Oil & Natural Gas Technology

DOE Award No.: DE-FC26-01NT41330

Semi-Annual Progress Report #41330R16 (October 2008 – March 2009)

Characterizing Natural Gas Hydrates in the Deep Water Gulf of Mexico: Applications for Safe Exploration and Production Activities

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Prepared for:
United States Department of Energy
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April 2009

Office of Fossil Energy

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ABSTRACT

In 2000, Chevron began a project to learn how to characterize the natural gas hydrate deposits in the deepwater portions of the Gulf of Mexico. A Joint Industry Participation (JIP) group was formed in 2001, and a project partially funded by the U.S. Department of Energy (DOE) began in October 2001. The **primary objective** of this project is to develop technology and data to assist in the characterization of naturally occurring gas hydrates in the deep water Gulf of Mexico (GOM). These naturally occurring gas hydrates can cause problems relating to drilling and production of oil and gas, as well as building and operating pipelines. Other objectives of this project are to better understand how natural gas hydrates can affect seafloor stability, to gather data that can be used to study climate change, and to determine how the results of this project can be used to assess if and how gas hydrates act as a trapping mechanism for shallow oil or gas reservoirs.

During October 2008 – March 2009, the JIP concentrated on:

- Conducting hazard and well bore stability analysis of selected sites;
- Analyzing new sites for drilling;
- Planning operations and selecting hole locations for Phase III drilling.

More information can be found on the JIP website.
http://gomhydratejip.ucsd.edu/

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1.0 Introduction

In 2000, Chevron Petroleum Technology Company began a project to learn how to characterize the natural gas hydrate deposits in the deepwater portion of the Gulf of Mexico. Chevron is an active explorer and operator in the Gulf of Mexico, and is aware that natural gas hydrates need to be understood to operate safely in deep water. In August 2000, Chevron working closely with the National Energy Technology Laboratory (NETL) of the United States Department of Energy (DOE) held a workshop in Houston, Texas, to define issues concerning the characterization of natural gas hydrate deposits. Specifically, the workshop was meant to clearly show where research, the development of new technologies, and new information sources would be of benefit to the DOE and to the oil and gas industry in defining issues and solving gas hydrate problems in deep water.

On the basis of the workshop held in August 2000, Chevron formed a Joint Industry Project (JIP) to write a proposal and conduct research concerning natural gas hydrate deposits in the deepwater portion of the Gulf of Mexico. The proposal was submitted to NETL on April 24, 2001, and Chevron was awarded a contract on the basis of the proposal.

The title of the project is **"Characterizing Natural Gas Hydrates in the Deep Water Gulf of Mexico: Applications for Safe Exploration and Production Activities".**

1.2 Objectives

The **primary objective** of this project is to develop technology and data to assist in the characterization of naturally occurring gas hydrates in the deep water Gulf of Mexico (GOM). These naturally occurring gas hydrates can cause problems relating to drilling and production of oil and gas, as well as building and operating pipelines. Other objectives of this project are to better understand how natural gas hydrates can affect seafloor stability, to gather data that can be used to study climate change, and to

determine how the results of this project can be used to assess if and how gas hydrates act as a trapping mechanism for shallow oil or gas reservoirs.

1.3 Project Phases

The project is divided into phases. **Phase I** of the project is devoted to gathering existing data, generating new data, and writing protocols that will help the research team determine the location of existing gas hydrate deposits. During **Phase II** of the project, Chevron will drill at least three data collection wells to improve the technologies required to characterize gas hydrate deposits in the deep water GOM using seismic, core and logging data. **Phase III** of the project began in September of 2007 and will focus on obtaining logs and cores of hydrate bearing sands in the GOM.

1.4 Research Participants

In 2001, Chevron organized a Joint Industry Participation (JIP) group to plan and conduct the tasks necessary for accomplishing the objectives of this research project. As of March 2009 the members of the JIP were Chevron, Schlumberger, ConocoPhillips, Halliburton, the Minerals Management Service (MMS), Total, JOGMEC, Reliance Industries Limited, The Korean National Oil Company (KNOC), and StatoilHydro.

1.5 Research Activities

The research activities began officially on October 1, 2001. However, very little activity occurred during 2001 because of the paperwork involved in getting the JIP formed and the contract between DOE and Chevron in place. Several Semi-Annual and Topical Reports have been written that cover the activity of the JIP through September 2008.

1.6 Purpose of This Report

The purpose of this report is to document the activities of the JIP during October 2008 – March 2009. It is not possible to put everything into this Semi-Annual report. However, many of the important results are included and references to the JIP website, http://gomhydratejip.ucsd.edu/, are used to point the reader to more detailed information concerning various aspects of the project. The discussion of the work performed during

October 2008 – March 2009 is organized by task and subtask for easy reference to the technical proposal and the DOE contract documents.

2.0 Executive Summary

Chevron formed a Joint Industry Participation (JIP) group to write a proposal and conduct research concerning natural gas hydrate deposits in the deepwater portion of the Gulf of Mexico. The proposal was submitted to NETL on April 24, 2001, and Chevron was awarded a contract on the basis of the proposal.

The title of the project is **"Characterizing Natural Gas Hydrates in the Deep Water Gulf of Mexico: Applications for Safe Exploration and Production Activities".**

The **primary objective** of this project is to develop technology and data to assist in the characterization of naturally occurring gas hydrates in the deep water Gulf of Mexico (GOM). **Other objectives** of this project are to better understand how natural gas hydrates can affect seafloor stability, to gather data that can be used to study climate change, and to determine how the results of this project can be used to assess if and how gas hydrates act as a trapping mechanism for shallow oil or gas reservoirs.

The project is divided into phases. **Phase I** of the project is devoted to gathering existing data, generating new data, and writing protocols that will help the research team determine the location of existing gas hydrate deposits. During **Phase II** of the project, Chevron will drill at least three data collection wells to improve the technologies required to characterize gas hydrate deposits in the deep water GOM using seismic, core and logging data. Phase III of the project is to collect data on hydrate bearing sands. Both logging and coring operations are planned.

A website has been developed to house the data and information that were collected in the Workshop, as well as other items submitted during the course of this research endeavor. The link to the JIP website is as follows:

http://gomhydratejip.ucsd.edu/

2.1 Seismic Analysis

G&G and drilling permits were prepared for GC955, GC781, GC825, WR313, EB922 and AC21. Well bore stability analysis and drilling maps completed for GC955, GC781, GC825, and WR313.

2.2 Site Selection

Hole locations were selected for EB922, AC21, GC781, and GC825. Final site selection reports received for GC955, GC781, GC825, and WR313.

2.3 Pressure Corer

Received proposals for additional equipment needed for pressure core handling equipment.

2.4 A new web site was developed.

The new web site will contain all of the digital records for the JIP. The URL for the site is http://gomhydratejip.ucsd.edu/.

3.0 Results and Discussion Phase II

3.1 Task 1.0 – Research Management Plan

Work on this task is complete and has been reported on in previous semi-annual reports.

3.2 Task 2.0 – Project Management and Oversight

Work on this task is complete and has been reported on in previous semi-annual reports.

3.3 Task 3.0 – Validation of New Gas Hydrate Sensors

Work on this task is complete and has been reported on in previous semi-annual reports.

3.4 Task 4.0 – Validation of the Well Bore Stability Model

Work on this task is complete and has been reported on in previous semi-annual reports.

3.5 Task 5.0 – Core and Well Log Data Collection – Area A

Work on this task is complete and has been reported on in previous semi-annual reports.

3.6 Task 6.0 – Data Analysis – Initial Cruise

Work on this task is complete and has been reported on in previous semi-annual reports.

3.7 Task 7.0 – Technical Conference

Work on this task is complete and has been reported on in previous semi-annual reports.

3.8 Task 8.0 – Field Sampling Device Development

Work on this task is complete and has been reported on in previous semi-annual reports.

3.9 Task 9.0 – Recommendation for Further Activities

Work on this task is complete and has been reported on in previous semi-annual reports.

4.0 Discussion and Results PHASE III A – Follow on Field Activities Drilling and Logging

Phase III activities are to include work focused on characterization and evaluation of hydrate occurrence within coarse-grained horizons within the Gulf of Mexico. The activities include preparation for these field activities through analyses and technology development, carrying out of the field activities and post field activity analysis and reporting. Field sites to be included in the investigation will be selected upon mutual agreement of the Recipient and DOE with the intent of testing alternative models of gas hydrate occurrence. Planned activities associated with Phase III are outlined in the task/subtask descriptions to follow.

4.1 Task 1.0 – Research Management Plan

The research management plan was prepared and submitted to the DOE.

4.2 Task 2.0 – Project Management and Oversight

Project Quarters 1 & 2: The project manager appointed by the JIP members held weekly conference calls with the DOE project managers and provided other reports and presentations as required. See Appendix A for a summary of milestones and progress to date.

The JIP Executive Board (EB) approved two new members—the Korean National Oil Company and StatoilHydro—to become members of the JIP.

Members of the EB also attended the site selection drill operations meeting.

The JIP web site is being maintained and a new web site at Scripps is being evaluated.

The chief scientist for the LWD leg was selected and candidates for the coring leg evaluated.

Total DOE project funds are approximately 56% spent and total project funds are 99% spent or obligated for the remaining Phase III A estimated costs.

Project Quarters 3 & 4: The project manager appointed by the JIP members held weekly conference calls with the DOE project managers and provided other reports and presentations as required. See Appendix A for a summary of milestones and progress to date.

The Korean National Oil Company and StatoilHydro became members of the JIP.

The JIP web site is being maintained and a new web site at Scripps is being designed.

Total DOE project funds are approximately 59% spent and total project funds are 92% spent or obligated for the remaining Phase III A estimated costs.

Project Quarters 5 & 6: The project manager appointed by the JIP members held weekly conference calls with the DOE project managers and provided other reports and presentations as required. See Appendix A for a summary of milestones and progress to date.

The new JIP Web site is on line and ready for the public.

Project status and goals were presented to the NRC committee evaluating the DOE program.

Total DOE project funds are approximately 59% spent and total project funds are 97% spent or obligated for the remaining Phase III A estimated costs.

4.3 Task 3.0 – Field Program – Drilling/Logging

Project Quarters 1 & 2: Several meetings were held in Houston between the LWD contractor (Schlumberger), Chevron drilling engineers, and the USGS Chief Scientist for the LWD leg. A design of the LWD tool string has been developed but may change before the cruise.

Safety training for the personnel on the LWD leg has been determined and will be arranged.

Locations for hazard analysis have been selected and hazard analysis will begin in April. See Appendix B for location maps of the holes.

A drill ship has been selected and drilling and logging is being planned for late June into July but could change because of drill ship schedule. In the worse case the ship schedule could slip into late 2008.

Project Quarters 3 & 4: A design of the LWD tool string has been developed that will allow for both tool strings to be used.

Safety training for the personnel on the LWD leg has been determined and conducted.

Locations for hazard analysis have been selected and hazard analysis completed.

The drill ship selected was unable to complete other work in time for this program to conduct drilling in the time we had contracted. The contract was revised and we are now planning on conducting LWD operations under the same terms in the first or second quarter of 2009.

Project Quarters 5 & 6:
All necessary cruise planning work was completed and permits filed with the required agencies. The estimated start date for the LWD leg is 16 April 2009 with a duration of approximately 21 days.

4.4 Task 4.0 – Data Analysis

Project Quarters 1 & 2: No work accomplished this period.
Project Quarters 3 & 4: No work accomplished this period.
Project Quarters 5 & 6: No work accomplished this period.

4.5 Task 5.0 – Improved Hydrate Recovery, Detection and Measurement Equipment

Project Quarters 1 & 2: No work accomplished this period.

Project Quarters 3 & 4: No work accomplished this period.

Project Quarters 5 & 6:

Proposals for the additional equipment needed to handle and transfer pressure cores on the ship were received and reviewed.

4.6 Task 6.0 – Detailed Seismic Study of Selected Drilling Locations

Project Quarters 1 & 2:

3-D analysis of GC955 and WR313 is complete and a report from the site selection group is expected in May.

Project Quarters 3 & 4:

A draft of the final report for GC955 and WR 313 is compete and is expected in November 2008.

Project Quarters 5 & 6:

Final site selection reports received for GC955, GC781, GC825, and WR313. The report of GC955 is attached to this report as Appendix B the other site selection reports may be found on the JIP Web Site.

Site selections reports are being prepared for EB992 and AC21.

4.7 Task 7.0 – Well Bore Stability

Project Quarters 1 & 2: Analysis of the three sites (AC, GC, and WR) areas has been started and waiting on final well locations to be completed.

Project Quarters 3 & 4: Well bore stability analysis completed for AC and is progress for GC and WR. A final report is expected in November of 2009.

Project Quarters 5 & 6:

Well bore stability analysis, well maps, and pore pressure predictions completed and received for GC955, GC781, GC825, WR313, EB922, and AC21.

4.8 Task 8.0 – Data on Lab Samples

Project Quarters 1 & 2: No work accomplished this period.

Project Quarters 3 & 4: No work accomplished this period.

Project Quarters 5 & 6: No work accomplished this period.

5.0 PHASE III B – FOLLOW ON FIELD ACTIVITIES (CORING) AND FINAL REPORTING

Phase III B activities are to include work focused on characterization and evaluation of hydrate occurrence within coarse grained horizons within the Gulf of Mexico. The activities include preparation for these field activities through analyses and technology development, carrying out of the field activities and post field activity analysis and reporting. Field sites to be included in the investigation will be selected upon mutual agreement of the Recipient and DOE with the intent of testing alternative models of gas hydrate occurrence. Planned activities associated with Phase III B are outlined in the task/subtask descriptions to follow.

5.1 Task 1.0 – Revised Research Management Plan

Project Quarters 1 & 2: No work accomplished this period.

Project Quarters 3 & 4: No work accomplished this period.

Project Quarters 5 & 6: No work accomplished this period.

5.2 Task 2.0 – Project Management and Oversight

Project Quarters 1 & 2: No work accomplished this period.

Project Quarters 3 & 4: No work accomplished this period.

Project Quarters 5 & 6: No work accomplished this period.

5.3 Task 3.0 – Field Program – Coring

Project Quarters 1 & 2: No work accomplished this period.

Project Quarters 3 & 4: No work accomplished this period.

Project Quarters 5 & 6: No work accomplished this period.

5.4 Task 4.0 – Data Analysis

Project Quarters 1 & 2: No work accomplished this period.

Project Quarters 3 & 4: No work accomplished this period.

Project Quarters 5 & 6: No work accomplished this period.

5.5 Task 5.0 – Improved Hydrate Recovery, Detection and Measurement Equipment

Project Quarters 1 & 2: No work accomplished this period.

Project Quarters 3 & 4: No work accomplished this period.

Project Quarters 5 & 6: No work accomplished this period.

5.6 Task 6.0 – Detailed Seismic Study of Selected Drilling Locations

Project Quarters 1 & 2: No work accomplished this period.

Project Quarters 3 & 4: No work accomplished this period.

Project Quarters 5 & 6: No work accomplished this period.

5.7 Task 7.0 – Well Bore Stability

Project Quarters 1 & 2: No work accomplished this period.

Project Quarters 3 & 4: No work accomplished this period.

Project Quarters 5 & 6: No work accomplished this period.

5.8 Task 8.0 – Data on Lab Samples

Project Quarters 1 & 2: No work accomplished this period.

Project Quarters 3 & 4: No work accomplished this period.

Project Quarters 5 & 6: No work accomplished this period.

5.9 Task 9.0 – Technical Conference and Compilation of Scientific Papers

Project Quarters 1 & 2: No work accomplished this period.

Project Quarters 3 & 4: No work accomplished this period.

Project Quarters 5 & 6: No work accomplished this period.

6.0 Experimental

Experimental work was conducted during the period of this report. Photos and drawings of some of the experimental equipment that was used on the cruise were presented in previous semi-annual reports.

7.0 Conclusions

Drilling targets were identified for AC21, GC781, and EB922. Hazard analysis for the locations was complete.

Planning for the LWD Cruise was complete and operations are scheduled to begin in April of 2009.

Proposal for additional equipment for the pressure corer was received.

8.0 References

No external references were used for this report.

9.0 Appendix A, B

APPENDIX A

Milestone Table A1

#	Milestone	Plan date	Progress	Comments
1	Select LWD Locations	Q2 08	Complete. Another block may be selected in October.	Site selection report for GC955 and WR313 is expected in May and will be included in the next semi-annual report. AC818 report was included in Semi-Annual Report 41330R13. An additional location for LWD drilling may be selected in October of 2008 as an alternate to AC818.
2	Complete Design of Pressure Coring Equipment	Q2 08	Design work complete; final report is expected in October.	
3	LWD Selected Locations	Q3 08	LWD locations were selected.	
4	Report on LWD Phase III A Task 3 Deliverable	Q4 08	LWD drilling was delayed until March 2009 due to drill ship schedule.	
5	Complete Research Management Plan	Q1 09	Complete	
6	DOE Approval to Proceed to Phase III B	Q2 09		
7	Complete Construction of New Pressure Coring Equipment	Q3 09		
8	Field Test Pressure Coring Equipment	Q4 09		
9	Select Sites for Coring Leg	Q4 09		
10	Conduct a Hazard Analysis of Sites and Apply for Permits	Q2 10		
11	Core Selected Locations	Q3 10		
12	Report on Lab and Coring Data	Q4 10		
13	Final Report	Q4 10		

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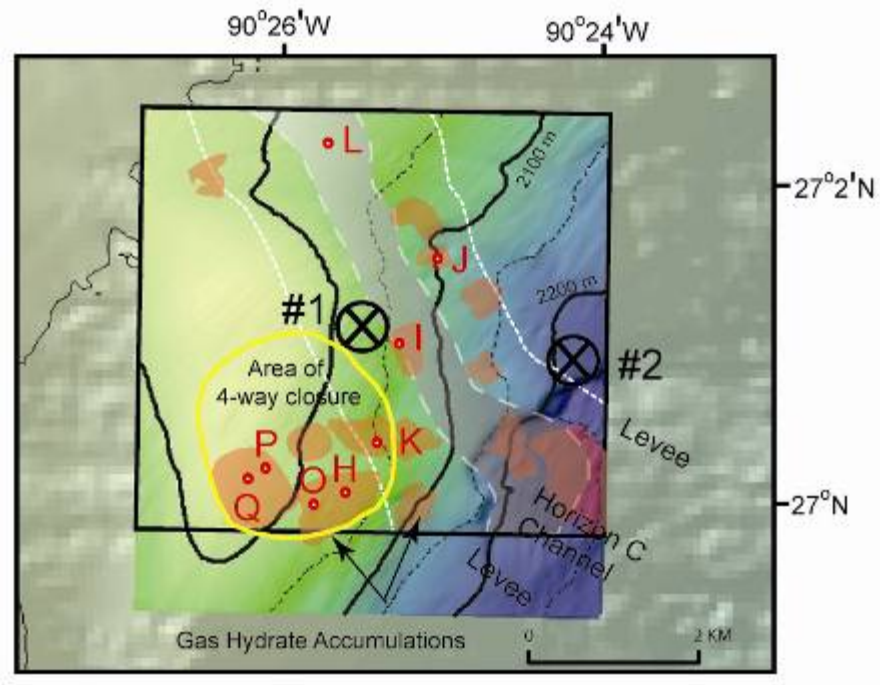
Gas Hydrate Drilling Targets at GC955

JIP Site Report – 13 April 2009



Gulf of Mexico JIP Site Selection Team

Members

Ray Boswell, Department of Energy
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Gas Hydrate Drilling Targets at GC955

Introduction

Identifying high saturations of gas hydrate in sandy marine sediments is one of the primary objectives of the Phase III 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 GC955 support the interpretation of gas hydrate within the hydrate stability zone. (1) An initial study of the site prior to drilling GC955#1 (McConnell, 2000) indicates the likelihood of several sand units in the tophole, with one occurring near the base of inferred hydrate stability (horizon 30) in a region of high amplitudes on the 2D and 3D seismics used in the hazards analysis. Subsequent drilling of GC955#1 confirmed the presence of sand interpreted in the gamma and resistivity logs in the deeper channel system. (2) For the JIP analysis, WesternGeco processing and inversion of the 3D seismic cube indicated saturations in excess of 50 %, with sand calibrated from the GC955#1 drill hole. (3) MMS (J. Hunt) conducted a detailed analysis of GC955 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 GC955#1 well provides lithologic, depth, and other information for modeling and interpreting the seismic data (Table 1).

