Direct Seismic Indicators of Gas Hydrates in the Walker Ridge and Green Canyon Areas, Deepwater Gulf of Mexico*

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Abstract

This article presents seismic evidence for the presence of free gas, gas hydrates, and bottom simulating reflectors (BSRs) in the sedimentary mini-basins of the Green Canyon (GC) and the Walker Ridge (WR) protraction areas in the deepwater Gulf of Mexico. BSRs correspond to the base of the gas-hydrate stability zone (BHSZ). The BSRs result from an acoustic impedance contrast between hydrate-cemented sediments within the gas hydrate stability zone (GHSZ) and free gas trapped in the sediments beneath the BHSZ (Shipley et al., 1979). BSRs observed on pre-stack time/depth-migrated 2D and 3D reflection seismic data are interpreted to be underlain by free gas, indicated by both the high negative seismic amplitudes and the overlying blanking zones. In this study area there is no direct one-to-one relationship between gas hydrate concentration, strong BSRs, and amplitude blanking. After the article by Kou et al. (2007), was published, over 100 BSRs have been interpreted in the deepwater of Gulf of Mexico as three different classes - continuous, discontinuous, and pluming (Shedd et al, 2009). The MMS published the "Preliminary Evaluation of In-Place Gas Hydrate Resources: Gulf of Mexico Outer Continental Shelf" (Frye et al., 2008) based on geological and geophysical mapping and stochastic modeling. In April and May, 2009, DOE - Chevron Joint Industry Project (JIP) Leg II drilled above BSRs at Alaminos Canyon (AC) 21, WR 313 and GC 955 in the Gulf of Mexico and discovered rich gas hydrates. Log analysis indicates that gas hydrates concentrations in some sand reservoirs can exceed 90% (Boswell et al., 2009).

References

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Direct Seismic Indicators of Gas Hydrates in the Walker Ridge and Green Canyon areas, Deepwater Gulf of Mexico

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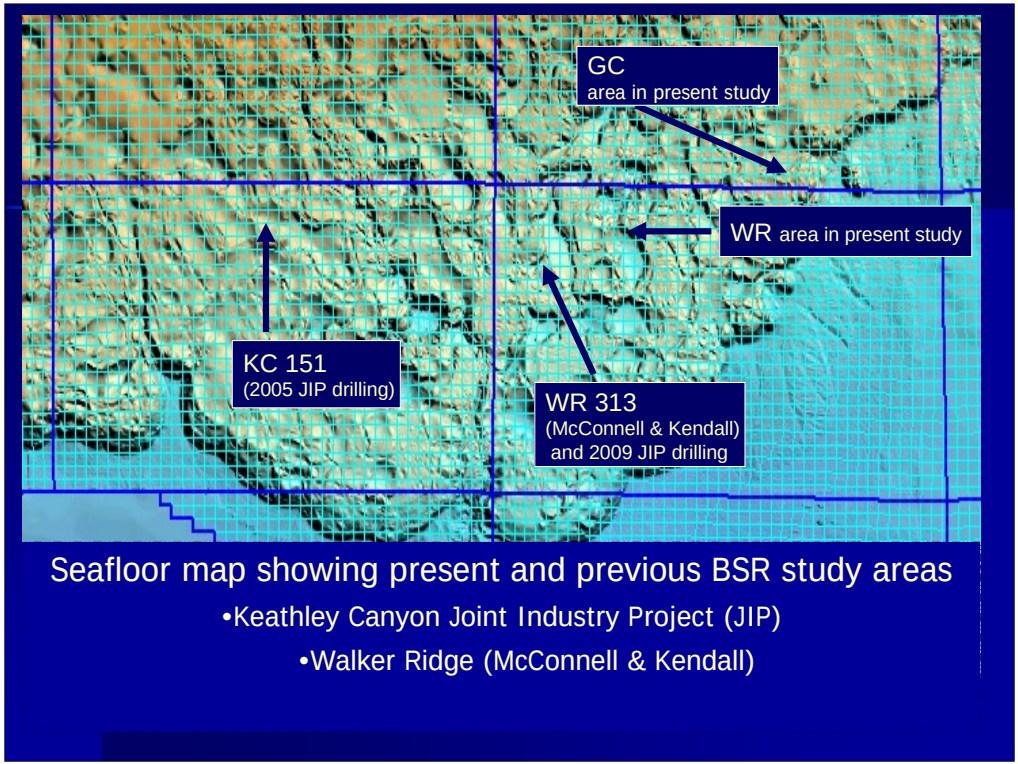
presented at the Deepwater and Ultra Deepwater Reservoirs in the Gulf of Mexico session, AAPG Geoscience Technology Workshop, Houston, Texas, March 17, 2010

modified from W. Wei-Huu Kou, M.A. Smith, A. Ahmed, and R. Kuzela, (Minerals Management Service, Gulf of Mexico Region), Direct seismic indicators of gas hydrates in the Walker Ridge and Green Canyon areas, deepwater Gulf of Mexico, published in Leading Edge, vol. 26, no. 2, February, 2007.

