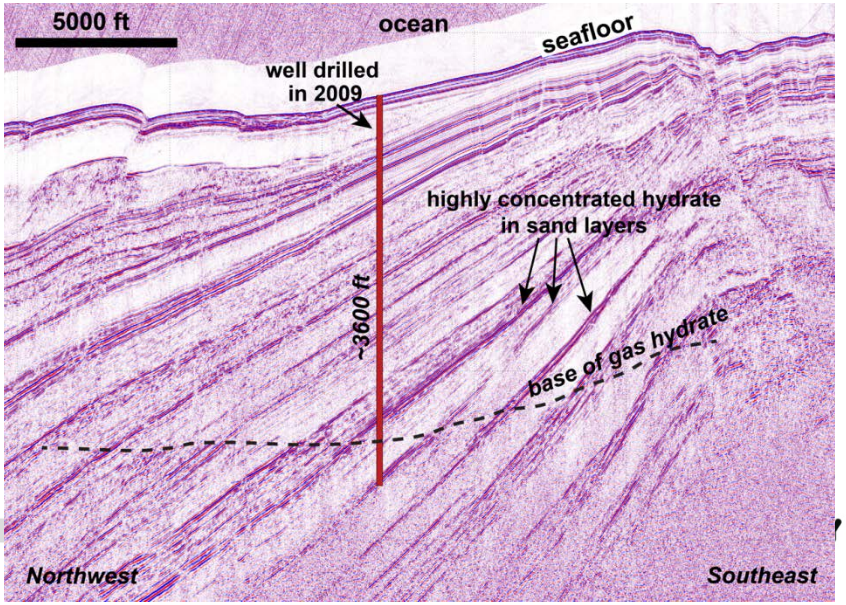
FY13 Interagency: GoM 2D and OBS Seismic

Conducted by USGS; Planned and co-funded by USGS, DOE, and BOEM

- Collect adv. seismic at JIP Leg II sites – not possible under CA due to new DOE NEPA guidance
- USGS has collected 2D (pseudo 3D) and OBS
- First OBS at sites with known concentrated hydrate and extensive log calibration data.
- Improved interpretation of detailed architecture at each site: guidance to future coring programs
- Insight into GH exploration using V_s in addition to traditional V_p data
- Completed Spring, 2013 from *RV Pelican*
- USGS ~$650k; DOE ~$650k; BOEM ~$175k