Table 1: Well information from GC955#1 Well

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

This report summarizes the geologic framework in the GC955 area and information about the proposed 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 exists because of the uncertainty in interference with drilling by some of the 12 anchors set on the sea floor in 2008 for drilling of a well by Anadarko (drilling by Delmar Systems, Inc., DWG No. 3933-MP-01).

Geologic Setting

The Green Canyon GC955 site lies along the seaward side of the Sigsbee Escarpment at the mouth of Green Canyon (Figure 1A). The Sigsbee Escarpment is formed by the seaward extent of the lower slope salt canopy (Diegel et al., 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 1B).

Two wells provide lithologic and stratigraphic control in GC955. The GC955#1 well drilled by Statoil in 1999 sits structurally to the east of and off the crest of the salt-cored closure mound (Figure 2, Table 1). The GC955#2 well is near the base of the east-sloping sea floor to the east-southeast of GC955#1. Well-logs from the GC955#2 well only became public in spring, 2009, and were therefore not used in the 2007-2008 well analysis part of the site-selection process. The existing GC955#1 well penetrated 26 m of permeable sand at a depth of ~366 m below the seafloor (McConnell, 2000). A resistivity anomaly of ~4.2 Ωm at the depth of the sand coincides with a region of high-amplitudes in the seismic data (Figure 3). 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 1A). A small surface channel crosses the study area towards Green Knoll. Seismic data acquired at GC955 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 4), indicating that channelization is a long-lived process in this area (McConnell, 2000; Heggland, 2004). Channels often contain turbidite and mass wasting deposits that are frequently coarse-grained.

A consequence of the salt uplift forming a closure structure is that including the deepest channel mapped in the seismic data, identified as the horizon C channel (Figures 3-5), now slopes towards the north (Figure 5C), whereas it originally transported material out of Green Canyon, on a south-sloping surface. In Figure 5, 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 GC955. 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 6). A small mud volcano in the southern part of GC955 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 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 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 GC955#1, the depth to the top of gas, interpreted to be 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 pure methane as the hydrate former, seawater as the pore water, and a bottom water temperature of 4 ^{o}C. This thermal gradient places these permeable sandy units within the hydrate stability zone.

Estimates for the thermal conditions at each target in the GC955 area are given in Table 1.

Permit	SF (ft)	BGHS (ft) relative to seafloor	SF-BGHS(ft)	P[1] (MPa)	T_{eq} (ºC) BGHS[2]	dT/dz (ºC/km) for BWT=2 ºC	dT/dz (ºC/km) for BWT=4 ºC
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	1664	25.0	19.8	35.1	31.1

[1] Hydrostatic pressure calculated at the BGHS
[2] Calculated using 3.3% NaCl pore waters and methane-only gas hydrate

Drilling Targets

Site GC955 offers three geologic environments, a four-way closure structure formed by uplifted salt, a dipping and tilted channel (associated with horizon C), and proximal levees adjacent to the horizon C channel. Distal levees occur within the four-way closure structure. 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 Sgh 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 channel 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 also posed the greatest safety issue because of deeper higher trough amplitudes interpreted as possible gas. The levee system was also attractive because of good confidence in lithology (ties to the existing drill holes) with good amplitude and Sgh anomalies. 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 3.

Table 3: Recommendations for GC955

Drill Site (permit name)	Comment
H	Consensus #1
I	Preferred #2
L, K, Q	For consideration #3

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

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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.

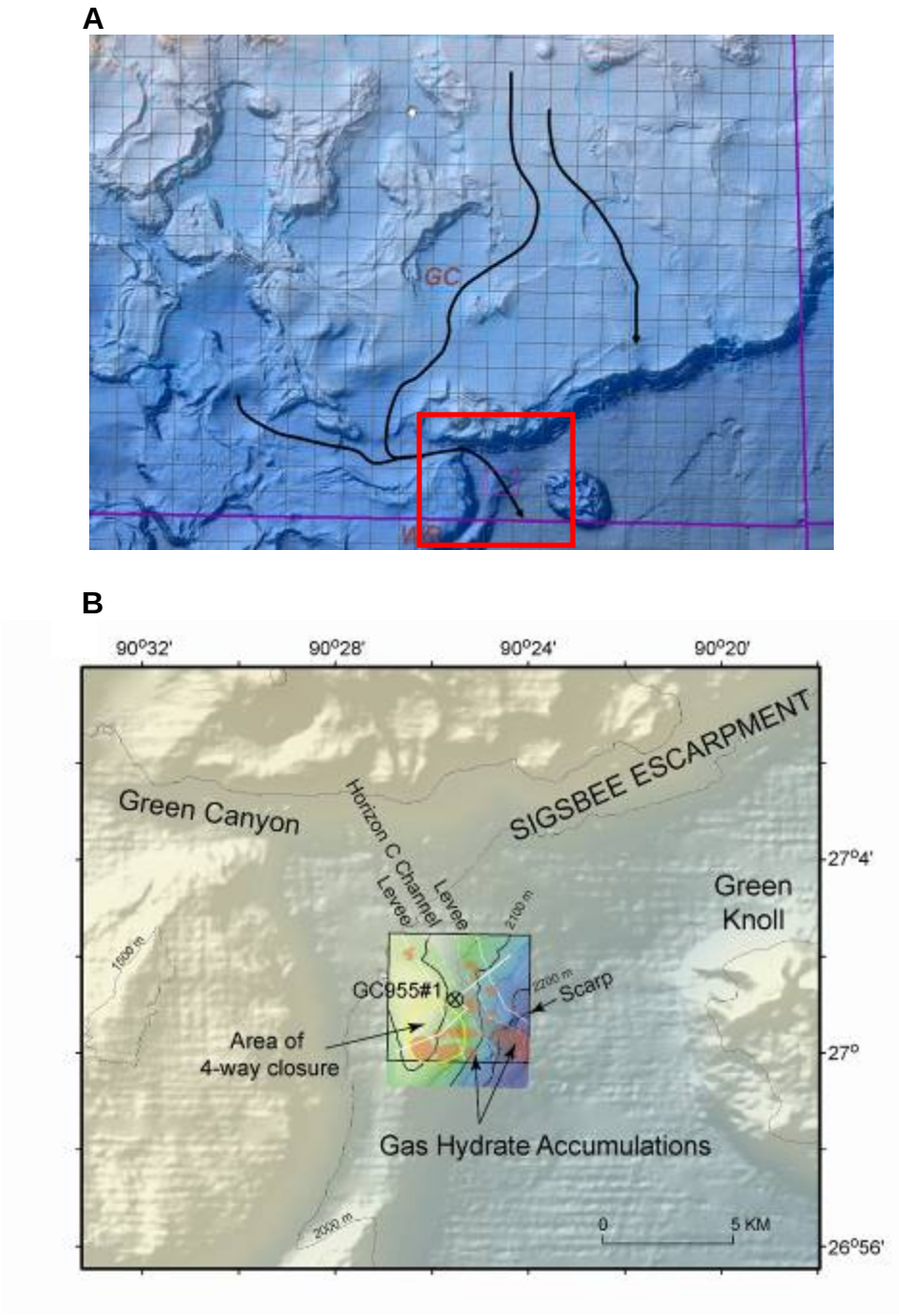


Figure 1: A. Map of the Green Canyon protraction area showing Green Canyon drainage. Box outlined in red shows location of enlargement shown in B. (Source: AOA ppt, March 27, 2008). B. Location map of the GC955 area showing the GC955#1 well and interpreted gas hydrate accumulations (brown) and channel-levee system (white lines and gray shading) from the seismic data. Lease block GC955 is outlined in black (from Hutchinson et al., 2008).

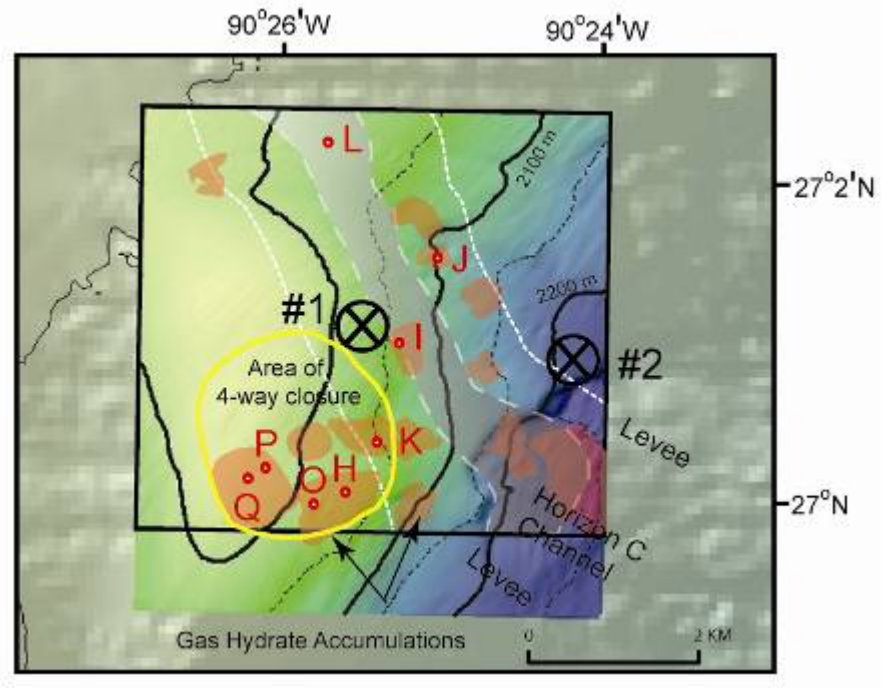


Figure 2: Permitted locations in GC955 together with locations of GC955#1 and GC955#2.

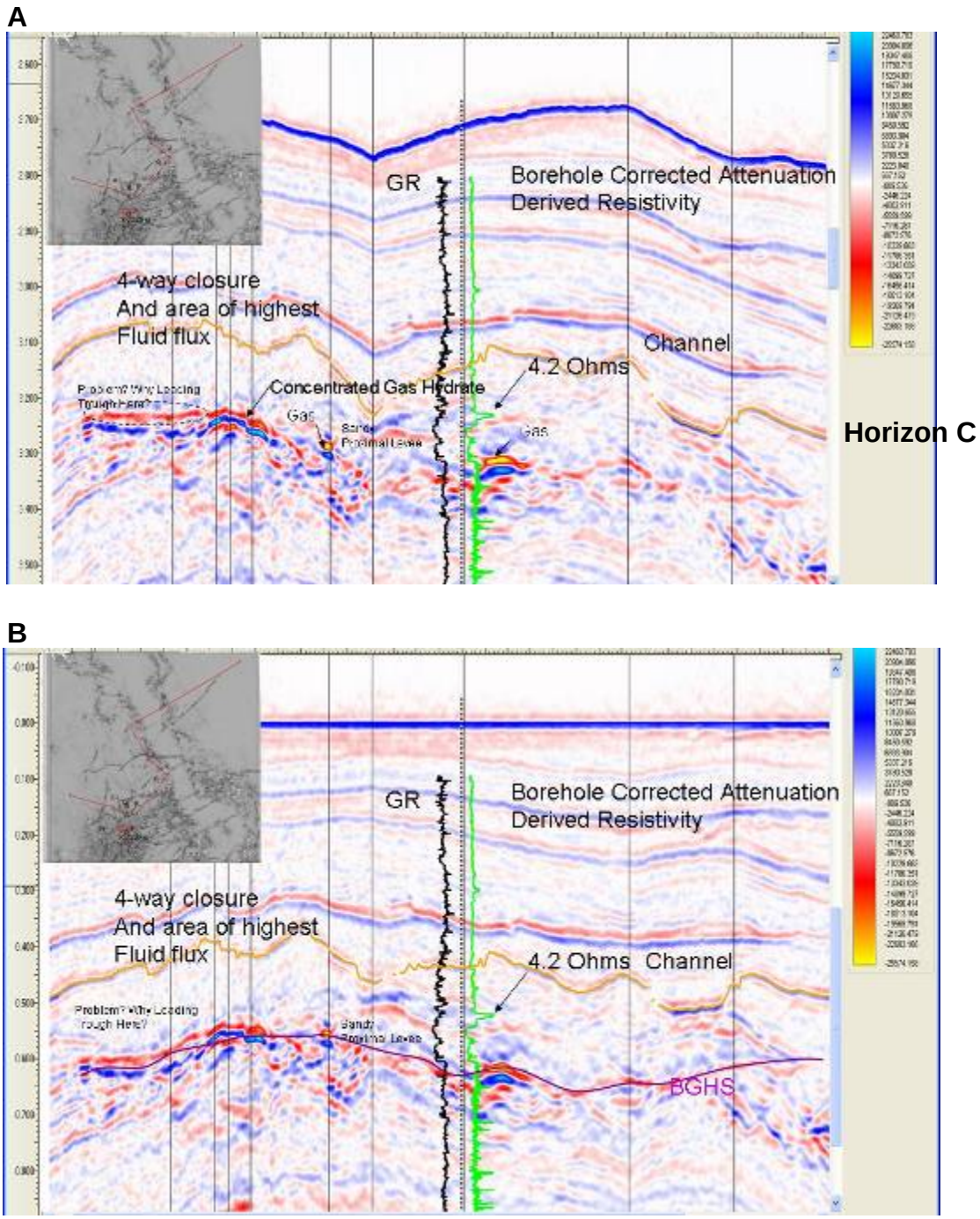


Figure 3: A. Random seismic line through the GC955#1 well showing the target (Horizon C highlighted in orange) with channel and area of 4-way closure. B. Same section flattened on the sea floor showing BGHS. Gas and gas hydrate are interpreted at ~3.2-3.3 s where the bright (red/blue) amplitudes stand out. Source: McConnell jpegs created 10/8/2007.

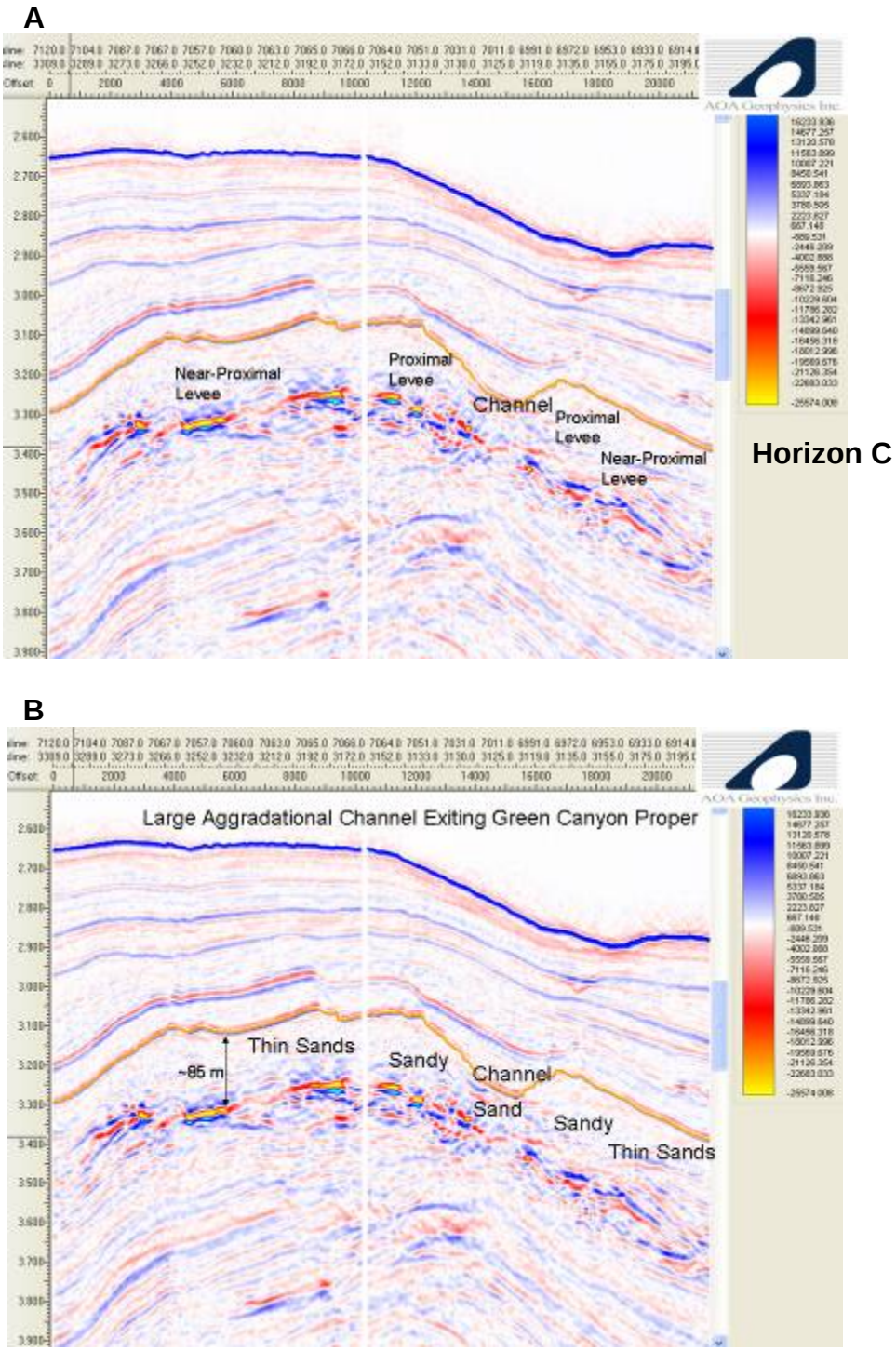


Figure 4: A. Seismic section showing interpreted geology of targeted channel/levee system at GC955. B. Seismic section showing interpreted lithology in channel/levee system at GC955. (Source: AOA ppt GC955_targets2, 19 October, 2007).

