GOM^2: Prospecting, Drilling and Sampling Coarse-Grained Hydrate Reservoirs in the Deepwater Gulf of Mexico

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Abstract

The UT-GOM2-1 Hydrate Pressure Coring Expedition will drill two holes in Green Canyon Block 955 in the deepwater Gulf of Mexico to pressure core and wireline log a coarse-grained methane hydrate reservoir. We will take ten, 10 ft, pressure cores in each well. The cores will be imaged and logged under pressure. Samples will be degassed to interpret hydrate concentration. Microbiological and porewater analyses will be performed. 20 3 ft pressure cores will be returned to shore for analysis. The log and core data will provide a foundation for scientific exploration by the greater hydrate research community.

Introduction

Sediments of the world's continental margins contain vast amounts of natural gas hydrates, composed predominantly of methane. Methane hydrates can occur where there is a sufficient methane supply and pressure is high enough and temperature low enough for hydrate to be thermodynamically stable [1-5].
The amount of carbon stored in methane hydrates is comparable to that stored in other global near-surface reservoirs such as fossil fuels, soil, land plants, etc. [6-9].

Much of what we know today about marine methane hydrates is gleaned from scientific ocean drilling [3, 10-12]. Drilling allows us to obtain samples, make in situ measurements, and validate inferences from geophysical surveys and theoretical models. Most drilling studies have concentrated on methane hydrates within fine-grained, low-permeability sediments, which likely contain the largest fraction of the global hydrate reservoir [13]. Experiments and observations, however, show that hydrate formation is favored in the large pores of coarse-grained sediments, where hydrates can occupy a large fraction of pore space. Concentrated methane hydrates in coarse-grained, permeable sediments are the most attractive reservoirs for energy resources [14].

The University of Texas (U.T.) leads a multi-disciplinary and multi-institutional team studying methane hydrates in the Gulf of Mexico supported by the U.S. Department of Energy. Over 6 years (2014-2020), we will execute two drilling expeditions in the deepwater Gulf of Mexico to drill, sample, and test methane hydrate deposits within coarse-grained reservoirs. Through analysis of state-of-the-art log data and hydrate core acquired and preserved at in-situ pressure, we will illuminate the origin and evolution of Gulf of Mexico gas hydrate systems. This will include pore-scale imaging of gas hydrate habit within the pore space and the first measurements of gas and water geochemistry, microbiology, and static and dynamic mechanical and petrophysical properties of coarse-grained hydrate reservoir systems. Through downhole testing, we will test the response of the hydrate reservoir to short-time depressurization. U.T. joins the Lamont-Doherty Earth Observatory, Ohio State University, The University of Washington, Oregon State University, the University of New Hampshire, the US Geological Survey, the US Bureau of Ocean Energy Management, GeoTek, and the National Energy Technology Laboratory in this effort.

The first of these expeditions is entitled the ‘UT-GOM2-1 Hydrate Pressure Coring Expedition’. We will drill, wireline log, and take pressure cores at Green Canyon Block 955 (GC955), Gulf of Mexico, at the site of the previously drilled Chevron JIP ‘GC955-H’ well [15-18]. Our primary goal is to demonstrate the engineering capability of the pressure-coring tool (PCTB) to effectively and consistently capture, collect, and recover hydrate-bearing sand sediment pressure core. We will also demonstrate the ability to 1) log and image pressure cores, 2) subsample pressure cores and store subsamples in pressure vessels, and 3) obtain geochemical and petrophysical data from pressure cores. The depressurized and pressurized cores and logging data that result will provide opportunity for scientific exploration by the greater hydrate research community.

UT-GOM2-1 Hydrate Pressure Coring Expedition

Location

We will perform the UT-GOM2-1 Expedition in the US Gulf of Mexico in Green Canyon Block 955 (Figure 1). This is located offshore approximately 145 miles SSW of Port Fourchon, LA. Green Canyon 955 lies between Green Knoll to the east and the Sigsbee escarpment to the northwest (Fig. 1). Two industry wells have been drilled in Green Canyon block 955 and three wells were previously drilled at this location during the 2009 Gas Hydrates JIP Leg II Logging While Drilling (LWD) program (Figure 2) [15, 16, 19]