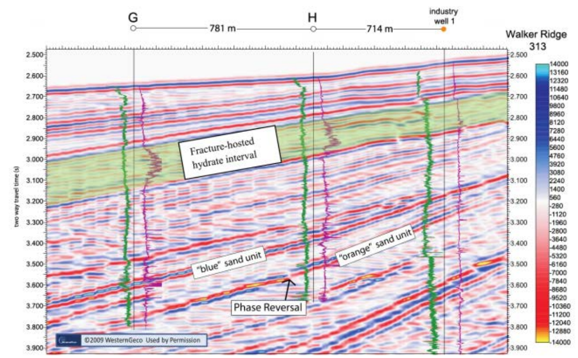


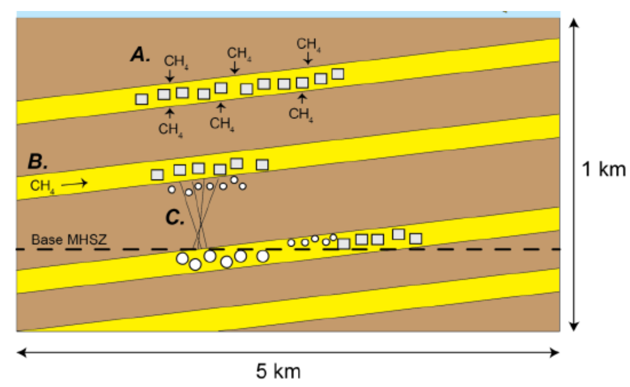


FY13 New Project: The University of Texas - Austin

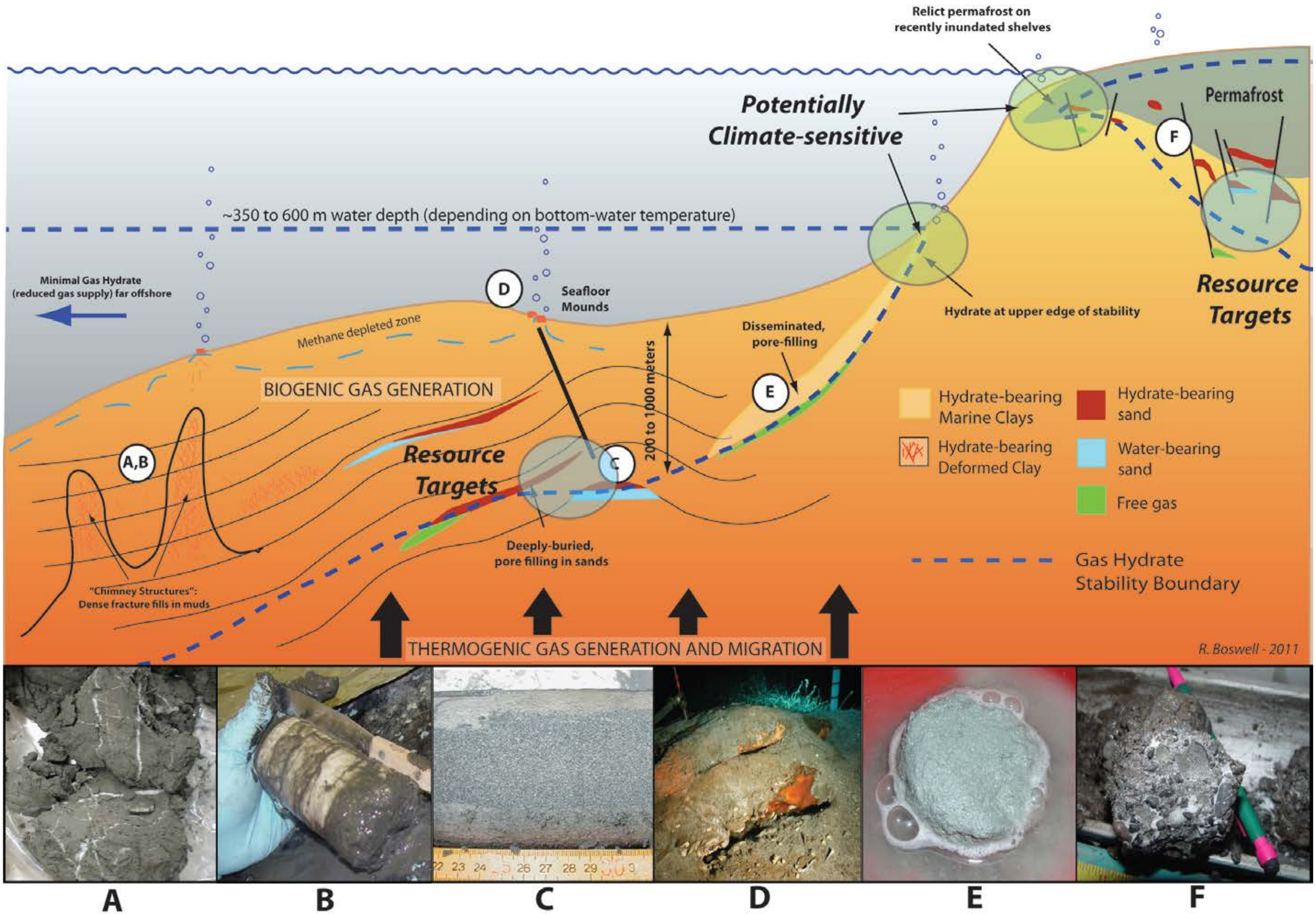
Methane Transport and Hydrate Accumulation in Coarse-Grained Reservoirs

- Global hydrate models assume all methane is locally-sourced. Even the recent BOEM GoM assessment assumed primarily bio-genic gas. However, JIP Leg II drilling suggested significant sourcing from deeper sources.
- UTA will model various modes of gas sourcing/migration under the constraints of the WR313 geology and drilling observations
- Gain insight on what is needed to create resource-relevant accumulations (dissolved or free gas; local or distant gas).
- Gain insight on the time dimension of methane hydrate reservoir development
- Inform future assessments.
- **Partners:** The Ohio State University, Columbia University – Lamont Doherty Earth Observatory