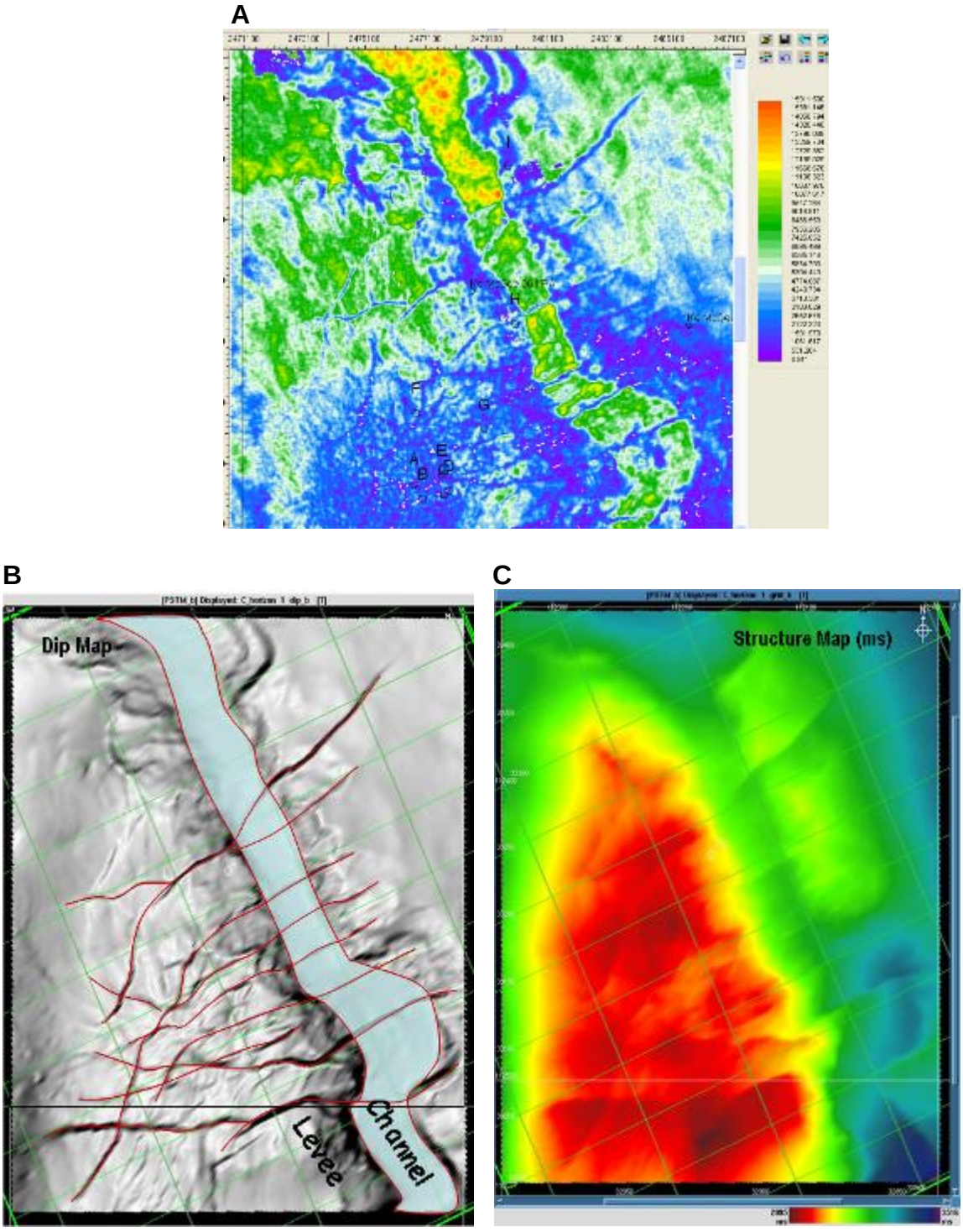


Figure 5: A: Time slice showing the horizon C channel based on amplitudes (Source: AOA ppt presentation, GC955_AOA_JIP_March_27_08). Ignore letter designations, which refer to old targets. B: Time slice showing the horizon C channel based on dips, highlighting the faults. C: Structure map on horizon C showing north end of channel dipping north and area of salt uplift, shown in red. (Source for B and C: Jian Dai, WesternGeco, 11 June 2008).

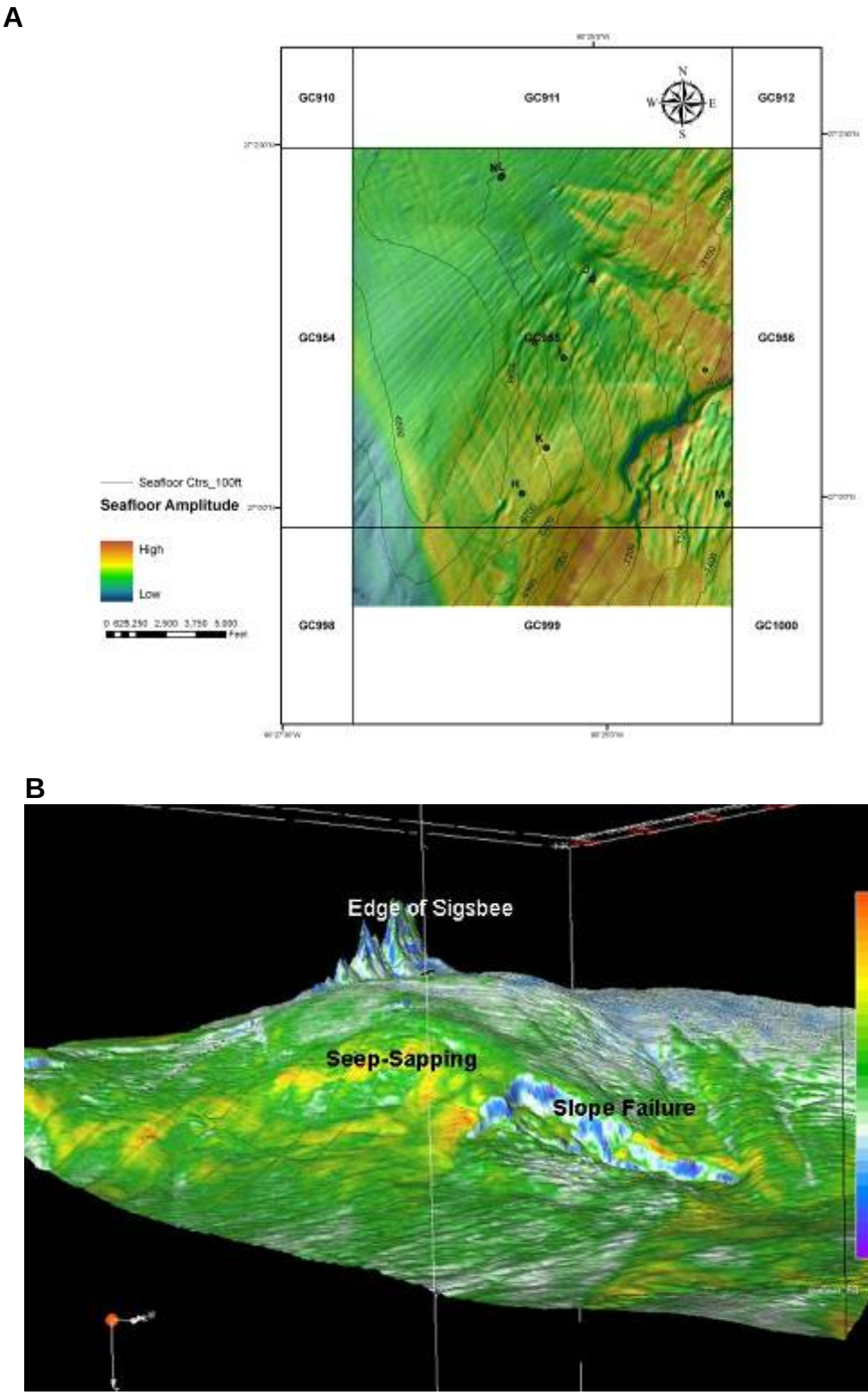


Figure 6: A. Map of seafloor amplitude over shaded relief of the GC955 mapping area. B. Perspective view of sea floor showing region of fluid flow (seep-sapping) and slope failure (view is looking northwest. (source: AOA ppt, GC955_targets2, 19 October 2007).

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,

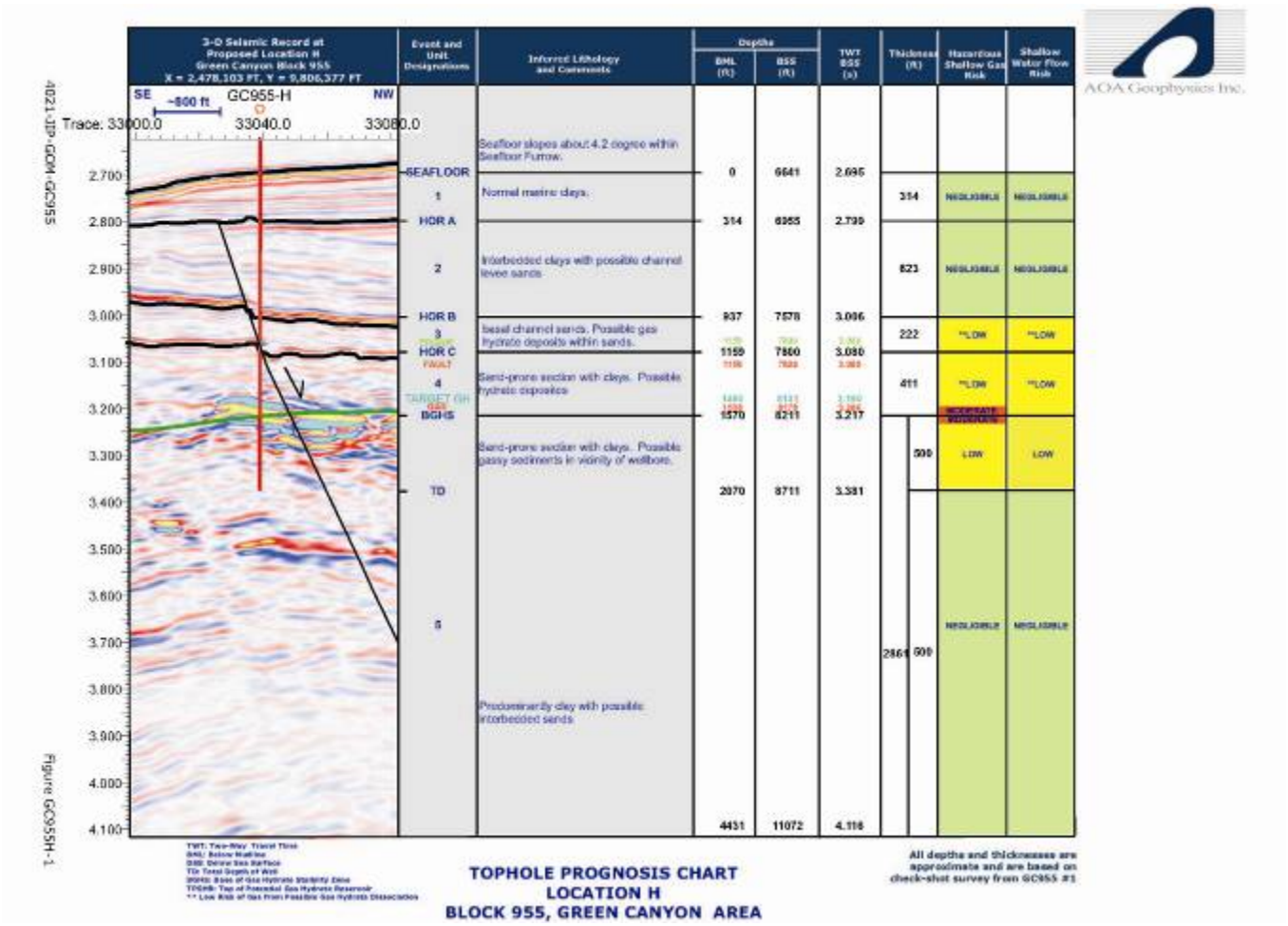
Table 2: Proposed Hole General Information

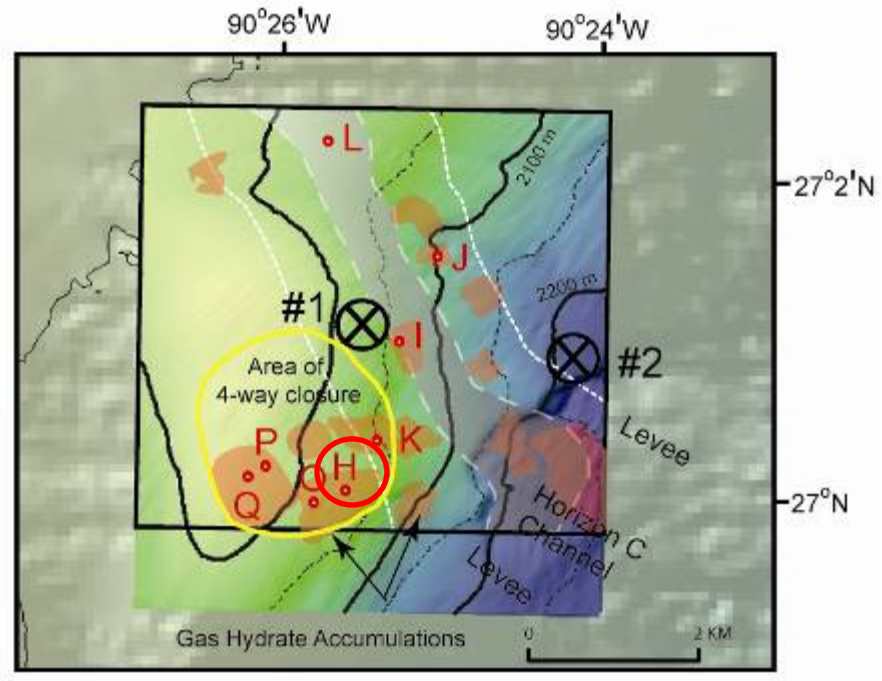
Site Name	Permitted H, JIP AA
General Area	*Seaward of the Sigsbee Escarpment, between Green Canyon proper and Green Knoll*
Location	Latitude: *27° 00' 03.828" N* Longitude: *90° 25' 37.432" W*
Coordinate Datum	*NAD27*
Water Depth	*6641 ft BSS*
OPD/Lease Block	*GC955*
Seismic lines at hole	*Inline 112333,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

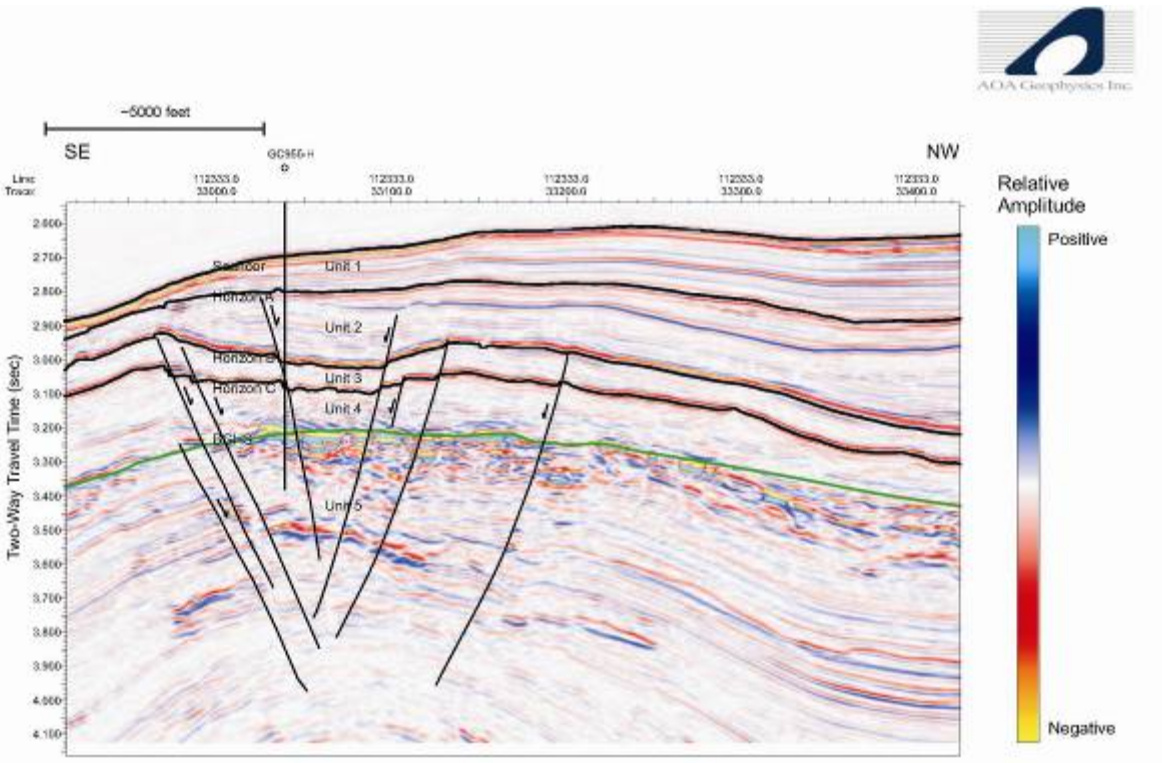
Table 3: Proposed Hole Drilling Information

Proposed penetration	*2070 ft BML 8711 ft BSS*
Seafloor slope	*4.2° to the east*
Expected lithologies	*0-314 ft: normal marine clays* *314-937 ft: interbedded clays with possible channel levee sands* *937-1159 ft: basal channel sands, possibly with gas hydrate* *1159-1570 ft: sand prone section with clays, possibly with gas hydrate* *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)* *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

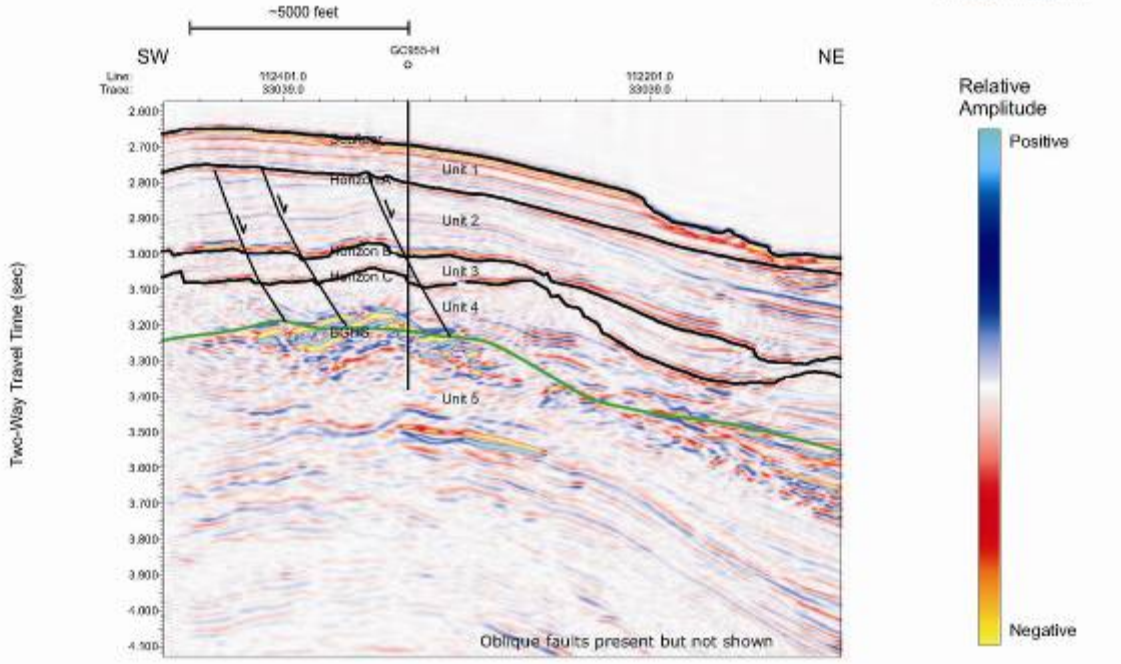
BML: Below Mud Line
BSS: Below Sea Surface
TGHO: Top of Gas Hydrate Occurrence
BGHZ: Base of Gas Hydrate stability Zone