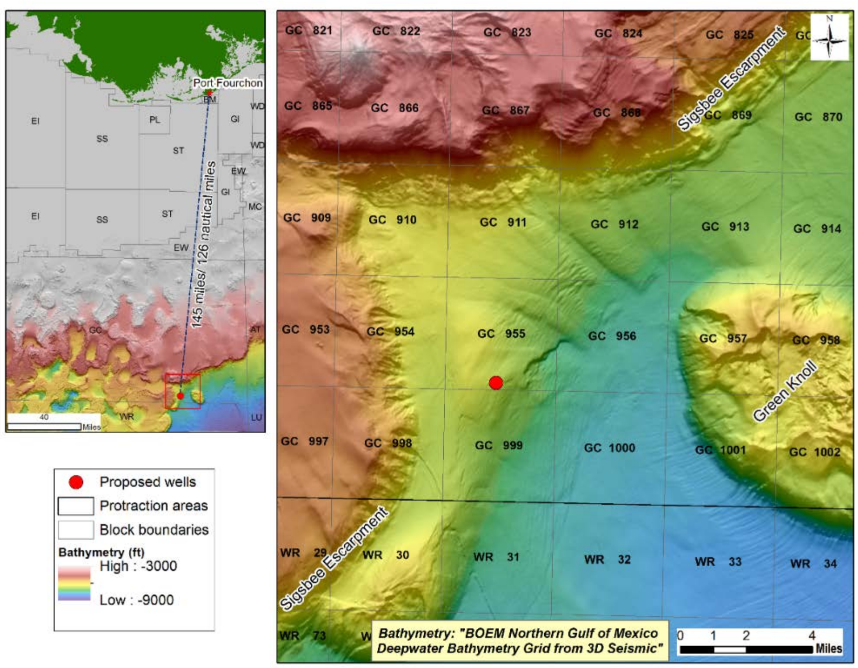

Figure 1: The UT-GOM2-1 Hydrate Pressure Coring Expedition will be performed at Green Canyon 955. Expanded map (right) shows detailed sea floor topography around block Green Canyon 955. The seafloor at Green Canyon 955 records a local topographic high. The red dot locates the proposed wells for Expedition UT-GOM2-1. GC Block 955 is at the toe of the Sigsbee Escarpment adjacent to the Green Canyon reentrant. Bathymetry data from the BOEM Northern Gulf Of Mexico Deepwater Bathymetry Grid.