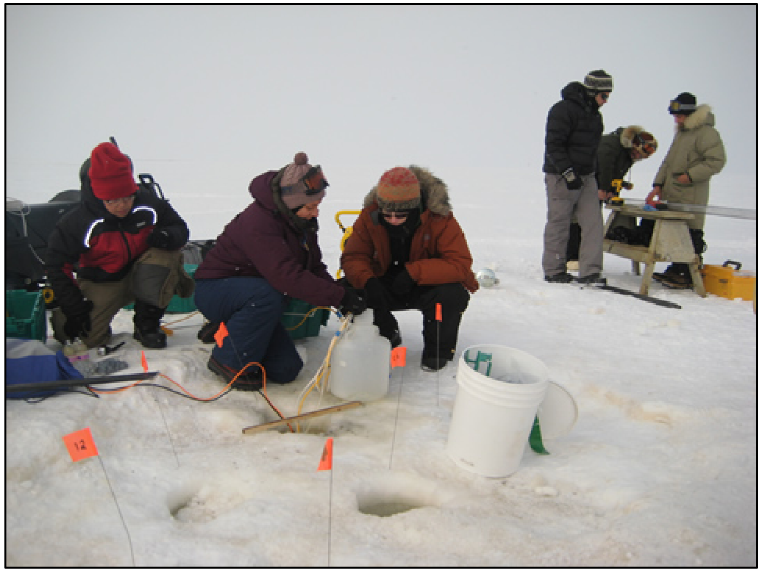


Gas Hydrate in the Global Environment



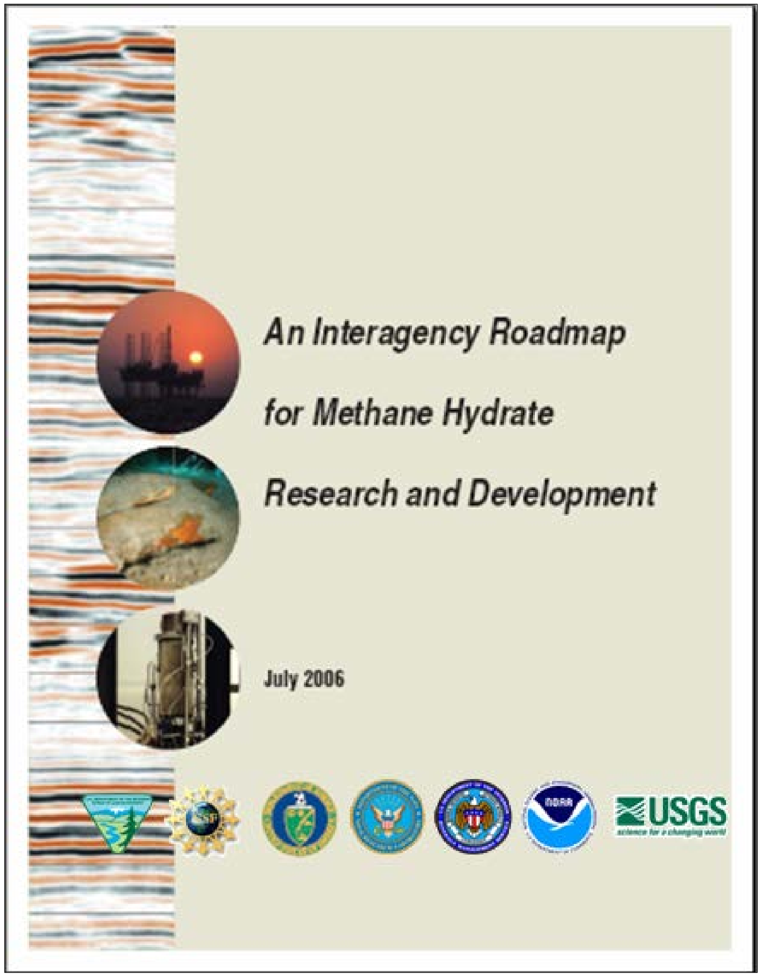
Plan for Gas Hydrate – Global Environment

- **DOE has supported this research since ~2006**
  - …it is stipulated in the MHR&D Act
  - …it is a recognized science need that the cooperating federal agencies cannot fund.
  - …it is an opportunity to demonstrate integrated consideration of all public issues related to a potential new resource prior to the "land rush"
  - …serious scientific bang for the buck



- **Three high-value projects awarded in FY13 have enabled a broad portfolio that is accessing large external resources**
  - Alaska (shelf and slope) w/ USGS, Scripps, SMU
  - Norway (slope) w/ Oregon St.
  - U.S. East Coast w/ MIT, USGS, UNH
  - U.S. West Coast w/ U. Washington
- **Current portfolio could support determination re the nature of potential near-term GH/GCC linkages**

