# Gulf of Mexico Gas Hydrate Joint Industry Project Leg II:
# Green Canyon 955 Site Selection

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## Introduction

Identifying high saturations of gas hydrate in sandy marine sediments is one of the primary objecatives of the Phase II drilling program of the Gulf of Mexico Gas Hydrates Joint Industry Project (JIP). Analyses of the Green Canyon 955 site show good potential for the occurrence of high saturation gas hydrate within coarse-grained material of a channel-levee system near the base of the gas hydrate stability zone.

Three independent analyses of data from GC 955 support the interpretation of gas hydrate within the hydrate stability zone. (1) An existing well indicates sand (McConnell, 2000), and seismic shows a clear and persistant channel system; (2) For the JIP analysis, WesternGeco processing and inversion of the 3-D seismic cube indicated patchy hydrate saturations in excess of 50 % calibrated from the GC 955 #001 drill hole. (3) The Minerals Management Service (MMS) conducted a detailed analysis of GC 955 using time structure maps, seafloor seep locations, top-of-sand maps generated for the MMS gas-hydrate assessment, well-log analysis, and familiarity with geological models in this part of the Gulf and proposed good likelihood of gas hydrate in a transect across the lease block. The GC 955 #001 well provides lithologic, depth, and other information for modeling and interpreting the seismic data  show strong evidence of gas supply to the GHS, particularly within a closed structure in the southwest corner of the block, with numerous clear faults that could further focus gas migration (Table T1).

This report summarizes the geologic framework in the GC 955 area and information about eight potential drilling targets. The drilling targets were chosen to (1) delineate potential gas hydrate accumulations, thus providing guidance for a later phase of planned coring; and (2) yield data for calibration of geophysical data across the range of interpreted gas hydrate saturations, thicknesses, and lithologies. To provide these recommendations, a geologic interpretation has been merged with the quantitative estimates of gas hydrate saturations from analysis of seismic data to identify the conditions under which gas hydrate might be found in both the proximal levee sands and the distal finer-grained deposits. The relatively large number of proposed drill sites exist because of the uncertainty in interference with drilling by some of the 12 anchors set on the sea floor in 2008 for drilling of the GC 955 #002 well by Anadarko.

## Geologic Setting

The Green Canyon GC 955 site lies along the seaward side of the Sigsbee Escarpment at the mouth of Green Canyon

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| Lease Block No. | GC955 |
|---|---|
| Well name | GC955#1 |
| Water depth (m) | 2026 |
| Base of gas hydrate stability (m) | 2499 |
| Seafloor to base of gas hydrate stability (m) | 473 |
| Thermal gradient (mK/m) | ~32 |
| Target facies sampled at the well | Pleistocene levee sands |

**Table T1:** GC 955 #001 well information

(Figure F1A). The Sigsbee Escarpment is formed by the seaward extent of the lower slope salt canopy (Diegel, 1995). Other allochthonous salt bodies, such as the one forming Green Knoll, exist seaward of the escarpment. Within the study area, an uplifted mound which is cored by salt and deforms the overlying fine-grained sediments, has more than 60-m relief and forms a four-way closure structure (Figure F1C).

Two wells provide lithologic and stratigraphic control in GC 955. The GC 955 #001 well drilled by Statoil in 1999 sits structurally to the east of and off the crest of the salt-cored closure (Figure F2 and Table T1). Well-logs from the GC 955 #002 well became public in spring, 2009, and were therefore not used in the 2007-2008 well analysis part of the site-selection process. The existing GC 955 #001 well penetrated 26 m of sand at a depth of ~366 m below the seafloor (McConnell, 2000). A resistivity anomaly of ~4.2 Ωm withinn the sand coincides with a region of high-amplitudes in the seismic data (Figure F3). The sands, resistivity anomaly, and high amplitudes are the target region for the occurrence of gas hydrate.

The mouth of Green Canyon, in the northeast part of the study area, represents the exit point where sediments can debouch onto the deep seafloor of the Gulf of Mexico (Figure F1B). A small surface channel crosses the study area towards Green Knoll. Seismic data acquired at GC 955 show that channels similar to this surface channel occur at approximately the same location in several of the deeper Pleistocene horizons that were mapped (Figure F4), indicating that channelization is a long-lived process in this area (McConnell, 2000; Heggland, 2004). Channels, and their associated leveee and overbank deposits, particularly in areas of large decreases in the thalweg gradient, such as at the mouth of the Green Canyon, often contain turbidite and mass wasting deposits that are frequently coarse-grained.

A consequence of the salt uplift forming a closure structure is that the deepest channel mapped in the seismic data, identified as the horizon C channel (Figures F3-F5), presently slopes towards the north (Figure F5C), whereas it originally transported material out of Green Canyon on a south-sloping surface. In Figure F5, numerous faults can be seen crossing the channel. The horizon C channel and its associated proximal and distal levees are the targets for gas hydrate drilling. There is some indication that the horizon C channel may be one part of a much larger and extensive channel system.

Several good indicators of active fluid flow exist at site GC 955. A young slump scarp with 91 m of headwall relief occurs on the east side of the salt-cored uplift. The headwall and the uplift are associated with faults, and many of the faults have associated gas chimneys inferred to be conduits for gas migration from the deep to shallow section (Heggland, 2004). Numerous seep sites can be mapped on the seafloor (Figure F6). A small mud volcano in the southern part of GC 955 provides additional evidence of fluid expulsion in this young system. Overall, the horizon C channel probably represents a Pleistocene fairway that has been penetrated by fluid expulsion features.

Taken together, these data indicate that the components of a petroleum system are present. The well log and seismic data suggest a high potential for sand reservoirs in the channel levees. A trap is provided by uplift from a rising salt body that forms a four-way closure in the southwest corner of the block. The apparent seal for the reservoir sand package is a regional shale layer (horizon C) that occurs above the interpreted sandy levees. The system contains numerous migration pathways along abundant faults. Gas chimneys, numerous seismic indicators of gas (particularly within the structural closure), and seafloor features consistent with fluid expulsion (e.g., mud volcano, slump scarp) provide evidence for migrating gas. The geographic coincidence of the gas chimneys with the faults

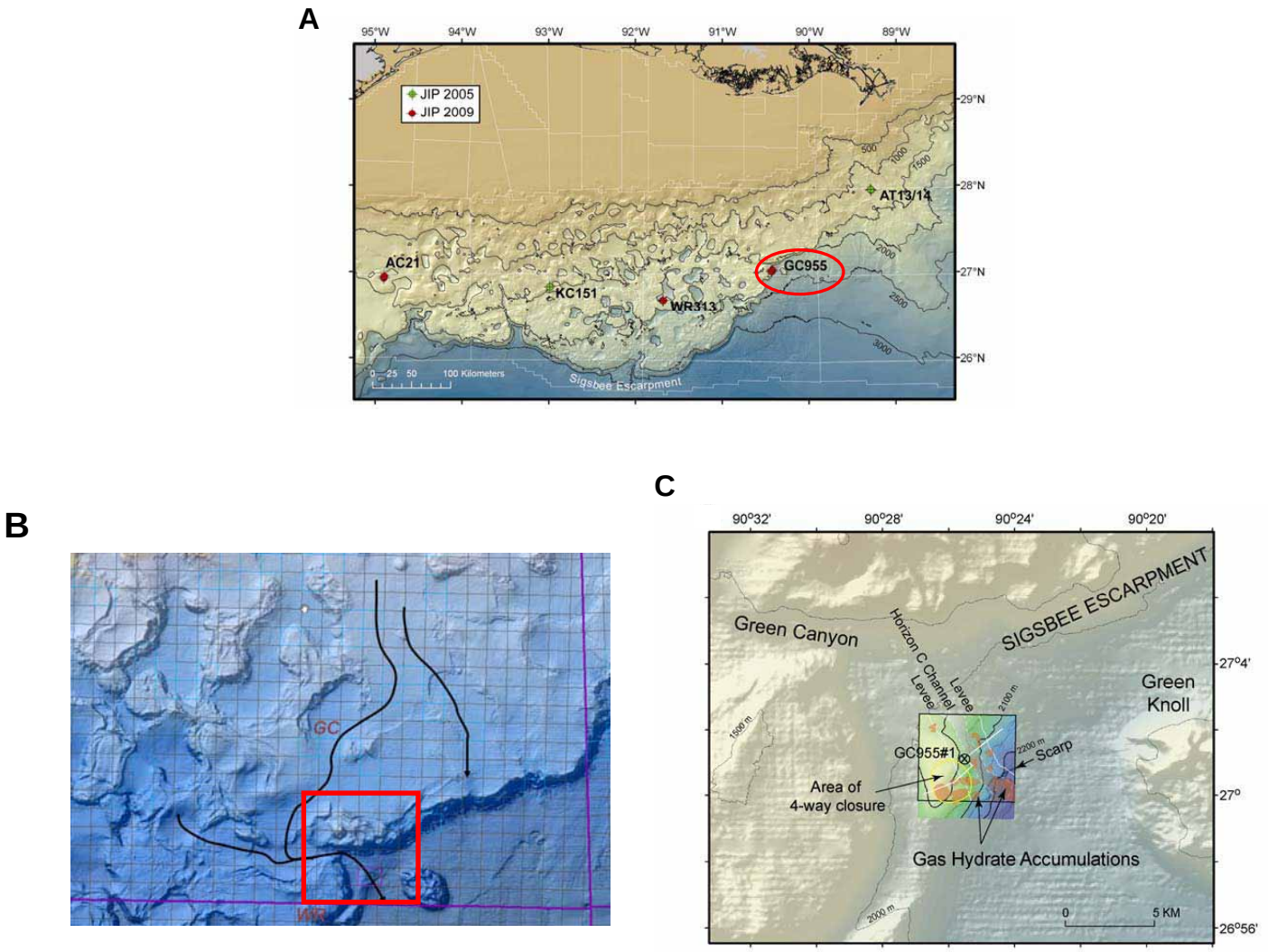



**Figure F1:** *(A) Location map of the northern Gulf of Mexico showing the proposed 2009 JIP sites (red) and 2005 JIP drilling locations (green). Red oval surrounds location of GC 955. (B) Map of the Green Canyon protraction area showing Green Canyon drainage. Box outlined in red shows location of enlargement shown in C. (Source: AOA ppt, March 27, 2008). (C) Location map of the GC 955 area showing the GC 955 #001 well, interpreted gas hydrate accumulations (brown), and channel-levee system (white lines and gray shading) from the seismic data. Lease block GC 955 is outlined in black (from Hutchinson et al., 2008). Inset provided by Schlumberger.*

indicates active gas migration into the shallow sedimentary section. Hence, there is good confidence in the geologic interpretation for this site.

## Pressure Temperature Conditions

At GC 955 #001 the base of the gas hydrate stability zone, is estimated to be at 473 m. This corresponds to a thermal gradient of 32 mK/m, assuming the hydrate formed from pure methane, the pore water is composed of seawater, and bottom water temperature is 4 °C. This thermal gradient places these permeable sandy units within the hydrate stability zone.

Estimates for the thermal conditions at each target in the GC 955 area are given in Table T2.

## Gas Hydrate Saturation

Gas hydrate saturations were estimated using the methodology of Dai (2008a). The five-step process utilizes seismic reprocessing for highest possible resolution, detailed geological (lithological) interpretation to identify possible gas hydrate-bearing zones, seismic attribute analysis to refine the extent of the gas-hydrate-bearing zones, seismic inversion to estimate elastic parameters in the gas-hydrate-bearing zones, and quantifying gas hydrate saturation using elastic parameters and rock physics

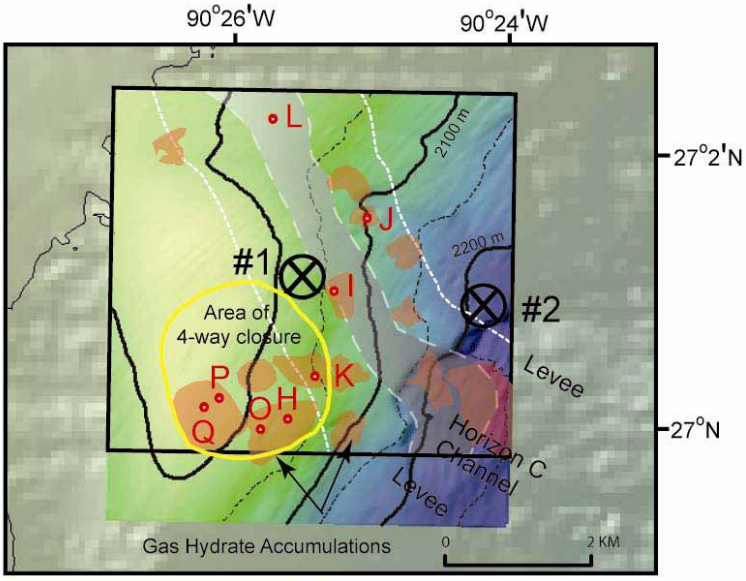
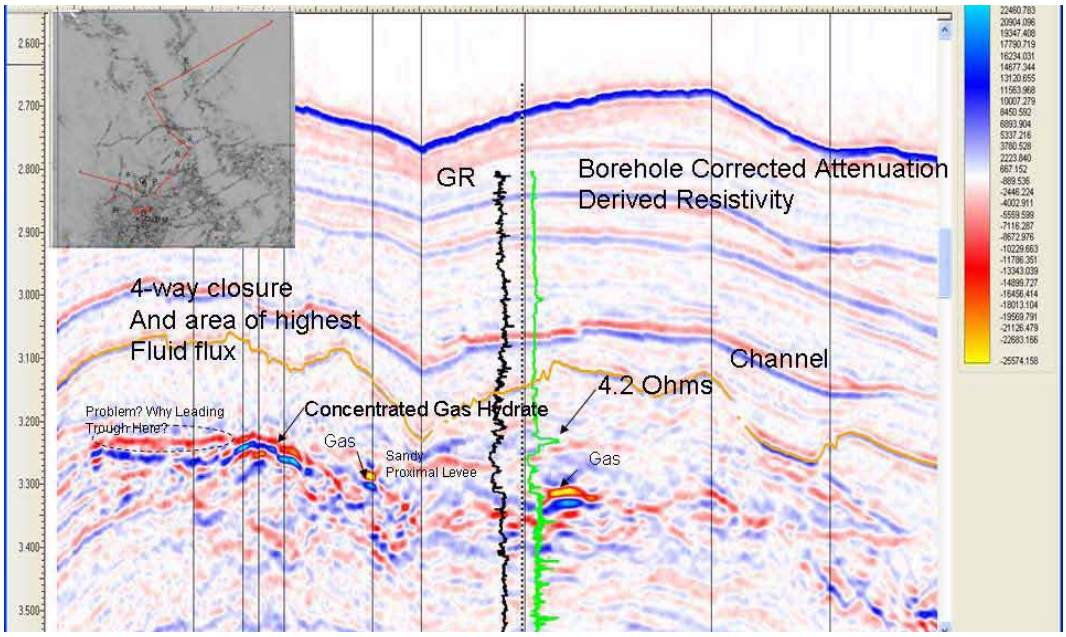



**Figure F2:** *Permitted locations in GC 955 together with locations of wells GC 955 #001 and GC 955 #002. Inset provided by Schlumberger.*

| Permit | SF (ft) | BGHS (ft) relative to seafloor | SF-BGHS (ft) | P[1] (MPa) | $T_{eq}$ (° C) at BGHS[2] | dT/dz (° C/km) for BWT=2° C | dT/dz (° C/km) for BWT=4° C |
|---|---|---|---|---|---|---|---|
| H | 6641 | 8211 | 1570 | 25.2 | 19.85 | 37.3 | 33.1 |
| I | 6765 | 8598 | 1833 | 26.35 | 20.2 | 32.6 | 29.0 |
| J | 6893 | 8574 | 1681 | 26.3 | 20.2 | 35.5 | 31.6 |
| K | 6719 | 8309 | 1590 | 25.5 | 19.95 | 37.0 | 32.9 |
| L | 6614 | 8778 | 2164 | 26.9 | 20.4 | 27.9 | 24.9 |
| O | 6598 | 8198 | 1600 | 25.1 | 19.8 | 36.6 | 32.5 |
| P | 6511 | 8195 | 1684 | 25.1 | 19.8 | 34.7 | 30.8 |
| Q | 6490 | 8154 | 1684 | 25.0 | 19.8 | 35.1 | 31.1 |

**Table T2:** *Estimated Pressure-Temperature Conditions for proposed holes at GC 955. (SF=Seafloor, BGHS=Base of gas hydrate stability, P=Pressure, $T_{eq}$= equilibrium temperature, dT/dZ=temperature gradient, BWT=bottom water temperature)*
*[1]Hydrostatic pressure calculated at the BGHS. [2]Calculated using 3.3% NaCl pore waters and methane-only gas hydrate*

**A**




**B**

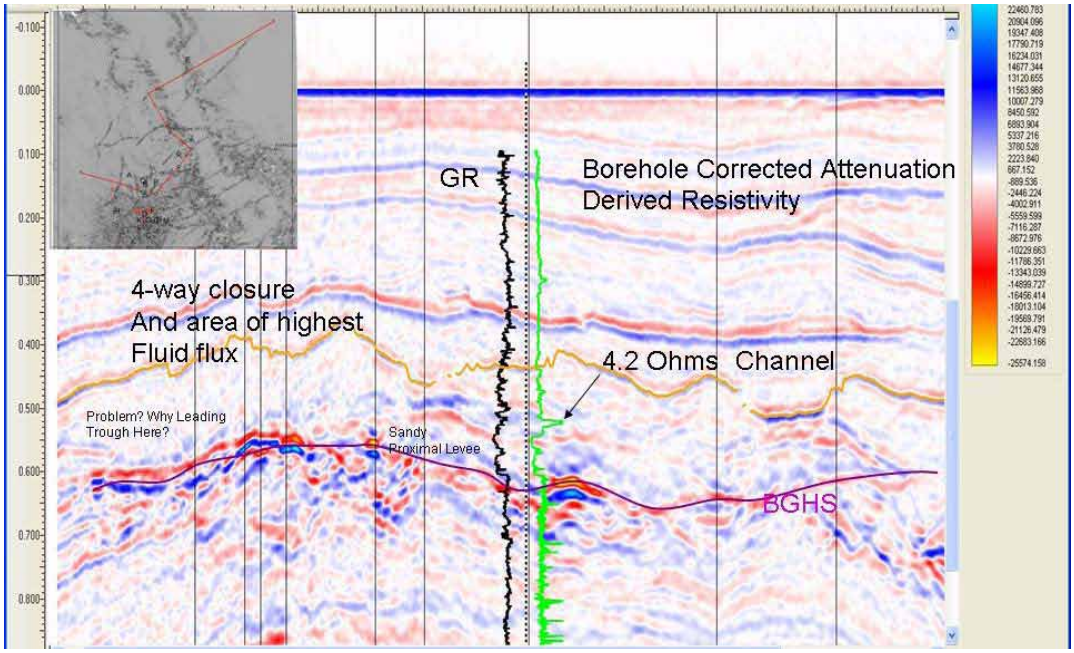
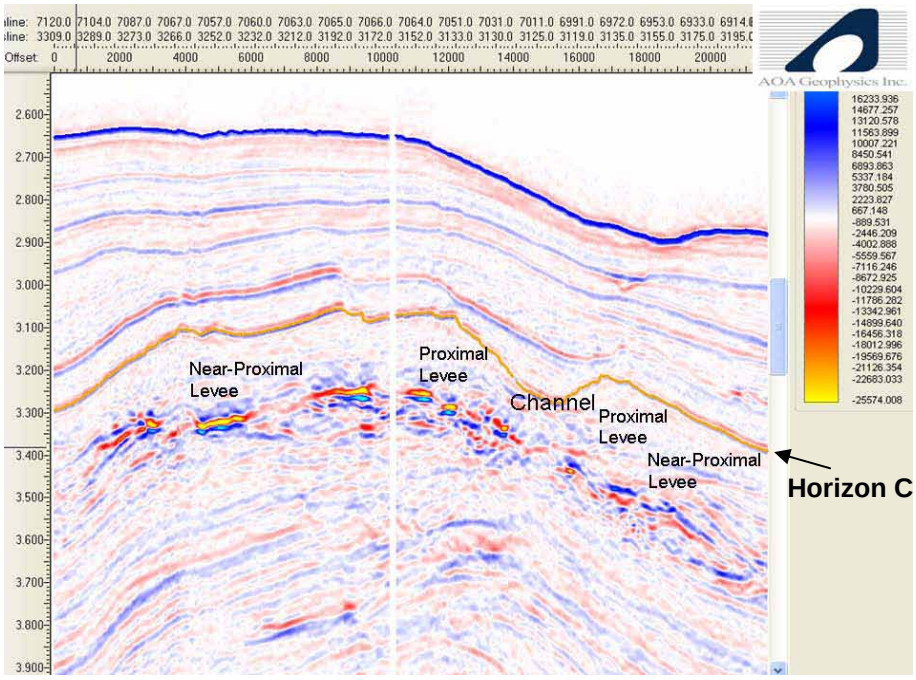