3-D Seismic Record at Proposed Location H
Green Canyon Block 955
X = 2,478,103 FT, Y = 9,806,377 FT
SE
~800 ft
GC955-H
NW
Trace: 33000.0
33040.0
33080.0
Event and Unit Designations
Inferred Lithology and Comments
Depths
BML (ft)
BSS (ft)
TWT BSS (s)
Thickness (ft)
Hazardous Shallow Gas Risk
Shallow Water Flow Risk
SEAFLOOR
HDR A
HDR B
HDR C
FAULT
BGHS
TD
Seafloor slopes about 4.2 degree within Seafloor Furrow.
Normal marine clays.
Interbedded clays with possible channel levee sands.
Basal channel sands. Possible gas hydrate deposits within sands.
Sand-prone section with clays. Possible hydrate deposits.
Sand-prone section with clays. Possible gassy sediments in vicinity of wellbore.
Predominantly clay with possible interbedded sands.
0
6641
2.695
314
6355
2.709
937
7578
3.036
1159
7800
3.080
1570
8211
3.217
2070
8711
3.331
4431
11072
4.116
314
823
222
411
600
2864
600
NEGLIGIBLE
**LOW
LOW
4021-JIP-GOM-GC955
Figure GC955H-1
TOPHOLE PROGNOSIS CHART
LOCATION H
BLOCK 955, GREEN CANYON AREA
All depths and thicknesses are approximate and are based on check-shot survey from GC955 #1


90°26'W
90°24'W
27°2'N
27°N
2100 m
2200 m
L
J
I
K
P
Q
H
#1
#2
Area of 4-way closure
Levee
Horizon C Channel
Levee
Gas Hydrate Accumulations
0
2 KM



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



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

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,

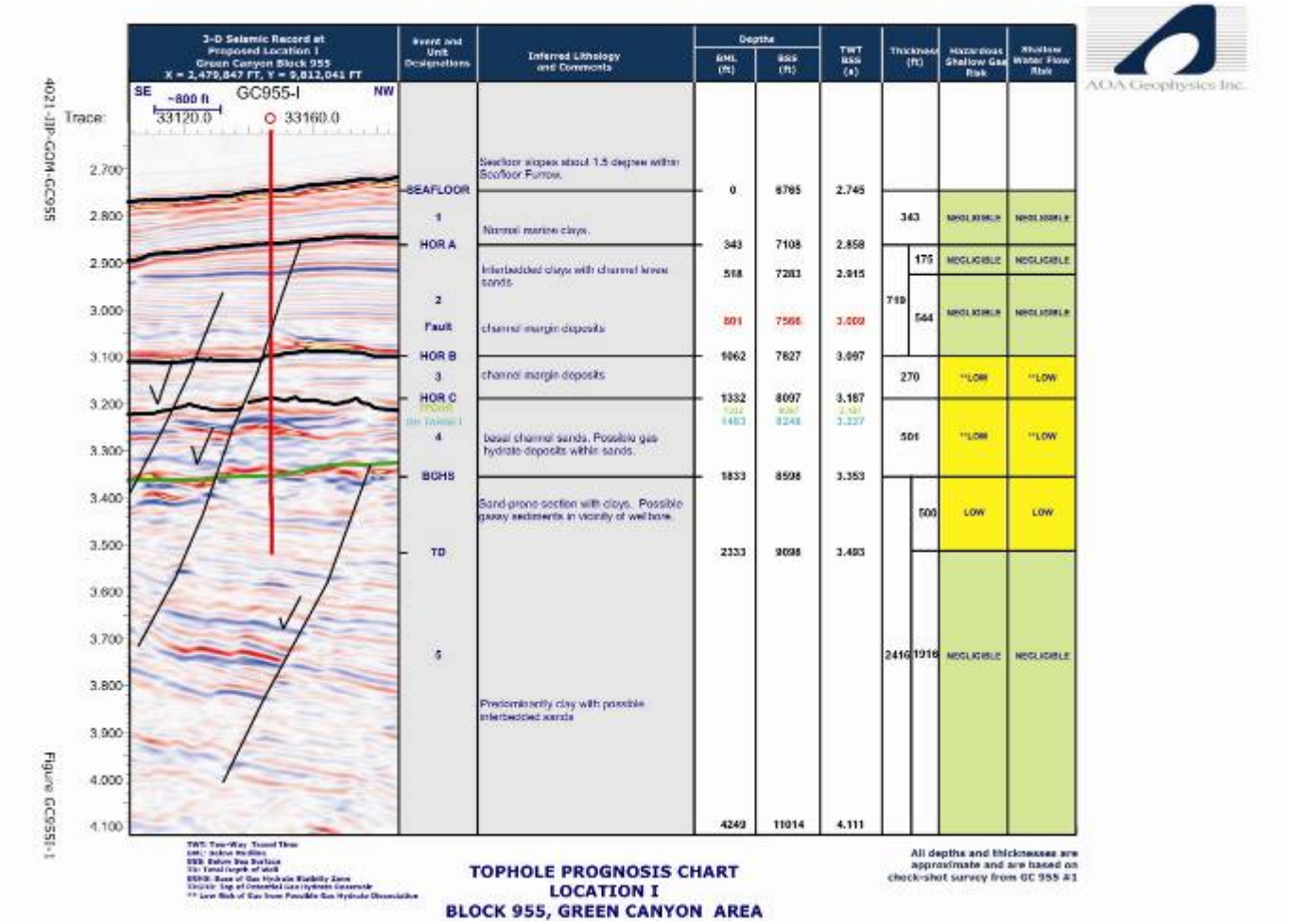
Table 2: Proposed Hole General Information

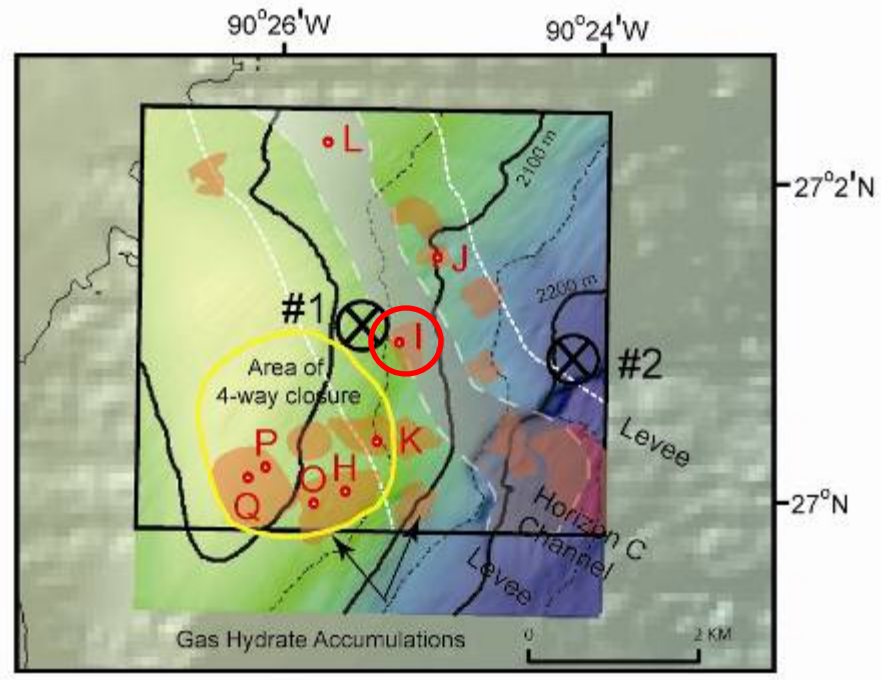
Site Name	Permitted I, JIP KK
General Area	*Seaward of the Sigsbee Escarpment, between Green Canyon proper and Green Knoll*
Location	Latitude: *27° 00' 59.529" N* Longitude: *90° 25' 16.885" W*
Coordinate Datum	*NAD27*
Water Depth	*6765 ft BSS*
OPD/Lease Block	*GC955*
Seismic lines at hole	*Inline 112237,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

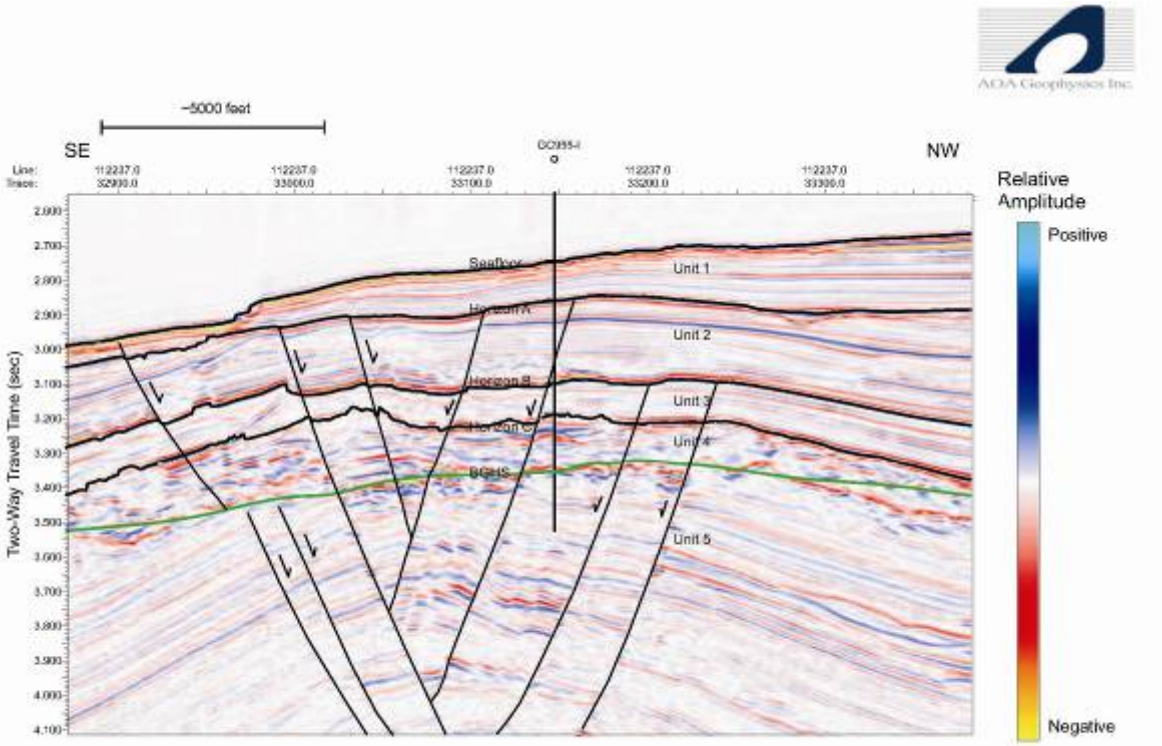
Table 3: Proposed Hole Drilling Information

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* *343-1062 ft BML: interbedded clays with channel levee sands going into channel margin deposits at the bottom of the unit* *1062-1332 ft BML: channel margin deposits (sand prone), contains buried channel* *1332-1833 ft BML: basal channel sands possibly with gas hydrate* *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

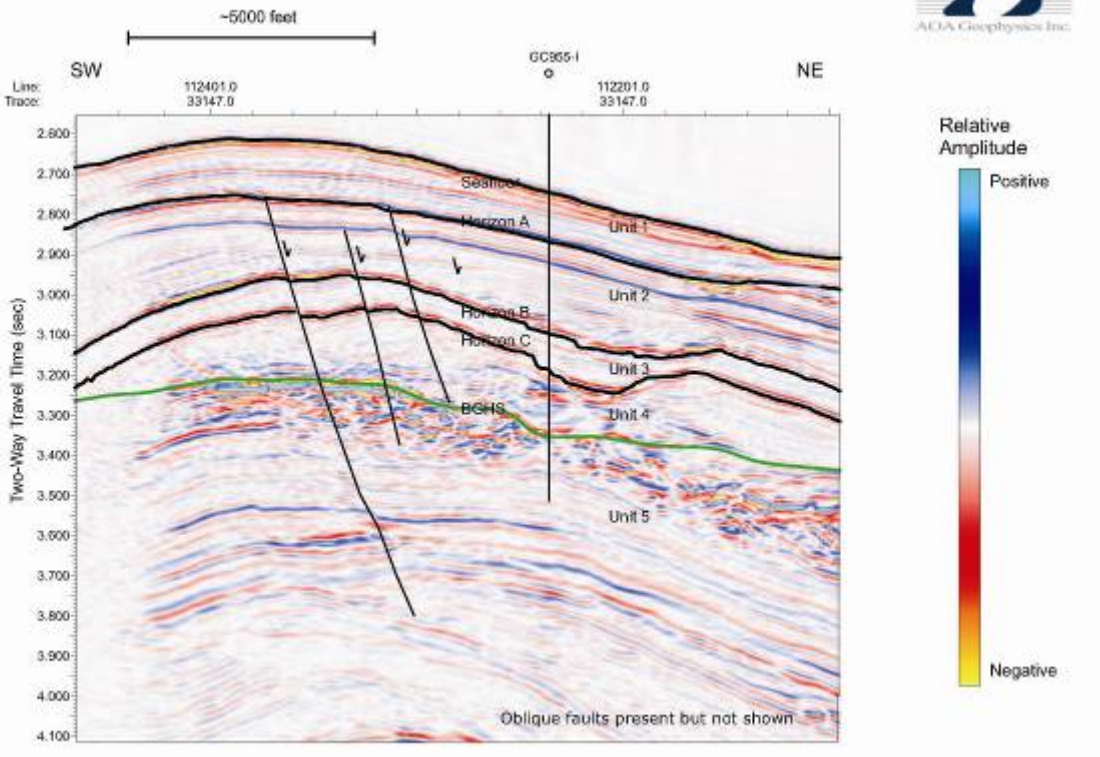
BML: Below Mud Line
BSS: Below Sea Surface
TGHO: Top of Gas Hydrate Occurrence
BGHZ: Base of Gas Hydrate stability Zone


3-D Seismic Record at Proposed Location I Green Canyon Block 955 X = 2,479,847 FT, Y = 9,812,041 FT
SE
~800 ft
GC955-I
NW
Trace:
33120.0
33160.0
Event and Unit Designations
Inferred Lithology and Comments
Depths
MML (ft)
BSS (ft)
TWT BSS (s)
Thickness (ft)
Hazardous Shallow Gas Risk
Shallow Water Flow Risk
SEAFLOOR
HOR A
Fault
HOR B
HOR C
BGHS
TD
Seafloor slopes about 1.5 degree within Scafloor Furrow.
Normal marine clays.
Interbedded clays with channel lense sands.
channel margin deposits
channel margin deposits
basal channel sands. Possible gas hydrate deposits within sands.
Sand-prone section with clays. Possible gassy sediments in vicinity of well bore.
Predominantly clay with possible interbedded sands
0
6785
2.745
343
7108
2.858
175
568
7283
2.915
719
544
801
7566
3.059
1062
7827
3.097
270
1332
8097
3.187
501
1483
8248
3.237
1833
8598
3.353
500
2333
9098
3.493
2416
1918
4249
11014
4.111
NEGLIGIBLE
LOW
2.700
2.800
2.900
3.000
3.100
3.200
3.300
3.400
3.500
3.600
3.700
3.800
3.900
4.000
4.100
TOPHOLE PROGNOSIS CHART
LOCATION I
BLOCK 955, GREEN CANYON AREA
All depths and thicknesses are approximate and are based on check-shot survey from GC 955 #3
4021-JIP-GOM-GC955
Figure GC955I-1


90°26'W
90°24'W
27°2'N
27°N
L
J
I
K
P
H
Q
#1
#2
Area of 4-way closure
2100 m
2200 m
Levee
Horizon C Channel
Levee
Gas Hydrate Accumulations
0
2 KM



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



3D Seismic Record, Crossline 33147, Location I Block 955, Green Canyon Area

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,

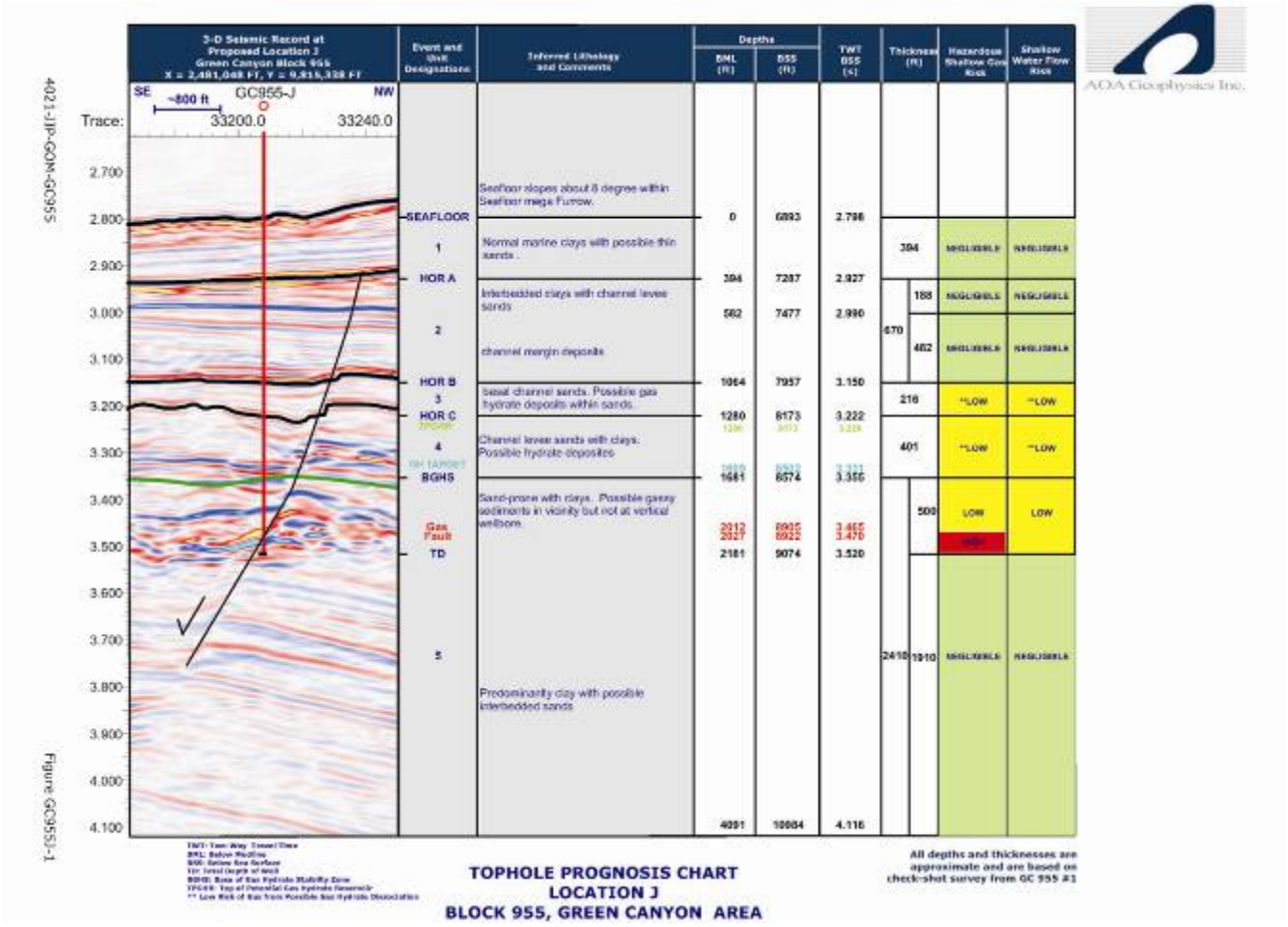
Table 2: Proposed Hole General Information

