DOE Award No.: DE-FE0023919

Quarterly Research Performance Progress Report

(Period Ending 12/31/20)

Deepwater Methane Hydrate Characterization & Scientific Assessment

Project Period 5: 10/01/20 - 09/30/22

Submitted by:

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U.S. DEPARTMENT OF ENERGY | NATIONAL ENERGY TECHNOLOGY LABORATORY

Office of Fossil Energy

DISCLAIMER

1 ACCOMPLISHMENTS

This report outlines the progress of the first quarter of the seventh fiscal year of the project (Budget Period 5, Year 1). Highlights from this period include:

- **AAPG Annual Convention and Exhibition (ACE):** UT with UNH made five presentations on GOM2 work at the October 1, 2020, AAPG Virtual Conference, Theme 9: Analysis of Natural Gas Hydrate Systems I & II.
- **UT-GOM2-2 Permits**: UT and Ohio State completed geological and geophysical analysis for all 4 wells to be permitted under UT-GOM2-2. The Geology and Geophysics section of the BOEM Exploration Plan was completed. Shallow Hazard Assessment reports were completed for all wells.
- **UT-GOM2-2 Operations Plans**: UT and Ohio State updated the UT-GOM2-2 Operations Plan to incorporate changes made to the BOEM Exploration Plan, the UT-GOM2-2 Science and Sample Distribution Plan, Shallow Hazard Assessments, and detailed drilling schedule, mud volume, and resource estimates.
- **UT-GOM2-2 Vessel Procurement**: Rig Specification requirements and Operational Summary, Schedule, and Well Design documents were sent to prospective vessel contractors.
- **Pressure Core Preservation**: Explored three potential remedial measures for reducing pressure core degradation – minimizing volume of storage fluid, sealing the core from storage fluid, and charging storage fluid with methane without creating additional hydrate (Section 1.2.2.2.1). Conducted 2D radial diffusion and advection modeling of hydrate dissociation in pressure core over two year period (Section 1.2.2.2.4)
- **PCTB Ball-Valve Testing and Modifications**: Geotek concluded post-*PCTB Land Test II* evaluation of the PCTB. Additional modifications were made to the PCTB Mk. 5. Final design and design validation testing of the PCTB Mk. 5 were completed. In the final design upgrade validation testing 20 identical tests were performed with the PCTB Mk. 4 and Mk. 5. The PCTB Mk. 4 had a 10% pass rate; the MK. 5 had a 100% pass rate.

1.1 Major Project Goals

The primary objective of this project is to gain insight into the nature, formation, occurrence and physical properties of methane hydrate-bearing sediments for the purpose of methane hydrate resource appraisal. This will be accomplished through the planning and execution of a state-of-the-art drilling, coring, logging, testing and analytical program that assess the geologic occurrence, regional context, and characteristics of marine methane hydrate deposits in the Gulf of Mexico Continental Shelf. Project Milestones are listed in Table 1-1, Table 1-2, and Table 1-3.

Table 1-1: Previous Milestones

Budget Period	Milestone	Milestone Description	Estimated Completion	Actual Completion	Verification Method
1	M1A	Project Management Plan	Mar-15	Mar-15	Project Management Plan
	M1B	Project Kick-off Meeting	Jan-15	Dec-14	Presentation
	M1C	Site Location and Ranking Report	Sep-15	Sep-15	Phase 1 Report
	M1D	Preliminary Field Program Operational Plan Report	Sep-15	Sep-15	Phase 1 Report
	M1E	Updated CPP Proposal Submitted	May-15	Oct-15	Phase 1 Report
	M1F	Demonstration of a Viable Pressure Coring Tool: Lab Test	Sep-15	Sep-15	Phase 1 Report
2	M2A	Document Results of BP1/Phase 1 Activities	Dec-15	Jan-16	Phase 1 Report
	M2B	Complete Updated CPP Proposal Submitted	Nov-15	Nov-15	QRPPR
	M2C	Scheduling of Hydrate Drilling Leg by IODP	May-16	May-17	Report directly to DOE PM
	M2D	Demonstration of a Viable Pressure Coring Tool: Land Test	Dec-15	Dec-15	PCTB Land Test Report, in QRPPR
	M2E	Demonstration of a Viable Pressure Coring Tool: Marine Test	Jan-17	May-17	QRPPR
	M2F	Update UT-GOM2-2 Operational Plan	Feb-18	Apr-18	Phase 2 Report
3	M3A	Document results of BP2 Activities	Apr-18	Apr-18	Phase 2 Report
	M3B	Update UT-GOM2-2 Operational Plan	Sep-19	Jan-19	Phase 3 Report
4	M4A	Document results of BP3 Activities	Jan-20	Apr-20	Phase 3 Report
	M4B	Demonstration of a Viable Pressure Coring Tool: Lab Test	Feb-20	Jan-20	PCTB Lab Test Report, in QRPPR
	M4C	Demonstration of a Viable Pressure Coring Tool: Land Test	Mar-20	Mar-20	PCTB Land Test Report, in QRPPR

Table 1-2: Current Milestones

Budget Period	Milestone	Milestone Description	Estimated Completion	Actual Completion	Verification Method
5	M5A	Document Results of BP4 Activities	Dec-20	-	Phase 4 Report
	M5B	Complete Contracting of UT-GOM2-2 with Drilling Vessel	May-21	-	QRPPR
	M5C	Complete Project Sample and Data Distribution Plan	Jul-22	-	Report directly to DOE PM
	M5D	Complete Pre-Expedition Permitting Requirements for UT-GOM2-2	Dec-21	-	QRPPR
	M5E	Complete UT-GOM2-2 Operational Plan Report	May-21	-	QRPPR
	M5F	Complete UT-GOM2-2 Field Operations	Jul-22	-	QRPPR

Table 1-3: Future Milestones

Budget Period	Milestone	Milestone Description	Estimated Completion	Actual Completion	Verification Method
6	M6A	Document Results of BP5 Activities	Dec-22	-	Phase 5 Report
	M6B	Complete Preliminary Expedition Summary	Dec-22	-	Report directly to DOE PM
	M6C	Initiate comprehensive Scientific Results Volume	Jun-23	-	Report directly to DOE PM
	M6D	Submit set of manuscripts for comprehensive Scientific Results Volume	Sep-24	-	Report directly to DOE PM

1.2 What Was Accomplishments Under These Goals

1.2.1 Previous Project Periods

Tasks accomplished in previous project periods (Phase 1, 2, 3, and 4) are summarized in Table 1-4, Table 1-5, Table 1-6, and Table 1-7.

Table 1-4: Tasks Accomplished in Phase 1

PHASE 1/BUDGET PERIOD 1	
Task 1.0	**Project Management and Planning**
Task 2.0	**Site Analysis and Selection**
Subtask 2.1	*Site Analysis*
Subtask 2.2	*Site Ranking / Recommendation*
Task 3.0	**Develop Operational Plan for UT-GOM2-2 Scientific Drilling Program**
Task 4.0	**Complete IODP Complimentary Project Proposal**
Task 5.0	**Pressure Coring and Core Analysis System Modifications and Testing**
Subtask 5.1	*PCTB Scientific Planning Workshop*
Subtask 5.2	*PCTB Lab Test*
Subtask 5.3	*PCTB Land Test Prep*

Table 1-5: Tasks Accomplished in Phase 2

PHASE 2/BUDGET PERIOD 2	
Task 1.0	**Project Management and Planning**
Task 6.0	**Technical and Operational Support of Complimentary Project Proposal**
Task 7.0	**Continued Pressure Coring and Core Analysis System Modifications and Testing**
Subtask 7.1	*Review and Complete NEPA Requirements for PCTB Land Test*
Subtask 7.2	*PCTB Land Test*
Subtask 7.3	*PCTB Land Test Report*
Subtask 7.4	*PCTB Modification*
Task 8.0	**UT-GOM2-1 Marine Field Test**
Subtask 8.1	*Review and Complete NEPA Requirements for UT-GOM2-1*
Subtask 8.2	*UT-GOM2-1 Operational Plan*
Subtask 8.3	*UT-GOM2-1 Documentation and Permitting*
Subtask 8.4	*UT-GOM2-1 Marine Field Test of Pressure Coring System*
Subtask 8.5	*UT-GOM2-1 Marine Field Test Report*
Task 9.0	**Develop Pressure Core Transport, Storage, and Manipulation Capability**
Subtask 9.1	*Review and Complete NEPA Requirements for Core Storage and Manipulation*
Subtask 9.2	*Hydrate Core Transport*
Subtask 9.3	*Storage of Hydrate Pressure Cores*
Subtask 9.4	*Refrigerated Container for Storage of Hydrate Pressure Cores*

Subtask 9.5	*Hydrate Core Manipulator and Cutter Tool*
Subtask 9.6	*Hydrate Core Effective Stress Chamber*
Subtask 9.7	*Hydrate Core Depressurization Chamber*
Task 10.0	**Core Analysis**
Subtask 10.1	*Routine Core Analysis (UT-GOM2-1)*
Subtask 10.2	*Pressure Core Analysis (UT-GOM2-1)*
Subtask 10.3	*Hydrate Core-Log-Seismic Synthesis (UT-GOM2-1)*
Task 11.0	**Update Science and Operational Plans for UT-GOM2-2 Scientific Drilling Program**
Task 12.0	**UT-GOM2-2 Scientific Drilling Program Vessel Access**

Table 1-6: Tasks Accomplished in Phase 3

PHASE 3/BUDGET PERIOD 3	
Task 1.0	**Project Management and Planning**
Task 6.0	**Technical and Operational Support of CPP Proposal**
Task 9.0	**Develop Pressure Core Transport, Storage, and Manipulation Capability**
Subtask 9.8	*X-ray Computed Tomography*
Subtask 9.9	*Pre-Consolidation System*
Task 10.0	**Core Analysis**
Subtask 10.4	*Continued Pressure Core Analysis (UT-GOM2-1)*
Subtask 10.5	*Continued Hydrate Core-Log-Seismic Synthesis (UT-GOM2-1)*
Subtask 10.6	*Additional Core Analysis Capabilities*
Task 11.0	**Update Science and Operational Plans for UT-GOM2-2 Scientific Drilling Program**
Task 12.0	**UT-GOM2-2 Scientific Drilling Program Vessel Access**
Task 13.0	**Maintenance and Refinement of Pressure Core Transport, Storage, and Manipulation Capability**
Subtask 13.1	*Hydrate Core Manipulator and Cutter Tool*
Subtask 13.2	*Hydrate Core Effective Stress Chamber*
Subtask 13.3	*Hydrate Core Depressurization Chamber*
Subtask 13.4	*Develop Hydrate Core Transport Capability for UT-GOM2-2 Scientific Drilling Program*
Subtask 13.5	*Expansion of Pressure Core Storage Capability for UT-GOM2-2 Scientific Drilling Program*
Subtask 13.6	*Continued Storage of Hydrate Cores from UT-GOM2-1*
Task 14.0	**Performance Assessment, Modifications, and Testing of PCTB**
Subtask 14.1	*PCTB Lab Test*
Subtask 14.2	*PCTB Modifications/Upgrades*
Task 15.0	**UT-GOM2-2 Scientific Drilling Program Preparations**
Subtask 15.1	*Assemble and Contract Pressure Coring Team Leads for UT-GOM2-2 Scientific Drilling Program*
Subtask 15.2	*Contract Project Scientists and Establish Project Science Team for UT-GOM2-2 Scientific Drilling Program*

Table 1-7: Tasks Accomplished in Phase 4

PHASE 4/BUDGET PERIOD 4	
Task 1.0	**Project Management and Planning**
Task 10.0	**Core Analysis**
Subtask 10.4	*Continued Pressure Core Analysis (GOM2-1)*
Subtask 10.5	*Continued Hydrate Core-Log-Seismic Synthesis (UT-GOM2-1)*
Subtask 10.6	*Additional Core Analysis Capabilities*
Subtask 10.7	*Hydrate Modeling*
Task 11.0	**Update Science and Operational Plans for UT-GOM2-2 Scientific Drilling Program**
Task 12.0	**UT-GOM2-2 Scientific Drilling Program Vessel Access**
Task 13.0	**Maintenance and Refinement of Pressure Core Transport, Storage, and Manipulation Capability**
Subtask 13.1	*Hydrate Core Manipulator and Cutter Tool*
Subtask 13.2	*Hydrate Core Effective Stress Chamber*
Subtask 13.3	*Hydrate Core Depressurization Chamber*
Subtask 13.4	*Develop Hydrate Core Transport Capability for UT-GOM2-2 Scientific Drilling Program*
Subtask 13.5	*Expansion of Pressure Core Storage Capability for UT-GOM2-2 Scientific Drilling Program*
Subtask 13.6	*Continued Storage of Hydrate Cores from UT-GOM2-1*
Subtask 13.7	*X-ray Computed Tomography*
Subtask 13.8	*Pre-Consolidation System*
Task 14.0	**Performance Assessment, Modifications, and Testing of PCTB**
Subtask 14.1	*PCTB Lab Test*
Subtask 14.2	*PCTB Modifications/Upgrades*
Subtask 14.3	*PCTB Land Test*
Task 15.0	**UT-GOM2-2 Scientific Drilling Program Preparations**
Subtask 15.3	*Permitting for UT-GOM2-2 Scientific Drilling Program*

1.2.2 *Current Project Period*

Current project period tasks are shown in Table 1-8.

Table 1-8: Current Project Tasks

PHASE 5/BUDGET PERIOD 5	
Task 1.0	**Project Management and Planning**
Task 10.0	**Core Analysis**
Subtask 10.4	*Continued Pressure Core Analysis (UT-GOM2-1)*
Subtask 10.5	*Continued Hydrate Core-Log-Seismic Synthesis (UT-GOM2-1)*
Subtask 10.6	*Additional Core Analysis Capabilities*
Subtask 10.7	*Hydrate Modeling*
Subtask 10.8	*Routine Core Analysis (UT-GOM2-2)*
Subtask 10.9	*Pressure Core Analysis (UT-GOM2-2)*
Subtask 10.10	*Core-log-seismic Integration (UT-GOM2-2)*
Task 11.0	**Update Science and Operational Plans for UT-GOM2-2 Scientific Drilling Program**
Task 12.0	**UT-GOM2-2 Scientific Drilling Program Vessel Access**
Task 13.0	**Maintenance and Refinement of Pressure Core Transport, Storage, and Manipulation Capability**
Subtask 13.1	*Hydrate Core Manipulator and Cutter tool*
Subtask 13.2	*Hydrate Core Effective Stress Chamber*
Subtask 13.3	*Hydrate Core Depressurization Chamber*
Subtask 13.4	*Develop Hydrate Core Transport Capability for UT-GOM2-2 Scientific Drilling Program*
Subtask 13.5	*Expansion of Pressure Core Storage Capability for UT-GOM2-2 Scientific Drilling Program*
Subtask 13.6	*Continued Maintenance and Storage of Hydrate Pressure Cores from UT-GOM2-1*
Subtask 13.7	*Maintain X-ray CT*
Subtask 13.8	*Maintain Preconsolidation System*
Subtask 13.9	*Transportation of Hydrate Core from UT-GOM2-2 Scientific Drilling Program*
Subtask 13.10	*Storage of Hydrate Cores from UT-GOM2-2 Scientific Drilling Program*
Subtask 13.11	*Hydrate Core Distribution*
Task 14.0	**Performance Assessment, Modifications, and Testing of PCTB**
Subtask 14.4	*PCTB Modifications/Upgrades*
Subtask 14.5	*PCTB Land Test III*
Task 15.0	**UT-GOM2-2 Scientific Drilling Program Preparations**
Subtask 15.3	*Permitting for UT-GOM2-2 Scientific Drilling Program*
Subtask 15.4	*Review and Complete NEPA Requirements*
Subtask 15.5	*Finalize Operational Plan for UT-GOM2-2 Scientific Drilling Program*
Task 16.0	**UT-GOM2-2 Scientific Drilling Program Field Operations**
Subtask 16.1	*Mobilization of a Scientific Ocean Drilling and Pressure Coring Capability*
Subtask 16.2	*Field Project Management, Operations and Research*
Subtask 16.3	*Demobilization of Staff, Labs, and Equipment*

1.2.2.1 Task 1.0 – Project Management & Planning

Status: Ongoing

1. **Coordinate the overall scientific progress, administration and finances of the project:**
    - Monitored and controlled project scope, costs, and schedule.
    - Onboarded new project team members.

2. **Communicate with project team and sponsors:**
    - Organized and coordinated project team and stakeholder meetings.
    - Organized task-specific team working meetings to plan and execute project tasks (e.g. PCTB development, PCTB development, UT-GOM2-2 operations planning, UT-GOM2-2 science and sample distribution planning, UT-GOM2-2 permitting, and UT-GOM2-2 vessel selection.).
    - Organized sponsor meetings.
    - Managed SharePoint sites, email lists, and archive/website.

3. **Coordinate and supervise subcontractors and service agreements:**
    - Actively managed subcontractors.
    - Monitored schedules and ensured that contractual obligations were met.
    - Held discussions with Geotek regarding cost, schedule, and scope work for continued performance assessment, modification, and testing of the PCTB (Task 14).
    - Drafted amendment to Geotek service agreement to be finalized and executed in the next quarter. We plan for Geotek to perform the following scope of work in continuation of Task 14:
        1. Upgrade the PCTB toolsets to Mk. 5 specifications
        2. Conduct Pressure Actuation Testing of the PCTB Mk. 5 toolsets and the T2P
        3. Conduct Land testing of the PCTB

1.2.2.2 Task 10.0 – Core Analysis

Status: Ongoing

1.2.2.2.1 Subtask 10.4 – Continued Pressure Core Analysis (UT-GOM2-1)

A. Pressurized Core Analysis

A1. Quantitative Degassing and Gas Analysis

- Ohio State collected noble gas geochemistry measurements on the cores listed in Table 1-9. While a majority of samples displayed results similar to the last batch of GOM2 gas samples measured at Ohio State, section 7FB-3 A within the central hydrate bearing zone displayed significant contributions of thermogenic natural gas (Table 1-9, Table 1-10), suggesting migration from yet unidentified deeper source that apparently migrated along a localized discontinuity (possibly a fault) within or proximal to this section.
- Noble gas data confirm the presence of dominantly microbial methane with a prominent increase in thermogenic natural gas within section 7FB-3 A, as evidenced by the abundance of He and lower C1/C2+. Increased concentrations of heavier hydrocarbons (C2+) are also observed in the believed thermogenic section (Table 1-10). $^{20}Ne/^{36}Ar$ display values near that of Air Saturated Seawater.
- Based on the concentrations of radiogenic ^{4}He, we conclude that the residence time of natural gas residing in methane hydrates conservatively displays residence times of less than 60 kyr, with the exception of the sample that displayed significant contributions of thermogenic methane.

Table 1-9: Noble gas concentrations of gas samples from GC 955 hydrate-bearing sandy silt quantitative degassing studies.

Table 1. Noble gasses. **Samples**	^{3}He pcc/cc	^{4}He μcc/cc	^{20}Ne μcc/cc	^{36}Ar μcc/cc	^{40}Ar μcc/cc	R/R_A	^{4}He / ^{20}Ne	^{20}Ne / ^{36}Ar	N_2 / Ar
H005-2FB-2 B 842020	1.17	0.98	2.154	4.59	1358.48	0.8607	0.46	0.469	75.18
H005-2FB-2 A 842020	1.33	1.14	1.884	4.83	1429.24	0.8430	0.61	0.390	74.39
H005-7FB-3 A 842020	6.04	23.28	1.134	1.78	528.36	0.1874	20.52	0.636	52.44
H005-7FB-3 A 6262020	30.22	223.57	2.645	5.45	1619.22	0.0977	84.53	0.485	64.76
H005-2FB-2 A 7172020	3.19	2.76	3.421	10.12	2984.18	0.8351	0.81	0.338	63.92
H005-7FB-3 B 742020	0.68	0.61	0.577	1.33	393.84	0.7989	1.06	0.433	56.50
H005-2FB-2 B 7172020	1.12	0.91	1.689	6.13	1813.36	0.8933	0.54	0.275	66.14
H005-7FB-3 B 6262020	1.82	1.57	0.719	6.92	2046.57	0.8354	2.19	0.104	81.48
H002-04CS-2	0.37	0.26	0.502	1.08	322.16	1.0126	0.53	0.467	50.17

Table 1-10: Hydrocarbon concentrations of gas samples from GC 955 hydrate-bearing sandy silt quantitative degassing studies.

Table 2. Hydrocarbon gasses. **Samples**	CH_4 / C_2H_6+	CH_4 ccSTP/cc	C_2H_6 ccSTP/cc	C3 ccSTP/cc	Ci-4 ccSTP/cc	Cn-4 ccSTP/cc	Ci-5 ccSTP/cc	C-5 ccSTP/cc	C-6 ccSTP/cc
H005-2FB-2 B 842020	2.38E+03	0.878	3.55E-04	8.75E-06	2.41E-06	1.34E-06	2.14E-06	b.d.l.	b.d.l.
H005-2FB-2 A 842020	1.42E+03	0.877	5.99E-04	9.28E-06	2.75E-06	1.88E-06	3.36E-06	1.16E-06	b.d.l.
H005-7FB-3 A 842020	1.41E+03	0.966	6.69E-04	9.02E-06	6.00E-06	1.54E-06	b.d.l.	b.d.l.	b.d.l.
H005-7FB-3 A 6262020	3.66E+02	0.882	1.62E-03	4.13E-04	7.40E-05	1.49E-04	6.05E-05	6.78E-05	2.54E-05
H005-2FB-2 A 7172020	2.59E+03	0.769	2.90E-04	3.97E-06	9.53E-07	8.70E-07	2.00E-06	b.d.l.	b.d.l.
H005-7FB-3 B 742020	1.31E+03	0.972	7.26E-04	9.13E-06	2.08E-06	1.64E-06	2.26E-06	b.d.l.	b.d.l.
H005-2FB-2 B 7172020	2.24E+03	0.862	3.76E-04	4.80E-06	1.05E-06	0.00E+00	2.64E-06	b.d.l.	b.d.l.
H005-7FB-3 B 6262020	2.12E+03	0.804	3.68E-04	6.69E-06	1.47E-06	1.35E-06	2.94E-06	b.d.l.	b.d.l.
H002-04CS-2	2.92E+03	0.976	3.34E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	b.d.l.	b.d.l.

A2. Permeability measurement of pressure core

- During this quarter, UT finished the hydrate dissolution test of the pressure core UT-GOM2-1-H005-2FB-2 (Figure 1-1) measuring the intrinsic permeability of 2FB-2 core (2FB-2-01) with brine.
- The methane concentration starts at a near theoretic value (0.0743 mol/kg pure water at 6.5 °C). The concentration of methane in the produced water gradually decreases as there is less and less methane hydrate left to dissociate (Figure 1-1).
- We found that the intrinsic permeability of core 2FB-2-01 is 40 mD before the sample was reloaded to in-situ stress. At in situ stress, the intrinsic permeability is measured as 31 mD (Figure 1-2).

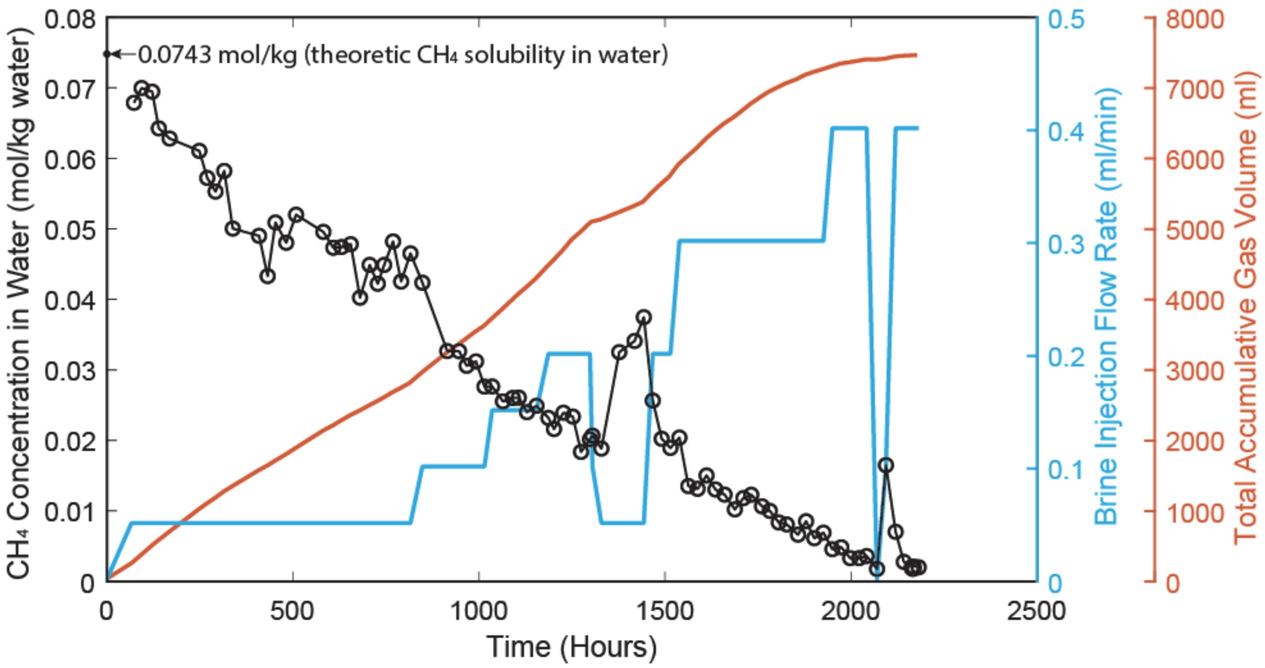


Figure 1-1: Evolution of methane dissolution during a continuous brine injection in the core sample 2FB2-1.

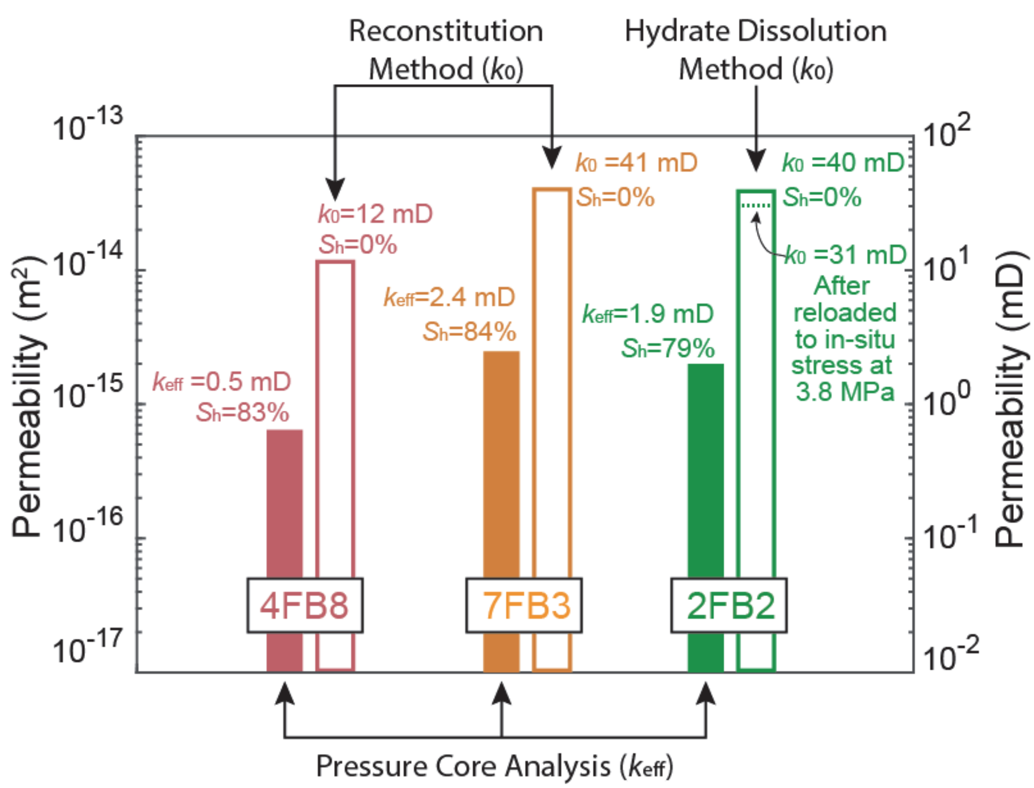


Figure 1-2. A summary of comparison between effective permeabilities and intrinsic permeabilities of UT-GOM2-1 hydrate bearing sandy silt sediments. The solid bars show the effective permeability values, which are measured by pressure core analysis (K0 permeameter). The empty bars show the intrinsic permeability values that are measured by two different methods: (1) intrinsic permeabilities of core sample 4FB8 and 7FB3 are measured by reconstitution method; (2) intrinsic permeability of core sample 2FB2 is measured by pressure core analysis (K0 permeameter) after hydrate dissolution.

B. Pressure Core Degradation

- Explored three potential remedial measures for reducing pressure core degradation – minimizing volume of storage fluid, sealing the core from storage fluid, and charging storage fluid with methane without creating additional hydrate. Determined remedial measures that will be taken for UT-GOM2-2 cores:
    - Reducing the core storage inner diameter
    - Consolidating PCATS cuts to reduce the storage fluid cycling
    - Eliminating use of core liner as a spacer
    - Design and test a weighted seal cap
    - Design and test a spring loaded spacer
    - Design and test a way to charge storage fluid with methane

C. Depressurized Pressure Core Analysis: Bulk sediment CHNS elemental analysis, Bulk sediment TOC, N, and S isotopes

- UNH continues to work on synthesizing the grainsize, CHNS, and sediment composition data to document the sediment transport regimes throughout the reservoir and subsequent early diagenesis of the GC-955 hydrate-bearing sediments. UNH completed the final TOC replicate measurements and full data analyses for all of the GOM2-1 samples (Figure 1-3). These data document the low, but consistent presence of terrestrial dominated TOC throughout the reservoir, a clear detrital carbonate phase presence throughout the reservoir and AOM at two distinct intervals likely in response to changing sedimentation rates in the levee environment of the GOM2 reservoir. A publication with all of the UNH GOM2-1 data sets is being prepared.

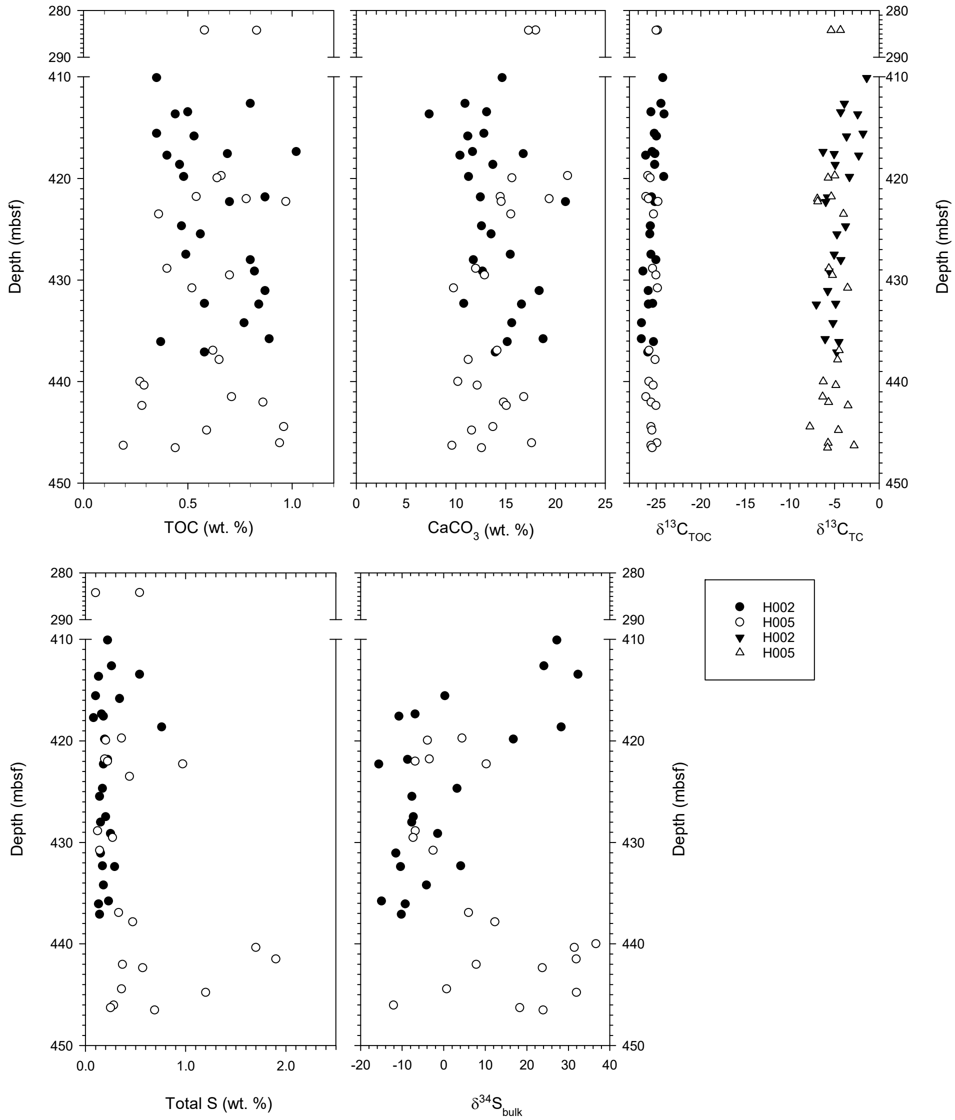


Figure 1-3: Reservoir variability in TOC, CaCO3, ⍰ 13CTOC, ⍰ 13CTC, TS, and ⍰ 34S in the GOM2 GC-955 wells H002 and H005.

1.2.2.2.2 Subtask 10.5 – Continued Hydrate Core-Log-Seismic Synthesis (UT-GOM2-1)

- No update this period.

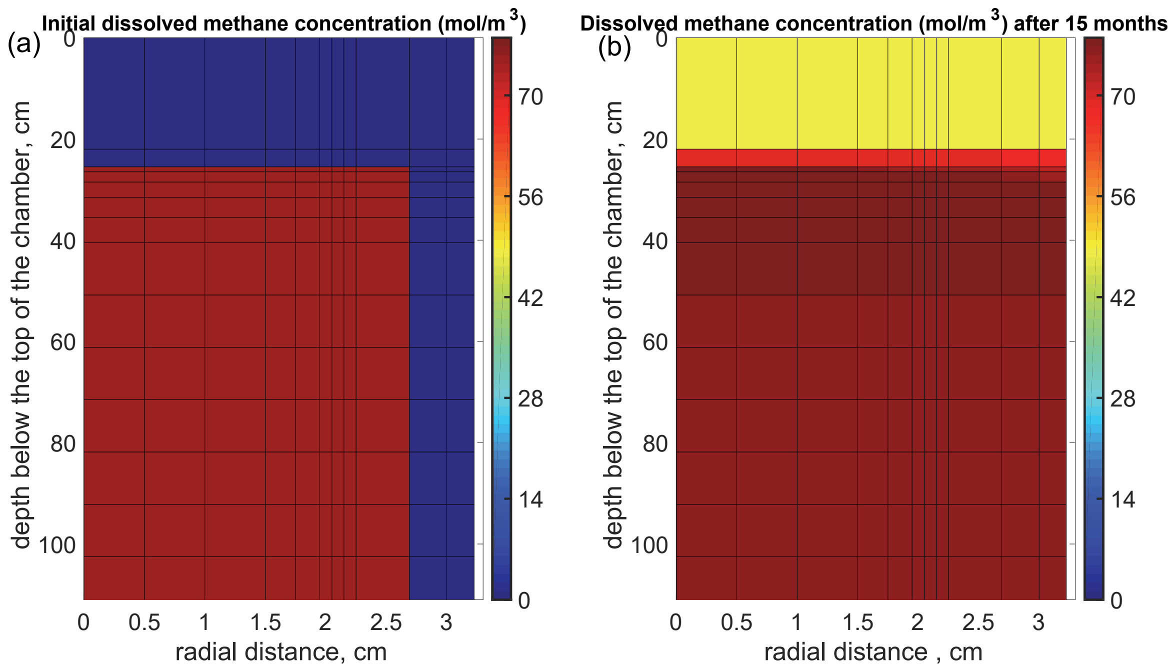
1.2.2.2.3 Subtask 10.6 – Additional Analysis Capabilities

- No update this period

1.2.2.2.4 Subtask 10.7 – Hydrate Modeling

- We developed a similar 2D radial numerical model to describe the loss of hydrate from hydrate-bearing pressure core during long-term storage. The difference of this model includes: (1) we keep the temperature within the entire chamber constant and equals room temperature (6 ^oC); (2) we keep the pressure constant within the entire chamber and equals 24 MPa; (3) the dissolved methane concentration within the hydrate-bearing sediment is in equilibrium with methane hydrate (or equals methane hydrate solubility) and is 0% in all other free space (Figure 1-4 a); (3) the salinity within the hydrate-bearing sediment equals seawater value (3.5 wt.%) and equals 0% in all other free space within the chamber (Figure 1-4 c).

  During storage, the diffusion of dissolved methane gradually transports methane from the hydrate-bearing core to the surrounding fresh water within the chamber (Figure 1-4 b). This drives methane hydrate at the top and radial surface of the core to gradually dissolve and hydrate saturation to decrease (Figure 1-4 e, f). At the same time, salt diffuses away from the hydrate-bearing core to the surrounding fresh water (Figure 1-4 d). This decreases the density of the pore water in the core and increases density of the fresh water surrounding the core, which induces density-driven flow of water and accelerates hydrate loss.



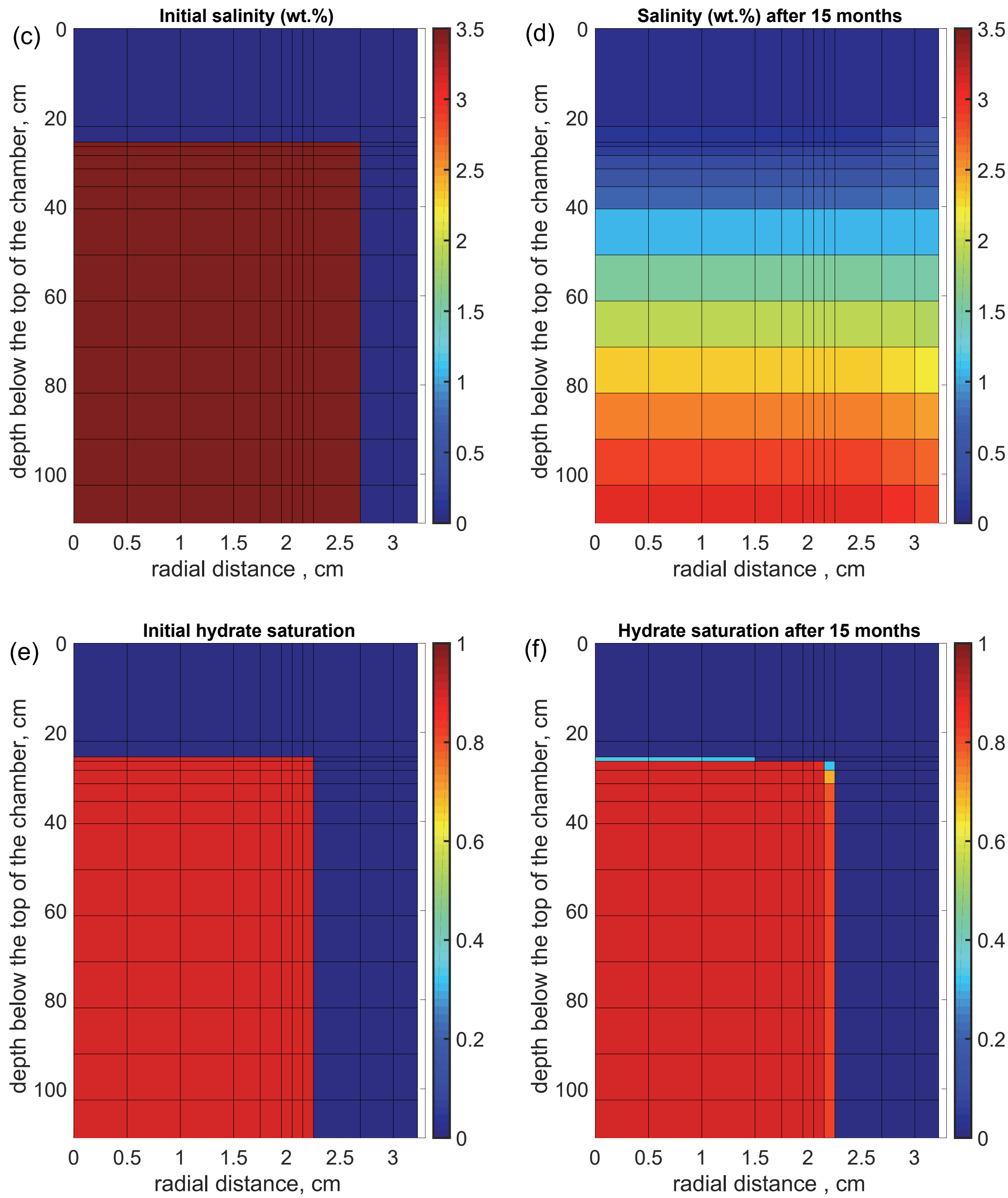


Figure 1-4. Dissolved methane concentration (a, b), salinity (c, d) and hydrate saturation (e, f) at the initial condition and after 15 months of storage at 24 MPa and 6.0 °C.