**Figure F3:** *(A) Random seismic line through the GC 955 #001 well showing the target (horizon C highlighted in orange) with channel and area of 4-way closure. (B) Same section flattened on the sea floor showing BGHS. Gas and gas hydrate are interpreted at ~3.2-3.3 s where the bright (red/blue) amplitudes stand out. Seismic images from WesternGeco.*

**A**




**B**

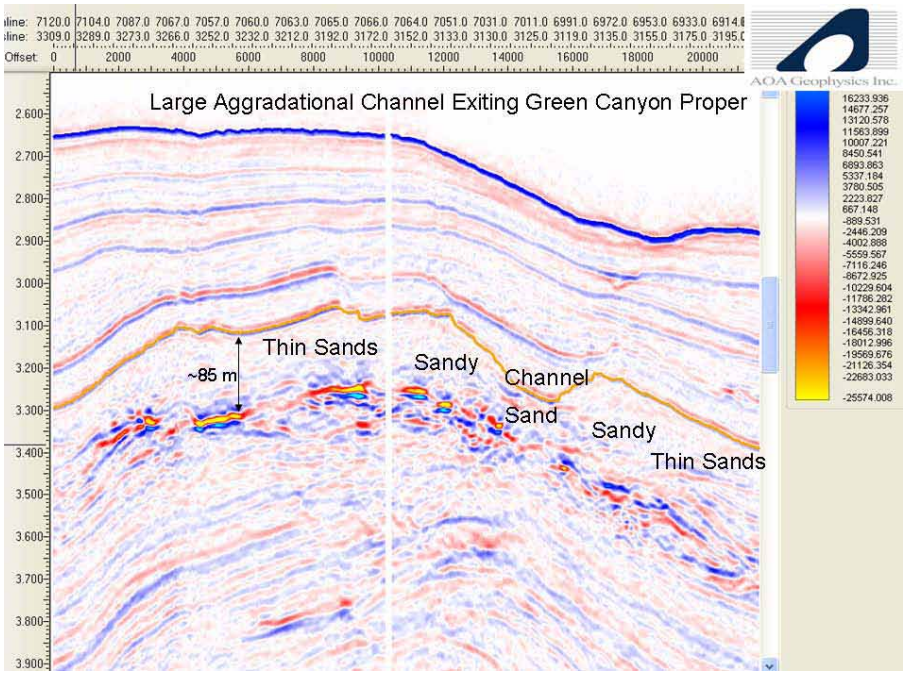



**Figure F4:** *(A) Seismic section showing interpreted channel/levee system at GC 955. (B) Seismic section showing interpreted lithology in channel/levee system at GC 955. Seismic images from WesternGeco.*

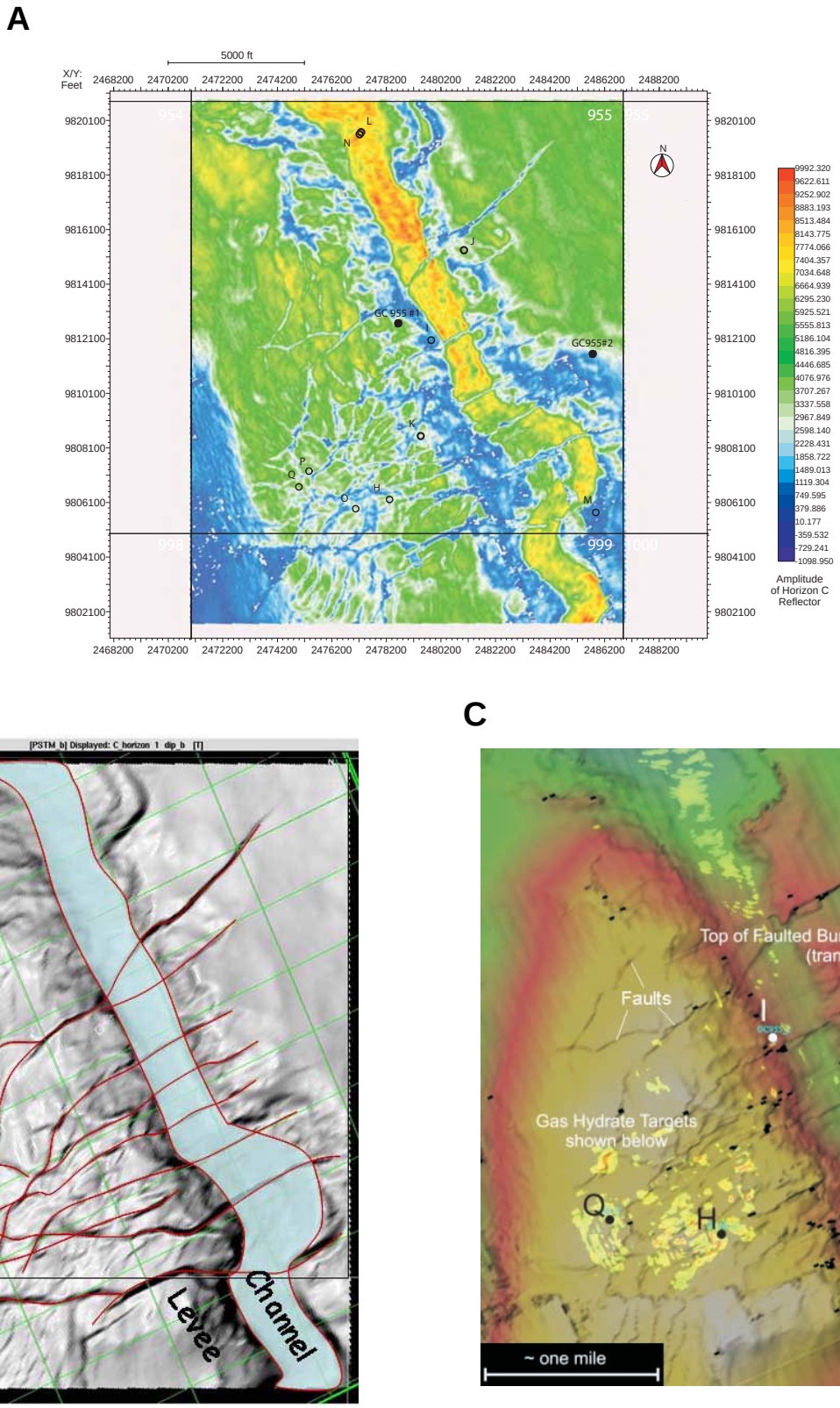
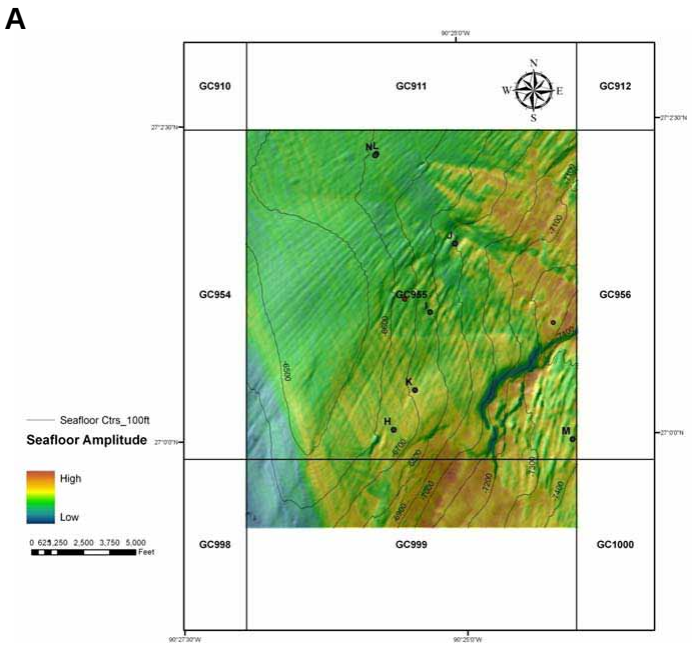



**Figure F5:** *(A) Time slice showing the horizon C channel based on amplitudes. (B) Time slice showing the horizon C channel based on dips, highlighting the faults. (C) Top of channel facies (transparent) showing gas hydrate targets below and JIP well locations. Image and data provided by Western Geco and Schlumberger.*



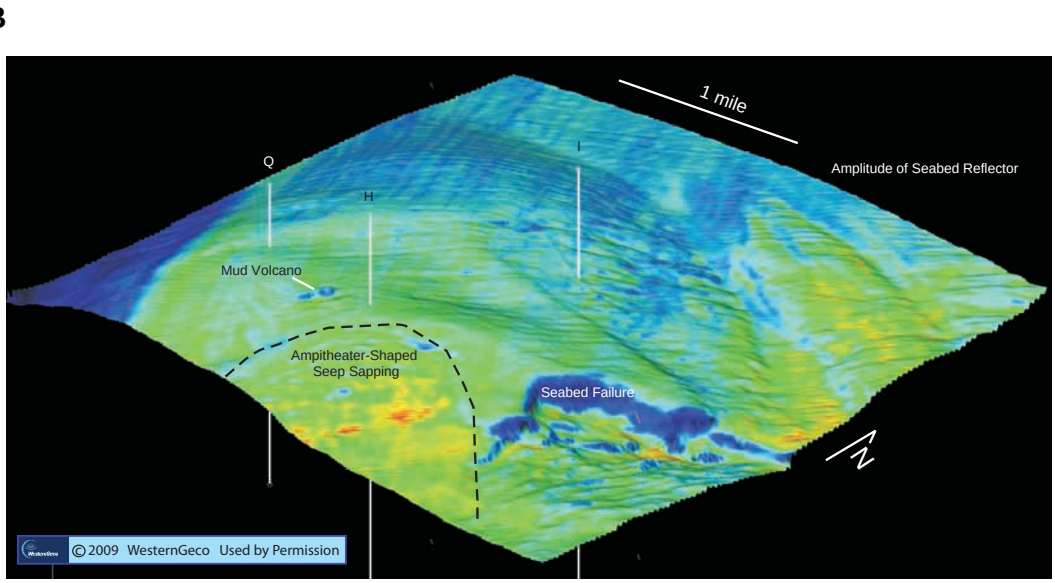




**Figure F6:** *(A) Map of seafloor amplitude over shaded relief of the GC 955 mapping area. (B) Perspective view of sea floor showing region of fluid flow (seep-sapping) and slope failure (view is looking northwest. Image courtesy of WesternGeco.*

models. Gas hydrate saturation ($S_{gh}$) is given as a percent of pore volume. This model was used to predict $S_{gh}$ at two sites drilled for gas hydrates in the Gulf of Mexico by the JIP in 2005, with encouraging success (Dai *et al*., 2008b).

## Drilling Targets

Site GC 955 offers three geologic environments, a four-way closure structure formed by uplifted salt, a dipping channel (associated with horizon C), and proximal levees associated with horizon C and potential older channels. With distance away from the likely channel location, the geologic risk (occurrence and quality of reservoir) increases. The eight drilling targets provide targets that sample the different aspects of the petroleum system:

***Proximal sand levee – west side of horizon C channel***

- H – near fluid expulsion mound, high $S_{gh}$ in maximum gassy area
- I – thickest part of levee (best sand??), west side of channel on upthrown side of fault that crosses the channel.
- K – edge of main closure structure

***Proximal sand levee – east side of horizon C channel***

- J – on downthrown side of fault (compare with Site I)

***Distal levee beneath closure structure***

- O – near surficial fluid expulsion mound
- P – near crest of closure structure, along fault
- Q – near crest of closure structure, upthrown side of fault, downdip of potential gas

***Lag deposit in horizon C-aged channel***

- near location where channel crosses base of gas hydrate stability (L)

Drilling at the sand-levee targets can test several alternative geologic models, including 1) presence of a relatively thin zone of high gas hydrate saturation within the sands that directly overlay the base of gas hydrate stability and may form a trap for free gas below; 2) the potential persistence of lower levels (seismically undetectable) of pore-filling gas hydrate throughout the sandy facies, perhaps extending to the level of the regional potential seal; and 3) the potential occurrence of zones of massive gas hydrate concentrated in near-vertical faults and fractures extending an unknown distance above the base of gas hydrate stability.

***Consensus recommendation:*** The site selection group agreed that the area that would yield the most likely recovery of high-saturation gas hydrate was within the four-way closure structure because of the associated fluid flux features. The closure structure also posed the greatest safety hazard because of seismic indicators of free gas. However, locations more proximal to the suspected channel trend provided greater confidence in lithology (ties to the existing drill holes). The channel fill represented a different geologic model to test with somewhat uncertain source for gas hydrate. With these ideas, the consensus targets to drill are in Table T3:

| Drill site (Permit name) | Comment |
|---|---|
| H | Consensus #1 |
| I | Preferred #2 |
| L, K, or Q | For consideration #3 |

**Table T3:** *Recommendations for site GC 955.*

Each of the proposed holes fulfills JIP objectives of (a) expecting to find high $S_{gh}$ for future coring; (b) testing the $S_{gh}$ prediction models of Schlumberger; and (c) testing the petroleum system of hydrate formation.

## Concerns about GC 955

GC 955 has clear indications of sand and fluids. The two wells providing control (GC 955 #001 and GC 955 #002) are both just north of the primary gas-charged zone. The gas reflections are contained in chaotic units, with no clear cross cutting bottom simulating reflection (BSR). The gas hydrate (at the base of the stability zone) and the gas (just beneath the base of the stability zone) are difficult to resolve. The petroleum system is there, but it could be an under-saturated – and therefore under-charged – system.
It could be that the channel fill is a fining-upward sand, the bulk of which is deeper than the gas hydrate stability zone. This geometry and lithologic fining upwards leads to a possible model of gas-hydrate occurrence in which saturation is gradational, not uniformly high. Because the inversions work best on discrete boundaries, rather than gradational occurrences, this situation contributes to the uncertainty in gas hydrate occurrence.

A small resistivity anomaly of 4.3 Ω-m within the sand penetrated by GC 955 #001 well could be an indicator of low-saturation gas hydrates. Numerous bright reflectors in

the seismic data beneath the levee sand are interpreted to be gas below the base of hydrate stability, but the chaotic geometry of these deeper reflections makes determination of a clear base of hydrate stability using seismic data ambiguous. Three pieces of evidence support the existence of gas hydrate. First is the presence of an elevated interval velocity anomaly within the overall channel-levee complex. This velocity anomaly is up to 600 m/s above the background velocity of 1.54 km/s and is difficult to explain in these kinds of unconsolidated sediments without invoking a mechanism such as the presence of gas hydrate. Second is the inversion result showing high saturation of gas hydrate along discrete reflections just above the depths estimated for the base of hydrate stability, within the region of elevated velocities. These saturations range from ~50% to 80% and coincide with patchy occurrences above trough reflections, i.e., not with reverse-polarity amplitudes expected from low-velocity gas at the base of hydrate stability. Third is the observation that gas hydrate saturations inferred within the deposits filling the bottom of the north-dipping horizon C channel increase toward the position where the channel intersects the base of hydrate stability. Deposits within the channel are interpreted to be a coarse lag which contains progressively higher amounts of gas hydrate near where the channel intersects the deeper gas-filled units. While containing uncertainties, these reasons are the motivation for drilling the GC 955 location.

## References

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Diegel, F.A., Karlo, J.F., Schuster, D.C., Shoup, R.C., and Tauvers, P.R., 1995. Cenozoic structural evolution and tectonno-stratigraphic framework of the northern Gulf Coast continental margin, in Jackson, M.P.A., Roberts, D.G., and Snelson, S., eds., Salt tectonics: a global perspective: AAPG Memoir 65, p. 109-154.

Heggland, R., 2004. Definition of geohazards in exploration 3-D seismic data using attributes and neural-network analysis. AAPG Bulletin, 88(6): p. 857-868.

McConnell, D., 2000. Optimizing deepwater well locations to reduce the risk of shallow water flow: Proceedins, Offshore Technology Conference, paper 11973, v. 32 (1) pp. 87-97.

## Appendix 1: Site and Target Summaries

The following pages provide detailed summaries of each drilling target with four tables of factual information and four figures (tophole prognosis chart [from MMS permitting], map showing the existing well and proposed targets, inline seismic section and crossline seismic section).

Explanation of Terms:

| | |
|---|---|
| Site Name | the name used during permitting (generally GC 955-letter) and the name developed during the site selection process (generally JIP-name) |
| NAD27 | datum used for latitude/longitude values (North America Datum 1927) |
| BSS | below sea surface |
| BML | below mud line |
| TGHO | top of gas hydrate occurrence |
| BGHS | base of gas hydrate stability |
| BSR | bottom simulating reflection |

# Target GC955-H (JIP AA)
# Drilling Target Documentation

Table 1: Background Information

| | |
|---|---|
| General Site Objective | *Test of channel levee system with good indicators of gas and fluid flow.* |
| Drilling target and Specific Hole Objective | *Strong peak over strong trough near BGHS at 1490 ft. May be hydrate filling fracture(fluids near fluid expulsion mound??)* |
| Other Drilling in Vicinity | GC955#1, GC955#2, |

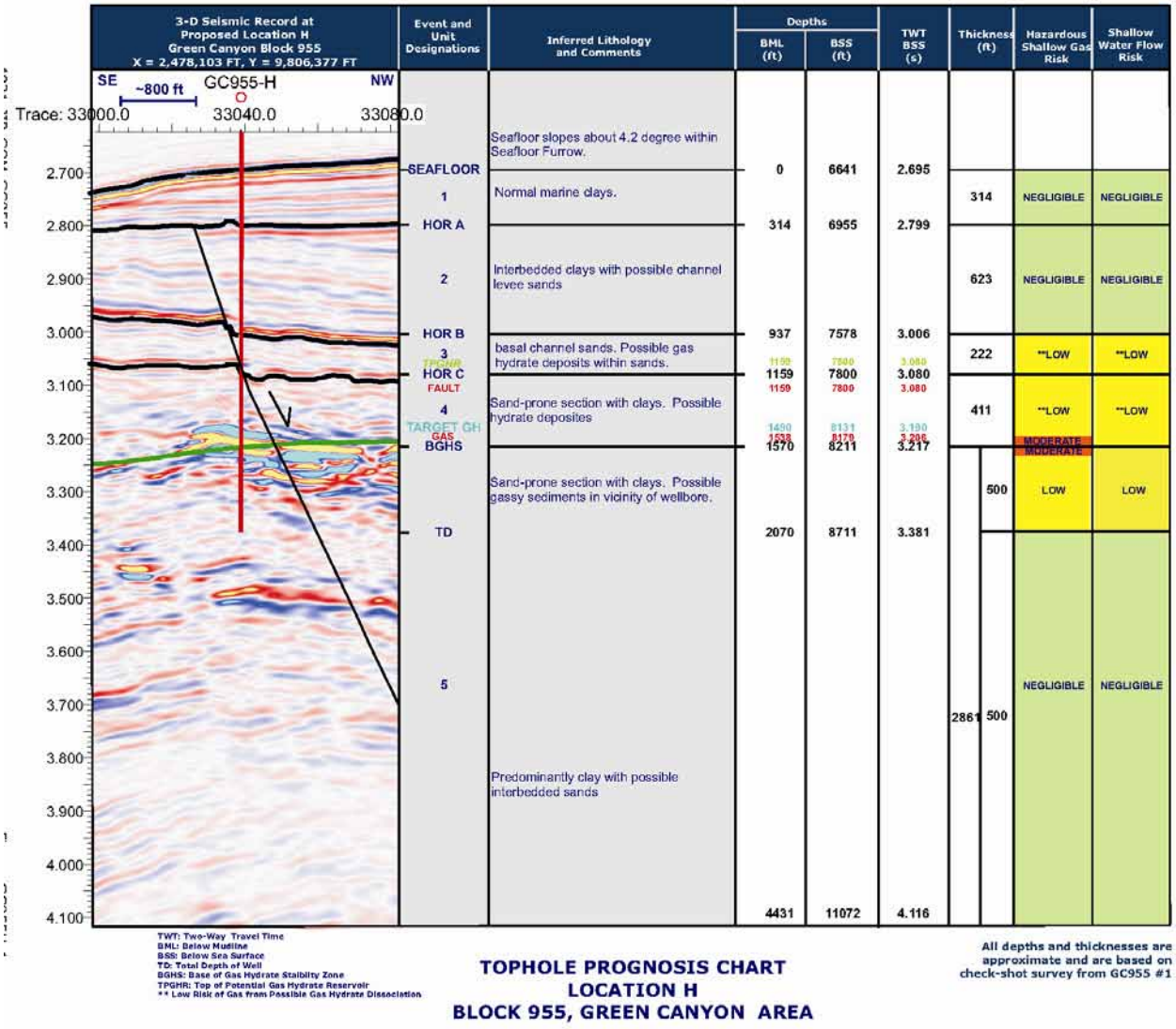
Table 2: Proposed Hole General Information

| | |
|---|---|
| Site Name | Permitted H, JIP AA |
| General Area | *Seaward of the Sigsbee Escarpment, between Green Canyon proper and Green Knoll* |
| Location | Latitude: *27° 00' 03.828" N* Longitude: *90° 25' 37.432" W* |
| Coordinate Datum | *NAD27* |
| Water Depth | *6641 ft BSS* |
| OPD/Lease Block | *GC955* |
| Seismic lines at hole | *Inline 112333, crossline 33039* |

