Oil & Natural Gas Technology

DOE Award No.: DE- FE0013961

Quarterly Research Performance Progress Report
(Period ending 3/31/2015)

Borehole Tool for the Comprehensive Characterization of Hydrate-Bearing Sediments

Project Period (10/1/2013 to 9/30/2016)

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National Energy Technology Laboratory

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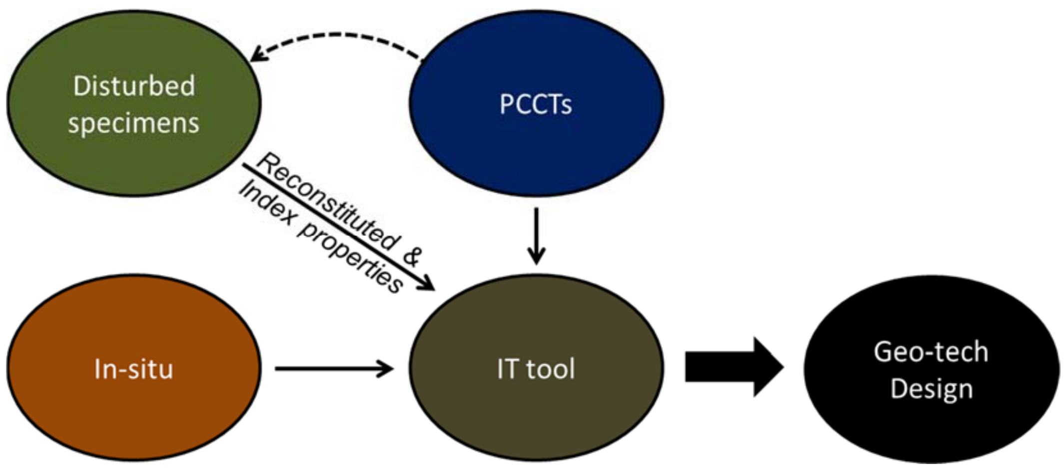
Office of Fossil Energy

DISCLAIMER:

ACCOMPLISHMENTS

Context – Goals. *The determination of physical properties for hydrate bearing sediments relies on correlations with geophysical measurements, and experimental data gathered on conventional and pressure cores; however, there are intrinsic uncertainty in correlations, inherent sampling disturbance, and testing difficulties when hydrate bearing sediments are involved. This research focuses on the development of a robust borehole tool for the comprehensive characterization of hydrate bearing sediments in-situ, complemented with an IT tool for the selection of appropriate material parameters.*



Accomplishments

The main accomplishments for this period include:

- IT tool (sub-task 2.1: Update database of hydrate-bearing sediment properties)
    - Model prediction
- Borehole tool design: body (sub-task 3.3: Design)
    - Body design for testing and deployment
- Borehole tool (sub-task 4.2: Design)
    - Camera module
- Borehole tool (sub-task 5.3: Deployment collaborator)
    - Design for Red Sea deployment tests

Plan - Next reporting period

Improve the interface and database management system, and finish user's manual. Tentative deployment at incremental depths in the Red Sea.

Research in Progress

Borehole Tool

The in-situ tool consists on: a train of modules, samplers (solids and fluids), a body and the reaction system. The train of modules were machined in SS316 for its high corrosion and stress resistance. Penetration is based on the weight of the drilling rods (either actively pushing or passive reaction).

Body design

The body is a cylindrical cavity (SS316) of 2 meters in length and 10 cm (4") wide, with two rigid caps. The body houses the electronics, tubing and other peripherals; also supports the train of modules and samplers on the lower cap. The top cap is able to couple with any available reaction system.

Figure 1 shows a sketch of the body design and available instrumentation, tubing and fluid sampling location. Figure 2 is an extruded version of the complete tool. The train of in-line modules and soil samplers are shown in cyan and dark grey at the bottom. The reaction system latches at the top. The hydraulic system (blue and green), electronics (red) and batteries (yellow) are housed inside the body. An internal plastic frame holds the hydraulic system and electronics in place during operation (white on Figure 2).

