Oil & Natural Gas Technology

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Quarterly Research Performance Progress Report

(Period ending 12/31/2013)

Advanced Hydrate Reservoir Modeling Using Rock Physics Techniques

10/1/2012 – 9/30/2014

Submitted by:
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Executive Summary

This research effort will focus on developing and refining techniques that integrate rock physics modeling, amplitude analysis, and spectral decomposition to characterize complex gas hydrate reservoirs. The expected outcome of the research efforts will be an enhanced ability to quantitatively evaluate and prioritize potential gas hydrate accumulations that may be selected as exploration drilling targets based on 3-D seismic data.

Accomplishments to date

- Reviewed related scientific/industry research efforts.
- Identified relevant research concepts.
- Investigated well logs data in WR 313 and GC955
- Selection of initial rock physics model.
- Progress on selection of possible statistical classification techniques.
- Contact with communities of interest after the award announcement. USGS, Colombian Petroleum Institute, KIGAM, Guanzhou Marine Geological Survey, Shell, BP, Chevron, Petronas, National University of Singapore, and Texas A&M University
- Continued professional development for Dr. Zhang, building on recent past work.
- Working with in-kind contribution Jason Workbench Suite of petrophysical and inversion software to develop analytical routines.
- Purchased Hampson Russell AVO and inversion software that can be used in this project
- Modeling mixtures of methane and thermogenic gas hydrate signatures against flux and geothermal gradients and depositional architecture.

Progress, Results, and Discussion Summary of technical progress

The project was postponed for the period January 1, 2013 to September 30, 2013. Task Groups 1 (Project Management and Planning) and 2 (Project Initiation) were completed prior to this reporting period. Work was also done on Task Group 3 (Development of Project Research Concepts) prior to the work hiatus. The project restarted with continuation of work within Task Group 3 and Task Group 4.

Review previous research projects

We continued review of rock physics models in the literature. Lee and Collett (1999) use the weighted equation to predict gas hydrate concentrations within sandy sediments from P-wave and S-wave data collected at the Mallik 2L-38 hydrate research well at the depth of approximately 1000 m. Carcione and Tinivella (2000) use three-phase Biot-type equations to study AVO responses for consolidated sandstone. Helgerud et al. (1999) and Jakobsen et al. (2000) use effective medium theory to estimate gas hydrate concentration within clayey sediments at the Ocean Drilling Program (ODP) Leg 164, site 995 at the depth of approximately 400 m below the seafloor. These papers illustrate that the rock physics models can be used to quantify the amount of gas hydrate in sub-surface sandy sediments and clayey sediments from seismic or well log data.

Identify technical research concepts

The various seismic steps/technologies proposed to perform in the ongoing project have been reviewed, including rock physic model, seismic post-stack and pre-stack amplitude analysis, attenuation and dispersion, anisotropy, spectrum decomposition, seismic inversion, seismic modeling, and geostatistics. Although all these technologies that can aid in identifying gas hydrate have been successful to some degree, our strategy is to integrate rock physics model with well logs and seismic data to separate highly concentrated thick reservoir-level gas hydrate deposits from other sediments. Therefore, we are primarily using rock physics modeling, spectral decomposition, and geostatistics in the ongoing project.

Investigation of well log data

LWD data are acquired in a relative high-noise, high-vibration environment and data quality are affected by the drilling noise. After going through these log data, we found that slight increase in Vp of low saturated hydrate-bearing sediments is difficult to distinguish from the noise. In the soft unconsolidated formations, the LWD sonic acquisition and processing, especially shear wave, are still challenging (Tang et al., 2005, Goldberg et al., 2003, Wang and Tao, 2011). We do not have Vs data.

Vp, density, GR, porosity, estimated hydrate saturations from resistivity are available to our study in five wells in WR 313 and GC 955. LWD tools, drilling and logging operations, and logging results for WR 313 are summarized or discussed in detail by Boswell et al. (2012), Collett et al. (2012).
We are building synthetic seismic models using Jason Workbench Software and Hampson Russell software from the LWD logs.

Develop protocol to test and verify techniques

The rock physics model is used to calculate predicted elastic velocities, and then, generate seismic responses. The predicted velocities are being compared and correlated with the results of laboratory measurements of similar conditions of pressure and lithology. The comparison allows us to verify our model and evaluate its effectiveness. The calibration and correlation also provide the crucial information about the relationship between pressures and the empirical parameter and coordinate numbers in the model.

We want to identify water sands, gas sands, hydrate sands, and/or hydrate-over-gas sands from seismic data. We will verify our classifications by comparing our predictions to interpretations of JIP well logs and industrial well logs in WR313 and GR955.