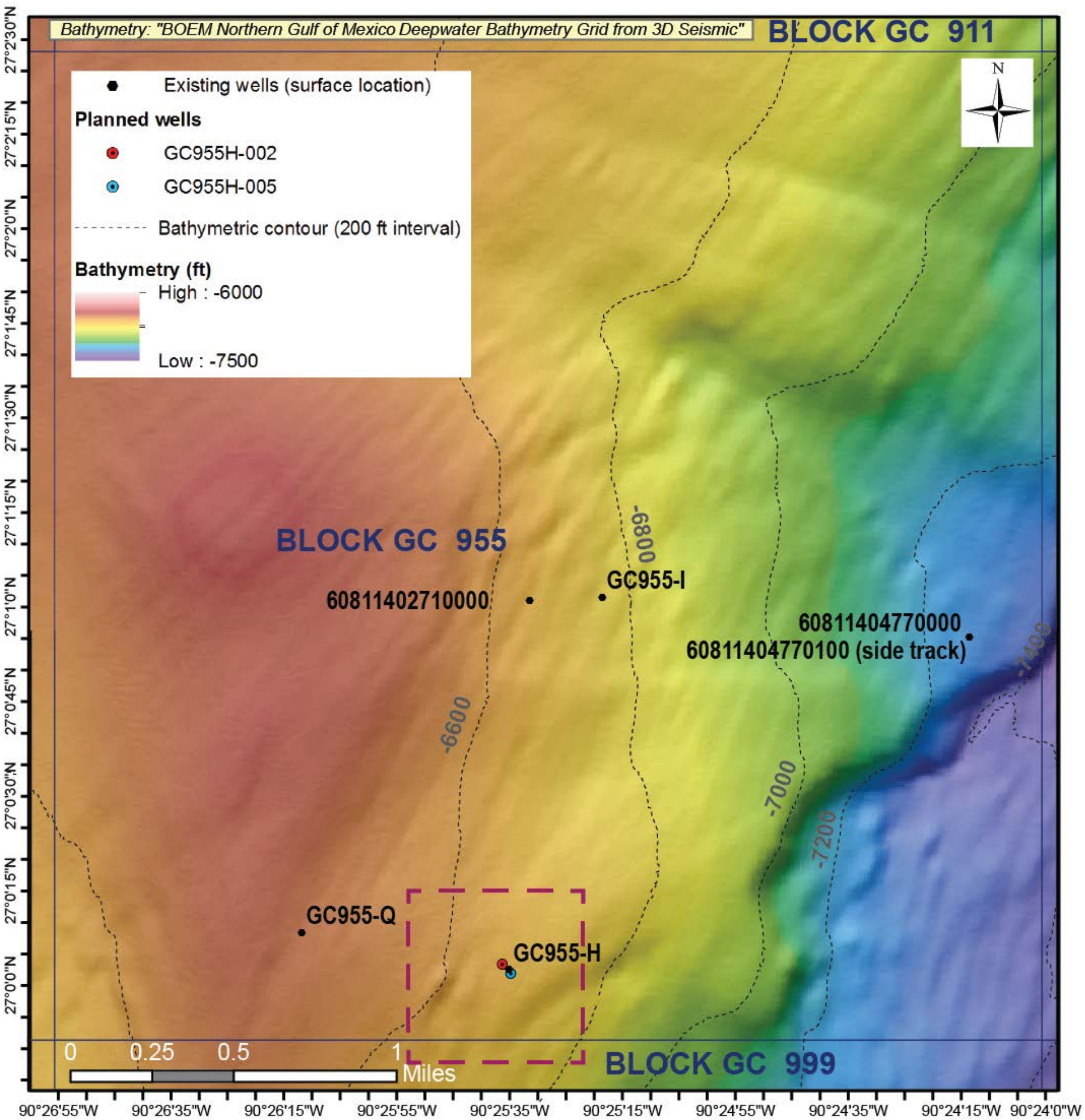

Figure 2: Bathymetry over Green Canyon Block 955. The Gas Hydrates JIP Leg II LWD program drilled the H, I, and Q wells in 2009. Two industry wells are located by their API #: the 60811402710000 well was drilled in 1999, and the 60811404770000 well (and its sidetrack) was drilled in 2006-2007. During Expedition UT-GOM2-1, two wells will be drilled adjacent to the H well (red and blue circles). Bathymetry data from the BOEM Northern Gulf Of Mexico Deepwater Bathymetry Grid. This figure is located in Figure 1.