Objectives

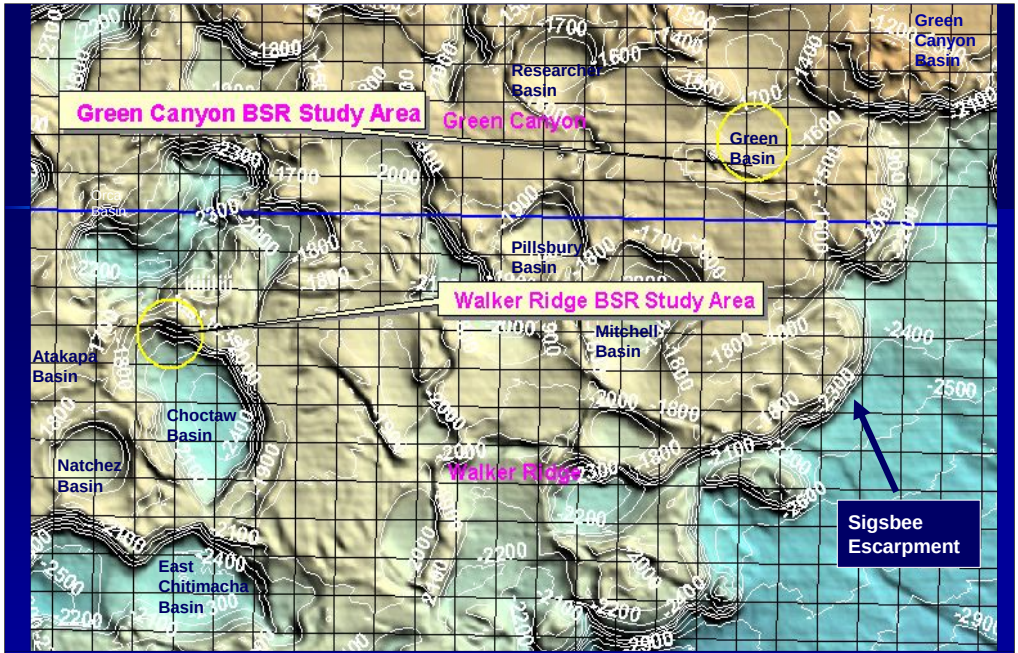
- identify Bottom Simulating Reflectors (BSRs) in the deepwater Gulf of Mexico
- relate BSRs to free gas, blanking and their manifestation on seismic sections
- relate BSR presence to gas hydrate and stratigraphic variations
- discuss recent developments in Joint Industry Project (JIP) gas hydrate exploration and the modeling of gas hydrate resource assessment in the Gulf of Mexico by the MMS



Presenter's Notes:

This slide shows the Walker Ridge and Green Canyon study areas.

It also indicates the Keathley Canyon 151 study area by GIP in 2005 and McConnell and Kendall (2002) study area.



Seafloor rendering showing Walker Ridge and Green Canyon BSR study areas, Gulf of Mexico. Bathymetry is in meters (*Background seafloor rendering courtesy of GEMS*)

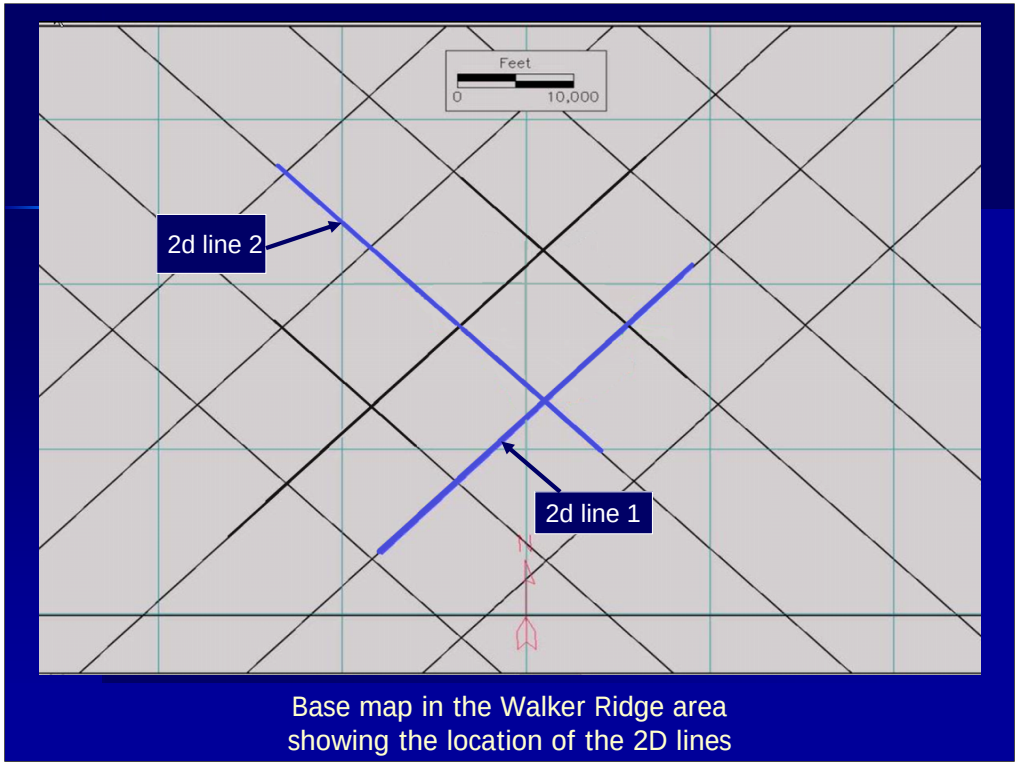
Presenter's Notes:

This slide indicates that the Walker Ridge BSR study area is located on the north corner of Choctaw Basin.

The Green Canyon study is at the south side of the Green Basin.

This area is about 20 miles SW of Green Canyon Basin.

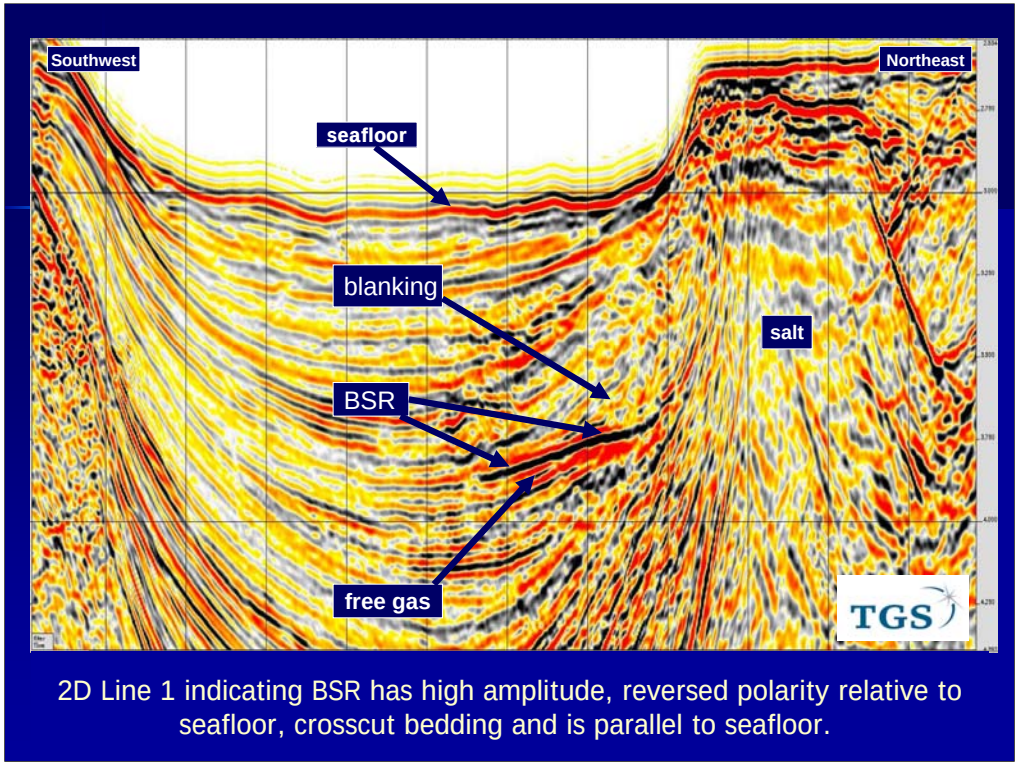
The water depth is about 6000 feet in the Walker Ridge area and 5000 feet in the Green Canyon study area.