Development of analytical techniques

We divided our analytical techniques into four sections, including rock physics seismic modeling, spectral decomposition, geostatistical classification, and estimation of hydrate saturation.

Identification of rock physics seismic modeling

We are examining and evaluating our rock physics model in several aspects, such as if our model over-estimates or under-estimates physical properties of hydrate-bearing sediments and how our model compares to other rock physics models. We also compared the results computed from our rock physics model with velocity log in Walker Ridge 313G well in the paper. We concluded that the model can be used in this project.

Spectral decomposition

Spectral decomposition work has not been completed yet.

Geostatistical classification

A Gaussian classification analysis will be carried out to separate highly concentrated thick hydrate sands, highly concentrated thick hydrate-over-gas sands, low concentrated (or thin) gas sands, low concentrated (or thin) hydrate-over-gas sands, thick gas sands, and water sands from seismic. Bayesian distance and Mahalanobis distance classifications are two common procedures of the Gaussian classification. We are coding the programs for the Bayesian distance and Mahalanobis distance.

Estimation of gas hydrate saturation

Gas hydrate saturation work has not been completed yet

Other considerations: attenuation and dispersion

Attenuation and dispersion work is underway but not completed yet

Methane Hydrate Models for testing

There are a number of depositional elements in which highly concentrated gas hydrate could be present, but for which seismic geomorphology affected by filling within the gas hydrate has not been studied well.

In our previous study, we have illustrated that seismic amplitude is determined from an interaction between layer thickness, hydrate saturation and gas saturation by using numerical modeling. However, the modeling is restricted to 1D geologic model and so is of limited applicability. The purpose of the current study is to present and evaluate three deepwater depositional elements; channel complex sands, sheet sands, and overbank or levee sands. Comparisons are made between 2-D seismic synthetic seismograms of the elements with and without gas hydrate filling in sands.

We do not yet have permission to use the 3D seismic data in GC955 or WR 313, so we are hindered from doing detailed reservoir architecture studies. We are, however, looking at different depositional architectures with varying gas hydrate fill patterns in advance of applying these concepts to the analysis of seismic response of the architecture and hydrate fill.

Depositional elements

Channel complex sands. Channel-fill deposits are usually interpreted to be sand-rich. The channel widths can be greater than 3 km or less than 200m. The distribution of these sand-prone deposits and their architecture are depend to some degree on the extent of channel meanders (Posamentier and Kolla, 2003). If a meandering channel does not migrates laterally, the channel-fill deposits could remain around one location with vertical stacking. In contrast, if the channel migrates by sediment erosion, the deposits could several times larger than the width of a single channel. Seismically, these deposits are characterized by high amplitude and discontinuous reflections. Model of the deposits is presented in figure 1. We will model two hydrate fill behaviors, hydrate filling as one body within sands and as individual layers.

Sheet sands. Sheet sands are deposits as frontal splay, turbidite fan or distributary-channel complexes at the end of channels. Unlike channel sands which are commonly sand-rich, the sheet sands are prone to mud-sand to mud dominated systems, and are laterally continuous clay interbedded with sand bodies. Posamentier and Kolla (2003) indicate that the thickness of the sheet sands can be up to 65 m high and 10 km long. These sheet sands are often composed of thin sand-rich levee and overbank deposits but their thickness are below the seismic vertical resolution. these deposits are characterized by moderate to high amplitude and continuous reflections. Model of the deposits is present in figures 2 and 3. We will model two kind of sheet sands – 10m and 50m thick sands. In the 10m thick sands, hydrate is present as one body filling with it. In the 50m thick sands, hydrate is present as several layers.

Overbank or levee sands. Overbank or levee sands are formed by overbank flow or sediment gravity flows on bank. Posamentier and Kolla (2003) show these overbank-levee deposits reach heights of 20m and widths of 2-3 km. The overbank-levee sediments are prone to muddy sand to mud-dominated systems. However, Posamentier and Kolla (2003) indicate that overbank-levee deposits have been documents to contain reservoir-quality thin-bedded sands. They often present as a lateral continuity in stratigraphic architectures, but could intercept by erosions. Seismically, these deposits are characterized by low-to moderate amplitude and continuous to discontinuous reflections. Model of the deposits is present in figures 4 and 5. We will model lateral and tilted overband-levee sands. Hydrate is assumed to fully fill with the sands.

For generation of the seismogram of above examples, Jason seismic software will be used. We will first generate a 30 Hz synthetic wavelet, then create an zero-offset synthetic seismic data, final a noise would be added into the data. If an expected result is reached, we would further investigate AVO effects that partial synthetic stack data are generated.