Interagency R&D Roadmap

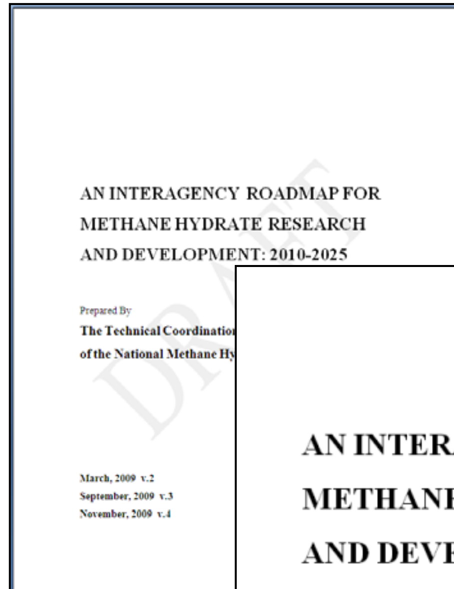


An Interagency Roadmap

for Methane Hydrate

Research and Development

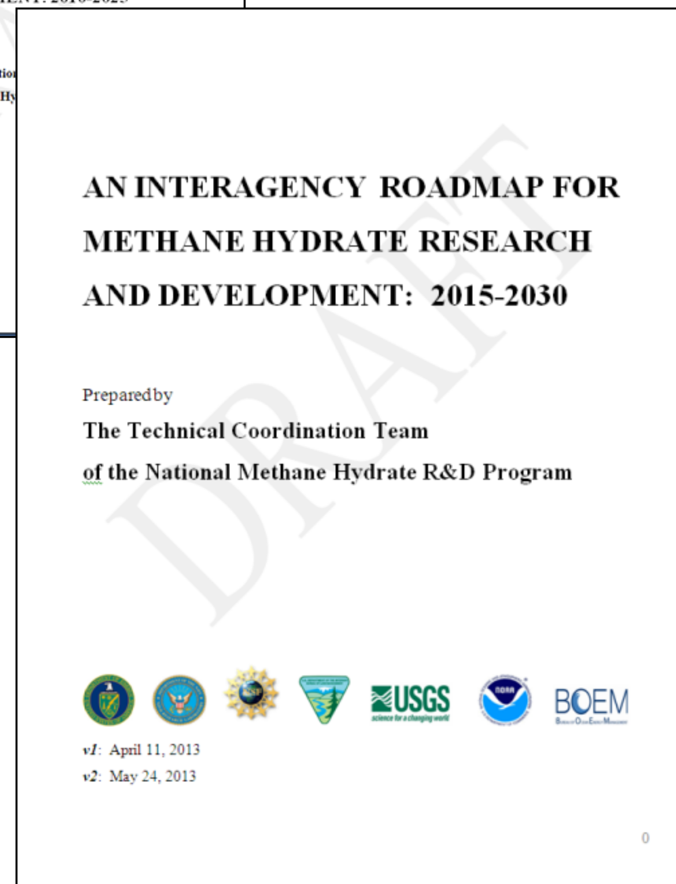
July 2006



AN INTERAGENCY ROADMAP FOR
METHANE HYDRATE RESEARCH
AND DEVELOPMENT: 2010-2025

Prepared By
The Technical Coordinatio
of the National Methane Hy

March, 2009 v.2
September, 2009 v.3
November, 2009 v.4



AN INTERAGENCY ROADMAP FOR
METHANE HYDRATE RESEARCH
AND DEVELOPMENT: 2015-2030

Prepared by
The Technical Coordination Team
of the National Methane Hydrate R&D Program

v1: April 11, 2013
v2: May 24, 2013

0

Methane Hydrate Fellowship

9 selected since 2007

Evan Solomon (Scripps)
Now at U. Washington

Ann Cook (Columbia)
Now at Ohio St.

Jeffrey Marlow (Cal Tech)
Active NETL-NAS Fellow

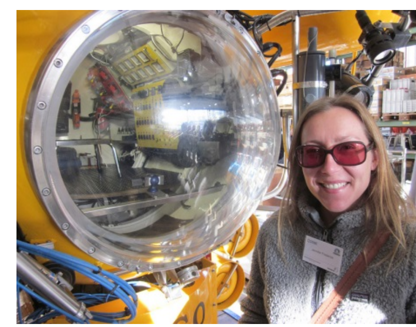
Laura Lapham (FSU)
Now at U. Maryland

Hugh Daigle (Rice)
Now at U. Texas

Rachel Wilson (FSU)
Active NETL-NAS Fellow

Laura Brothers (USGS)
Now at USGS

Monica Heinz (UCSB)
Now with ARCADIS



Jennifer Frederick (UC Berkeley) Active at DRI

RESEARCH ASSOCIATESHIP PROGRAMS
Fellowships Office
THE NATIONAL ACADEMIES

Outreach

MARINE AND PETROLEUM GEOLOGY
Thematic Set on
Resource and hazard implications of gas hydrates in the Northern Gulf of Mexico: Results of the 2009 Joint Industry Project Leg II Drilling Expedition
Guest Editors
Timothy S. Collett
Ray Boswell
Thematic Set on
Guest Editors
Ray Boswell
Tim Collett
Brian Anderson
Thematic Set on
Guest Editors
Carolyn Ruppel
Ray Boswell
Emrys Jones