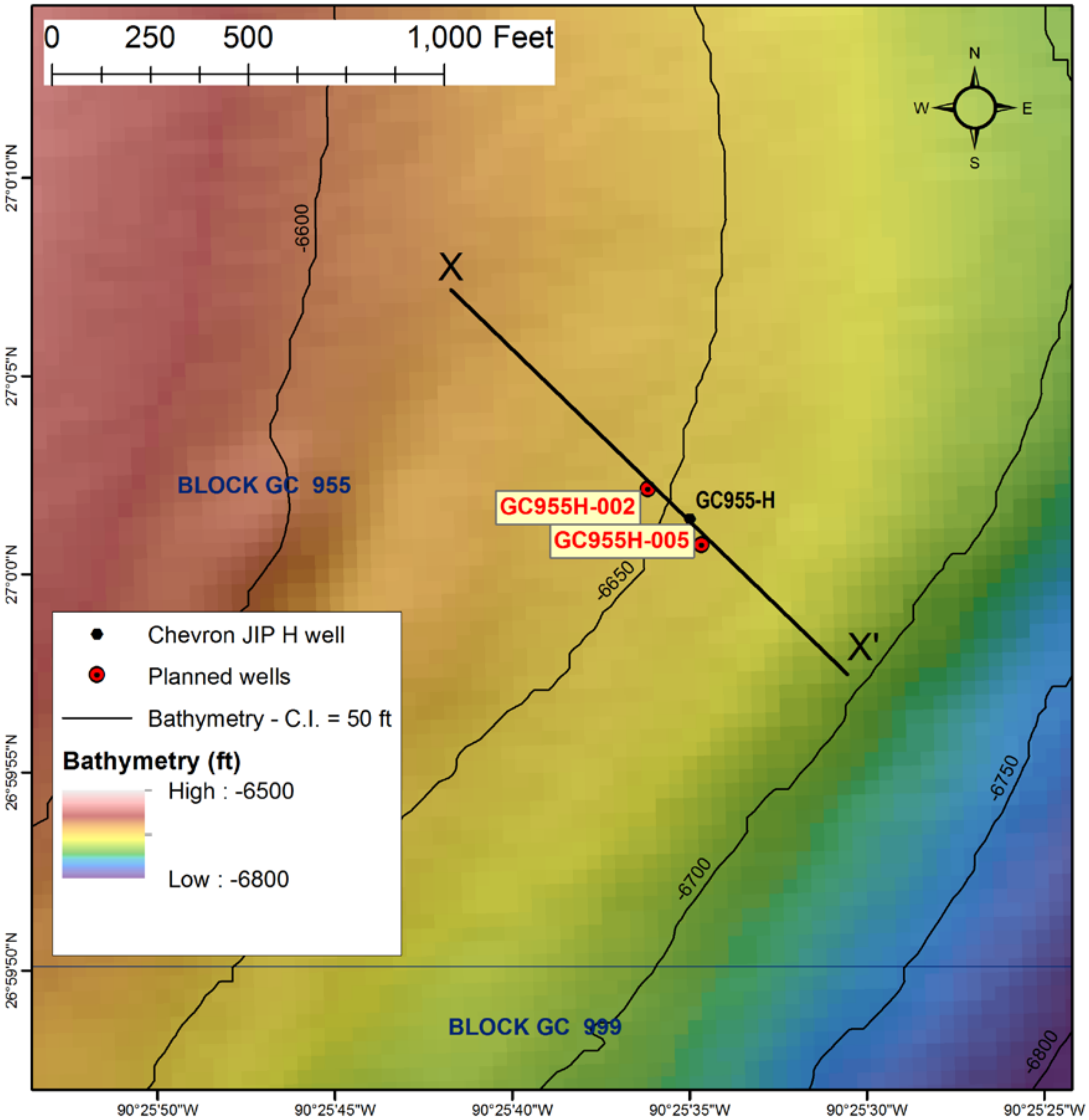

Figure 3: The GC955H-002 and the GC955H-005 wells (red circles) will be drilled adjacent to the H well location (black circle). Line X-X' locates the cross section presented in Figure 4. This figure is located on Figure 2. Bathymetry data from the BOEM Northern Gulf Of Mexico Deepwater Bathymetry Grid.

Geological Overview:

The UT-GOM2-1 Expedition targets methane hydrates trapped in sand reservoirs at the crest of a salt-cored anticline. The GC955-Q and GC955-H well were previously drilled to 1511 feet below sea floor (fbsf) and 1933 fbsf, respectively, using logging-while-drilling technology (Figure 2) [17]. In the GC955-H well, a 330 foot thick sand-rich interval was encountered between 1270 and 1600 feet below seafloor (yellow zone in 'Lithologic Units,' Fig. 4) based on the interpretation of the gamma ray, caliper, and resistivity data (Fig. 4). We interpret that the upper 50 feet of this interval becomes more mud prone upward because the gamma ray values increase upward as the borehole washout decreases. Within this 330' sand-rich interval, there are three zones of high resistivity and high velocity where hydrate is interpreted to be present (green in 'Lithologic Units', Figure 4). The uppermost zone is 86 feet thick. Where hydrate is not present in this sand-rich interval, significant borehole washout is present as is indicated from the enlarged borehole (caliper) and low density values. Based on the review of the 2012 LWD data

[15, 16, 19] , we interpret the entire 330' sand-rich interval is composed of interbedded sand and mud; the gas hydrate most likely occurs as pore-fill within thin-bedded sands within this sequence (Fig. 4).