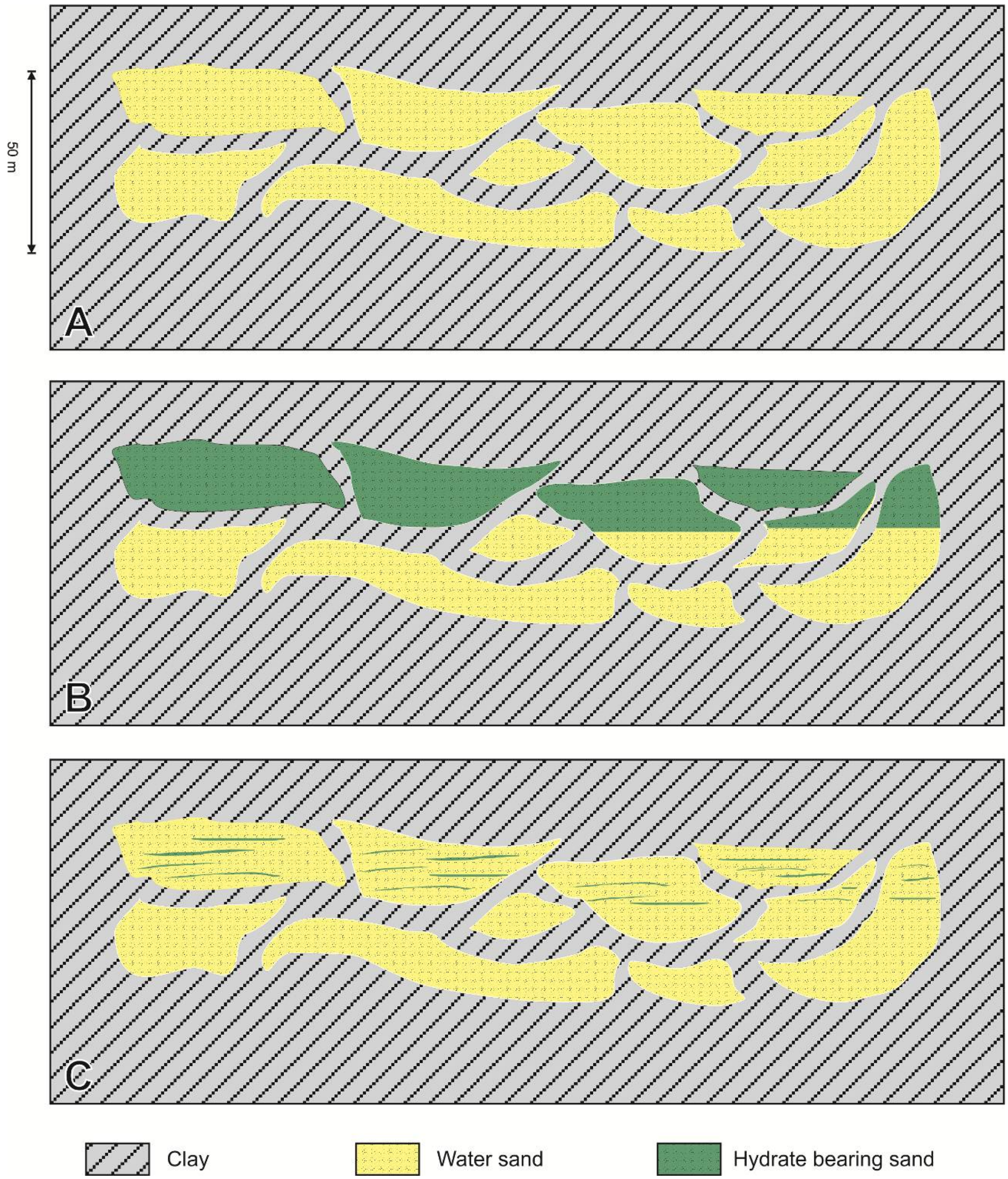

Figure 1: Channel complex model. Model “A” contains water sand. Model “B” shows bulk hydrate filling within sand, while model “C” shows thin layer hydrate filling with the sand.