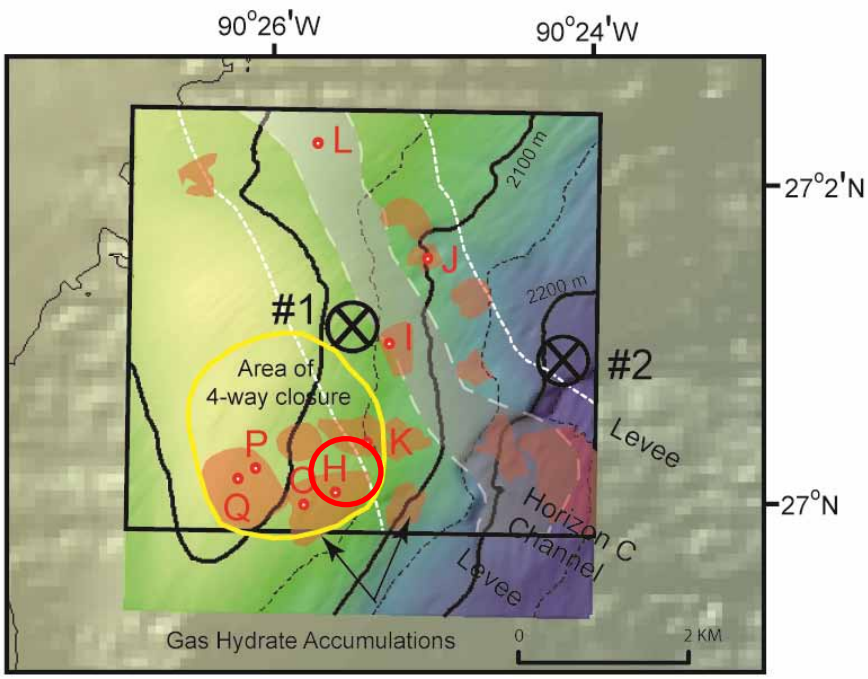
Table 3: Proposed Hole Drilling Information

| | |
|---|---|
| Proposed penetration | *2070 ft BML 8711 ft BSS* |
| Seafloor slope | *4.2° to the east* |
| Expected lithologies | *0-314 ft: normal marine clays*<br>*314-937 ft: interbedded clays with possible channel levee sands*<br>*937-1159 ft: basal channel sands, possibly with gas hydrate*<br>*1159-1570 ft: sand prone section with clays, possibly with gas hydrate*<br>*1570-2070 ft: sand prone section with clays, possible gas sediments.* |
| Expected ages/section | *PlioPleistocene* |
| Estimated depth to TGHO | *1159 ft BML (7800 ft BSS)* |
| Estimated depth to BGHZ | *1570 ft BML (8211 ft BSS)* |
| Estimated GH interval | *1159-1570 ft BML (411 ft thick)* |
| Estimated GH saturation | *High (~76 % for sand model)* |
| Anomalous conditions? | *Negligible-low hazards except at BGHZ (moderate risk of gas-1538 ft BML, 8179 ft BSS)*<br>*Fault crosscuts well bore at about 1,159 ft BML (7800 ft BSS)* |
| Other relevant information | *Velocities of ~2.5 km/s are considered too high to be gas below the BGHS; BGHS has a ~5 ohm resistivity anomaly at GC955#1.* |
| Date of Information | 21 May, 2008 |

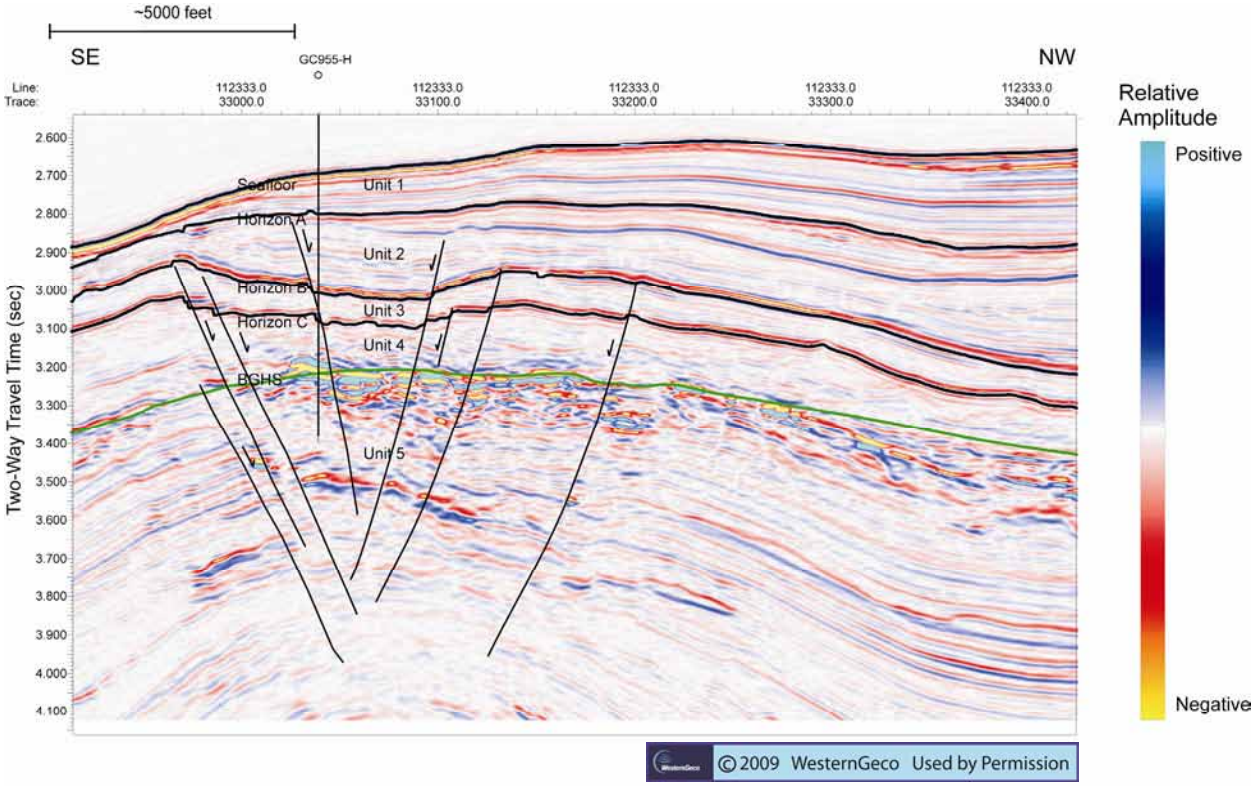
BML: Below Mud Line
BSS: Below Sea Surface
TGHO: Top of Gas Hydrate Occurrence
BGHZ: Base of Gas Hydrate stability Zone




**Appendix F1:** *Stratigraphic interpretation, from AOA Geophysics; Seismic image provided by WesternGeco.*

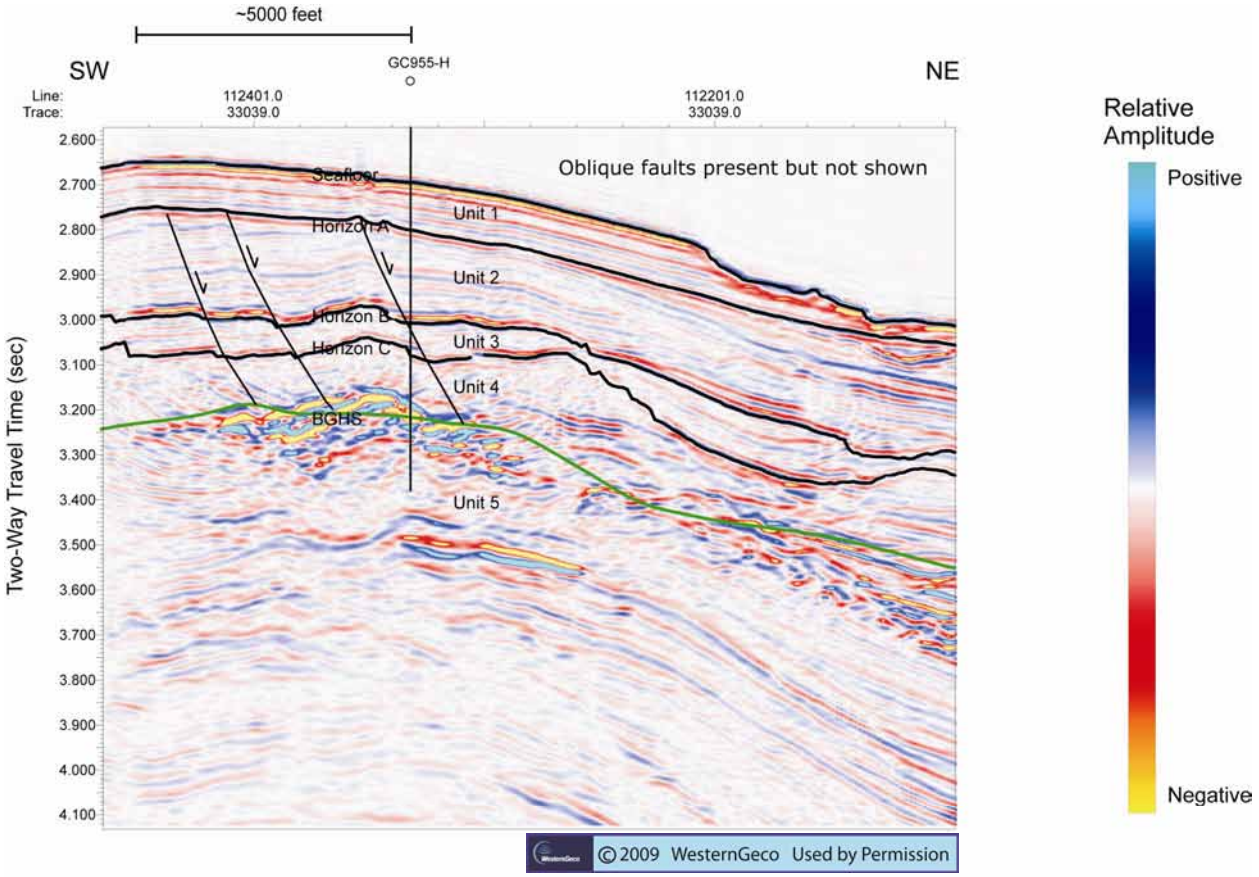



**Appendix F2:** *Map showing location of proposed site GC955-H. Colored bathymetry from WesternGeco.*




3D Seismic Record, Line 112333, Location H Block 955, Green Canyon Area

**Appendix F3:** *Inline seismic profile across GC955-H. Seismic image courtesy of WesternGeco.*




3D Seismic Record, Crossline 33039, Location H Block 955, Green Canyon Area

**Appendix F4:** *Crossline seismic profile across GC955-H. Seismic image courtesy of WesternGeco.*

# Target GC955-I (JIP KK)
# Drilling Target Documentation

Table 1: Background Information

| | |
|---|---|
| General Site Objective | *Test of channel levee system with good indicators of gas and fluid flow.* |
| Drilling target and Specific Hole Objective | *Strong anomaly at top of basal channel sands at 1483 ft BML (8248 ft BSS). (Location in thickest part of western channel levee system)* |
| Other Drilling in Vicinity | GC955#1, GC955#2, |

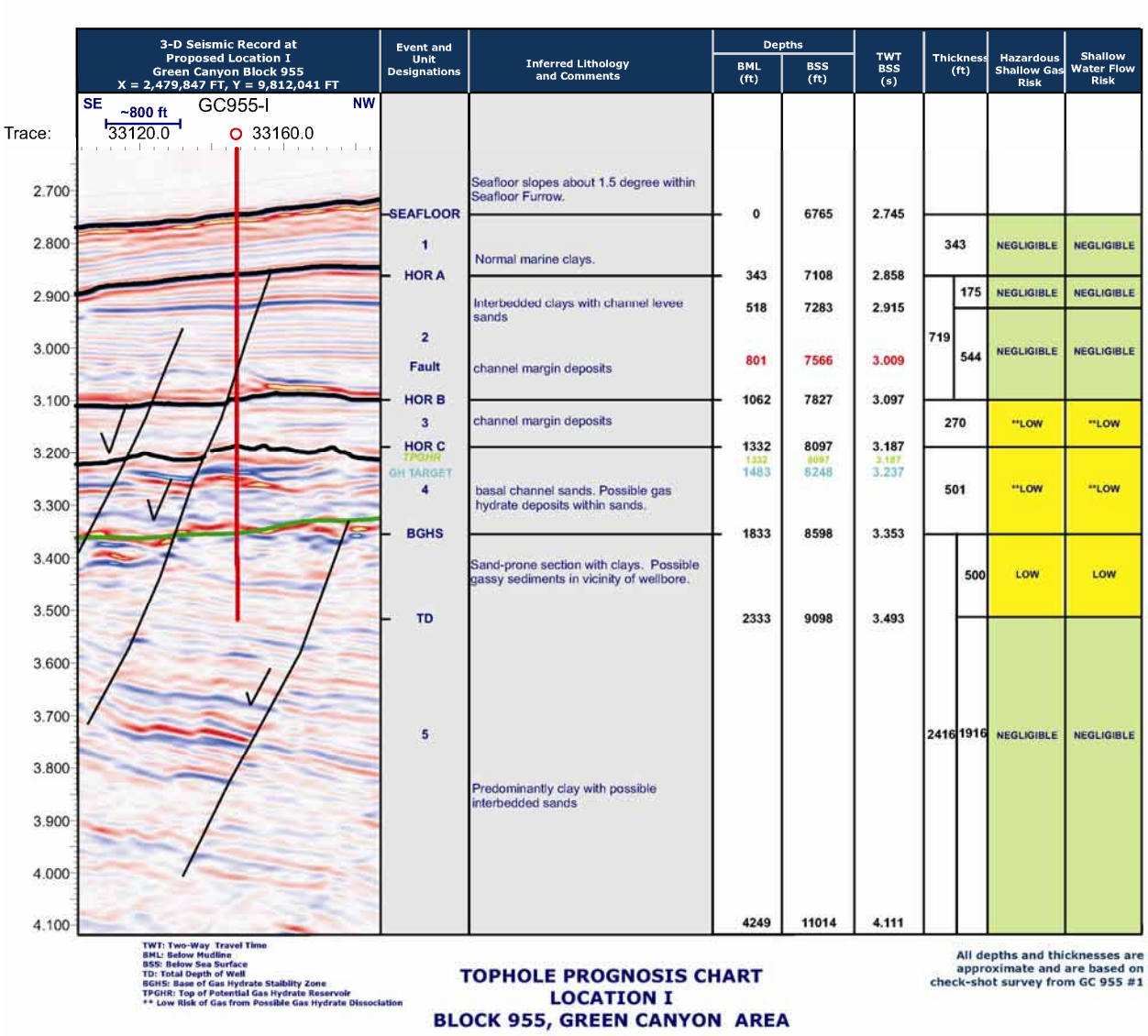
Table 2: Proposed Hole General Information

| | |
|---|---|
| Site Name | Permitted I, JIP KK |
| General Area | *Seaward of the Sigsbee Escarpment, between Green Canyon proper and Green Knoll* |
| Location | Latitude: *27° 00' 59.529" N* Longitude: *90° 25' 16.885" W* |
| Coordinate Datum | *NAD27* |
| Water Depth | *6765 ft BSS* |
| OPD/Lease Block | *GC955* |
| Seismic lines at hole | *Inline 112237, crossline 33147* |

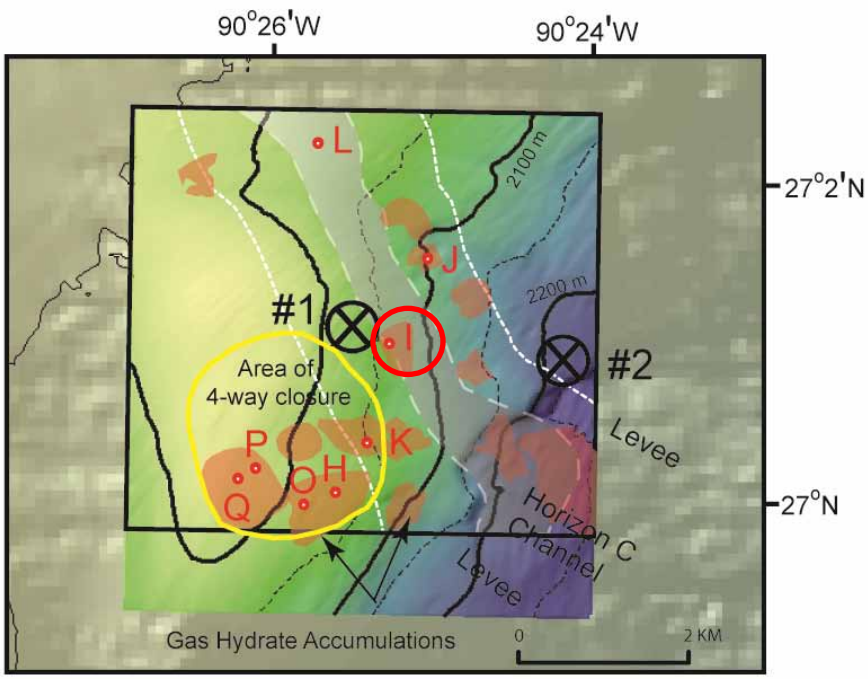
Table 3: Proposed Hole Drilling Information

| | |
|---|---|
| Proposed penetration | *2333 ft BML 9098 ft BSS* |
| Seafloor slope | *~4° to the east* |
| Expected lithologies | *0-343 ft BML: normal marine clays with possible sands at the bottom*<br>*343-1062 ft BML: interbedded clays with channel levee sands going into channel margin deposits at the bottom of the unit*<br>*1062-1332 ft BML: channel margin deposits (sand prone), contains buried channel*<br>*1332-1833 ft BML: basal channel sands possibly with gas hydrate*<br>*1833-2333 ft BML: sand prone section with clays, possibly gassy seds.* |
| Expected ages/section | *PlioPleistocene* |
| Estimated depth to TGHO | *1332 ft BML (8097 ft BSS)* |
| Estimated depth to BGHZ | *1833 ft BML (8598 ft BSS)* |
| Estimated GH interval | *1332-1833 ft BML (501 ft thick)* |
| Estimated GH saturation | *Moderate (~50 %??)* |
| Anomalous conditions? | *Fault crosscuts the wellbore at 801 ft BML.* |
| Other relevant information | *Hole is within area of mega furrows of about 10 ft amplitude that may have been created by currents up to 40 cm/s* |
| Date of Information | 21 May, 2008 |