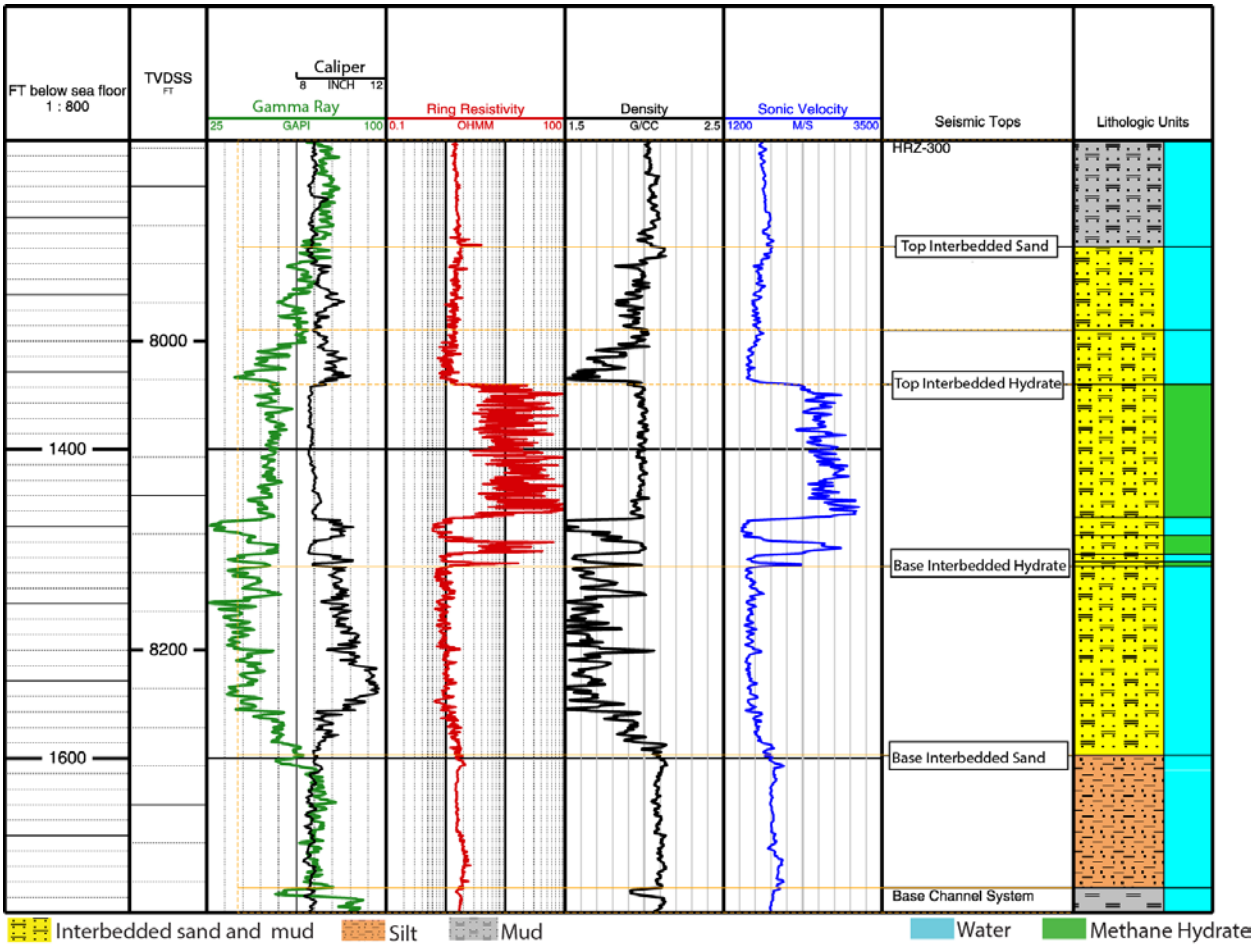

Figure 4: Expanded view of the hydrate-bearing section in the GC955H well from Logging While Drilling (LWD) data. Zones of high resistivity and high velocity within areas of low gamma ray are interpreted to be hydate-bearing sands (delineated with green on the far right). The abrupt changes in the resistivity in this interval are interpreted to record interbedded sands and muds. The GC955H well results have been discussed in detail previously [15, 16, 18, 19]. TVDSS: true vertical depth beneath sea surface.

We mapped the top and base of the 330' thick sand-rich interval away from the H well location (Fig. 5). We illustrate the location of the interbedded hydrate layer in green (Fig. 5). We mapped away from the H well by tracing seismic reflectors that correlate to the top and base of the sand-rich section. We assumed the ~100 foot thick hydrate interval maintained a constant thickness away from the well bore.