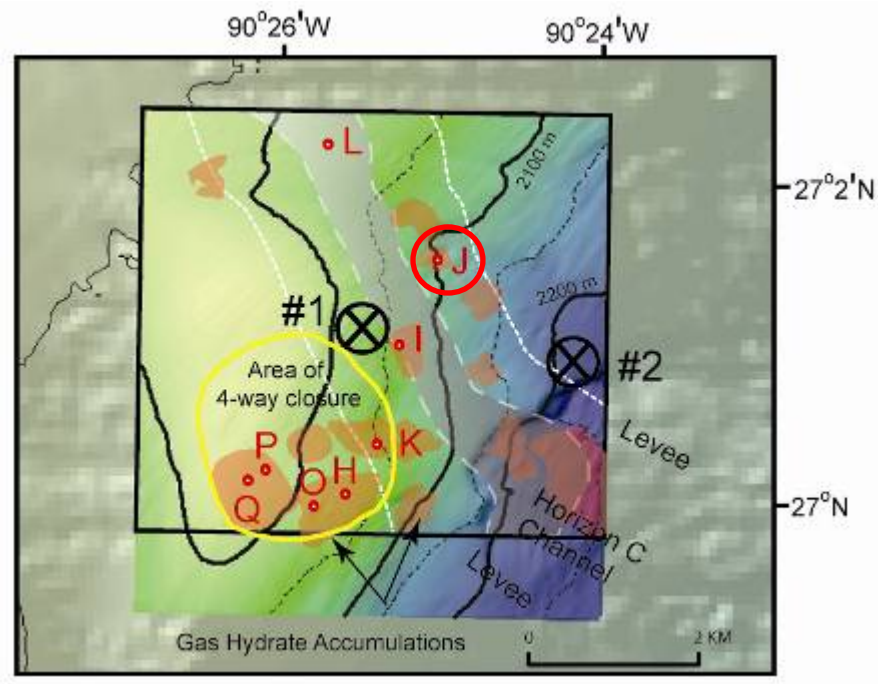
Site Name	Permitted J, JIP NN
General Area	*Seaward of the Sigsbee Escarpment, between Green Canyon proper and Green Knoll*
Location	Latitude: *27° 01' 31.918" N* Longitude: *90° 25' 02.872" W*
Coordinate Datum	*NAD27*
Water Depth	*6893 ft BSS*
OPD/Lease Block	*GC955*
Seismic lines at hole	*Inline 112177,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

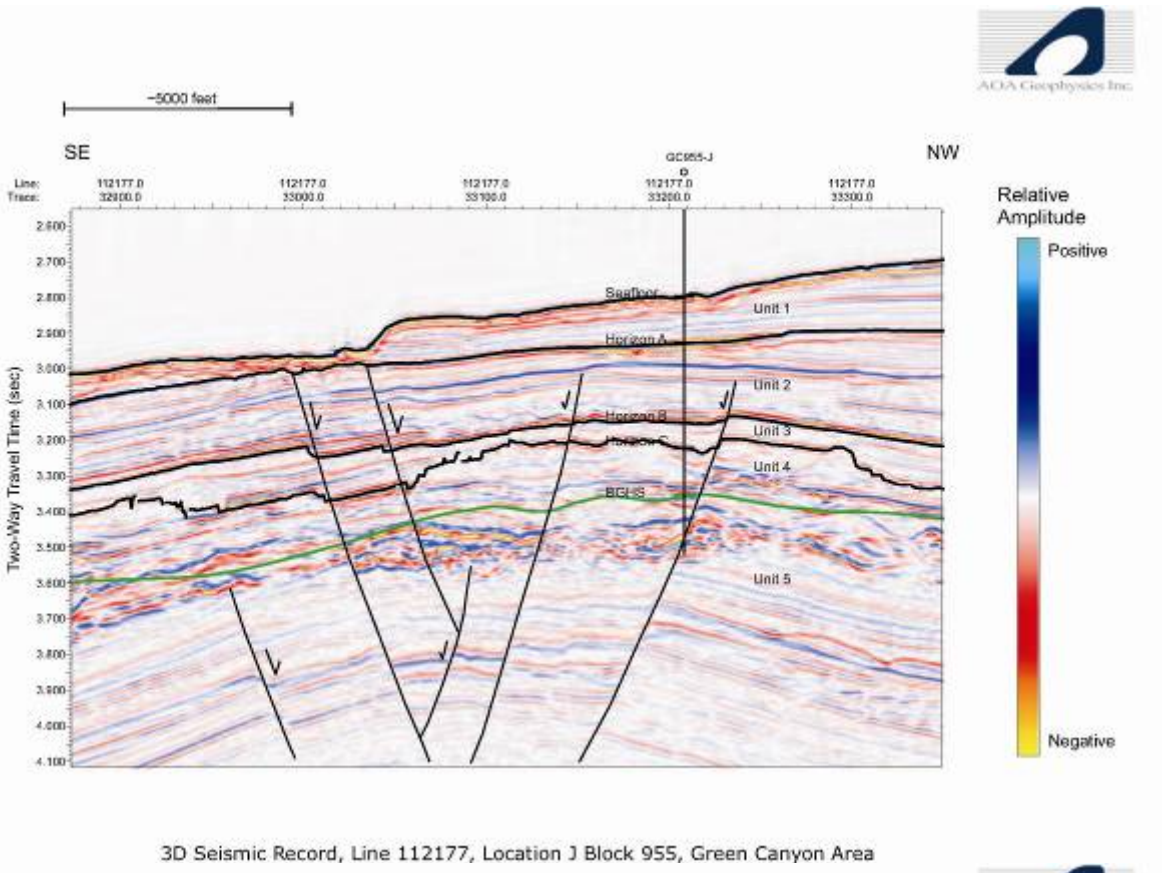
Table 3: Proposed Hole Drilling Information

Proposed penetration	*2181 ft BML (consider stopping before 2012 ft BML) 9074 ft BSS*
Seafloor slope	*8° to the southeast*
Expected lithologies	*0-394 ft BML: normal marine clays with minor sands* *394-1064 ft BML: interbedded clays with channel levee sands going into channel margin deposits* *1064-1280 ft BML: basal channel sands with possible gas hydrate1280-1681 ft BML: channel levee sands with some clay and gas hydrate* *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)* *~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

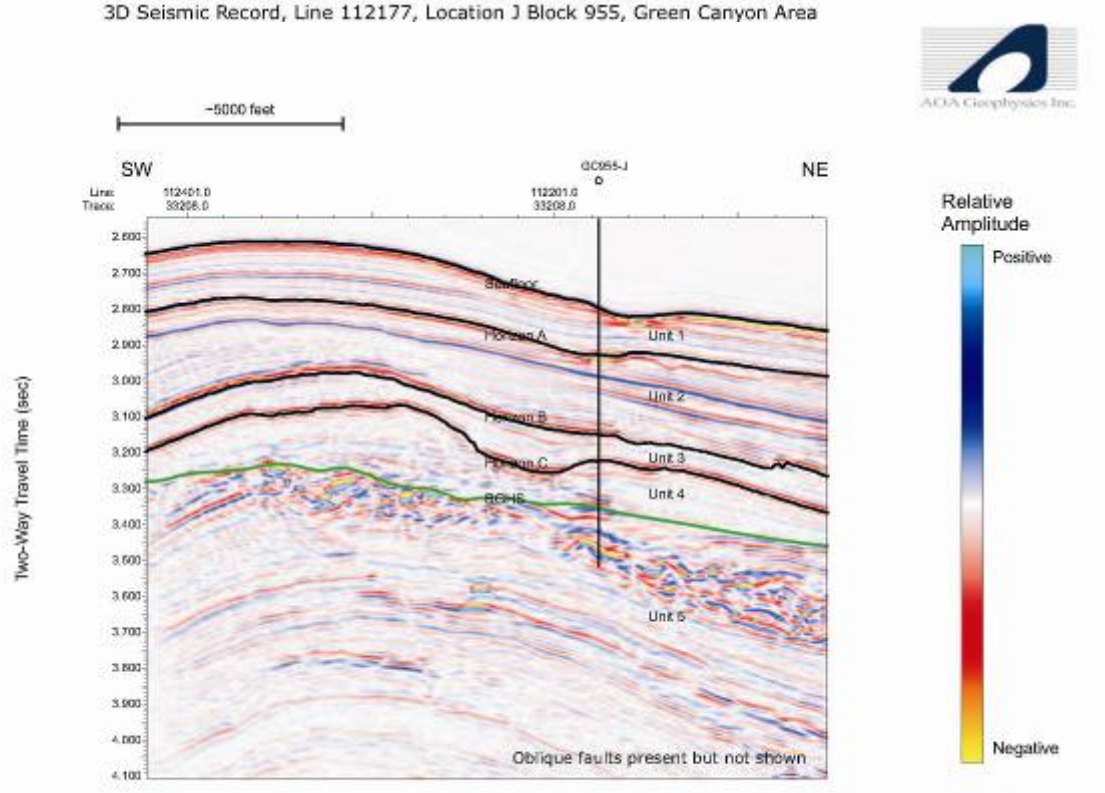
BML: Below Mud Line
BSS: Below Sea Surface
TGHO: Top of Gas Hydrate Occurrence
BGHZ: Base of Gas Hydrate stability Zone


4021-JIP-GOM-GC955
3-D Seismic Record at Proposed Location J Green Canyon Block 955
SE
~800 ft
GC955-J
NW
Trace:
33200.0
33240.0
Event and Unit Designations
Inferred Lithology and Comments
Depths
BML (ft)
BSS (ft)
TWT BSS (s)
Thickness (ft)
Hazardous Shallow Gas Risk
Shallow Water Flow Risk
SEAFLOOR
Seafloor slopes about 8 degree within Seafloor mega Furrow.
0
6893
2.798
1
Normal marine clays with possible thin sands .
394
NEGLIGIBLE
NEGLIGIBLE
HOR A
394
7287
2.927
Interbedded clays with channel levee sands
582
7477
2.990
188
NEGLIGIBLE
NEGLIGIBLE
670
2
channel margin deposits
482
NEGLIGIBLE
NEGLIGIBLE
HOR B
1064
7957
3.150
3
Seal channel sands. Possible gas hydrate deposits within sands.
216
**LOW
**LOW
HOR C
1280
8173
3.222
4
Channel levee sands with clays. Possible hydrate deposites
401
**LOW
**LOW
BGHS
1681
8574
3.355
Sand-prone with clays . Possible gassy sediments in vicinity but not at vertical wellbore
500
LOW
LOW
Gas Fault
2012
2027
8905
8922
3.465
3.470
TD
2181
9074
3.520
5
2410
1910
NEGLIGIBLE
NEGLIGIBLE
Predominantly clay with possible interbedded sands
4091
10084
4.116
2.700
2.800
2.900
3.000
3.100
3.200
3.300
3.400
3.500
3.600
3.700
3.800
3.900
4.000
4.100
TWT: Two-Way Travel Time
BML: Below Mudline
BSS: Below Sea Surface
BGHS: Base of Gas Hydrate Stability Zone
** Low Risk of Gas from Possible Gas Hydrate Dissociation
TOPHOLE PROGNOSIS CHART
LOCATION J
BLOCK 955, GREEN CANYON AREA
All depths and thicknesses are approximate and are based on check-shot survey from GC 955 #1
AOA Geophysics Inc.
Figure GC955J-1


90°26'W
90°24'W
27°2'N
27°N
L
2100 m
J
2200 m
#1
I
#2
Area of
4-way closure
P
K
H
Q
Levee
Horizon C
Channel
Levee
Gas Hydrate Accumulations
0
2 KM



3D Seismic Record, Line 112177, Location J Block 955, Green Canyon Area



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

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,

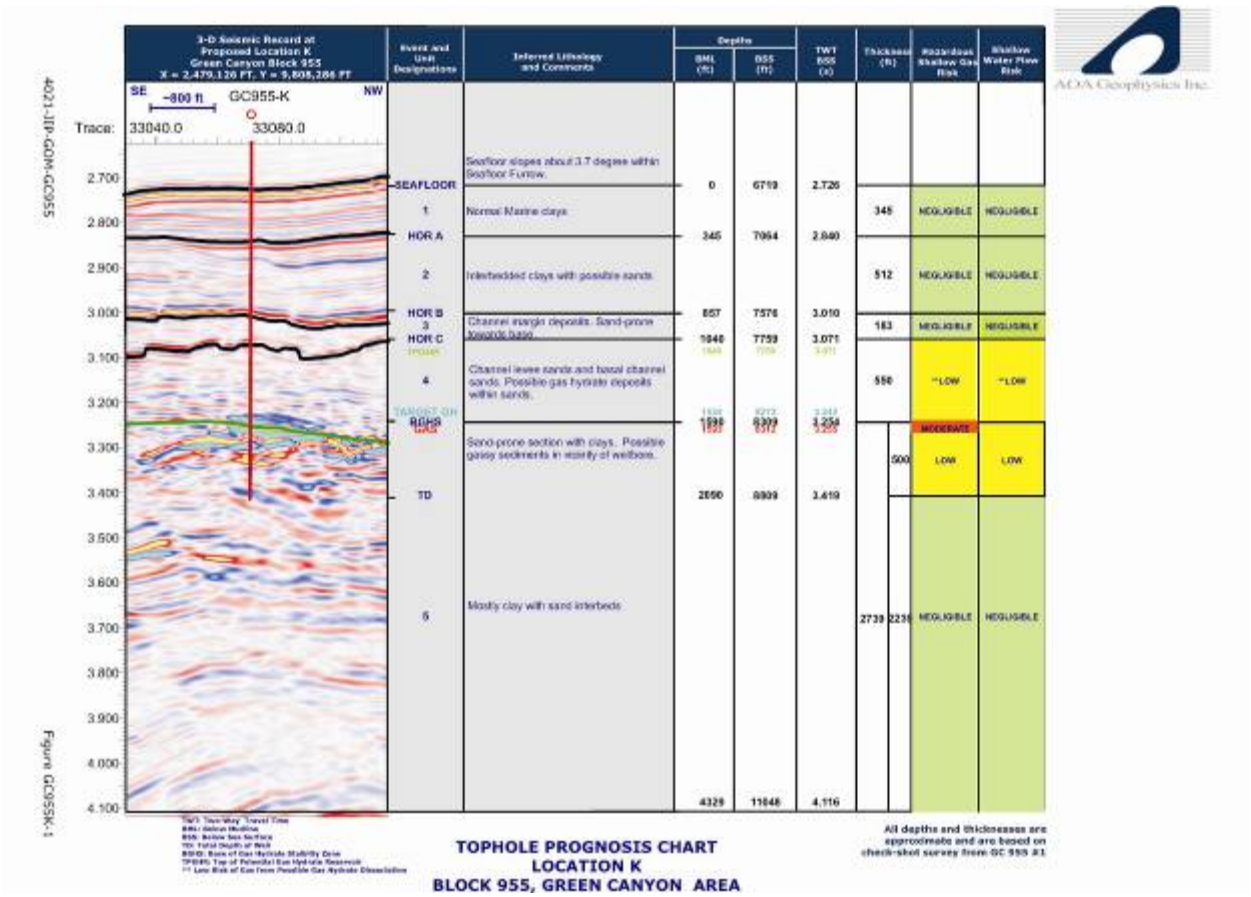
Table 2: Proposed Hole General Information

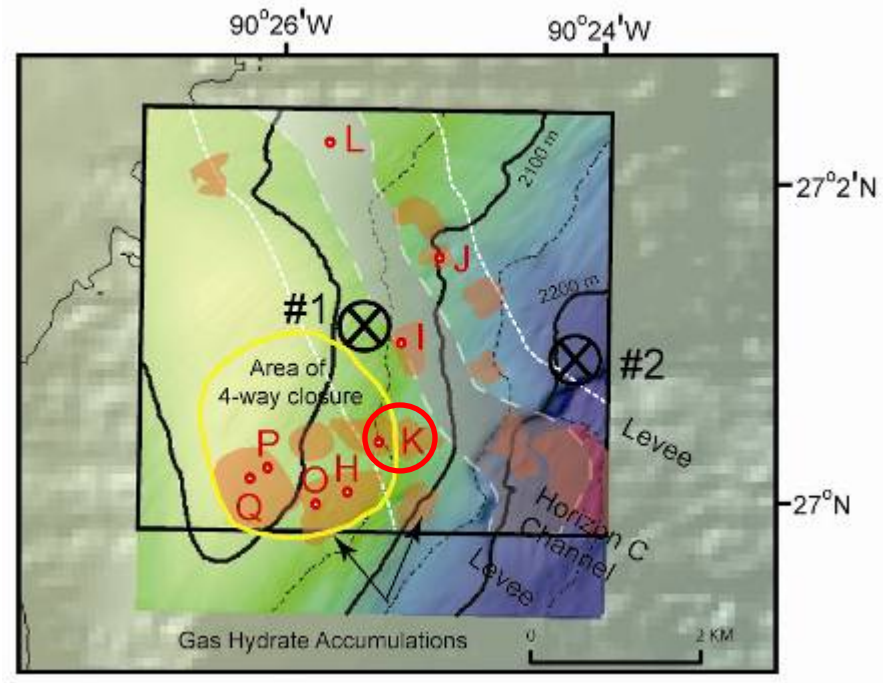
Site Name	Permitted K, JIP QQ
General Area	*Seaward of the Sigsbee Escarpment, between Green Canyon proper and Green Knoll*
Location	Latitude: *27° 00' 22.513"N* Longitude: *90° 25' 25.704" W*
Coordinate Datum	*NAD27*
Water Depth	*6719 ft BSS*
OPD/Lease Block	*GC955*
Seismic lines at hole	*Inline 112291,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

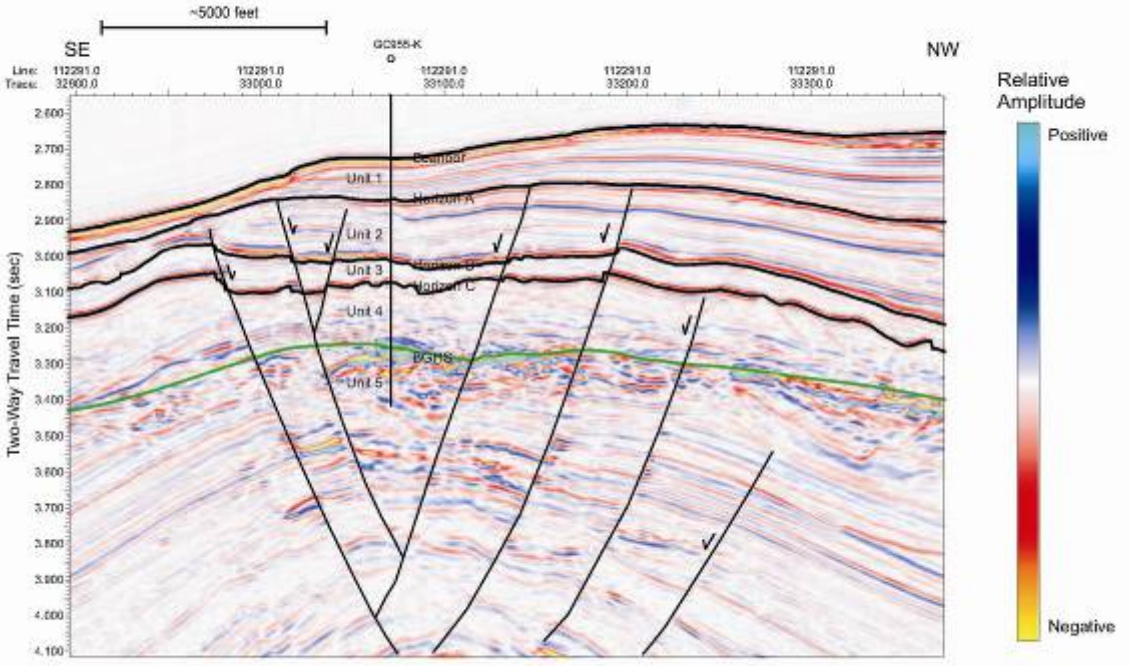
Table 3: Proposed Hole Drilling Information