Base map in the Walker Ridge area
showing the location of the 2D lines

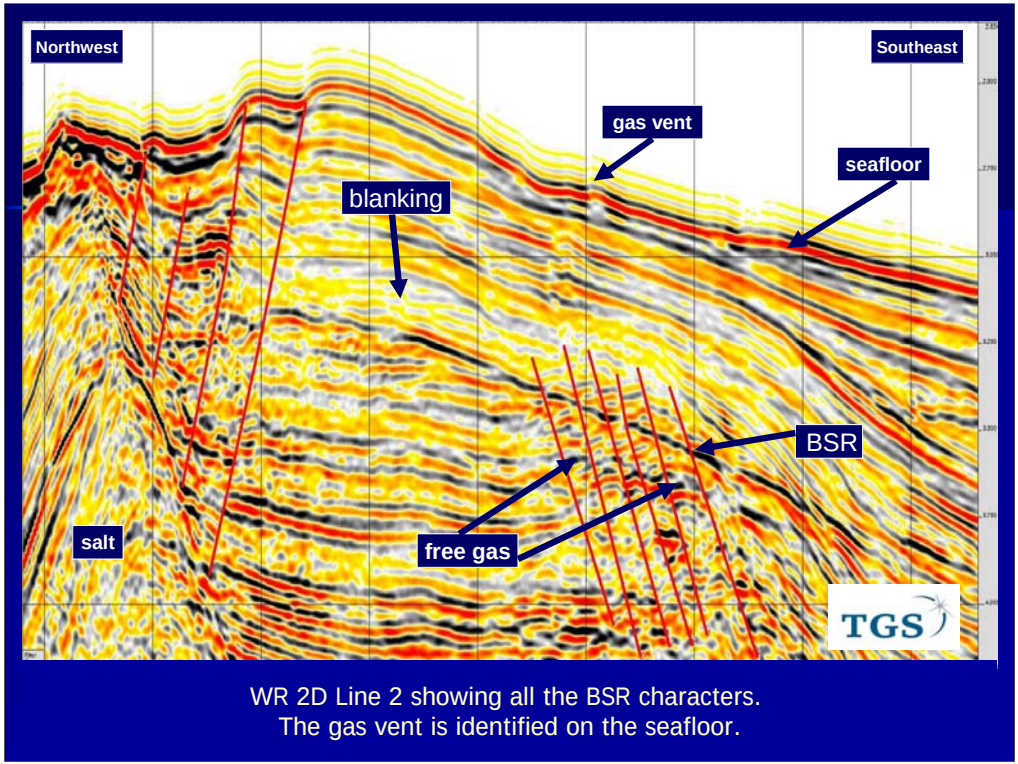
Presenter's Notes:

The locations of the two 2D (blue) seismic cross sections found on the next two slides are shown here.



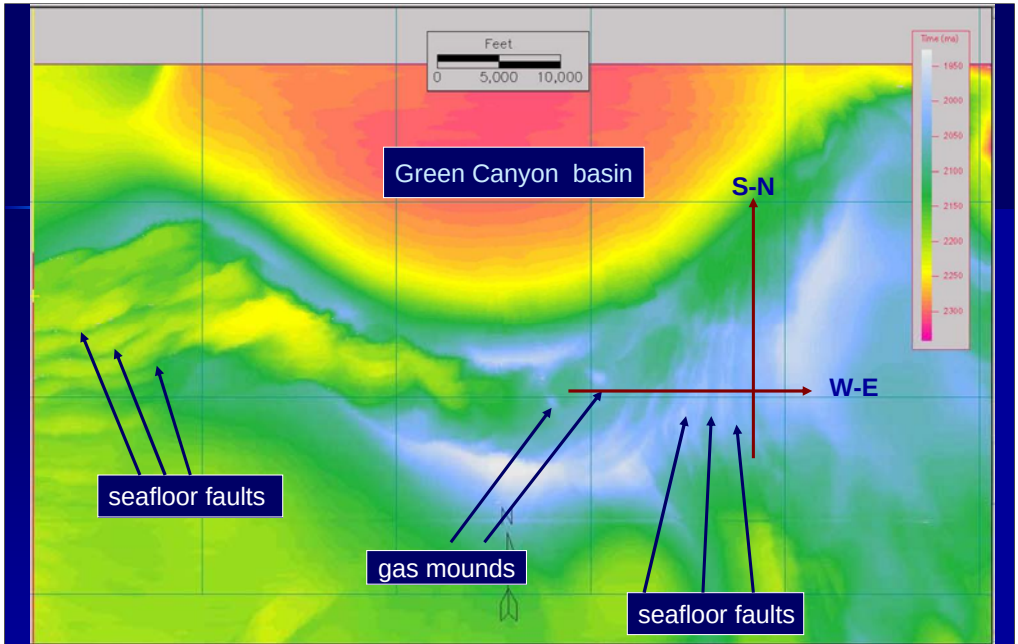
Presenter's Notes:

This is a 2D Line from SW to NE, indicating: strong BSR, free gas underneath, and blanking above the BSR.