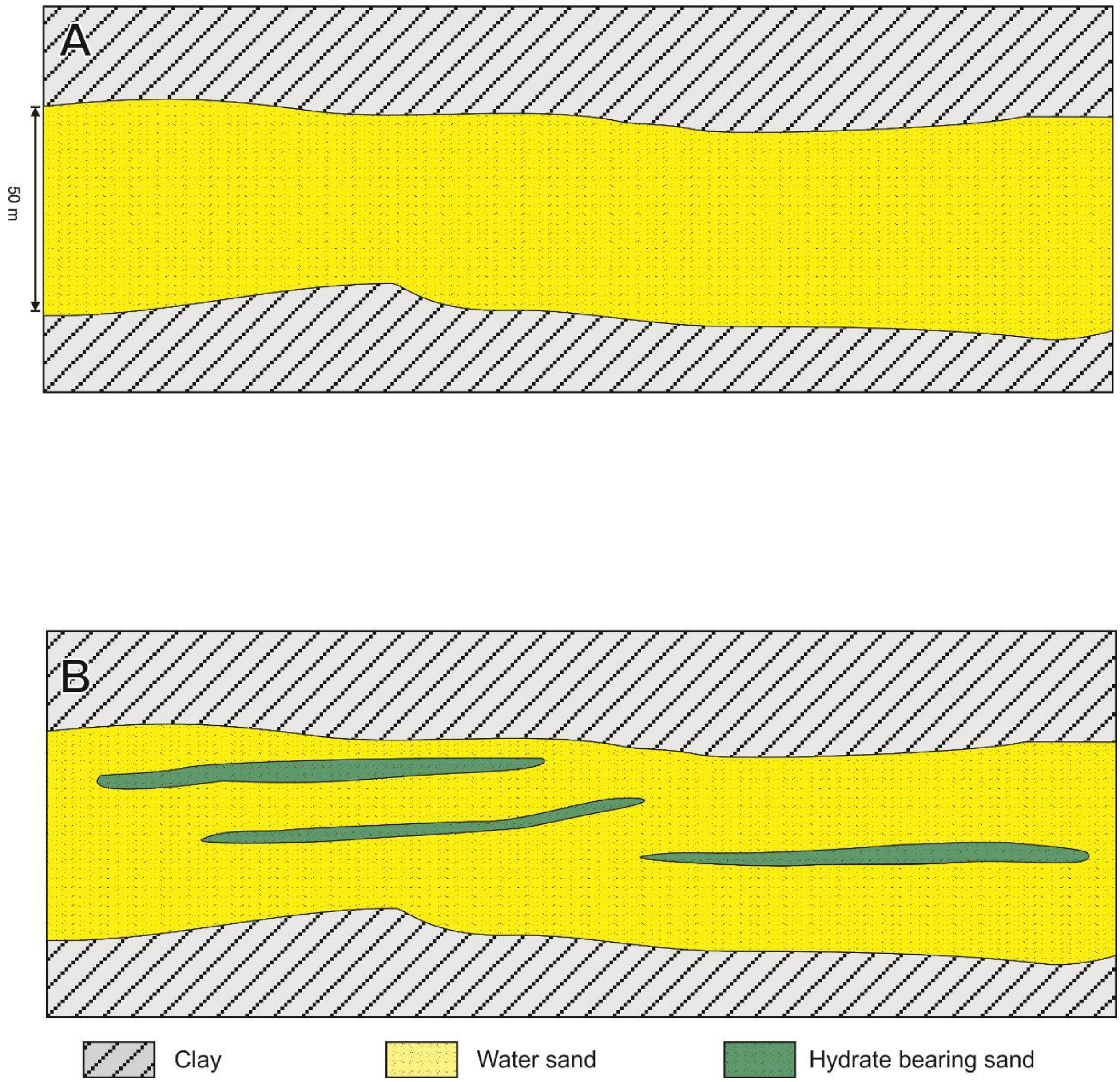

Figure 2: Thick sheet sand model. Model “A” contains water sand. Model “B” shows hydrate layers filling with the sand.