Proposed penetration	*2090 ft BML 8809 ft BSS*
Seafloor slope	*3.7° to the east*
Expected lithologies	*0-345 ft BML: normal marine clays* *345-857 ft BML: interbedded clays with possible sands* *857-1040 ft BML: channel margin deposits, sand-prone towards base* *1040-1590 ft BML: channel levee sands and basal channel sands with possible gas hydrate* *1590-2090 ft BML: sand-prone section with clays, possible gassy sediments near well-bore*
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* *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

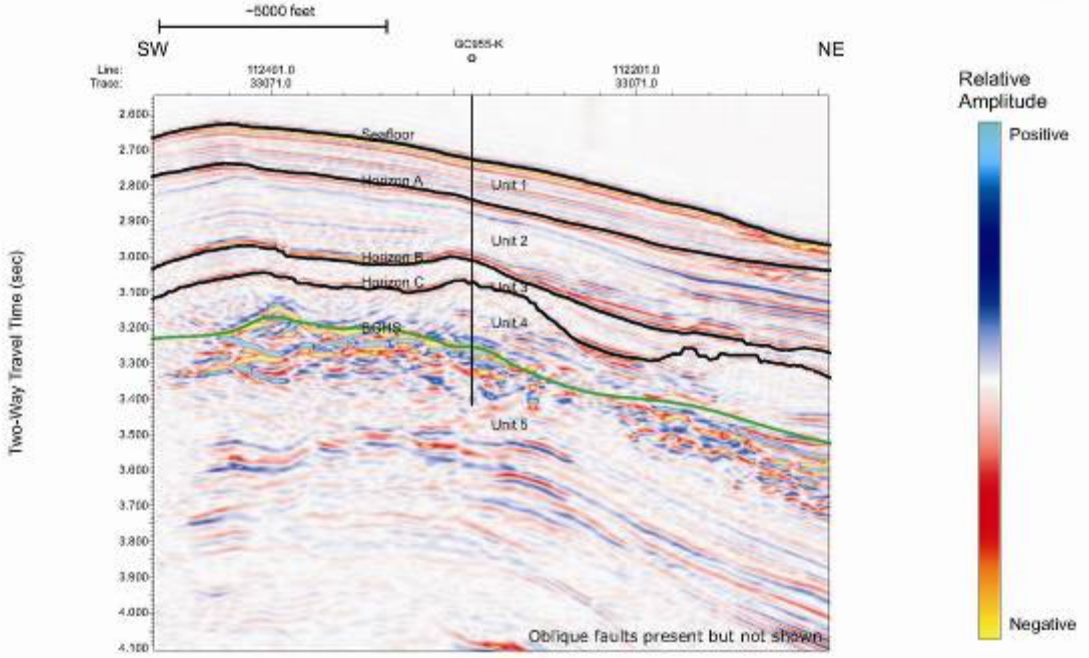
BML: Below Mud Line
BSS: Below Sea Surface
TGHO: Top of Gas Hydrate Occurrence
BGHZ: Base of Gas Hydrate stability Zone


3-D Seismic Record at
Proposed Location K
Green Canyon Block 955
X = 2,479,126 FT, Y = 9,805,286 FT
SE
~800 ft
GC955-K
NW
Trace:
33040.0
33080.0
Event And Unit Designations
Inferred Lithology and Comments
Depths
BML (ft)
BSS (ft)
TWT BSS (s)
Thickness (ft)
Hazardous Shallow Gas Risk
Shallow Water Flow Risk
SEAFLOOR
Seafloor slopes about 3.7 degree within Seafloor Furrow.
1
Normal Marine clays
HOR A
2
Interbedded clays with possible sands
HOR B
3
Channel margin deposits. Sand-prone
HOR C
4
Channel levee sands and basal channel sands. Possible gas hydrate deposits within sands.
TARGET OF BOEM
BOEM
Sand-prone section with clays. Possible gassy sediments in vicinity of wellbore.
TD
5
Mostly clay with sand interbeds
0
6719
2.726
345
7064
2.840
857
7576
3.010
183
1040
7759
3.071
550
**LOW
**LOW
1590
8309
3.259
MODERATE
900
LOW
LOW
2690
9909
3.619
2739
2236
NEGLIGIBLE
NEGLIGIBLE
4329
11648
4.116
TOPHOLE PROGNOSIS CHART
LOCATION K
BLOCK 955, GREEN CANYON AREA
All depths and thicknesses are approximate and are based on check-shot survey from GC 955 #1
4021-1EP-GOM-GC955
Figure GC955K-1


90°26'W
90°24'W
27°2'N
27°N
L
J
I
K
P
H
Q
#1
#2
Area of
4-way closure
2100 m
2200 m
Levee
Horizon C
Channel
Levee
Gas Hydrate Accumulations
0
2 KM



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



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

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,

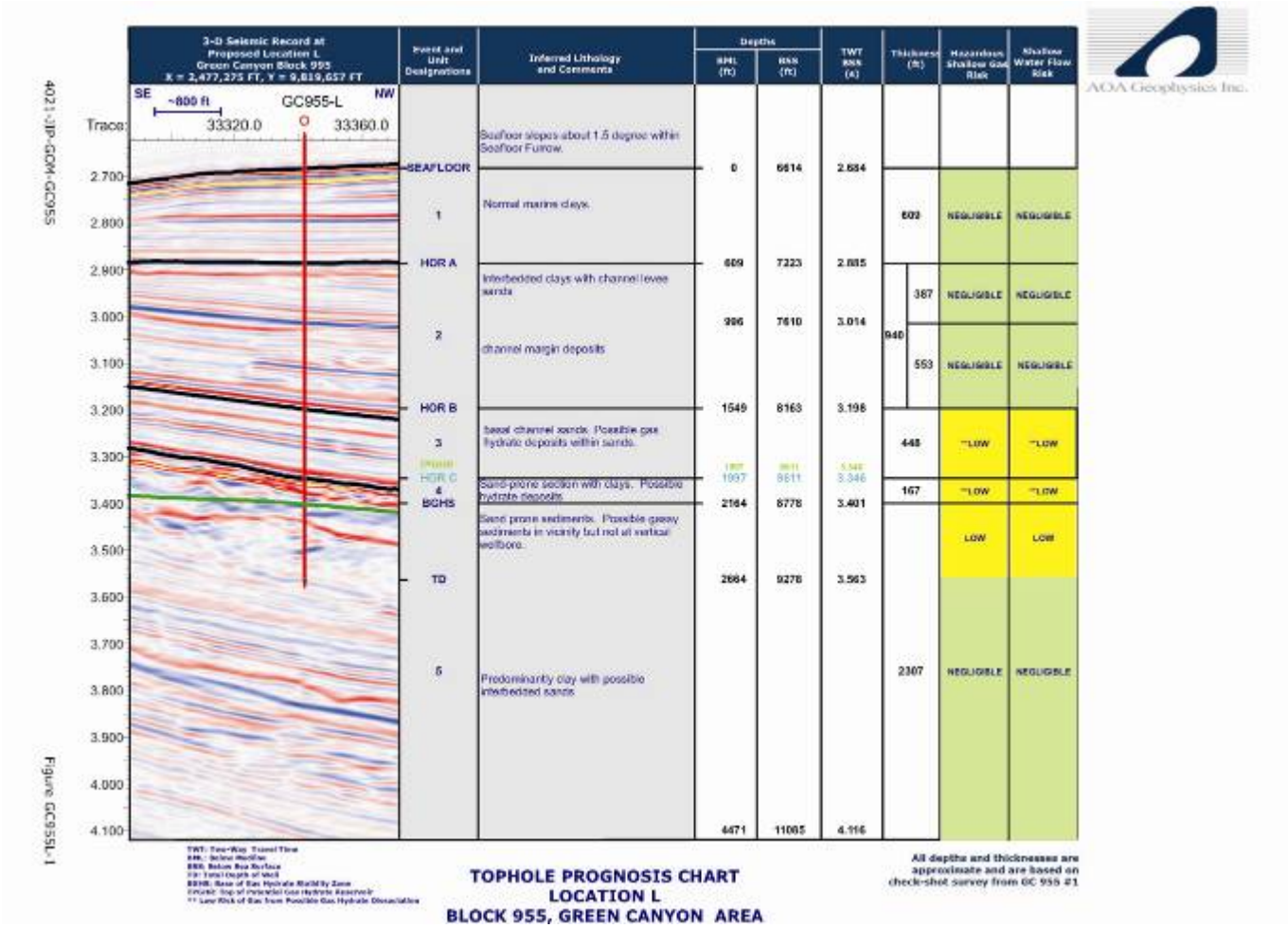
Table 2: Proposed Hole General Information

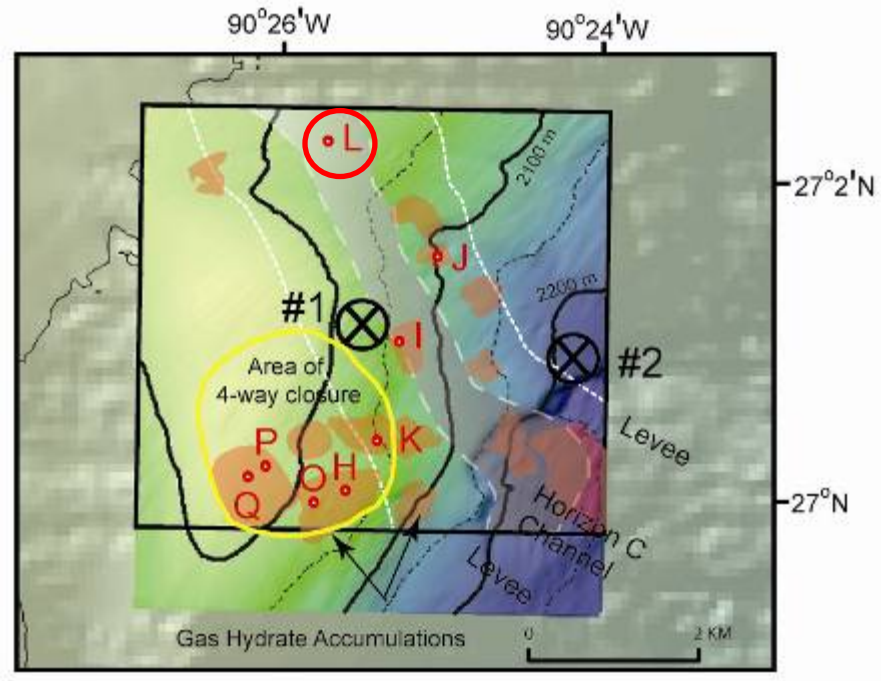
Site Name	Permitted L, JIP RR
General Area	*Seaward of the Sigsbee Escarpment, between Green Canyon proper and Green Knoll*
Location	Latitude: *27° 02' 15.428" N* Longitude: *90° 25' 43.592" W*
Coordinate Datum	*NAD27*
Water Depth	*6614 ft BSS*
OPD/Lease Block	*GC955*
Seismic lines at hole	*Inline 112217,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

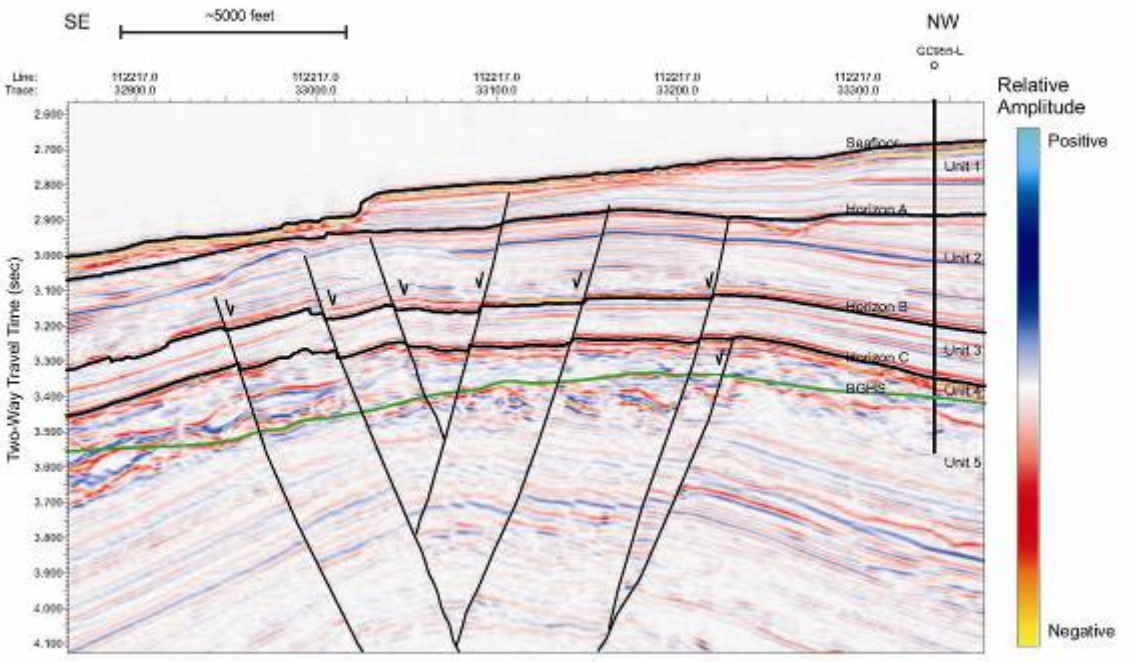
Table 3: Proposed Hole Drilling Information

Proposed penetration	*2664 ft BML 9278 ft BSS*
Seafloor slope	*1.5° to the southeast*
Expected lithologies	*0-609 ft BML: normal marine clays* *609-1549 ft BML: Interbedded clays with channel levee sands going into deeper channel margin deposits* *1549-1997 ft BML: basal channel sands with possible gas hydrate* *1997-2164 ft BML: sand prone section with clays, also gas hydrate* *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

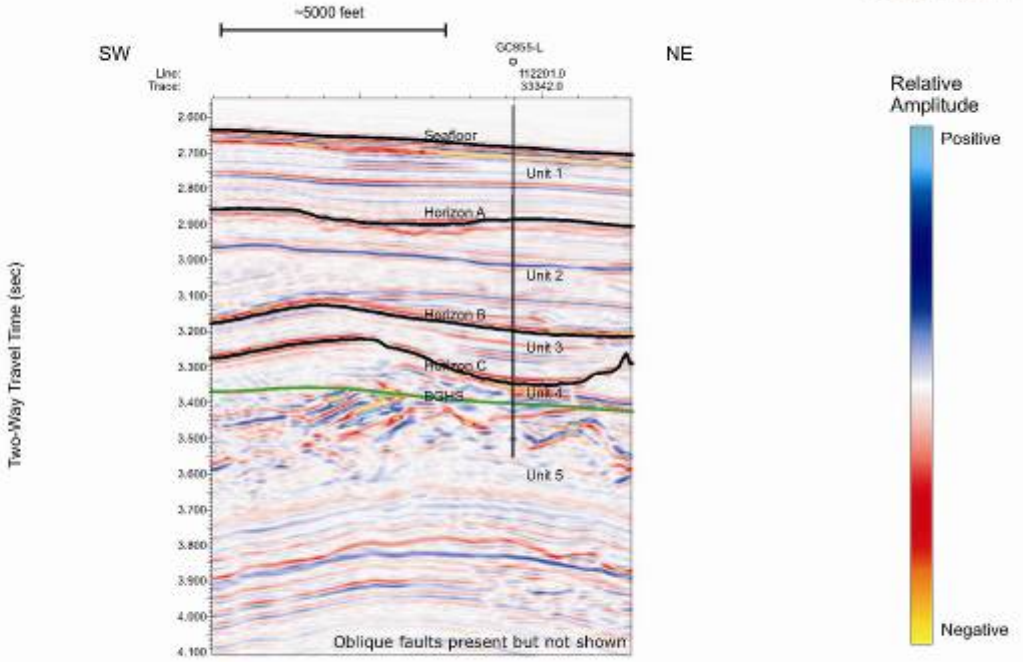
BML: Below Mud Line
BSS: Below Sea Surface
TGHO: Top of Gas Hydrate Occurrence
BGHZ: Base of Gas Hydrate stability Zone


3-D Seismic Record at Proposed Location L Green Canyon Block 955 X = 2,477,275 FT, Y = 9,819,657 FT
SE
~800 ft
GC955-L
NW
Trace
33320.0
33360.0
Point and Unit Designations
Inferred Lithology and Comments
Depths
BML (ft)
BSS (ft)
TWT BSS (s)
Thickness (ft)
Hazardous Shallow Gas Risk
Shallow Water Flow Risk
Seafloor slopes about 1.5 degree within Seafloor Furrow.
SEAFLOOR
0
6614
2.684
Normal marine clays.
1
602
NEGLIGIBLE
NEGLIGIBLE
HDR A
609
7223
2.885
Interbedded clays with channel levee sands
387
NEGLIGIBLE
NEGLIGIBLE
2
996
7610
3.014
940
channel margin deposits
553
NEGLIGIBLE
NEGLIGIBLE
HDR B
1549
8163
3.198
basal channel sands. Possible gas hydrate deposits within sands.
3
448
**LOW
**LOW
HDR C
1997
8611
3.346
Sand-prone section with clays. Possible hydrate deposits.
4
167
**LOW
**LOW
BGHS
2164
8778
3.401
Sand prone sediments. Possible gassy sediments in vicinity but not at vertical wellbore.
LOW
LOW
TD
2684
9278
3.563
5
Predominantly clay with possible interbedded sands
2307
NEGLIGIBLE
NEGLIGIBLE
4471
11065
4.116
TWT: Two-Way Travel Time
BML: Below Mudline
BSS: Below Sea Surface
TD: Total Depth of Well
BGHS: Base of Gas Hydrate Stability Zone
(Purple) Top of Potential Gas Hydrate Reservoir
** Low Risk of Gas from Possible Gas Hydrate Dissociation
All depths and thicknesses are approximate and are based on check-shot survey from GC 955 #1
TOPHOLE PROGNOSIS CHART
LOCATION L
BLOCK 955, GREEN CANYON AREA
4021-JIP-GOM-GC955
Figure GC955L-1


90°26'W
90°24'W
27°2'N
27°N
L
J
I
K
P
H
Q
#1
#2
Area of 4-way closure
2100 m
2200 m
Levee
Horizon C Channel
Levee
Gas Hydrate Accumulations
0
2 KM