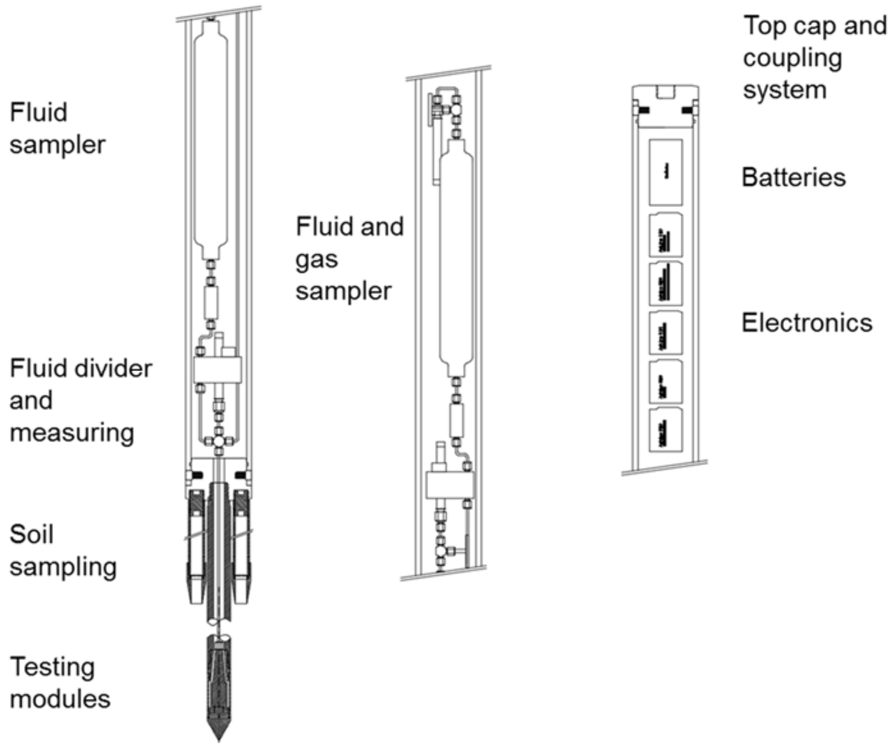


Figure 1: Body sketch and components

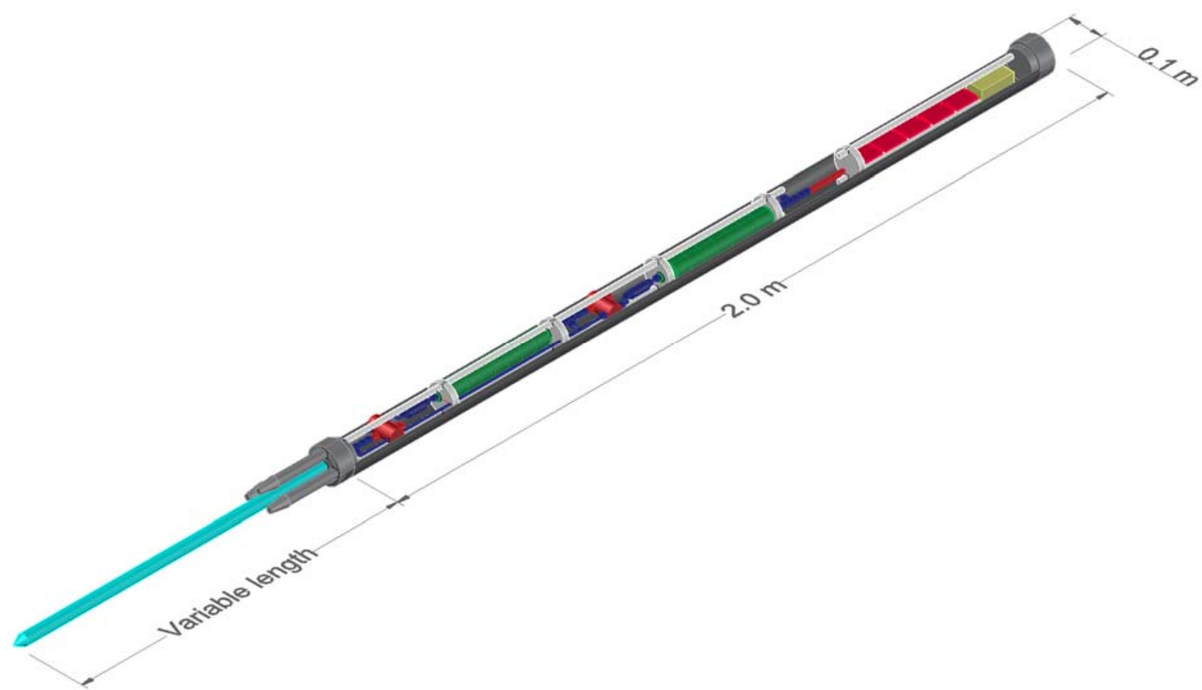


Figure 2: Body: extruded sketch. Cyan: module train; dark grey: soil samplers; red: electronics; yellow: batteries; blue: tubing system and green: fluid sampling storage.