Presenter's Notes:

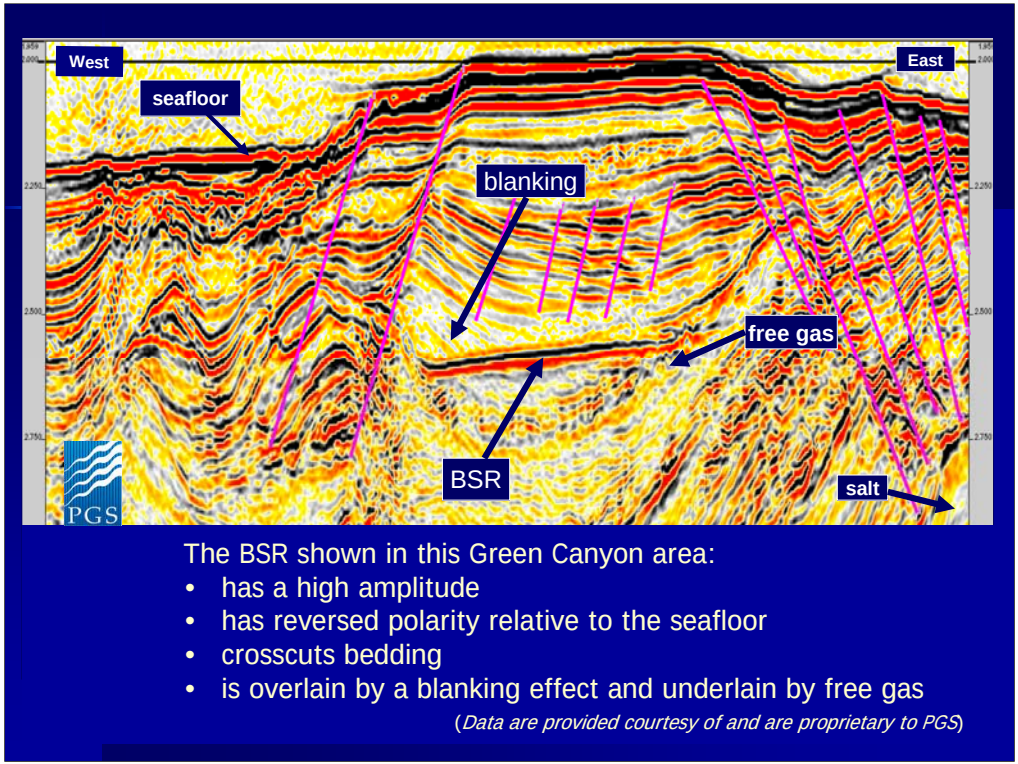
2D Line 2 is perpendicular with the previous 2D Line 1. The BSR cuts faults and reflectors with free gas underneath and blanking above the BSR. A gas vent is on the seafloor of the BSR location. Unfortunately, there is no well near the area; therefore, we cannot tie any well logs to the BSR in the study area.



This seismically-rendered bathymetric map indicates seafloor features in the Green Canyon (GC) BSR study area, derived from 3D time-migrated data, and location of the two seismic cross-sections.

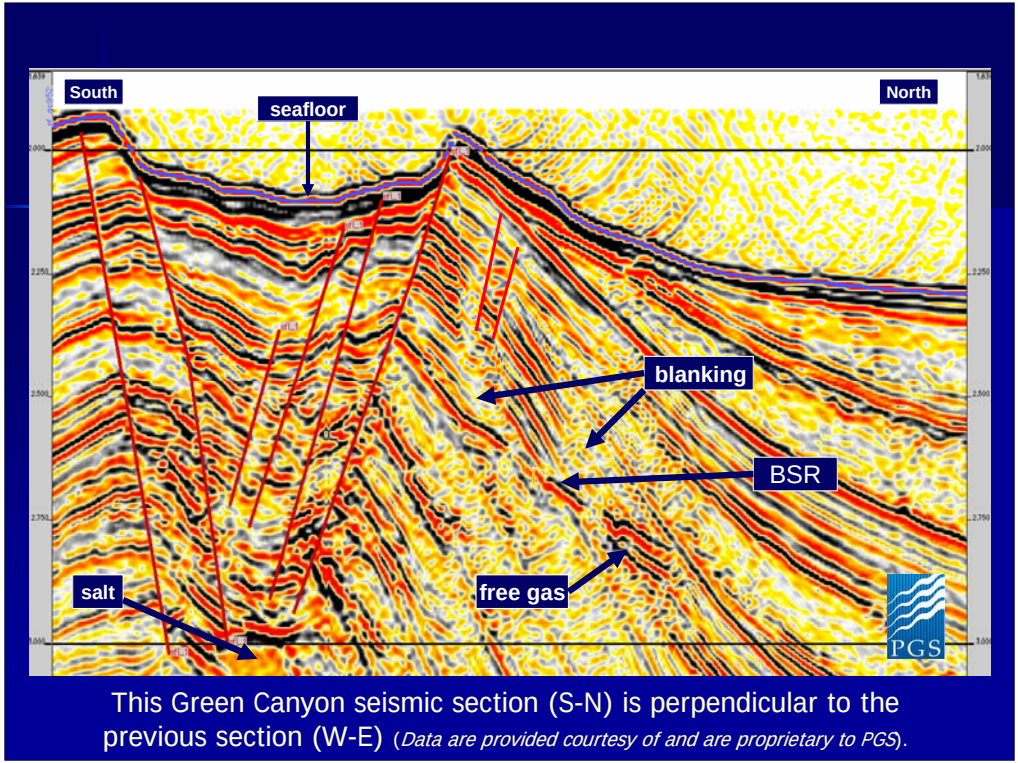
Presenter's Notes:

This slide shows seafloor features in the Green Canyon BSR study area, from 3D time-migrated data. They include seafloor faults, gas mounds and the location of Sigsbee scarp.