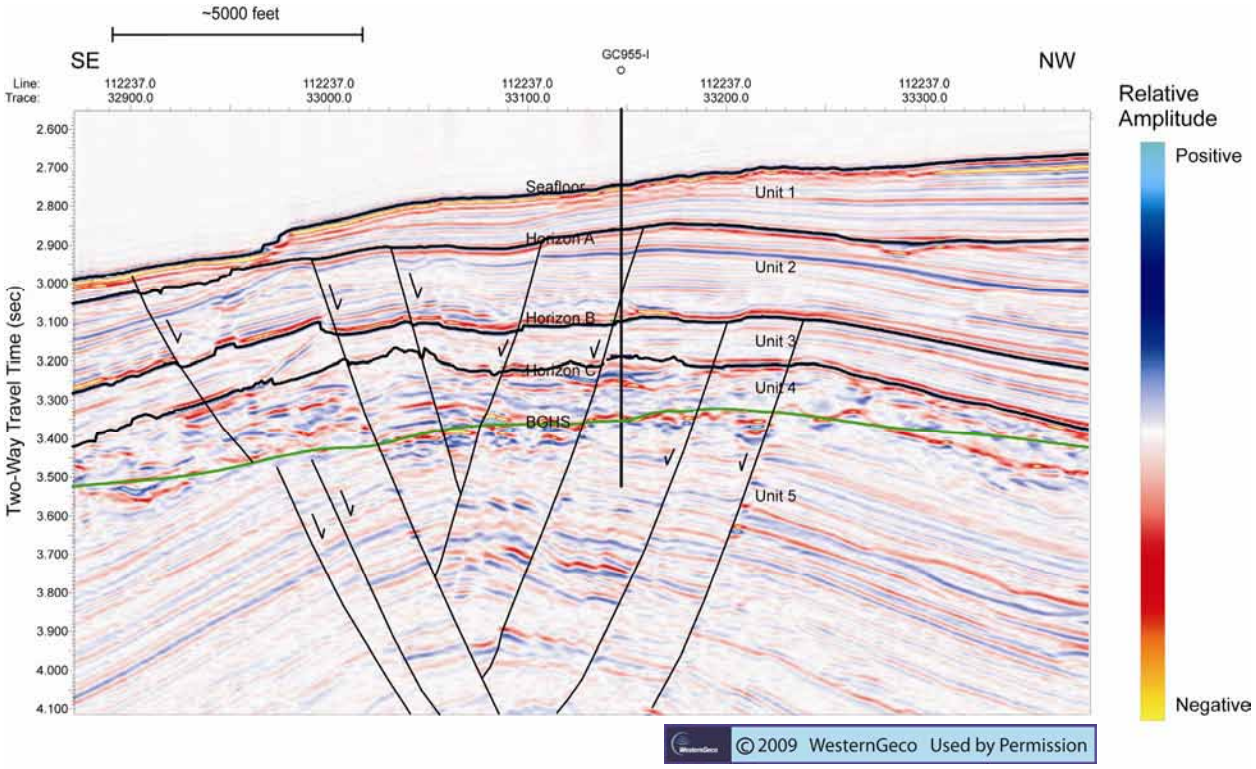
BML: Below Mud Line
BSS: Below Sea Surface
TGHO: Top of Gas Hydrate Occurrence
BGHZ: Base of Gas Hydrate stability Zone




**Appendix F5:** *Stratigraphic interpretation, from AOA Geophysics; Seismic image provided by WesternGeco.*

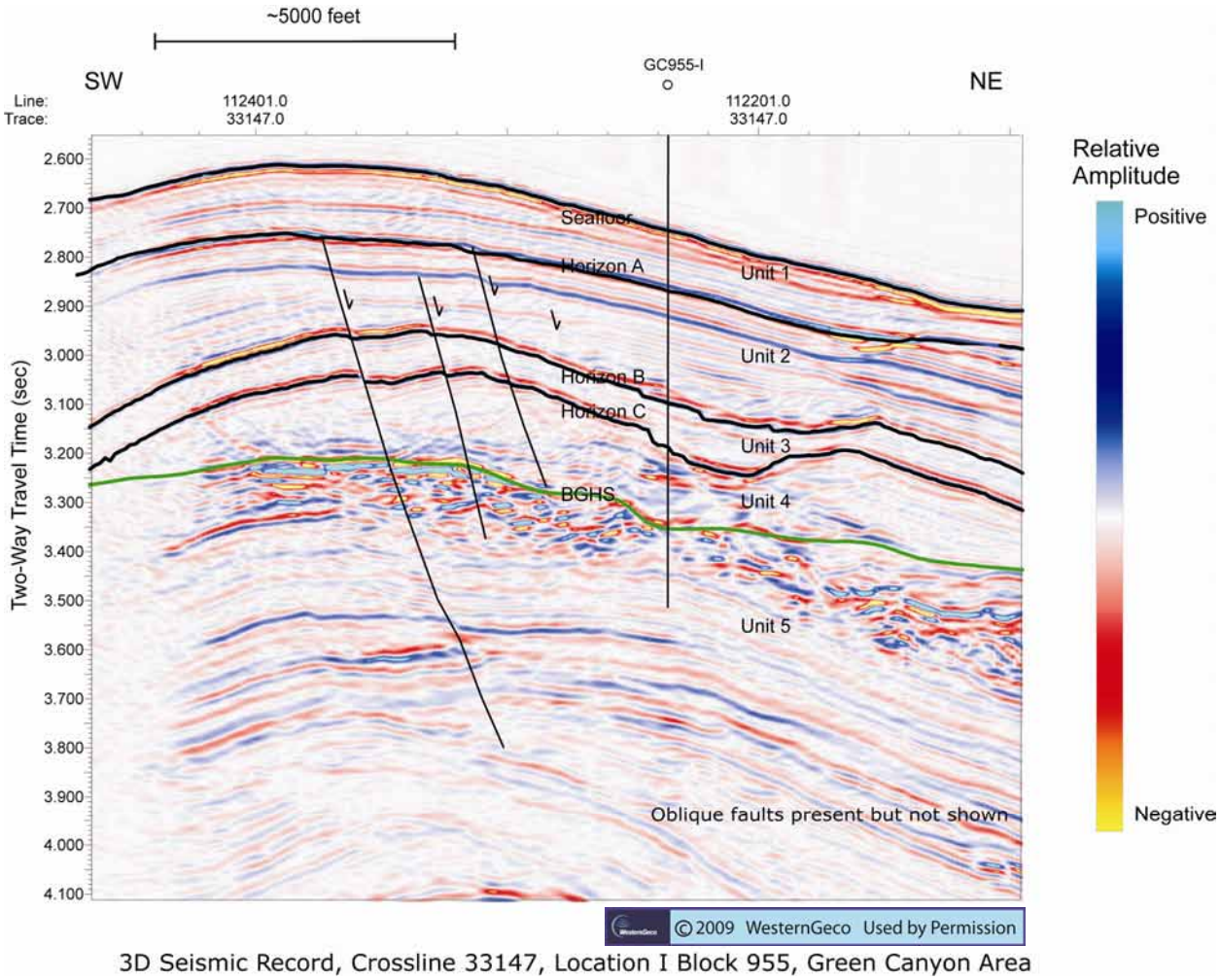



**Appendix F6:** *Map showing location of proposed site GC955-I. Colored bathymetry from WesternGeco.*




3D Seismic Record, Line 112237, Location I Block 955, Green Canyon Area

**Appendix F7:** *Inline seismic profile across GC955-I. Seismic image courtesy of WesternGeco.*




**Appendix F8:** *Crossline seismic profile across GC955-I. Seismic image courtesy of WesternGeco.*

# Target GC955-J (JIP NN)
# Drilling Target Documentation

Table 1: Background Information

| | |
|---|---|
| General Site Objective | *Test of channel levee system with good indicators of gas and fluid flow.* |
| Drilling target and Specific Hole Objective | *Gas hydrate target at 1609 ft BML (8502 ft BSS) and high saturation gas* hydrate *may also exist near 1877 ft BML (8770 ft BSS; on eastern levee, separated from faults)* |
| Other Drilling in Vicinity | GC955#1, GC955#2, |

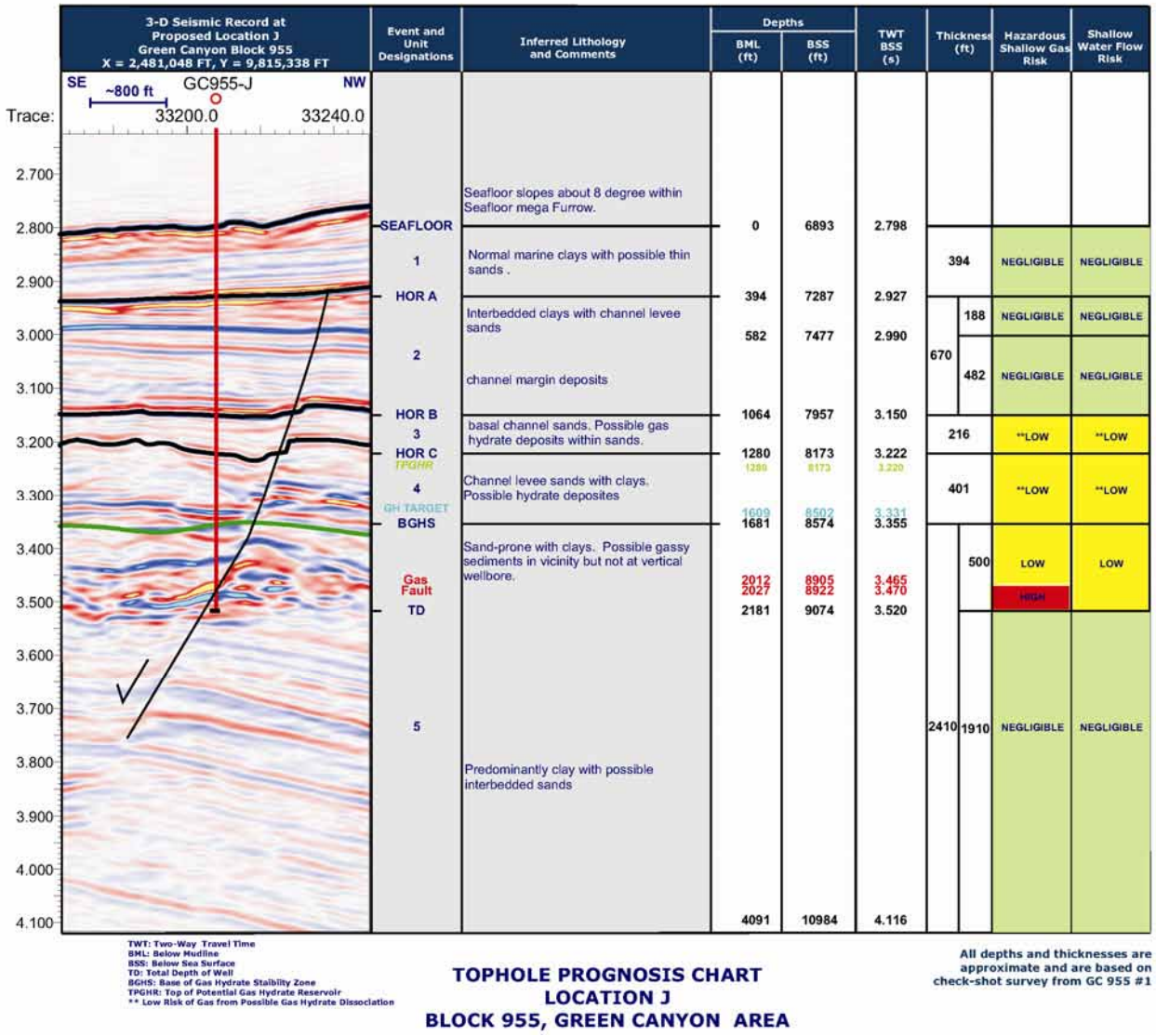
Table 2: Proposed Hole General Information

| | |
|---|---|
| Site Name | Permitted J, JIP NN |
| General Area | *Seaward of the Sigsbee Escarpment, between Green Canyon proper and Green Knoll* |
| Location | Latitude: *27º 01' 31.918" N* Longitude: *90º 25' 02.872" W* |
| Coordinate Datum | *NAD27* |
| Water Depth | *6893 ft BSS* |
| OPD/Lease Block | *GC955* |
| Seismic lines at hole | *Inline 112177, crossline 33208* |

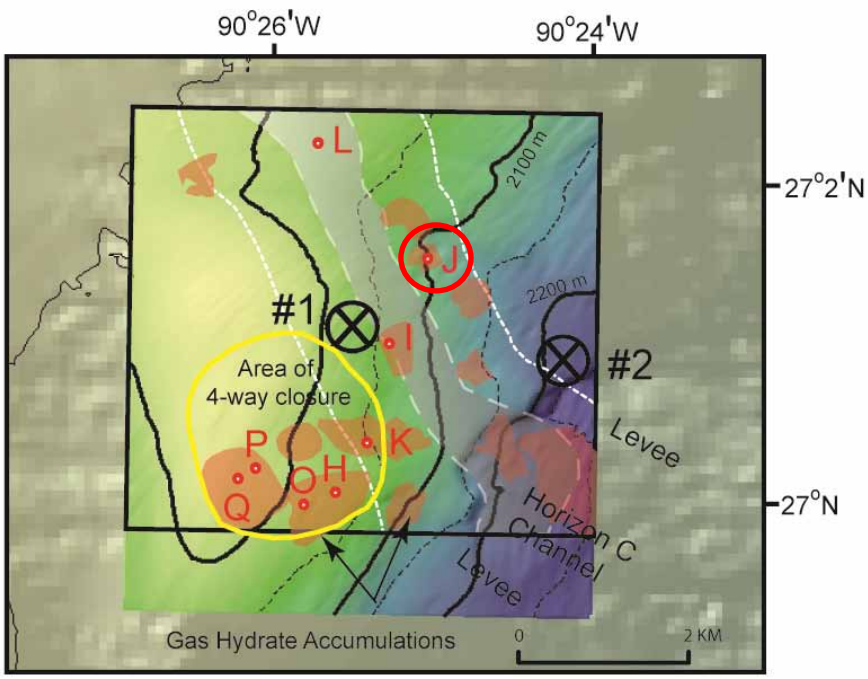
Table 3: Proposed Hole Drilling Information

| | |
|---|---|
| Proposed penetration | *2181 ft BML (consider stopping before 2012 ft BML) 9074 ft BSS* |
| Seafloor slope | *8º to the southeast* |
| Expected lithologies | *0-394 ft BML: normal marine clays with minor sands*<br>*394-1064 ft BML: interbedded clays with channel levee sands going into channel margin deposits*<br>*1064-1280 ft BML: basal channel sands with possible gas hydrate1280-1681 ft BML: channel levee sands with some clay and gas hydrate*<br>*1681-2181 ft BML: sand-prone section with clays, possible gassy sediments near but away from wellbore.* |
| Expected ages/section | *PlioPleistocene* |
| Estimated depth to TGHO | *1280 ft BML (8173 ft BSS)* |
| Estimated depth to BGHZ | *1681 ft BML (8574 ft BSS)* |
| Estimated GH interval | *1280-1681 ft BML (401 ft thick)* |
| Estimated GH saturation | *moderate* |
| Anomalous conditions? | *Gas (?) near a buried fault at 2012 ft BML (8905 ft BSS)*<br>*~381 ft to mooring cable northeast of location J* |
| Other relevant information | *Hole is within area of mega furrows of about 10 ft amplitude that may have been created by currents up to 40 cm/s* |
| Date of Information | 21 May, 2008 |

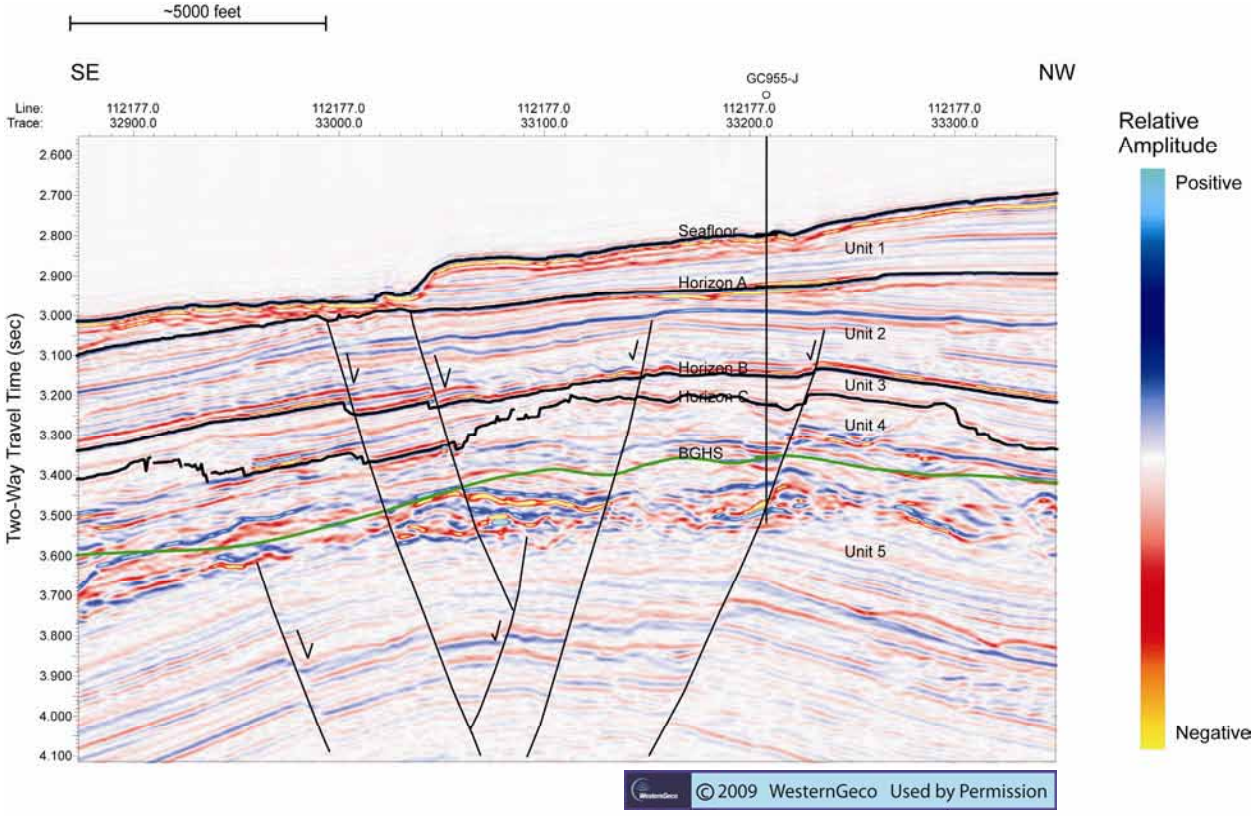
BML: Below Mud Line
BSS: Below Sea Surface
TGHO: Top of Gas Hydrate Occurrence
BGHZ: Base of Gas Hydrate stability Zone