1.2.2.2.5 Subtask 10.8 – Routine Core Analysis (UT-GOM2-2)

- Future Task.

1.2.2.2.6 Subtask 10.9 – Pressure Core Analysis (UT-GOM2-2)

- Future Task.

1.2.2.2.7 Subtask 10.10 – Core-log-seismic Integration (UT-GOM2-2)

- Future Task.

1.2.2.2.8 Other – Publication and Presentation Work

- UT with UNH prepared five presentations for the AAPG virtual Conference, Oct 1, Theme 9: Analysis of Natural Gas Hydrate Systems I & II
    - Kehua You, *Impact of Coupled Free Gas Flow and Microbial Methanogenesis on the Formation and Evolution of Concentrated Hydrate Deposits*
    - Peter Flemings, *Pressure Coring a Gulf of Mexico Deep-Water Turbidite Gas Hydrate Reservoir: The UT-GOM2-1 Hydrate Pressure Coring Expedition*
    - Stephen Phillips, *High Concentration Methane Hydrate in a Silt Reservoir from the Deep-Water Gulf of Mexico*
    - Joel Johnson, *Grain Size, TOC, and TS in Gas Hydrate Bearing Turbidite Facies at Green Canyon Site 955, Gulf of Mexico*
    - Yi Fang, *Petrophysical Properties of Hydrate-Bearing Siltstone from UT-GOM2-1 Pressure Cores*
    - Manasij Santra, *Gas Hydrate in a Fault-Compartmentalized Anticline and the Role of Seal, Green Canyon, Abyssal Northern Gulf of Mexico*
- UT made two presentations at the NETL Methane Hydrates Project Review Meeting on October 27, 2020.
- Ohio State and UT presented at the AGU Fall Meeting
    - Wei, L., Cook, A. and You, K., Methane Migration Mechanisms for the GC955 Gas Hydrate Reservoir, Northern Gulf of Mexico. OS029-0008. AGU 2020 Fall Meeting
    - You, K., M. Santra, L. Summa, and P.B. Flemings, 2020, Impact of focused free gas flow and microbial methanogenesis kinetics on the formation and evolution of geological gas hydrate system, Abstract presented at 2020 AGU Fall Meeting, 1-17 Dec, Virtual
- Ohio State has four AAPG papers in review or in press
    - Oti, E., Cook, A.E., Phillips, S., and Holland, M., (accepted pending revisions) Using X-ray Computed Tomography (XCT) to Estimate Hydrate Saturation in Sediment Cores from Green

Canyon 955, northern Gulf of Mexico. AAPG Bulletin. Accepted, Additional revisions were submitted this quarter.

- Moore, M., Phillips, S., Cook, A.E. and Darrah, T., (in review) Microbial source of methane in hydrates from Green Canyon Block 955 in the Gulf of Mexico. Submitted this quarter. AAPG Bulletin. Revisions are currently in process.
- Cook, A.E. and Portnov, A., (in review) Chapter 5. Seismic detection of natural gas hydrate systems in Interpretation of seismic data in complex systems. Elsevier.
- Wei, L., Cook, A.E., You, K. (in review). Methane Migration Mechanisms for the GC 955 Gas Hydrate Reservoir, Northern Gulf of Mexico. AAPG Bulletin.

- Ohio State and UT submitted 5 abstracts with GOM2 data to the AAPG 2021 Spring meeting. Preliminary titles are as follows
    - Using Noble Gasses and Hydrocarbon Tracers to Constrain the Source and Residence Time of Methane Gas Hydrates in the Gulf of Mexico (Wulsin)
    - Methane Migration Mechanisms for the GC 055 Gas Hydrate Reservoir, Northern Gulf of Mexico (Wei)
    - Using Machine Learning to Estimate P-Wave Velocity for Computing Hydrate Saturation (Naim)
    - Architectural elements of the Orange Sand Hydrate reservoir in WR 313 (Varona)
    - Seal capacity and fluid expulsion in hydrate systems (Meazell)
- UT submitted four papers to AAPG
    - Fang, Y., Flemings, P.B., Daigle, H., Phillips, S.C., O'Connell, J., (submitted) Permeability of methane hydrate-bearing sandy silts in the deepwater Gulf of Mexico (Green Canyon block 955). AAPG Bulletin.
    - Fang, Y., Flemings, P.B., Daigle, H., Germaine, J.T., Phillips, S.C., O'Connell, J., (submitted) The Compression behavior of the hydrate reservoir at Green Canyon Block 955, Gulf of Mexico. AAPG Bulletin.
    - Phillips, S.C., Flemings, P.B., You, K., Waite, W., (submitted) Thermodynamic insights into the production of methane hydrate reservoirs from depressurization of pressure cores. AAPG Bulletin.
    - You, K., Santra, M., Summa, L., Flemings, P.B., Fang, Y., (submitted) Focused Free Gas Flow Forms Concentrated Methane Hydrate in Coarse-Grained Layers in Geological Systems. AAPG Bulletin.
- Oregon State revised their paper
    - *Impact of X-ray imaging on Biochemistry*, Frontiers in Microbiology. Frontiers Microbiology – Terrestrial Microbiology
- AAPG Editors continued working on the AAPG Volumes 2-3.
- UT, Ohio State, UNH, UW, and Columbia all continued preparing UT-GOM2-1 Data Reports.

1.2.2.3 Task 11.0 – Update Science and Operations Plans for UT-GOM2-2 Scientific Drilling Program

Status: Ongoing

Operations Plan

UT and Ohio State updated the *UT-GOM2-2 Operations Plan.* Moderate revisions were made throughout the *UT-GOM2-2 Operations Plan* to incorporated updates from the BOEM Exploration Plan, Science and Sample Distribution Plan, logistics planning, and time, mud, and resource estimates. Figures and tables were updated throughout the document with minor edits. Discussion of potential H2S hazards were added.

The *UT-GOM2-2 Operations Plan Rev. 2.0* was completed on December 11, 2020, and is attached as **Appendix A**. The purpose of the operations plan is to define the scope and technical activities required to achieve the scientific goals of this project. Therefore, this document will continue to be refined, as required, prior to the UT-GOM2-2 field program.

UT and Ohio State developed an addendum to the *UT-GOM2-2 Operations Plan,* to address an expanded science program in the event that additional funding becomes available for the UT-GOM2-2 expedition.

The expanded science program would greatly enhance our ability to inform reservoir-scale production models, reservoir hydrate formation models, and basin-scale exploration models mainly through a more extensive characterization of our primary target, the Orange sand, at a second up-dip location. The expanded science program would drill two additional wells up dip from WR313 H002 at a new location not previously logged. The two wells include a Logging-while-Drilling (LWD) well (WR313 F001) and a 'twinned' corehole (WR313 F002), located within 50 feet of the WR313 F001.

This document, entitled '*UT-GOM2-2 Operations Plan Addendum A*', is an addendum to the UT-GOM2-2 Operational Plan and describes required changes to the original 2-well plan for the expanded science program (extended plan). *UT-GOM2-2 Operations Plan Addendum A* will be finalized in January, 2021.

Science and Sample Distribution Plan

- Work began on version 2 of the UT-GOM2-2 Science and Sampling Plan. Additional planning included
  - Conventional Core Flow updated for seamless movement of core from whole core logging through split core analysis.
  - Revisited required Science Party personnel on-board by container and hole
  - Revisited required containers on-board adding deck placement and service requirements
  - Confirmed method for shallow pressure coring with Geotek
  - Reviewed time resources available for Pressure Core logging, requested an increase in long storage chambers (SC_{350}s) on-board

1.2.2.4 Task 12.0 – UT-GOM2-2 Scientific Drilling Program Vessel Access

Status: Ongoing

The Vessel Procurement Team held weekly meetings to work the issues of vessel selection and acquisition strategy.

UT and Pettigrew Engineering completed detailed Drilling Schedule, Mud Volume, and Resource Estimates for Base Cases and Contingency Cases for the 2-well plan and the 4-well plan. These updates were incorporated into the UT-GOM2-2 Operations Plan, UT-GOM2-2 Operations Plan Addendum, and the Science and Sample Distribution Plan.

UT completed two documents for distribution prospective vessel contractors:

1. UT-GOM2-2 Rig Specification Requirements
2. UT-GOM2-2 Operations Summary, Schedule, and Well Design.

UT distributed these documents to DOE, USGS, Geotek, and Pettigrew Engineering to review for accuracy & completeness. UT held a web-conference with DOE, USGS, Geotek, and Pettigrew Engineering on November 20, 2020, to review and incorporate feedback into the rig contractor documents. Outstanding issues were resolved, and the documents were finalized.

The *UT-GOM2-2 Rig Specification Requirements* and *UT-GOM2-2 Operations Summary, Schedule, and Well Design* documents were distributed to target vessel contractors in December, 2020, for the purpose of stimulating technical discussions around fit-for-purpose concerns. The intended targets of the updated specifications were the contractors of the smaller vessels (intervention / geotechnical vessels), since larger drilling rigs will easily meet the technical specifications of our project. Requests for Quote will not be sent out until the fit-for-purpose concerns have been evaluated and the list of potential contractors is determined.

1.2.2.5 Task 13.0 – Maintenance & Refinement of Pressure Core Transport, Storage, & Manipulation Capability

Status: Ongoing

- During this quarter, UT completed K0 Permeameter testing of core H005-2FB-2.
- UT was still unable to achieve sealing of the K0 bottom cap and generate hydraulic axial loading.
- UT continues work to resolve the K0 bottom cap sealing issue identified in March 2020, with assistance from Geotek.

- UT purchased two higher scale load cells from Geotek to remedy the maxed out load cell readings identified during the K0 dummy sample testing in Q3, 2020. The new load cells have been delivered and will be tested when the K0 sealing issue has been corrected to allow testing at higher loads.
- In this performance period, UT designed and constructed a clear, acrylic testing chamber to assist with the evaluation of the K0 bottom cap sealing issue and potential remedies (Figure 1-5). The internal dimensions of the chamber match the dimensions and geometry of the K0 Permeameter. The clear nature of the chamber allows UT to observe the interaction of components and sediments during core sample extrusion. Also, the chamber will allow for testing potential corrective remedies of the K0 sealing issue. Further testing will work to identify the proper type of seals and procedures necessary to allow sealing of the bottom cap. Once bottom cap sealing has been achieved, axial loading of a pressure core sample will be tested using hydraulic pressure.

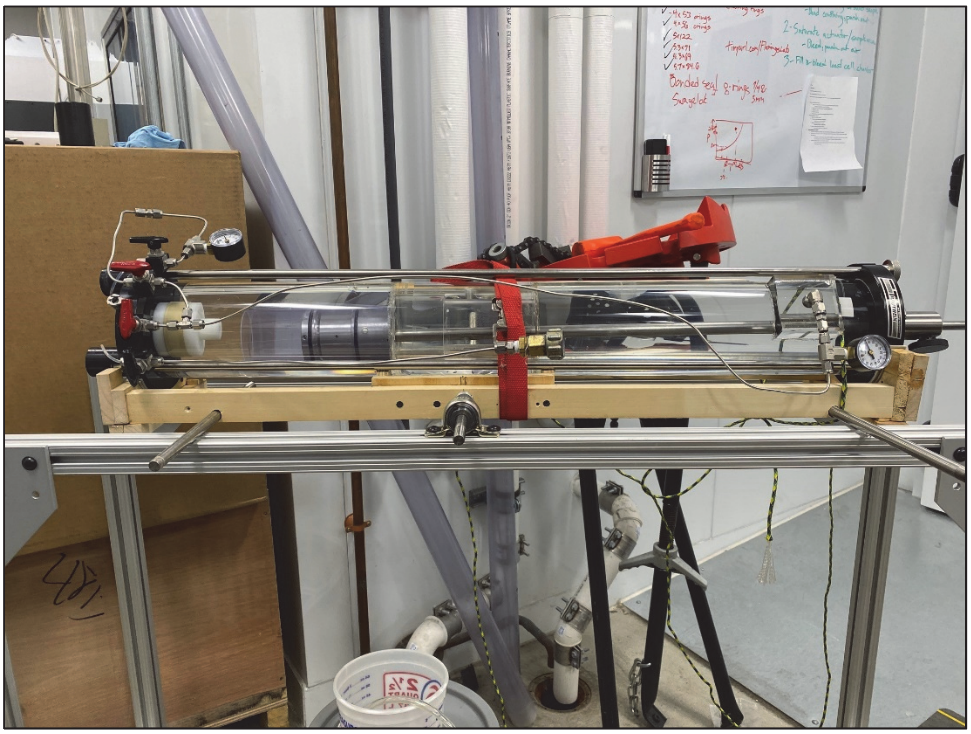


Figure 1-5: Image of the K0 testing chamber to evaluate components that need to seal more consistently. We are able to seal the bottom cap using clean, dummy core samples. We are unable to consistently seal the bottom cap when we move to gritty pressure cores from UT-GOM2-1. Fluid communication was seen between pore fluid and actuator fluid. A variety of different seal types have been tested during pressure core tests and sealing still fails.

1.2.2.5.1 Subtask 13.1 – Hydrate Core Manipulator and Cutter Tool

- System underwent a maintenance teardown with replacement of seals and bearings. In addition to the cleaning of mPCATS sediment traps.
- The x-ray system underwent a quarterly calibration.

1.2.2.5.2 Subtask 13.2 – Hydrate Core Effective Stress Chamber

- One pressure core sample has undergone long-term K0 testing till completion:
    1. H005-2FB-2 - Sample has undergone permeability testing with the presence of hydrate. Then the hydrate was dissolved out of the sample while maintaining an axial load and radial effective stress. The sample will then undergo permeability testing without the presence of hydrate.
        - i. Two intrinsic permeability measurements - one after the hydrate dissolution test without reconsolidation, and one after hydrate dissolution with reconsolidation to in-situ stress. Then the sample was unloaded and CT scanned.
        - ii. Measured the grain size and MAD density.
        - iii. Sample unloaded and CT scanned.
    2. System underwent its yearly maintenance teardown with the replacement of seals and bearings.

1.2.2.5.3 Subtask 13.3 – Hydrate Core Depressurization Chamber

- The system was used to quantify dissolved and dissociated methane hydrate from H005-2FB-2.
- The system underwent maintenance and cleaning.

1.2.2.5.4 Subtask 13.4 – Develop Hydrate Core Transport Capability for UT-GOM2-2

- No update this period.

1.2.2.5.5 Subtask 13.5 – Expansion of Pressure Core Storage Capability for UT-GOM2-2

- New core chamber orientation supports are undergoing design refinement. UT is reviewing quotes to manufacture. A single quad configuration base to be ordered for evaluation.
- Expansion of pressure maintenance system is required to increase storage capability sufficient to receive UT-GOM2-2 cores. UT is reviewing quotes for additional pressure lines.
- Expansion of pressure safety venting system will also be required. UT is reviewing quotes for additional venting lines.
- Evaluation and maintenance testing of methane monitoring system and possible expansion being explored.

1.2.2.5.6 Subtask 13.6 – Continued Storage of Hydrate Cores from UT-GOM2-1

- Core storage expansion in the PCC is anticipated to accommodate any remaining pressure cores acquired from UT-GOM2-1, even when additional cores are collected during UT-GOM2-2 and transferred to the PCC.

1.2.2.5.7 Subtask 13.7 – X-ray Computed Tomography

- The X-Ray CT continues to operate as designed.
- During this period, the system was calibrated.

1.2.2.5.8 Subtask 13.8 – Pre-Consolidation System

- One of the Pre-Consolidation System hydraulic accumulators had developed a leak at the gas charging port in Q3, 2020. Replacement parts have been received from Geotek LTD. The parts will be installed and tested in Q1, 2021.

1.2.2.5.9 Subtask 13.9 – Transportation of Hydrate Core from UT-GOM2-2 Scientific Drilling Program

Future Task.

1.2.2.5.10 Subtask 13.10 – Storage of Hydrate Cores from UT-GOM2-2 Scientific Drilling Program

Future Task.

1.2.2.5.11 Subtask 13.11 – Hydrate Core Distribution

Future Task.

1.2.2.6 Task 14.0 – Performance Assessment, Modifications, And Testing Of PCTB

Status: Ongoing

1.2.2.6.1 Subtask 14.4 – PCTB Modifications/Upgrades

Geotek concluded post-*PCTB Land Test II* evaluation of the PCTB. After numerous experiments and detailed engineering review of the ball valve actuation components, a set of upgraded parts were manufactured. The effect of the new components were tested using the same conditions in which the PCTB Mk. 4 experienced failure. The upgrades included improvements to the seal carrier, ball valve housing, ball follower, cutting shoe sleeve, housing extension, and ball valve return spring. The design improvements focused on diverting grit away and cleaning the sliding surfaces with wiper rings, improving centralization throughout actuation, and improving flow paths throughout the tool to route drilling fluids away from the sliding surfaces.

The following parts were modified for the PCTB Mk. 5 design:

1. Cutting shoe sleeve
    a. Extended length and moved diversion seal from inner to outer diameter
2. Housing Extension

    a. Decreased flow port angles to improve flow path through ports. Added inner diameter seal surface for diversion seal on cutting shoe sleeve.
3. Seal Carrier
    a. Revised part to use Polypack seal, improved surface finish for better dynamic sealing, increased back shoulder length for improved centralizing throughout actuation
4. Ball follower
    a. Adjusted shoulder length to fit ball valve return spring
    b. Machined slots and wrapped slots in 75um stainless steel mesh around the diameter of the ball follower to solve hydro-locking problem created by adding wiper ring seals to the system and filtering particles from building up on the follower surface
    c. Designed new ball valve return spring
5. Ball valve housing
    a. Added wiper ring grooves on the inner diameter for the seal carrier and ball follower to ride on.

Geotek conducted final design upgrade validation testing of the PCTB in which 20 identical tests were performed with the PCTB Mk. 4 and Mk. 5. The PCTB Mk. 4 assembly produced 2/20 'passes', or a pass rate of 10%. The Mk. 5 assembly produced 20/20 'passes', or a pass rate of 100%. This demonstrates that the upgraded ball valve assembly in the Mk. 5 will perform better in downhole environments, specifically in CTTF where ball valve jamming failures were first confirmed.

Geotek submitted a 2020 PCTB Ball Valve Upgrades and Testing Report (**Appendix B**). This report documents all efforts conducted to investigate and remediate the ball-valve failure encountered during the PCTB Land Test II at Schlumberger CTTF:

1. Post CTTF 2020 ball valve isolation testing and root cause analysis
2. Design modifications
3. Design upgrade validation testing.

UT, Geotek, and Pettigrew Engineering held a web-conference on December 11, 2020 to review the 2020 PCTB Ball Valve Upgrades and Testing Report (**Appendix B**) and determine the path forward. The objectives of this discussion were to discuss and confirm the PCTB Mk. 5 modifications, discuss modifications to the service contract, and agree upon what further testing is required. We agreed that all of the proposed modifications upgrading the PCTB Mk. 4 to Mk. 5 specifications were needed and should be fully incorporated into the tool design. We agreed that pressure actuation bench tests of the upgraded PCTB Mk. 5 tool sets should be conducted at the Geotek Coring test facility in Salt Lake City, Utah. We also agreed that the upgraded PCTB Mk. 5 tool sets should undergo a further land test at Schlumberger CTTF.

1.2.2.6.2 Subtask 14.5 – PCTB Land Test III
Future Task.

1.2.2.7 Task 15.0 – UT-GOM2-2 Scientific Drilling Program Preparations

Status: In Progress

1.2.2.7.1 Subtask 15.3 – Permitting for UT-GOM2-2 Scientific Drilling Program

- The UT-GOM2-2 Permit Team (consisting of UT and Ohio State) continued to hold weekly web conferences to work on permits for the H002 and G002 that will be drilled as part of the UT-GOM2-2 Scientific Drilling Program. UT and Ohio State also continued work on the F001 and F002 well permits that will be permitted, but only drilled if additional funding is available.
- The Permitting Team continued collaboration with the Science and Core Analysis Team on technical issues, including:
    1. The committed plan for coring points
    2. Maximum number of cores per well based on processing and storage limitations
    3. Contingency coring plans to respond to different geological scenarios at possible updip location
    4. Time, mud, and resources estimates for each well
- UT finalized the blowout scenario (conditions required to encounter free gas leg(s) due to trajectory deviation
- UT and Ohio State finalized Shallow Hazard Assessment reports for each proposed UT-GOM2-2 drilling location, pursuant to 30 CFR 250.214(f) and 250.244 (f). The Shallow Hazard Reports will accompany the UT-GOM2-2 BOEM Exploration Plan.

1.2.2.7.2 Subtask 15.4 – Review and Complete NEPA Requirements
Future Task.

1.2.2.7.3 Subtask 15.5 – Finalize Operational Plan for UT-GOM2-2 Scientific Drilling Program
Future Task.

1.2.2.8 Task 16.0 – UT-GOM2-2 Scientific Drilling Program Field Operations

Status: Future Task

1.2.2.8.1 Subtask 16.1 – Mobilization of Scientific Ocean Drilling and Pressure Coring Capability

Future Task.

1.2.2.8.2 Subtask 16.2 – Field Project Management, Operations, and Research

Future Task.

1.2.2.8.3 Subtask 16.3 – Demobilization of Staff, Labs, and Equipment

Future Task.

1.3 What Will Be Done In The Next Reporting Period To Accomplish These Goals

1.3.1 Task 1.0 – Project Management & Planning

UT will continue to execute the project in accordance with the approved PMP. UT will continue to manage and control project activities in accordance with their established processes and procedures to ensure subtasks and tasks are completed within schedule and budget constraints defined by the PMP.

1.3.2 Task 10.0 – Core Analysis

- Work will continue on measuring the petrophysical and geomechanical properties of pressure cores using the UT K0 Permeameter once the tool sealing issues have been resolved.
- Work will continue on quantifying core degradation during long-term storage and testing for improved core preservation will start.
- Work will continue on finalizing and posting Data Reports
- UT, Ohio State, and the University of New Hampshire continue working on contributions to the AAPG Special Bulletin Volumes (2, and 3).
- Oregon State with Texas A&M Corpus Christi will continue assessing the microbial communities in GC 955 sediment as possible depending on how long labs are shut down.

1.3.3 Task 11.0 – Update Operations Plan for UT-GOM2-2 Scientific Drilling Program

- UT will update the Operations Plan, as required.
- UT will continue to develop the UT-GOM2-2 Science and Sample Distribution Plan incorporating recommendations from the TAG and the Core Analysis Team, updating planning for the use of PCATS on-board, adding plan for geomechanical testing of background and bounding mud, and drafting protocols for the handling of samples.

1.3.4 Task 12.0 – UT-GOM2-2 Scientific Drilling Program Vessel Access

- UT will continue preliminary discussions with prospective vessel contractors.
- UT will finalize and initiate execution of the UT-GOM2-2 vessel procurement plan.

1.3.5 Task 13.0 – Maintenance And Refinement Of Pressure Core Transport, Storage, & Manipulation Capability

- The Mini-PCATS, PMRS, analytical equipment, and all storage chambers will undergo continued observation and maintenance at regularly scheduled intervals and on an as-needed basis. Installation of new or replacement parts will continue to ensure operational readiness.

- After successful proof of concept and dummy sample testing, UT has continued to conduct testing of the Geotek remedies to ensure their viability with real world pressure core analysis. Real world engineering tests with the K0 Permeameter and real pressure cores will be used to evaluate remedies and procedures to correct the K0 sealing issue.
- UT will pursue testing in a small, clear, acrylic testing chamber in an attempt to observe K0 bottom cap sealing in real world environmental conditions without the expense of using real pressure cores. The chamber has been constructed and pressure tested for operation.

1.3.6 Task 14.0 – Performance Assessment, Modifications, And Testing Of PCTB

- The PCTB toolsets will be upgraded to Mk. 5 specifications.
- The PCTB will undergo pressure actuation testing at the Geotek Coring Facility in Salt Lake City, Utah.
- The PCTB will undergo a land test (PCTB Land Test III) at Schlumberger CTTF.

1.3.7 Task 15.0 – UT-GOM2-2 Scientific Drilling Program Preparations

- UT will submit the Exploration Plan (EP), Right-of-Use-and-Easement (RUE), and Geological and Geophysical (G&G) permit documents and Shallow Hazards Assessments to BOEM.

1.3.8 Task 16.0 – UT-GOM2-2 Scientific Drilling Program Field Operations

- No update.

2 PRODUCTS

Project publications webpage: https://ig.utexas.edu/energy/gom2-methane-hydrates-at-the-university-of-texas/gom2-publications/

2.1 Publications

Boswell, R., Collet, T.C., Cook, A.E., Flemings, P.B., 2020, Introduction to Special Issue: Gas Hydrates in Green Canyon Block 955, deep-water Gulf of Mexico: Part I: AAPG Bulletin, v. 104, no. 9, p. 1844-1846, http://dx.doi.org/10.1306/bltnintro062320.

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Chen, X., Verma, R., Espinoza, D. N., and Prodanović, M., 2018, Pore-Scale Determination of Gas Relative Permeability in Hydrate-Bearing Sediments Using X-Ray Computed Micro-Tomography and Lattice Boltzmann Method: Water Resources Research, v. 54, no. 1, p. 600-608. https://doi.org/10.1002/2017wr021851

Chen, X. Y., and Espinoza, D. N., 2018b, Surface area controls gas hydrate dissociation kinetics in porous media: Fuel, v. 234, p. 358-363. https://doi.org/10.1016/j.fuel.2018.07.030

Cook, A. E., and Portnov, A., 2019, Gas hydrates in coarse-grained reservoirs interpreted from velocity pull up: Mississippi Fan, Gulf of Mexico: COMMENT: Geology, v. 47, no. 3, p. e457-e457. https://doi.org/10.1130/g45609c.1

Cook, A. E., and Sawyer, D. E., 2015, The mud-sand crossover on marine seismic data: Geophysics, v. 80, no. 6, p. A109-A114. https://doi.org/10.1190/geo2015-0291.1

Cook, A. E., and Waite, W. F., 2018, Archie's Saturation Exponent for Natural Gas Hydrate in Coarse-Grained Reservoirs, v. 123, no. 3, p. 2069-2089. https://doi.org/10.1002/2017jb015138

Darnell, K. N., and Flemings, P. B., 2015, Transient seafloor venting on continental slopes from warming-induced methane hydrate dissociation: Geophysical Research Letters, p. n/a-n/a. https://doi.org/10.1002/2015GL067012

Darnell, K. N., Flemings, P. B., and DiCarlo, D., 2019, Nitrogen-Driven Chromatographic Separation During Gas Injection Into Hydrate-Bearing Sediments: Water Resources Research. https://doi.org/10.1029/2018wr023414

Ewton, E., 2019, The effects of X-ray CT scanning on microbial communities in sediment coresHonors]: Oregon State University, 21 p.

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Flemings, P. B., Phillips, S. C., Boswell, R., Collett, T. S., Cook, A. E., Dong, T., Frye, M., Guerin, G., Goldberg, D. S., Holland, M. E., Jang, J., Meazell, K., Morrison, J., O'Connell, J., Pettigrew, T., Petrou, E., Polito, P. J., Portnov, A., Santra, M., Schultheiss, P. J., Seol, Y., Shedd, W., Solomon, E. A., Thomas, C., Waite, W. F., and You, K., 2020, Pressure coring a Gulf of Mexico Deepwater Turbidite Gas Hydrate Reservoir: Initial results from the UT-GOM2-1 hydrate pressure coring expedition: AAPG Bulletin, v. 104, no. 9, p. 1847-1876. https://doi.org/10.1306/05212019052

Flemings, P. B., Phillips, S. C., Collett, T., Cook, A., Boswell, R., and Scientists, U.-G.-E., 2018, UT-GOM2-1 Hydrate Pressure Coring Expedition Summary, *in* Flemings, P. B., Phillips, S. C., Collett, T., Cook, A., Boswell, R., and Scientists, U.-G.-E., eds., UT-GOM2-1 Hydrate Pressure Coring Expedition Report: Austin, TX, University of Texas Institute for Geophysics.

Hillman, J. I. T., Cook, A. E., Daigle, H., Nole, M., Malinverno, A., Meazell, K., and Flemings, P. B., 2017a, Gas hydrate reservoirs and gas migration mechanisms in the Terrebonne Basin, Gulf of Mexico: Marine and Petroleum Geology, v. 86, no. Supplement C, p. 1357-1373. https://doi.org/10.1016/j.marpetgeo.2017.07.029

Hillman, J. I. T., Cook, A. E., Sawyer, D. E., Küçük, H. M., and Goldberg, D. S., 2017b, The character and amplitude of 'discontinuous' bottom-simulating reflections in marine seismic data: Earth and Planetary Science Letters, v. 459, p. 157-169. https://doi.org/10.1016/j.epsl.2016.10.058

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Majumdar, U., Cook, A. E., Shedd, W., and Frye, M., 2016, The connection between natural gas hydrate and bottom-simulating reflectors: Geophysical Research Letters. https://doi.org/10.1002/2016GL069443

Meazell, K., Flemings, P., Santra, M., and Johnson, J. E., 2020, Sedimentology and stratigraphy of a deepwater gas hydrate reservoir in the northern Gulf of Mexico: AAPG Bulletin, v. 104, no. 9, p. 1945–1969, https://doi.org/10.1306/05212019027

Meyer, D. W., 2018, Dynamics of gas flow and hydrate formation within the hydrate stability zone [Doctor of Philosophy: The University of Texas at Austin.

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Moore, M., Phillips, S., Cook, A.E. and Darrah, T., (2020) Improved sampling technique to collect natural gas from hydrate-bearing pressure cores. Applied Geochemistry, Volume 122, November 2020, p. 104773, https://doi.org/10.1016/j.apgeochem.2020.104773.

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Cook, A.E., and Waite, B., 2016, Archie's saturation exponent for natural gas hydrate in coarse-grained reservoir. Presented at Gordon Research Conference, Galveston, TX.

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Santra, M., et al., 2018, Channel-levee hosted hydrate accumulation controlled by a faulted anticline: Green Canyon, Gulf of Mexico. Poster presented at American Geophysical Union, Fall Meeting, Washington, D.C. OS51F-1324

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Wei, L., Cook, A. and You, K., 2020, Methane Migration Mechanisms for the GC955 Gas Hydrate Reservoir, Northern Gulf of Mexico. Abstract OS029-0008. AGU 2020 Fall Meeting

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You, K.Y., Flemings, P.B., & DiCarlo, D., 2015, Quantifying methane hydrate formation in gas-rich environments using the method of characteristics. Poster presented at 2016 Gordon Research Conference and Gordon Research Seminar on Natural Gas Hydrates, Galveston, TX.

2.3 Proceeding of the UT-GOM2-1 Hydrate Pressure Coring Expedition

Volume contents are published on the UT-GOM2-1 Expedition website and on OSTI.gov.

2.3.1 Volume Reference

Flemings, P.B., Phillips, S.C, Collett, T., Cook, A., Boswell, R., and the UT-GOM2-1 Expedition Scientists, Proceedings of the UT-GOM2-1 Hydrate Pressure Coring Expedition, Austin, TX (University of Texas Institute for Geophysics, TX), https://dx.doi.org/10.2172/1646019

2.3.2 Prospectus

Flemings, P.B., Boswell, R., Collett, T.S., Cook, A. E., Divins, D., Frye, M., Guerin, G., Goldberg, D.S., Malinverno, A., Meazell, K., Morrison, J., Pettigrew, T., Philips, S.C., Santra, M., Sawyer, D., Shedd, W., Thomas, C., You, K. GOM2: Prospecting, Drilling and Sampling Coarse-Grained Hydrate Reservoirs in the Deepwater Gulf of Mexico. Proceeding of ICGH-9. Denver, Colorado: ICGH, 2017. http://www-udc.ig.utexas.edu/gom2/UT-GOM2-1%20Prospectus.pdf.

2.3.3 Expedition Report Chapters

Flemings, P.B., Phillips, S.C, Collett, T., Cook, A., Boswell, R., and the UT-GOM2-1 Expedition Scientists, 2018. UT-GOM2-1 Hydrate Pressure Coring Expedition Summary. In Flemings, P.B., Phillips, S.C, Collett, T., Cook, A., Boswell, R., and the UT-GOM2-1 Expedition Scientists, Proceedings of the UT-GOM2-1 Hydrate Pressure Coring Expedition, Austin, TX (University of Texas Institute for Geophysics, TX). https://dx.doi.org/10.2172/1647223.

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2.3.4 Data Reports

Fortin, W.F.J., Goldberg, D.S., Küçük, H.M., 2020, Data Report: Prestack Waveform Inversion at GC 955: Trials and sensitivity of PWI to high-resolution seismic data, In Flemings, P.B., Phillips, S.C, Collett, T., Cook, A., Boswell, R., and the UT-GOM2-1 Expedition Scientists, Proceedings of the UT-GOM2-1 Hydrate Pressure Coring Expedition: Austin, TX (University of Texas Institute for Geophysics, TX). http://dx.doi.org/10.2172/1647733, 7 p.

Heber, R., Cook, A., Sheets, J., Sawyer, 2020. Data Report: High-Resolution Microscopy Images of Sediments from Green Canyon Block 955, Gulf of Mexico. In Flemings, P.B., Phillips, S.C, Collett, T., Cook, A., Boswell, R., and the UT-GOM2-1 Expedition Scientists, Proceedings of the UT-GOM2-1 Hydrate Pressure Coring Expedition: Austin, TX (University of Texas Institute for Geophysics, TX). https://dx.doi.org/10.2172/1648312, 6 p.

Heber, R., Cook, A., Sheets, J., and Sawyer, D., 2020. Data Report: X-Ray Diffraction of Sediments from Green Canyon Block 955, Gulf of Mexico. In Flemings, P.B., Phillips, S.C, Collett, T., Cook, A., Boswell, R., and the UT-GOM2-1 Expedition Scientists, Proceedings of the UT-GOM2-1 Hydrate Pressure Coring Expedition: Austin, TX (University of Texas Institute for Geophysics, TX). https://dx.doi.org/10.2172/1648308, 27 p.

Phillips, I.M., 2018. Data Report: X-Ray Powder Diffraction. In Flemings, P.B., Phillips, S.C, Collett, T., Cook, A., Boswell, R., and the UT-GOM2-1 Expedition Scientists, Proceedings of the UT-GOM2-1 Hydrate Pressure

Coring Expedition: Austin, TX (University of Texas Institute for Geophysics, TX). https://dx.doi.org/10.2172/1648320 14 p.

2.4 Websites

- Project Website:
https://ig.utexas.edu/energy/genesis-of-methane-hydrate-in-coarse-grained-systems/
- UT-GOM2-1 Expedition Website:
https://ig.utexas.edu/energy/genesis-of-methane-hydrate-in-coarse-grained-systems/expedition-ut-gom2-1/
- Project SharePoint:
https://sps.austin.utexas.edu/sites/GEOMech/doehd/teams/
- Methane Hydrate: Fire, Ice, and Huge Quantities of Potential Energy:
https://www.youtube.com/watch?v=f1G302BBX9w
- Fueling the Future: The Search for Methane Hydrate:
https://www.youtube.com/watch?v=z1dFc-fdah4
- Pressure Coring Tool Development Video:
https://www.youtube.com/watch?v=DXseEbKp5Ak&t=154s

2.5 Technologies Or Techniques

Nothing to report.

2.6 Inventions, Patent Applications, and/or Licenses

Nothing to report.

3 CHANGES/PROBLEMS

3.1 Changes In Approach And Reasons For Change

Nothing to report.

3.2 Actual Or Anticipated Problems Or Delays And Actions Or Plans To Resolve Them

Nothing to report

3.3 Changes That Have A Significant Impact On Expenditures

Nothing to report.

3.4 Change Of Primary Performance Site Location From That Originally Proposed

Nothing to report.

4 SPECIAL REPORTING REQUIREMENTS

4.1 Current Project Period

Task 1.0 – Revised Project Management Plan

Subtask 15.5 – Final UT-GOM2-2 Scientific Drilling Program Operations Plan

4.2 Future Project Periods

Task 1.0 – Revised Project Management Plan

Subtask 17.1 – Project Sample and Data Distribution Plan

Subtask 17.3 – UT-GOM2-2 Scientific Drilling Program Scientific Results Volume

5 BUDGETARY INFORMATION

The Budget Period 5 cost summary is provided in Table 5-1.