Camera module

A module is specially designed to house an Arduino-compatible camera. This module can be coupled in series with any other module. Figure 3 shows the general design of the video-module. It consists of two pieces in series, the cavity to house the camera and a sapphire window that is rated for the operation pressure. LED lights will also be located close to the window to provide the necessary illumination. The cavity is large and allows for tubing and cables to pass through without disturbing the camera. Full 3D stress analyses verified the design (Figure 3).

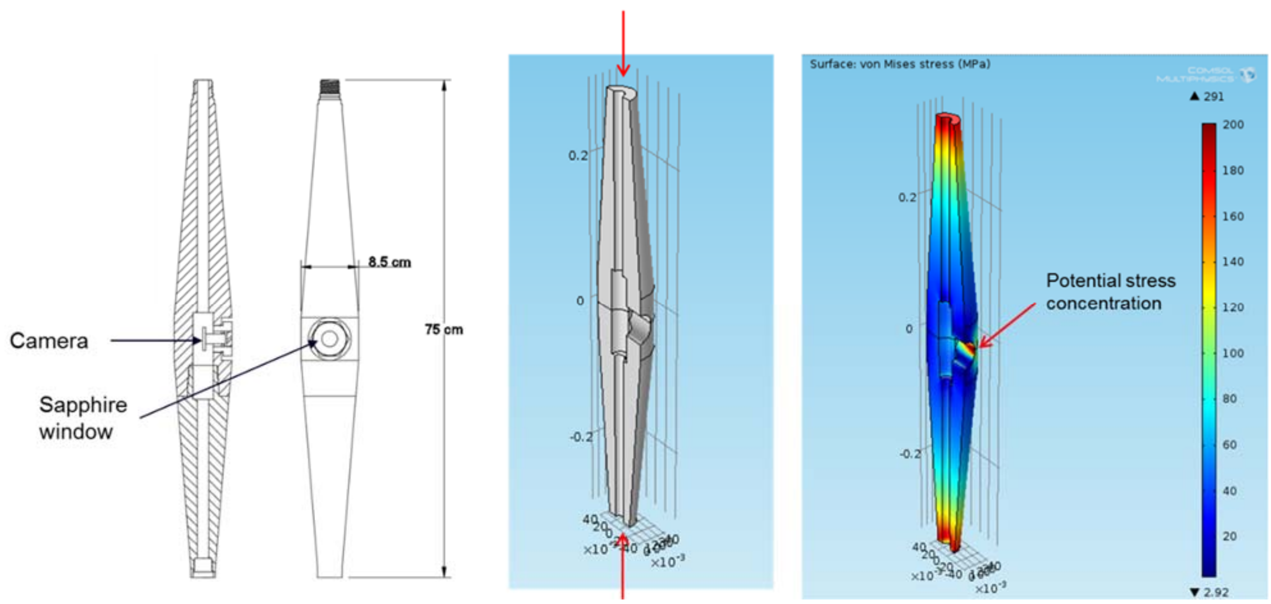


Figure 3: Camera module: general design and stress verification.

Deployment collaboration

Close relationship has been developed with the Red Sea Research Center (KAUST, Saudi Arabia) to run the first series of tests on near-surface sediments at different water depths in the Red Sea. A coupler was designed to link with the Research Center's vessel and lifting system (Figure 4-a and -b). It involves ingots in series with a guiding rod.

Figure 4: Collaboration with Red Sea Center, a) Research vessel; b) Dead weight coupled to the tool for near-surface sediment tests.