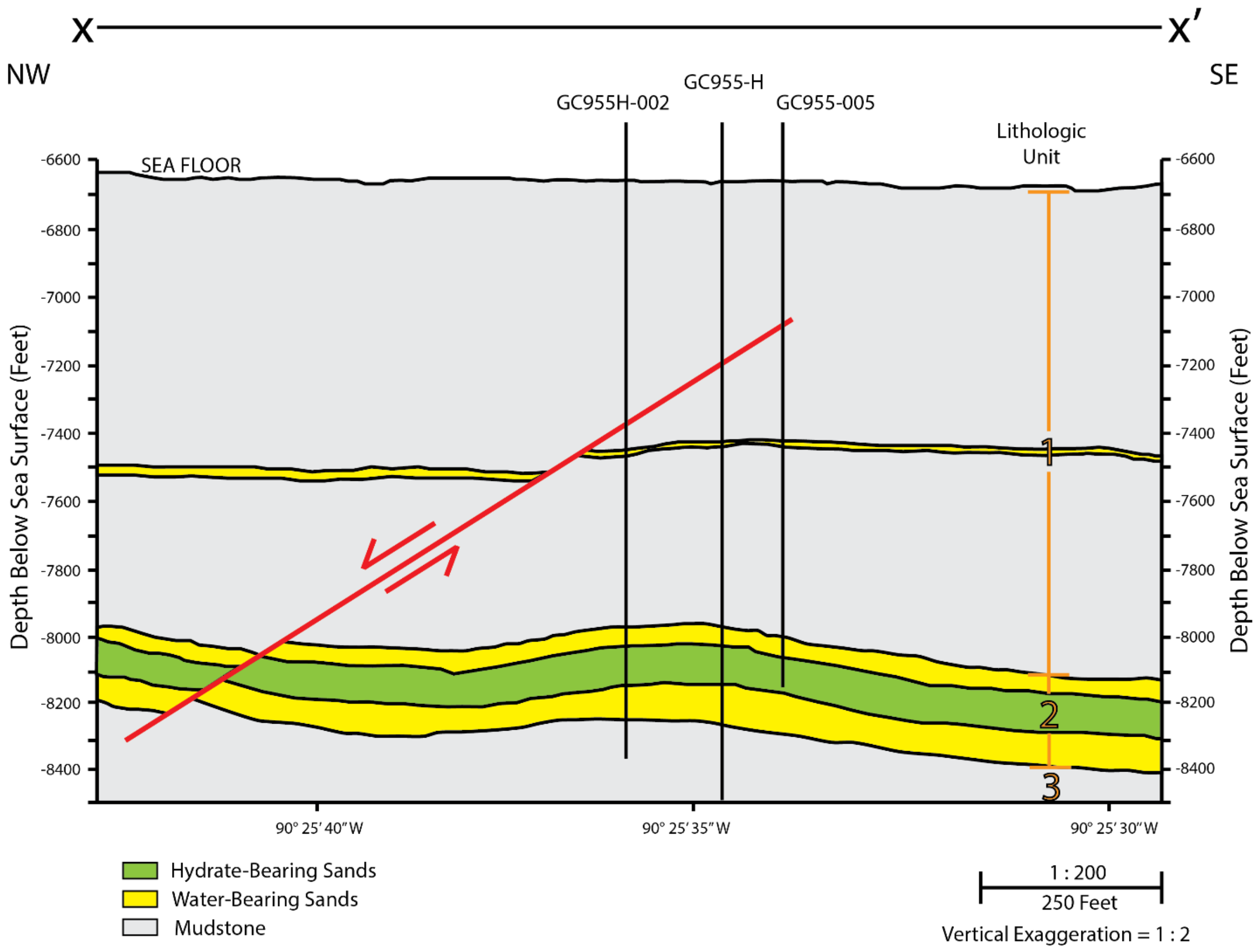

Figure 5: NW-SE oriented geological cross section (XX') through the previously drilled well GC955-H and the proposed locations (GC955H-002, and GC955H-005), showing major structural and stratigraphic features (located in Figure 3). The stratigraphic section is dominated by mudstone (grey). There are two sand intervals in the GC955-H well (delineated in yellow). At ~7450 feet below seafloor, there is a very thin (~3 foot thick) sand and at the base of the section, there is an approximately 330 foot thick interval composed of interbedded sands and muds. Within this 330 foot zone, there is 100 foot thick zone of interbedded hydrate encountered at the GC955-H well that is delineated in green (see the zone between 'top-interbedded hydrate' and 'base interbedded hydrate' in Fig. 4).

Scientific Objectives

Our engineering objective is to demonstrate the ability of the PCTB tool to acquire pressure-cores of hydrate-bearing sands and to transfer those samples under pressure to advanced laboratory facilities for further evaluation. The drilling, logging, and coring program will also address key scientific questions related to the nature of the GC955 hydrate accumulation. The GoM JIP Leg II program clearly documented the occurrence of gas hydrate in sand-rich sediments at the site; however, the limitation of that program to log data (no physical samples were recovered) challenged further interpretation of the accumulation's development and reservoir properties [16]. Acquisition of gas samples are expected to illuminate the source of gas. Pore water samples, along with observation of sediment textures will aid in the interpretation on the specific controls on gas hydrate occurrence, including both the uncertain control on the uppermost occurrence of gas hydrate as well as the occurrence of interbedded gas-hydrate and water-bearing zones at the base. Within the main reservoir unit, core samples will further confirm the internal distribution of gas hydrate as continuous or patchy within sand-rich units.

Drilling Program

We will drill the 955H-002 well first and then the 955H-005 well (Figures 3, 5). There will be no conventional coring. We will drill the 002 well with the cutting-shoe configuration of the Pressure Coring Tool with Ball (PCTB) system. We will use a center bit to drill from seafloor to 15 feet above the hydrate-bearing interval (~ 1348'). We will then pressure-core across the hydrate interval to a depth of 1474 fbsf. We will then drill out 250' to 1724 fbsf to provide a hole of proper depth to run the wireline logs. We will then raise the drill pipe to ~1155 fbsf and wireline log through the drill string. We will then abandon Well 955H-002 and drill hole 955H-005. At 955H-005, we will use the face-bit assembly of the PCTB. We will core the same hydrate-bearing interval. After our last core, at a depth of 1464 fbsf, we will pull out of the hole and abandon the well.

Coring Program

At Hole 955H-002, we target the methane hydrate-bearing sand interval between 1363 and 1449 fbsf (415.5 and 441.8 mbsf) (Figure 4, 6). We will take ten, 10' (~3.04 m) long, pressure cores in each well using the Pressure Coring Tool with Ball (PCTB). Each core will be 2.0'' (5.08 cm) in diameter. The two wells will test alternative bottom-hole assemblies. In the first well, we will test a cutting-shoe configuration of the PCTB. In the second well, we will test a face-bit configuration that is designed to limit rotation of the core during acquisition. We will begin coring 1.5 core lengths (15') above the inferred contact of the hydrate-bearing interval (Figure 6). We then plan to take 6 continuous pressure cores and an additional 4 continuous core toward and through the base of the hydrate-bearing section. These core locations are designed to capture both the hydrate-bearing sand and the interfaces between hydrate-bearing and non-hydrate bearing sediments.