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



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

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

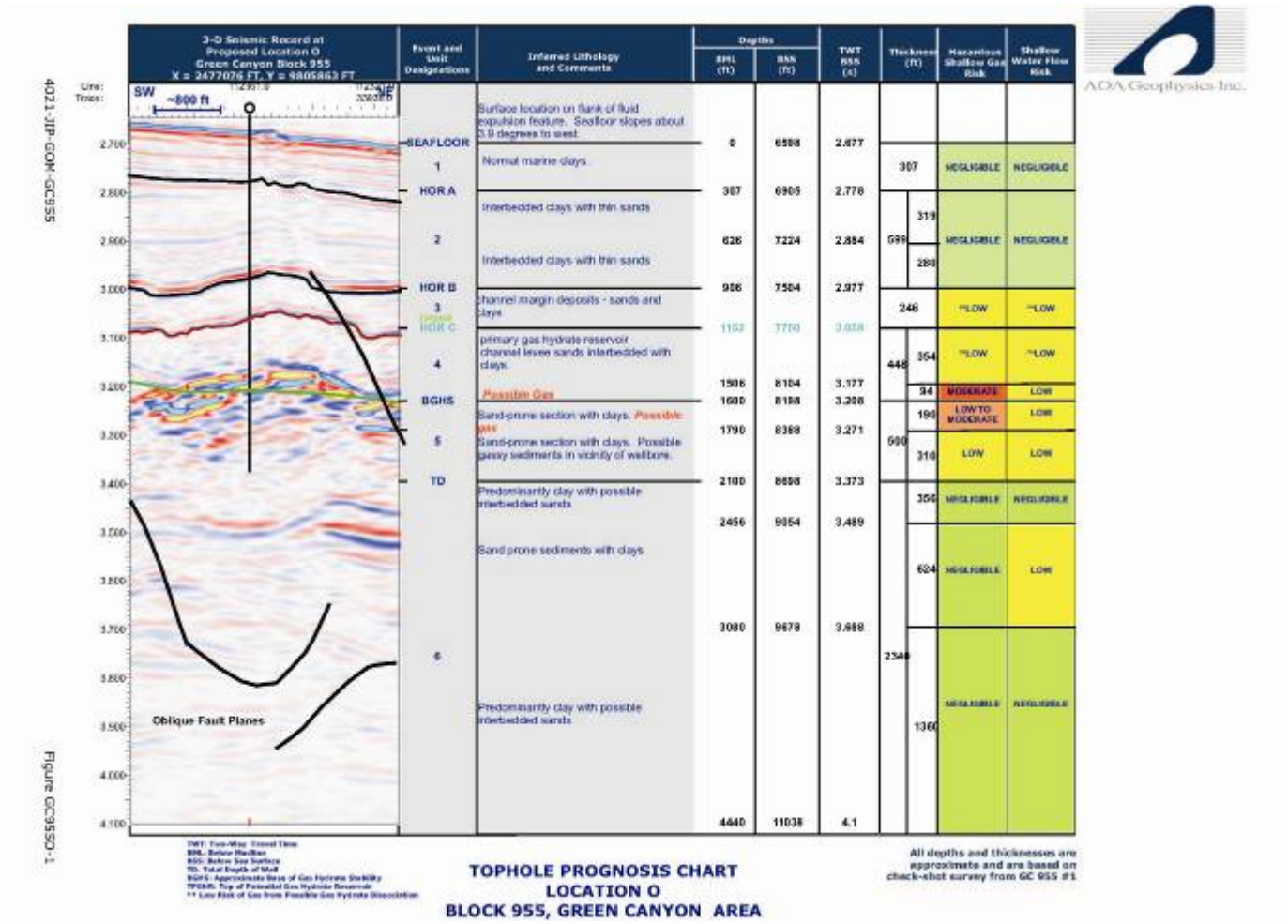
Site Name	Permitted O JIP VV
General Area	*Between the Sigsbee Escarpment and Green Knoll, near Green Canyon proper*
Location	Latitude: *26° 59' 58.950" N* Longitude: *90° 25' 48.902" W*
Coordinate Datum	*NAD27*
Water Depth	*6598 ft BSS*
OPD/Lease Block	*GC955*
Seismic lines at hole	**Inline 112361,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

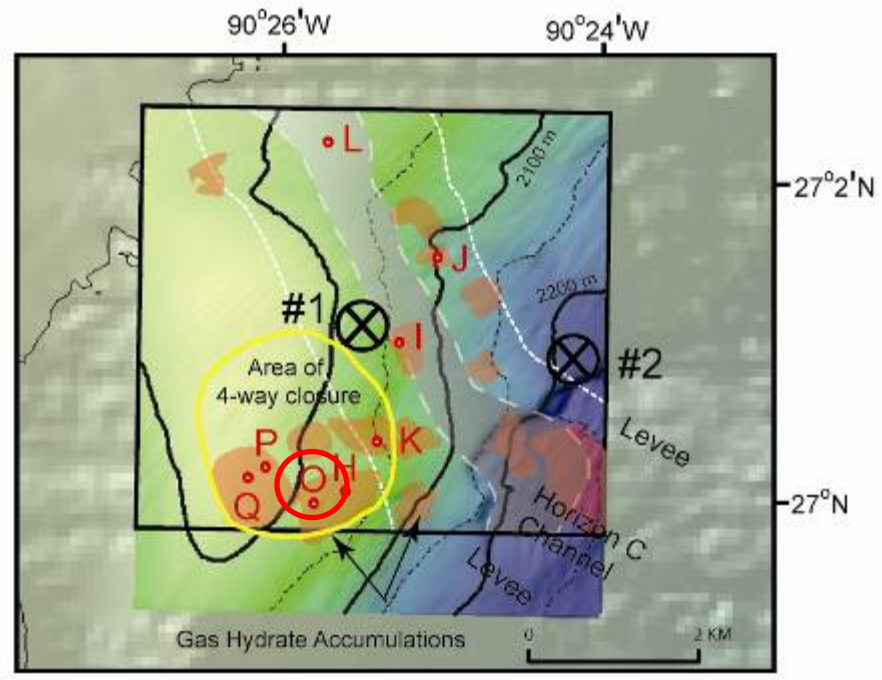
Table 3: Proposed Hole Drilling Information

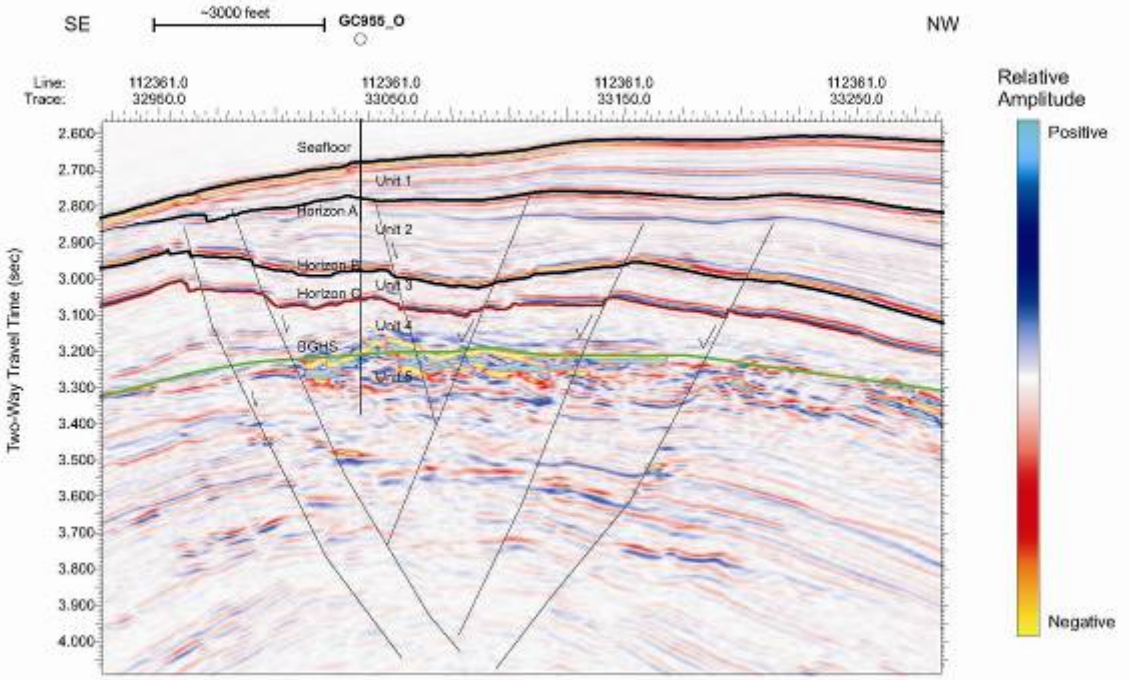
Proposed penetration	*2100 ft BML 8698 ft BSS*
Seafloor slope	*3.9° to the west*
Expected lithologies	*307' Unit 1 mud-rich sediments* *599' Unit 2 interbedded clays with thin sands* *246' Unit 3 channel margin deposits, sand prone* *Major Unconformity* *448' Unit 4 channel levee sands (gas hydrate reservoir)* *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* *Fluid expulsion mound (30 ft relief) ~180 ft west of "O"* *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.

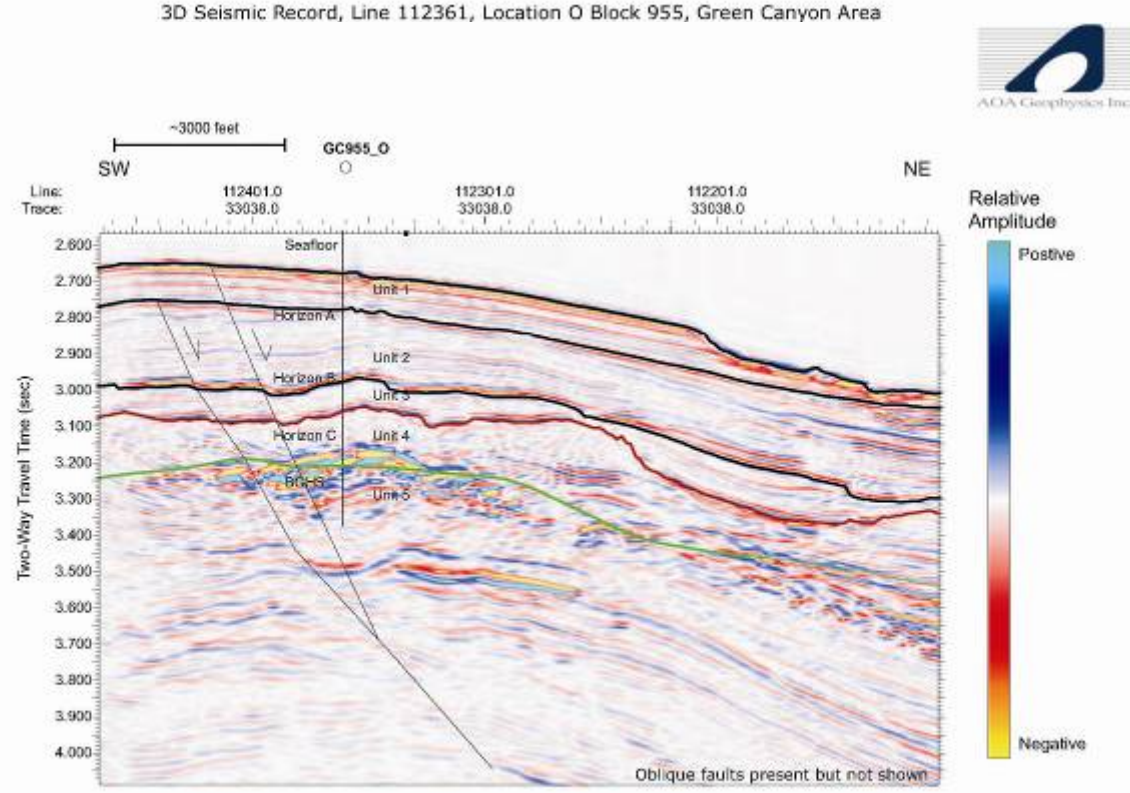
BML: Below Mud Line
BSS: Below Sea Surface
TGHO: Top of Gas Hydrate Occurrence
BGHZ: Base of Gas Hydrate stability Zone


AOA Geophysics Inc.
4021-JIP-GOM-GC955
Figure GC955O-1
3-D Seismic Record at Proposed Location O Green Canyon Block 955 X = 2477076 FT, Y = 9805863 FT
Event and Unit Designations
Inferred Lithology and Comments
Depths
BML (ft)
BSS (ft)
TWT BSS (s)
Thickness (ft)
Hazardous Shallow Gas Risk
Shallow Water Flow Risk
SW
~800 ft
NE
SEAFLOOR
HOR A
HOR B
HOR C
BGHS
TD
Surface location on flank of fluid expulsion feature. Seafloor slopes about 3.9 degrees to west
Normal marine clays
Interbedded clays with thin sands
Interbedded clays with thin sands
Channel margin deposits - sands and clays
primary gas hydrate reservoir channel levee sands interbedded with clays
Possible Gas
Sand-prone section with clays. Possible gassy sediments in vicinity of wellbore.
Sand-prone section with clays. Possible gassy sediments in vicinity of wellbore.
Predominantly clay with possible interbedded sands
Sand prone sediments with clays
Predominantly clay with possible interbedded sands
Oblique Fault Planes
0 6588 2.877
387 6905 2.778
626 7224 2.884
956 7584 2.977
1153 7780 3.038
1506 8104 3.177
1600 8198 3.208
1790 8388 3.271
2100 8698 3.373
2456 9054 3.489
3080 9678 3.688
4440 11038 4.1
387
319
280
248
364
84
190
310
356
624
1360
NEGLIGIBLE
LOW
LOW TO MODERATE
MODERATE
TWT: Two-Way Travel Time
BML: Below Mudline
BSS: Below Sea Surface
TD: Total Depth of Well
BGHS: Approximate Base of Gas Hydrate Stability
TPGHR: Top of Potential Gas Hydrate Reservoir
** Low Risk of Gas from Possible Gas Hydrate Dissociation
All depths and thicknesses are approximate and are based on check-shot survey from GC 955 #1
TOPHOLE PROGNOSIS CHART
LOCATION O
BLOCK 955, GREEN CANYON AREA


90°26'W
90°24'W
27°2'N
27°N
L
J
I
K
P
O
H
Q
#1
#2
Area of 4-way closure
2100 m
2200 m
Levee
Horizon C Channel
Levee
Gas Hydrate Accumulations
0
2 KM



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



3D Seismic Record, Crossline 33038, Location O Block 955, Green Canyon Area

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* *704' Unit 2 interbedded clays with possible thin sands* *252' Unit 3 channel margin deposits, sand prone* *Major Unconformity* *355' Unit 4 channel levee sands – gas hydrate reservoir* *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,* *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* *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