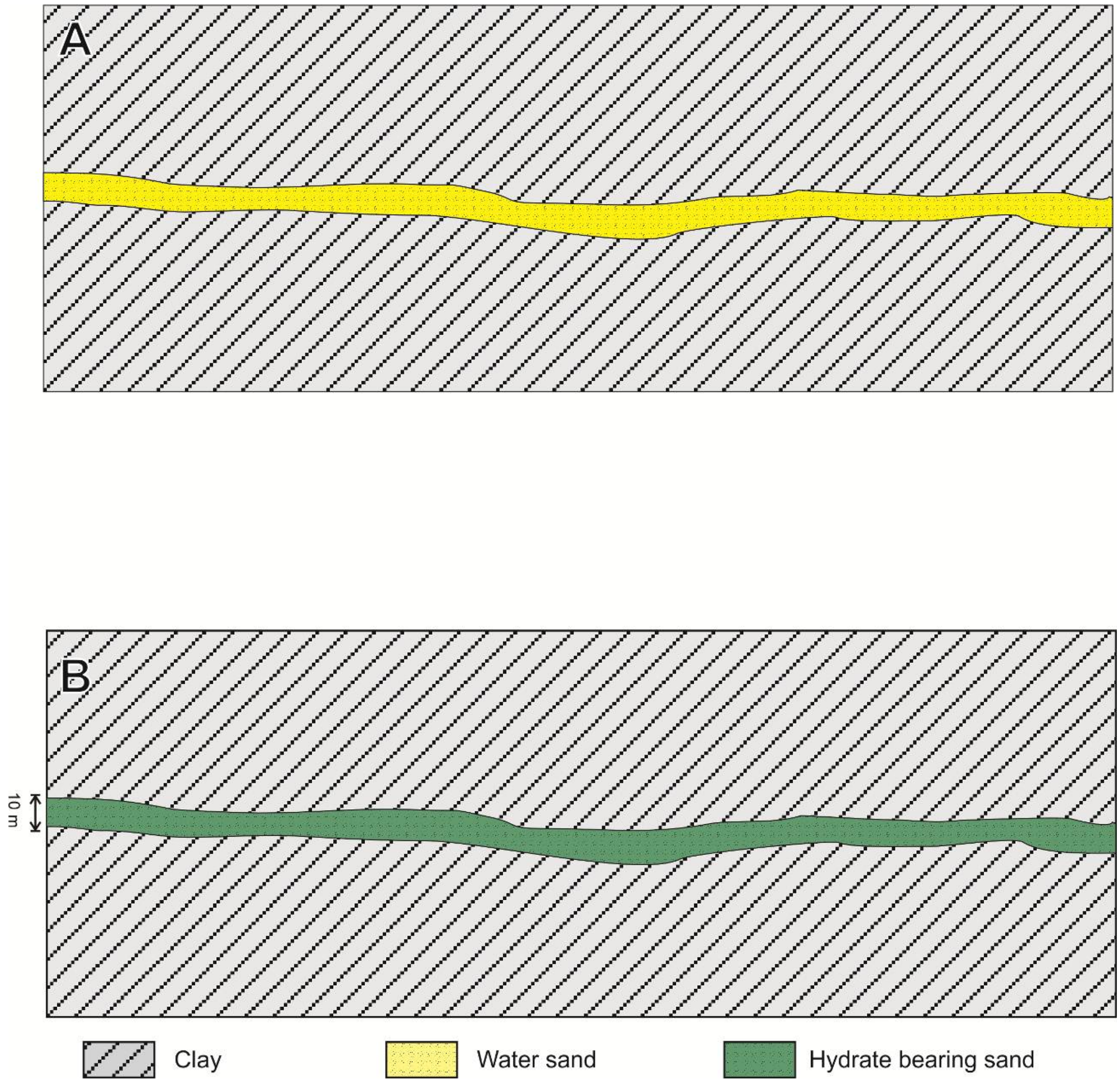

Figure 3: Thin sheet sand model. Model “A” contains water sand. Model “B” shows hydrate fully filling with the sand.