Presenter's Notes:

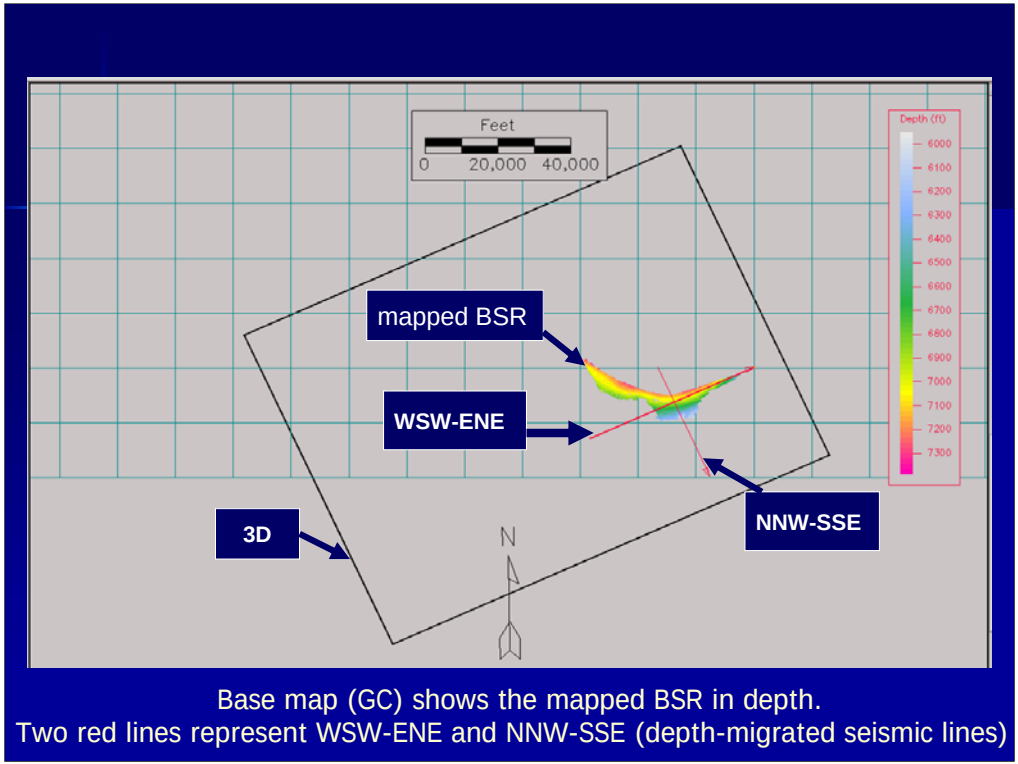
This W-E seismic section shows all the BSR characters. The blanking zones above BSR do not go through to the seafloor. The blanking may indicate the thickness of gas hydrates in the area.



This Green Canyon seismic section (S-N) is perpendicular to the previous section (W-E) (*Data are provided courtesy of and are proprietary to PGS*).

Presenter's Notes:

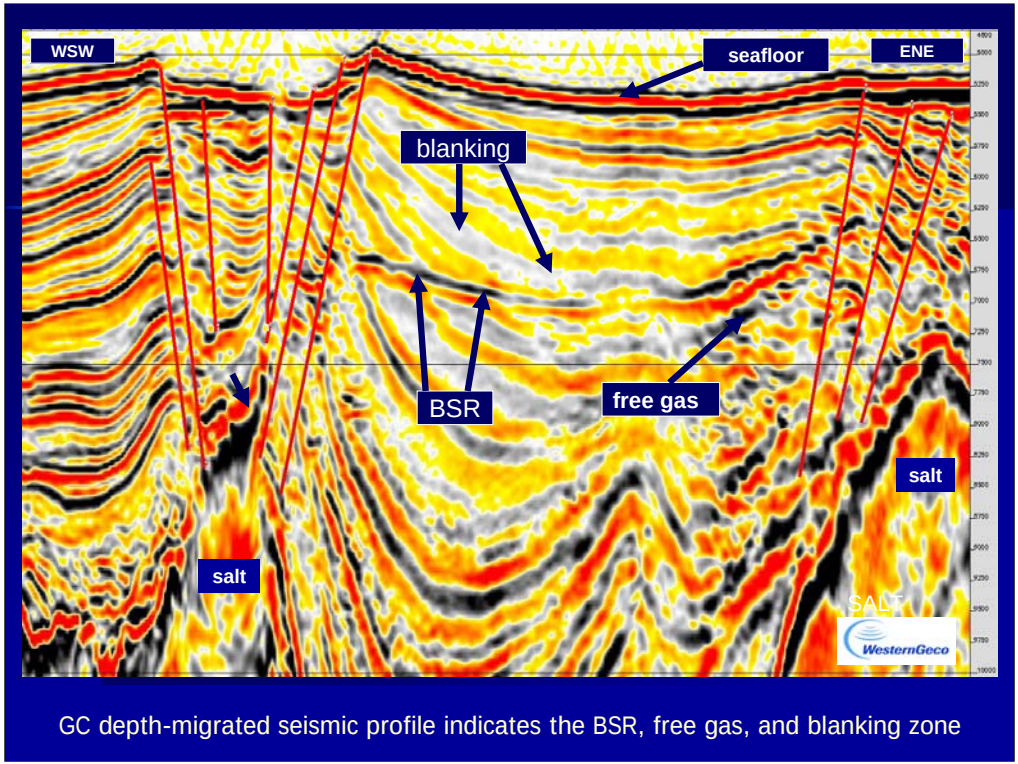
This S-N 3D time-migrated seismic section shows some chimney features above the BSR and free gas underneath the BSR.



Base map (GC) shows the mapped BSR in depth.
Two red lines represent WSW-ENE and NNW-SSE (depth-migrated seismic lines)

Presenter's Notes:

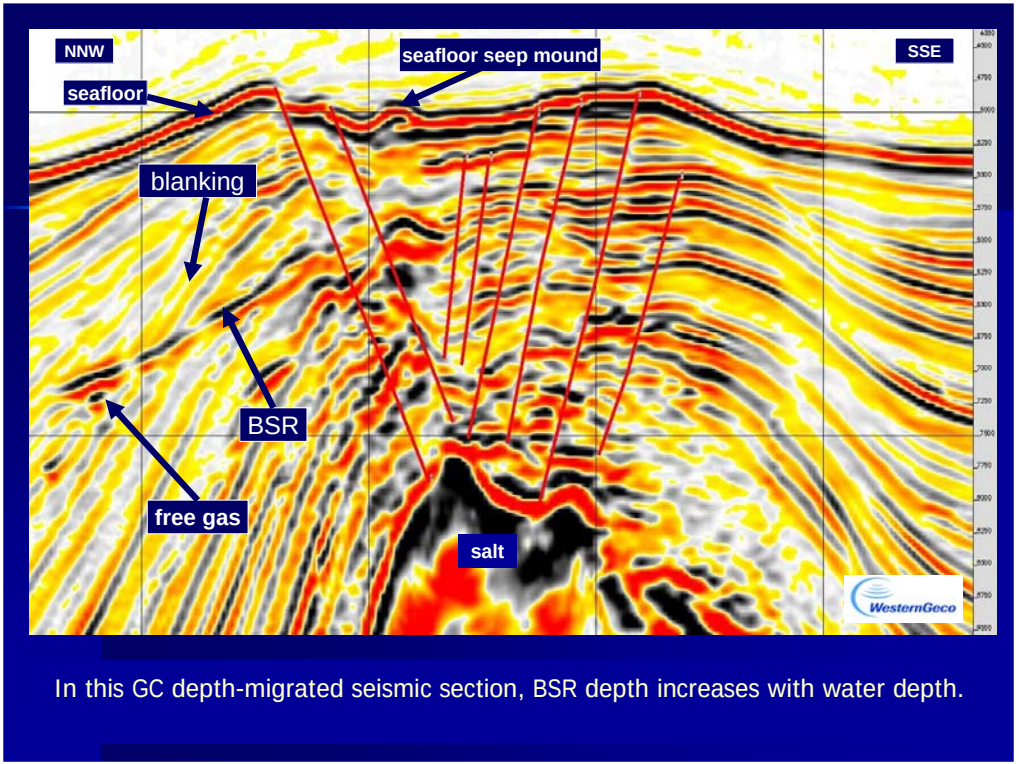
In Green Basin study area, the water depth is from 4800-5660 ft. The BSR is about 1200-1700 ft below mud line. The total BSR mapped is about 6000 acres. This map is from 3D-depth-migrated data. The locations of two perpendicular seismic sections are in red.



GC depth-migrated seismic profile indicates the BSR, free gas, and blanking zone

Presenter's Notes:

This depth-migrated seismic section (WSN-ENE) shows that the BSR cross the reflectors; high negative amplitude under the BSR indicates free gas. Blanking is above the BSR.



Presenter's Notes:

This NNW-SSE depth-migrated seismic section shows BSR parallel to seafloor and reverse polarity with the seafloor; it shows free gas underneath and blanking above the BSR. A gas mound on the seafloor is also present above the location of BSR. On the other side of the high, there are some chimney features but no BSRs are present.

Summary from Kou et al, 2007, Direct seismic indicators of gas hydrates in the Walker Ridge and Green Canyon areas, deepwater Gulf of Mexico, Leading Edge, vol. 26, no. 2

- We conclude that BSRs exist in the deepwater of the Gulf of Mexico when the temperature, pressure, and other geologic conditions are right for gas hydrate to form
- Our seismic data shows that strong BSR development in the deepwater Gulf of Mexico requires a certain amount of free gas beneath the hydrate cemented sediment
- No one-to-one relationship between hydrate concentration and amplitude blanking exists in the deepwater Gulf of Mexico
- Gas hydrates may be a potential geohazard for drilling and/or production activity

Presenter's Notes:

BSRs exist in Deepwater of GOM when the temperature, pressure, and other geologic conditions are conducive for gas hydrate to form.

Our seismic data indicate that the development of strong BSR may require free gas beneath the hydrated cemented sediment.

There is no one-to-one relationship between hydrate concentration and amplitude blanking in the deepwater of GOM.

Gas trapped as hydrate may be a potential geohazards.

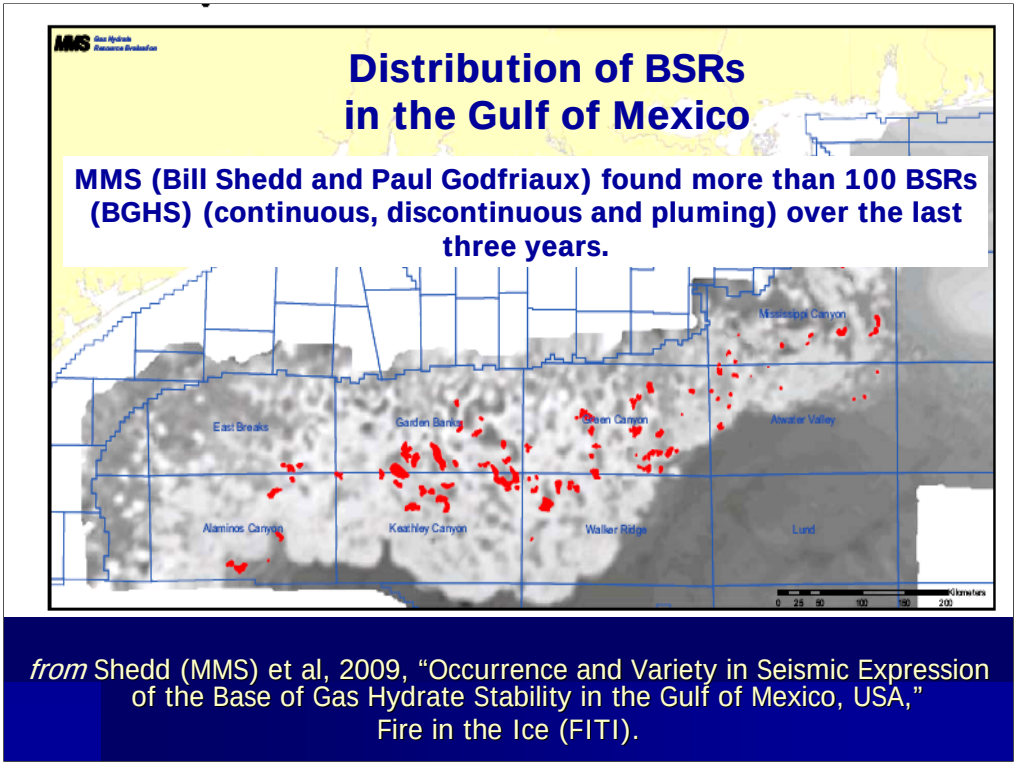
Preliminary Evaluation of In-Place Gas Hydrate Resources, Gulf of Mexico Outer Continental Shelf

Minerals Management Service [U.S. Dept. of the Interior, (OCS Report MMS 2008-004)],
Resource Evaluation Division, February 1, 2008
Compiled by: Matthew Frye