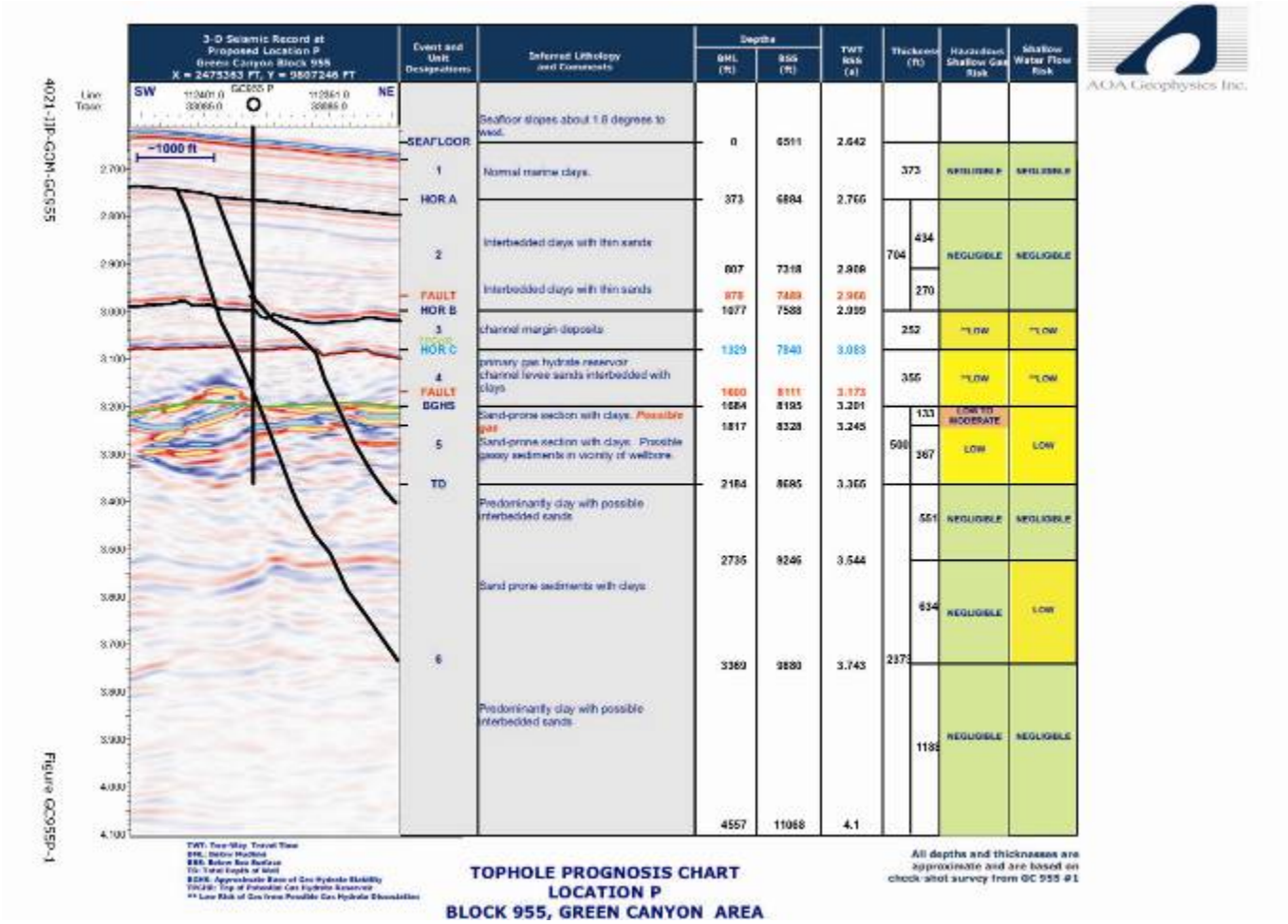
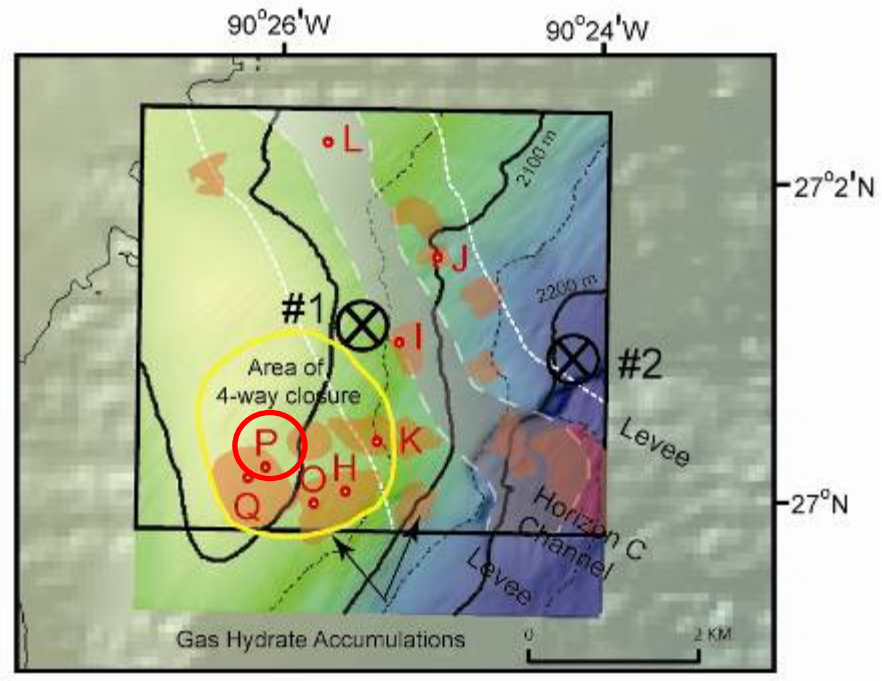
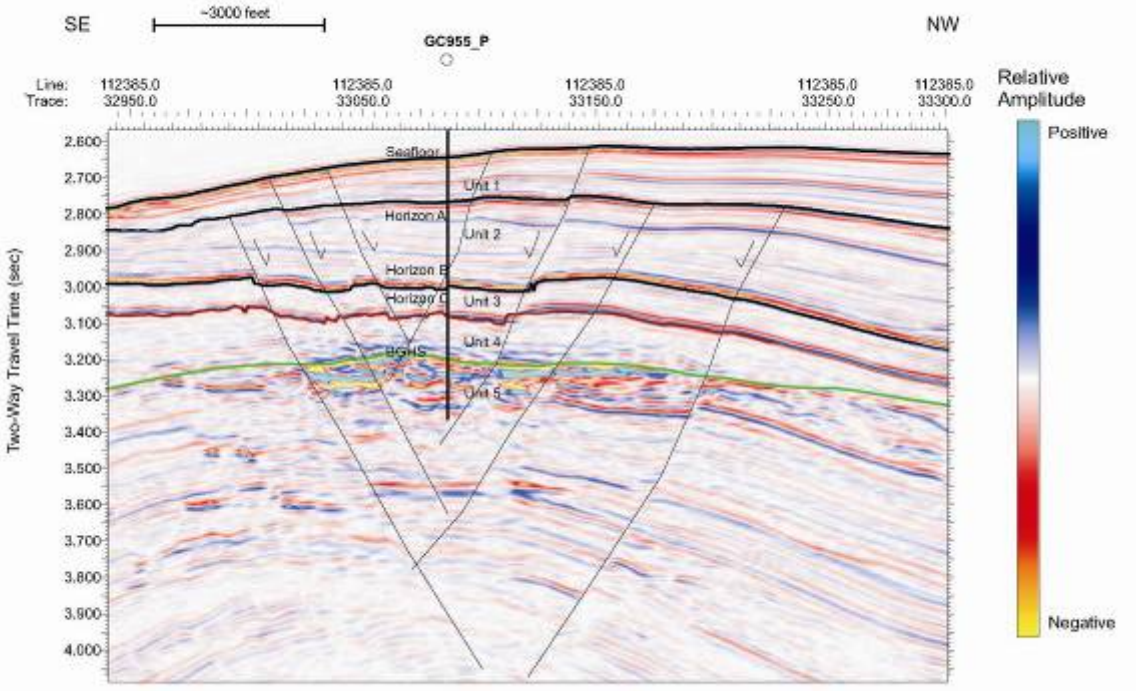
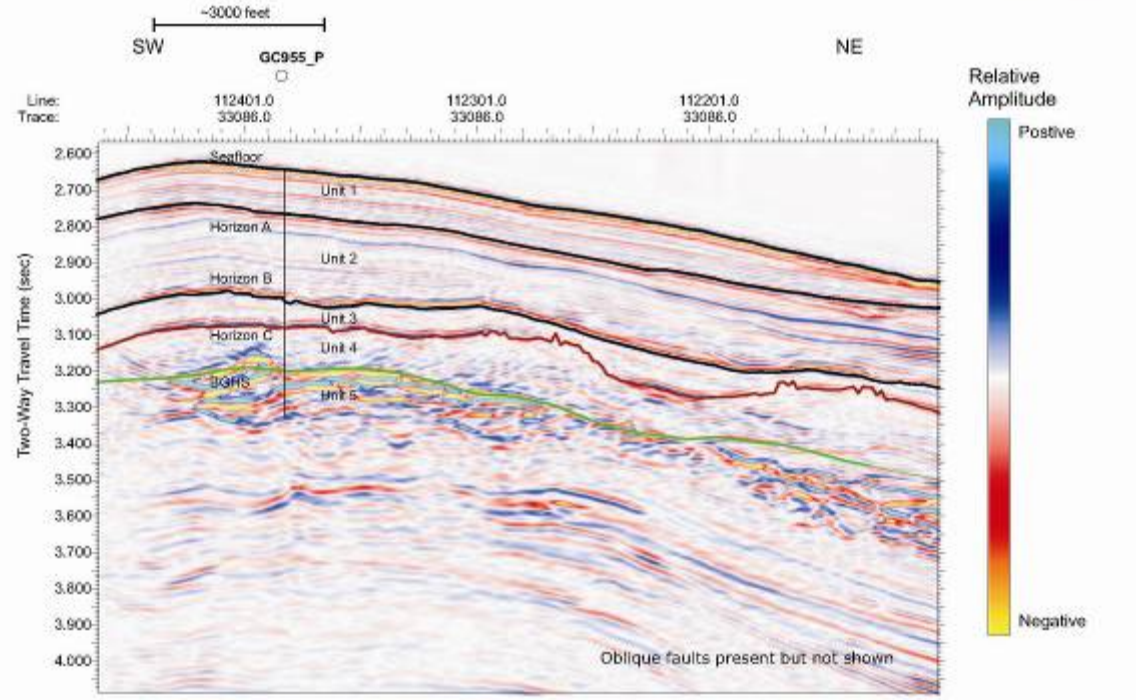


Figure GC955P-1





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



3D Seismic Record, Crossline 33086, Location P Block 955, Green Canyon Area

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)

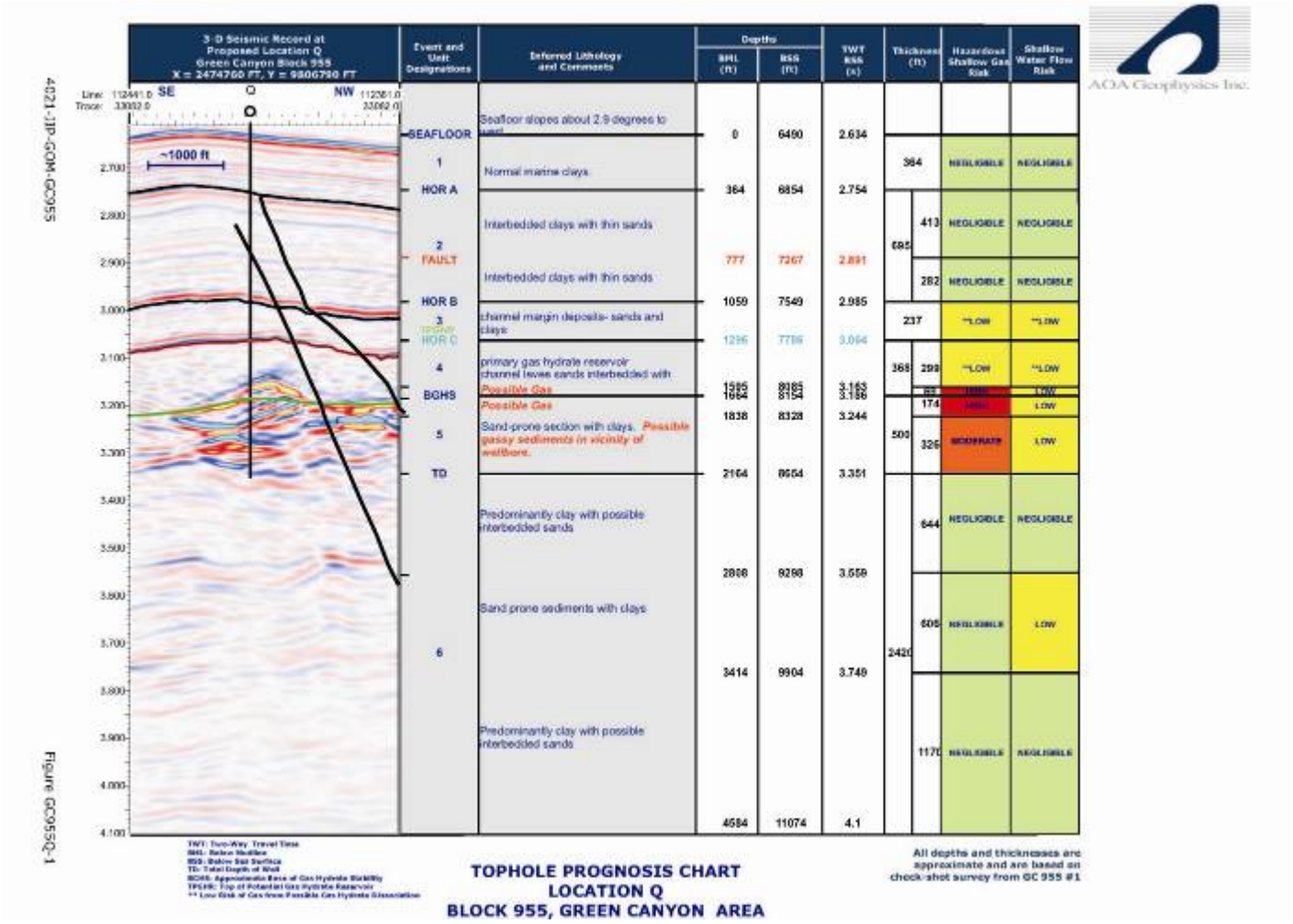
Table 2: Proposed Hole General Information

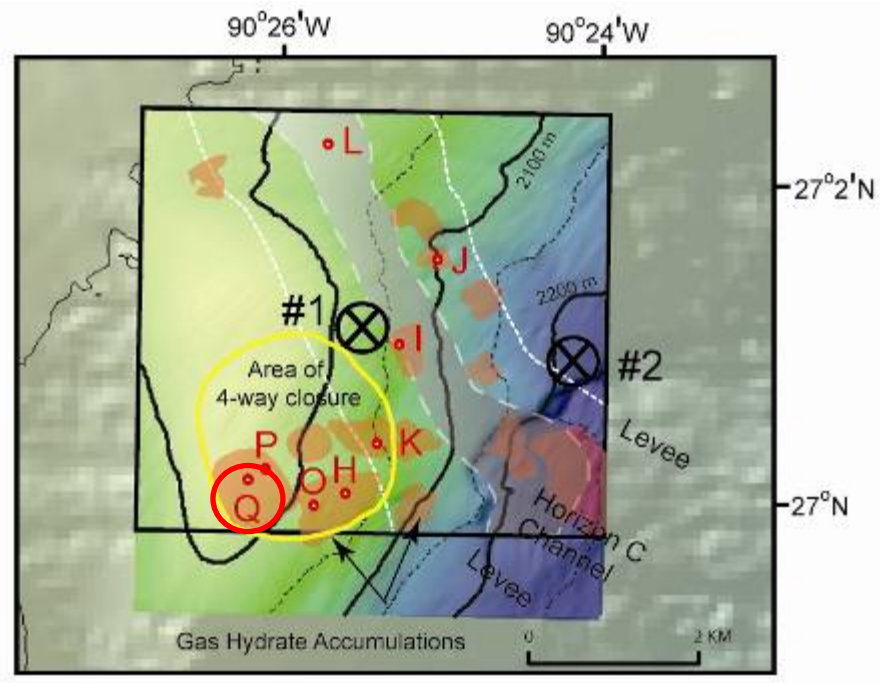
Site Name	Permitted **Q**; JIP XX
General Area	*Between the Sigsbee Escarpment and Green Knoll, near Green Canyon proper*
Location	Latitude: *27°00' 08.589" N* Longitude: *90° 26' 14.281" W*
Coordinate Datum	*NAD27*
Water Depth	*6490 ft BSS*
OPD/Lease Block	*GC955*
Seismic lines at hole	*Inline 112403,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

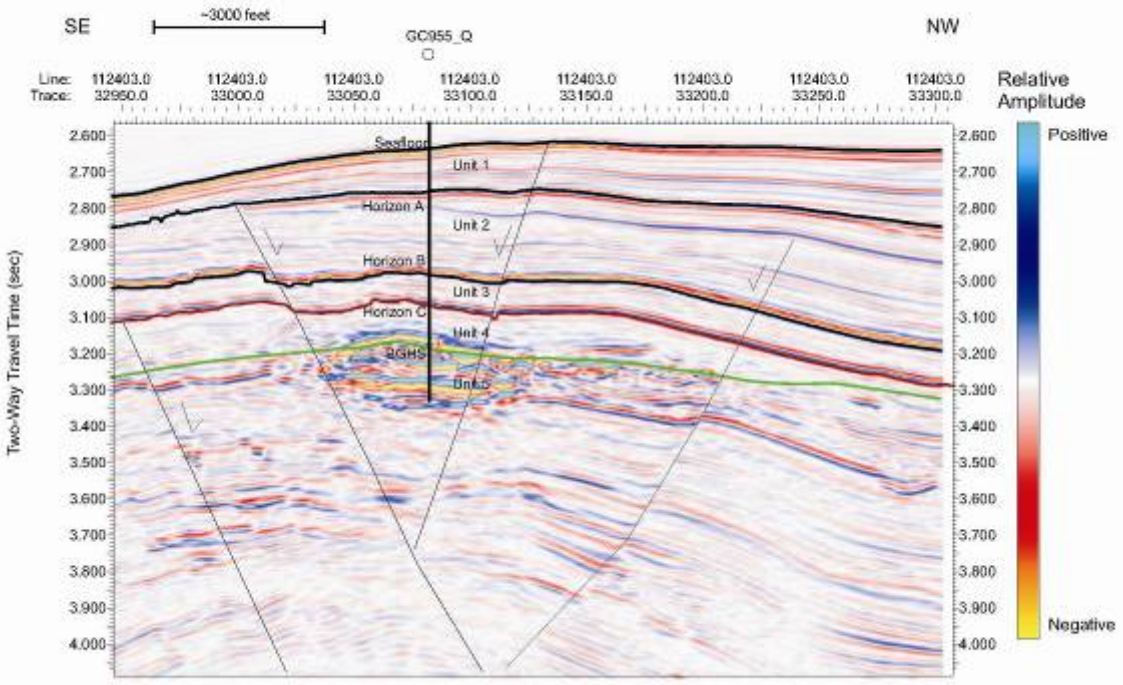
Table 3: Proposed Hole Drilling Information

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* *695' Unit 2 – interbedded clays with possible thin sands* *237' Unit 3 – channel margin deposition, mostly sand prone* *Major Unconformity* *368' Unit 4 – channel levee sands* *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,* *sea floor escarpment with ~400 ft relief is ~1.4 mi east of Q* *fluid expulsion mound (~30 ft relief) ~2300 ft SE of Q* *~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*

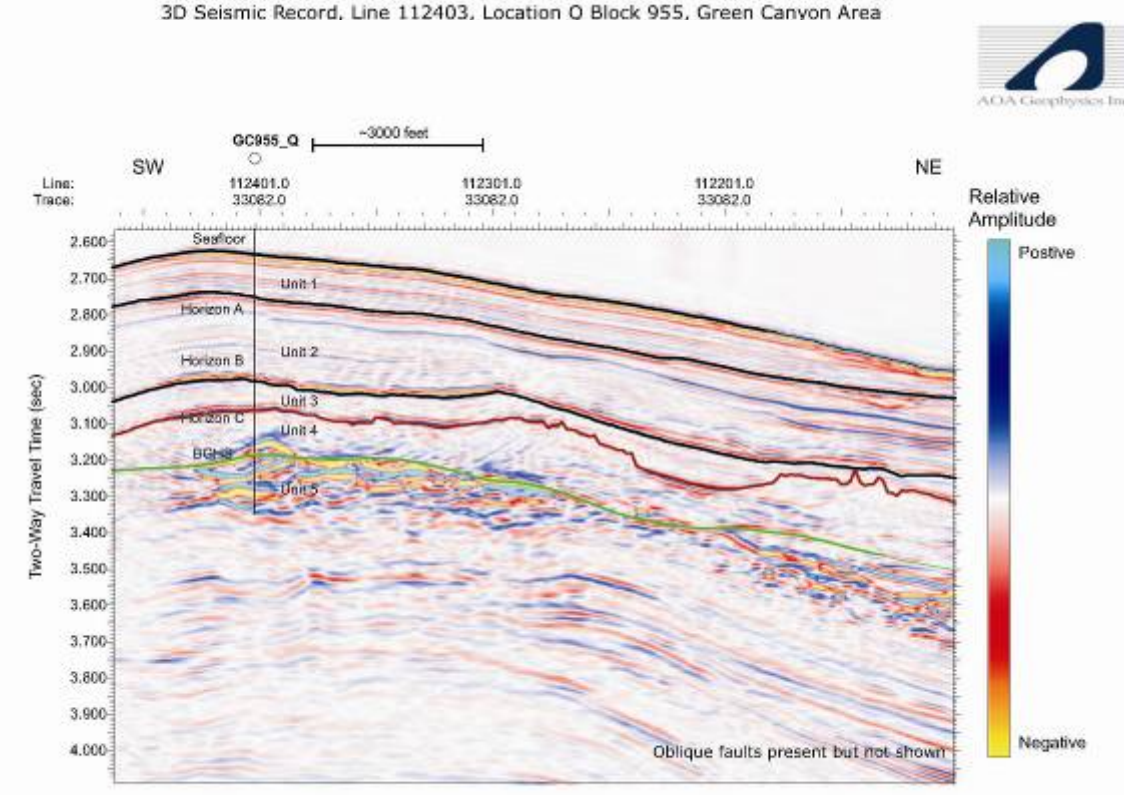
BML: Below Mud Line
BSS: Below Sea Surface
TGHO: Top of Gas Hydrate Occurrence
BGHZ: Base of Gas Hydrate stability Zone


3-D Seismic Record at Proposed Location Q Green Canyon Block 955 X = 2474760 FT, Y = 9806790 FT
Event and Unit Designations
Inferred Lithology and Comments
Depths
BML (ft)
BSS (ft)
TWT BSS (s)
Thickness (ft)
Hazardous Shallow Gas Risk
Shallow Water Flow Risk
SE
NW
~1000 ft
SEAFLOOR
Seafloor slopes about 2.9 degrees to west
Normal marine clays
HOR A
Interbedded clays with thin sands
FAULT
Interbedded clays with thin sands
HOR B
Channel margin deposits- sands and clays
HOR C
primary gas hydrate reservoir channel levee sands interbedded with
BGHS
Possible Gas
Possible Gas
Sand-prone section with clays. Possible gassy sediments in vicinity of wellbore.
TD
Predominantly clay with possible interbedded sands
Sand prone sediments with clays
Predominantly clay with possible interbedded sands
0
6490
2.634
364
6854
2.754
777
7267
2.891
1059
7549
2.985
1296
7786
3.064
1585
8075
3.163
1664
8154
3.186
1838
8328
3.244
2164
8654
3.351
2808
9298
3.559
3414
9904
3.749
4584
11074
4.1
384
413
282
237
293
174
326
644
605
1170
NEGLIGIBLE
LOW
MODERATE
TOPHOLE PROGNOSIS CHART
LOCATION Q
BLOCK 955, GREEN CANYON AREA
All depths and thicknesses are approximate and are based on check-shot survey from GC 955 #1
4021-3P-GOM-GC955
Figure GC955Q-1


90°26'W
90°24'W
27°2'N
27°N
L
J
I
#1
#2
Area of 4-way closure
P
K
H
Q
2100 m
2200 m
Levee
Horizon C Channel
Levee
Gas Hydrate Accumulations
0
2 KM



3D Seismic Record. Line 112403. Location O Block 955. Green Canyon Area



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

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