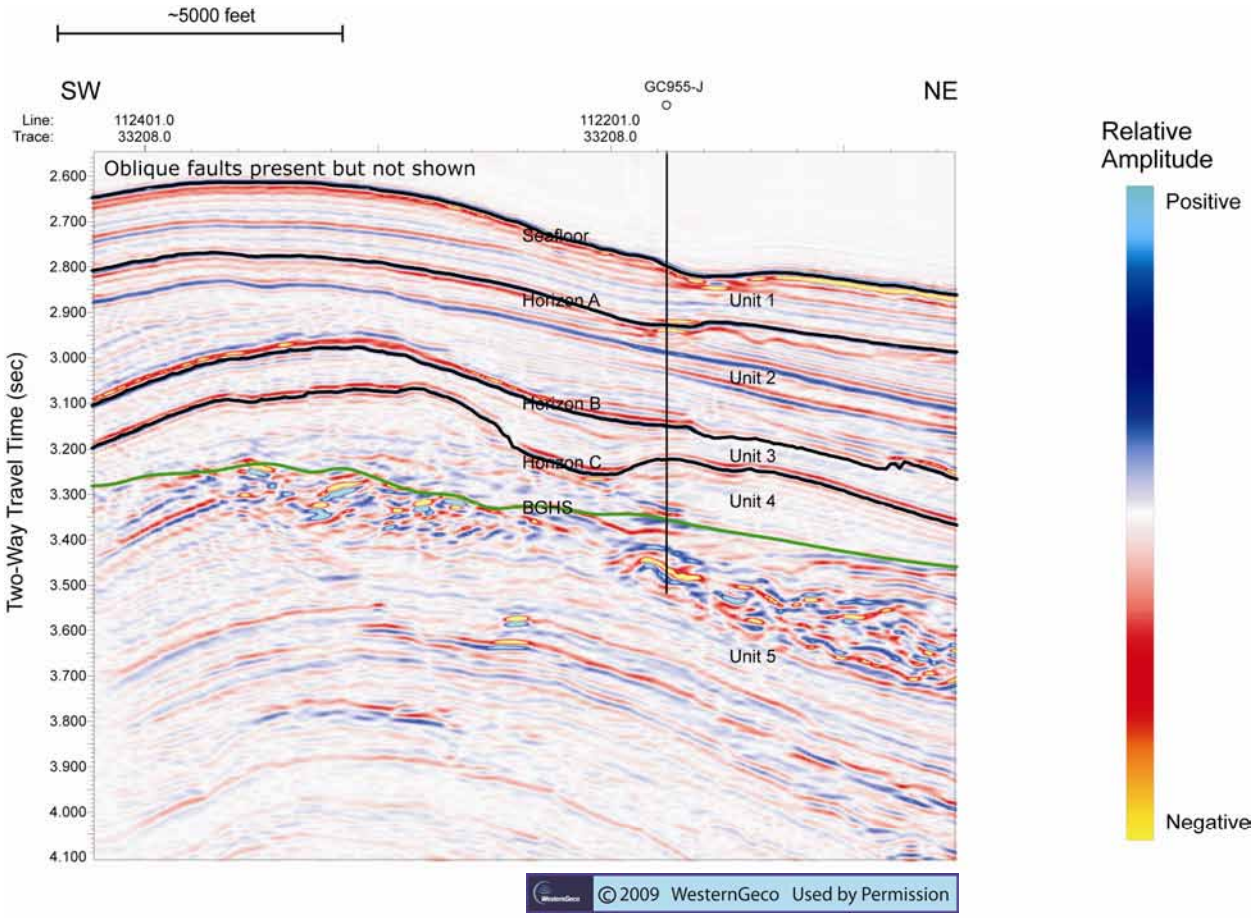

**Appendix F9:** *Stratigraphic interpretation, from AOA Geophysics; Seismic image provided by WesternGeco.*




**Appendix F10:** *Map showing location of proposed site GC955-J. Colored bathymetry from WesternGeco.*




**Appendix F11:** *Inline seismic profile across GC955-J. Seismic image courtesy of WesternGeco.*




3D Seismic Record, Crossline 33208, Location J Block 955, Green Canyon Area

**Appendix F12:** *Crossline seismic profile across GC955-J. Seismic image courtesy of WesternGeco.*

# Target GC955-K (JIP QQ)
# Drilling Target Documentation

Table 1: Background Information

| | |
|---|---|
| General Site Objective | *Test of channel levee system with good indicators of gas and fluid flow.* |
| Drilling target and Specific Hole Objective | *Strong peak over strong trough gas hydrate target at 1554 ft BML (8273 ft BSS), about 36 ft above BGHS, in down dip position of main closure.* |
| Other Drilling in Vicinity | GC955#1, GC955#2, |

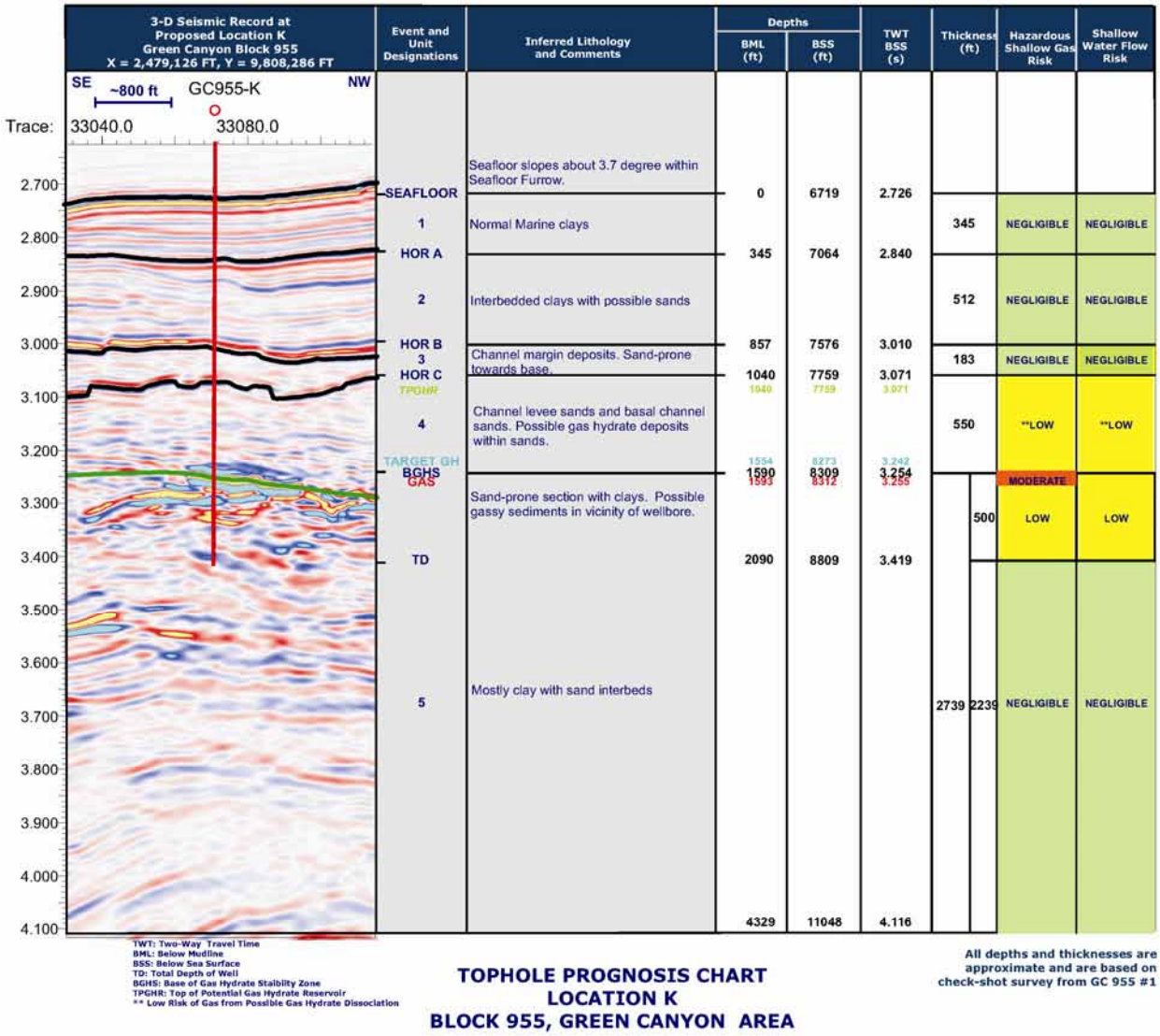
Table 2: Proposed Hole General Information

| | |
|---|---|
| Site Name | Permitted K, JIP QQ |
| General Area | *Seaward of the Sigsbee Escarpment, between Green Canyon proper and Green Knoll* |
| Location | Latitude: *27° 00' 22.513"N* Longitude: *90° 25' 25.704" W* |
| Coordinate Datum | *NAD27* |
| Water Depth | *6719 ft BSS* |
| OPD/Lease Block | *GC955* |
| Seismic lines at hole | *Inline 112291, crossline33071* |

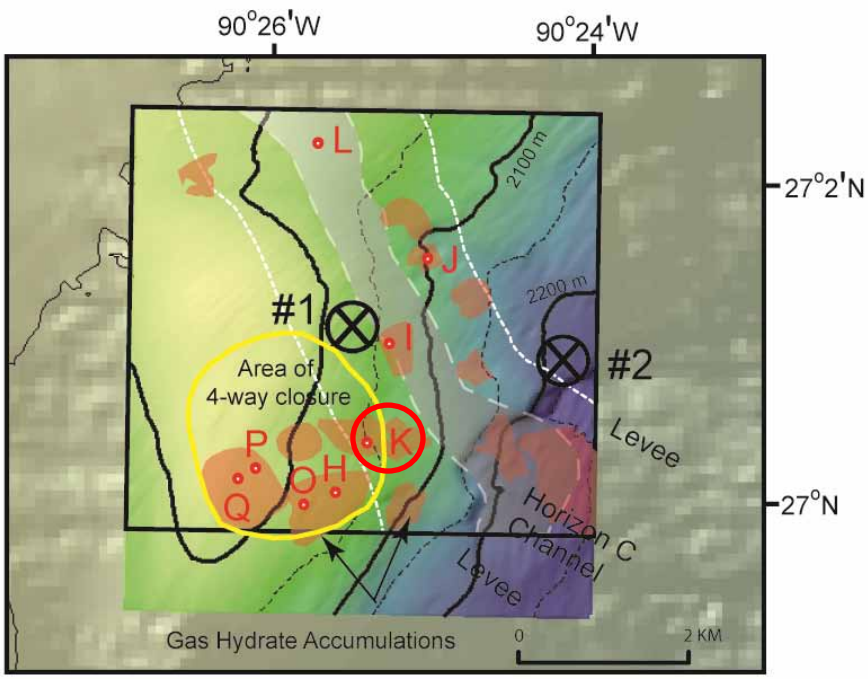
Table 3: Proposed Hole Drilling Information

| | |
|---|---|
| Proposed penetration | *2090 ft BML 8809 ft BSS* |
| Seafloor slope | *3.7° to the east* |
| Expected lithologies | *0-345 ft BML: normal marine clays*<br>*345-857 ft BML: interbedded clays with possible sands*<br>*857-1040 ft BML: channel margin deposits, sand-prone towards base*<br>*1040-1590 ft BML: channel levee sands and basal channel sands with possible gas hydrate*<br>*1590-2090 ft BML: sand-prone section with clays, possible gassy sediments near wellbore* |
| Expected ages/section | *PlioPleistocene* |
| Estimated depth to TGHO | *1040 ft BML (7759 ft BSS)* |
| Estimated depth to BGHZ | *1590 ft BML (8309 ft BSS)* |
| Estimated GH interval | *1040-1590 ft BML (550 ft thick)* |
| Estimated GH saturation | *High* |
| Anomalous conditions? | *~925 ft to mooring cable north northwest of location K*<br>*Possible gas near 1593 ft BML (8312 ft BSS)* |
| Other relevant information | *Hole is within area of mega furrows of about 10 ft amplitude that may have been created by currents up to 40 cm/s* |
| Date of Information | 21 May, 2008 |

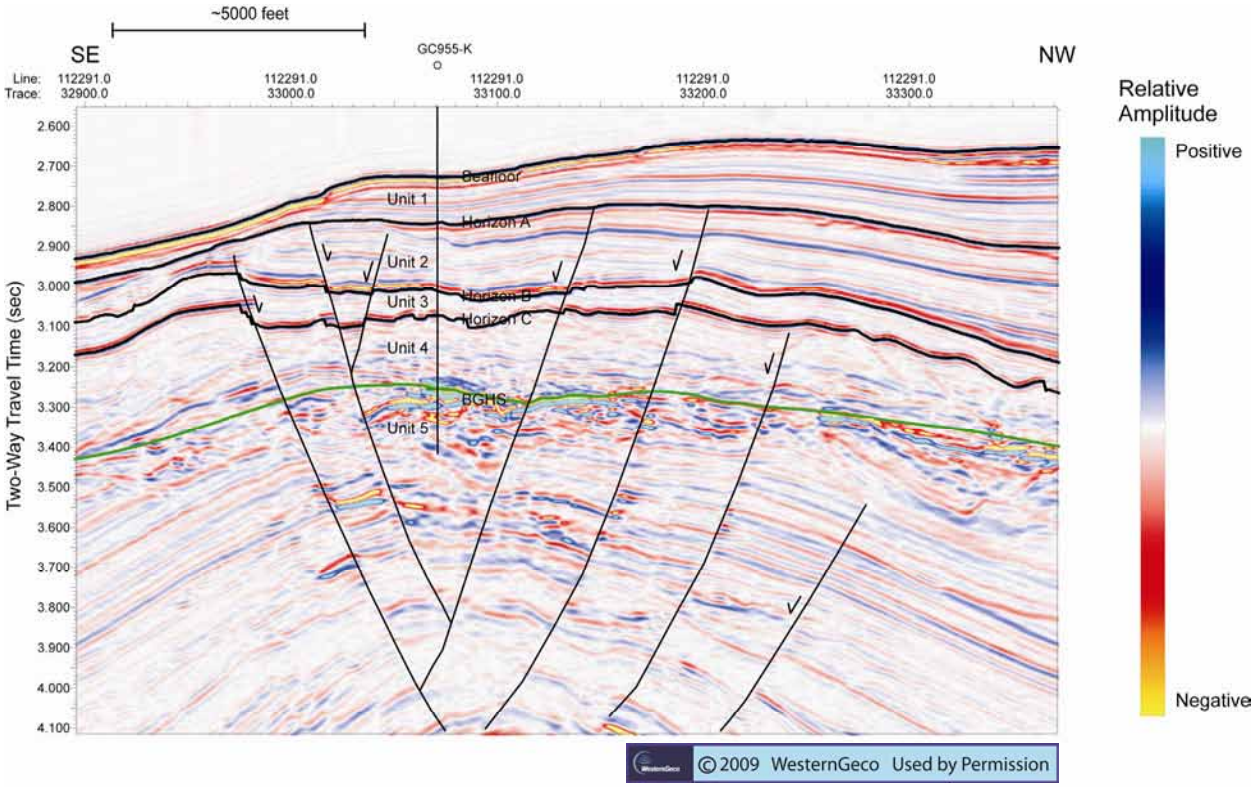
BML: Below Mud Line
BSS: Below Sea Surface
TGHO: Top of Gas Hydrate Occurrence
BGHZ: Base of Gas Hydrate stability Zone




**Appendix F13:** *Stratigraphic interpretation, from AOA Geophysics; Seismic image provided by WesternGeco.*

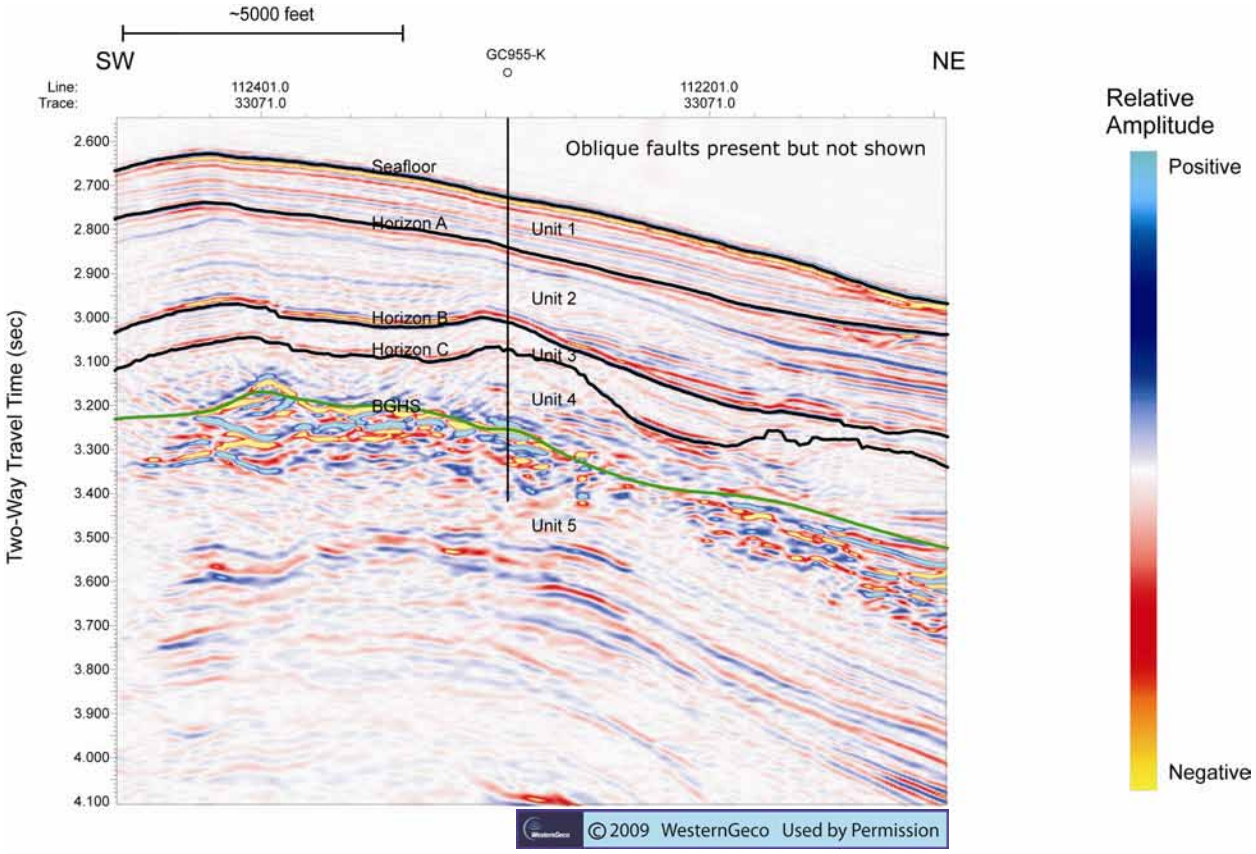



**Appendix F14:** *Map showing location of proposed site GC955-K. Colored bathymetry from WesternGeco.*




3D Seismic Record, Line 112291, Location K Block 955, Green Canyon Area

**Appendix F15:** *Inline seismic profile across GC955-K. Seismic image courtesy of WesternGeco.*




3D Seismic Record, Crossline 33071, Location K Block 955, Green Canyon Area

**Appendix F16:** *Crossline seismic profile across GC955-K. Seismic image courtesy of WesternGeco.*

# Target GC955-L (JIP RR)
# Drilling Target Documentation

Table 1: Background Information

| | |
|---|---|
| General Site Objective | *Test of channel levee system with good indicators of gas and fluid flow.* |
| Drilling target and Specific Hole Objective | *Gas hydrate target at 1997 ft BML (8611 ft BSS), channel at north end of block near intersection with BGHZ* |
| Other Drilling in Vicinity | GC955#1, GC955#2, |