- A probabilistic model built on a mass balance approach to assessments provides a high degree of spatial resolution and supported by detailed mapping
- Basic geologic data for the model:
  - bathymetry
  - depth to top of basement
  - percent sand
  - surficial seismic anomalies
- The model results in a Monte Carlo distribution of in-place resources with a mean of 21,444 trillion cubic feet (TCF)
- This model predicts 6,717 TCF in sand reservoirs and 14,727 TCF finely disseminated in shale and in fractured shale reservoirs

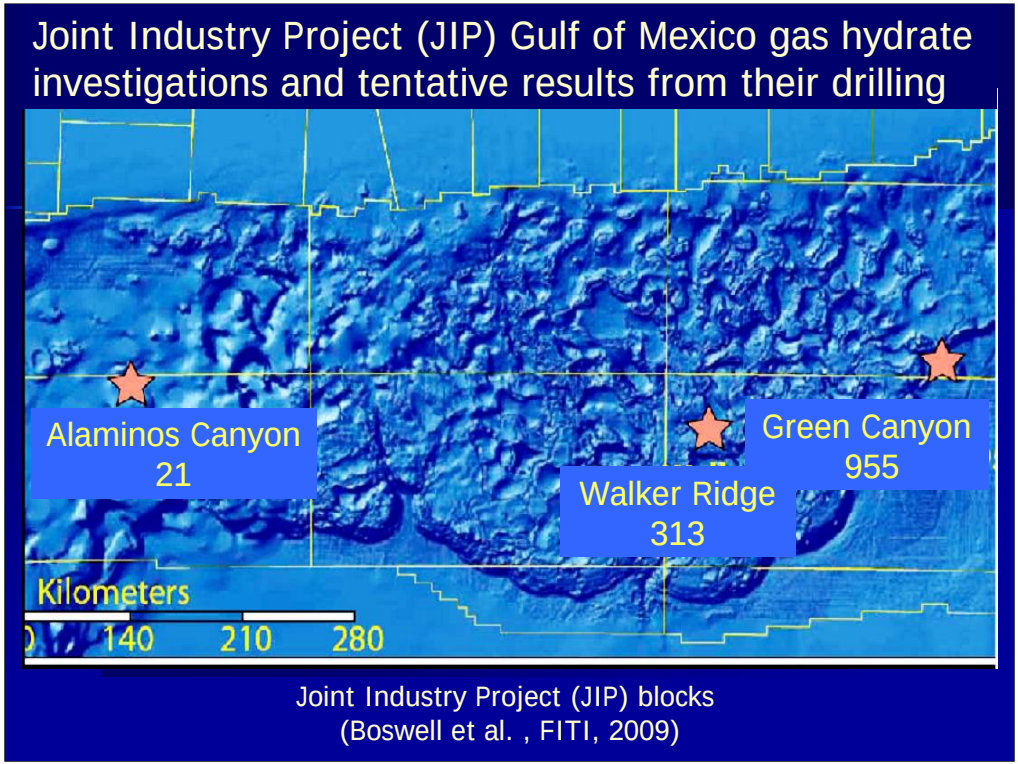
Presenter's Notes:

The MMS gas hydrate assessment model employs mass balance calculations. The total volume of biogenically gas generated in-place with a mean 21,444 TCF, 6717 TCF in sandstone reservoirs, and 14727 TCF in shale and fractured reservoirs.



Presenter's Notes:

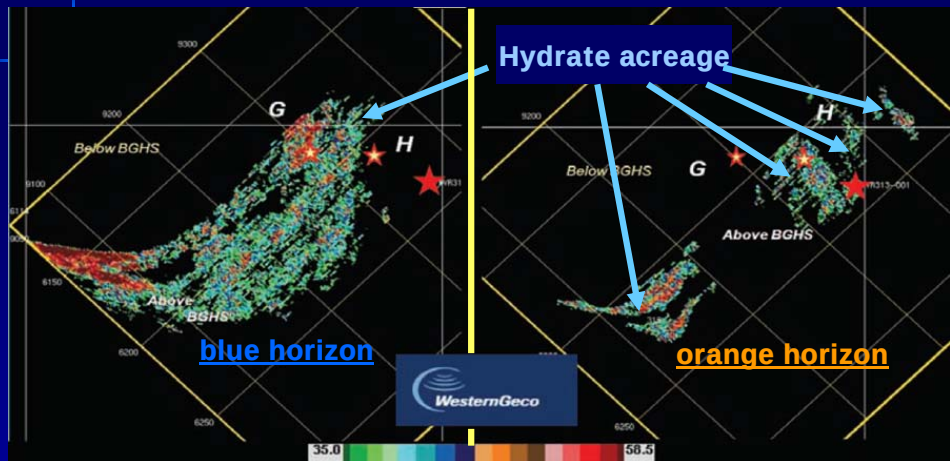
Over 100 different BSRs mapped by MMS in the deep water GOM identified during last 3 years: three classes-- continuous, discontinuous, and pluming. Pluming BSRs are not parallel to seafloor due temperature of the salt underneath (heat-flow variations).



Presenter's Notes:

Three blocks were drilled in GOM by JIP last year--AC 21, WR 313, and GC 955.