Table 5-1: Phase 5 / Budget Period 5 Cost Profile

Baseline Reporting Quarter	Budget Period 5							
	Y1Q1		Y1Q2		Y1Q3		Y1Q4	
	10/01/20-12/31/20		01/01/21-03/31/21		04/01/21-06/30/21		07/01/21-09/30/21	
	Y1Q1	Cumulative Total	Y1Q2	Cumulative Total	Y1Q3	Cumulative Total	Y1Q4	Cumulative Total
Baseline Cost Plan								
Federal Share	$ 587,651	$ 31,973,595	$ 581,151	$ 32,554,746	$ 5,466,306	$ 38,021,052	$ 581,151	$ 38,602,203
Non-Federal Share	$ 150,293	$ 23,871,255	$ 148,630	$ 24,019,885	$ 1,398,018	$ 25,417,903	$ 148,630	$ 25,566,533
Total Planned	$ 737,944	$ 55,844,850	$ 729,781	$ 56,574,631	$ 6,864,324	$ 63,438,955	$ 729,781	$ 64,168,736
Actual Incurred Cost								
Federal Share	$ 589,548	$ 589,548						
Non-Federal Share	$ 220,056	$ 220,056						
Total Incurred Cost	$ 809,604	$ 809,604						
Variance								
Federal Share	$ 1,897	$ 1,897						
Non-Federal Share	$ 69,763	$ 69,763						
Total Variance	$ 71,661	$ 71,661						
Baseline Reporting Quarter	**Budget Period 5**							
	Y2Q1		Y2Q2		Y2Q3		Y2Q4	
	10/01/21-12/31/21		01/01/22-03/31/22		04/01/22-06/30/22		07/01/22-09/30/22	
	Y2Q1	Cumulative Total	Y2Q2	Cumulative Total	Y2Q3	Cumulative Total	Y2Q4	Cumulative Total
Baseline Cost Plan								
Federal Share	$ 4,433,883	$ 43,036,085	$ 749,973	$ 43,786,058	$ 20,274,089	$ 64,060,147	$ 710,837	$ 64,770,984
Non-Federal Share	$ 700,232	$ 26,266,765	$ 118,441	$ 26,385,206	$ 3,201,835	$ 29,587,040	$ 112,261	$ 29,699,301
Total Planned	$ 5,134,114	$ 69,302,850	$ 868,414	$ 70,171,264	$ 23,475,924	$ 93,647,188	$ 823,097	$ 94,470,285
Actual Incurred Cost								
Federal Share								
Non-Federal Share								
Total Incurred Cost								
Variance								
Federal Share								
Non-Federal Share								
Total Variance								

6 ACRONYMS

Table 6-1: List of Acronyms

ACRONYM	DEFINITION
AAPG	American Association of Petroleum Geologists
ACE	Annual Convention and Exhibition
APL	Ancillary Project Letter
BOEM	Bureau of Ocean Energy Management
CFR	Code of Federal Regulation
CPP	Complimentary Project Proposal
CT	Computed Tomography
CTTF	Cameron Test Testing Facility
DOE	U.S. Department of Energy
EP	Exploration Plan
G&G	Geologic and Geophysical
GC	Green Canyon
IODP	International Ocean Discovery Program
JIP	Joint Industry Project
LWD	Logging While Drilling
NEPA	National Environmental Policy Act
NETL	National Energy Technology Laboratory
PCATS	Pressure Core Analysis and Transfer System
PCC	Pressure Core Center
PCTB	Pressure Core Tool with Ball Valve
PCTB-CS	Pressure Core Tool with Ball Valve - Cutting Shoe
PCTB-FB	Pressure Core Tool with Ball Valve - Face Bit
PDT	Probe Deployment Tool
PM	Project Manager
PMP	Project Management Plan
PMRS	Pressure Maintenance and Relief System
QRPPR	Quarterly Research Performance and Progress Report
RPPR	Research Performance and Progress Report
RUE	Right-of-Use-and-Easement
SOPO	Statement of Project Objectives
T2P	Temperature to Pressure Probe
TAG	Technical Advisory Group
TOC	Total Organic Carbon
TS	Total Sulfur
UNH	University of New Hampshire
UT	University of Texas at Austin
UW	University of Washington
XCT	X-ray Computed Tomography
XRD	X-ray Diffraction

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APPENDIX A

UT-GOM2-2 Operations Plan Rev. 2.0

UT-GOM2-2 OPERATIONS PLAN

Deepwater Methane Hydrate Characterization and Scientific Assessment

DOE Award No. DE-FE0023919

The University of Texas at Austin

U.S. Department of Energy

National Energy Technology Laboratory

Updated December 11, 2020

PREFACE

This document has been prepared by The University of Texas at Austin and the DE-FE0023919 project team. The purpose of this document is to define the technical and operational activities required to achieve the science goals of the UT-GOM2-2 Scientific Drilling Program. This document will be revised on an as-needed basis to update information, incorporate changes, and provide clarification on the UT-GOM2-2 Scientific Drilling Program prior to its execution.

Major revisions to the document will be tracked in the 'Record of Revisions' table provided below.

Record of Revisions

REV.	DATE	AUTHORS	DESCRIPTION
0.0	04/12/18	Flemings, Houghton, Thomas	Initial issuance following approval of CPP & scheduling of IODP Expedition 386.
1.0	10/01/19	Cook, Flemings, Houghton, Morrison, Phillips, Pettigrew, Polito, Portnov, Santra, Thomas	Major revisions throughout, including presumed use of drilling vessel other than *JR* and significantly revised field program focused on coring two existing LWD locations in Terrebonne Basin.
1.1	12/13/19	Cook, Flemings, Houghton, Morrison, Polito, Santra, Thomas	Minor edits throughout document based on technical input from Geotek and quality control review.
1.2	12/16/19	Santra, Houghton	Updated Mud Weight Plots on pages 31, 32.
1.3	12/20/19	Houghton	Minor edits and corrections throughout. Updated List of Acronyms.
1.4	7/3/20	Portnov, Santra, Cook, Thomas, Morrison	Hole locations edited to ~50 ft from original JIP location, tops tables and resulting text changes. Updated Coring Plan and container logistics.
2.0	12/11/20	Flemings, Morrison, Portnov, Santra, Pettigrew, Thomas, Cook, Houghton	Moderate revisions throughout to incorporate updates from Exploration Plan, Science and Sample Distribution Plan, and logistics planning. Figures and tables updated throughout with minor edits. Added discussion of H2S hazards.

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Appendices

1 Executive Summary

The UT-GOM2-2 Scientific Drilling Program is part of the *Deepwater Methane Hydrate Characterization & Scientific Assessment Project* (DE-FE0023919), funded by the Department of Energy and advised by the United States Geological Survey (USGS) and the Bureau of Ocean Energy Management (BOEM). The objective of the project is to gain insight into the nature, formation, occurrence and physical properties of methane hydrate bearing sediments for the purpose of methane hydrate resource appraisal through the planning and execution of drilling, coring, logging, testing and analytical activities that assess marine methane hydrate deposits in the northern Gulf of Mexico.

This is the operational plan for the UT-GOM2-2 Scientific Drilling Program. The UT-GOM-2 expedition will be accomplished with a deepwater drilling/intervention vessel that is commercially contracted. The expedition is currently planned between 1/2/2022 to 6/1/2022.

Two wells will be drilled in Walker Ridge Block 313 (WR313) in the northern Gulf of Mexico. The surface location of each well will be approximately 50 feet of a well previously drilled with logging while drilling (LWD) tools as part of the 2009 JIP II Methane Hydrates LWD program (Collett et al., 2009). Water depths at the well locations range between 6,460 and 6,567 feet below sea level. In the first well (WR313 H002), multiple pressure-cores will be obtained from three hydrate-bearing targets (Red, Blue, & Orange sands) using the PCTB-FB tool. The depth of intermittent pressure-cores ranges from 379 to 3010 feet below seafloor (fbsf). In the second well (WR313 G002), conventional cores (APC, and XCB tools), pressure cores (PCTB-CS and PCTB-FB tools), and temperature and pressure measurements (T2P tool) will be obtained using the PCTB-CS and PCTB-FB BHAs. The coring plan includes continuous conventional core from the seafloor to ~250 fbsf followed by intermittent pressure coring throughout the hole to 3073.3 fbsf, with a special focus on the Upper Blue sand. The wells will be permanently abandoned at the conclusion of the program. There will be no pipelines or other facilities installed that would require decommissioning.

The Geotek pressure Core Analysis and Transfer System (PCATS) will be used onboard to perform characterization, cutting, and transfer of pressure cores. Sections of pressure cores will be selected for quantitative degassing and future analysis at UT and other institutions. Pressure cores will be demobilized via supply vessel. PCATS and quantitative degassing manifolds will be remobilized at the dock to complete the processing of any remaining pressure core not addressed onboard.

The Geotek MSCL-IR scanner will be used to scan conventional core as it reaches the rig floor. Pore water squeezing will be conducted on sections of conventional and depressurized core onboard to assess ephemeral properties. Pore water samples will also be preserved for additional analysis on shore. Conventional and depressurized whole round core samples will also be cut and preserved for moisture and density, geomechanical testing, other physical properties, headspace gas analysis, and microbiology. Dockside, whole round conventional and depressurized core will be scanned using the Geotek MSCL and CT imaging. After imaging, core will be split, photographed, and scanned using the Geotek, Geoscan camera, color spectrophotometry, magnetic susceptibility, and x-ray florescence scanner. A team of scientists will conduct conventional core analysis including smear slide preparation and microscopy, initial biostratigraphy, sediment weight and dry weights. Plugs of material will also be preserved for future analysis at various institutions.

The scientific program will require approximately 11.5 weeks to complete (Table 1-1). The program begins with a one-week period for staging equipment in the port of embarkation. Mobilization, requiring 3.8 days, involves transporting equipment and personnel to the drilling vessel and preparing for field science operations. The onboard drilling and science program will require 33.7 days, followed by demobilization of personnel and equipment, requiring 3 days. A dockside core analysis program will then be initiated, requiring an estimated 30 days to complete. This is followed by approximately 3 days of final demobilization.

Table 1-1. UT-GOM2-2 Scientific Drilling Program Schedule.

No.	TASK	LOCATION	ESTIMATED DURATION (Days)	CUMULATIVE DURATION (Days)
1	Premobilization Staging	Port of Embarkation	7	7
2	Mobilization	Port of Embarkation	3.8	10.8
3	WR313 H002 Coring Program	Walker Ridge 313	15.6	26.4
4	WR313 G002 Coring Program	Walker Ridge 313	18.1	44.5
5	Stage 1 Demobilization	Walker Ridge 313	3.0	47.5
6	Dockside Core Processing	Port Fourchon, LA	30.0	77.5
7	Stage 2 Demobilization	Port Fourchon, LA	3.0	80.5

2 Science Objectives

The prioritized science objectives for the UT-GOM2-2 Scientific Drilling Program are as follows.

2.1 Characterize the primary (Orange sand) and secondary (Blue sand) hydrate reservoirs and their bounding units.

At the first hole, WR313 H002, we will perform pressure coring in the Orange sand, Blue sand and their bounding units. We will characterize the 1) hydrate concentration, 2) lithology (grain size, mineralogy, sedimentary structures), 3) geochemistry (gas and pore water composition), 4) permeability and 5) mechanical properties (compressibility and strength). Conventional core analysis will be done on depressurized cores.

At the second hole, WR313 G002, we will pressure core the hydrate-bearing Blue sand and its bounding units.

2.2 Contrast hydrate reservoir properties at different structural levels within a dipping sand ("up-dip to down-dip relationship")

We will compare and contrast hydrate concentration, pore fluid composition, and gas composition at different distances above the bottom simulating reflection (BSR) both within a single sand (the Blue sand) and within different sands. The Blue sand is the only significant hydrate-bearing sand penetrated in both WR313 H002 and WR313 G002.

2.3 Characterize dissolved methane concentration and gas molecular composition with depth

We will acquire a depth profile of dissolved gas concentration and the gas molecular/isotopic composition to characterize the gas source and the microbial methane production. If the dissolved methane concentration is at saturation, we will know that hydrate is likely to be forming. To get the methane concentration, the total amount of gas and its molecular composition (e.g. C1 to C5) must be determined from degassing of pressure cores. This and associated measurements will illuminate whether the methane is of microbial origin. The isotopes of C and H in methane will also illuminate the pathways of methanogenesis. These measurements must be made on pressure cores because in conventional cores, gas comes out of solution, and fractionation occurs when the core is retrieved and undergoes depressurization.

2.4 Measure the in-situ temperature and pressure profile

We will measure pressure and temperature with a penetrometer to a depth of ~1640 feet below seafloor (fbsf) in hole WR313 G002. We will use the 'Temperature 2 Pressure' (T2P) probe, which is only compatible with PCTB-CS BHA, which is depth limited to approximately 1640 fbsf (lithology dependent). These data will allow us to estimate whether the base of the hydrate stability zone is at the three-phase boundary (methane hydrate-seawater-methane vapor) as is commonly assumed. Without the measurements, thermal gradients must be estimated from other thermodynamic models.

2.5 High resolution geochemical and sedimentary profiles: moving towards an exploration model

A sedimentary profile with high resolution pore water sampling and microbiological sampling will be acquired at hole WR313 G002. We will continuously core to 258 fbsf and then spot conventional cores and pressure cores to total depth. We will do the following:

1. Measure organic carbon with depth to constrain the degree of microbial biogenesis
2. Observe abrupt transitions in the first 258 fbsf and general behavior to total depth of the pore water composition to infer fluid flow, hydrate formation/dissociation, diagenesis.
3. Develop an age model from which we can characterize glacial-interglacial variation in sedimentation rates, organic carbon input, and physical properties (top-down drivers of hydrate system evolution)
4. Observe continuous record of lithologic properties in bounding seals and reservoirs.

2.6 Reservoir characterization—other targets of interest

WR313 H002 and WR313 G002 contain many other sands of interest that will be characterized given sufficient time. Coring these sands will provide insight on a variety of questions including: 1) does hydrate formation in thin sands occur via methane diffusion? What are the hydrate and gas saturations across the BSR? What is the form and concentration of fracture-filling hydrate in clay? What is the fluid and dissolved gas composition in sands below the BSR?

3 Geologic Program

3.1 Introduction

The study area in Walker Ridge Block 313 (WR313) is located near the southern boundary of Terrebonne Basin (Figure 3-1). The Terrebonne Basin is an intraslope salt withdrawal minibasin in the Walker Ridge protraction area (Figure 3-1, Figure 3-2). The Terrebonne Basin is a salt-floored, salt-bounded, minibasin (Frye et al., 2012), with water depths ranging between 6000 ft and 6800 ft. The local seafloor topographic gradient at the proposed well sites vary between 2° and 3°.

One exploration well, WR313 001, was drilled in the ‘Orion south’ prospect in 2001 by Devon Energy (Figure 3-1). The WR313 G001, and WR313 H001 wells (Figure 3-1, Table 3-1, Table 3-2) were drilled during the 2009 Gas Hydrates Joint Industry Project Leg II (JIP II) LWD program (Boswell et al., 2012a; Boswell et al., 2012b; Shedd et al., 2010). Two major gas hydrate-bearing units, the Blue and Orange sands (Figure 3-4), were encountered during the 2009 JIP II drilling.

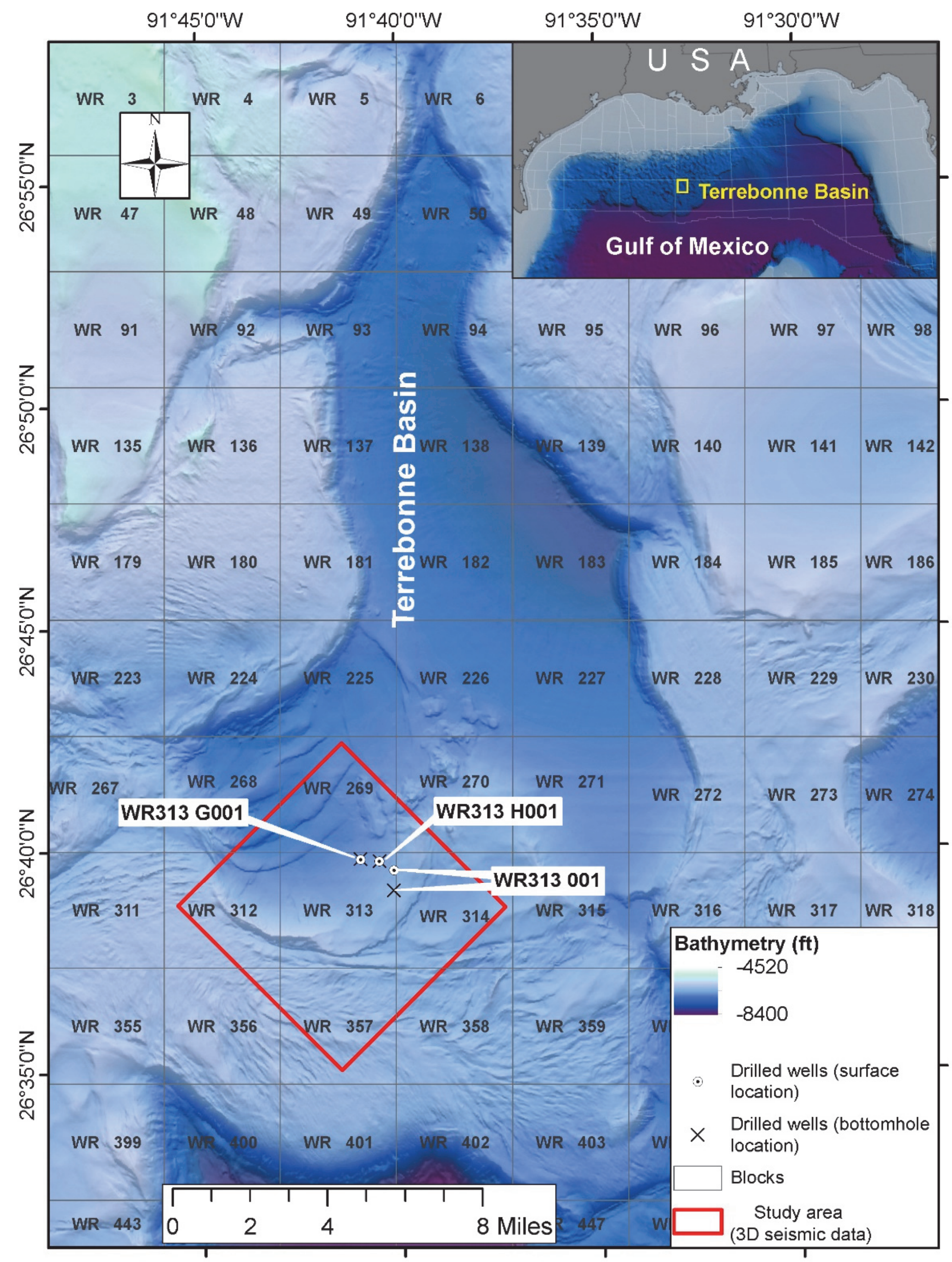

Figure 3-1. Shaded relief map of sea floor in the northwestern part of Walker Ridge Protraction Area showing Terrebonne Basin and existing wells in Walker Ridge Block 313 (WR313). Inset map shows the position of Terrebonne Basin in northern Gulf of Mexico. Bathymetry data are from BOEM Northern Gulf of Mexico Deepwater Bathymetry Grid from 3D Seismic (Kramer and Shedd, 2017).

Table 3-1. Existing wells - Locations in Walker Ridge Block 313.

Well Name	API Well Number	Surface Lat. (NAD27)	Surface Long. (NAD27)	X (NAD 27 UTM 15N US ft)	Y (NAD 27 UTM 15N US ft)	Bottom Lat. (NAD27)	Bottom Long. (NAD27)	X (NAD 27 UTM 15N US ft)	Y (NAD 27 UTM 15N US ft)
WR313 001	608124000700	26.659120	-91.669906	2074707	9675848	26.651294	-91.670086	2074674	9673003
WR313 G001	608124003900	26.663190	-91.683872	2070127	9677280	26.663308	-91.683837	2070138	9677323
WR313 H001	608124004000	26.662458	-91.676041	2072687	9677040	26.662498	-91.675882	2072739	9677055

Table 3-2. Existing wells – Well information.

Well Name	API Well Number	Total MD, RKB (ft)	Total TVD, RKB (ft)	Air Gap (ft)	Water Depth (ft)
WR313 001	608124000700	16,720	16,072	72	6,216
WR313 G001	608124003900	10,200	10,199	52	6,562
WR313 H001	608124004000	9,888	9,887	51	6,462

3.2 Proposed Well Locations

We will drill two locations in Walker Ridge Block 313: WR313 H002 and WR313 G002. WR313 H002 and WR313 G002 will be located approximately 50 ft from the existing wells WR313 H001 and WR313 G001, respectively.

Table 3-3. Planned well locations and depths. Geographic coordinates, projected coordinates, water depth, and planned total depth below seafloor are listed.

Proposed Locations	Latitude NAD27	Longitude NAD27	X NAD27 UTM15N	Y NAD27 UTM15N	X WGS84 UTM15N	Y WGS84 UTM15N	Water depth	Total depth below seafloor
	degree (N)	degree (W)	(ft)	(ft)	(m)	(m)	(ft)	(ft)
WR313 H002	26.662375	91.676210	2072632.0	9677009.4	631730.5	2949756.6	6460	3010
WR313 G002	26.663253	91.683993	2070087.4	9677302.2	630954.8	2949845.8	6567	3085

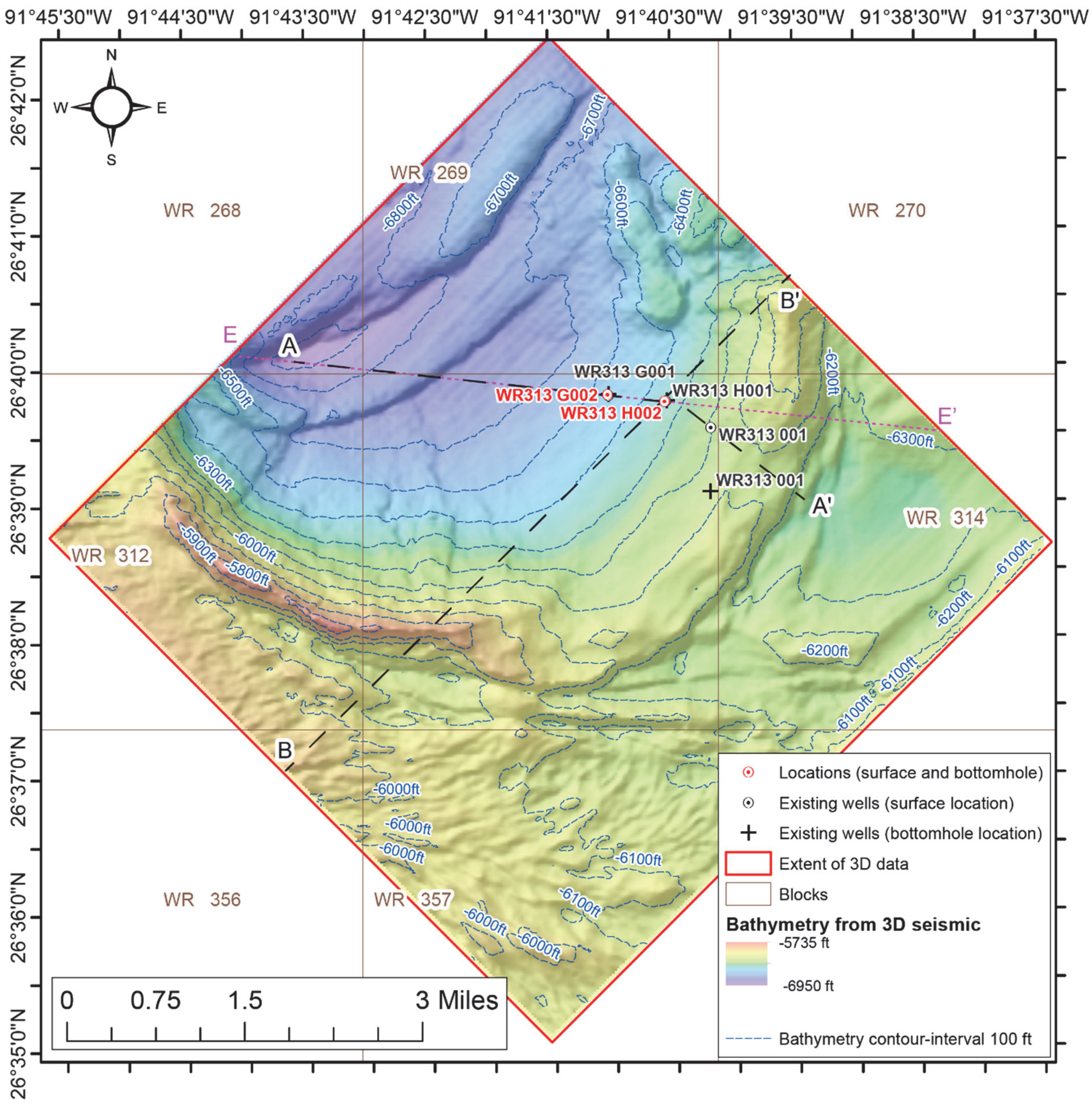

Figure 3-2. Bathymetry map of the study area based on 3D seismic data in southern Terrebonne Basin. The map shows existing wells and proposed locations in Walker Ridge Block 313 (WR313). 3D seismic data were used with permission of WesternGeco.

3.3 Top Hole Stratigraphy

The shallow sedimentary succession at WR313 consists of hemipelagic sediments, turbidites from channel-levee systems, and mass transport deposits. A discontinuous BSR is imaged in seismic data (Figure 3-4). This is interpreted as the base of gas hydrate stability zone.

Intervals with low gamma ray values that are coarse-grained were found in both wells at multiple levels, often with high gas hydrate saturations (S_h>70%) (Boswell et al., 2012a; Boswell et al., 2012b; Collett et al., 2009; Collett et al., 2010; Frye et al., 2012). In our interpretation (Figure 3-3), we assume coarse-grained sediments are defined by low gamma-ray (API < 65), which distinguish them from higher gamma ray mud-rich sediments (Table 3-4). Hydrate-bearing coarse-grained sediments have high resistivity and velocity coupled with low gamma ray (API < 65); because both the resistivity and velocity have corresponding increases (without increase in density) these intervals are most likely pore-filling hydrate (Table 3-4). Similarly, some thin mud intervals also have corresponding moderate increases in resistivity and velocity which we also interpret as pore-filling (Table 3-4). Water bearing sands have low resistivity (often lower than background), enlarged borehole size and low gamma ray (API < 65) (Table 3-4). Fracture-filling gas hydrates have also been observed at Terrebonne (Cook et al., 2014). These intervals are primarily marine mud and have increases in resistivity, fractures visible on resistivity image logs, and propagation resistivity curve separation (Cook et al., 2010). One notable hydrate-filled fracture interval is called the JIP unit, a several hundred meter thick mud unit that appears in both holes (Cook et al., 2014) (Figure 3-8 & Figure 3-9).

Table 3-4. Interpretation of sediment type, pore constituents, and fractures based on well log response.

Sediment Type	Approximate Gamma Ray (API)	Interpretation	Well Log Response
coarse-grained sediment (sand and coarse silt sized grains)	<65	pore-filling hydrate	corresponding moderate to high increase in resistivity and velocity above background, possible slight drop in density, caliper near bit size
		gas-bearing	increase in resistivity or background resistivity with a drop in velocity, caliper measuring borehole enlargement
		water-bearing	resistivity and velocity at or slightly below background, drop in density, caliper measuring borehole enlargement
marine mud sediment (silt and clay sized grains)	>65	pore-filling hydrate	corresponding moderate increase in resistivity and velocity above background, possible slight drop in density, caliper near bit size
		fracture-filling hydrate	increase in resistivity, fractures visible on borehole images, propagation resistivity curve separation, little to no increase in velocity above background, caliper near bit size
		water-bearing	resistivity and velocity at background, caliper near bit size

The two major coarse-grained intervals encountered in WR313 H001 well, the Upper Blue sand and the Orange sand, are associated with two prominent seismic reflectors called the Blue Horizon and the Orange Horizon (Boswell et al., 2012a; Boswell et al., 2012b; Frye et al., 2012) (Figure 3-4, Figure 3-5). The hydrate-bearing Upper Blue sand in WR313 H001 is just above the interpreted Blue Horizon. The WR313 G001 well encountered hydrate-bearing coarse-grained sediments both above and below the

Blue Horizon, the Upper Blue sand and Lower Blue sand, respectively. The Orange sand was intersected in both WR313 G001 and WR313 H001 wells. The WR313 H001 intersected a relatively thick coarse-grained package with high gas hydrate saturation at this level. However, the WR313 G001 encountered a thin, water-bearing, muddy/coarse package below the BSR at the Orange Horizon. An additional thin coarse-grained interval, the Kiwi sand (Hillman et al., 2017), was encountered in well WR313 G001 at the base of gas hydrate stability zone and contains both gas hydrate and a low saturation of gas (Figure 3-4).

The stratigraphic nomenclature used in this document is different from published studies in this area such as Boswell et al. (2012a), Boswell et al. (2012a), or Hillman et al. (2017). Each mapped stratigraphic surface was assigned a numerical designation; for example, the Orange Horizon is Horizon 0300 (Hrz 0300; see Figure 3-4 for the names and positions of stratigraphic surfaces). In addition to the stratigraphic surfaces, a surface was also generated connecting the discontinuous but locally strong BSR, which is interpreted to record the base of the gas hydrate stability zone (BHSZ) (Figure 3-4). The Orange Horizon/Hrz 0300, and Blue Horizon/Hrz 0400 are prominent reflectors in 3D seismic data and display a distinct phase reversal when they intersect the BSR. This phenomenon, which is a result of transition between gas hydrate (above) and free gas (below) within the pore spaces, guided our mapping strategy. Each of these three stratigraphic surfaces was traced as a seismic peak above the BSR, and following the phase reversal, traced as a seismic trough below the BSR (see Boswell et al. (2012b) for an explanation of mapping strategy).

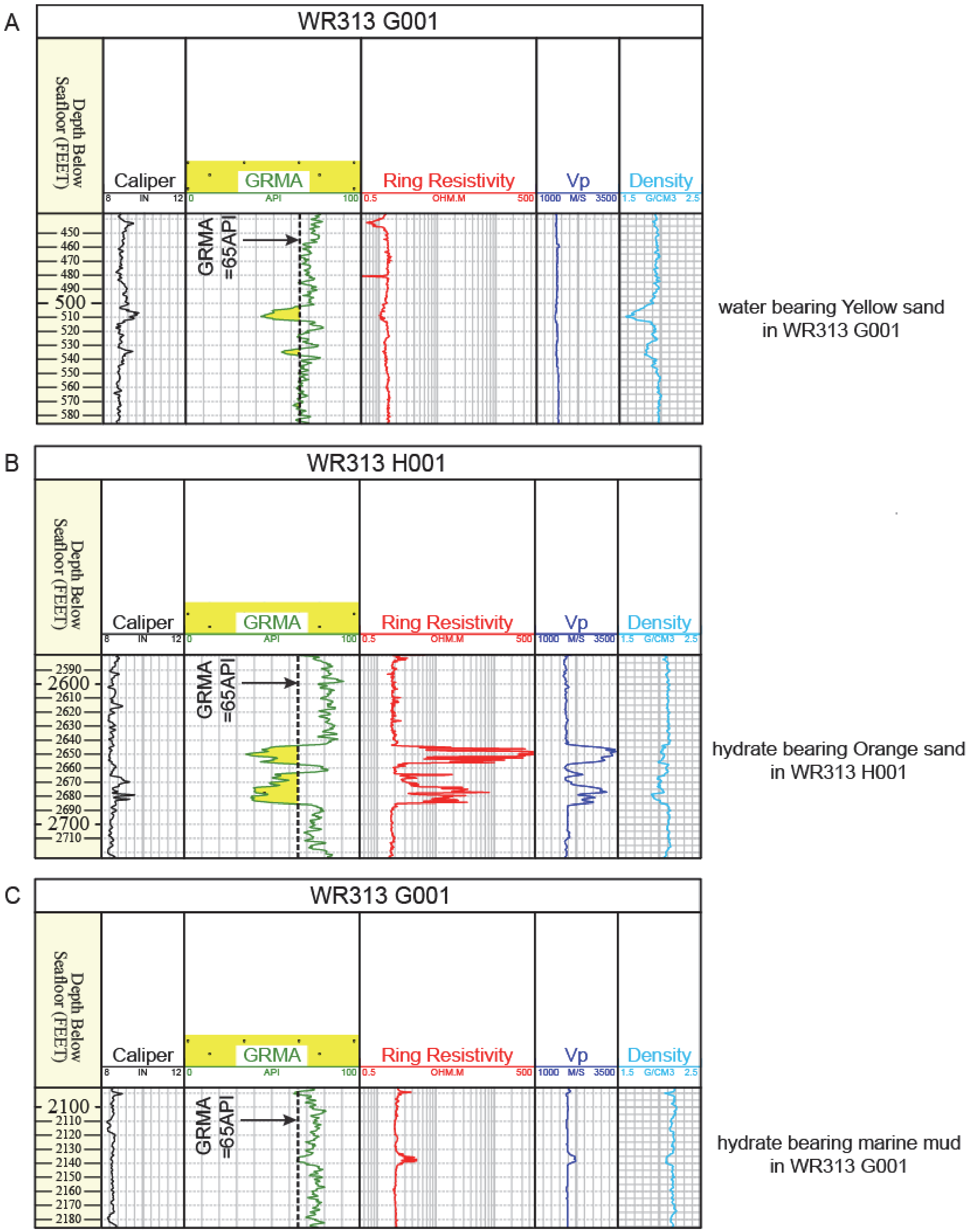

Figure 3-3. Identification of coarse-grained intervals (hydrate bearing or water bearing) and interpreted hydrate bearing marine mud from LWD data. A) Example of interpreted coarse-grained intervals with water showing low gamma ray (GRMA <65) values and low resistivity (lower than background); B) example of a hydrate bearing coarse-grained interval with low gamma ray

(GRMA<65), high resistivity, high p-wave velocity, and low density; C) example of an interpreted hydrate bearing marine mud interval with moderately low gamma ray values, moderately high resistivity, and moderately high p-wave velocity.

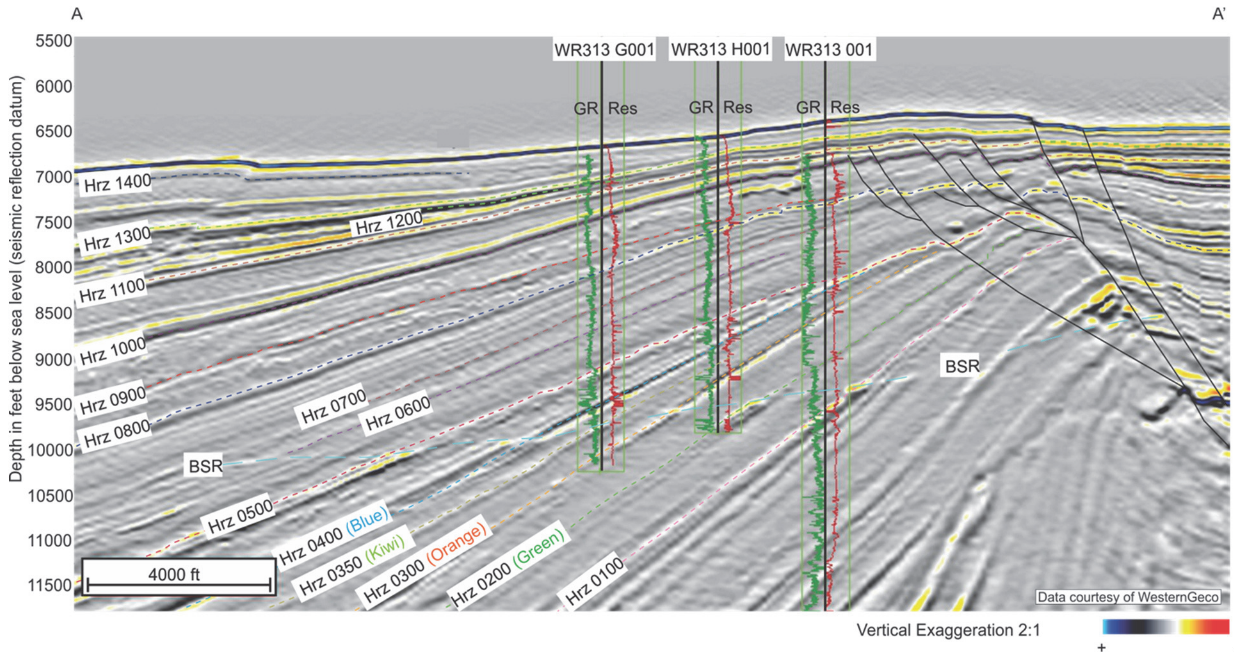

Figure 3-4. Seismic section AA' through existing wells in block WR313 (location in Figure 3-2), showing all interpreted stratigraphic horizons, BSR, and gamma ray (GR) and resistivity (Res) logs at existing wells. Stratigraphic nomenclature used for some previous studies in the area for relevant reservoir intervals (Boswell et al., 2012b; Frye et al., 2012; Hillman et al., 2017) are presented for comparison with nomenclature used in this study. Seismic data courtesy of WesternGeco.

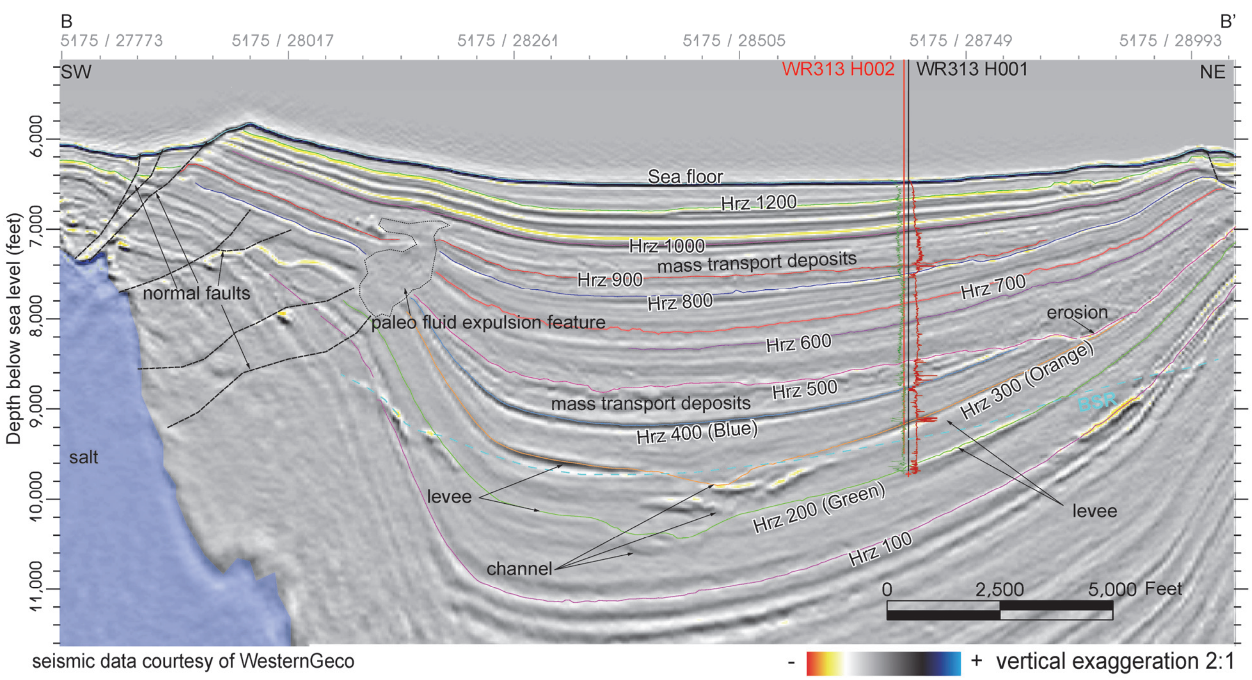

Figure 3-5. SW-NE oriented seismic section BB' (location in Figure 3-2) through well WR313 H001 showing major stratigraphic features in the study area. Resistivity (RES) and gamma ray (GR) logs are shown at WR313 H001 well. High resistivity indicates presence of gas hydrate. Seismic data courtesy of WesternGeco.

Five major lithostratigraphic units are identified based on seismic reflection character and log response from existing wells WR313 H001 and WR313 G001.

Unit 1 extends from seafloor to the depth of 773 fbsf in WR313 G001 and to 520 fbsf in WR313 H001. In the seismic data Unit 1 is imaged as sub-parallel reflections (Figure 3-4). In log character, it has a high gamma ray response indicating marine mud, with few relatively thin low-gamma-ray intervals. The base of Unit 1 is defined by Horizon 1000. Unit 1 is interpreted as fine-grained hemipelagic interval, with thin, coarse-grained layers, identified as the Aqua and Yellow sands (Table 3-5 & Table 3-6). In WR313 G001, part of this unit contains very low-concentration gas hydrate in near-vertical fractures, called the Mendenhall unit.