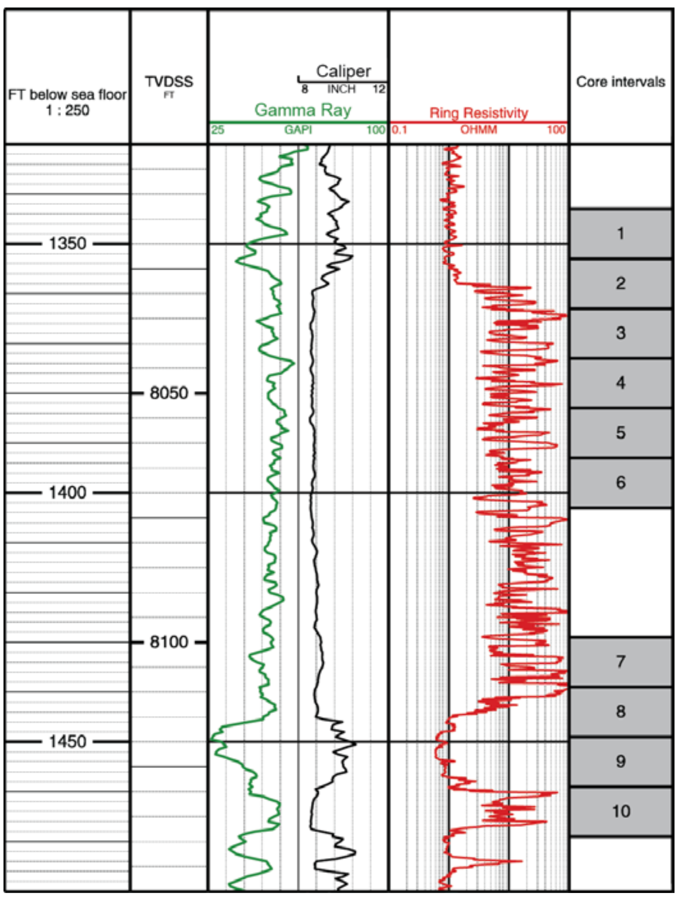

Figure 6: Coring program for Hole 955H-002. Coring will begin above the hydrate interface with the goal of capturing the hydrate reservoir boundary at the center of the second pressure core. Coring will be interrupted after the sixth core. Coring will be resumed to capture interfaces present near the base of the hydrate-bearing interval.The coring program for Hole 955H-005 will be designed based on the findings from the first well. TVDSS: true vertical depth beneath sea surface.

Core Analysis Program

As much as 200 feet of pressure core could be recovered (100 % recovery). The Pressure Core Analysis and Transfer System (PCATS) [20] from Geotek Limited will be used to characterize cores and transfer the samples to pressurized storage devices while on the drilling vessel. As pressure cores arrive on deck, they will be transferred to PCATS where they will get a "Quick-Scan" (Figure 7). During the quick-scan, cores will be logged (velocity, density) and single scan 2D x-ray images will be taken. After quick-scanning, the log and x-ray data will be analyzed and the subsequent processing and sub-sampling of the core will be determined

Up to ~80 feet of pressure core will be preserved as 3.3' to 3.9' (1.0 to 1.2 m) subsamples. These will be shipped to the UT Pressure Core Center (PCC) for storage, further analysis, and distribution to the gas hydrate scientific community. The remaining pressure cores will be quantitatively degassed to estimate hydrate concentration or if there is insufficient time for quantitative degassing, then they will be rapidly degassed (Fig 7). Gas samples taken will be measured for light hydrocarbons and permanent gases on board, and additional samples will be collected for shore-based bulk isotopic analysis. Samples for pore water chemistry and microbiological analysis will be taken from depressurized cores and preserved for immediate shore-based analysis. No microbiological analysis will be done on the pressure cores immediately. Depressurized core will be logged, split, and described at Ohio State after the expedition.