IT Tool

Model parameters and properties based on the IT tool

The database includes physical properties of a wide range of sediments, and it allow us to identify links among index parameters and sediment properties. Consider the shear strength of hydrate-bearing sediments. The shear strength of hydrate-bearing sediments is well captured by the following model:

$$q_f = \frac{\cos\varphi'}{1-\sin\varphi'}c' + \frac{\sin\varphi'}{1-\sin\varphi'}\sigma_3' + \alpha S_h^{\beta}$$

The regression analysis shows that the α-factor is inversely related to porosity (figure 5), while the β-exponent is ~1.5.

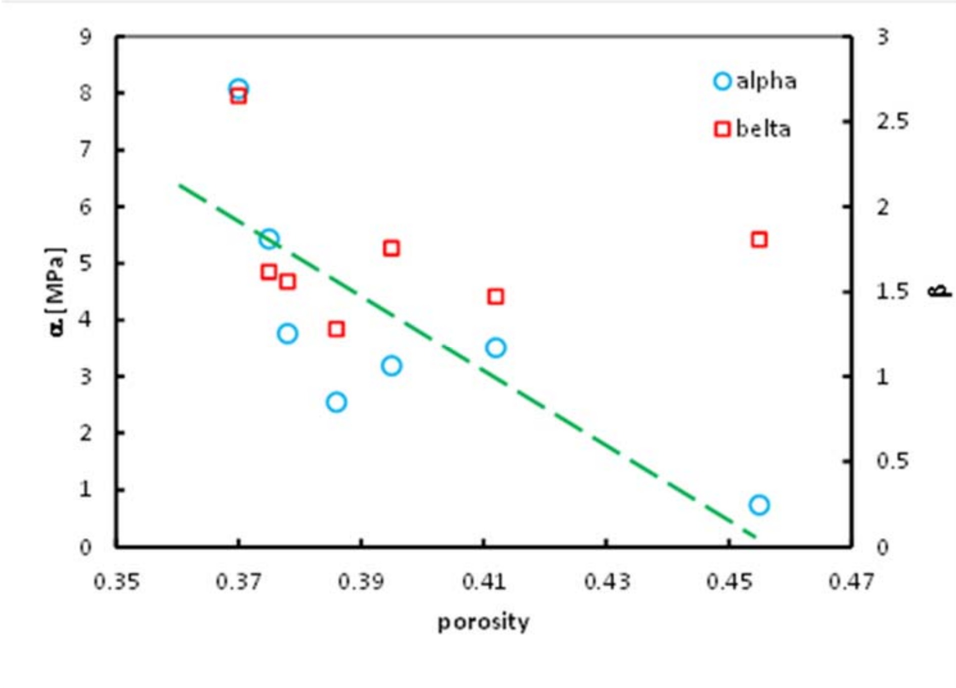


Figure 5. Inverse relationship between α-factor and porosity.

These values reflect grain-scale mechanisms in hydrate-bearing sediments. For example, hydrates formed in pores hinder grain rotation or slippage of adjacent particles (Figure 6). This mechanism is related to coordination number; in turn, coordination number evolves with porosity. For example, the simple cubic packing of mono-sized spherical particles has porosity 0.476 and coordination number of 6, while face-centered cubic packing and tetrahedral packing have porosity 0.26 and coordination number 12.

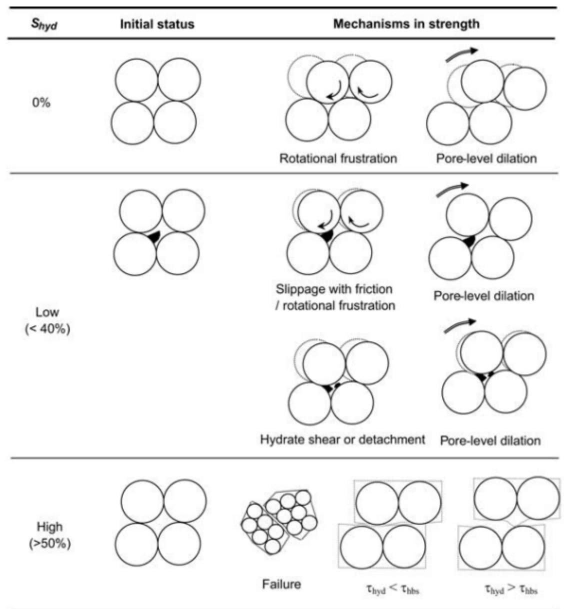


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Figure 6. Possible particle-level mechanisms involved in the shear strength of hydrate-bearing sediments at various hydrate saturations [Yun, T. S., Santamarina, J. C., & Ruppel, C. (2007). Mechanical properties of sand, silt, and clay containing tetrahydrofuran hydrate. Journal of Geo-physical Research: Solid Earth (1978–2012), 112(B4)p

