Oil & Natural Gas Technology

DOE Award No.: DE-FE0009949

Quarterly Research Performance Progress Report (Period ending 6/30/2013)

A new approach to understanding the occurrence and volume of natural gas hydrate in the northern Gulf of Mexico using petroleum industry well logs

10/1/2012-9/30/2015

Submitted by:
Ann E. Cook

Ohio State University, School of Earth Sciences
317 Mendenhall Lab, 125 S. Oval Mall
Columbus, OH 43210
DUNS: 832127323
Email: cook.1129@osu.edu
Phone number: (614) 247-6085

Prepared for:
United States Department of Energy
National Energy Technology Laboratory

NETL

Office of Fossil Energy

EXECUTIVE SUMMARY

The main objective of the project is to significantly increase our understanding of the occurrence, volume and fine scale distribution of natural gas hydrate in the northern Gulf of Mexico using petroleum industry and Gulf of Mexico Gas Hydrate Joint Industry Project (JIP) well logs.

In the first quarter (October 1, 2012-December 13, 2012), the initial steps were to establish an estimate for the base of gas hydrate stability zone (GHSZ) for each industry well in the Gulf of Mexico and begin ordering industry well data. For the modeling side of the project, student Brian Tost completed a formation model for JIP2 wells in Alaminos Canyon, Gulf of Mexico. Ann Cook and Barbara Anderson began constructing formation models for the sand reservoir in Green Canyon, Gulf of Mexico.

In the second quarter (January 1, 2013-March 31, 2013) well orders were completed for each block in the Gulf of Mexico, by Cook, Urmi Majumdar (PhD student), Abby Crock (undergraduate hourly) and Samyra Ismail (undergraduate hourly). Eleven total DVDs were ordered from the Bureau of Safety and Environment Enforcement (BSEE). Student Brian Tost defended his master's thesis on the JIP Alaminos Canyon wells. Undergraduate senior Abby Crock completed her thesis on Alaminos Canyon industry wells in Block 857.

In the third quarter (April 1, 2013 – June 30, 2013) Urmi Majumdar and Samyra Ismail began working on well assessments by Gulf of Mexico Block. This involved opening each well log, noting the types of logs available in the GHSZ and analyzing the log for any signs of natural gas hydrate By the end of June, Majumdar completed initial reports on all of the wells in East Breaks and Keathley Canyon (found on pages 7-12 in this report). The plan is to produce reports of this type for all assessed Gulf of Mexico Blocks. At the end of May, Tost and Cook submitted a conference article entitled, 'Do Gas Hydrates Occur in Alaminos Canyon, Gulf of Mexico?' the the Unconventional Resources Technology Conference, which will be presented in August 2013. Tost was moved to a part time hourly worker for the summer (June 1-August 16) so he can complete the manuscript on Alaminos Canyon for the Journal of Geophysical Research. Cook and Anderson worked on resistivity formation models for JIP2 Hole GC955-H. Unfortunately, some of the Schlumberger proprietary models have changed and do not match the well conditions in Hole GC955-H. Anderson is working on having Schlumberger reinstate the old models.

PROGRESS, RESULTS AND DISCUSSION

See Table 1 for Project Timeline on each task and subtask.

Task 1.0 – Project Management Plan

During October and November, the Cook worked with Skip Pratt to develop the PMP for the project. It was completed on November 27, 2012.

Cook participated in a project kickoff conference call with DOE on November 7, 2012.

Task 2.0: Evaluation of gas hydrate occurrence in petroleum industry well logs

Subtask 2.1: **Calculate the depth of the GHSZ depth in the Gulf of Mexico using ArcGIS.**
Gas hydrate stability zone models for the Gulf of Mexico were received from Matt Frye, BOEM. These models contain minimum, mean and maximum estimates as well as breakdowns from P10-P90. The Frye models were assessed and by Cook and students, and compared to a blanket GIS calculation based only on bathymetric depth. We decided Frye models were likely more accurate, and decided to use the P90 gas hydrate stability zone depth as a cutoff for the log order. Thus, wells that contains only logs depths deeper than P90 will not be ordered.

Students Tost and Ismail worked on outputting spreadsheet data from the GIS to make the industry well log orders. Some GIS issues, including missing wells, were encountered and hopefully fixed.

The first well data order from BSEE was on December 7, 2012 and ordering continued through he end of Q2. Two undergraduate students, Crock and Ismail, PhD student Majumdar, and Cook ordered well data and compiled spreadsheets on each well (Subtask 2.2). In total, 11 DVDs were ordered full of logging data from the Gulf of Mexico. This task was completed at the end of Q2.