Unit 2 extends from the base of Unit 1 (marked by Horizon 1000) to 1316 fbsf at WR313 G001 and 1038 fbsf at WR313 H001; on the well logs, gas hydrate was identified in this interval in near-vertical fractures. The gamma ray in Unit 2 are slightly lower than overlying section. Based on discontinuous and chaotic seismic reflections of variable amplitude (Figure 3-4 & Figure 3-5), we interpret this section as mass transport deposits (MTD) possibly with a higher amount of silty material compared to hemipelagic deposits described in Unit 1.

Unit 3 underlies Unit 2 (base marked by Horizon 0800) and extends down to 2,412 fbsf at WR313 G001 and 2,000 fbsf at WR313 H001). In seismic data, Unit 3 is characterized by continuous parallel reflections of moderate amplitude (Figure 3-4 & Figure 3-5), while in the wells WR313 G001 and WR313 H001, the corresponding section shows high gamma ray that changes to slightly lower gamma ray in the lower part of Unit 3. The lower boundary of this unit is a prominent seismic reflector identified as Horizon 500. Unit 3 is interpreted as a hemipelagic mud-dominated section.

Unit 4 underlies Unit 3 and extends from Hrz 500 down beneath the Upper Blue sand interval to 2,796 fbsf at WR313 G001 and 2,285 fbsf at WR313 H001. Horizon 500 is a strong seismic reflector, which has the characteristics of an erosion surface (Figure 3-4 & Figure 3-5) and is associated with abrupt increase in gamma ray in both wells. The seismic reflection data within the lower-most section of Unit 4 (below Horizon 500) is characterized by discontinuous reflections with variable amplitude. This section has been interpreted as mass transport deposits (MTD), which may be silt-rich mud as indicated by moderately low gamma ray. Very thin low gamma-ray and low resistivity streaks within this zone indicate presence of thin water-bearing coarse-grained intervals. The hydrate-bearing Upper Blue sand interval (2180-2256 fbsf in WR313 H001, 2706-2779 fbsf in WR313 G001) is near the base of this interval. The Upper Blue sand is a prominent hydrate bearing interval in both WR313 H001 and WR313 G001.

Unit 5, which underlies Unit 4, includes three major coarse-grained intervals associated with Hrz 0400 (Lower Blue sand), Hrz 0300 (Orange sand), and Hrz 0200 (Green sand); as indicated by low gamma ray values recorded in wells WR313 G001 and WR313 H001. These three coarse-grained intervals are separated by intervals of marine mud with higher gamma ray values. High resistivity, high P-wave velocity (V_P) and low density in the Blue and Orange sand indicate the presence of pore-filling, high saturation gas hydrate (Table 3-4).

In both WR313 G001 and WR313 H001, the top of Unit 5 is at the prominent reflector marked as Horizon 0400 (2,796 fbsf in WR313 G001; 2,285 fbsf in WR313 H001). The Lower Blue sand interval (just below Horizon 0400) is present in WR313 G001 well but absent or of poor quality in WR313 H001 well. Frye et al. (2012) interpreted that the Blue sand represented mud-rich intra-slope ponded submarine fan complex, with both sand sheets and leveed channels. Seismic amplitude distribution at Horizon 0400 (Blue Horizon) suggests channel and sheet-like coarse-grained deposits (Figure 3-6). The Blue sand is followed by a predominantly high gamma-ray (interpreted as mud) interval in both wells, which extends down to the top of the next major coarse-grained interval that starts just above Horizon 0300 (3370 and 2642 fbsf in WR313 G001 and WR313 H001 respectively).

In WR313 G001 a thin low gamma-ray interval can be identified at 3042-3063 fbsf, which contains both gas hydrate and low saturation gas (Hillman et al., 2017). This thin sand interval coincides with a discontinuous but locally prominent reflector, mapped as Horizon 0350 in this study and previously described as the Kiwi sand (Hillman et al., 2017).

The low gamma ray interval associated with Horizon 0300 (Orange sand) is gas hydrate bearing with high gas hydrate saturation in WR313 H001 but water-bearing and mud rich in WR313 G001 (alternatively, the Orange sand is completely missing in WR313 G001). The Orange sand as encountered in wells WR313 H001, was interpreted as coarse-grained levee deposits associated with a submarine channel (Frye et al., 2012). A NNE-SSW oriented channel, and coarse-grained levee deposits on its both flanks can be identified on an amplitude map at Horizon 0300 (Figure 3-7).

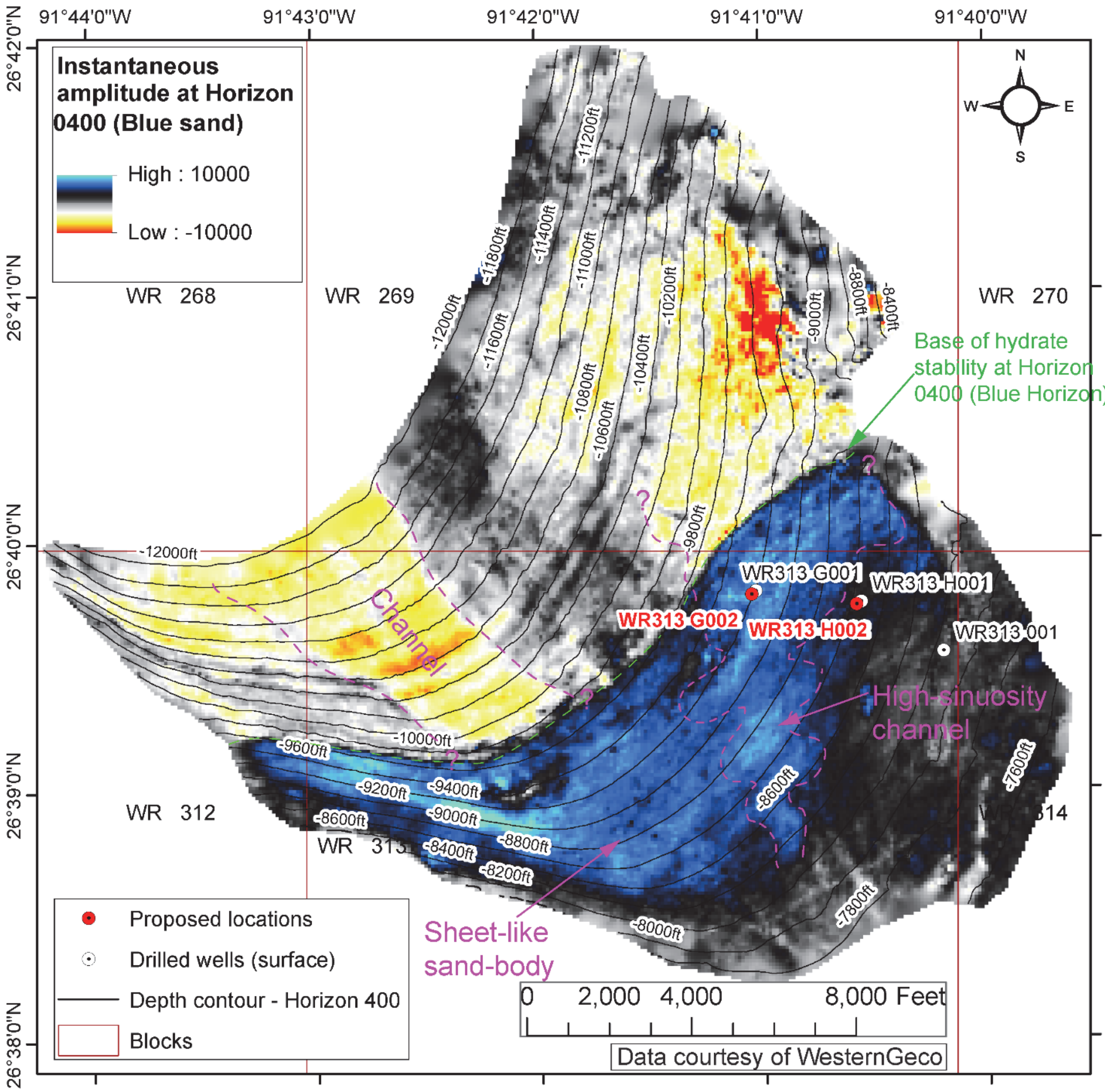

Figure 3-6. Instantaneous amplitude map extracted at Horizon 0400 (Blue Horizon) showing geological interpretation for the Blue sand – the upper of the two hydrate bearing target intervals. Maps generated from 3D seismic data used with permission of WesternGeco.

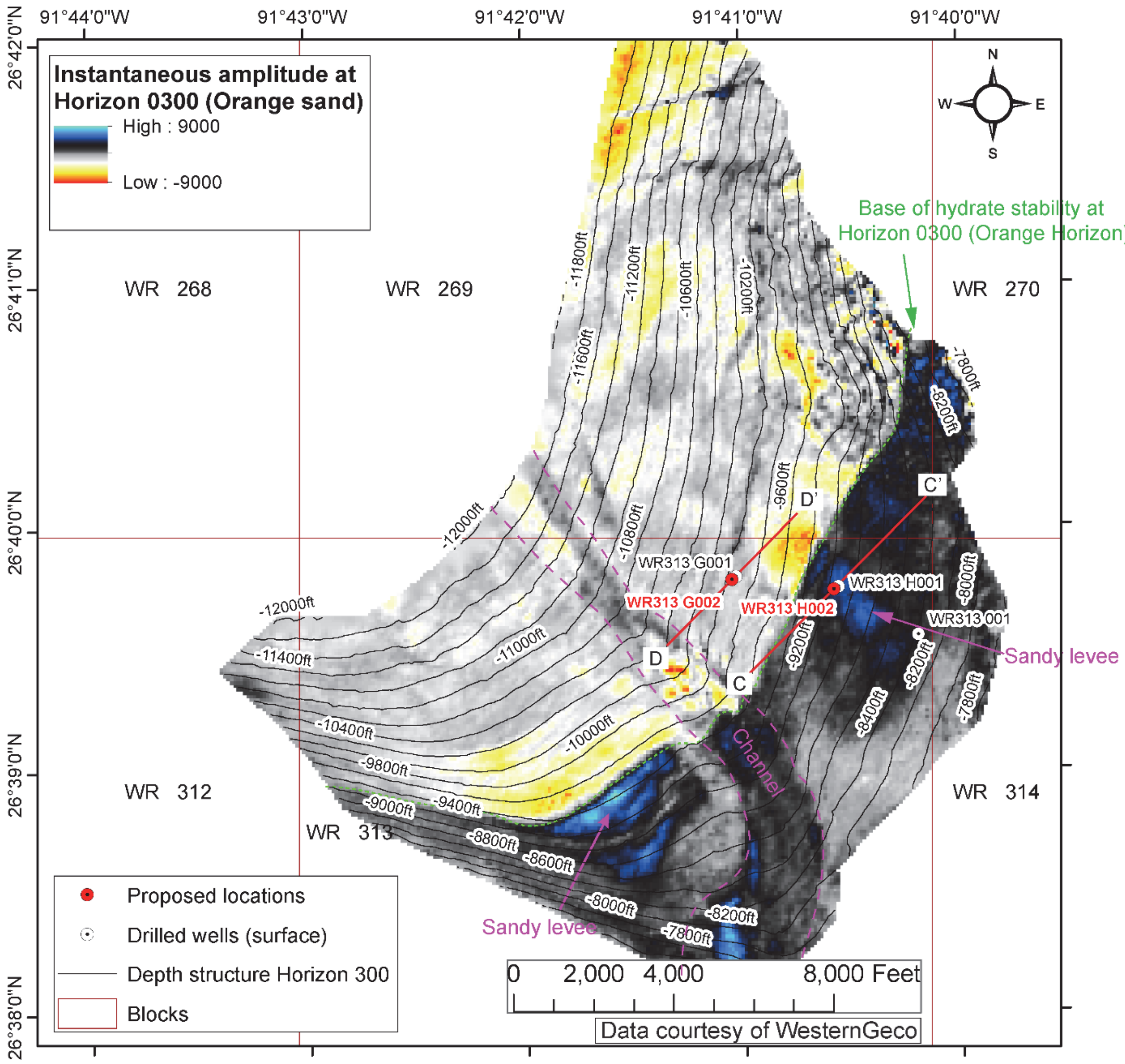

Figure 3-7. Instantaneous amplitude map extracted at Horizon 0300 (Orange Horizon) showing geological interpretation for the Orange sand – the lower of the two hydrate bearing target intervals. The well WR313 H001 and the proposed location WR313 H002 target gas hydrate-bearing sandy levee deposits showing strong positive amplitude response. Maps generated from 3D seismic data used with permission of WesternGeco.

3.4 Top Hole Prognosis

3.4.1 Identification and projection of tops from existing well data

Major boundaries were identified in WR313 H001 and WR313 G001, including tops and bases of coarse-grained units and hydrate-bearing marine mud units. These were tied to the seismic data to identify corresponding seismic reflections. The seismic reflections were then projected to the proposed locations. The WR313 H002 and WR313 G002 wells are located ~50 feet from the original locations. We estimated the tops depth at the new wells by examining the difference in seismic depths between the existent well location and the projected location. We identified the depth of the events in the new wells by adding or subtracting the difference in seismic depth to the tops mapped in the known well (Table 3-5 and Table 3-6).

3.4.2 WR313 H002

WR313 H002 is located ~51.5 ft to the SW, approximately along strike from the well WR313 H001 (Table 3-3 and Figure 3-2). WR313 H001 was drilled previously without incident (Collett et al., 2009). A top-hole prognosis for WR313 H002 is shown in Figure 3-8 and Table 3-5. The seafloor at WR313 H002 is projected to be at 6460 feet below sea level (fbsl). We infer we will encounter similar lithology and horizon depths as the WR313 H001 well.

Unit 1 (0-524.4 fbsf) is composed of mud interlayered with thin coarse-grained layers. Within this mud interval, there are two intervals containing coarse-grained sediments, identified as the Aqua sand (203.0-265.5 fbsf, with a total of 12 ft of sand) and the Yellow sand (336.4-347.4 fbsf, with a total of 9.5 ft of sand) (Table 3-5). Both coarse-grained layers likely water-saturated however, the Aqua sand might contain a low concentration of gas hydrate in a ~1.5 ft thick interval. These intervals correlate with seismic reflections that are continuous between wells; the Aqua Sand has positive polarity and the Yellow sand has negative polarity. In the WR313 H001 well, Unit 1 was drilled with only water and occasional gel sweeps (Collett et al., 2009). No flows into the well bore were reported.

Unit 2 (524.4-1041.2 fbsf) is composed of mud with hydrate in near-vertical fractures and is called the JIP mud unit. The interval is interpreted as a mass transport deposit and is more compacted or de-watered than the overlying mud. The Red sand, an 8 ft thick coarse-grained layer is present in this interval at 957.8-965.8 fbsf (Table 3-5) and has hydrate at high saturation. The Red sand does not connect between the drilled wells WR313 H001 and WR313 G001. The Red sand is associated with a mappable seismic reflection (Horizon 0800), however, reflection characteristics are laterally variable. In the WR313 H001 well, this unit was drilled with only water and occasional gel sweeps (Collett et al., 2009). No flows into the well bore were reported.

Unit 3 (1041.2 -2000 fbsf) is predominantly mud with one interval containing water-bearing thin coarse-grained layers (1098.6-1101.6 fbsf) and two thin marine muds containing pore-filling hydrate (1717.6-1723.6 fbsf and 1838-1852 fbsf) (Table 3-5).

Unit 4 (2000-2292.1fbsf) is a muddy mass transport deposit, with two coarser intervals. The upper interval is a thinly-bedded hydrate-bearing coarse-grained interval (2015.3-2041.3 fbsf, total thickness of coarse-grained sediments is 12 ft). The lower interval is part of our key reservoirs for coring: the hydrate-bearing, thinly bedded Upper Blue sand interval (2187-2263 fbsf, total thickness of coarse-grained layers is 13 feet).

Unit 5 (beginning at 2292.1) is predominantly mud but contains one hydrate bearing thin pore-filling mud interval (2586.3-2588.3 fbsf) and the Orange sand (2649.9-2693.9, total thickness of coarse-grained sediments is 39 ft), which is a thick hydrate-bearing reservoir and the primary coring target in WR313 H002. The BHSZ is likely to be encountered at WR313 H002 at approximately 2900 fbsf, however, there is no indication of this event on the well logs or seismic at the H002 location. The total depth of the well will be 3010 fbsf and it will lie within Unit 5. Based on interpolation of the BSR from nearby locations, the base of the hydrate stability zone is interpreted to be at 2900 fbsf. Thus, the well will cross the base of the hydrate stability zone. However, Unit 5 is composed of marine muds and no hydrate or free gas is expected in this interval as was demonstrated by the adjacent WR313 H001 well.

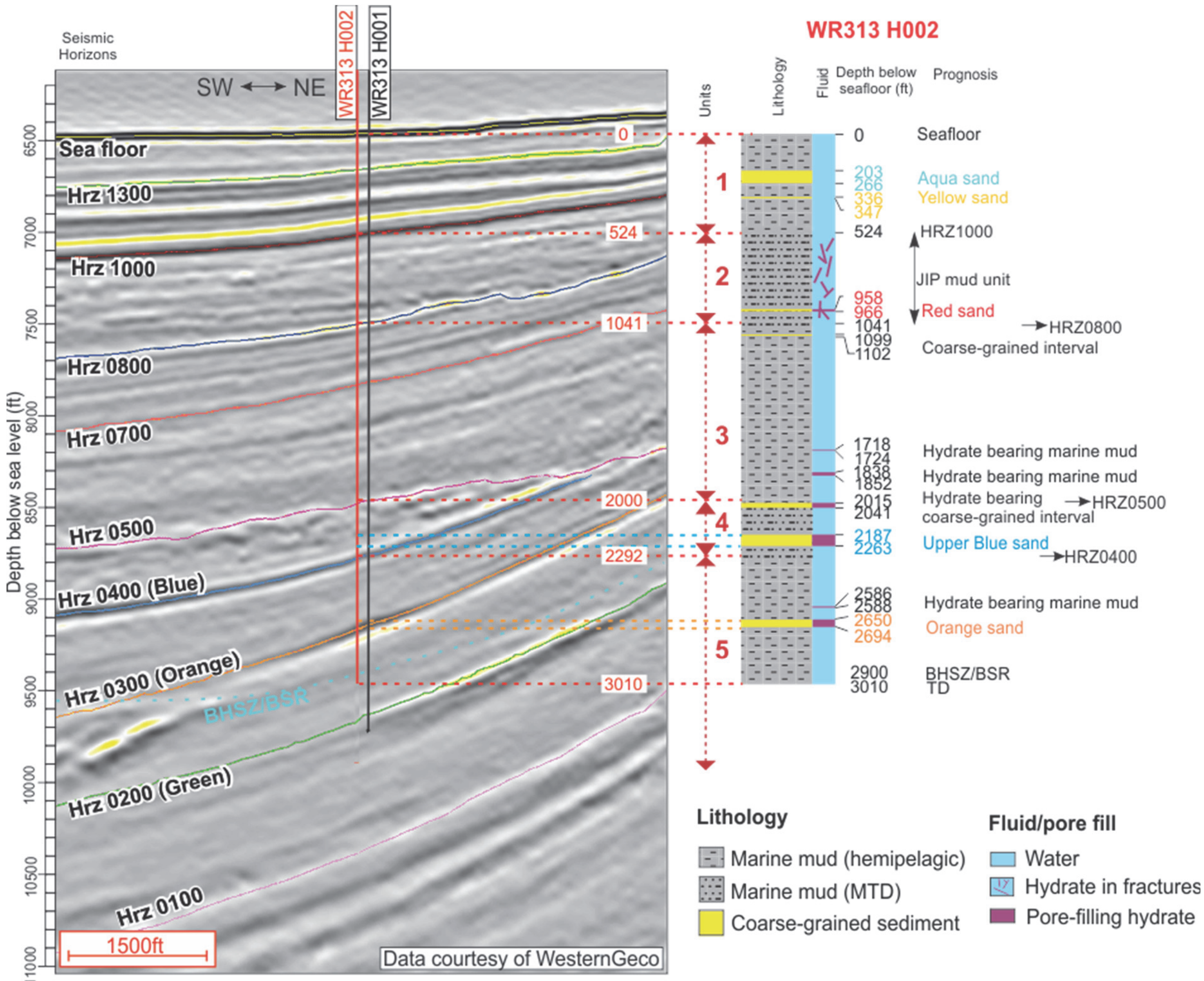

Figure 3-8. Seismic cross section CC' through Location WR313 H002 with interpreted lithology , hydrocarbon presence and major stratigraphic tops. Lithologic units (Units 1, 2, 3, 4, and 5) are marked next to lithology column in red; The line of section is located in Figure 3-7.

Table 3-5. Projected tops for the proposed location WR313 H002 (Table 3-3).

			Water depth (ft)	Drilled Footage (fbsf)	Total depth (fbsl)
WR313 H002			6,460.0	3,010.0	9,470.0
Events, Sands & Units			**WR313 H001**	**WR313 H002**	
			Depth (fbsf)	Projected Depth (fbsf)	Projected Depth (fbsl)
Seafloor			-	-	6,460.0
water bearing **Aqua sand**	Top	**Unit 1**	201.5	203.0	6,663.0
	Base		264.0	265.5	6,725.5
water bearing **Yellow sand**	Top		333.0	336.4	6,796.4
	Base		344.0	347.4	6,807.4
Horizon 1000			520.0	524.4	6,984.4
JIP mud unit with low concentration hydrate	Top	**Unit 2**	520.0	524.4	6,984.4
hydrate bearing **Red sand**	Top		958.0	957.8	7,417.8
	Base		966.0	965.8	7,425.8
JIP mud unit with low concentration hydrate	Base		1,038.0	1,041.2	7,501.2
Horizon 0800			1,038.0	1,041.2	7,501.2
water bearing coarse-grained interval	Top	**Unit 3**	1,096.0	1,098.6	7,558.6
	Base		1,100.0	1,101.6	7,561.6
hydrate bearing marine mud	Top		1,716.0	1,717.6	8,177.6
	Base		1,722.0	1,723.6	8,183.6
hydrate bearing marine mud	Top		1,832.0	1,838.0	8,298.0
	Base		1,846.0	1,852.0	8,312.0
Horizon 0500			2,000.0	2,000.0	8,460.0
hydrate bearing coarse-grained interval	Top	**Unit 4**	2,017.0	2,015.3	8,475.3
	Base		2,042.0	2,041.3	8,501.3
hydrate bearing **Upper Blue sand**	Top		2,180.0	2,187.0	8,647.0
	Base		2,256.0	2,263.0	8,723.0
Horizon 400			2,285.0	2,292.1	8,752.1
hydrate bearing marine mud	Top	**Unit 5**	2,578.0	2,586.3	9,046.3
	Base		2,580.0	2,588.3	9,048.3
hydrate bearing **Orange sand**	Top		2,642.0	2,649.9	9,109.9
	Base		2,686.0	2,693.9	9,153.9
Interpreted base of hydrate stability			2,935.0	2,935.0	9,395.0
WR313 H002 TD				3,010.0	9,470.0

3.4.3 WR313 G002

The surface location for WR313 G002 is 46 feet west of WR313 G001 (Table 3-3 and Figure 3-2). A top-hole prognosis for WR313 G002 is shown in Figure 3-9 and Table 3-6. The seafloor at WR313 G002 is ~ 6567 fbsl. We expect to encounter similar lithology and stratigraphy as the WR313 G001 well.

Unit 1 (0-773.8 fbsf) is composed of mud interlayered with thin coarse-grained sediments. Within the mud interval, there is a unit containing low concentrations of gas hydrate in near-vertical fractures, which is called the Mendenhall unit (Hillman et al., 2017) from 106.6 to 349.3 fbsf (Figure 3-9 and Table 3-6). Below the Mendenhall, there are two intervals containing thin coarse-grained sediments, identified as the Aqua sand (349.3-432.3 fbsf, with a total of 40 ft of sand) and the Yellow sand (500.2-539.2 fbsf, with a total of 19 ft of sand) (Table 3-6). Both are water-saturated however, the Aqua sand has a 5 ft thick layer where gas hydrate appears in the sand in WR313 G001. The Aqua and Yellow sand intervals are associated with seismic reflections that are continuous between wells. In the WR313 G001 well, this unit was drilled with only water and occasional gel sweeps (Collett et al., 2009). No flows into the well bore occurred.

Unit 2 (773.8-1316.8 fbsf) is composed of mud with hydrate in near-vertical fractures, and is called the JIP mud unit (Figure 3-9 and Table 3-6). The interval is interpreted as a mass transport deposit and is more compacted or de-watered than the overlying mud. In the WR313 G001 well, this unit was drilled with only water and occasional gel sweeps (Collett et al., 2009). No flows into the well bore occurred.

Unit 3 (1316.8-2419.1 fbsf) is predominantly mud with a number of coarser-grained layers. Near the top of the unit there is a water-bearing coarse-grained layer from 1651.3-1733.3 ft (with a total of 30 ft of coarse-grained sediments in this layer). The Purple sand occurs from 1979.3 to 1989.3 and contains high saturation, pore-filling gas hydrate. Farther down, there is a series of thin mud-rich layers between 2 and 8 ft thick that contain pore-filling gas hydrate (Figure 3-9 and Table 3-6).

Unit 4 (2419.1– 2806.2 fbsf) hosts another water-bearing coarse-grained interval (2693.2 – 2697.2) and the Upper Blue sand (2714.4-2787.4). The Upper Blue sand is a reservoir targeted for coring, and contains high-saturation gas hydrate in a total of 27 ft of coarse-grained sediment.

Unit 5 (beginning at 2806.2) contains the Lower Blue sand interval, from 2813.6-2873.6 fbsf, and has a total of 30 ft of high saturation gas hydrate in coarse-grained sediments, which is one of our key reservoir intervals for coring. Below the Lower Blue at the BHSZ, there is a thin coarse-grained layer (total of 7 ft of coarse-grained sediments) called the Kiwi Sand (from 3051.4 – 3072.4 fbsf). The Kiwi sand has a mix of gas hydrate at high saturation, water bearing intervals, and a very low gas saturation.

The planned total depth of WR313 G002 is 3085 fbsf.

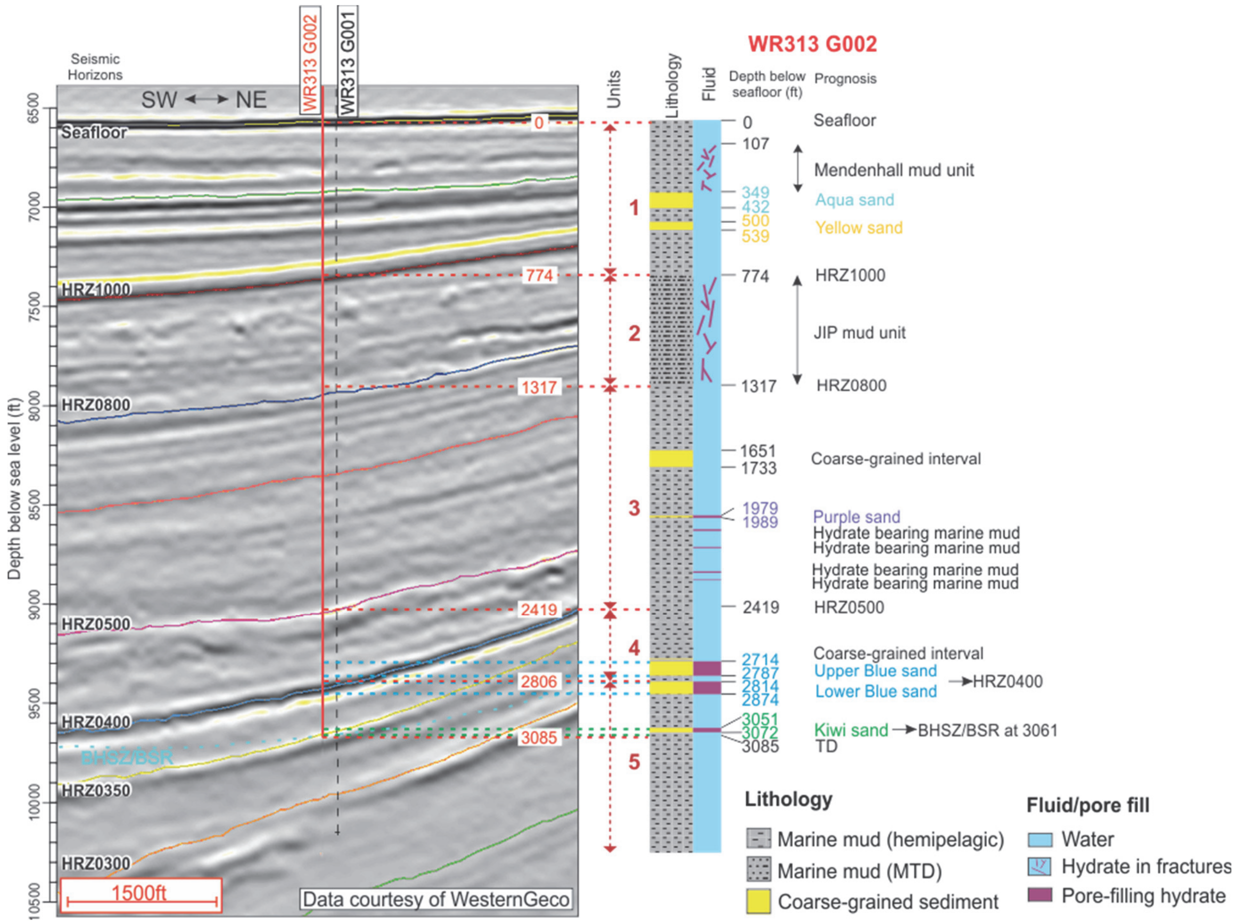

Figure 3-9. Seismic cross section DD' through Location WR313 G002 with interpreted lithology , hydrocarbon presence and major stratigraphic tops. Lithologic units (Units 1, 2, 3, 4, and 5) are marked on lithology column in red; the line of section is located in Figure 3-7.

Table 3-6. Projected tops for the proposed location WR313 G002 (Table 3-3).

			Water depth (ft)	**Drilled Footage (fbsf)**	**Total depth (fbsl)**
WR313 G002			6,567.0	3,085.0	9,652.0
Events, coarse-grained interval & Units			**WR313 G001**	**WR313 G002**	
			Depth (fbsf)	Projected Depth (fbsf)	Projected Depth (fbsl)
Seafloor			-	-	6,567.0
Mendenhall mud unit with low concentration hydrate	Top	**Unit 1**	102.0	106.6	6,673.6
	Base	**Unit 1**	347.0	349.3	6,916.3
water bearing **Aqua sand**	Top	**Unit 1**	347.0	349.3	6,916.3
	Base	**Unit 1**	430.0	432.3	6,999.3
water bearing **Yellow sand**	Top	**Unit 1**	499.0	500.2	7,067.2
	Base	**Unit 1**	538.0	539.2	7,106.2
Horizon 1000			773.0	773.8	7,340.8
JIP mud unit with low concentration hydrate	Top	**Unit 2**	773.0	773.8	7,340.8
	Base	**Unit 2**	1,316.0	1,316.8	7,883.8
Horizon 0800			1,316.0	1,316.8	7,883.8
water bearing coarse-grained interval	Top	**Unit 3**	1,644.0	1,651.3	8,218.3
	Base	**Unit 3**	1,726.0	1,733.3	8,300.3
hydrate bearing **Purple sand**	Top	**Unit 3**	1,972.0	1,979.3	8,546.3
	Base	**Unit 3**	1,982.0	1,989.3	8,556.3
hydrate bearing marine mud	Top	**Unit 3**	2,040.0	2,045.9	8,612.9
	Base	**Unit 3**	2,047.0	2,052.9	8,619.9
hydrate bearing marine mud	Top	**Unit 3**	2,132.0	2,135.4	8,702.4
	Base	**Unit 3**	2,140.0	2,143.4	8,710.4
hydrate bearing marine mud	Top	**Unit 3**	2,240.0	2,251.9	8,818.9
	Base	**Unit 3**	2,250.0	2,261.9	8,828.9
hydrate bearing marine mud	Top	**Unit 3**	2,278.0	2,289.7	8,856.7
	Base	**Unit 3**	2,282.0	2,293.7	8,860.7
Horizon 0500			2,412.0	2,419.1	8,986.1
water bearing coarse-grained interval	Top	**Unit 4**	2,680.0	2,693.2	9,260.2
	Base	**Unit 4**	2,684.0	2,697.2	9,264.2
hydrate bearing **Upper Blue sand**	Top	**Unit 4**	2,706.0	2,714.4	9,281.4
	Base	**Unit 4**	2,779.0	2,787.4	9,354.4
Horizon 0400			2,796.0	2,806.2	9,373.2
hydrate bearing **Lower Blue sand**	Top	**Unit 5**	2,806.0	2,813.6	9,380.6
	Base	**Unit 5**	2,866.0	2,873.6	9,440.6
hydrate bearing **Kiwi sand**	Top	**Unit 5**	3,042.0	3,051.4	9,618.4
BSR		**Unit 5**	3,058.0	3,061.0	9,628.0
hydrate bearing **Kiwi sand**	Base	**Unit 5**	3,063.0	3,072.4	9,639.4
WR 313 G002 TD				3,085.0	9,652.0

3.5 Borehole Temperature and Hydrate Stability Field

In-situ temperatures and the methane hydrate stability-boundary have been estimated for the proposed WR313 locations (Figure 3-10). The in-situ temperatures were estimated based on the following assumptions: 1) the base of the hydrate stability zone at three-phase equilibrium 2) seawater salinity of 35 ppt, 3) pore pressure gradient of 0.465 psi/ft, 4) seafloor temperature of 4.0 °C or 39.2 °F (Boyer et al., 2018), and 5) temperature increasing linearly with depth from the seafloor. The base of the hydrate stability zone at the well locations was estimated using the BSR identified and mapped in 3D seismic data, and tied-to the depth of the Kiwi sand in existing well WR313 G001 (Table 3-6).

The predicted in situ temperature at WR313 G001 and WR313 H001 wells are shown as blue dashed line and green dashed line respectively (Figure 3-10). At the WR313 G001 well, we estimate the temperature at the base of the hydrate stability zone to be 72.1°F (22.3°C) and the gradient to be 10.7° F/1000 ft (5.9°C/1000 ft). At the WR313 H001 well, we estimate the temperature at the base of the hydrate stability zone to be 71.7°F (22.0 °C) and the gradient to be 11.0°F/1000 ft (6.1°C/1000 ft). The recorded temperature at WR313 G001 and WR313 H001 wells (blue and green lines respectively in Figure 3-10) show that flushing of the cooler drilling fluid brings down the borehole temperature considerably below the in-situ temperature, making the borehole more stable for hydrates.

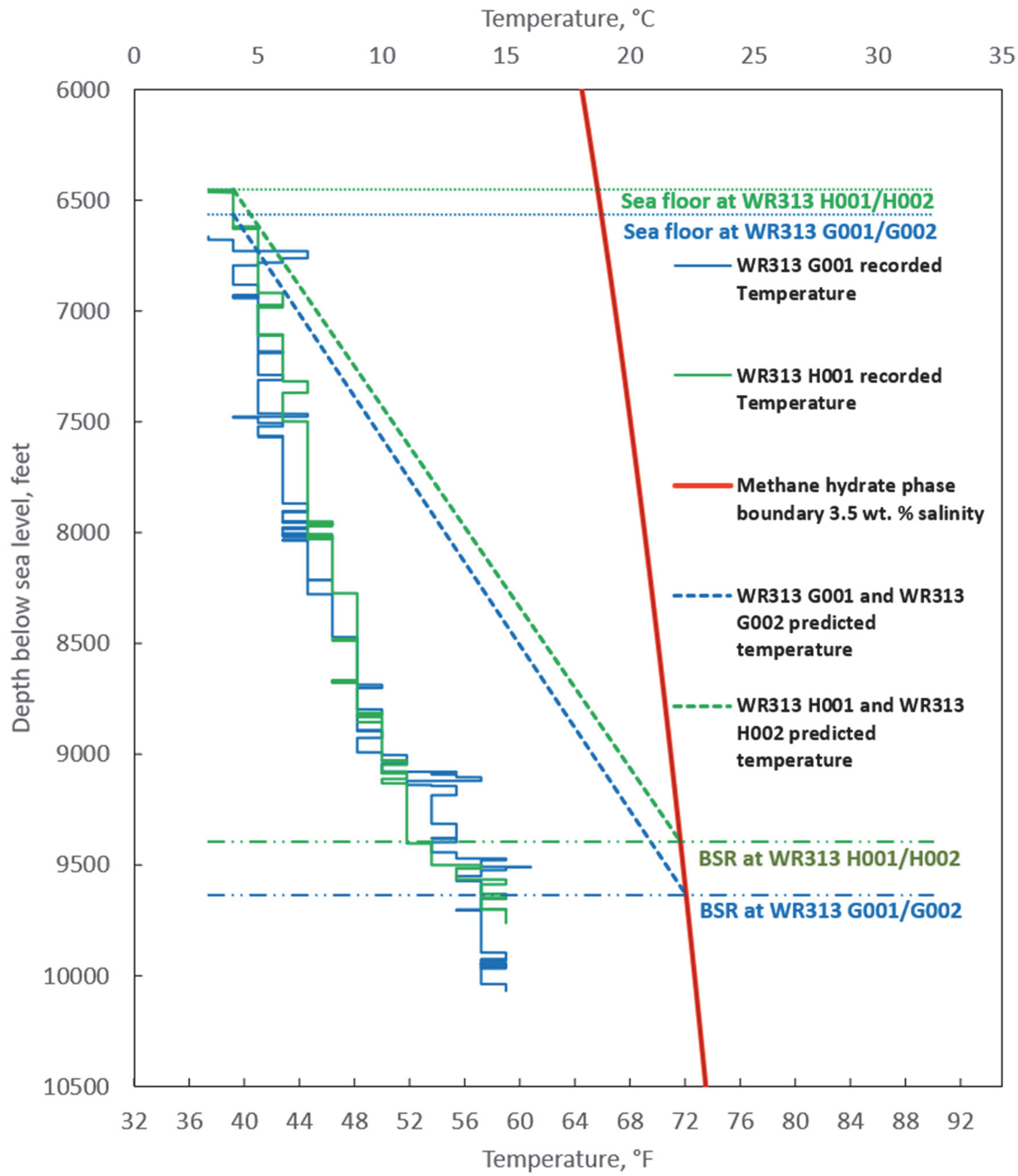

Figure 3-10. Estimated thermal gradient for WR313 G001 (blue dashed line) and WR313 H001 (green dashed line), in comparison with recorded borehole temperature (solid blue and green lines). Methane hydrate is stable on the left side of the hydrate stability phase boundary plotted in red. Horizontal lines represent interpreted base of hydrate stability zone in the wells, which intersect the corresponding predicted in situ temperature profiles at the hydrate stability phase boundary.

3.6 Pore Pressure Plots

3.6.1 Methodology

Based on seismic interpretation and offset well information from WR313 H001 and WR313 G001, the formations penetrated at the proposed locations are expected to be normally pressured. Figure 3-11 illustrates the well paths for the planned WR313 G002 well and the planned WR313 H002 well. This diagram emphasizes the location of the wells relative to significant hydrate reservoirs (the Blue, Orange, and Green sand). Although the Green sand is interpreted to be a significant hydrate-bearing reservoir, we will not be able to penetrate it in the hydrate-bearing section based on our decision to locate our wells at the previously drilled WR313 H001 and WR313 G001 locations (Figure 3-11). Within these reservoirs, we interpreted a gas leg to be present down dip from the hydrate-bearing zones (red zones, Figure 3-11). No gas leg is interpreted to be present in the Purple sand, and we have not included it in the diagram. The wells, which were all drilled in these locations previously without incident, are designed to avoid encountering free gas beneath the hydrate stability zone by penetrating the sands in the hydrate bearing intervals (green zones, Figure 3-11). Where we will penetrate the Blue and the Orange sand (Figure 3-11), we are at least 1,000 feet laterally away from the gas leg. We will penetrate the Kiwi sand at its gas-water contact (Figure 3-11). However, the sand is very thin and a significant gas leg is not interpreted to be present.