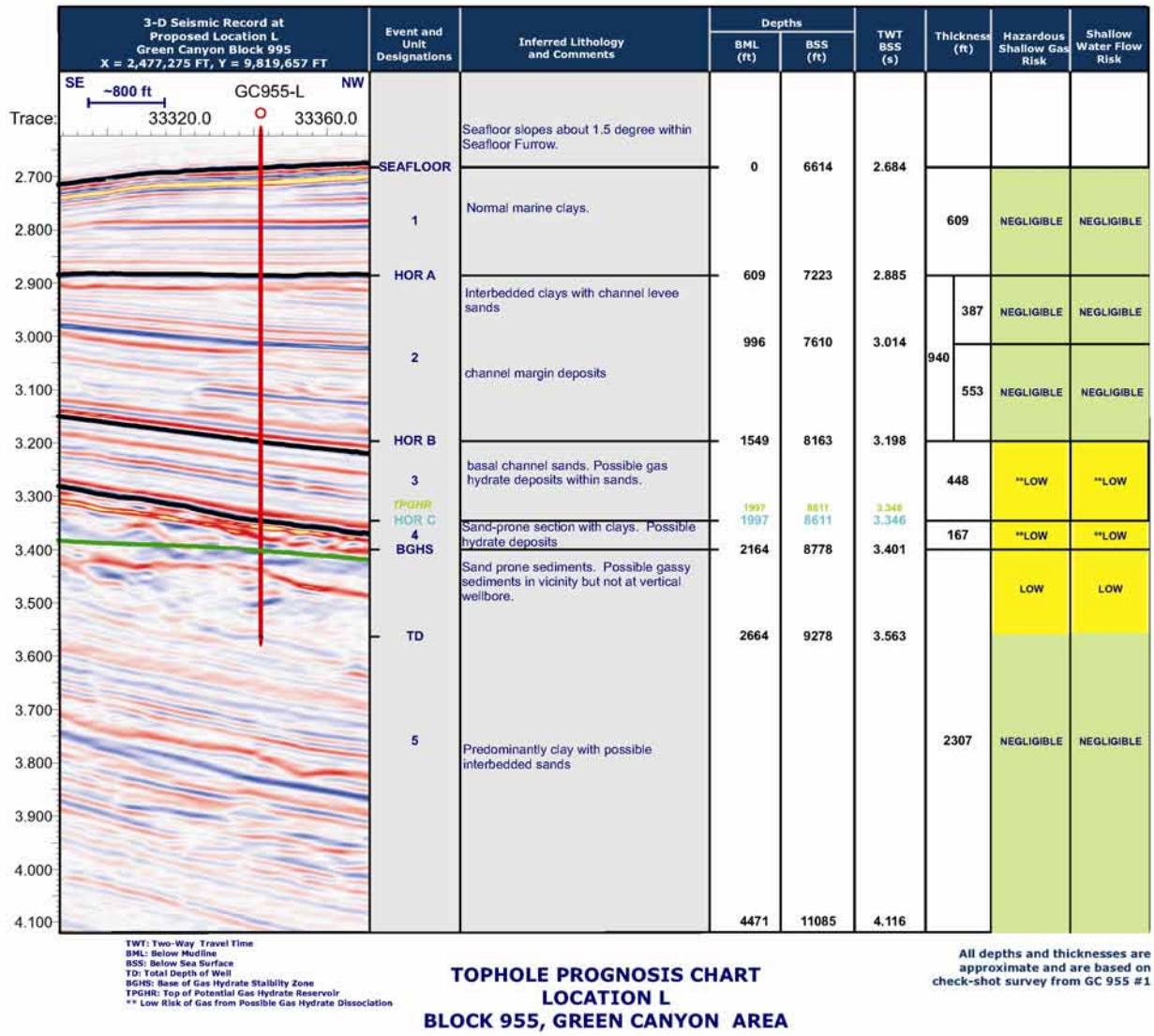
Table 2: Proposed Hole General Information

| | |
|---|---|
| Site Name | Permitted L, JIP RR |
| General Area | *Seaward of the Sigsbee Escarpment, between Green Canyon proper and Green Knoll* |
| Location | Latitude: *27° 02' 15.428" N* Longitude: *90° 25' 43.592" W* |
| Coordinate Datum | *NAD27* |
| Water Depth | *6614 ft BSS* |
| OPD/Lease Block | *GC955* |
| Seismic lines at hole | *Inline 112217, crossline 33342* |

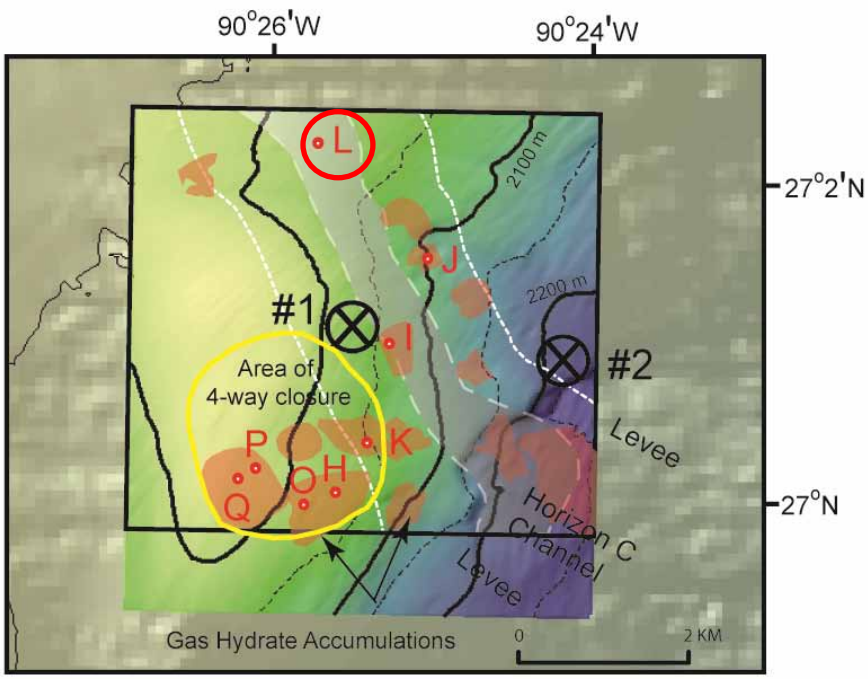
Table 3: Proposed Hole Drilling Information

| | |
|---|---|
| Proposed penetration | *2664 ft BML 9278 ft BSS* |
| Seafloor slope | *1.5° to the southeast* |
| Expected lithologies | *0-609 ft BML: normal marine clays*<br>*609-1549 ft BML: Interbedded clays with channel levee sands going into deeper channel margin deposits*<br>*1549-1997 ft BML: basal channel sands with possible gas hydrate*<br>*1997-2164 ft BML: sand prone section with clays, also gas hydrate*<br>*2164-2664 ft BML: sand prone sediments, possibly gassy* |
| Expected ages/section | *PlioPleistocene* |
| Estimated depth to TGHO | *1997 ft BML (8611 ft BSS)* |
| Estimated depth to BGHZ | *2164 ft BML (8778 ft BSS), could be as deep as 2281 / 8895 ft* |
| Estimated GH interval | *1997-2164 ft BML (167 ft thick)* |
| Estimated GH saturation | *high* |
| Anomalous conditions? | *~1535 ft to mooring cable southeast of location K* |
| Other relevant information | *Hole is within area of mega furrows of about 10 ft amplitude that may have been created by currents up to 40 cm/s* |
| Date of Information | 21 May, 2008 |

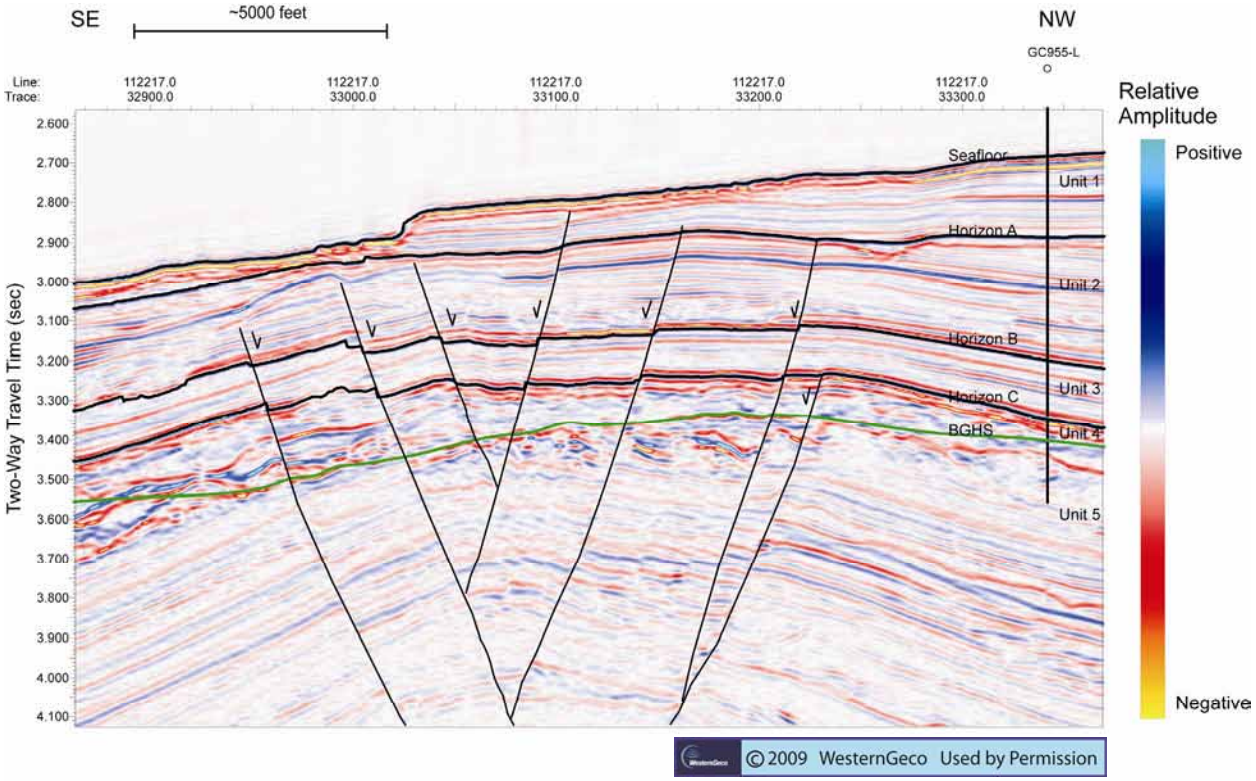
BML: Below Mud Line
BSS: Below Sea Surface
TGHO: Top of Gas Hydrate Occurrence
BGHZ: Base of Gas Hydrate stability Zone




**Appendix F17:** *Stratigraphic interpretation, from AOA Geophysics; Seismic image provided by WesternGeco.*

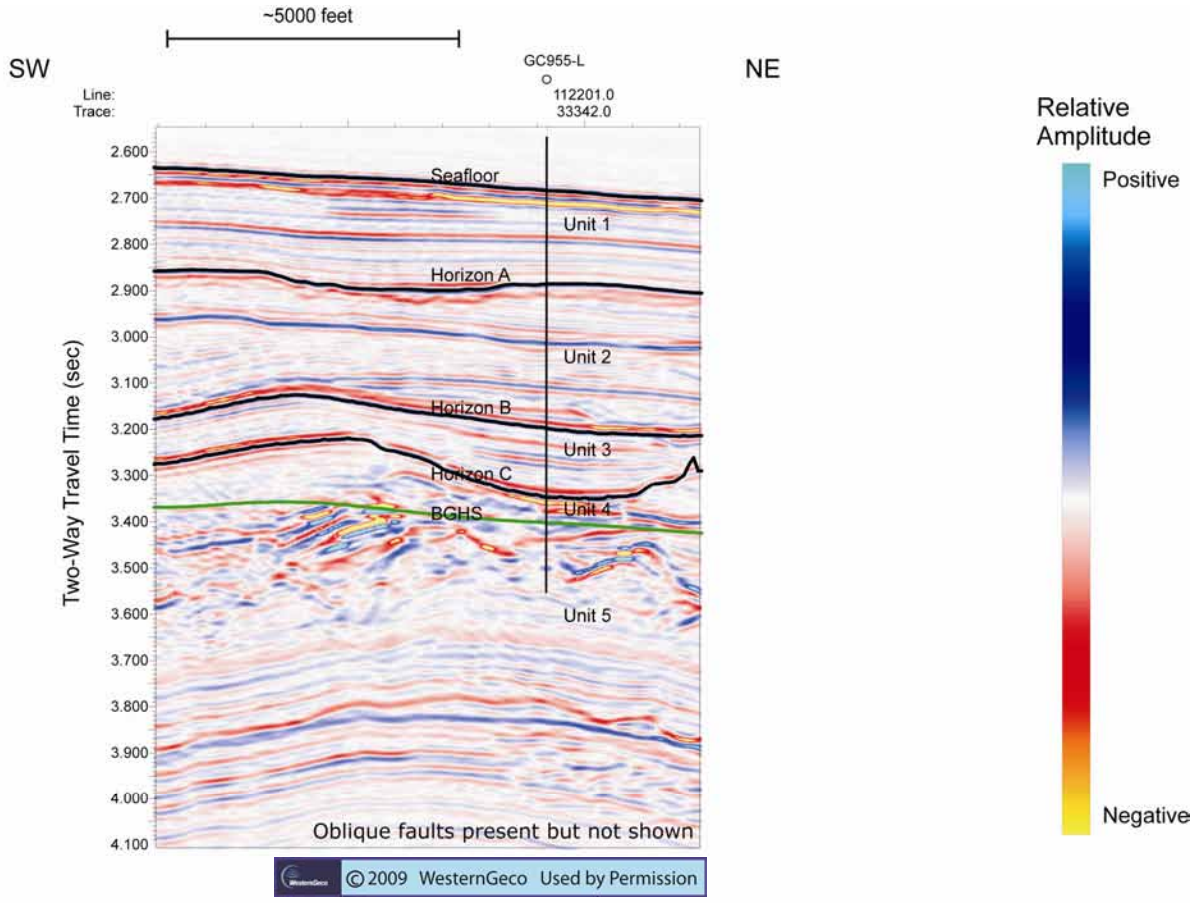



**Appendix F18:** *Map showing location of proposed site GC955-L. Colored bathymetry from WesternGeco.*




3D Seismic Record, Line 112217, Location L Block 955, Green Canyon Area

**Appendix F19:** *Inline seismic profile across GC955-L. Seismic image courtesy of WesternGeco.*




3D Seismic Record, Crossline 33342, Location L Block 955, Green Canyon Area

**Appendix F20:** *Crossline seismic profile across GC955-L. Seismic image courtesy of WesternGeco.*

# Target GC955-O (JIP VV)
# Drilling Target Documentation

Table 1: Background Information

| | |
|---|---|
| General Site Objective | *Test of channel levee sands with nearby indicators of gas and fluid flow.* |
| Drilling target and Specific Hole Objective | *Strong peak over trough reflection at 1506 ft BML (8104 ft BSS), near surficial fluid expulsion mound, distal levee in closure structure.* |
| Other Drilling in Vicinity | GC955#1 (1.3 mi to the NE), GC955#2 (1.9 mi to the NE) |

Table 2: Proposed Hole General Information

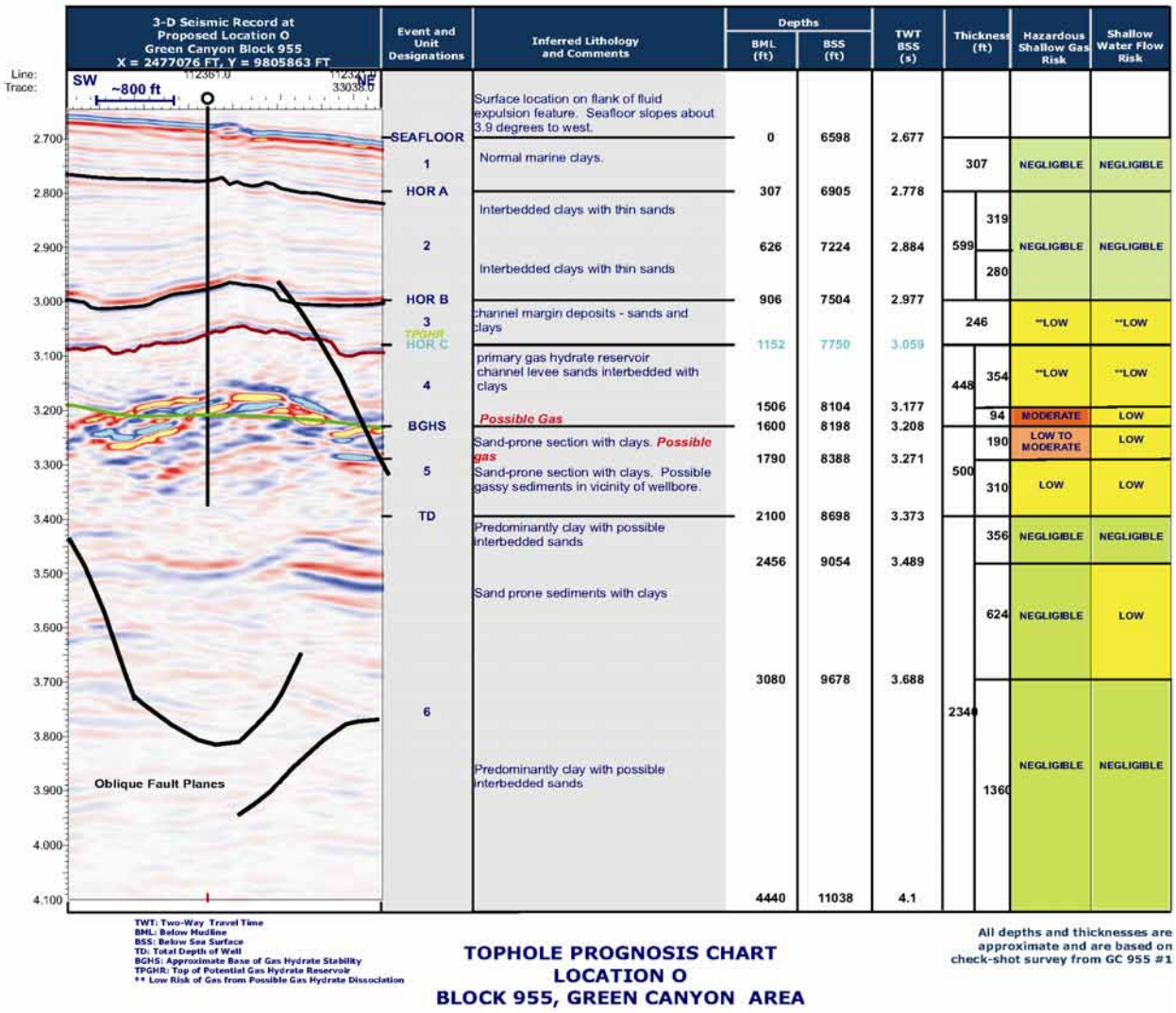
| | |
|---|---|
| Site Name | Permitted O JIP VV |
| General Area | *Between the Sigsbee Escarpment and Green Knoll, near Green Canyon proper* |
| Location | Latitude: *26° 59' 58.950" N* Longitude: *90° 25' 48.902" W* |
| Coordinate Datum | *NAD27* |
| Water Depth | *6598 ft BSS* |
| OPD/Lease Block | *GC955* |
| Seismic lines at hole | **Inline 112361, crossline 33038* |

Table 3: Proposed Hole Drilling Information

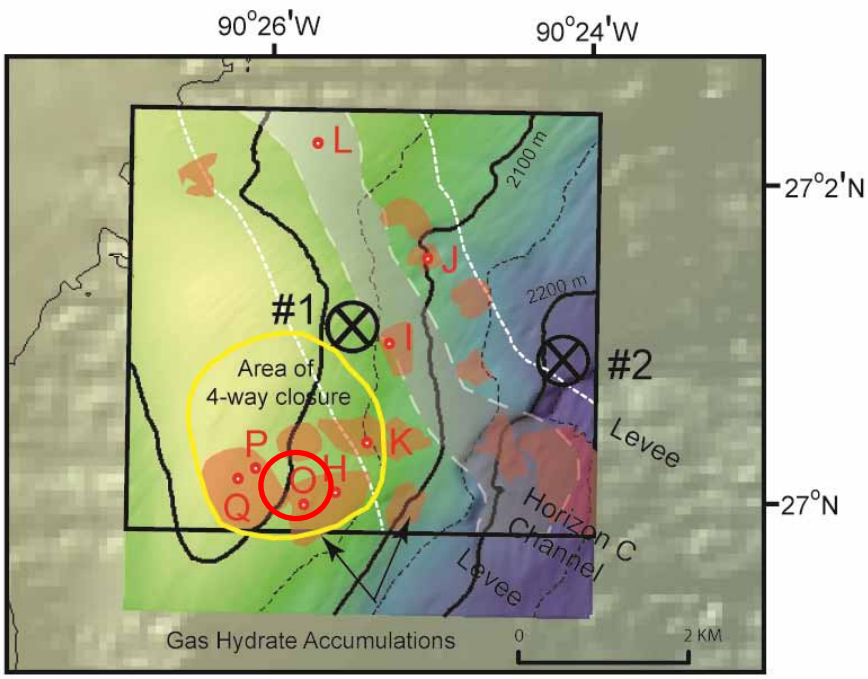
| | |
|---|---|
| Proposed penetration | *2100 ft BML 8698 ft BSS* |
| Seafloor slope | *3.9° to the west* |
| Expected lithologies | *307' Unit 1 mud-rich sediments*<br>*599' Unit 2 interbedded clays with thin sands*<br>*246' Unit 3 channel margin deposits, sand prone*<br>*Major Unconformity*<br>*448' Unit 4 channel levee sands (gas hydrate reservoir)*<br>*500' Unit 5 sand-prone with clays, gas possible* |
| Expected ages/section | *PlioPleistocene* |
| Estimated depth to TGHO | *1152 ft BML 7750 ft BSS* |
| Estimated depth to BGHZ | *1600 ft BML 8198 ft BSS* |
| Estimated GH interval | *448 ft thick* |
| Estimated GH saturation | *85 %* |
| Anomalous conditions? | *Moderate – low gas hazard at and below BGHZ* |
| Other relevant information | *Sea floor escarpment with 400 ft relief ~ 1 mi to the east*<br>*Fluid expulsion mound (30 ft relief) ~180 ft west of "O"*<br>*May penetrate faults associated with fluid expulsion feature (unresolved)* |
| Source of Information | *AOA Hazards Summary 4021-JIP-GOM-GC955O 14 June, 2008* |

* Proposed alternate location ~280 ft SW of "O", x-112367, in-33035.