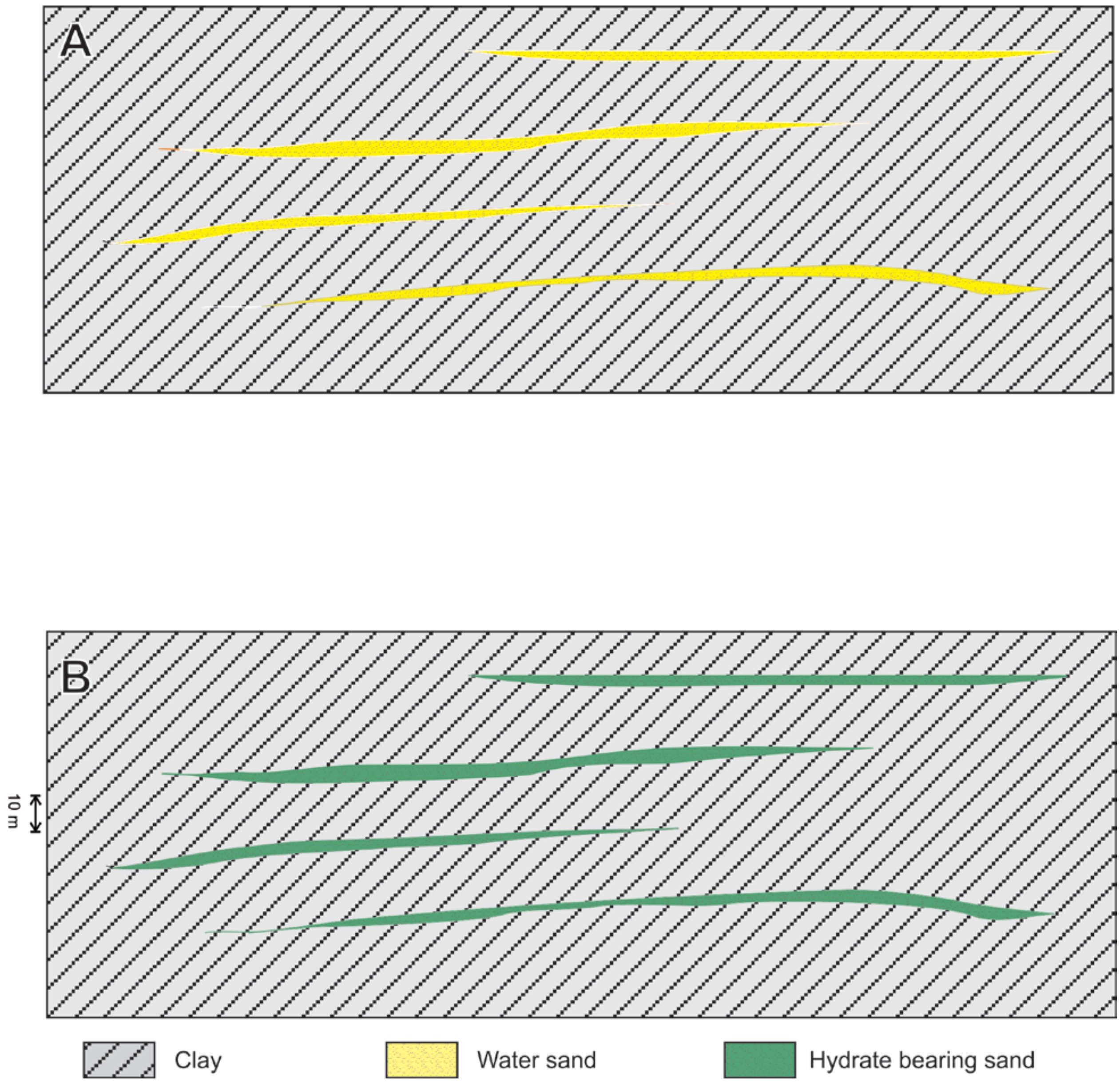

Figure 4: Lateral overband-levee sand model. Model “A” contains water sand. Model “B” shows hydrate fully filling with the sand.