We generated pore pressure and fracture gradient plots for WR313 H002 (Figure 3-12) and WR313 G002 (Figure 3-13). The plots are based on the following assumptions. 1) The overburden stress (σ_v) was generated by integrating the density log from the LWD data acquired in WR313 H001 and WR313 G001. In zones where there were washouts and the density values recorded values near the density of water, density values were interpolated from the overlying and underlying zones to more effectively determine the overburden. 2) Pore water pressure was assumed to be hydrostatic (u_h) because there was no evidence of any elevated pore pressures during previous drilling of these wells. Hydrostatic pore pressure (u_h) is expressed with a pore pressure gradient of 8.95 ppg, or seawater gradient of 0.465 psi/ft. 3) The least principle stress (σ_{hmin}) was estimated using Equation 3-1.

Equation 3-1

$$\sigma_{hmin} = K * (\sigma_v - u_h) + u_h$$

Equation 3-1 is commonly used to model the fracture gradient (Eaton, 1969). K is termed the effective stress ratio and is equal to the ratio of the horizontal effective stress to the vertical effective stress. It is commonly used to model least principal stress in sedimentary basins. It is commonly observed in deepwater wells that in the shallow section (e.g. 1,000 feet below mud line), K values can approach 1.0. An upper bound of K = 0.9 and a lower bound of K = 0.7 is assumed (green dashed line and orange dashed line in Figure 3-12 and Figure 3-13).

The WR313 H002 well penetrates both the Orange and Blue sands in the hydrate-bearing interval (Figure 3-11). The WR313 H001 well at this location was drilled without incident with 10.5 PPG mud. We will drill with 10.5 PPG mud below 1600' ("mud program" in Figure 3-12). There is a gas leg in the Orange and Blue sands that is offset from the drilling location (e.g., Figure 3-11). Direct experience (two wells were drilled in this area) and observations of very low permeability in hydrate bearing intervals support that we will not observe these gas pressures at the location where the wells penetrate the hydrate-bearing interval.

The WR313 G002 well penetrates only the Blue sands in the hydrate-bearing interval (Figure 3-11). We illustrate a pore pressure plot of this well in Figure 3-13. The WR313 G001 well at this location was drilled without incident with 10.0 PPG mud. We will drill with 10.5 PPG mud below 1600' ('mud program', Figure 3-13). There is a gas leg in the Orange and Blue sands that is offset from the drilling location (e.g., Figure 3-11). Direct experience (two wells were drilled in this area) and observations of very low permeability in hydrate bearing intervals support the interpretation that we will not observe these gas pressures where the well penetrates the hydrate-bearing interval.

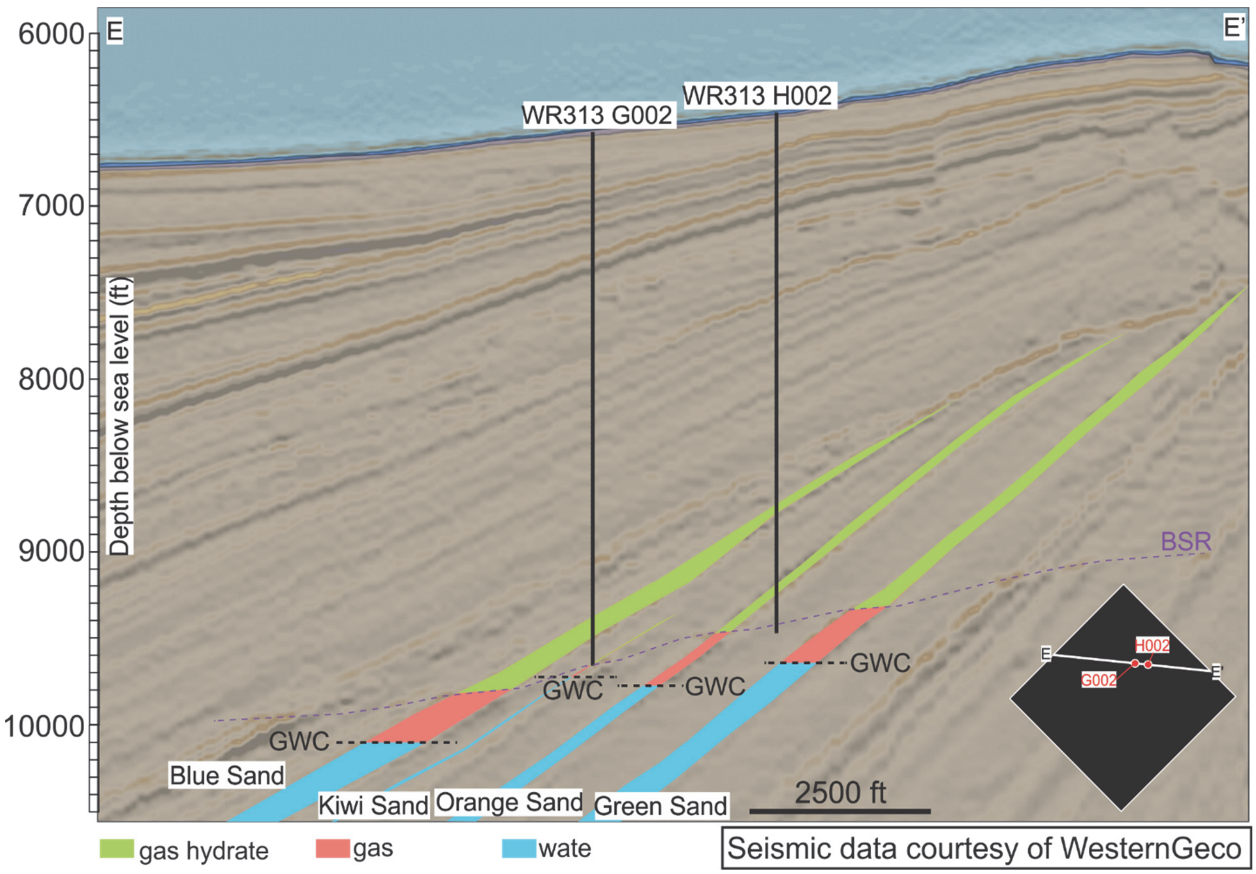

Figure 3-11. Seismic section EE' through proposed wells, showing hydrate-bearing sands, hydrate-gas contacts, and gas-water contacts.

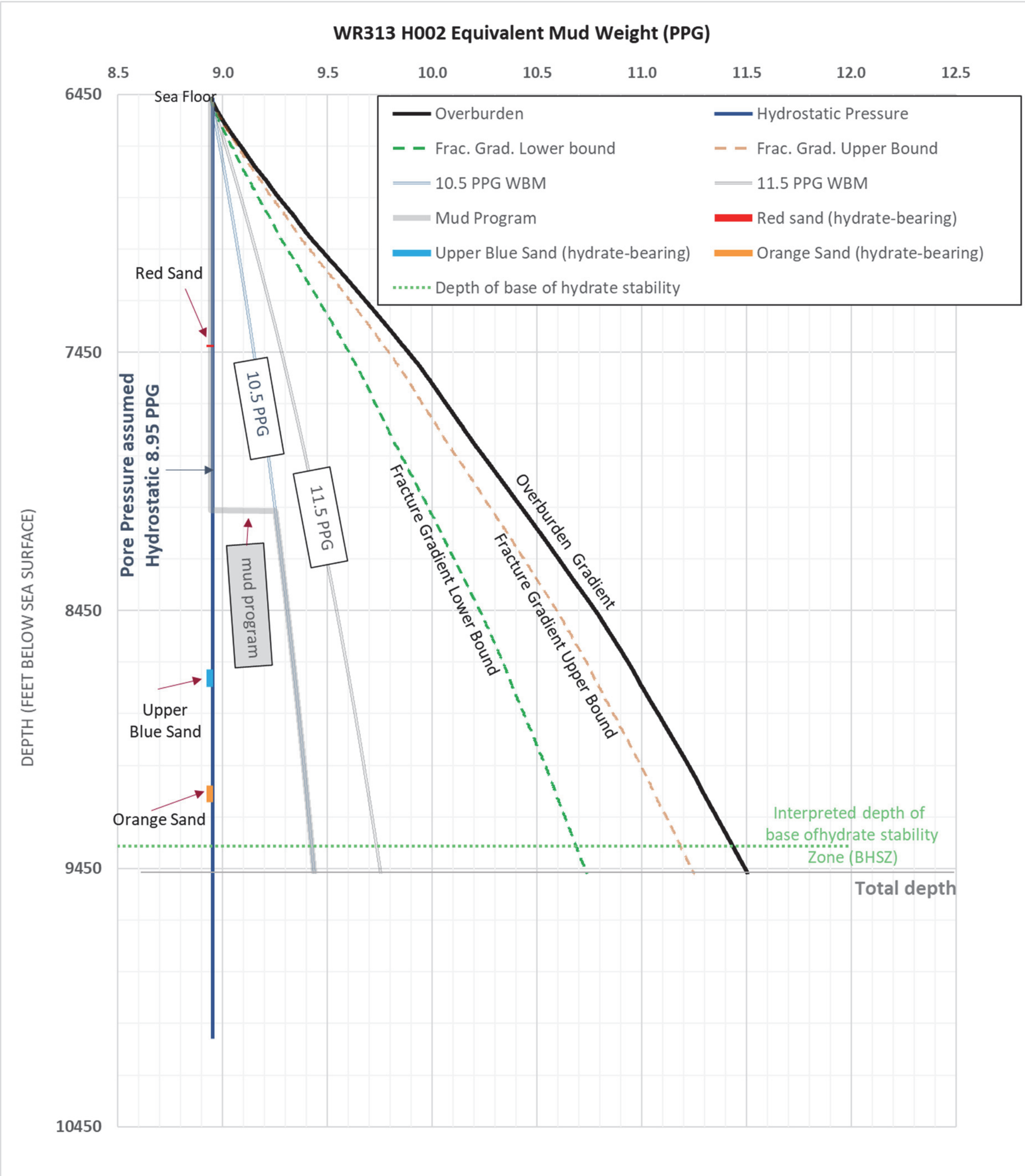

Figure 3-12. Equivalent mud weight plot for the planned WR313 H002.

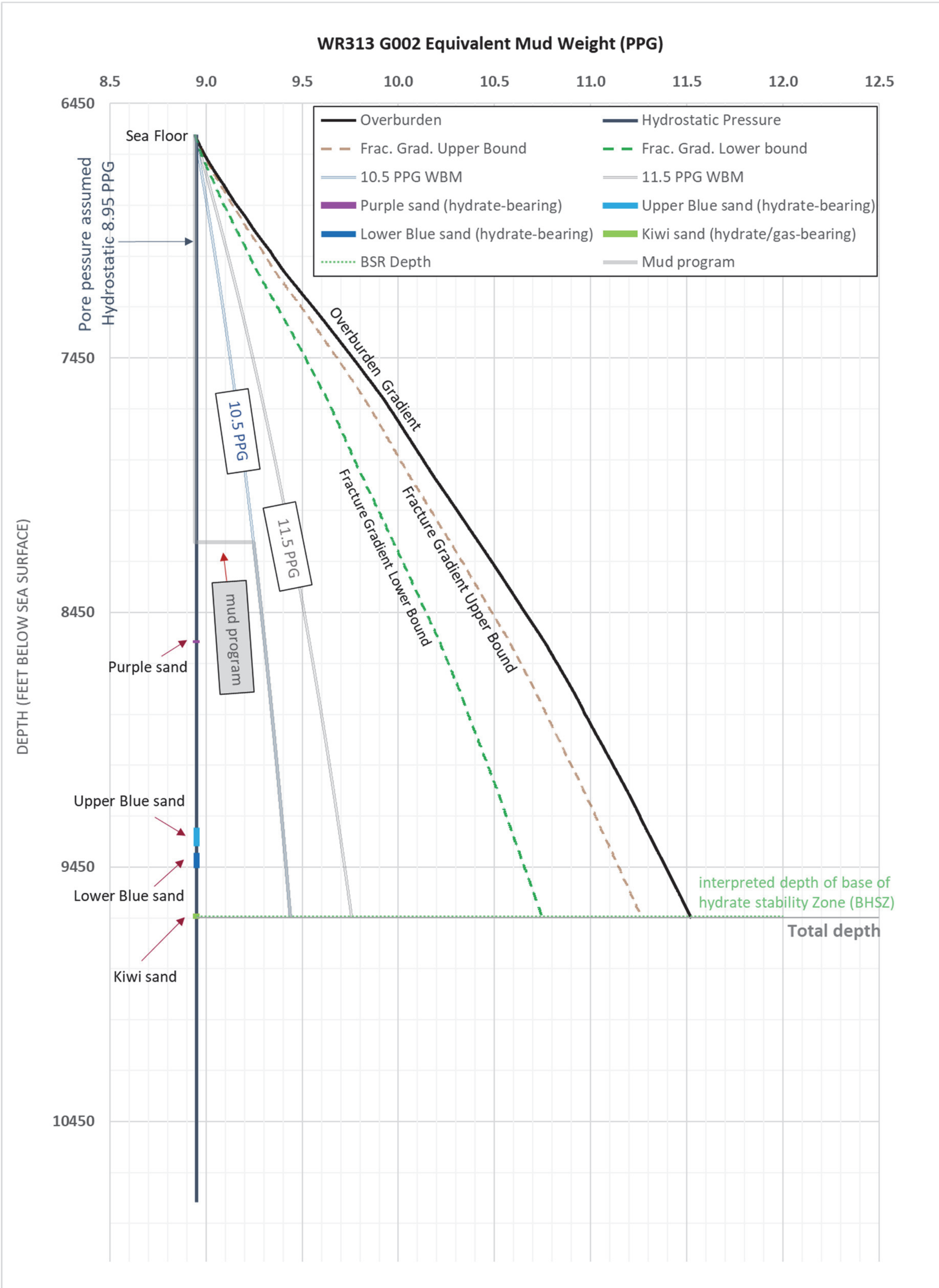

Figure 3-13. Equivalent mud weight plot for planned WR313 G002.

3.6.2 Previous drilling

From the Gulf of Mexico Gas Hydrate Joint Industry Project Leg II: Logging-While-Drilling Operations and Challenges (Collett et al., 2009) and the IADC Drilling Reports for WR313 G and WR313 H wells:

WR313 G001 was drilled during the Gulf of Mexico JIP Leg II (April 17-April 21, 2009) using LWD technology. The seafloor was tagged at 6,614 ft md RKB (includes 52 ft air gap). A dual diameter BHA, with a 6-3/4" drill bit followed by an 8-1/2" hole opener, was used to drill from mudline to total depth at 10, 200 md RKB (3,586 fbsf). From spud to 7,116 ft md RKB (0-502 fbsf) instantaneous ROP ranged from 70 to >400 ft/hr with rate of rotation between 0 to-100 rpm. From 7, 116 to 9,244 ft md RKB (502-2,630 fbsf), drilling was performed using seawater pumped at 380-410 gpm with sweeps of 10.5 ppg drilling fluid as needed. The instantaneous ROP within this interval ranged between 70 and 200 ft/hr with the average of ~150 ft/hr. Drilling was slowed to 100 ft/hr when capturing higher resolution log images over a zone of interest. A thick unit with elevated resistivity (4-10 Ωm) and gas hydrate in near-vertical fractures in the marine mud was found from 7,458 to 7,850 ft md RKB (844-1,236 fbsf). From 8,264 md RKB (1,650 fbsf), it became necessary to backream each stand. Drilling became difficult despite an increase in mud sweeps. Rotary speed was increased to 120 rpm in response to torque, and the drill string would occasionally pack-off despite multiple backreams per stand. It became increasingly more difficult to maintain hole stability and remove drill cuttings from the hole. It is important to note that the backreaming employed in WR313 G001 was not done for precautionary reasons, it was done in response to the observed increases in torque and was conducted to protect the LWD BHA and to advance the hole. Due to a major packoff at 9,244 ft md RKB (2,630 fbsf), stalling the rotary and requiring ~140k lbs of overpull to free the drill string, drilling continued using 10 ppg WBM. The main target (~70-ft gross thickness high-saturation gas hydrate) was encountered at 9,412 ft md RKB (2,798 fbsf). The average instantaneous ROP increased to ~270 ft/hr. Drilling continued using 10 ppg WBM down to 9,598 ft md RKB (2,984 fbsf) where the mud weight was increased to 10.5 ppg due to issues with torque. After the total depth of 10,200 ft md RKB (3,586 fbsf) was reached, the hole was displaced to 12 ppg WBM for abandonment. Max overpull of 90 klbs at 7,890 ft md RKB (1,276 fbsf) was experienced on the trip out of the hole.

It appears that the occurrence of gas hydrate provided some resistance to mechanical erosion with most of the hydrate-bearing sand sections exhibiting near in-gauge borehole calipers with no significant washouts. Excessive backreaming was shown to adversely affect the quality of the acquired downhole log data. Despite the large volumes of gas hydrate drilled during the GOM JIP Leg II, most of the drilling problems encountered were attributed to common drilling problems, including drill cuttings removal.

WR313 H001 was also drilled during Gulf of Mexico JIP Leg II from Q4000 (April 29-May 1, 2009) using LWD technology. The seafloor was tagged at 6,501 ft md RKB (includes 52 ft air gap). A dual diameter BHA, with a 6-3/4" drill bit followed by an 8-1/2" hole opener, was used to drill from mudline to total depth at 9,886 ft md RKB (3,385 fbsf). The well spud protocol, developed to maintain good borehole conditions at the top of the hole, was followed: The first ~60 ft of the hole was drilled while circulating between 200-250 gpm of seawater and a rate of rotation of about 10-50 rpm. From 6,561 to 6,671 ft md RKB (60 - 170 fbsf), the pump rate was slowly increased to ~250 gpm and the bit-rotation was increased to 50 rpm; after which point the drilling parameters were increased to 350 gpm and ~70 to 110 rpm. At 6,841 md RKB (340 fbsf), the pump rate was increased to 385 gpm to facilitate MWD directional surveys. From 6,501-8,501 ft md RKB (0-2,000 fbsf), the hole was drilled using seawater with WBM sweeps pumped very few stands. Fracture filling gas hydrate was encountered at 7,050-7,400 ft md RKB (549-

899 fbsf). At 8,501 ft md RKB (2,000 fbsf), the instantaneous ROP was decreased to ~160 ft/hr in preparation for drilling the target zone of interest and the drilling fluid was changed to 10.5 ppg WBM. The controlled ROP of ~160 ft/hr and use of 10.5 ppg WBM continued for the remainder of the well. The primary target, consisting of two hydrate-bearing sand lobes (~15 ft and ~21 ft gross thickness), was encountered at ~9,096 ft md RKB (2,595 fbsf). After reaching the total depth of 9,886 ft md RKB (3,385 fbsf), the hole was circulated with 10.5 ppg drilling fluid, followed by displacement to 12 ppg WBM for abandonment.

Additional information on the drilling history can be found in the Gas Hydrate Joint Industry Project Leg II operational summary (Collett et al., 2009).

4 Drilling Program

The UT-GOM2-2 Scientific Drilling Program calls for penetrating several potential hydrate bearing sands throughout the boreholes. Cores, both unpressurized conventional and pressurized, will be acquired at various depths throughout the boreholes. Based on drilling results from the 2009 JIP II Methane Hydrate LWD program, anticipated typical drilling/coring operations are as follows.

1. Drill/core to the top of the uppermost hydrate bearing zone with the potential to flow, or a maximum depth of 8103 fbsl (1640 fbsf) in Hole WR313 H002 and a maximum depth of 8212 fbsl (1640 fbsf) in Hole WR313 G002, while circulating sea water and pumping 10.5 ppg high viscosity mud sweeps as required for hole cleaning.
2. Prior to penetrating the uppermost hydrate zone with the potential to flow, or a maximum depth of 8103 fbsl (1640 fbsf) in Hole WR313 H002 and a maximum depth of 8212 fbsl (1640 fbsf) in Hole WR313 G002, begin continuous circulation of 10.5 ppg water-based mud for better hole cleaning, increased hole stability, and to counterbalance any overpressure from gas or water that may be present, and pumping 10.5 ppg high viscosity mud sweeps as required for hole cleaning.
3. At total depth (TD), displace borehole to 11.5 ppg high viscosity pad mud to support the cement plug from TD to approximately 150 feet above the upper most hydrate bearing zone with the potential to flow.
4. Emplace a cement plug beginning approximately 150 feet above the uppermost hydrate bearing zone with the potential to flow and extending upward for 500 feet.
5. Displace borehole with 11.0 ppg mud from top of cement plug to seafloor.
6. All boreholes will be visually observed via ROV continuously from spud to abandonment with an electronic video made and archived.
7. H_2S precautions will be taken when retrieving cores above sulfate-methane transition (SMT) (0 to approximately 65 fbsf) and within the SMT zone in WR313 G002, as H_2S may be entrained in the cores. No cores will be taken above or within the SMT in WR313 H002. Neither well will have circulation back to surface while drilling/coring through the shallow interval above the SMT. Walker Ridge 313 has been classified as H_2S absent per email from Thomas Bjerstedt, Minerals Management Service (MMS), dated 4/3/2008.

4.1 Coring Bits

Two types of 9-7/8 in (250.8 mm) diameter Polycrystalline Diamond Compact (PDC) coring bits will be used. The first type is referred to as a face bit. The face bit has an opening through the bit face equal to the core diameter. The face bit not only drills the borehole but also trims the core prior to it entering the core barrel (Figure 4-1). The second type is referred to as a cutting shoe bit. The cutting shoe bit has a hole through the bit face large enough to allow the core barrel to extend through the bit face (Figure 4-1). The cutting shoe bit drills the borehole while a cutting shoe attached to the bottom of the core barrel trims the core prior to it entering the core barrel.

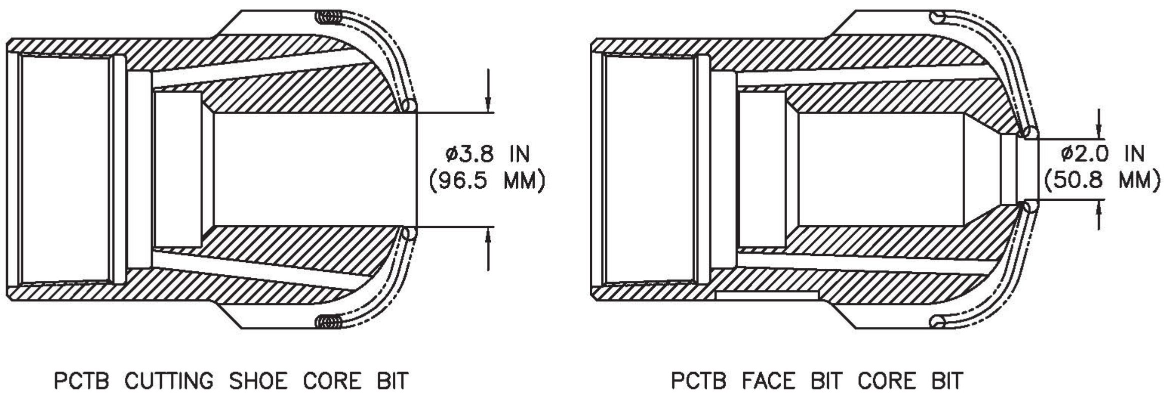

Figure 4-1. PCTB Coring Bit Configurations (Flemings et al., 2018)

4.2 Center Bit

For drilling ahead in either coring bit configuration, a center bit is deployed via slickline which fills the hole through the coring bit face. The bottom end of the center bit incorporates PDC cutters so as to extend the coring bit cutting structure across the entire bit face.

4.3 Drill String

A cleaned, rattled, and rabbited (gauge-checked) drill string with a minimum 4-1/8 inch (104.8 mm) internal diameter is required to pass the coring tools which are deployed via slickline through the drill string. A 5-7/8 in, 28.3 ppf (adjusted weight), S-135 drill string with XT-57 connections (minimum drift diameter of 4.125 inches) will be used.

4.4 Bottom Hole Assembly

Two different bottom hole assemblies (BHA) referred to as the face bit BHA and cutting shoe BHA will be employed (Figure 4-2). As with the drill string, the BHA must have a minimum 4-1/8 inch (104.8 mm) internal diameter to pass the coring tools. The BHA provides weight and stiffness for drilling as well as a means for landing and latching the coring tools. The BHA is composed of custom 8-1/2 inch (215.9 mm) outside diameter by 4-1/8 inch (104.8 mm) inside diameter by 30 feet (9.1 m) long drill collars. Various subs for landing and latching the coring tools and attaching the coring bits are also included in the BHA. The face bit BHA and cutting shoe BHA are identical except for the type of coring bit attached. Both BHAs will have flapper valves installed to prevent back flow into the drill string when a coring tool or center bit is not in place.

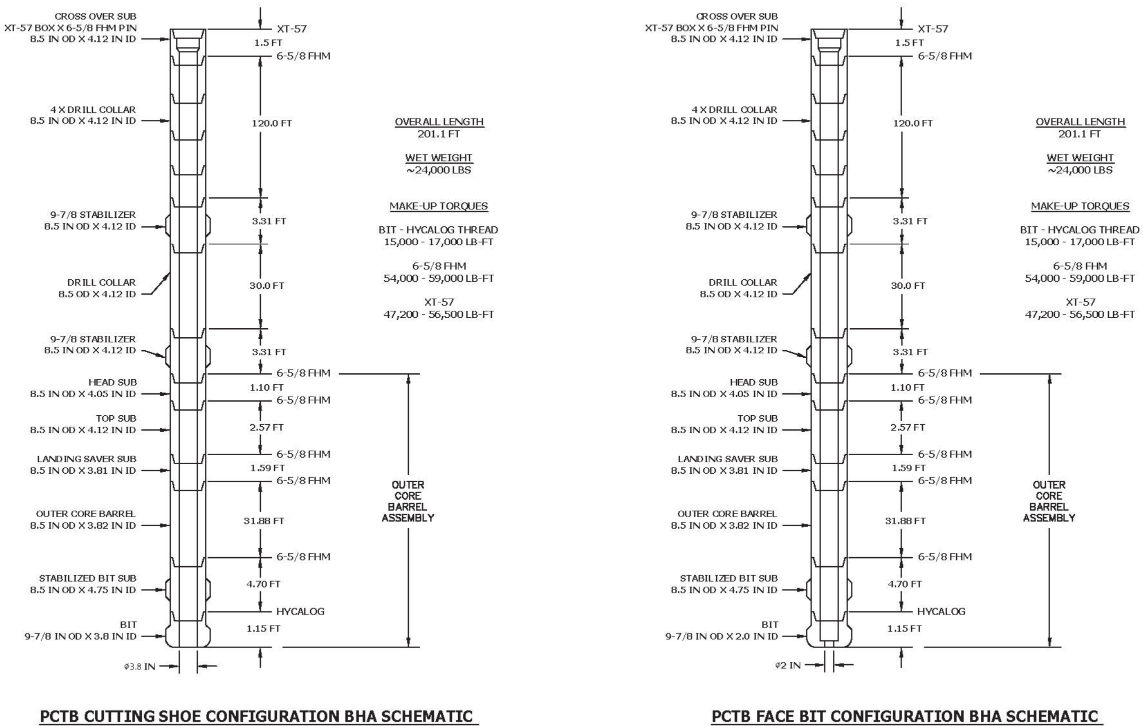

Figure 4-2. Drilling/Coring Bottom Hole Assemblies Configurations (Flemings et al., 2018).

4.5 Coring Tools

Several different types of coring tools will be employed as identified below. All of the coring tools are deployed via slickline and the compatibility of all tools with the PCTB-FB and PCTB-CS BHA's is outlined in Table 4-1.

Table 4-1. BHA to tool compatibility chart.

Coring Tools Compatibility Chart

Tool	Geotek PCTB-CS BHA	Geotek PCTB-FB BHA	IODP (USIO) APC/XCB BHA	IODP (USIO) RCB BHA	IODP (Japan) APC/XCB BHA	IODP (Japan) RCB BHA	Notes
APC (IODP USIO)	Yes	No	Yes	No	Yes	No	Geotek space out confirmation required.
XCB (IODP USIO)	No	No	Yes	No	No	No	Requires conversion to bottom drive to be compatible with PCTB-CS and IODP (Japan) APC/XCB BHA.
RCB (IODP USIO)	No	No	No	Yes	No	No	Requires conversion to bottom drive to be compatible with PCTB-FB and IODP (Japan) RCB BHA.
APC (IODP Japan)	Yes	No	Yes	No	Yes	No	Geotek space out confirmation required.
XCB (IODP Japan)	Yes	No	No	No	Yes	No	Geotek space out confirmation required.
RCB (IODP Japan)	No	Yes	No	No	No	Yes	Geotek space out confirmation required.
GAPC (Geotek)	Yes	No	Yes	No	Yes	No	Geotek space out confirmation required.
GXCB (Geotek)	Yes	No	No	No	Yes	No	Geotek space out confirmation required.
GRCB (Geotek)	No	No	No	No	No	Yes	May be compatible with PCTB-FB BHA in future.
PCTB-FB	No	Yes	No	No	No	Yes	Geotek space out confirmation required.
PCTB-CS	Yes	No	No	No	Yes	No	Geotek space out confirmation required.
T2P	Yes	No	Yes	No	Yes	No	T2P OD too large to pass through RCB/face bit.

GAPC: The Geotek Advanced Piston Corer is used to recover soft sediment cores unpressurized and requires the use of a cutting shoe BHA. Once the GAPC is landed in the BHA the drill string is pressurized until shear pins in the GAPC shear resulting in the GAPC core barrel being thrust through the coring bit and 31 feet (9.5 m) into the formation. After extraction of the GAPC the borehole is drilled down 31 feet (9.5 m) to undisturbed sediments (Figure 4-3).

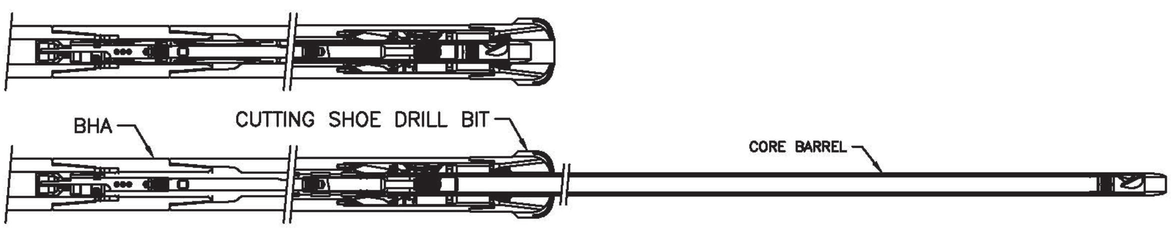

Figure 4-3. Geotek Advanced Piston Corer.

GXCB: The Geotek eXtended Core Barrel is used to recover semi-indurated sediment core samples unpressurized and requires the use of a cutting shoe BHA. Once landed and latched in the BHA the GXCB rotates with the BHA while the borehole is advanced 31 feet (9.5 m) while capturing the core (Figure 4-4).

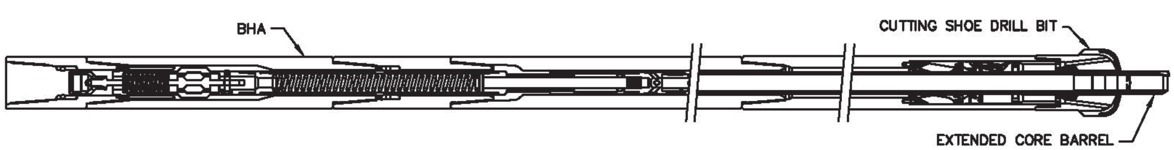

Figure 4-4. Geotek eXtended Core Barrel.

PCTB-FB: The Pressure Coring Tool with Ball Valve in the face bit configuration is used to recover pressurized core samples and requires the use of the PCTB-FB BHA. Once landed and latched in the BHA the borehole can be advanced up to 10 feet (3 m) while capturing the core. Upon recovery of the PCTB-FB, the ball valve is closed and the pressure chamber is sealed. The PCTB-FB is then recovered with the core maintained at near in situ pressure. (Figure 4-5, A and B)

PCTB-CS: The Pressure Coring Tool with Ball Valve in the cutting shoe configuration is used to recover pressurized hydrate core samples and requires the use of the PCTB-CS BHA. Once landed and latched in the BHA the borehole can be advanced up to 10 feet (3 m) while capturing the core. Upon recovery of the PCTB-CS, the ball valve is closed and the pressure chamber is sealed. The PCTB-CS is then recovered with the core maintained at near in situ pressure. (Figure 4-5, C and D)

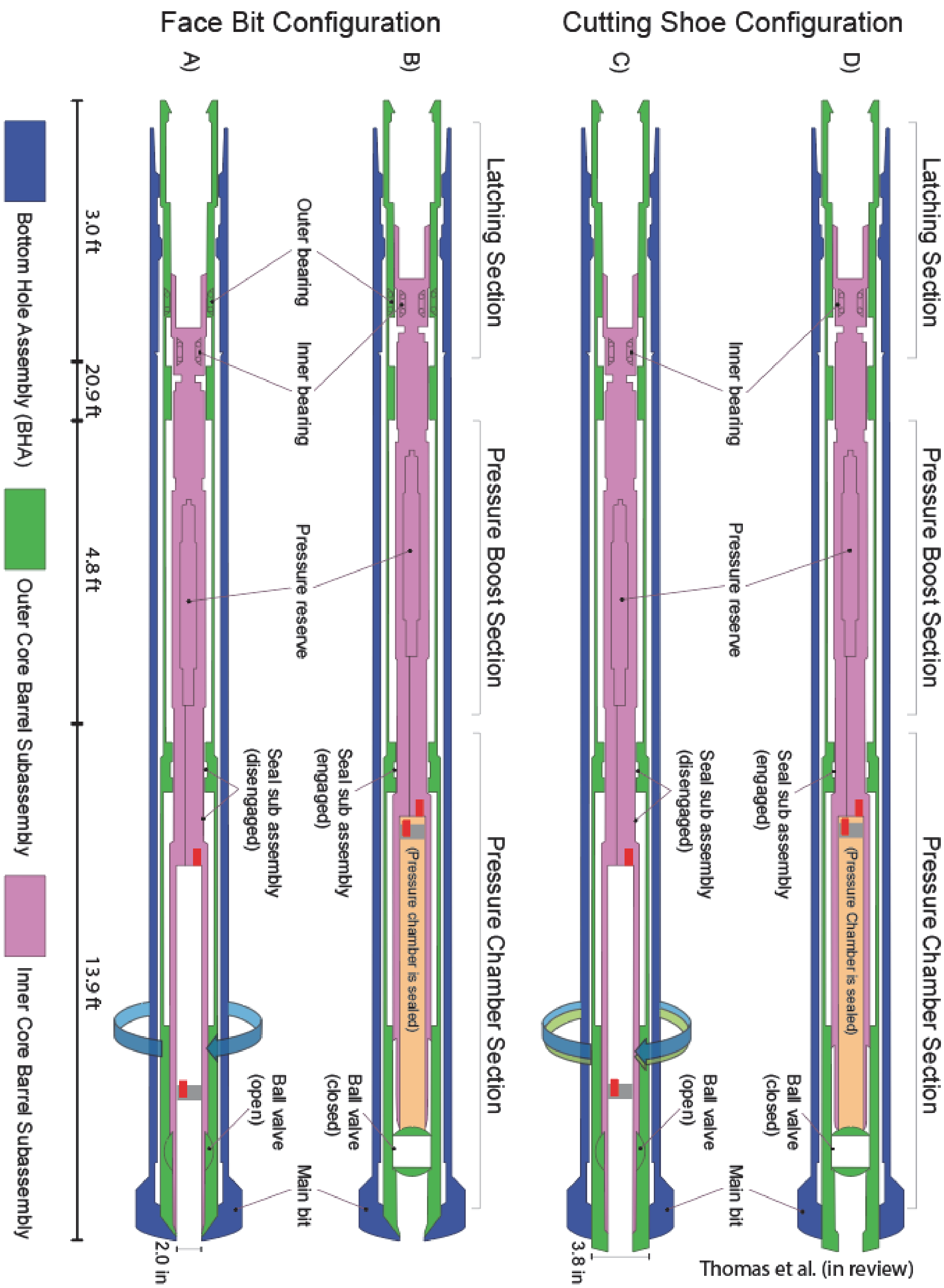

Figure 4-5. Pressure Coring Tool (PCTB) schematic Configurations. (A) PCTB-FB configuration during coring. In this configuration, the Outer (green) and Inner (pink) Core Barrel Subassembly move independently from each other and from the BHA. The blue arrow indicates direction of BHA rotation. (B) PCTB-FB during core retrieval. (C) PCTB-CS configuration during coring. In this configuration, only the Inner Core Barrel Subassembly moves independently from the BHA and the Outer Core Barrel Subassembly is locked to the BHA. The blue arrow indicates direction of BHA rotation and green arrow indicates that the Outer Core Barrel Subassembly rotates with the BHA. (D) PCTB-CS configuration during core retrieval. To initiate core retrieval the inner core barrel subassembly (in pink) is pulled up relative to the outer core barrel subassembly (in green). The locations of the Data Storage Tags are shown in red. The lower tag resides within a portion of the tool that moves up as the core fills the liner

referred to as the rabbit. A third tag (not shown) is located in the pulling tool. The ratio of the width and length of the tool is not to scale; see scales (Thomas et al., 2020).

4.6 Slickline

A slickline is required for deployment of the coring tools, center bits, and survey tool. The slickline to be used is a 5/16 in (8 mm) diameter braided wireline with a safe working load capacity of 10,530 pounds. The slickline will be deployed through the top drive equipped with a line wiper such that any flow up the drill string can be controlled during coring operations. A third party slickline unit and appropriate operators will be supplied.

4.7 Borehole Inclination/Azimuth Surveys

All boreholes will be surveyed at least every 1000 feet of penetration and at total depth, for inclination and azimuth, using a third-party surveyor and gyroscopic survey tool deployed on slickline.

4.8 Rig Position Survey

Rig position surveys using a certified surveyor will be conducted prior to spudding to ensure proper location of the boreholes.

4.9 Site Surveys

Seafloor "as found" surveys will be conducted using an ROV at each location prior to spudding the boreholes to document condition of seafloor and to identify if any archaeological resources or obstructions are encountered. After abandonment, an "as left" site survey will be conducted using an ROV at each location and a clearance report will be prepared verifying that the site is clear of obstructions. All survey data will be archived electronically.

5 Mud Program

The UT-GOM2-2 Scientific Drilling Program operations will be carried out riserless resulting in all mud pumped out of the boreholes settling on the seafloor.

16 ppg water-based drilling mud will be delivered to the vessel via work boat. The 16 ppg working drilling mud will then be diluted onboard the vessel with water to achieve the desired weight. Chemicals will be added to the mud during the mixing process to achieve the desired viscosity and properties. A description of the various types of drilling mud anticipated to be used during the UT-GOM2-2 Scientific Drilling Program is given below.

5.1 Working Mud

16 ppg water-based mud will be delivered to the vessel via work boats and stored on board. The 16 ppg mud will be diluted with water to achieve the desired weight. Chemicals will be added to the mud during mixing process to achieve the desired viscosity and properties.

5.2 Kill Mud

600 barrels (2x deepest hole volume) of 13.0 ppg mud will be held in reserve in the event that flow from a borehole occurs and heavy mud is required to stop the flow.

5.3 Drilling and Coring Mud

10.5 ppg mud will be continuously circulated while drilling and coring beginning prior to penetrating the upper most hydrate zone.