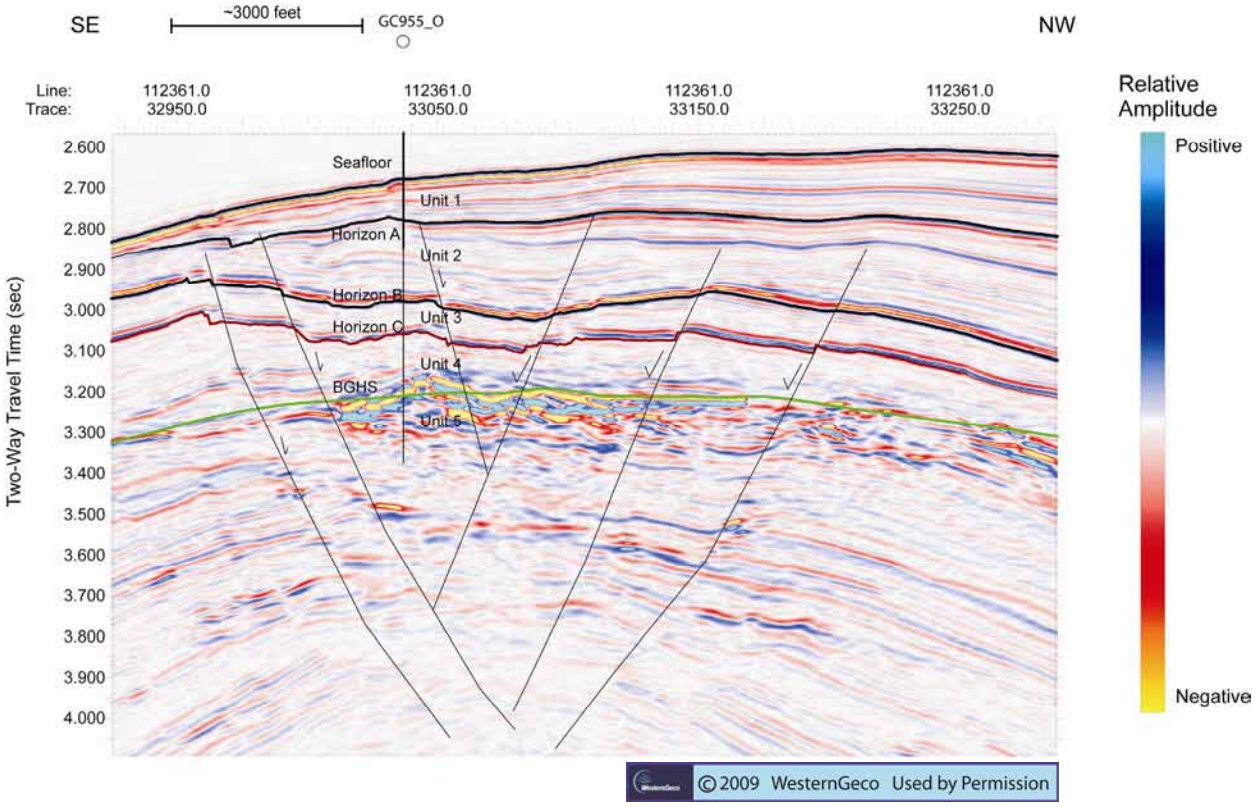
BML: Below Mud Line
BSS: Below Sea Surface
TGHO: Top of Gas Hydrate Occurrence
BGHZ: Base of Gas Hydrate stability Zone




**Appendix F21:** *Stratigraphic interpretation, from AOA Geophysics; Seismic image provided by WesternGeco.*

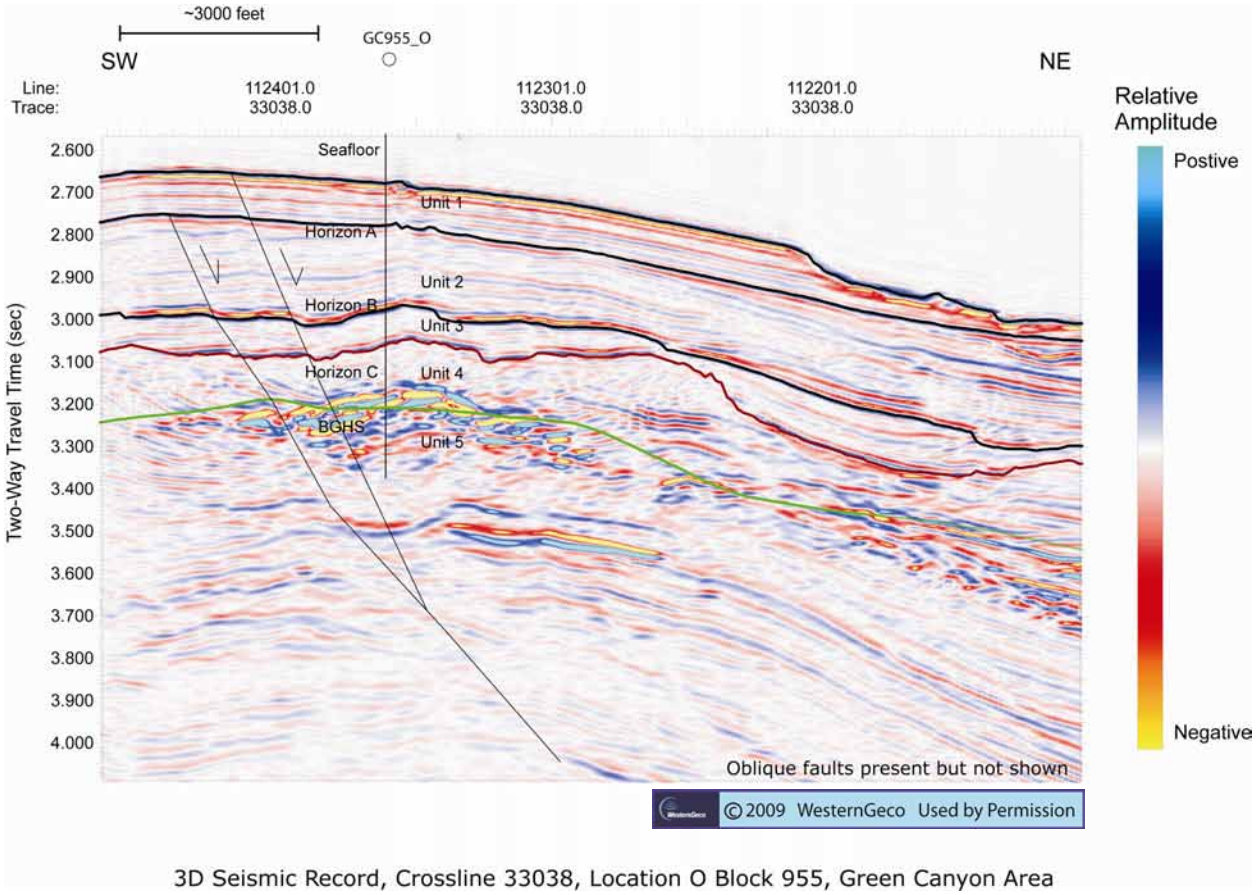



**Appendix F22:** *Map showing location of proposed site GC955-O. Colored bathymetry from WesternGeco.*




3D Seismic Record, Line 112361, Location O Block 955, Green Canyon Area

**Appendix F23:** *Inline seismic profile across GC955-O. Seismic image courtesy of WesternGeco.*




**Appendix F24:** *Crossline seismic profile across GC955-O. Seismic image courtesy of WesternGeco.*

# Target GC955-P (JIP WW )
# Drilling Target Documentation

Table 1: Background Information

| | |
|---|---|
| General Site Objective | *Test of channel levee sands with nearby indicators of gas and fluid flow.* |
| Drilling target and Specific Hole Objective | *Strong peak anomaly at 1817 ft BML (8328 ft BSS) near crest of the large closure structure, along principal seafloor fault* |
| Other Drilling in Vicinity | GC955#1 (1.2 mi to the NE), GC955#2 (2.1 mi to the ENE) |

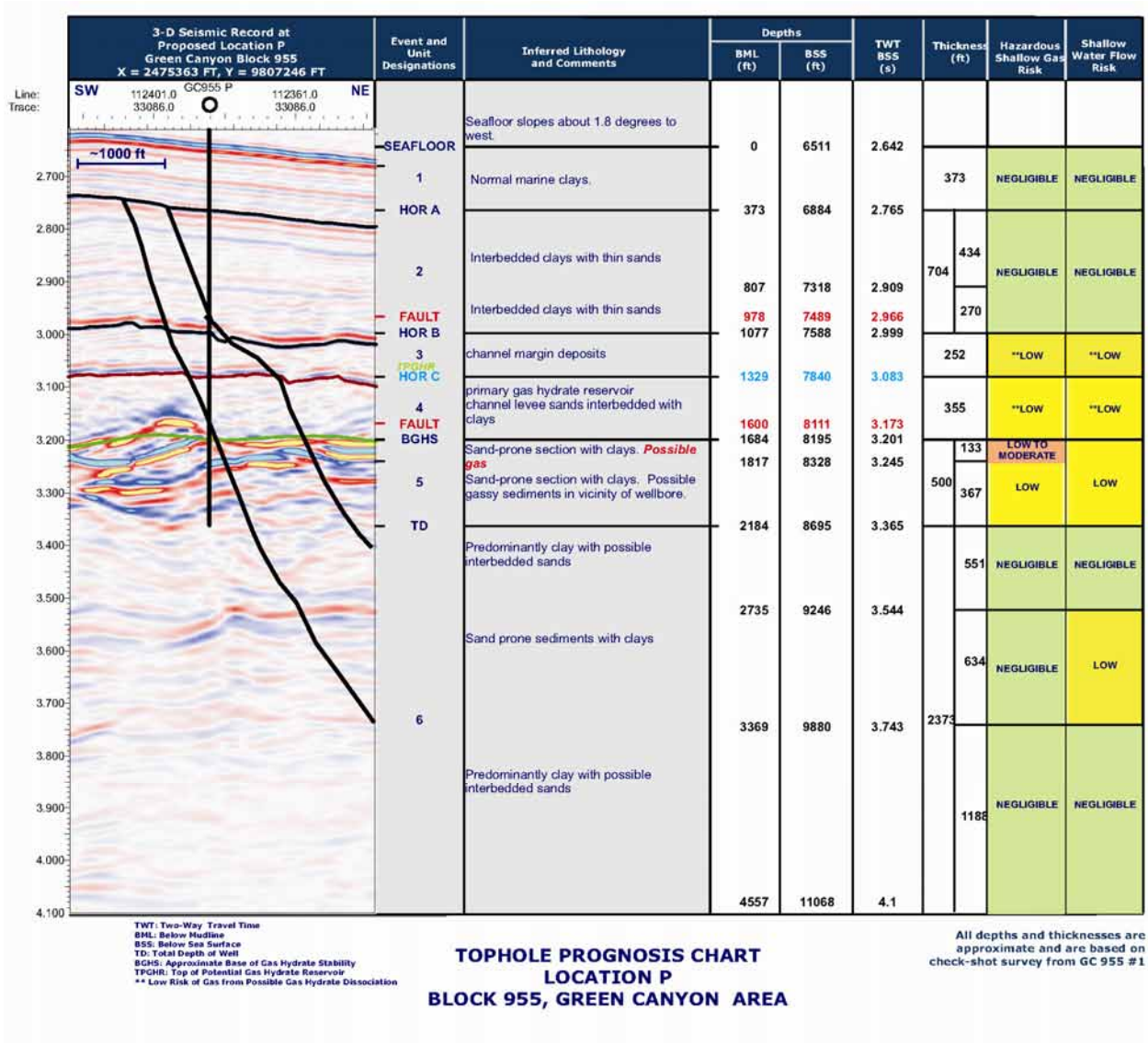
Table 2: Proposed Hole General Information

| | |
|---|---|
| Site Name | *Permitted **P**; JIP WW* |
| General Area | *Between the Sigsbee Escarpment and Green Knoll, near Green Canyon proper* |
| Location | Latitude: *27°00'12.978" N* Longitude: *90° 26' 07.511" W* |
| Coordinate Datum | *NAD27* |
| Water Depth | *6511 ft BSS* |
| OPD/Lease Block | *GC955* |
| Seismic lines at hole | *Inline 112385 , crossline 33086* |

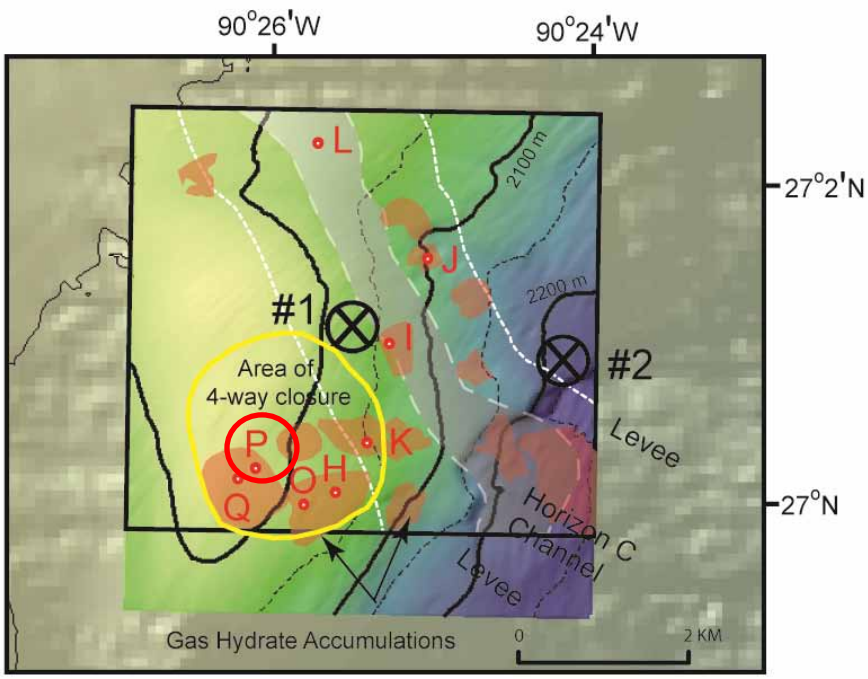
Table 3: Proposed Hole Drilling Information

| | |
|---|---|
| Proposed penetration | *2184 ft BML 8695 ft BSS* |
| Seafloor slope | *1.8° to the west* |
| Expected lithologies | *373' Unit 1 mud rich recent sediments*<br>*704' Unit 2 interbedded clays with possible thin sands*<br>*252' Unit 3 channel margin deposits, sand prone*<br>*Major Unconformity*<br>*355' Unit 4 channel levee sands – gas hydrate reservoir*<br>*500 ' Unit 5 upper – clays with sands and sand prone sediments with clays* |
| Expected ages/section | *PlioPleistocene* |
| Estimated depth to TGHO | *1329 ft BML 7840 ft BSS* |
| Estimated depth to BGHZ | *1684 ft BML 8195 ft BSS* |
| Estimated GH interval | *355 ft thick* |
| Estimated GH saturation | *70 % (lower at BGHS)* |
| Anomalous conditions? | *Fault at 978 ft BML, oriented N/S and dips east,*<br>*Fault at ~1600 ft BML, oriented SW/NE and dips SE* |
| Other relevant information | *Sea floor escarpment with 400 ft relief ~ 1.3 mi to the east*<br>*Fluid expulsion mound (30 ft relief) ~2060 ft sw of "P"* |
| Source of Information | *AOA Hazards Summary 4021-JIP-GOM-GC955P 14 June, 2008* |

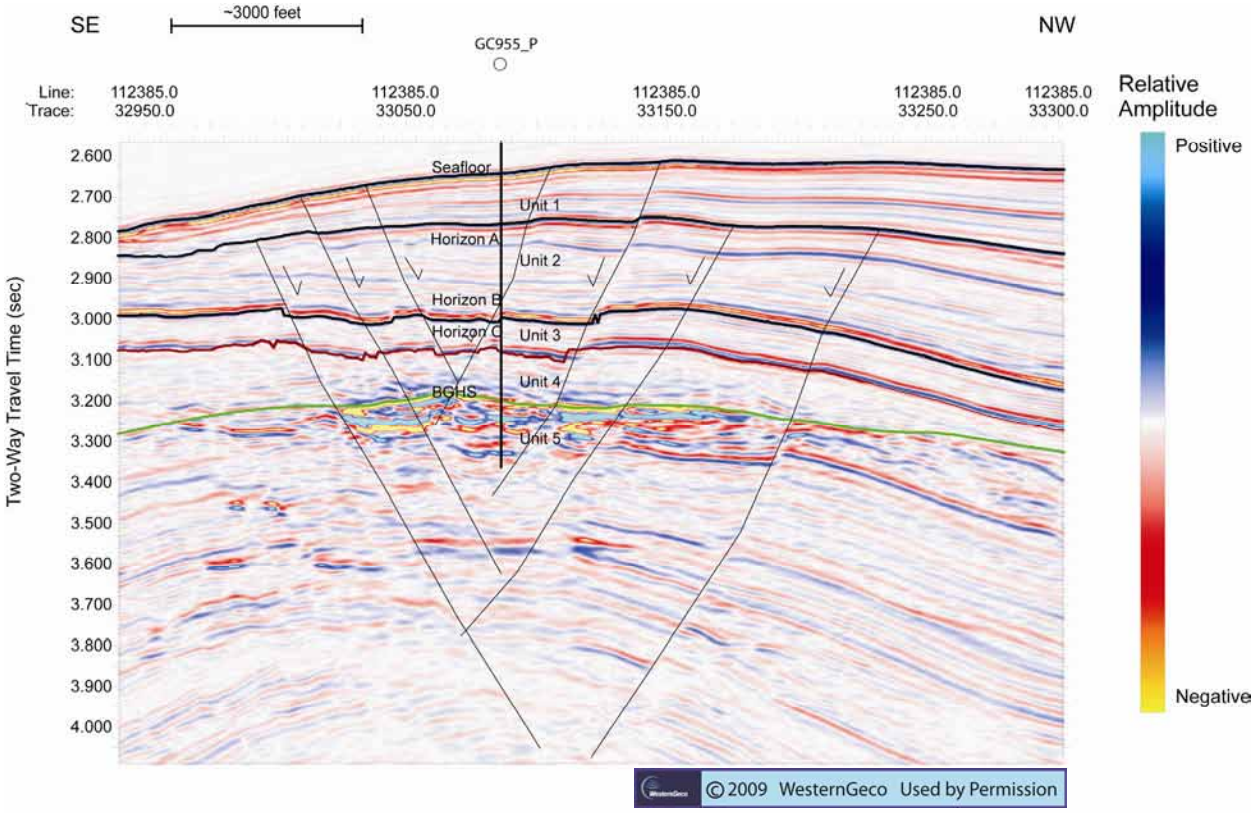
BML: Below Mud Line
BSS: Below Sea Surface
TGHO: Top of Gas Hydrate Occurrence
BGHZ: Base of Gas Hydrate stability Zone