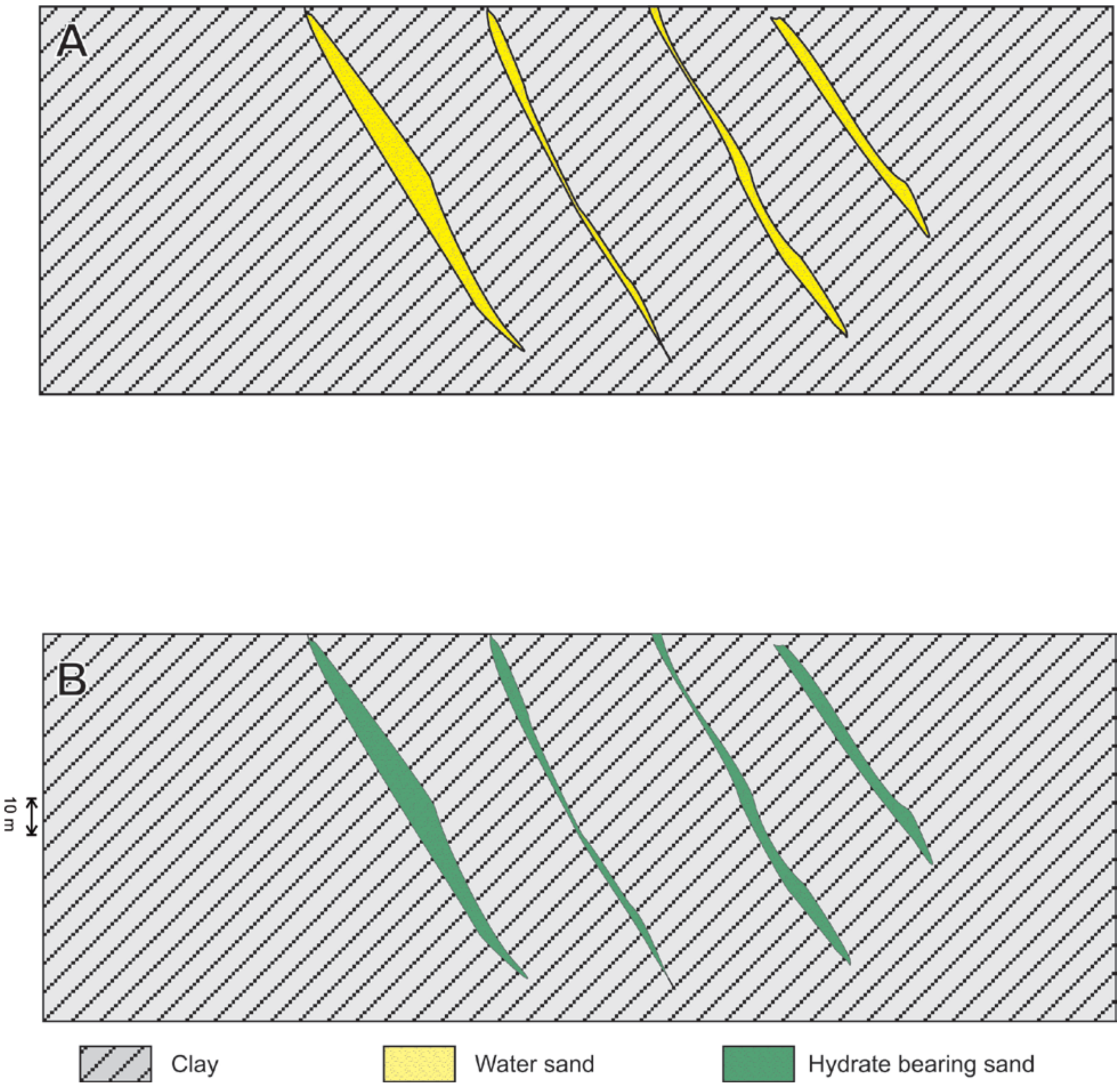

Figure 5: Tilted overband-levee sand model. Model “A” contains water sand. Model “B” shows hydrate fully filling with the sand.

Future work in next reporting period

- We will continue to work on the development of analytical techniques and protocols to distinguish class-type gas hydrate reservoirs in next reporting period.
- We will present elements of the work to date at the Gordon Research Conference in Galveston in March.
- Continue to work to secure the3-D seismic volumes for testing and calibration.
- Renew the in-kind contribution of Jason Workbench Suite petrophysical and inversion software

Key References

Boswell, R., T.S. Collett, M. Frye, D. McConnell, D. Shelander, 2012, Subsurface gas hydrates in the northern Gulf of Mexico: Marine and Petroleum Geology 34, 4-30.

Carcione, J. M., and U. Tinivella, 2000, Bottom-simulating reflectors: Seismic velocities and AVO effects: Geophysics, 65, 54–67.

Collett, T.S, M.W. Lee, M.V. Zyrianova, S.A. Mrozewski, G. Guerin, A. Cook, and D.S. Goldberg, 2012, Gulf of Mexico Gas Hydrate Joint Industry Project Leg II Logging-While-Drilling Data Acquisition and analysis: Marine and Petroleum Geology, 34, 41-61.

Goldberg, D., A. Cheng, J. Blanch, J. Byun, and S. Gullick, 2003, Analysis of LWD sonic data in low-velocity formations: 73rd Annual International Meeting, SEG, Expanded Abstracts, 301–304.

Helgerud, M.B., J. Dvorkin, A. Nur, A. Sakai, and T. Collett, 1999, Elastic-wave velocity in marine sediments with gas hydrates: Effective medium modeling: Geophysical research letters, 26, 2021–2024.

Jakobsen, M., J.A. Hudson, T.A. Minshull, and S.C. Singh, 2000, Elastic properties of hydrate-bearing sediment using effective medium theory: Journal Geophysical Research, 105, 561–577.

Kim, G., B. Yi, D. Yoo, B. Ryu, and M. Riedel, 2011, Evidence of gas hydrate from downhole logging data in the Ulleung Basin, East Sea: Marine and Petroleum Geology, 28, 1979-1985

Lee, M.W., and T.S. Collett, 1999, Amount of gas hydrate estimated from compressional- and shear-wave velocities at the JAPEX/JNOC/GSC Mallik 2L-38 gas hydrate research well: in Dallimore, S. R., Uchida, T., and Collet, T. S., Eds., Scientific result from JPEX/JNOC/GSC Mallik 2L-38 gas hydrate research well, Mackenzie Delta, northwest Territories, Canada: Geological Survey of Canada Bulletin, 544, 313–322.

Lee, M. W. and W.F. Waite, 2007, Amplitude loss of sonic waveform due to source coupling to the medium: Geophysical Research Letters, 34, L05303.

Posamentier H. W.,; Kolla V. 2003. Seismic Geomorphology and stratigraphy of depositional elements in deep-water settings. Journal of Sedimentary Research, v.73, p. 367-388

Tang, X. M., Y. Zheng, and D. Vladimir, 2005, Logging while drilling acoustic measurement in unconsolidated slow formations: SPWLA 46th Annual Logging Symposium, OnePetro paper no. 2005-R.

Wang, H., and G. Tao, 2011, Wavefield simulation and data-acquisition-scheme analysis for LWD acoustic tools in very slow formations: Geophysics, 76, E59-E68.