5.4 Sweep Mud

10.5 ppg high viscosity mud will be mixed and stored for use in cleaning the borehole as required.

5.5 Pad Mud

11.5 ppg high viscosity pad mud, sufficient to support the planned cement column, will be mixed and used to displace the bottom of the borehole up to the depth at which the cement plug will be emplaced.

5.6 Abandonment Mud

11 ppg mud will be mixed and used to displace the borehole from the top of the cement plug to the sea floor.

6 Coring Program

6.1 Coring Plan Overview

At WR313, we will acquire pressure cores at WR313 H002 using the PCTB-FB and PCTB bottom hole assembly (BHA), twinning the WRW313 H001 location. Pressure cores will be acquired in the Orange sand, Blue sand, Red sand and at select locations to characterize the background mud. At WR313 G002, we will acquire conventional cores, pressure cores, and in situ pressure/temperature measurements (Table 6-1). In WR313 G002, we will use the APC, XCB, PCTB-CS, and penetrometer with the PCTB-CS BHA to refusal and the PCTB-FB and PCTB-FB BHA below refusal. We will collect pressure cores in the Aqua sand, Blue sand, and Kiwi sand, continuous conventional cores at the top of the hole into the Mendenhall unit, and conventional and pressure cores at select locations to characterize the background mud.

6.1.1 WR313 H002

We will begin spot pressure coring acquiring 2 background spot core pairs above the Red sand to acquire background mud and make our first measurements of the dissolved methane concentration. We will acquire three pressure cores within the Red sand and in its bounding units to characterize hydrate-bearing sands at different thermodynamic states. We will take 3 continuous pressure cores in the hydrate-bearing Upper Blue sand. We will then take 3 pressure spot core pairs between the Upper Blue sand and the Orange sand and 8 continuous pressure cores capturing the compete thickness of the Orange sand and its bounding mud. Finally, we will capture two spot pressure core pairs below the Orange sand (Table 6-1, Figure 6-1).

6.1.2 WR313 G002

Using the Geotek Advanced Piston Corer (G-APC), we will continuously conventional-core from the seafloor to approximately 258 fbsf, to characterize the sulfate-methane transition (SMT) and at least one glacial-interglacial cycle. In this same interval, will use the PCTB-CS to and make our first measurements of the dissolved methane concentration (Table 6-1, Figure 6-1).

We will continue drilling with the PCTB-CS BHA and a center bit to refusal which is estimated at approximately 1640 fbsf. In this interval, we will take five intermittent spot core sequences consisting of one each of G-XCB conventional-core (Geotek Extended Core Barrel), PCTB-CS pressure-core, and a T2P deployment (Table 6-1, Figure 6-1). One of these five deployments will be in the thin Aqua sand, with the four additional spot-deployments evenly distributed to develop the dissolved gas and geochemical profile (Table 6-1, Figure 6-1).

Between refusal and the top of the Upper Blue sand we will complete four intermittent spot core sequences to capture background and JIP mud using the PCTB-FB to develop the dissolved gas and geochemical profiles (Table 6-1 & Figure 6-1).

Four continuous pressure-cores will also be acquired in the Upper Blue sand, one PC set in the Lower Blue sand, one PC set between the Lower Blue sand and Kiwi sand and 3 continuous cores in the Kiwi sand and at the BSR (Table 6-1 & Figure 6-1). These cores will not cover the full thickness of these sands but will aim to collect representative intervals.

We have also developed contingency plans in the case of problems with drilling, coring or hole re-entry. We believe the highest risk is failure occurs when we attempt to re-enter Hole WR313 G002 when we exchange coring BHAs near 1640 fbsf. If this failure occurs, we plan to spud a new hole, WR313 G003 within 50 ft of Hole WR313 G002, and drill down to the next coring point that was planned for Hole WR313 G002.

Table 6-1. WR313 G002 and WR313 H002 preliminary coring plan . Each pressure core can have a maximum length of 10 ft.; each conventional core can have a maximum length of 31 ft.

LOCATION	CORE TYPE	CORING INTERVAL (fbsf)	BHA	CORING TOOL	NOTES
WR313 H002	Pressure Core	379-3010	PCTB-FB	PCTB-FB	7 spot pressure-core pairs (14): 6 – Dissolved gas profile (12) 1 – BSR (2)
					3 pressure-cores in Red sand
					3 pressure-cores in Upper Blue sand
					8 pressure-cores in Orange sand
WR313 G002	Con-ventional Core	0-258	PCTB-CS	G-APC	Continuously conventional core from 0-258 with PCTB-CS and G-APC.
		258-1640	PCTB-CS	G-XCB	Spot conventional core immediately above spot pressure cores
	Pressure Core	186-1640	PCTB-CS	PCTB-CS	6 spot pressure cores: 1 – Immediately below SMT 5– Dissolved gas profile / thin sands
		1640-3073.3	PCTB-FB	PCTB-FB	5 spot pressure-core pairs (10)
					6 pressure-cores in Blue sand
					3 pressure-cores in Kiwi sand

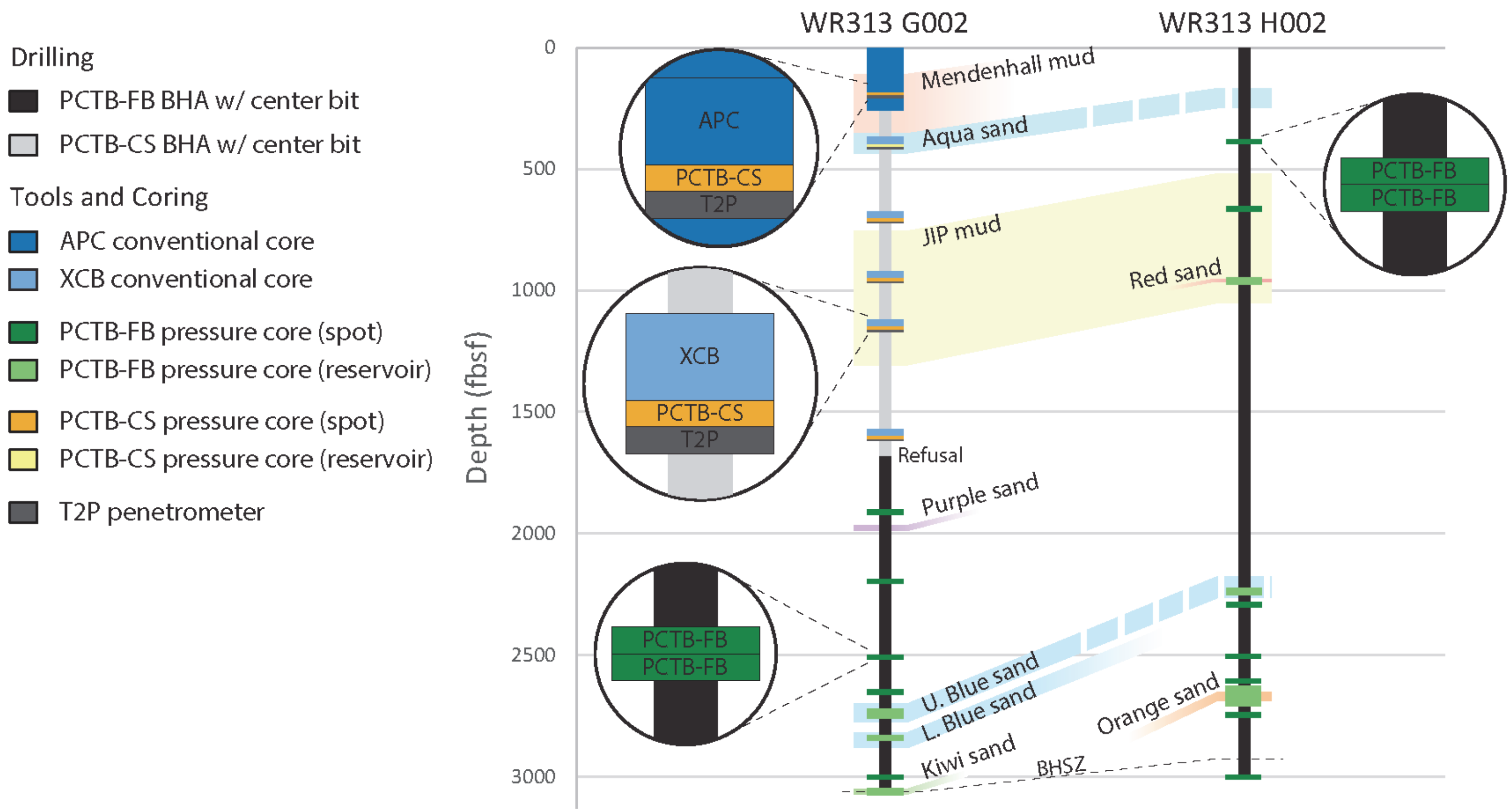

Figure 6-1. UT-GOM2-2 drilling and coring plan for WR313 G002 and WR313 H002. Not to scale.

The total length of pressure core recovered for WR313 H002 and WR313 G002, including expected fall-in material, assuming 100% successful coring runs and 100% recovery, is 530 ft (161.5 m). This is the expected amount of core that will need to be logged using the PCTAS Quick Scan method (see below). If 100% of the first pressure core in a spot or series is fail-in material, then we expect 340 ft (103.6 m) of pressure core that will receive PCATS full-scan.

The total length of conventional core recovered for WR313 G002 and WR313 H002, including expected fall-in material, assuming 100% successful coring runs and 100% recovery is 403 ft (122.8 m). This is the expected amount of core that will be logged using the Geotek IR and MSCL scanners. Table 6-2 outlines the various estimates of pressure and conventional core considering core type.

Table 6-2. Estimated total amount of pressure and conventional core based on core type, quality, pressure coring run success (core is sealed and held at a pressure within the hydrate stability zone) and core recovery (% of core barrel fill). Note that the amount of conventional core to process will increase assuming failed pressure coring runs produce depressurized core that can be treated as conventional core.

	Total Pressure Core		Total Conventional Core		Total Pressure Core, not incl fall-in		Total Conventional Core not incl fall-in	
	ft	m	ft	m	ft	m	ft	m
TOTAL 2 HOLES (100% PC success, 100% recovery)	530	162	403	123	340	104	353	108
TOTAL 2 HOLES (70% PC success, 100% recovery)	371	113	562	171	238	73	455	139
TOTAL 2 HOLES (70% PC success, 80% recovery)	297	91	450	137	190	58	364	111

6.2 On-board Core Analysis

The UT-GOM2-2 core analysis program will focus on analysis of both pressurized and conventional cores. On-board core analyses are summarized in Table 6-3 Details of the core analysis will be provided in the UT-GOM2-2 Science and Sample Distribution Plan.

Table 6-3. Summary of analysis types and core types, with required laboratory space equipment, and staffing.

Sample Type	Analysis	Where: Container or Lab	Required Equipment
Pressure core	P-wave, density, natural gamma, magnetic susceptibility, resistivity, CT imaging	PCATS11 + PCATS8	PCATS, PCATS water tank, supplies
Pressure core	Quantitative degassing w/ gas sampling	R17	Degassing stations, storage tanks and racks, copper tubes, stainless steal tubes, other supplies
Gas samples	Hydrocarbons, CO2	Geotek 40 ft Whole Core Receiving Lab	GC, computers, supplies
Whole round conventional core	H2S Detection, Thermal imaging, Sediment Shear, Void gas, hydrate-bearing sediment collection,	Next to and in Geotek 40 ft Whole Core Receiving Lab	H2S sniffers, MSCL-IR, vane shear device, other supplies
Whole core sections	Preservation for Pore water squeezing, Microbiology, headspace gas, thermal conductivity	UT Core Processing Lab	Cutting tools and supplies, N2 glove box, -80 C and -20 C Freezers, Whirl paks, thermal conductivity probe, etc.
Pore Water	Pore Water Squeezing and time-sensitive analysis	UT Pore Water Lab	Ti squeezers, press, glove bags, alkalinity titrator, refractometer, sampling bottles and preservation agents, refrigeration

6.2.1 Pressure Core Processing Flow

If the pressure coring program were 100% successful, we would acquire 53 10’ (3.1 m) cores.

As pressure cores arrive on deck, they will be transferred to PCATS where they will either get a “Quick scan” (1 cm resolution with 0 degree X-ray image), “Full scan” (0.5 cm resolution with 0 and 90 degree X-ray images), and or CT imaging as time allows. From PCATS they will be transferred to temporary storage. Geotek will provide a recommendation based on the Science Plan for which sections should receive 3D imaging and which lengths will be cut. This recommendation will be reviewed by UT, with solicitation from others, and UT will make the final decision. When time is available, pressure cores from storage will be returned to PCATS for continued scanning, imaging, cutting, and transfer. There is limited time available for shipboard processing of pressure cores, so some of this subsampling and analysis will be done On-Board and the remainder will be completed at the dock (See Schedule).

6.2.1.1 PCATS: Quick Scan Analysis

During the quick scan, cores will be logged (velocity, density) with 1 to 5 cm resolution and single scan 2D x-ray image will be taken. Then that core will be transferred to temporary storage in order to make PCATS available for the next core on deck. Fifteen temporary storage chambers capable of handling 10’ long pressure cores will be available.

6.2.1.2 PCATS: Full –Scan Analysis, Cutting, and Transfer

Because pressure core should not be directly depressurized within the longer temporary storage chambers, all core that is stored in the temporary storage chambers must be cut into shorter sections in PCATS.

First, we will run full scans to obtain more accurate data with a higher sampling frequency (gamma density and P-wave data at a 0.5 cm resolution, 0 and 90 degree X-ray images) and acquire 3D X-ray computed tomography. We will use this data to make additional specific cuts. Secondly, small sections of the core can be subsampled for quantitative degassing analysis. PCATS scans will allow the scientists to choose particular lithologies or zones within which to calculate dissolved methane in the pore water, hydrate concentration, and sample the resultant gasses. Thirdly, optimal 3.3’ (1.0 m) subsections will be transferred to UT.

6.2.1.3 Quantitative degassing

Sections cut for degassing will be quantitatively degassed on board. Gases will be preserved and/or analyzed on-board, and the remaining core material will be treated as conventional core (see below).

6.2.2 Conventional Core Processing Flow

Conventional cores will be IR-scanned and then cut into sections to be stored until dockside analysis. Some whole round sections will be cut for pore water squeezing, and ephemeral properties measured (alkalinity, pH, and salinity). Whole round sections will also be sampled and preserved for microbiology, headspace gas, and physical property measurements.

6.3 Dockside Core Analysis

The UT-GOM2-2 core analysis program is designed to meet the science objectives and will include the analysis of both pressurized and conventional core.

Table 6-4 shows the analyses planned, the core sample type required, in which container the analysis will be either be performed or samples for analysis on-shore will be preserved, the required equipment, and the required staff (count per shift).

Table 6-4. Planned Analyses including sample type, location, required equipment, and required staff.

Sample Type	Analysis	Where: Container or Lab	Required Equipment
Pressure core	P-wave and density, CT imaging	PCATS11 + PCATS8	PCATS, PCATS water tank, supplies
Pressure core	Quantitative degassing w/ gas sampling	R17	Degassing stations, storage tanks and racks, copper tubes, stainless steal tubes, other supplies
Gas samples	Hydrocarbons, CO2	Geotek 40 ft Whole Core Receiving Lab	GC, computers, supplies
Whole round conventional core	P-wave, density, natural gamma, magnetic susceptibility, resistivity, CT imaging	Geotek 20 ft MSCL	MSCL scanners, CT
Whole core sections	Preservation for Moisture and Density, physical properties, Geomechanics, Pore water squeezing, Microbiology, headspace gas, thermal conductivity	Geotek 40 ft Whole Core Receiving Lab, UT Core Processing Lab	Cutting tools and supplies, N2 glove box, -80 C and -20 C Freezers, Whirl paks, thermal conductivity probe, etc.
Whole core	Sediment shear, Void gas	Geotek 40 ft Whole Core Receiving Lab	Vane penetrometer
Pore Water	Pore Water Squeezing and time-sensitive analysis	UT Pore Water Lab	Ti squeezers, press, glove bags, alkalinity titrator, refractometer, sampling bottles and preservation agents, refrigeration
Split core	Magnetic susceptibility, Linescan images, color reflectance scans, X-ray fluorescence	Geotek 40 ft Split Core	Core splitting equipment, Split Core scanners
Split core	Visual description, and smear slide description, initial biostratigraphy, sediment wet and dry weights	Geotek 40 ft Split Core	Tables, Microscopes, computers, smear slide prep, balance, oven, other supplies
Sediment/Split core plugs	Sampling for XRD, CHNS, TOC, elemental/isotopic analysis, nannofossil biostratigraphy, grain size, rock mag, biomarkers, carbonate/sulfide nodules, moisture and density.	Geotek 40 ft Split Core	Sampling equipment and supplies

6.3.1 Dockside Pressure Core Processing Flow

Any cores that were not "Quick scanned" will be scanned dockside, followed by 'Full scan' analysis, CT imaging, cutting, and transfer. Geotek will provide a recommendation based on the Science Plan for which sections should receive 3D imaging and which lengths will be cut. This recommendation will be reviewed by UT, with solicitation from others, and UT will make the final decision. All remaining pressure cores will be fully processed.

6.3.1.1 PCATS: Quick Scan Analysis

During the quick scan, cores will be logged (velocity, density) with 1 to 5 cm resolution and single scan 2D x-ray image will be taken.

6.3.1.2 PCATS: Full –Scan Analysis, Cutting, and Transfer

We will run full scans to obtain more accurate data with a higher sampling frequency (gamma density and P-wave data at a 0.5 cm resolution, 0 and 90 degree X-ray images) and acquire 3D X-ray computed tomography. We will use this data to make additional specific cuts. Secondly, small sections of the core can be subsampled for quantitative degassing analysis. The PCATS scans will allow the scientists to choose particular lithologies or zones within which to calculate dissolved methane in the pore water, hydrate concentration, and sample the resultant gasses. Thirdly, optimal 3.3' (1.0 m) subsections can be chosen from the storage chambers and transferred UT.

6.3.1.3 Quantitative degassing

Sections cut for degassing will be quantitatively degassed on board. Gases will be preserved and /or analyzed at the dock, and the remaining core material will be treated as conventional core (see below).

6.3.2 Conventional Core Processing Flow

Conventional cores will be CT-scanned, logged using the MSCL, and split into archival and working halves. Split core will be scanned (magnetic susceptibility, photo-scan, X-ray fluorescence, and color reflectance) and photographed. Smear slides will be prepared and assessed. Initial biostratigraphy samples prepared and assessed. Sediment samples will be weighted wet, dried, and weighed again for moisture content. Additional samples will be extracted for lithostratigraphy and biostratigraphy on-shore.

7 Plugging and Abandonment

The plugging and abandonment procedure employed will adhere to all applicable regulations for plugging and abandoning a borehole in the Gulf of Mexico. Several alternate compliances will be required, similar to the alternate compliances required for UT-GOM2-1. The final procedure will be reviewed by a third party registered professional engineer and all applicable regulatory bodies prior to initiating.

The preliminary Plugging and Abandonment Plan calls for emplacing a cement plug in the borehole beginning at approximately 150 feet above the upper most hydrate bearing zone with the potential to flow and extending upward for a minimum of 500 feet. Emplacement of the cement plug above the hydrate bearing zone, rather than across the zone, was chosen to prevent possible disassociation of the gas hydrate, due to the heat of hydration produced by the curing cement, that may lead to degradation of the cement plug integrity (Figure 7-1).

Prior to emplacement of the cement, the drill bit will be positioned near the bottom of the borehole, a cement liner inserted in the BHA, and the borehole displaced with an 11.5 ppg high viscosity (~100 lb/100 ft^2) mud from total depth to approximately 150 feet above the upper most hydrate bearing zone with the potential to flow. The drill bit will then be raised to approximately 150 feet above the upper most hydrate bearing zone with the potential to flow where sufficient 16.4 ppg Class H cement to fill 500 feet of the borehole plus 100 percent annular volume excess to account for any cement loss and borehole washouts will be pumped. The drill bit will then be carefully raised clear of the seafloor and flushed with seawater while waiting for the cement to cure.

After sufficient cement curing time as elapsed, the drill bit will be lowered in the borehole until the top of the cement plug is encounter. To confirm the top and integrity of the cement plug, 15,000 pounds weight on bit will be applied to the top of the cement plug. After confirming the top and integrity of the cement plug, the borehole will be displaced to 11 ppg WBM and then the drill string will be recovered in preparation for abandonment of the borehole.

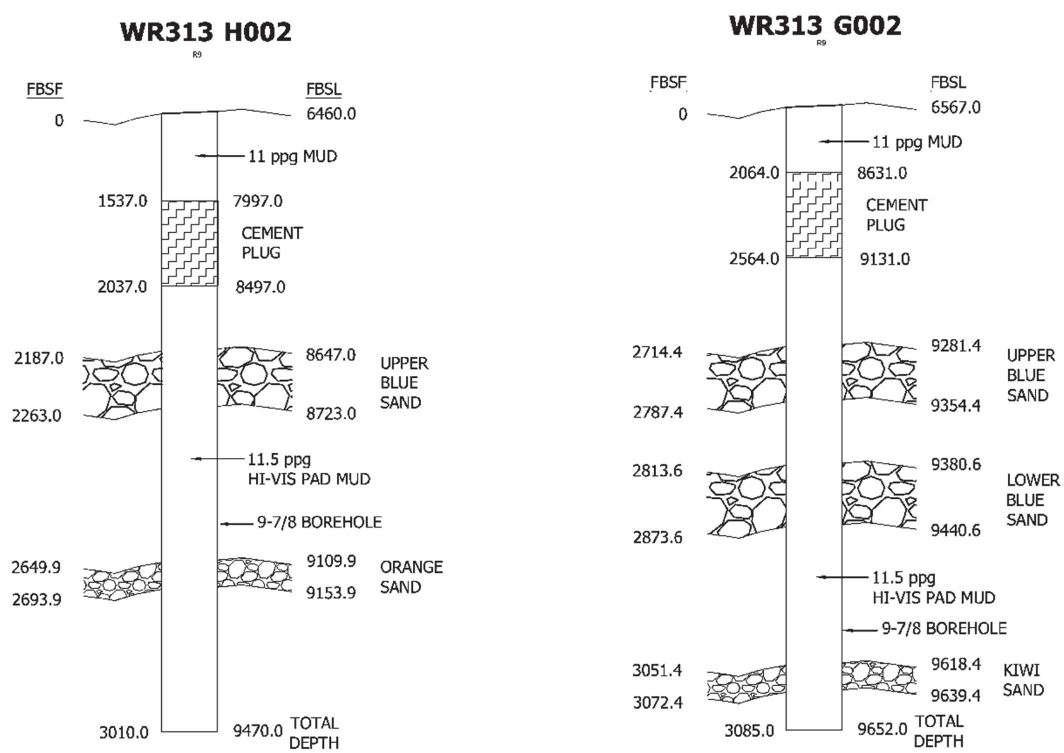

Figure 7-1. Plug and abandon cement plug emplacement hole schematics.

8 Schedule

8.1 UT-GOM2-2 Hydrate Expedition Schedule

The UT-GOM2-2 Scientific Drilling Program is scheduled to commence during in spring of 2022. The schedule begins with a one-week period for staging all expedition bound equipment in the port of embarkation. Mobilization, requiring 3.8 days, involves transporting the equipment from the port of embarkation to the vessel via work boats, loading the equipment onboard the vessel, and making all equipment ready for operations. Drilling and coring operations at sea require ~33.7 days to complete (Table 8-1, Table 8-2).

The time from start of mobilization to the first PCTB core on deck is ~4.2 days.

Demobilization, requiring 3 days, involves offloading all equipment from the vessel to work boats and transporting it to the port of debarkation. Once in the port of debarkation, most of the equipment will be shipped back to its origin while the remaining equipment will be used in port for shore-based core preliminary analysis. Shore based core preliminary analysis will take up to thirty days to complete, after which all remaining equipment will be shipped back to its origin. The cores will then be shipped to various institutions for further analysis.

Total time to complete all operations is approximately 11 weeks.

Table 8-1. UT-GOM2-2 Scientific Drilling Program Overview

Task	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
Mobilization						
UT-GOM2-2 Expedition						
Stage 1 Demob						
Dockside Core Processing						
Return Shipments						

Task	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12
Dockside Core Processing						
Return Shipments						

Table 8-2. UT-GOM2-2 Scientific Drilling Program Offshore Operations Schedule

Task	On Site Operations Time (days)	Mob-Demob Time (days)	16 ppg mud usage (bbl)	Cement Usage (sks)
Rig mobilization (on location WR313-H002)		3.75		
WR313-H002 coring operations. Transit to WR313-G002.	15.6		7,735	545
WR313-G002 coring operations	18.1		7,811	545
Rig demobilization (on location WR313-G002)		3.0		
Subtotals:	**33.7**	**6.75**	**15,546**	**1090**
Total Expedition Time:	**40.4**			

8.2 Core Processing Schedule

8.2.1 PCATS pressure core acquisition time

The time to acquire one core using the PCTB can range from 3-6 hours. The assumed average rate is 5 hours.

8.2.2 Pressure Core Processing Time

Quick-scanning and transfer from the PCTB pressure chamber to temporary storage, in Geotek SC_{350} chambers, takes 3.5 hours for a single 10' (3.1 m) pressure core. We assume that PCATS quick-scanning will be able keep up with the PCTB coring even during continuous coring operations. Because most of the pressure cores are intermittent, there is sometime enough time to completely process a pressure core in PCATS before the next one shows up. There are four PCTB pressure chambers and each pressure chamber must be emptied and cleaned before it is needed again at the rig floor. There are 15 SC_{350} chambers each of which must be emptied and cleaned below it is needed again at PCATS. 35-41 SC_{120} and 3-4 SC_{30} pressure chambers will be available for storage and quantitative degassing.

Full-scanning can take up to 11 hours to for each 10' pressure core in PCATS depending on the number of cuts that will be made under pressure. Some detail is given below and a detailed breakdown of the amount of PCATS time required for the various PCATS operations will be described in the UT-GOM2-2 Science and Sample Distribution Plan.

8.2.3 PCATS schedule

8.2.3.1 WR313 H002

In the first hole, there will not be enough time to fully process two pressure spot cores before the next pair arrives. Processing of the two spot cores will be limited. In the time available, we will run at least a quick-scan (3.5 hours) on each core, make cuts for quantitative degassing samples, and run full-scanning as possible.

During pressure coring of the Orange sand, PCATS will only run quick-scans on each core. After pressure coring the Orange sand there is extra time for full-scanning while collecting additional spot core pairs, after H002 coring operations have ended, and before the first pressure core from G002 arrives. Most of the 15 SC_{350} chambers will be empty before the first pressure core from G002 arrives.

8.2.3.2 WR313 G002

Spot coring in G002 consists of a conventional core followed by a pressure core. There is extra time during this period to fully process these pressure cores and finish processing cores remaining from the first hole. Processing of most pressure cores will be completed before refusal. Time is limited after refusal. We will run at least a quick-scan (3.5 hours) on each core.

Pressure cores can remain in the SC_{350}, SC_{120}, and 3-4 SC_{30} chambers during demobilization.

8.2.3.3 Dockside

The current plan is to transfer 15 pressure cores still in Geotek SC_{350} chambers to the dock for PCATS processing.

9 Risk Management

Risks are broken into 6 categories: Environmental, Personnel and Equipment, Meeting Science Objectives, Weather, Vessel Selection, and Cost Inflation.

9.1 Environmental

1. Release of fluids at the seafloor
    a. In any riserless offshore drilling operation, there is the risk of the release of wellbore fluids to the water column if hydrostatic control is not maintained. There are two possible types of borehole fluid flows at the Walker Ridge 313 locations: 1) water flows and 2) gas flows.
    b. Uncontrolled shallow flows can result in drilling delays or loss of well site.
    c. The risk of these events is minimized in the following manner:
        i. Avoid potential flow zones. Use seismic and previous well data to select surface locations and to design well paths that minimize the possibility of drilling into shallow formations with the potential of flowing fluids.
        ii. Maintain hydrostatic control. Use appropriately weighted drilling fluids during drilling and in response to flow events to slow/stop the flow of fluids. Minimize lost circulation.
        iii. Maintain visual observation of the wellbore returns at the seafloor via ROV camera for early detection of flow.
        iv. Review of offset well data.
2. Release of pollutants from the rig
    a. Spills can occur during transit (collision) or during transfer between rig & supply vessel. Spills of diesel fuel or other chemicals from the rig /supply vessel can also occur while on location.
    b. Any releases of diesel are expected to evaporate and biodegrade within a few days.
    c. Most chemicals used during the project will be either non-toxic or used in small quantities. Any spills are expected to have temporary localized impacts on water quality.
3. Operational discharges
    a. Will be regulated as per the NPDES General Permit GMG290000.
    b. Are expected to only have short-term localized degradation of marine water quality.
4. Emissions impact on air quality
    a. Emissions from routine activities are not expected to affect onshore air quality due to prevailing atmospheric conditions, emission heights, emission rates, distance of emissions from the coastline.
    b. There are no plans for burning or flaring during this project.
5. Impact on marine life
    a. Minimal to none expected.
6. Dissociation of gas hydrates
    a. Hydrate dissociation can be either gradual or instantaneous when hydrates are heated or depressurized.
    b. While drilling the boreholes, fluids cooler than the formation temperature will be introduced, which will act to further stabilize the hydrate zone.
    c. Drilling-fluid weight will be controlled to maintain a positive pressure on the formation.

d. During P&A, the cement abandonment plug will be set above the hydrate zone to minimize destabilization concerns due to the cement heat of hydration while the plug sets.

9.2 Personnel and Equipment

1. During Drilling
    a. Drilling involves dynamic use of heavy equipment, often under pressure, in a challenging and changing environment. There is risk to personnel and equipment inherit in this environment. Risks are mitigated by equipment & program design, preventative maintenance & inspections, strict adherence to procedure, job safety analyses, personnel competency & supervision, high quality safety culture, and use of a unified Safety Management System.
    b. Loss of drill string during drilling or coring. The drill string can be dropped or become stuck in the borehole resulting in loss of the bottom-hole assembly (BHA) and part of the drill string. Mitigation includes drill string inspection prior to project commencement, operating within drill string & BHA design limitations, following good drilling practices and preventative equipment maintenance.
    c. Loss of drill string due to geological event: It is possible, although very rare, that a submarine mass movement (e.g. landslide) could occur resulting in the loss of the drill string. Loss of equipment due to landslides is extremely rare. This risk is mitigated through location selection to avoid potential geological events.
2. While Handling High Pressured Samples
    a. We will be recovering, transferring, and storing samples that are at significant pore pressures (up to 35 MPa).
    b. The risk is mitigated in the following manner:
        i. All pressure vessels are equipped with pressure release safety valves.
        ii. Pressure cores will be transported by vehicle in 'over-pack' containers, a US DOT approved approach to transport of pressurized material.
        iii. Strict adherence to proper procedure in the presence of pressurized containers.
        iv. Hold pre-job safety discussions.
        v. Assure that personnel involved have been trained in the safe handling of pressurized samples.
3. While handling cores taken above and within the SMT zone in WR313 G002
    a. Release of H_2S at the rig floor /core processing areas is possible from H_2S entrained in cores taken above and in the SMT in WR313 G002.
    b. The risks are mitigated in the following manner:
        i. Strict adherence to proper procedure in the presence of cores potentially entrained with H_2S in WR313 G002.
        ii. Assure that personnel involved have been trained in H_2S awareness and core-handling H_2S protocols.

9.3 Meeting Science Objectives

1. Table 9-1 lists the identified highest risks to not meeting the science objectives. Probability and Impact on meeting the science objectives were given a rating of 1 (lowest) to 3 (highest). Risk

Rating is the product of the numerical values given to Probability and Impact. Risk Ratings correlate to the Risk Level as follows: 1-3 = Low, 4-6 = Med, 7-9 = High.

Table 9-1 Identified highest risks for meeting the Science objectives . A full list of all the identified risks and risk assessment for all the proposed objectives can be found at UT-GOM2-2_Risk_Analysis_2019-08-12.

UT-GOM2-2 Scientific Drilling Plan Identified Failures	Probability Rating	Impact Rating	Risk Rating	Risk Level
A1. Failure of the vessel operator to work with/understand requirements for pressure coring	1	3	3	Low
A2. Failure of the PCTB-FB to seal within the HSZ, tool error	1	3	3	Low
A4. Failure of the PCTB-CS to seal within the HSZ	2	1	2	Low
A6. Pressure Cores above 150-200m might not be good	2	1	2	Low
B2. G-RCB jams in the PCTB-FB BHA	2	2	4	Med
B6. Failure of the Geotek coring tool (G-RCB) to hold core	1	2	2	Low
E1. PCATS failure	1	3	3	Low
E2. Failure of any equipment on-board needed for ephemeral measurements	1	2	2	Low
E3. Failure of the T2P	2	2	4	Med
F0. Failure to secure a vessel	1	3	3	Low
F1. Failure to Secure Dockside rental space	1	2	2	Low
F2. Failure to Secure a location for conventional Core Analysis (e.g. Port Fourchon)	1	2	2	Low
H2. Bioactivity too low for any microbiology analyses	2	1	2	Low

9.4 Adverse Weather Conditions

1. During coring, bit bounce must be minimized/eliminated to allow successful recovery of the cored material. If the core bit lifts up off bottom before the core is completely cut; the core catcher will likely close on the core, making it impossible for more core to enter the inner tube. Keeping the bit on bottom is complicated by use of a floating drilling vessel which heaves in response to the sea state and other environmental conditions.
2. The maximum sea state for backloading and transporting pressured cores is 4 feet w/ wave heights up to 8.2 feet.
3. The risk is mitigated in the following manner:
    a. Use active heave systems on the drilling vessel while coring
    b. Schedule project to avoid hurricane season & minimize time during height of winter storm-season. The ideal weather window for coring activities in the Gulf of Mexico is April-May.

9.5 Vessel Selection / Availability

1. General vessel availability in the Gulf of Mexico is expected to continue to tighten either due to increased stacking, vessels leaving the area, and/or increased activity.
2. There are a limited number of vessels which can meet project requirements within the project budget.
3. Vessel must be able to meet the regulations for conducting a deep stratigraphic test in the Gulf of Mexico. Current MODU Certificate of Inspection or Certificate of Compliance is required.
4. The risk is mitigated in the following manner:
    a. Development of detailed minimum drilling vessel specifications.
    b. Early pre-screening of potential vessels; i.e. knowing the market
    c. Selecting and contracting vessel as soon as possible, well in advance of project execution date to secure time slot during preferred window.

9.6 Cost Inflation

1. The use of 2018 quotes and 2017 historical cost information may not be adequate for building a cost estimate for project execution in 2022
2. The risk is mitigated in the following manner:
    a. Apply an inflation factor to items not covered by a firm quote for execution in 2022.

10 Drilling Vessel

A fit-for-purpose oil-industry deepwater drilling or intervention vessel will be contracted. Specific vessel requirements can be found in Appendix A.

11 Personnel

11.1 Project Organization

The UT-GOM2-2 Scientific Drilling Program will be managed by the University of Texas Institute for Geophysics (UTIG), an Organized Research Unit recognized by the University of Texas at Austin (UT). UTIG will manage and oversee all operations and analytical activities to ensure that project science objectives are accomplished.

There are five sub-recipient universities on this project: Ohio State University (Ohio State), Oregon State University (Oregon State), University of New Hampshire (UNH), University of Washington (UW), and Lamont-Doherty Earth Observatory at Columbia University (LDEO). Sub-recipients will participate in the UT-GOM2-2 Scientific Drilling Program to varying degrees according to their statements of work.

UT will contract subcontractors to fulfill various roles in the UT-GOM2-2 Scientific Drilling Program, including Pettigrew Engineering, Geotek, and a to-be-determined Vessel Contractor.

A project organization chart for the UT-GOM2-2 Scientific Drilling Program and core analysis activities is shown in Figure 11-1.

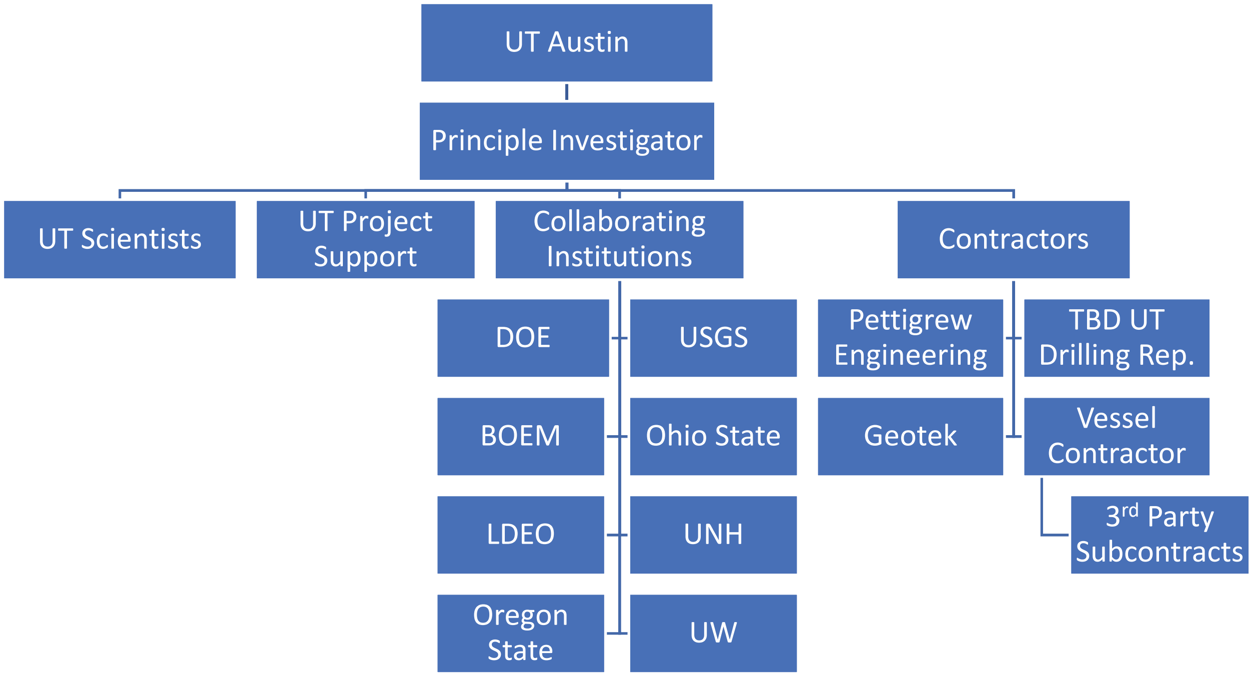

Figure 11-1. Personnel organization chart.

11.2 UT-GOM2-2 Scientific Drilling Program Personnel – Onboard

The roles, maximum number of persons, and anticipated institutions required to fulfill the UT-GOM2-2 Scientific Drilling Program, are shown in Table 11-1.

Table 11-1. UT-GOM2-2 onboard personnel

UT-GOM2-2 ONBOARD PERSONNEL			
ROLE / TASK	***PERSONS H002***	***PERSONS G002***	***INSTITUTION***
Chief Scientist	1	1	UT
Staff Scientist	1	1	UT
Operations Reporting	1	1	USGS
Observer	1	0	TBD
Drilling Data and Core Log Integration	2	2	Ohio State
Pore Water Geochemistry	2	4	UW, others
Quantitative Degassing	4	4	UT, Geotek
Whole Core Processing	3	4	Oregon State, Ohio State
Pressure Coring/PCATS	12	12	Geotek, others
T2P	0	1	UT
Company Man	2	2	Pettigrew Eng., TBD
Photography, Videography	2	0	TBD
TOTAL	**31**	**32**	

11.3 UT-GOM2-2 Scientific Drilling Program Personnel – Dockside Core Processing

The roles, number of persons, and anticipated institutions required to fulfill the UT-GOM2-2 dockside core analysis program, is shown in Table 11-2

Table 11-2. Dockside core analysis program personnel.