the ENERGY lab
Fire in the Ice
Vol. 9, Iss. 3
Methane Hydrate Newsletter
NETL
Joint Industry Project Leg II Discovers Rich Gas Hydrate Accumulations in Sand Reservoirs in the Gulf of Mexico
Ray Boswell, Tim Collett, Dan McConnell, Matt Frye, Bill Shedd, Stefan Mrozewski, Gilles Guerin, Ann Cook, Paul Godfriaux, Rebecca Dufrene, Rana Roy, and Emrys Jones
the ENERGY lab
Fire in the Ice
2013 Vol. 13, Issue 2
Methane Hydrate Newsletter
NETL
CONTENTS
Japan Completes First Offshore Production Test
Japan Completes First Offshore Methane Hydrate Production Test—Methane Successfully Produced from Deepwater Hydrate Layers
To prove the applicability of depressurization as a feasible method for producing methane from hydrates in deepwater sediments, Japan Oil, Gas, and Metals National Corporation (JOGMEC) conducted the first offshore methane hydrate production test off the coast of Honshu Island this past March, with funding from the Ministry of Economic Trade and

FEATURE STORY
Researching the Climate Change Implications of Methane Hydrates
Since 2001, the U.S. Department of Energy (DOE), through its National Energy Technology Laboratory (NETL), has been working with industry and academia to assess the potential of methane hydrates as a future source of natural gas.
Production Method for Methane Hydrate Sees Scientific Success
FROZEN HEAT
A GLOBAL OUTLOOK ON METHANE GAS HYDRATES
UNEP
G·R·I·D

the ENERGY lab
Where energy challenges converge and energy solutions emerge
Site Map
GO>
ABOUT NETL
ONSITE RESEARCH
TECHNOLOGIES
Oil & Natural Gas Supply
Deepwater Technology
Enhanced Oil Recovery
Gas Hydrates
Natural Gas Resources
The National Methane Hydrates R&D Program
2012 Ignik Sikumi gas hydrate field trial
August 2, 2013 - Project operations are complete. Read the Final Project Technical Report [PDF-44.1MB]
February 19, 2013 - Data from the 2011/2012 field test is now available! Click here to access data.
Download 2011/2012 Field Test Data
Ignik Sikumi #1 "Fire in the Ice" Video
Project Background
Participants
Ignik Sikumi Well Review
CO2-CH4 Exchange Overview
the ENERGY lab
Where energy challenges converge and energy solutions emerge
The National Methane Hydrates R&D Program
Methane Hydrate Reservoir Simulator Code Comparison Study
An International Effort to Compare Methane Hydrate Reservoir Simulators

A Global Gas Hydrate Assessment

UN Environmental Programme (scientific editors Boswell, Dallimore, Waite)

- **Illustrated, comprehensive review of gas hydrate science**
  - hard copy and web product
  - designed for national resource policy decision-makers, media, public
  - coordination by UNEP-Grid
  - steering committee from participating groups
  - www.methanegashydrates.org
- **Two Books - Seven Chapters**
  - GH science
  - GH in global carbon cycle
  - GH and climate change
  - GH in global energy systems
  - GH resources/exploration
  - GH production technologies
  - GH societal implications

World Wildlife Fund
http://www.worldwildlife.org

KIGAM
http://www.kigam.re.kr/

GEOMAR

NETL
http://www.netl.doe.gov/

Statoil
http://www.statoil.com/

USGS
http://energy.usgs.gov/other/gashydrates/

Gas Hydrates on the Norway-Barents Sea-Svalbard margin
http://folk.uib.no/nglbh/GANS/index.html

Schlumberger
http://www.slb.com/

Canadian Polar Commission
http://www.polarcom.gc.ca/

Geological Survey of Canada
http://gsc.nrcan.gc.ca/
The Geological Survey of Canada, a part of the

JOGMEC
http://www.jogmec.go.jp/english/index.html

GFZ German Research Centre for Geosciences
http://www.gfz-potsdam.de/

Directorate General of Hydrocarbons, India
http://www.dghindia.org/