**Appendix F25:** *Stratigraphic interpretation, from AOA Geophysics; Seismic image provided by WesternGeco.*

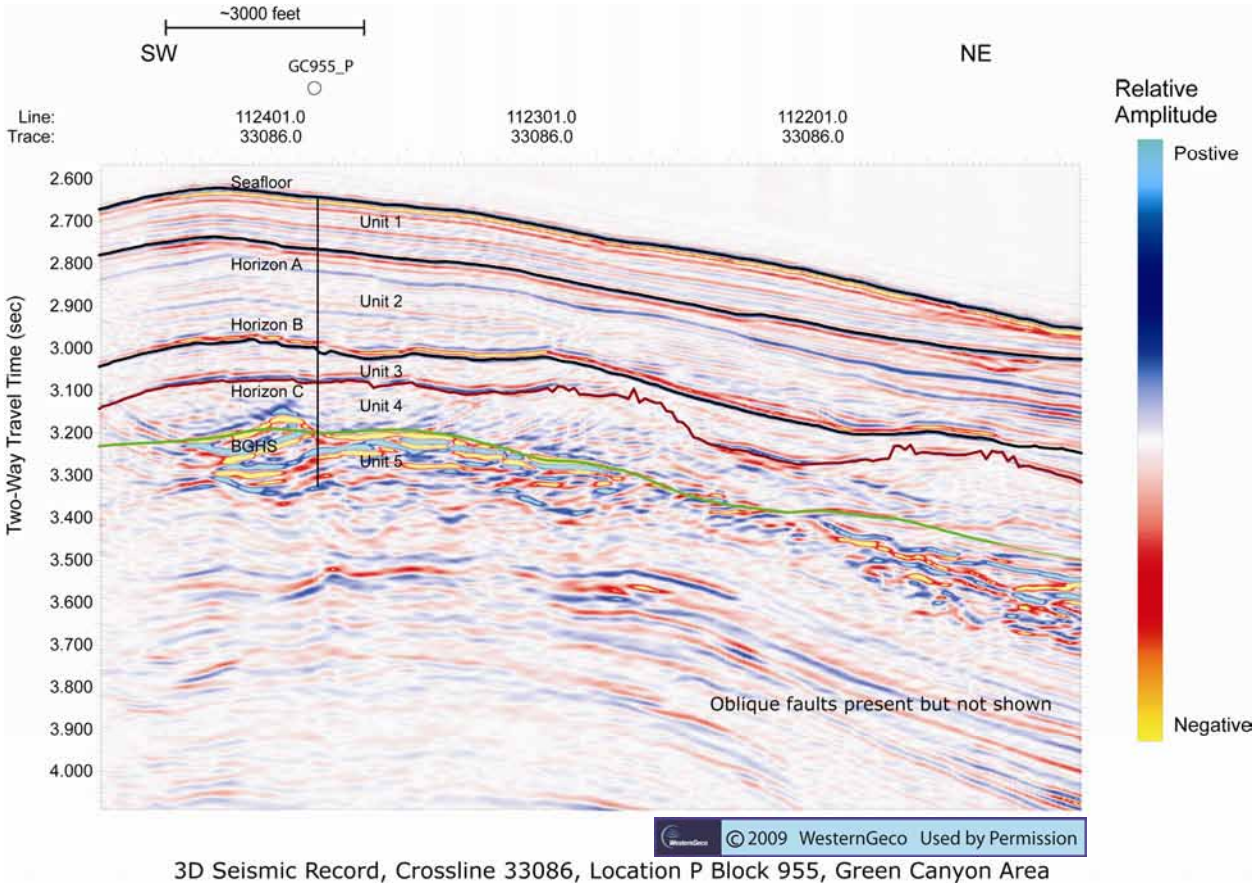



**Appendix F26:** *Map showing location of proposed site GC955-P. Colored bathymetry from WesternGeco.*




3D Seismic Record, Line 112385, Location P Block 955, Green Canyon Area

**Appendix F27:** *Inline seismic profile across GC955-P. Seismic image courtesy of WesternGeco.*




**Appendix F28:** *Crossline seismic profile across GC955-P. Seismic image courtesy of WesternGeco.*

# Target GC955-Q (JIP XX)
# Drilling Target Documentation

Table 1: Background Information

| | |
|---|---|
| General Site Objective | *Test of channel levee sands with nearby indicators of gas and fluid flow.* |
| Drilling target and Specific Hole Objective | *Strong peak over strong trough at 8085 ft BSS, on upthrown side of fault but downdip of potential gas beneath closure structure* |
| Other Drilling in Vicinity | #1 (1.3 mi to the NNE), #2 (2.3 mi to the NE) |

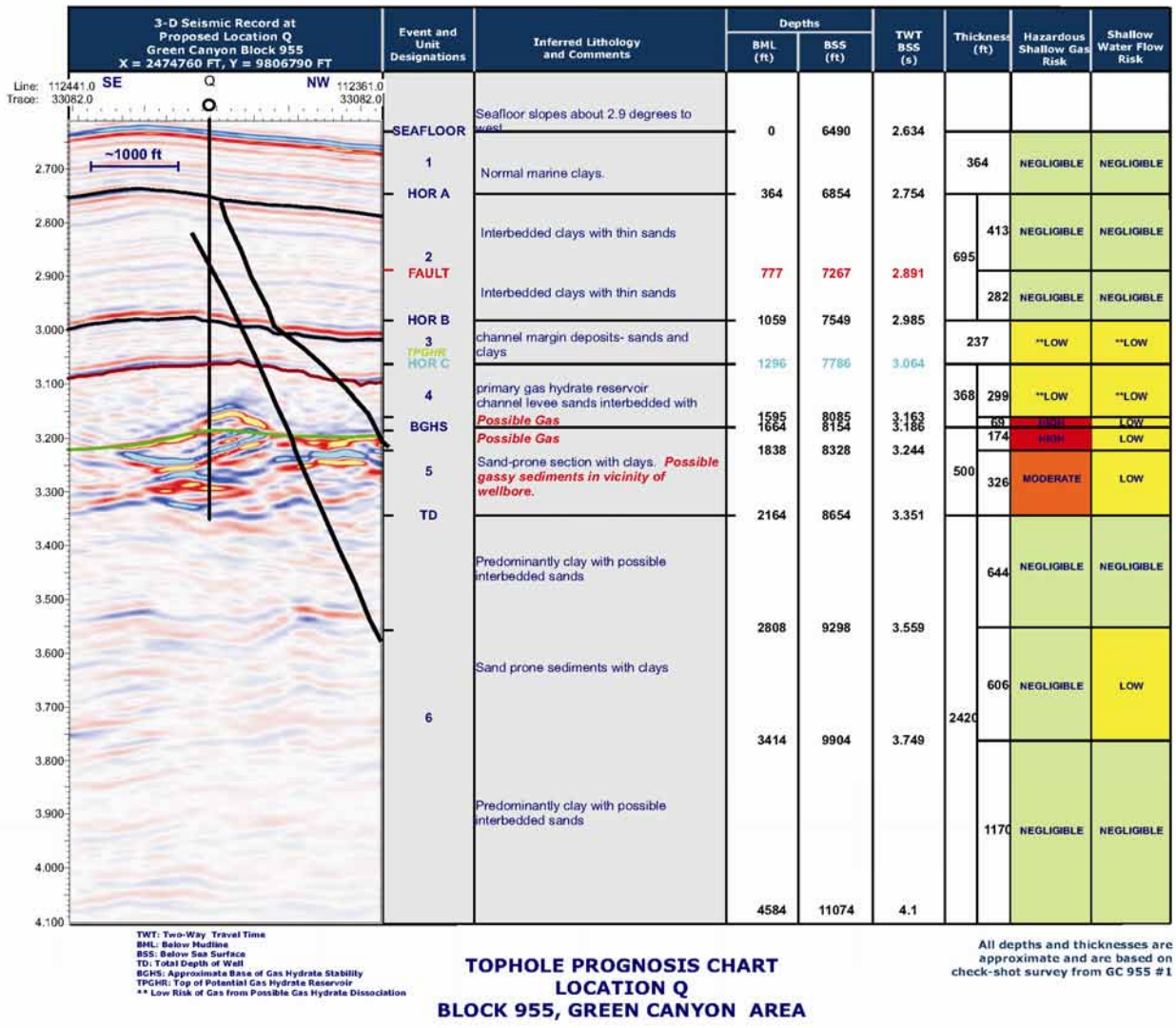
Table 2: Proposed Hole General Information

| | |
|---|---|
| Site Name | Permitted **Q**; JIP XX |
| General Area | *Between the Sigsbee Escarpment and Green Knoll, near Green Canyon proper* |
| Location | Latitude: *27°00' 08.589" N* Longitude: *90° 26' 14.281" W* |
| Coordinate Datum | *NAD27* |
| Water Depth | *6490 ft BSS* |
| OPD/Lease Block | *GC955* |
| Seismic lines at hole | *Inline 112403, crossline 33082* |

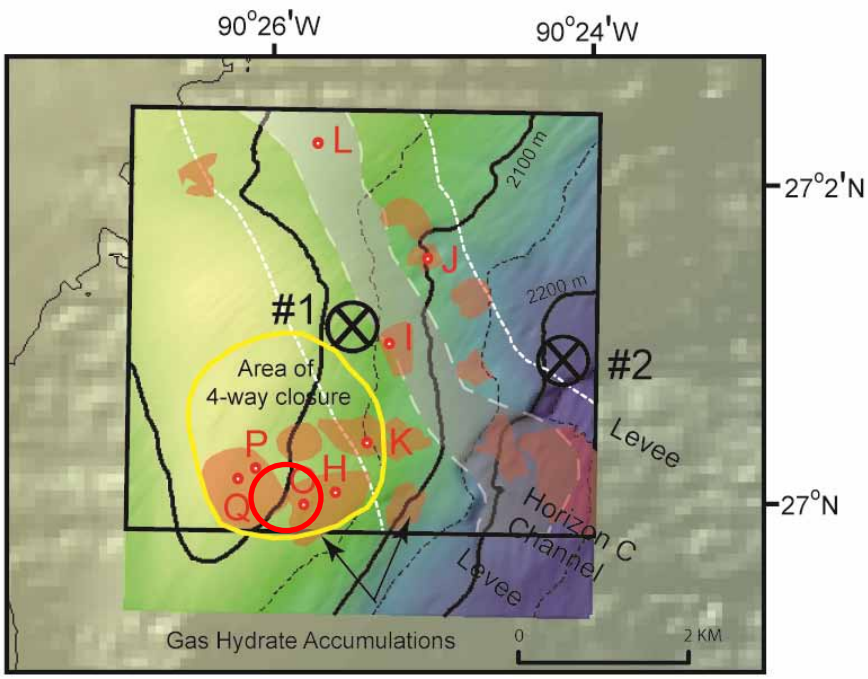
Table 3: Proposed Hole Drilling Information

| | |
|---|---|
| Proposed penetration | *2164 ft BML 8654 ft BSS* |
| Seafloor slope | *2.9 ° to the west* |
| Expected lithologies | *364' Unit 1 – flat lying mud-rich recent sediments*<br>*695' Unit 2 – interbedded clays with possible thin sands*<br>*237' Unit 3 – channel margin deposition, mostly sand prone*<br>*Major Unconformity*<br>*368' Unit 4 – channel levee sands*<br>*500' Unit 5 – clays with possible sands, sand prone sediments with clays* |
| Expected ages/section | *PlioPleistocene* |
| Estimated depth to TGHO | *1296 ft BML 7786 ft BSS* |
| Estimated depth to BGHZ | *1664 ft BML 8154 ft BSS* |
| Estimated GH interval | *368 ft thick* |
| Estimated GH saturation | *88 %* |
| Anomalous conditions? | *Fault at ~777 ft BML oriented N/S, dips east (no sea floor offset)* |
| Other relevant information | *Closest sea floor channel ~1.9 mi north east of Q,*<br>*sea floor escarpment with ~400 ft relief is ~1.4 mi east of Q*<br>*fluid expulsion mound (~30 ft relief) ~2300 ft SE of Q*<br>*~2000 ft outside area of potential anchor points for Anadarko side track* |
| Source of Information | *AOA Hazards Summary 4021-JIP-GOM-GC955-Q 14 June, 2008* |

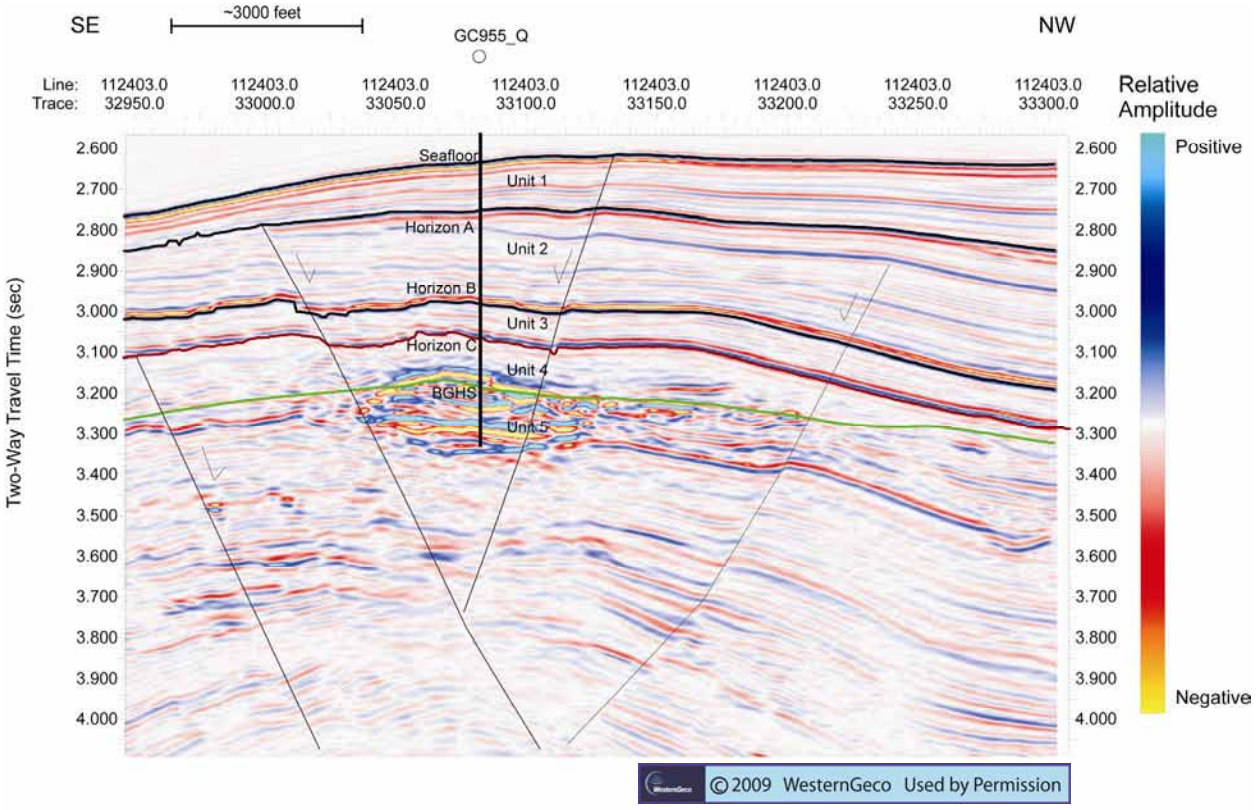
BML: Below Mud Line
BSS: Below Sea Surface
TGHO: Top of Gas Hydrate Occurrence
BGHZ: Base of Gas Hydrate stability Zone




**Appendix F29:** *Stratigraphic interpretation, from AOA Geophysics; Seismic image provided by WesternGeco.*

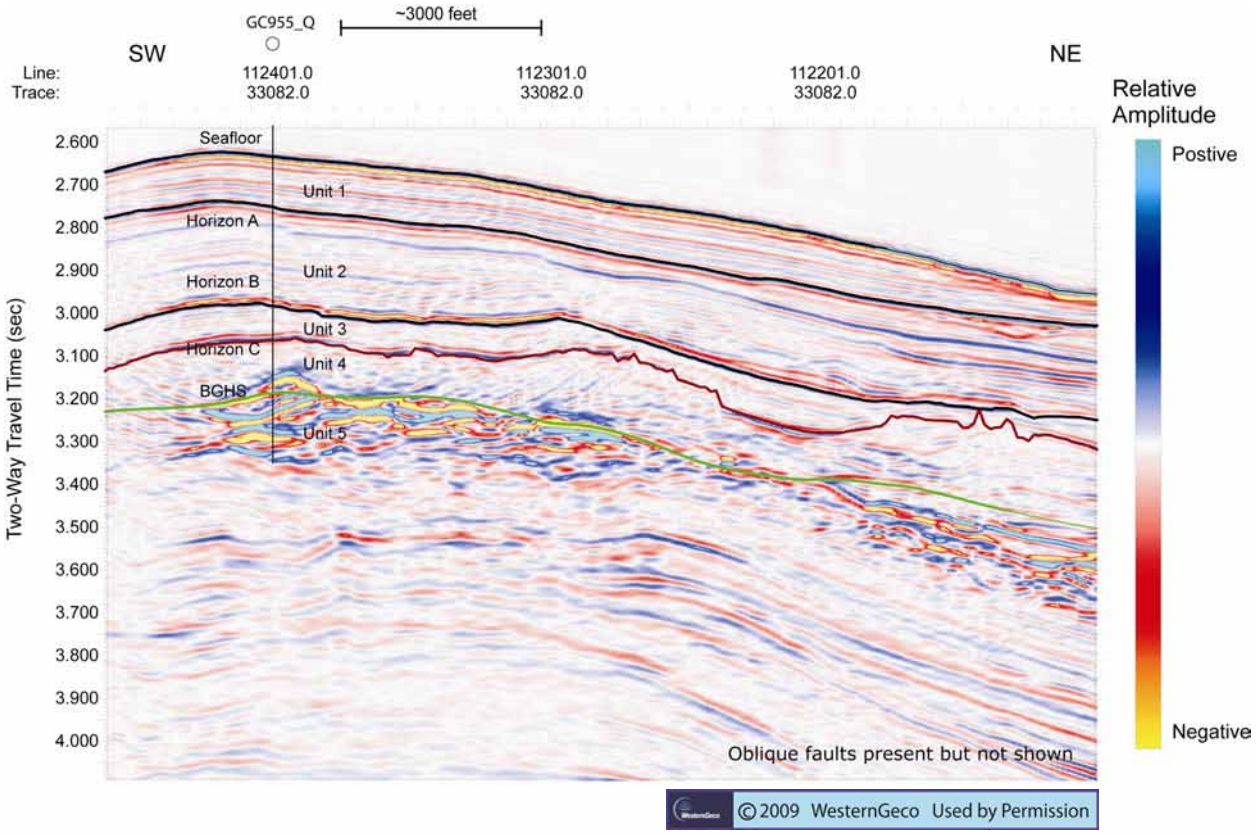



**Appendix F30:** *Map showing location of proposed site GC955-Q. Colored bathymetry from WesternGeco.*




3D Seismic Record, Line 112403, Location Q Block 955, Green Canyon Area

**Appendix 31:** *Inline seismic profile across GC955-Q. Seismic image courtesy of WesternGeco.*




3D Seismic Record, Crossline 33082, Location Q Block 955, Green Canyon Area

**Appendix F32:** *Crossline seismic profile across GC955-Q. Seismic image courtesy of WesternGeco.*