Joint Industry Project (JIP) gas hydrate wells

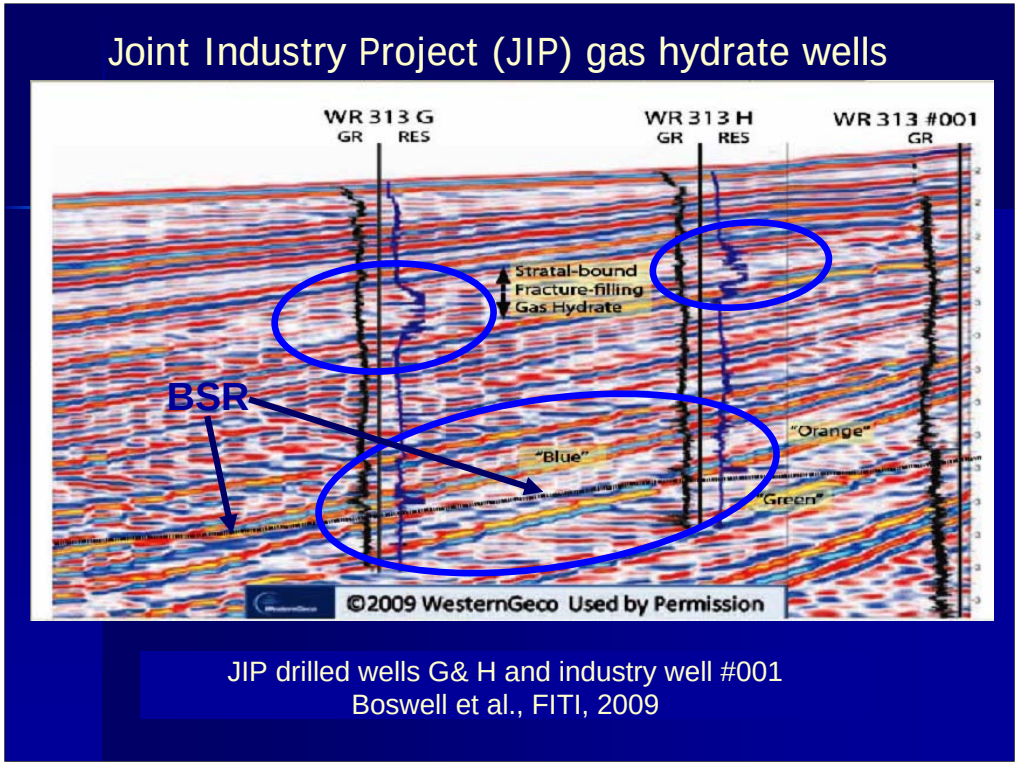


Pre-drilled gas hydrate saturation (%) calculated by seismic inversion model

JIP drilled wells WR313-G and WR313-H and industry wells in solid red star (Boswell et al., FITI, 2009)

Presenter's Notes:

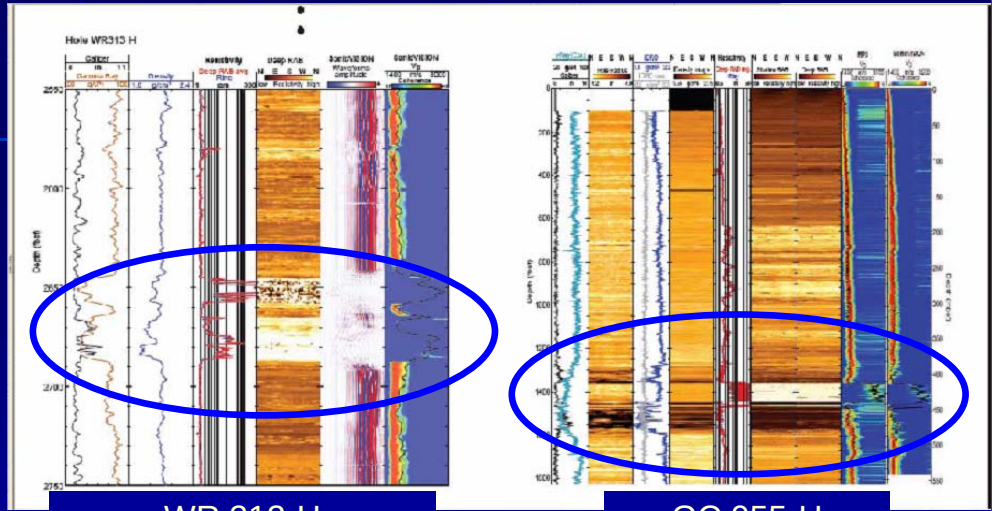
This slide shows location of drilled wells WR 313-G and H, and pre-existing industry well (solid red star) in relation to pre-drill predication of gas hydrate occurrence in the "blue" horizon (left) and the "orange" horizon (right). Results of seismic inversion for gas hydrates: from 58.5-35%. The total acres are about 1360 acres.



Presenter's Notes:

In WR 313, two wells (G and H) were drilled to test anomalous seismic amplitudes with phase reversals along horizons; they indicate the updip transition from gas to gas hydrates. Encountered was 500-ft-thick stratal-bound fracture-filling gas hydrate (20%); in G well, net 30 ft of sand with 80% gas hydrate saturated in blue horizon; in H well at orange horizon, 36 ft of sand in two lobes with resistivity 300 ohm-m for 80 ft gas hydrate . Dashed line is BSR.

Joint Industry Project (JIP) gas hydrate wells



Gas hydrate log expression on Walker Ridge 313 and Green Canyon 955 wells illustrating high resistivity

Boswell et al., FITI, 2009

Presenter's Notes:

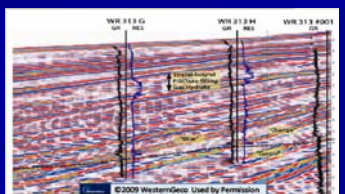
Log summary display of Well WR 313-H at the "orange "horizon left track shows sand; blue track shows reduced density, indicating significant porosity. Red track shows high resistivity, indicating that the porosity is not filled with water. Right-most track shows the unit has high acoustic velocities, indicating that the porosity is filled with gas hydrate.

Joint Industry Project (JIP) gas hydrate wells

Recent JIP findings for Walker Ridge and Green Canyon wells:

Walker Ridge 313-G well blue horizon:

- up to 90% gas hydrate saturation and ~42 feet sand
- high resistivity
- reduced density
- significant porosity
- high acoustic velocities



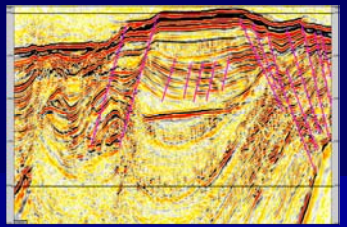
Walker Ridge 313-H well orange horizon:

- same log characteristics as WR 313-G blue horizon,
- 95% gas hydrate saturation and ~34 feet sand

Green Canyon 955-H well:

- up to 90% gas hydrate saturation in ~92 feet sand

Conclusions



- The BOEM, US Dept of Energy, Dept of Interior and industry groups continue to delineate where gas hydrates are found in the GOM
- Hydrate expression on seismic sections (BSR and blanking) and well logs (saturations) are becoming better known
- Preliminary evaluation of in-place gas hydrate resources is evolving


Time for Questions
Thanks for your attention!