DOCKSIDE CORE ANALYSIS PROGRAM PERSONNEL		
ROLE / TASK	***PERSONS***	***INSTITUTION***
Chief Scientist	1	UT
Staff Scientist	1	UT
Pore Water Geochemistry	2	UW, others
Quantitative Degassing	3	UTIG, others
Whole Core Processing	2	Oregon State, Ohio State
Core Description	2	UNH
Biostratigraphy	1	UT
Physical Properties	1	UT, others
Whole Core Logging	2	Geotek
Core Splitting and Split Core Logging	2	Geotek
PCATS	4	Geotek
Degassing and Core Transfers	4	Geotek
TOTAL	**26**	

12 Permitting

Because the depth of penetration below the sea floor will be greater than 500 ft in each well, the wells will be considered “deep stratigraphic tests” per BOEM definition and permitted as such.

The UT-GOM2-2 Scientific Drilling Program will be drilled under the following permits and permissions:

- BOEM ‘Right of Use & Easement’
- BOEM ‘Exploration Plan’ including Coastal Zone Management ‘Federal-Consistency Certification’
- BOEM ‘Permit to Conduct Geological or Geophysical Exploration for Mineral Resources or Scientific Research on the Outer Continental Shelf (BOEM-0327)’
- BSEE ’Permit to Drill’ (BSEE-0123)
- NPDES General Permit for the Western Portion of the Outer Continental Shelf of the Gulf of Mexico (GMG290000).
- NEPA Categorical Exclusion Designation

13 Logistics

13.1 Designated Port and Heliport / Boat and Helicopter Services

Providers of shore base/dockside and helicopter services are yet to be selected. Based on the area of the project operations, the dock chosen will most likely be in Port Fourchon, Louisiana. The heliport will most likely be based in Houma, Louisiana.

13.2 Mobilization / Demobilization Plans

UT will work with the Rig Contractor, Geotek, and Shore Base management to create Rig Mobilization and Demobilization logistics plans.

The Rig Mobilization Plan to include:

- Activities & Timeline
- Identification of Responsible Party
- Manifest
- Dimensions & weights of equipment to be transported to rig
- Equipment shipment-to-shore transport notes
- Dock requirements (cranes, fork lifts, power, staging area, personnel)
- Supply Boats (vessel selection, sea-fastening requirements, service hook up, order for loading and unloading, and deck layout of containers on the supply boat)
- Deck Layout of the containers on the rig
- Personnel (numbers and departure schedule)

The UT Drilling Representative and Rig Contractor will coordinate shore base logistics to ensure equipment arrives at the proper time and in the proper manner.

The Rig Demobilization Plan to include:

- Objectives of plan
- Activities & Timeline
- Identification of Responsible Party
- Manifest

- Dimensions & weights of equipment to be transported from rig
- Rig cranage required
- Dock requirements (cranes, fork lifts, power, staging area, container laydown area, personnel)
- Supply Boats (vessel selection, sea-fastening requirements, service hook up, order for back loading and unloading, and deck layout of containers on the supply boat)
- Dockside Geotek Site Plan (order of hook up at the dock and deck layout of the containers at the dock, power generators, fuel bowsers, etc.)
- Personnel (numbers and departure schedule)

13.3 Customs

UT, Geotek, and 3rd party members subcontracted by UT will work through UT with the Rig Contractor to ensure all personnel and equipment are properly documented and abide by US customs laws. Third party services subcontracted by the Rig Contractor will coordinate same through the Rig Contractor.

13.4 Trucking/Transport/Shipping

Arrangement for trucking of containers and equipment to/from the Shore Base facility will be the responsibility of the equipment owner/subcontractor. Prior to trucking; containers & contents will be properly secured for shipment and for offshore lifting. Loose equipment and materials are to be secured and transported in an offshore-rated basket. Mud materials are to be shrink-wrapped and palletized to protect materials during transport & storage. UT equipment and tools not stored in a container (e.g. BHA components) will be secured and transported in an offshore-rated basket. Third-party services subcontracted by the Rig Contractor will coordinate trucking delivery with the Rig Contractor, with input from the UT Drilling Representative. Return of containers, baskets, etc. will occur in a manner similar to delivery. All lifting elements (containers, slings, pad-eyes, etc.) will maintain current inspection and certification for offshore lifting (DNV) for the duration of the expedition.

13.5 Shore Base Support

Shipment of supplies and equipment will be coordinated between the Rig Contractor and the Shore Base Dispatcher with input from the UT Drilling Representative.

13.6 Supply Vessels and Crew Boats

Supply vessels and crew boats will be contracted by the logistics management provider (most likely the Rig Contractor) as required during execution.

13.7 Supplies and Equipment

13.7.1 Equipment

Sourcing and mobilization of 3rd party equipment subcontracted by the Rig Contractor will be handled by the 3rd party and the Rig Contractor with input from the UT Drilling Representative and UT.

All Geotek container/van logistics will be handled by Geotek; this includes but is not limited to shipping from UK, customs, storage, inspection, marking, and security. Geotek will also be responsible for the shipment and delivery of the PCTB storage van and heavy tools van should they not be returned to UT after the Land Test. Timing for mobilization will be developed in conjunction with Rig Contractor, UT Drilling Representative, UT, and Geotek.

UT will be responsible for:

- PCTB storage van and heavy tools van if these two containers/vans are stored at UT prior to the deployment.
- Vans and equipment related to whole round core sampling
- Shipment of all UT-supplied materials required by science team onboard the vessel during the expedition (e.g. RAID storage devices, printer, office supplies, etc.).
- Supplies and equipment related to Pore Water sampling; including providing a safe container lab with fridge, freezer (tbd, power, water, and drainage) for the pore water sampling work.

All UT equipment removed from a container while onboard will be stamped/stenciled/painted with “Property of UT.” All non-UT equipment and materials shall be stamped/stenciled/painted with the owner's name as per Title 30 CFR 250.300 (c).

13.7.2 Baskets & Containers

Five 20-ft baskets will be required for pipe, collars, Geotek chillers, and Geotek cold shuck.

Pressure core operations and analysis will require a total of 4 containers - a 40-ft container for the PCTB, a 40+20 ft container for PCATS operations, and a 20-ft container for pressure core storage and degassing.

Conventional core operations will require an additional 5 containers on-board. Geotek will provide a 20-ft size container for conventional coring tools (which needs to be placed next to the PCTB Tools Van) and a 40-ft container for MSCL-IR for cutting core into 1.5 m sections (which will be repurposed during demobilization to the dock for core splitting and curation). UT will provide a 20-ft container for whole round core (for microbiology, pore water, and physical properties) sampling; and a 20-ft container for porewater squeezing and analysis. Geotek will provide a 20-ft container for conventional core storage and additional pressure core storage.

A 20-30 ft container will be required for onboard science party office space. This container will require a minimum of 40’ linear feet of countertop space for users and workstations, 10 chairs, outlets for up to 10 computers/laptops operated at the same time, full network capabilities (either wired or wireless) that is both reliable and with internet access. It will need reliable climate control with ambient noise level in a range that is safe without hearing protection.

A 20-ft container may be required for vessel contracted Mud Engineering.

Expected basket & container requirements for the coring operations are summarized in Table 13-1 below.

Table 13-1. Name, type and size, container description, comparison to the previous expedition, container activities, mobilization location, and required hook-up, and required hook-up

Name	Type	Description	Reuse or New	Required Vessel Hook-up	Activities	Mobilization/ demobilization
Narrow Pipe	40' basket	6 collars	Same as GOM2-1	None		Only required for supply boat transfer
Wide Pipe 1	40' basket	Collars and BHA subs	Same as GOM2-1	None		Only required for supply boat transfer
Wide Pipe 2	40' basket	Collars and BHA subs	Same as GOM2-1	None	Sub storage	Onboard, via supply boat
Cold Shuck	20' basket	Cold Shuck, and cold bath, small chiller transport	Same as GOM2-1	None		Only required for supply boat transfer
Chiller Frame	20' Frame	Geotek large glycol chillers	Same as GOM2-1	Power 480 V 3 phase 60 amp, water (1" feed), air (1: feed), network/internet		Onboard, via supply boat, remobilize dockside
PCTB Van	40' container	PCTB coring	Same as GOM2-1	Power (480 V 3 phase 60 amp), Water, Air, Network/Internet	Some PCTB assembly, autoclave extraction	Onboard, via supply boat
CC Tools	20' container	Conventional Coring	NEW DNV	None	Geotek-APX/XCB parts and supplies	Onboard, via supply boat
PCATS11	40' container	PCATS Analysis	Same as GOM2-1	Waste water drain	Pressure core imaging, scanning, cutting, and transfer	Onboard, via supply boat, remobilize dockside
PCATS8	20' container	PCATS Autoclave and storage vessel handling	Same as GOM2-1	None	Pressure core imaging, scanning, cutting, and transfer	Onboard, via supply boat, remobilize dockside
R17	20' container	Pressure Core storage and degassing	Same as GOM2-1	None	Pressure Core Storage, quantitative degassing	Onboard, via supply boat, remobilize dockside
Core Storage	20' container	Pressure and Conventional Core Storage	NEW DNV reefer	None	Pressure Core Storage, Conventional core storage racks, and core transport	Onboard, via supply boat, then dockside
Core Receiving Lab	40' container	Geotek Whole Core Processing Laboratory	NEW DNV	Power, water, air	Whole core sectioning, MSCL-IR scanning, Gas Chromatography, Data Processing	Onboard, via supply boat, remobilize dockside
PC Storage	20' container	Additional storage space for additional SC350's	NEW or rented DNV reefer	Power (480v 3-phase), water, drain/sediment waste trap	SC_{350} long pressure core storage and transport	Onboard, via supply boat, remobilize dockside
Core Processing Lab	20' container	Microbiology, M&D	Same as GOM2-1	Power (480v 3-phase), water, drain/sediment waste trap	Whole Core cutting under N2, Microbiology and M&D sample handling	Onboard, via supply boat, remobilize dockside
Pore Water Lab	20' container	Pore Water Laboratory	NEW	Power, network, internet, intranet, desks	Pore water, squeezing, analysis, and storage	Onboard, via supply boat, remobilize dockside
3rd Party Conex	20' container	UT Office Space	Same as GOM2-1	None	Writing, Data Analysis	Onboard, via supply boat, remobilization dockside
T2P	Laydown Area	Wireline Pressure and Temperature Probe	NEW	Power (220 single phase)	T2P and PDT assembly	Onboard, via supply boat, remobilize dockside, possibly inside another container
Mud Engr Lab	20' container	Lab for Mud Engineer	Same as GOM2-1	Power, water, drain, vent, internet, desk	Mud checks, reports	Onboard, via supply boat

13.7.3 Personnel

13.7.3.1 Training

All personnel, prior to arriving on the vessel, will have completed all training and certifications required by their company and the Rig Contractor (e.g. Well Control, HUET, Rig Pass). The science team, Geotek, and the UT Drilling Representative(s) shall provide a copy of training/certification documentation and passport to UT the Project Manager prior arriving at the heliport for travel to the rig.

13.7.3.2 Travel to Heliport

Travel of all science team members to/from the heliport will be coordinated by UT. Travel of Rig Contractor, Geotek, and third-party personnel will be the responsibility of the company involved.

13.7.3.3 Travel to/from Rig

Transport of personnel between the heliport/shore-based facility and the rig will be coordinated between the UT Drilling Representative and the Rig Contractor. Transport of personnel will be primarily by helicopter. Helicopter trips will be scheduled/coordinated at maximum efficiency to reduce costs. At times, travel on crew boats or supply vessels may be required.

13.7.3.4 Passports / USCG Letter of Determination

All personnel will have a valid passport. Non-US citizens will also be required to have a USCG Letter of Determination allowing permission to work on the Outer Continental Shelf.

13.7.3.5 Rig Pass cards

Documentation denoting completion of the Rig Pass training program to be supplied by all personnel to the Rig Contractor, as required.

13.7.3.6 Luggage limits

All personnel will limit the size and weight of luggage under the assumption that they be transiting via helicopter.

13.7.3.7 Safety Management System

All personnel on-board the vessel will follow the Rig Contractor's Safety Management System. A bridging document will be prepared to identify and clarify which procedures/policies to follow if there are differences in policy between the Rig Contractor and UT. The highest standard will be followed.

13.7.3.8 Incident Notification

UT will prepare an Incident Notification document with flow chart and call list of contact names/numbers for Regulatory Agencies, UT Management, Geotek, UT Drilling Representative(s), and Science Team. BSEE notifiable incidents include: Fatalities, injuries that require evacuation, loss of well control, fires and explosions, spills > 1 bbl, reportable releases of hydrogen sulfide, collisions (equipment damage greater than $25,000), incidents involving crane or personnel/material handling operations, and incidents involving damage or disable safety systems or equipment including firefighting systems.

13.7.3.9 Shifts

All personnel will work a 12-hour shift. Shifts for the science team and Geotek will be coordinated prior to deployment. Rig Contractor and Third-Party Supervisors typically work a 6-6 shift (6 am to 6 pm or 6 pm to 6 am); with vessel and third-party crews working a 12-12 shift (noon to midnight or midnight to noon). The UT Drilling Representative(s), Principal investigator, and staff scientist will most likely work a 6-6 shift with the science team and Geotek will working on a 12-12 shift.

13.8 Demobilization from Rig

13.8.1 Materials and Equipment

13.8.1.1 Disembarking Materials and Equipment

The Rig Contractor will work with third party services, Geotek, and the UT Drilling Representative to ensure all supplies and equipment are removed from the vessel and delivered to the Shore Base. Prior to backloading any Geotek equipment, Geotek will lead and UT will support a complete inventory of all Geotek equipment. Geotek to provide supervisory oversight while their equipment is being backloaded to the demobilization vessel. Third party providers are responsible for securing and supervising the backloading of their equipment. A list of cement and mud products to be returned is to be provided to the UT Drilling Representative prior to the third-party representative leaving the drilling vessel. The UT Drilling Representative is responsible for inventory, securing and backloading of all UT owned equipment including new equipment purchased for the project such as adapters & subs.

13.8.1.2 Equipment left onboard

Should equipment be accidently left onboard the drilling vessel; UT will work with the Rig Contractor to ensure timely delivery to the Shore Base.

13.8.1.3 New Equipment

Any newly acquired UT-owned equipment (e.g. BHA subs delivered from factory directly to Rig Contractor) will be properly catalogued and prepared for demobilization along with existing equipment.

13.8.1.4 Waste

The Rig Contractor will backload mud and cement waste and coordinate disposal in an accredited onshore disposal site. The Rig Contractor will also coordinate the cleaning of the bulk tanks on the demobilization vessel after equipment and waste has been removed.

13.8.2 Personnel

13.8.2.1 Science Team and Third Party

Transport of personnel to the heliport will be coordinated between the UT Drilling Representative and the Rig Contractor. Helicopter flights will be scheduled/coordinated at maximum efficiency to reduce costs.

13.8.2.2 Pressure Core Observers

Geotek will elect two personnel to accompany the pressure cores on the demobilization vessel to ensure proper temperature and pressure is maintained in the transport containers at all times.

13.9 Remobilization Dockside

Pressure and conventional core processing will continue dockside in a dedicated area within the Shore Base. The processing area will be set-up using a number of containers demobilized from the rig. Additional containers and equipment will be mobilized to the processing area to complete the site.

13.9.1 Geotek Site Plan

Dockside container layout & hook-up will be as per the Geotek Site Plan (see Figure 13-1below for example plan). Geotek will be responsible for coordinating the order of hook up & deck layout of the containers at the dock. Hook-up includes appropriate dunnage, inclement weather engineering controls, power generators, fuel bowsers, air, water, etc.

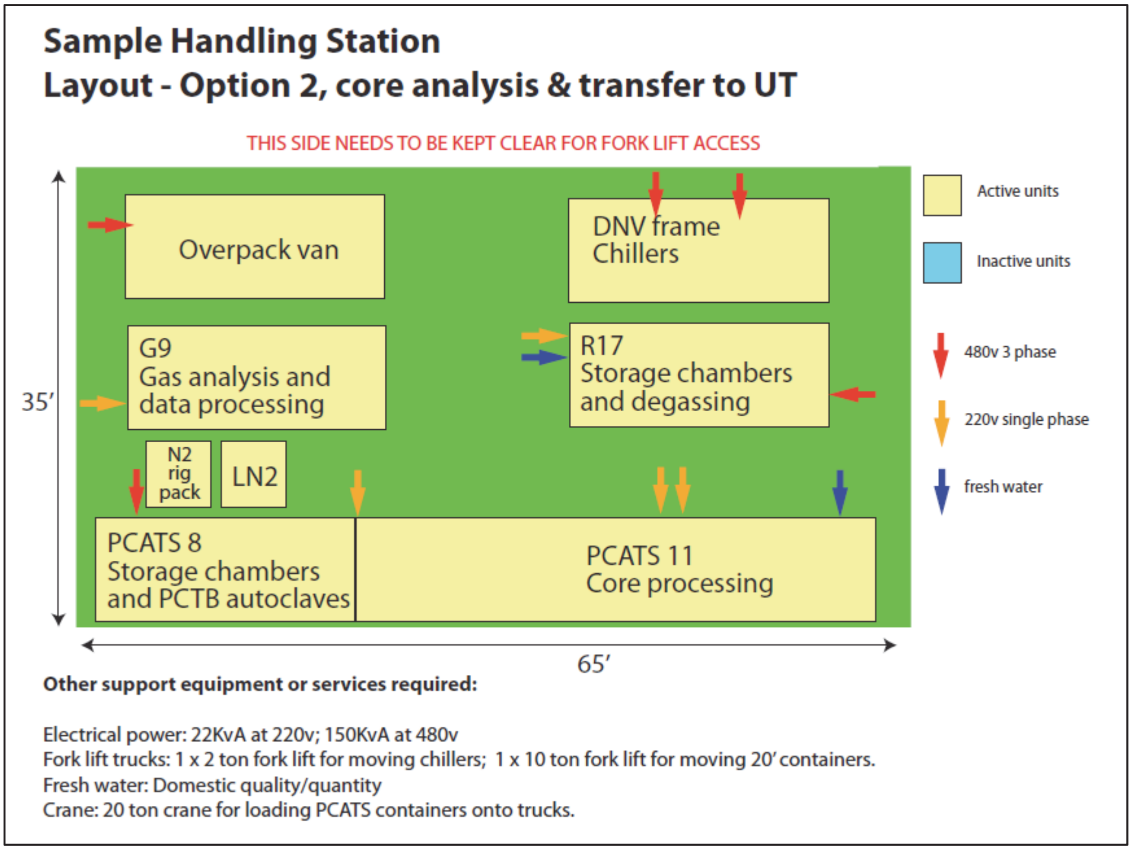

Figure 13-1. Example of Geotek Site Plan

13.9.2 Dockside Containers

Pressure core operations and analysis will require 3 containers to be remobilized dockside. Geotek will have a 40+20-ft container (for PCATS operations and storage chamber storage), and a 20-ft container for pressure core storage and degassing). The Geotek 40-ft trailer for the PCTB will be transferred to a TBD location for cleaning and preparation for long term storage.

Conventional core operations will require 6 containers, 4 remobilized and 2 new. Geotek will provide a new (not from the vessel) 20-ft trailer for MSCL scanning and CT imaging. The Geotek 40-ft container for whole core receiving and 20-ft container for core storage will be remobilized. UT's 20-ft container for whole round sampling will need to be remobilized dockside (TBD). UT's pore water container for pore water analysis will need to be remobilized dockside. Geotek will provide a 40-ft container for split core scanning, layout, and analysis. This 40-ft container will be fitted with an exterior covered lay down area for core splitting.

The UT 20-ft Office will need to be brought to the dock or remobilized dockside if it was needed on-board (TBD).

All containers require dunnage, which will be provided by the Shore Base Operator (contracted through the Rig Contractor). PCATS and the mud lab require drainage to a stillage. The Shore Base Operator will provide the stillage.

A reefer truck with the Geotek overpack system, two power generators, and a fuel bowser will be mobilized dockside.

Expected container requirements for the dockside core-processing operations are summarized in Table 13-2 below.

Table 13-2. Dockside Container - name, type and size, container description, comparison to the previous expedition, container activities, mobilization location, and required hook-up

Name	Type	Description	Reuse or New	Required demobilization supply boat Hook-up	Required Dockside Hook-up	Activities	Mobilization/ demobilization
PCATS11	40' container	PCATS Analysis	Same as GOM2-1	None	Power (2 - 220v single-phase), water, air, Network/Internet, timber supports	Pressure core imaging, scanning, cutting, and transfer	Onboard, via supply boat, remobilize dockside
PCATS8	20' container	PCATS Autoclave and storage vessel handling	Same as GOM2-1	Power	Power (480v 3-phase, 220v single-phase), air, timber supports	Pressure core imaging, scanning, cutting, and transfer	Onboard, via supply boat, remobilize dockside
R17	20' container	Pressure Core storage and degassing	Same as GOM2-1	Power	Power (480v 3-phase, 220v single-phase), water, air	Pressure Core Storage, quantitative degassing, gas sampling	Onboard, via supply boat, remobilize dockside
Core Storage	20' container	Pressure and Conventional Core Storage	NEW	Power	Power (480v 3-phase, 220v single-phase), water, air	Pressure and Conventional core storage racks, and core transport	Onboard, via supply boat, send to Stratum Reservoir, then dockside, then archival halves to storage facility
Core Receiving Lab	40' container	Geotek Whole Core Processing Laboratory	NEW DNV	Power	Power, air	Cold PC storage	Onboard via supply boat, remobilize dockside
PC Storage	20' container	Additional storage space for additional SC350's	NEW or rented DNV reefer	None	Power (480v 3-phase), water, drain/sediment waste trap	SC_{350} long pressure core storage and transport	Onboard, via supply boat, remobilize dockside
Core Processing Lab	20' container	Microbiology, M&D	Same as GOM2-1	TBD	Power (480v 3-phase), water, drain	Whole Core cutting under N2, Microbiology and M&D sample handling	Onboard, via supply boat, remobilize dockside
Pore Water Lab	20' container	Pore Water Laboratory	NEW	TBD	Power (480v 3-phase), water, drain	Pore Water Squeezing, Analysis, and storage	Onboard, via supply boat, remobilize dockside
3rd Party Conex	20' container	UT Office Space	Same as GOM2-1	None	Power, network, internet, desk	Writing, Data Analysis	Onboard, via supply boat, remobilization dockside is TBD
MSCL /X-ray	20' container	Core Scanning, Core imaging	NEW	NA	Power, water, air	Conventional Whole core scanning	Dockside only
Split Core Lab	40' container with 'tent'	Split Core Analysis	NEW	NA	Power, water, air	Split core scanning, layout, M&D weights, smear slide prep and sample preservation	Dockside only
Overpack	20' Reefer Truck	Overpack reefer truck	Same as GOM2-1	NA	None	Pressure Core Transport over land	Dockside only
Gen1		Power Generator #1	Same as GOM2-1	NA	None	NA	Dockside only
Gen2		Power Generator #2	Same as GOM2-1	NA	None	NA	Dockside only
Fuel		Fuel Bowser	Same as GOM2-1	NA	None	NA	Dockside only

13.10 Dockside Core Processing

13.10.1 Samples and Cores

Detailed movement and processing of samples and cores will be as outlined in the UT-GOM2-2 Science and Distribution Plan.

13.10.2 Reporting

UT will provide a daily update to the UT-GOM2-2 Advisory Team with additional updates as required. UT will maintain close contact with GOM2 project manager, program manager, and IT support team.

13.10.3 Personnel

13.10.3.1 Room and Board

UT personnel will coordinate room and board for the onshore/dockside science team. Third party members (e.g. Geotek) will be responsible for coordinating their own accommodations.

13.10.3.2 Shifts

Shift duration and timing will be decided by PI, staff scientist, and Geotek leads.

13.10.3.3 Supplies and Equipment

Shipment of supplies and equipment will be coordinated between UT, Geotek, and the Dockside Dispatcher.

13.10.3.4 Safety Management System

All personnel dockside will follow the port safety procedures. A bridging document will be prepared to identify and clarify which procedures/policies to follow if there are differences in policy between the Vessel Operator and UT. The highest standard will be followed.

13.10.3.5 Incident Notification

UT will prepare an Incident Notification document with flow chart and call list of contact names/numbers for Regulatory Agencies, UT Management, Geotek, and Science Team.

13.11 Demobilization from Dockside

Demobilization will be coordinated by Geotek, UT, and the Port Management. Exact division of responsibility will be agreed upon prior to departure but is dependent on yet to be decided factors, e.g. dockside location.

14 List of Acronyms

Table 14-1. List of Acronyms

ACRONYM	DEFINITION
°C	degrees Celsius
3D	3-Dimensional
APC	Advanced Piston Corer
API	American Petroleum Institute radioactivity unit
bbl	barrel
BHA	Bottom Hole Assembly
BHSZ	Base of Hydrate Stability Zone
BOEM	Bureau of Ocean Energy Management
BSEE	Bureau of Safety and Environmental Enforcement
BSR	Bottom Simulating Reflector
cm	centimeter
CPP	Complimentary Project Proposal
CT	Computed Tomography
DNA	Deoxyribonucleic Acid
DNV	De Norske Veritas AS
DOE	Department of Energy
DOT	Department of Transportation
fbsf	feet below sea floor
fbsl	feet below sea level
ft	feet
ft^2	square feet
g/cm3	gram per cubic centimeter
GAPC	Geotek Advanced Piston Corer
GC	Gas Chromatography
GHSZ	Gas Hydrate Stability Zone
GR	Gamma Ray
GRMA	Gamma Ray, Average
GWC	gas-water contact
GXCB	Geotek eXtended Core Barrel
HRZ	Horizon
HUET	Helicopter Underwater Escape Training
IEU	Internal-External Upset
IR	Infrared
JIP	Joint Industry Project
JR	JOIDES Resolution
LA	Louisiana
lb	pounds
LDEO	Lamont-Doherty Earth Observatory
LWD	Logging While Drilling
m	meter
m/s	meter per second
MD	Measured Depth

ACRONYM	DEFINITION
mm	millimeter
MODU	Mobile Offshore Drilling Unit
MSCL	Multi-Sensor Core Logger
msl	mean sea level
MTD	Mass Transport Deposits
NAD	North American Datum
NE	Northeast
NEPA	National Environmental Policy Act
NNE	North-Northeast
NPDES	National Pollutant Discharge Elimination System
PC	Pressure Core
PC	Pressure Core
PCATS	Pressure Core Analysis and Transfer System
PCTB	Pressure Coring Tool with Ball-Valve
PCTB-CS	Pressure Coring Tool with Ball-Valve - Cutting Shoe
PCTB-FB	Pressure Coring Tool with Ball-Valve - Face Bit
PDC	Polycrystalline Diamond Compact
PI	Principle Investigator
PPG	Pounds Per Gallon
psi	pounds per square inch
psi/ft	pounds per square inch, per foot
RAID	Redundant Array of Independent Disks
RES	Resistivity
RKB	Rotary Kelly Bushing (depth reference point)
RNA	Ribonucleic Acid
ROP	Rate of Penetration
ROV	Remotely Operated Vehicle
S_h	Hydrate Saturation (expressed as a % of pore volume)
sks	sacks
SMT	Sulfate-Methane Transition
SSW	South-Southwest
SW	Southwest
T2P	Temperature to Pressure Probe
TBD	To Be Determined
TD	Total Depth
TVD	Total Vertical Depth
UNH	University of New Hampshire
US	The United States of America
USCG	United States Coast Guard
USGS	United States Geological Survey
UT	The University of Texas at Austin
UTIG	The University of Texas at Austin Institute for Geophysics
UTM	Universal Transverse Mercator
UW	University of Washington
V_p	P-Wave Velocity

ACRONYM	DEFINITION
WBM	Water Based Mud
WR	Walker Ridge
XCB	eXtended Core Barrel
XCT	X-ray Computed Tomography

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APPENDIX B

2020 PCTB Ball Valve Upgrades and Testing Report

2020 PCTB IV BALL VALVE UPGRADES AND TESTING

UT/DOE 2020

GEOTEK LTD DOCUMENT NO. UT2020 (R1)

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UT/DOE

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2	PUBLIC RELEASE	GCI	PJS	14/01/2021

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PREAMBLE

The overall performance, recovery, and pressure retention statistics of the PCTB have improved over the years as design refinements have taken place, to the point where it is used in most situations with a high degree of success. However, there has been one aspect of the performance that has until now remained rather elusive to evaluate: the patchy performance of the pressure boost function. After redesign and upgrades to the upper seal section to resolve timing issues, "late pressure boosts" were eliminated. Surprisingly, fixing these timing issues did not solve all the pressure boost problems: tool runs where the core barrel sealed, but no pressure boost was present, remained common.

These tool runs, which showed no boost but were recovered at near in situ pressure, focused our attention on the ball valve mechanism. This attention came much more sharply into focus following the dismal pressure core retention during the most recent tests at CTTF. It was abundantly clear during these tests that fine grit was getting into the sprung-loaded slide mechanisms and preventing full closure of the main ball valve, resulting in failure to hold pressure. On more than one occasion, after the tool was recovered to the drill floor, the shock of handling caused the ball valve to complete its closure, implying that the forces opposing the spring mechanism were finely balanced. This observation accords well with field data, where tool runs that do not show a pressure boost often have a “late seal”. Our model of this behavior is that foreign particles (grit/fine sand) in the ball valve mechanism temporarily cause the ball valve to stick open, but the impact of the tool against the pipe during marine coring operations can dislodge these particles, allowing the springs to operate correctly and close the valve. However, in the shallower tests, in the more controlled environment at CTTF, the tool recovery is largely a smoother operation where the rattling of the tool in the pipe during recovery is less pronounced. This results in only partial activation of the springs and incomplete ball closure on recovery.

Previous ‘full function tests’ in the controlled environment of the laboratory and or test pit at Geotek’s facility in Salt Lake City have provided high degrees of success. However these have always been conducted with relatively clean fluids. Following our experience at CTTF we set about trying to recreate a test scenario whereby the ball valve mechanism would fail to close when we added small amounts of grit to the system. After some experimentation we developed a procedure which provided a grit-induced failure on a very repeatable basis. This can be clearly observed through a transparent water-filled tube. This procedure we believe is a fair representation of the problem we experienced at CTTF and enabled us to confidently test a number of design modifications. The observations made during these tests led to some subtle but important design changes that are detailed in this report. We are now confident that pressure boosts with resultant pressure recovery at or above in situ pressures will be seen much more regularly during the use of the PCTB and the sight of ball valves stuck open will be even less common.

EXECUTIVE SUMMARY

2020 PCTB IV Ball Valve upgrades and testing validation includes three primary sections:

1. Post CTTF 2020 Ball Valve testing and root cause analysis
2. Design modifications
3. Design upgrade validation testing

The first reported section includes a combination of testing designed to reproduce the ball valve actuation failures seen in CTTF 2020. A rotating clear acrylic test fixture was designed to actuate the isolated ball valve assembly in and record video data of tests for data extraction. Test failures were produced by actuating the ball valve in a water and fine grit (53-125 µm particle size) solution. A batch of 20 tests were performed using 0.24% solids by weight and produced a success rate of 12%.

The second reported section outlines design modifications for the ball valve assembly. The following parts were revised:

- **AES7612 – Cutting Shoe Sleeve**
  - Extended length and moved diversion seal from inner to outer diameter
- **CES7622 – Housing Extension**
  - Decreased flow port angles from 45 to 30 degrees to improve flow path through ports. Added inner diameter seal surface for diversion seal on cutting shoe sleeve
- **CES7515 – Seal Carrier**
  - Revised part to use Polypak seal, improved surface finish for better dynamic sealing, increased back shoulder length for improved centralizing throughout actuation
- **AES7609 – Ball Follower**
  - Adjusted shoulder length to fit ball valve return spring
- **AES7610 – Ball Valve Housing**
  - Added wiper ring grooves on the inner diameter for the seal carrier and ball follower to ride on

The final reported section includes the validation testing data of the upgraded parts. Two more modifications were made in order to improve the upgrade.

The first modification included machining slots and wrapping the slots in a 75 µm stainless steel mesh around the diameter of the ball follower, this solved a hydro-locking problem created by adding wiper ring seals to the system, while also filtering particles from building up on the follower surface.

The second modification included the design of a new ball valve return spring. The original revision of this spring caused failures when introducing fine grit to the system due to binding from the excess number of coils and total length of compression of the spring.

A batch of 20 identical tests with 0.24% solids by weight were performed on both the original and the final upgraded assembly. The original ball valve assembly produced a 12% pass rate, while the upgraded assembly produced a 100% pass rate.

1 CURRENT REVISION BALL VALVE ISOLATION TESTING

1.1 SECTION 1 SUMMARY

Different variations of isolated ball valve testing were performed to replicate the failures seen in CTTF. Failures were only achieved when fine grit Aluminum Oxide particles (53-125 µm) were introduced to the system. The grit was consistently successful in jamming the ball valve assembly during actuation in both water and viscous drilling fluids. When further troubleshooting the failures, we observed that the ball follower/ return spring was the primary culprit for stopping full rotation.

1.2 BALL VALVE DRY FIRE TESTING

The first set of testing is a dry fire of the isolated ball valve assembly using the collet release sleeve. By dry firing in air, the least viscous medium in this testing set, we were able to achieve baseline data for the quickest ball valve actuation. Figure 1 shows the dry fire setup of the isolated ball valve assembly.

Figure 1. Isolated ball valve assembly for dry firing

The results of the dry fire data were recorded by filming the ball valve in slow motion at 240 fps. The frames from the entire actuation are then counted using a video editing software. The results are shown in table 1 below.

TEST #	TOTAL FRAMES TO FIRE	FRAMERATE	TIME TO FIRE (S)
1	6	240	0.025
2	7	240	0.029
3	7	240	0.029
4	7	240	0.029
AVERAGE	6.75	240	0.028

Table 1. Dry fire test results

The four tests yield consistent results showing an average of 6.75 frames, or 0.028 seconds, to fully actuate the ball.

1.3 BALL VALVE WATER TESTING

A fixture was constructed out of a clear acrylic tube to house the ball valve assembly during actuation. The acrylic has a 4.75” ID, to closely simulate the bore size of the BHA. The fixture is displayed in Figure 2 with a ball valve assembly inside and full of water.

Figure 2. Acrylic test fixture

The ball valve was tested five times in tap water to compare baseline data in liquid. The results are documented in table 2 below.

TEST #	TOTAL FRAMES TO FIRE	FRAMERATE	TIME TO FIRE (S)
1	12	240	0.050
2	11	240	0.046
3	11	240	0.046
4	11	240	0.046
5	10	240	0.042
AVERAGE	11	240	0.046

Table 2. Water fire test data

Firing the ball in water slowed the actuation down by an average of 4.25 frames, or 0.018 seconds. All the actuations were smooth and consistent.

1.4 DRILLING FLUID POLYMER TESTING

In order to increase the viscosity of the fluid, Insta-Vis^{TM} Drilling Fluid Polymer was mixed with water to create three different test fluids. Each fluid viscosity was measured with a timed ball drop test and calculated knowing the size, density of the ball, and density of the fluid. Three different viscosity fluids were mixed, and the ball valve assembly was fired once in all three of the fluids. The three test results are listed in table 3 below.

TEST #	TOTAL FRAMES TO FIRE	FRAMERATE	TIME TO FIRE (S)	FLUID VISCOSITY (PA*S)
1	13	240	0.054	2.14
2	14	240	0.058	4.78
3	13	240	0.054	10.94

Table 3. Drilling fluid fire testing

The increased viscosity of the fluid proved to not slow the ball valve down in any meaningful way.

1.5 INTRODUCED GRIT TESTING

- **#149 µm size sand**

The first test with introduced grit included about 2 lbs of #100 mesh sand (149 µm particle size) mixed into a drill mud solution. The same sand was also applied to the ball valve assembly seal carrier, ball, and ball follower; with fluid film as a sticking agent, before deploying into the test fixture. Figure 3 below shows the ball valve before deployment.

Figure 3. Ball valve covered with #100 mesh sand

The ball valve actuated fully, and the #100 sand created no discernible issues during the test.

- **53-125 µm Aluminum Oxide blast media**

The next grit testing uses 53-125 µm Aluminum Oxide to create a failure during actuation. This material was picked based on the CTTF mud particle sizes extracted from a sample. Introducing Aluminum Oxide to the ball valve assembly began producing failures. Six various tests were performed with the Aluminum Oxide blast media and all the data was captured with slow motion videos.
Each header below will include the name of the recorded video followed by the test parameters, results, and observations.

  - **Al2_O3_1**

  The seal carrier, ball, ball follower, and housing extension flow ports are coated with fluid film and Aluminum Oxide is applied to the surface. The assembly pre-deployment is shown below in Figure 4.

Figure 4. Ball valve assembly with applied Aluminum Oxide

The ball valve was actuated in the test fixture filled with water and failed. The ball valve closes halfway before jamming.

- **Al2_O3_2**

The ball follower is coated with fluid film and Aluminum Oxide is applied to the surface. The tool was actuated in water and failed. The ball valve is jammed and closes approximately 5% of the stroke.

- **Al2_O3_3**

Four grams of Aluminum Oxide was measured and poured into the flow ports of the ball valve housing extension. The ball was actuated in water and failed. The ball valve closes approximately 25% of the stroke.

- **Al2_O3_4**

Four grams of Aluminum Oxide was measured and applied to the carrier and ball follower. The ball was actuated in water and failed. The ball valve closes approximately 10% of the stroke.

- **Al2_O3_5**

The assembly was lightly pressure washed and no more grit was added to the tool. The ball valve was actuated in water and failed. The ball valve closes approximately 10% of the stroke.

- **Al2_O3_6**

The ball valve assembly was fully disassembled, pressure washed, and rebuilt. No grit was applied to the assembly. A clear drilling fluid mixture was made to closely simulate CTTF mud specifications with the following parameters:

- Viscosity of 48 s/quart (determined from CTTF mud report)
- 0.24% Aluminum Oxide by weight added to drilling fluid

The tool was then actuated and failed. The ball valve closed approximately 90% of the stroke.

1.6 ALUMINUM OXIDE AND WATER TESTING

In order to further validate the test failures, three ball valve assemblies were tested 26 times in the same conditions.

Assembly #1 and #2 were assembled with upgraded Xylan coated parts, including the seal carrier, ball valve spring, and spring collet. Assembly #3 was assembled as the older revision ball valve, with no Xylan coated parts.

In order to achieve consistent data, a test procedure was developed and performed systematically for all 26 tests. The procedure included the following steps:

- Fully disassemble all ball valve assembly components
- Pressure wash each individual component until grit free
- Reassemble ball valve with all seals and lubrication used in the field
- Dry fire ball valve in vice with release sleeve, reset ball valve and reset sleeve
- Place ball valve assembly into acrylic test fixture
- Mix 2.5 gallons of water with 0.05lbs of Aluminum Oxide powder
- Pour solution into the test fixture to fill in and around the assembly
- Let solution settle for 15 seconds
- Fire ball valve by removing release sleeve
- Remove tool and wash out fixture in preparation for next test

Each test was filmed in slow motion at 240 fps. The results of this set of testing is shown below in Table 4,5, and 6.