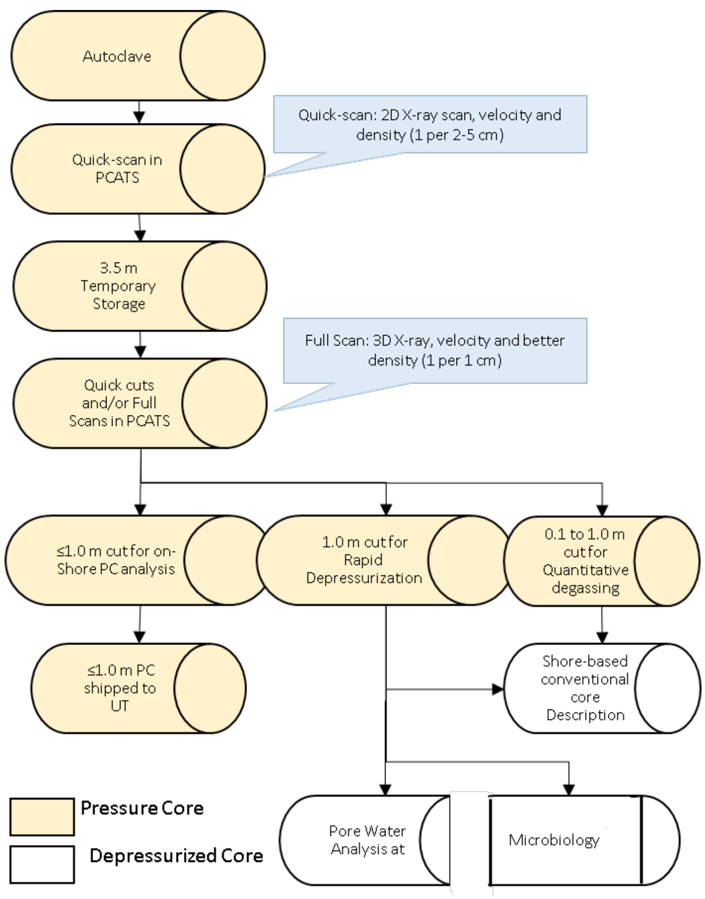

Figure 7: Planned core analysis program. As pressure cores arrive on deck, the will be 'quick-scanned' and then shuttled to temporary storage. The quick-scan data will be analyzed to decide on how the pressure core will be processed. As time allows, the cores will be returned from temporary storage into PCATS and samples will be cut for shore-based analysis, rapid depressurization, or quantitative degassing. Depressurized core will be analyzed on shore after the expedition.

Logging Program

We will wireline log across the cored interval in Hole 955H-002 where the hole is cored with the PCTB cutting-shoe configuration. The wireline logging tools cannot fit through the PCTB face-bit configuration. The logging suite will include gamma ray (GR-OH-C), resistivity (HRLA), density (HLDS), and sonic (DSI with P&S and Lower Dipole acquisition). The logging will allow us to quantitatively correlate the core locations to in-situ observations of lithology, hydrate presence, and pore fluid distribution; it will also allow us to correlate to the equivalent depths in the JIP well. In addition, logging measurements will determine the in situ physical properties of these formations and will complement the discrete sampling obtained from recovered pressure cores.

Time Prognosis

We present a very rough time prognosis in Table 1. On Day 8, we will begin drilling operations. Hole 955H-002 is estimated to be completed on Day 13. Hole 955H-005 is estimated to be completed 5 days later. Scientific planning has shown that there will be insufficient time to analyze all the recovered core on the drilling vessel. Thus, there will be approximately two weeks after the drilling program has completed to pursue core analysis at the dock in Port Fourchon.

Day	Day	Activity
1	**2**	**In Port Preparation**
3	**6**	**Transit to Site GC-955 and perform other activities**
7	**7**	**On Site Mobilization**
8	**8**	**Prepare Cutting Shoe BHA & Flow Test**
9	**9**	**Spud 955H-002, drill to 1348 fbsf**
10	**12**	**Pressure Core & Wireline Log**
13	**13**	**Abandon Hole 1, Prepare Face Bit BHA & Flow Test**
14	**15**	**Spud 955H-005, drill to 1338 fbsf**
15	**17**	**Pressure Core**
17	**17**	**Survey hole**
18	**18**	**Pull out of hole, Abandon Hole**
18	**20**	**Backload containers. Disembark.**
21	**21**	**Transport Containers to Port Fourchon**
22	**22**	**Offload Containers and prepare shore-based analysis**
23	**37**	**Shore-Based Analysis**

Table 1: Overview of time prognosis for the UT-GOM2-1 Hydrate Pressure Coring Expedition.

Scientific Reporting:

We will document the results of Expedition UT-GOM2-1 with two reports modeled after the methodology of the International Ocean Discovery Program. The Preliminary Report will overview the shipboard results. The Expedition Report will provide a detailed archive of the shipboard and immediate shore-based activities.

Conclusions:

The UT-GOM2-1 Hydrate Pressure Coring Expedition is the first pressure-coring program targeted at sandstone methane hydrate reservoirs in the deepwater Gulf of Mexico. The effort represents an integrated effort of industry, the federal government, and academia. The anticipated results will provide a detailed opportunity to understand the potential of these deposits as an energy resource of the future.

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