Oil & Natural Gas Technology

DOE Award No.: DE-FE0010160

Quarterly Research Performance Progress Report

(Period ending 12/31/2012)

Advanced Hydrate Reservoir Modeling Using Rock Physics Techniques

10/1/2012 – 9/30/2013

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

- 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.
- Society of Exploration Geophysicists 82nd Annual Meeting in Las Vegas 5-9 November 2012 as discussed.
- Other 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
- A general readership article for Petroleum Review aimed at the Oil and Gas Industry
- Continued professional development for Dr. Zhang, building on recent past work.
- Secured an in-kind contribution of Jason Workbench Suite of petrophysical and inversion software for a 12 month period.

Progress, Results, and Discussion Summary of technical progress

We were awarded the project with an October start, but we there were several issues that took time to be negotiated. The project timeline for initiatingTask 3 shifted to mid-December. We do count several meeting, contacts, and other efforts as being consistent with advancing the research project but these are not reflected in the budget spend to date. In the initial phase, we have been working on the project planning and the development of research strategy and working to secure seismic data and tools.

Review previous research projects

We have reviewed some important papers of rock physics models. 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.

We took part in Society of Exploration Geophysicists 82nd Annual Meeting in Las Vegas 5-9 November 2012. Many new technologies and ideas related to seismic exploration were presented by people from oil companies, service companies, and universities. Integrating different data and quantitatively interpreting these data were highlights of the meeting. This is also our research strategy for the project. We presented a paper in the meeting, titled as “AVO crossplot analysis in unconsolidated sediments containing gas hydrate and free gas: Green Canyon 955, Gulf of Mexico”- work done prior to the DOE award. The work however does partially support the current research to identify relevant technical concepts, the paper shows an analysis of amplitude variation with offset (AVO) observations applied in hydrate-bearing sands, free-gas- charged sands, and hydrate-over-gas sands. We investigated log data of GC 955 well in the paper as well. Parts of elastic model parameters (Vp, Vs, and density) are obtained from well log measurements. Some good suggestions and recommendations for audiences were helpful to identify technical research concepts for the project. For example: attenuation and dispersion may not be our main concerns, but they could affect seismic amplitude in multi-layers hydrate deposits.

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 availability of well log data

Industry is moving toward LWD measurement from wireline logging because it significantly reduces offshore operation time and cost in deepwater environment. In addition, Erosion of the borehole wall and drilling fluid invasion are relatively reduced in the LWD measurement compared to the wireline logging due to shorter exposure time between drilling and logging (Collett et al., 2012). Although the LWD measurements have their advantages and have been used to characterize the presence of gas hydrate in the Gulf of Mexico (Collett et al., 2012) and other areas (Kim et al., 2011), they are carried out 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).

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 would be 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 have been working on the rock physics model for gas hydrate for several years before beginning this research project. After considerable effort, we have applied our rock physics model to dry sands, water sands, and hydrate filling sands, then compared our results to lab measurements. This work will be published in Geophysics (Zhang et. al., in press). 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
We will start this section in the second quarter.

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. We will examine and compare the two methods in the second quarter.

Estimation of gas hydrate saturation
We will start this section in the second quarter.

Other considerations: attenuation and dispersion
We infer that the distribution of gas hydrate could be layered and stacked based on findings in the GC955 H well. It will be necessary to investigate the effect of wave attenuation and dispersion in gas hydrate layers at seismic scale. We are studying possible seismic amplitude changes with respect to attenuation. However, attenuation mechanisms in hydrate reservoirs are not clear (Lee and Waite, 2007). We will carry on these studies in the second quarter.

Future work in next reporting period

- We will continue to work on the development of analytical techniques in next reporting period.
- As part of our technology transfer effort, we would be submitted an abstract in April for the 2013 Society of Exploration Geophysicists annual meeting.
- Work to secure 3-D seismic volumes for testing and calibration.
- Learn Jason Workbench Suite petrophysical and inversion software

Key References

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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. In the proposal, it was envisioned that this research would make use of Fugro-owned advanced commercial seismic inversion software, Jason Workbench as well as technical collaboration from Fugro-Jason. Also, the research will require 3-D seismic data to test ideas and calibrate models. Although we hope to be able secure the research use of 3-D seismic data over the JIP Leg II locations to build gas hydrate reservoir models at those location, those data have not been secured for the project yet. We did anticipate being able to choose from a wide range of 3-D seismic data from Fugro Multiclient Services and use these data in the research project to help test models. These plans were put in jeopardy when Fugro announced the sale of its Geoscience Division to CGG-Veritas which included the Jason software company and multiclient seismic data. Eventually an agreement to supply the research effort with the software was reached.

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.

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, Fugro Employee (Netherlands)
Nearest month worked	0	0	0
Collaboration outside USA	Not this reporting period	Not this reporting period	None this reporting period
Travel outside USA to communities of interest	Yes, China, 1 week	Yes, China, Singapore 1 week	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.

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
$8,892 has been spent from a budget allocation of $93,750. The federal share of the costs per this reporting period is $7,114 and the cost sharing is $1,778. We do count several meeting, contacts, and other efforts as being consistent with advancing the research project but these are not reflected in the budget spend to date.

Exhibit I Milestone Status

Milestone 1, Task 1 was completed November 14, 2012
Milestone 2 has been delayed to July 1, 2013

Exhibit 2 Cost Plan

Baseline Reporting Quarter	Budget Period 1							
	Q1		Q2		Q3		Q4	
	Q1	Comulative Total	Q2	Comulative Total	Q3	Comulative Total	Q4	Comulative Total
Baseline Cost Plan								
Federal Share	75000	75000						
Non-Federal Share	18750	18750						
Total Planned	93750	93750						
Actual Income Cost								
Federal Share	7114	7114						
Non-Federal Share	1778	1778						
Total Incurred Costs	8892	8892						
Variance								
Federal Share	(67886)	(67886)						
Non-Federal Share	(16972)	(16972)						
Total Variance	(84858)	(84858)						

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