Zhang, Z, D. Han, and D. R. McConnell, 2013, Characterization of elastic properties of near-surface and sub-surface deepwater hydrate-bearing sediments: Geophysics, 78, 169-179.

Changes or Problems

The announcement that Fugro entered into an agreement to sell its Geoscience division to CGG Veritas caused uncertainty and delays for the project. Participation of CGG- Jason and CGG is in doubt but can hopefully be resolved.

Delays in the work timeline were caused by time spent in post-award negotiations. The shift in the timeline has been communicated to the NETL project manager.

We have still not secured the 3D seismic volumes over GC955 and WR313 for this project. CGG has made those volumes available to Oklahoma State University for related hydrate research in the same DOE funding cycle. Our efforts to secure the same have not been successful so far. We will continue to seek the data donation. We also need CGG to renew the data donation of the Jason Workbench software as well as reaffirm their pre-divestiture technical commitments to this project.

There are no significant changes or problems with the direction of the project as originally proposed.

Participants and Other Collaborating Organizations

	Zijian Zhang, Geophysicist, Fugro Employee	Dan McConnell, Principal Investigator, Fugro Employee	Peter Mesdag, Technical Advisor, ex Fugro now after divestiture a CGG Employee (Netherlands)
Nearest month worked this reporting period	1	0	0
Collaboration outside USA	Not this reporting period	Not this reporting period	None this reporting period
Travel outside USA to communities of interest	None this reporting period	None this reporting period	None this reporting period

Other Collaborating Organizations:

Jason has granted a license of the Jason Workbench suite of petrophysics and inversion software to the research project for a 12 month period beginning Jan 29th 2013. Jason will also provide technical advice through employee Peter Mesdag based in Netherlands. We are seeking a renewal of the license because of the hiatus in work on this research project.

Oklahoma State University and Fugro GeoConsulting have agreed to share progress and results from their respective DOE research projects (DE-FE0009904 and this project DE-FE0010160).

Impact

The potential advances that this research might identify have a high likelihood for technology transfer and the adoption of new practices. For instance, Fugro GeoConsulting will advise Jason of techniques and potential methodologies that can discriminate gas hydrate reservoirs in return for their in-kind contribution of the software. More broadly, we can anticipate, if some of the research objectives are realized, that the findings could be adopted, considered, modified, or improved by the collaborators and within the oil and gas industry. If so, the work may contribute to safety of installations with respect to the design of wells and foundations in gas hydrate prone areas as well as contributing to the identification and quantification of potential gas hydrate resource.

The research findings from this project may potentially contribute to the US gas hydrate resource assessment but also international science and governmental organizations that are measuring gas hydrate exploration potential in Japan, Korea, China, India, Colombia, New Zealand, and elsewhere.

Additionally the findings from this project can also have the potential to aid imaging of sequestered C02 gas hydrate for greenhouse gas reduction if that technology advances.

Special Reporting Requirements
None this quarter.

Budgetary Information
$50,594 has been spent from a budget allocation of $85,378 to date. The federal share of the costs to date is $40,475 and the cost sharing is $10,119. The federal share of the costs per this reporting period is $17,135 and the cost sharing is $4,284.

Exhibit I Milestone Status

Milestone 1, Task 1 was completed November 14, 2012
Milestone 2 has been delayed to August 21, 2014

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Exhibit 2 Cost Plan

Baseline Reporting Quarter	Budget Period 1									
	Q1		Q2		Q3		Q4		Q1	
	Sept- Dec 2012		Jan-Mar 2013		April-June 2013		June-Sept 2013		Sept-Dec 2013	
	Q1	Cumulative Total	Q2	Cumulative Total	Q3	Cumulative Total	Q4	Cumulative Total	Q1	Comulative Total
Baseline Cost Plan										
Federal Share	34151	34151	0	34151	0	34151	0	34151	34151	68302
Non-Federal Share	8538	8538	0	8538	0	8538	0	8538	8538	17076
Total Planned	42689	42689	0	42689	0	42689	0	42689	42689	85378
Actual Income Cost										
Federal Share	7114	7114	16226	23340	0	23340	0	23340	17135	40475
Non-Federal Share	1778	1778	4057	5835	0	5835	0	5835	4284	10119
Total Incurred Costs	8892	8892	20283	29175	0	29175	0	29175	21419	50594
Variance										
Federal Share	(27037)	(27037)	16226	(10811)	0	(10811)	0	(10811)	(17016)	(27827)
Non-Federal Share	(6760)	(6760)	4057	(2703)	0	(2703)	0	(2703)	(4254)	(6957)
Total Variance	(33797)	(33797)	20283	(13514)	0	(13514)	0	(13514)	(21270)	(34784)

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