MILESTONE LOG

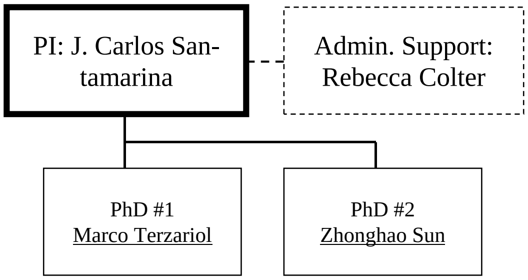
	Milestone	Completion Date	Comments
Title Planned Date Verification method	Completion PMP November 2013 Report	11/2013	
Title Planned Date Verification method	Insertion – Tool design September 2014 Report	9/2014	
Title Planned Date Verification method	Database and IT tool September 2014 Report	9/2014	Paper in preparation
Title Planned Date Verification method	Electronics in operation January 2015 Report	In progress	
Title Planned Date Verification method	Lab testing of prototype September 2015 Report	In progress	
Title Planned Date Verification method	Tool deployment Before September 2016 Report		

PRODUCTS

- **Publications – Presentations:** None at this point
- **Website:** Publications and key presentations are included in http://pmrl.ce.gatech.edu/. (for academic purposes only)
- **Technologies or techniques:** None at this point.
- **Inventions, patent applications, and/or licenses:** None at this point.
- **Other products:** None at this point.

PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS

Research Team: The current team is shown next. We anticipate including external collaborators as the project advances



IMPACT

None at this point.

CHANGES/PROBLEMS:

None at this point.

SPECIAL REPORTING REQUIREMENTS:

We are progressing towards all goals for this project.

BUDGETARY INFORMATION:

As of the end of this research period, expenditures are summarized in the following table (Note: in our academic cycle, higher expenditures typically take place during the summer quarter):

Baseline Reporting Quarter DE-FE0013961	Budget Period 1								Budget Period 2							
	Q1		Q2		Q3		Q4		Q1		Q2		Q3		Q4	
	10/1/13 - 12/31/13		1/1/14 - 3/31/14		4/1/14 - 6/30/14		7/1/14 - 9/30/14		10/1/14 - 12/31/14		1/1/15 - 3/31/15		4/1/15 - 6/30/15		7/1/15 - 9/30/15	
	Q1	Cumulative Total	Q2	Cumulative Total	Q3	Cumulative Total	Q4	Cumulative Total	Q1	Cumulative Total	Q2	Cumulative Total	Q3	Cumulative Total	Q4	Cumulative Total
Baseline Cost Plan																
Federal Share	34,736	34,736	34,736	69,472	34,736	104,208	34,736	138,944	30,000	168,944	30,000	198,944	30,000	228,944	86,571	315,515
Non-Federal Share	13,326	13,326	13,327	26,653	13,327	39,980	-	39,980	10,495	50,475	10,495	60,970	10,495	71,465	10,945	82,410
Total Planned	48,062	48,062	48,063	96,125	48,063	144,188	34,736	178,924	40,495	219,419	40,495	259,914	40,495	300,409	97,516	397,925
Actual Incurred Cost																
Federal Share	-	-	20,865	20,865	45,109	65,973	55,929	121,902	64,746	186,648	38,605	225,253		225,253		225,253
Non-Federal Share	-	-	-	-	39,980	39,980	-	39,980	10,601	50,580	27,525	78,105		78,105		78,105
Total Incurred Costs	-	-	20,865	20,865	85,089	105,953	55,929	161,881	75,347	237,228	66,130	303,358	-	303,358	-	303,358
Variance																
Federal Share	-34,736	-34,736	-13,871	-48,607	10,373	-38,235	21,193	-17,042	34,746	17,704	8,605	26,309				
Non-Federal Share	-13,326	-13,326	-13,327	-26,653	26,653	0	0	0	106	105	17,030	17,135				
Total Variance	-48,062	-48,062	-27,198	-75,260	37,026	-38,235	21,193	-17,043	34,852	17,809	25,635	43,444				

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