******The naming convention for the videos denotes A#, for assembly number, G# for grit test number, Pass for sealed after actuation, and Fail for leaking.* *

ASSEMBLY #	VIDEO NAME	APPROX. % BALL CLOSED	SEALED (Y/N)	FRAME COUNT	ACTUATION TIME (S)

1	A1_G1_Fail	75	N	14	0.058
1	A1_G2_Pass	95	Y	12	0.050
1	A1_G3_Fail	80	N	19	0.079
1	A1_G4_Fail	90	N	14	0.058
1	A1_G5_Fail	25	N	16	0.067
1	A1_G6_Fail	80	N	17	0.071
1	A1_G7_Fail	80	N	14	0.058
1	A1_G8_Fail	80	N	23	0.096
1	A1_G9_Fail	80	N	24	0.010

Table 4. Assembly #1 water and grit test results

Assembly #1 failed to fully fire and seal 8/9 times. After each failure, the ball valve was removed from the test fixture and evaluated by putting downward pressure on the ball follower. On 6/8 failures, pushing on the ball follower would reduce the jamming and help the ball finish the stroke. The seal carrier would remain in contact with the ball and continue its downward motion. During these tests, a noticeable amount of grit was built up around the ball follower causing the resistance of downward motion.

On 2/8 of the failures, when the ball follower was pushed down the seal carrier remained jammed. The carrier would then finish its stroke and seal after a small delay. This can be seen in video **A1_G8_Jammed Seal Carrier**.

ASSEMBLY #	VIDEO NAME	APPROX. % BALL CLOSED	SEALED (Y/N)	FRAME COUNT	ACTUATION TIME (S)
2	A2_G1_Pass	100	Y	11	0.046
2	A2_G2_Pass	100	Y	21	0.088
2	A2_G3_Fail	25	N	16	0.067
2	A2_G4_Pass	100	Y	14	0.058
2	A2_G5_Pass	100	Y	16	0.067
2	A2_G6_Pass	95	Y	17	0.071
2	A2_G7_Pass	100	Y	15	0.063
2	A2_G8_Pass	100	Y	15	0.063
2	A2_G9_Fail	85	N	28	0.117
2	A2_G10_Pass	100	Y	14	0.058

Table 5. Assembly #2 water and grit test results

Assembly #2 failed to fully fire and seal on 2/10 tests. Pressure was applied to the ball follower on both failures and the seal carrier would remain unjammed throughout the length of the remaining stroke.

Although assembly #2 fired and sealed on 8/10 tests, the timing of the successful tests was slower than the baseline average. The successful assembly #2 tests took an average 15.375 frames, or 0.064 seconds to close. This is 28% slower than the baseline water fire data average of 11 frames, or 0.046 seconds.

ASSEMBLY #	VIDEO NAME	APPROX. % BALL CLOSED	SEALED (Y/N)	FRAME COUNT	ACTUATION TIME (S)

3	A3_G1_Pass	100	Y	15	0.063
3	A3_G2_Fail	5	N	NA	NA
3	A3_G3_Fail	80	N	16	0.067
3	A3_G4_Fail	5	N	NA	NA
3	A3_G5_Fail	25	N	15	0.063
3	A3_G6_Fail	5	N	NA	NA
3	A3_G7_Fail	50	N	17	0.071

Table 6. Assembly #3 water and grit test results

Assembly #3 failed at the highest rate of 6/7 tests. This assembly included no Xylan coated parts and consistently jammed at an earlier state in the ball valve stroke than both assembly #1 and assembly #2. On three of the assembly #3 tests, the ball valve jams immediately, and no useful timing data could be collected. On all the failures the seal carrier was not jammed when the ball follower was pressed down, and the stroke would complete.

1.7 SECTION 1 CONCLUSION

Overall, each of the three ball valve assemblies tested in water and a 53-125 µm grit solution failed. The fine grit particles successfully jammed the sliding surfaces inside the ball valve assemblies and created partial actuations. Frame by frame timing data on the successful firing tests shows that grit in the system slows down the actuation when compared to the baseline water-only testing performed.

2 BALL VALVE ASSEMBLY DESIGN MODIFICATIONS

2.1 MODIFICATIONS PARTS IN THE BALL VALVE ASSEMBLY

The modifications include the following parts:

- Extended seal carrier
- Modified ball valve housing
- Modified ball follower
- Modified housing extension
- Extended cutting shoe sleeve

2.2 EXTENDED SEAL CARRIER

The seal carrier was modified to have a single seal groove to fit a low-friction Polypak lip seal. The second seal groove was eliminated along with using O-rings. The seal carrier was also modified to have an extended back shoulder that fits tightly into the spring collet. This feature should help with centralizing the seal carrier during actuation and eliminate any potential sticking when sliding through the seal bore. The seal carrier was also modified to have a finer surface finish to reduce friction during actuation and improve dynamic sealing.

2.3 MODIFIED BALL VALVE HOUSING

The ball valve housing was modified to include an upper and lower seal groove for loose wiper rings. These wiper rings should assist in diverting fine grit particles away from the tight tolerance sliding seal surfaces. The wiper rings will ride on both the seal carrier and the ball follower during actuation.

2.4 MODIFIED BALL FOLLOWER

The ball follower modification includes lengthening the upper shoulder to ensure that the wiper ring remains in contact with the follower shoulder during the entire actuation.

2.5 EXTENDED CUTTING SHOE SLEEVE

The cutting shoe sleeve was modified to eliminate the inner seal groove and O-ring. The seal groove was changed to the outer diameter and sized to fit a custom diversion seal. The part was extended in length so that the diversion seal now seals on the inner diameter of the housing extension and the flow path is now not directed at the ball follower sliding surface. This should eliminate particles building up between the surface of the ball follower and cutting shoe sleeve and prevent jamming.

2.6 MODIFIED HOUSING EXTENSION

The modified housing extension includes steeper angled flow ports to better streamline flow through the housing extension and out of the cutting shoe. This modification should improve the flow through the cutting shoe ports and help prevent plugging and bit balling when coring with the cutting shoe.

3 BALL VALVE MODIFICATION TESTING DATA

3.1 SECTION 3 INTRODUCTION

In this iteration of testing we perform isolated ball valve actuation tests in air, water, and fine grit particles on the following upgrades:

- Extended seal carrier
- Modified ball follower
- Modified housing extension
- Modified ball valve housing
- Extended cutting shoe inner sleeve
- Upgraded diversion seal, seal carrier lip seal, wiper rings, return spring

Different combinations of the upgrades were tested together in different configurations to compare ball closing speed and consistency. All tests were recorded at 240 FPS and a video processing software was used to log the number of frames for the ball valve to actuate.

3.2 CONFIGURATION 1

The first configuration tested included the low-end upgrades while keeping the current top end configuration the same. This configuration includes the following:

- Upgraded cutting shoe inner sleeve
- Upgraded diversion seal
- Upgraded housing extension
- Upgraded ball follower

The current revision of the seal carrier was used with two O-rings in the seal carrier O-ring grooves.

The first set of testing performed on this configuration included dry fire ball valve actuations. The results of this testing can be seen below in table 7.

DRY FIRE TESTING CONFIGURATION 1

TEST #	Frames to fire	Framerate (FPS)	Time to fire (s)	Notes	Video hyperlink
1	8	240	0.033	Smooth fire, full close	Dry Fire 1
2	9	240	0.038	Smooth fire, full close	Dry Fire 2
3	8	240	0.033	Smooth fire, full close	Dry Fire 3
AVERAGE	8.3	240	0.036	------------------	------------------

Table 7. Dry fire test results for configuration 1

The upgraded assembly including the new low-end parts and current seal carrier yielded consistent results throughout all three tests. The ball closed quickly with no interruptions.

The next test performed on this configuration included firing the ball valve inside of the clear acrylic test fixture while filled with water. The results can be seen below in table 8.

WATER FIRE TESTING CONFIGURATION 1

TEST #	Frames to fire	Framerate (FPS)	Time to fire (s)	Notes	Video hyperlink
1	44	240	0.183	Full close, lags when pushing O-rings into seal bore	Water Fire 1
2	42	240	0.175	Full close, lags when pushing O-rings into seal bore	Water Fire 2
3	49	240	0.204	Full close, lags when pushing O-rings into seal bore	Water Fire 3
AVERAGE	45	240	0.188	---------------------------	----------------

Table 8. Water fire test results for configuration 1

The water fire results yielded slower actuations than the dry fire results by an average of 81%. The ball valve would consistently lag throughout the actuation but consistently closed fully on all three tests. This could be due to the high friction of the two O-rings on the seal carrier when seating into the seal bore or a potential hydro locking issue.

3.3 CONFIGURATION 2

The next group of testing consisted of a configuration including the upgraded extended seal carrier and a single low friction lip seal. The low end included all the current revision parts.

Five dry fire tests were performed on configuration 2. The results can be seen below in table 9.

DRY FIRE TESTING CONFIGURATION 2

TEST #	Frames to fire	Framerate (FPS)	Time to fire (s)	Notes	Video hyperlink
1	10	240	0.042	Smooth fire, full close	Dry Fire 1
2	27	240	0.113	Smooth closure to 90%, failed to fully close	Dry Fire 2
3	39	240	0.163	Slow closure to 90%, failed to fully close	Dry Fire 3
4	14	240	0.058	Changed out cutting shoe and inner sleeve, smooth fire, full close	Dry Fire 4
5	16	240	0.067	Smooth fire, full close	Dry Fire 5

Table 9. Configuration 2 dry fire results

The dry fire results on configuration 2 yielded inconsistent results. The ball failed to fully actuate on two of the five tests. After the second failure, the cutting shoe inner sleeve, and inner sleeve O-ring diversion seal were replaced. The next two tests resulted in two successful actuations.

Three water fire tests were performed, the results can be seen below in table 10.

WATER FIRE TESTING CONFIGURATION 2

TEST #	Frames to fire	Framerate (FPS)	Time to fire (s)	Notes	Video hyperlink
1	16	240	0.067	Smooth fire, full close	Water Fire 1
2	15	240	0.063	Smooth fire, full close	Water Fire 2
3	15	240	0.063	Smooth fire, full close	Water Fire 3
AVERAGE	15.3	240	0.064	------------------------------	-----------------

Table 10. Configuration 2 water fire results

The three water fire tests resulted in three successful and consistent tests. Each actuation closed quickly and smoothly. The average time to close was 0.064 seconds.

Overall, configuration two performed inconsistently between the dry fire and water fire testing. Changing out the cutting shoe inner sleeve improved the rest of the test results.

3.4 CONFIGURATION 3

The third configuration included all of the new upgraded parts except for the two ball valve housing wiper rings.

Three dry fire tests were performed, and the results can be seen below in table 11.

DRY FIRE TESTING CONFIGURATION 3

TEST #	Frames to fire	Framerate (FPS)	Time to fire (s)	Notes	Video hyperlink
1	7	240	0.029	Smooth fire, full close	Dry Fire 1
2	6	240	0.025	Smooth fire, full close	Dry Fire 2
3	8	240	0.033	Smooth fire, full close	Dry Fire 3
AVERAGE	7	240	0.029	------------------------------	----------------------

Table 11. Dry fire testing results for configuration 3

The three dry fire tests resulted in smooth, quick, and full actuations. The average time to actuate was 0.029 seconds, making this the quickest configuration up to this point in testing.

Three water fire tests were performed on configuration 3. The results are displayed below in table 12.

WATER FIRE TESTING CONFIGURATION 3

TEST #	Frames to fire	Framerate (FPS)	Time to fire (s)	Notes	Video hyperlink
1	28	240	0.117	Smooth fire, full close	Water Fire 1
2	27	240	0.113	Smooth fire, full close	Water Fire 2
3	28	240	0.117	Smooth fire, full close	Water Fire 3
AVERAGE	27.7	240	0.115	------------------------------	----------------------

Table 12. Water fire testing results for configuration 3

The three water fire tests on configuration 3 all successfully closed smoothly. The time it took to close was slower than previous configuration water testing even though this configuration was the fastest dry fire closing configuration.

3.5 CONFIGURATION 4

The fourth configuration includes all of the upgraded parts, including both wiper ring seals positioned in the ball valve housing.

Three dry fire tests were performed, the results can be viewed below in table 13.

Dry fire testing configuration 4

Test #	Frames to fire	Framerate (FPS)	Time to fire (s)	Notes	Video hyperlink

1	8	240	0.033	Smooth fire, full close	Dry Fire 1
2	10	240	0.042	Smooth fire, full close	Dry Fire 2
3	10	240	0.042	Smooth fire, full close	Dry Fire 3
Average	9.3	240	0.039	-------------------------------	----------------------

Table 13. Dry fire test results for configuration 4

The three dry fire results all fired smooth and quickly. The average time to fully close the ball valve was 0.039 seconds. This actuation time was 2.3 frames, or .010 seconds, slower than configuration 3 with no wiper rings.

Three water fire tests were performed on configuration 4, the results are displayed below in table 14.

WATER FIRE TESTING CONFIGURATION 4

TEST #	Frames to fire	Framerate (FPS)	Time to fire (s)	Notes	Video hyperlink
1	13	240	0.054	Smooth fire, full close	Water Fire 1
2	14	240	0.058	Smooth fire, full close	Water Fire 2
3	11	240	0.046	Smooth fire, full close	Water Fire 3
AVERAGE	12.7	240	0.053	-------------------------------	----------------------

Table 14. Water fire testing for configuration 4

The three water fire tests of configuration 4 all closed smoothly. During actuation there was a noticeable amount of air released underneath the ball after firing. This led us to further investigate a solution to better bleeding air out of the ball valve before actuating.

3.6 UPSIDE-DOWN TESTING

After further investigating potential air pockets in the tool, we decided we could better bleed the air out of the system by filling and actuating the tool upside down in the test fixture.

By filling and actuating the tool upside down, we can verify that the system is bled and rigid where the air pocket is currently being trapped. Testing upside down should also reveal any potential hydro locking issues in the sealed cavity below the ball follower for the upgraded assembly.

The first set of upside-down testing was performed on configuration 4, including all new upgrades and both wiper ring seals. The results can be viewed below in table 15

UPSIDE-DOWN WATER FIRE TESTING CONFIGURATION 4

TEST #	Frames to fire	Framerate (FPS)	Time to fire (s)	Notes	Video hyperlink

1	82	240	0.342	Slow actuation, fired to 80% stopped before closing	Water Fire 1
2	88	240	0.367	Slow actuation, fired to 90% stopped before closing	Water Fire 2
3	98	240	0.408	Slow actuation, fired to 90% stopped before closing	Water Fire 3
4	8	240	0.033	Removed cutting shoe, inner sleeve, and diversion seal. Quick actuation, full closure	Water Fire 4

Table 15. Upside down water testing on configuration 4

Three upside-down water fire tests were performed with configuration 4 and all three failed to actuate fully. The actuation was noticeably slower and would close about 90% of the way before stopping. A fourth test was performed after removing the cutting shoe and cutting shoe inner sleeve. This test actuated quickly and closed fully.

3.7 BALL FOLLOWER HYDRO-LOCKING MODIFICATION

After failing the upside-down water tests, we modified the ball follower to allow for fluid compensation during actuation. Four, ½” wide by 1 ½” long slots were milled around the diameter of the ball follower. This modification is displayed below in Figure 5.

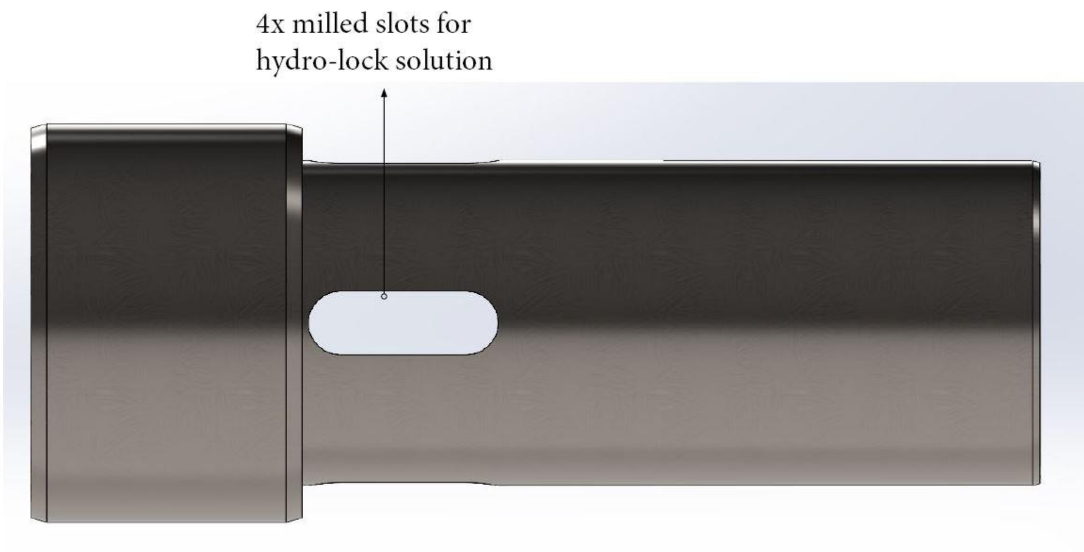

Figure 5. Modified fluid compensation ports in ball follower

3.8 CONFIGURATION 5

After modifying the ball follower to prevent hydro locking, 10 upside-down water fire tests were performed on the configuration including all new upgrades and a modified ball follower. The results are displayed below in table 16.

UPSIDE-DOWN WATER FIRE TESTING CONFIGURATION 5

TEST #	Frames to fire	Framerate (FPS)	Time to fire (s)	Notes	Video hyperlink
1	10	240	0.042	Smooth fire, fully closed	Water Fire 1
2	10	240	0.042	Smooth fire, fully closed	Water Fire 2
3	9	240	0.038	Smooth fire, fully closed	Water Fire 3
4	11	240	0.046	Smooth fire, fully closed	Water Fire 4
5	11	240	0.046	Smooth fire, fully closed	Water Fire 5
6	10	240	0.042	Smooth fire, fully closed	Water Fire 6
7	11	240	0.046	Smooth fire, fully closed	Water Fire 7
8	9	240	0.038	Smooth fire, fully closed	Water Fire 8
9	10	240	0.042	Smooth fire, fully closed	Water Fire 9
10	11	240	0.046	Smooth fire, fully closed	Water Fire 10
AVERAGE	10.2	240	0.043	----------------------------------	----------------

Table 16. Upside down water fire tests of configuration 5

The 10 tests all resulted in successful fully closed actuations. The average time for the 10 tests to fully close was 0.043 seconds. This configuration proved to actuate the quickest in the water fire testing out of all the configurations.

3.9 FINE GRIT PARTICLE TESTING

Fine grit particle testing was performed to further validate the new design upgrades. The grit testing was performed upside down in the acrylic test fixture. The following steps were followed for each of the tests:

- Fully disassemble all ball valve assembly components
- Pressure wash each individual component until grit free
- Reassemble ball valve assembly with all seals and lubrication used in the field
- Dry fire ball valve in vice with release sleeve, reset ball valve and reset sleeve
- Place ball valve assembly into the acrylic test fixture
- Mix 2.5 gallons of water with 0.05 lbs. of Aluminum Oxide powder
- Pour solution into the test fixture to fill in and around the assembly
- Let solution settle for 15 seconds
- Fire ball valve by removing release sleeve
- Remove tool and wash out fixture in preparation for next test

Four tests were performed, and the results are displayed below in table 17.

UPSIDE-DOWN FINE GRIT TESTING CONFIGURATION 5

TEST #	Frames to fire	Framerate (FPS)	Time to fire (s)	Notes	Video hyperlink
1	12	240	0.050	Smooth actuation, fully closed	Grit test 1

2	12	240	0.050	Full disassembly and pressure wash, failed actuation, ball fires to 80% of stroke	Grit test 2
3	14	240	0.058	Full disassembly and pressure wash, failed actuation, ball fires to 80% of stroke	Grit test 3
4	15	240	0.063	Full disassembly and pressure wash, failed actuation, ball fires to 80% of stroke	Grit test 4

Table 17. Grit tests on upgraded configuration 5

Three out of the four tests performed failed to fully close the ball valve. The grit interrupted the actuation to cause failure consistently at approximately 80% of the ball valve stroke.

3.10 BALL VALVE RETURN SPRING PROBLEM

In order to isolate the component causing failure, we began eliminating different components and testing the assembly in water and grit solutions.

The first components we eliminated include the cutting shoe, cutting shoe inner sleeve, inner sleeve diversion seal, and the ball valve return spring.

Each of the three tests performed in this configuration closed quickly and fully.

The next configuration we added back in the cutting shoe and cutting shoe inner sleeve but removed the ball valve return spring. The results of these three tests are displayed below in table 18.

UPSIDE-DOWN FINE GRIT TESTING CONFIGURATION 5 (NO RETURN SPRING)

TEST #	Frames to fire	Framerate (FPS)	Time to fire (s)	Notes	Video hyperlink
1	12	240	0.050	Fully closed, smooth actuation	Grit Test 1
2	11	240	0.046	Fully closed, smooth actuation	Grit Test 2
3	14	240	0.058	Fully closed, smooth actuation	Grit Test 3

Table 18. Grit testing with configuration 5 without the ball valve return spring

By removing the ball valve return spring, we were able to consistently fully actuate the ball in the grit solution. This group of testing proves the issue of the ball valve return spring hanging up during the actuation when grit is introduced.

The current spring has a free length of 10.625” and 9.5 total coils with a solid height of 1.125”. At the springs initial state, before the ball valve fires, the spring is compressed 7.29”, leaving it at 77% compressed relative to the solid height length. In the final state, after the ball valve fires, the spring is compressed 9.025”, or 95% compressed.

Two different prototype ball valve return springs were designed to test in the modified design assembly to meet the following specifications:

- Reduce total coils
- Reduce compression amount relative to spring solid height
- Maintain similar spring rate
- Maintain similar forces at initial and final spring state

By reducing the total coils and compression ratio percentage this should eliminate the tightly compressed area produced with the current spring where binding occurs.

The spring specifications for all three springs can be seen in Table 19 below.

BALL VALVE RETURN SPRING PROTOTYPES

SPRING	Spring rate [lb/in]	Free length [in]	Solid height [in]	Final compression %	Total coils	Initial force [lbf]	Final force [lbf]
CURRENT REVISION	2	10.625	1.125	95	10	14.55	18.03
PROTO 1	3.12	6	0.69	83	6	8.27	13.07
PROTO 2	7.34	4	0.50	67	4	4.81	17.67

Table 19. Ball valve return spring specifications

3.11 RETURN SPRING PROTOTYPE TESTING

The two new prototype springs were tested in the upgraded ball valve configuration. In order to fully validate the upgraded assembly with the new prototype springs, a test fixture modification was manufactured to allow for actuating the ball valve in the right-side up configuration. The new test fixture seals on both ends, holds the tool in place, and rotates on two pillow block bearings. This design allows for the tool to be rotated to help fully bleed the air out of any potential trapped area, as well as circulate the grit throughout the tool. The test fixture modifications can be seen below in Figure 6.

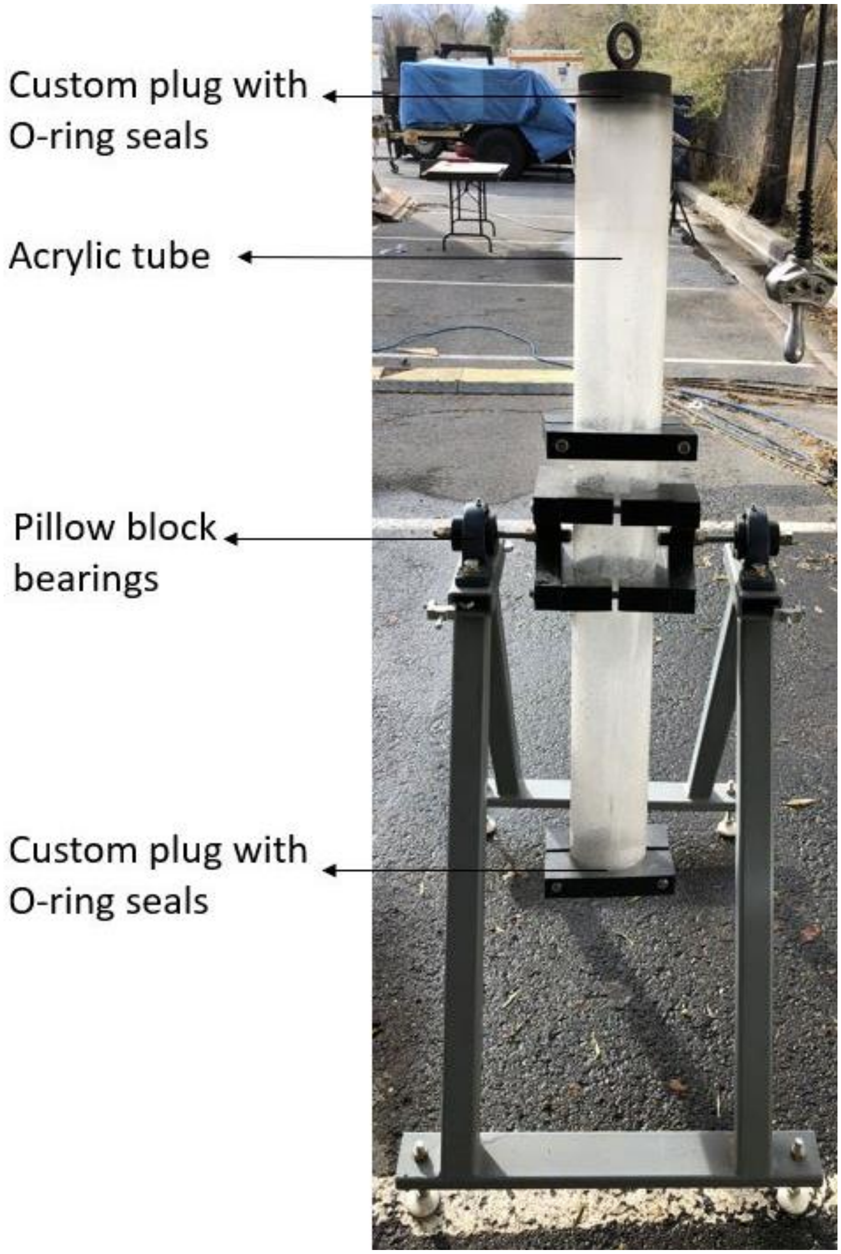

Figure 6. Modified test fixture to allow for right-side up testing

3.12 CONFIGURATION 6

Configuration 6 includes all upgraded ball valve assembly parts and spring prototype 1. Five tests were performed with configuration 6, the results are shown below in Table 20.

SPRING PROTOTYPE 1 GRIT TESTING CONFIGURATION 6

TEST #	Frames to fire	Framerate	Time to fire (s)	Notes	Video Hyperlink
1	14	240	0.058	Smooth actuation, fully closed	Grit test_1
2	12	240	0.050	Smooth actuation, fully closed	Grit test_2
3	12	240	0.050	Smooth actuation, fully closed	Grit test_3
4	11	240	0.046	Smooth actuation, fully closed	Grit test_4
5	16	240	0.067	Smooth actuation, fully closed	Grit test_5
AVERAGE	13	240	0.054	-----------------------------	---------------

Table 20. ball valve return spring prototype 1 grit testing

The upgraded assembly with spring prototype 1 successfully fired and fully closed in each of the five tests. The spring modification with a shorter length, reduced number of coils, and light spring rate eliminated jamming during actuation. The ball valve actuated at an average of 13 frames, or 0.054 seconds, proving the assembly is robust and consistent in heavy grit scenarios.

3.13 CONFIGURATION 7

Configuration 7 includes all upgraded ball valve assembly parts and spring prototype 2. Five tests were performed with configuration 7, the results are shown below in Table 21.

SPRING PROTOTYPE 2 GRIT TESTING CONFIGURATION 7

TEST #	Frames to fire	Framerate	Time to fire (s)	Notes	Video Hyperlink
1	14	240	0.058	Smooth actuation, fully closed, ball slacks at initial state due to lower spring force at top of stroke	Grit test_1
2	14	240	0.058	Smooth actuation, fully closed	Grit test_2
3	12	240	0.050	Smooth actuation, fully closed, ball slacks at initial state due to	Grit test_3

				lower spring force at top of stroke	
4	13	240	0.050	Smooth actuation, fully closed	Grit test_4
5	14	240	0.058	Smooth actuation, fully closed	Grit test_5
AVERAGE	13.4	240	0.056	------------------------------	----------------

Table 21. ball valve return spring prototype 2 grit testing

Each of the five tests were successful in fully actuating the ball valve in a grit and water solution. The ball valve took an average of 13.4 frames, or 0.056 seconds to close. On two separate occasions, test 1 and test 3, the ball slacked slightly down before actuation. This was due to the lower initial spring force acting on the ball follower as seen in section 3.10, table 19.

This slacking would be eliminated during a full actuation test due to the core liner preventing the ball to rotate down. One immediate solution to prevent the slacking for this prototype spring could be the addition of a 1" spring spacer added above the cutting shoe sleeve. This would compress the spring another inch and increase the initial force from 4.81 lbs. to 12.15 lbs. This force would be sufficient to keep the ball follower in place before actuation.

3.14 FURTHER BALL FOLLOWER MODIFICATIONS

It was noted that a considerable amount of grit was building up on the ball follower surface during testing due to the fluid compensation slots added. A final modification was made to the ball follower design to reduce this build-up while also not interfering with the fluid compensation mechanism. The modified design is shown below in Figure 7.

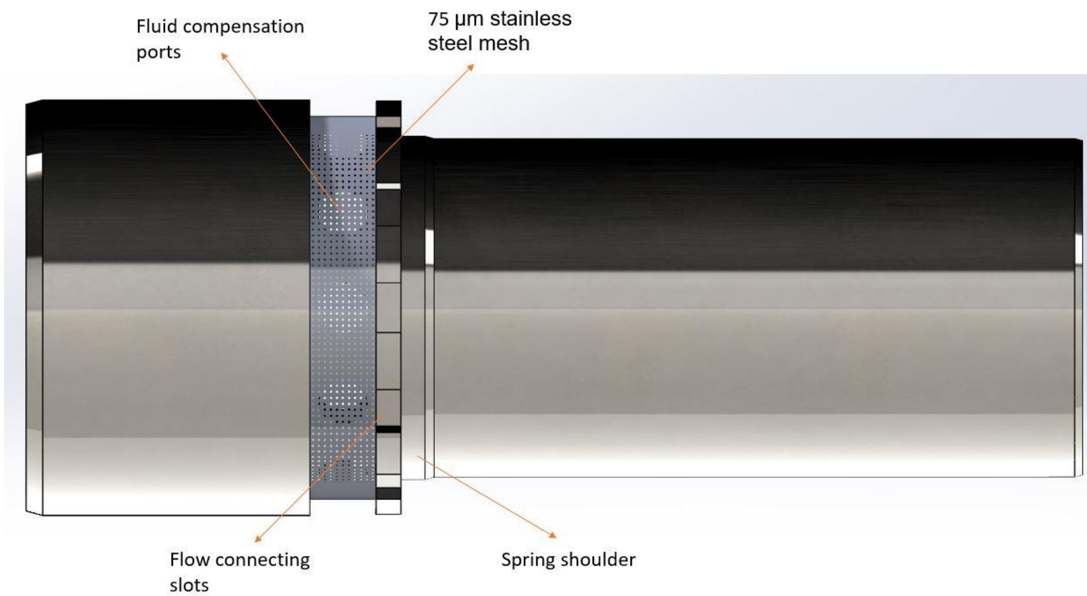

Figure 7. Modified ball follower design including mesh filter, flow ports, spring shoulder, and connectivity slots

The design modification includes 12 fluid compensation holes drilled around the diameter of the ball follower, recessed in a groove. There is also a 75 µm stainless steel mesh covering these flow ports to help filter out grit while still allowing communication. A 75 µm mesh size was chosen to provide as much protection from ingress of particles whilst maintaining sufficient flow area so as to not slow the fluid compensation. The ball follower also includes 12 slots aligning with each of the fluid compensation holes to also assist in preventing hydro-locking. Lastly, the modified design includes a shoulder that the ball valve return spring fits tightly on to keep the spring central around the spring bore during actuation.

3.15 FRICTION TESTING

A friction test was designed to help further quantify the best configuration to pass the grit and water testing. This test includes measuring the force it takes to move the ball through the length of the stroke of three different ball valve configuration assemblies. The test setup includes a hydraulic press, a Delrin extension rod to push the seal carrier through the stroke, and a scale to measure the resistance.

The three different assemblies include the following:

- Original ball valve assembly revision (no upgrades)
- Upgraded ball valve assembly with 6” long return spring prototype
- Upgraded ball valve assembly with 4” long return spring prototype

The goal with testing these three variations is to show which upgraded assembly provides the least resistance upon actuation, as well as providing a baseline comparison to the previous ball valve assembly revision. The results are shown below in Figure 8.

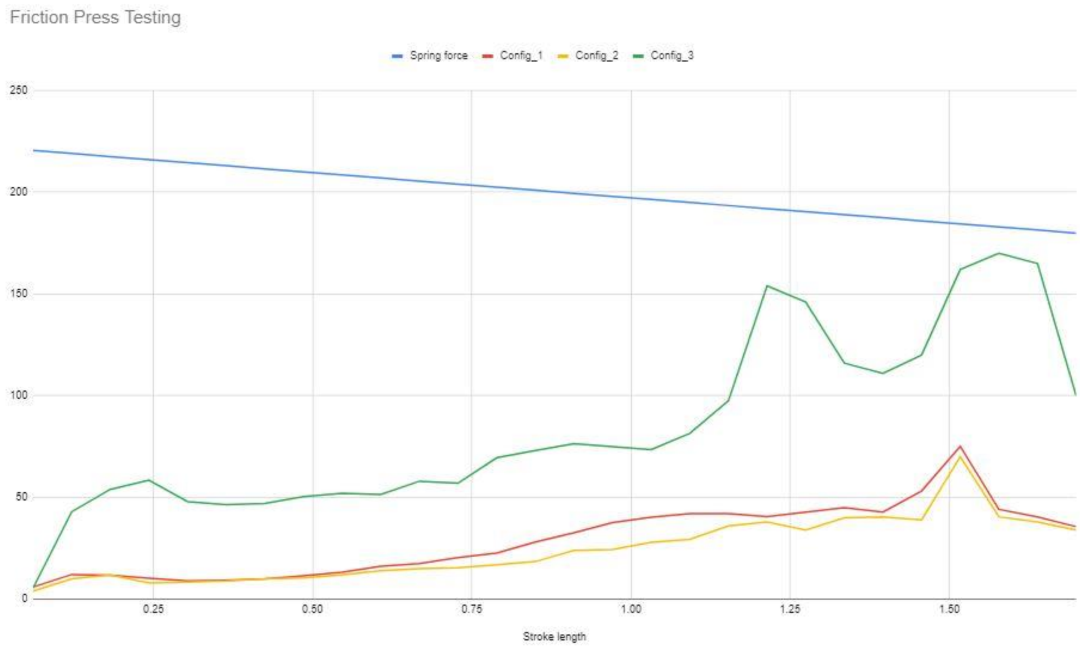

Figure 8. Friction testing results

Figure 8 above shows a plot of the stroke length vs the force registered on the scale. The blue curve represents the spring force at each given position in the stroke length. The green curve represents the original ball valve assembly and shows noticeably higher forces registering throughout the stroke. The yellow curve represents the upgraded ball valve assembly with the 4" long prototype return spring, this configuration results in the lowest forces throughout the entirety of the stroke. There is a noticeable spike at about the 1.5" position in the stroke length, this is due to the force of the seal carrier seal entering the seal bore of the ball valve housing.

The results of this testing combined with the preliminary water and grit testing lead us to the decision to use the upgraded ball valve assembly with the 4" return spring for the final batch of validation testing.

3.16 ORIGINAL BALL VALVE ASSEMBLY BATCH TESTING

To establish a larger, more consistent data set, a batch of 20 identical tests were performed on the original ball valve assembly. Each test was performed following the sequence below:

1. Place the assembled ball valve into the acrylic test fixture with core liner section through the tool
2. Measure out 0.05 lbs of 53-125 µm Aluminum Oxide per 2.5 gallons of water
3. Mix and pour the grit and water solution into the test fixture
4. Allow the grit to settle throughout the assembly

5. Assemble clamps, plugs, and other fixturing to secure the tool inside of the test cylinder
6. Rotate the fixture multiple times to fully circulate the grit throughout the tool
7. Remove plug and add actuation fixturing to the release sleeve
8. Remove core liner section from the assembly
9. Use the overhead crane to pull the release sleeve and actuate the ball valve while recording a slow-motion video for data
10. Disassemble and pressure wash all components in preparation for the next test

The 20 tests yielded a **10% pass rate**. Each test was recorded as a pass or fail, and the ball valve pivot screw position was measured to document the failure distance relative to the stroke length. The data for this batch of testing is shown below in table 22.

MARK 4 BALL VALVE ASSEMBLY TEST DATA

TEST #	Pass/Fail	Stroke Length [in]
1	Fail	1.217
2	Fail	0.963
3	Fail	0.515
4	Pass	NA
5	Fail	1.478
6	Fail	0.798
7	Fail	1.235
8	Fail	1.455
9	Fail	0.905
10	Fail	1.322
11	Fail	1.263
12	Fail	1.110
13	Fail	1.397
14	Pass	NA
15	Fail	0.904
16	Fail	0.563
17	Fail	0.435
18	Fail	0.737
19	Fail	0.947

20	Fail	1.142

Table 22. Mark 4 ball valve assembly test results for batch of 20 tests

3.17 UPGRADED BALL VALVE ASSEMBLY BATCH TESTING

Following all the upgrades to parts in the ball valve assembly this new configuration is now designated as Mark 5. A batch of 20 tests was also performed on the Mark 5 ball valve assembly. This batch of tests followed the same procedure outlined in section 3.16.

The results yielded 20/20 passing tests, or a **100% pass rate**. The results are shown below in table 23.

MARK 5 BALL VALVE ASSEMBLY TEST DATA

TEST #	Pass/Fail	Stroke Length [in]
1	Pass	NA
2	Pass	NA
3	Pass	NA
4	Pass	NA
5	Pass	NA
6	Pass	NA
7	Pass	NA
8	Pass	NA
9	Pass	NA
10	Pass	NA
11	Pass	NA
12	Pass	NA
13	Pass	NA
14	Pass	NA
15	Pass	NA
16	Pass	NA
17	Pass	NA
18	Pass	NA

19	Pass	NA
20	Pass	NA

Table 23. Mark 5 ball valve assembly test results for batch of 20 tests

3.18 CONCLUSION

A test procedure was developed whereby we were able to reliably reproduce the ball valve actuation failures observed in CTTF 2020 using the PCTB Mk 4 tool. The procedure involved adding small amounts of fine grit particles between 53-125 µm to a water solution caused relatively consistent jamming between the sliding surfaces of the assembly upon actuation. Without the grit in the water this procedure reliably produced 100% success using the Mk 4 assembly.

After a number of experiments and a detailed engineering review of the ball valve actuation components a set of upgraded parts were manufactured. The effect of the new components were tested with confidence using the same conditions that the Mk4 revision of the ball valve assembly was failing in. The upgrades included improvements to the seal carrier, ball valve housing, ball follower, cutting shoe sleeve, housing extension, and ball valve return spring. The design improvements focused on diverting grit away and cleaning the sliding surfaces with wiper rings, improving centralization throughout actuation, and improving flow paths throughout the tool to route drilling fluids away from the sliding surfaces.

A batch of 20 tests was performed on both the Mark 4 and Mark 5 assemblies. The Mark 4 assembly produced 2/20 passes, or a pass rate of 10%. The Mark 5 assembly produced 20/20 passes, or a pass rate of 100%. This testing proves that the upgraded ball valve assembly in the Mk5 should perform better in all downhole environments, specifically in CTTF where ball valve jamming failures were first confirmed.

New protocols for tool assembly/disassembly and cleaning will be documented and implemented as a result of the modifications to Mark 5.