Subtask 2.2: **Well log evaluation and database development.**
Spreadsheets were developed for each block in the Gulf of Mexico for wells drilled in water column greater than 1400 ft. Orders were then compiled on the BSEE website using their well query system. Each well was queried using the API number. The BSEE seafloor depth at each well was crosschecked with GIS bathymetry data to make sure hydrate stability zone calculations were reasonably valid. Well logs that were above the P90 cutoff were ordered in each well, including (but not limited to) gamma ray, resistivity, velocity, density, neutron porosity and caliper. Most frequently, wells only contained resistivity and gamma ray logs. Additionally, we will not know how shallow some of the logs were recorded until the log data is analyzed. Typically the top of logged interval is only reported for the top of any log and typically does not represent the top of logged interval for all logs.

Each well that was ordered will be analyzed completely through the Mean GHSZ estimate and anything of interest was noted through the P90 GHSZ estimate. We note year of logging and operator for each well. Logs available through the Mean GHSZ are noted, as well as mud type in the Mean GHSZ, and any well deviation in the GHSZ. Initial well assessment spreadsheets and reports were completed for East Breaks and Keathley Canyon in Q3. This subtask is on track to be completed in Q2 of next year.

Task 3.0: Modeling of resistivity measurements from JIP Leg 2

***Subtask 3.1:* Develop true resistivity models for sand reservoirs for JIP Leg 2 Holes**

A resistivity model that incorporates the measured resistivity and the seismic trace in for JIP2 Holes AC-21A and AC-21B has been developed by Tost and Cook.

An initial model for JIP2 Hole GC-955H was completed in December 2012. Anderson and Cook are collaborating to produce more accurate models, unfortunately, some of the Schlumberger proprietary codes were changed since our first model run, and the newer models were mismatched. Anderson is working on trying to get these models revered back to the original. This task may take longer than planned, depending on if the proprietary models can be fixed.

***Subtask 3.2:* Determine hydrate saturation using best-fit ANISBED models.**

This task will begin once task 3.1 is complete.

Task 4.0: Determining volume of methane in gas hydrate in the northern Gulf of Mexico

This task and associated subtasks are on track to begin in Phase II.

Task 5.0: Publication, presentation and dissemination of results.

A conference paper was submitted for the Unconventional Resources Technology Conference, 'Do Gas Hydrates Occur in Alaminos Canyon, Gulf of Mexico?' with authors Tost and Cook. Tost will present this work in August 2013.

A publication is being prepared on the resistivity anomaly in Alaminos Canyon for the *Journal of Geophysical Research* with authors Tost and Cook. We hope to submit this paper at the beginning of August.

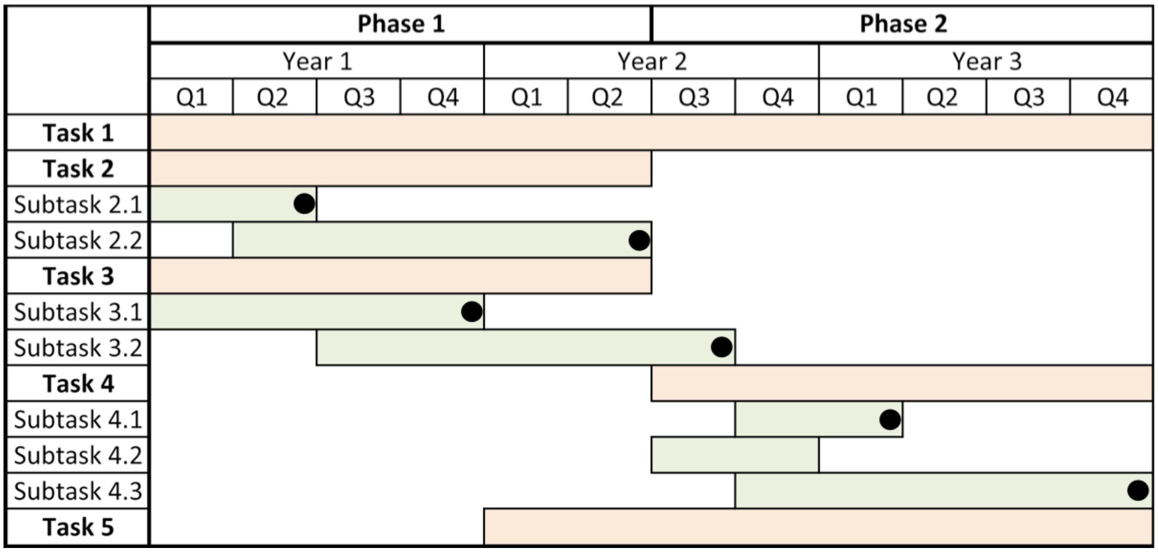

Table 1. Project timeline by task (tan bars) and subtask (green bars). Total project time is 2, 18 month-long phases (3 years). Subtask 2.1 has been completed and the first milestone was met. Milestones are indicated by a black dot.

PARTICIPANTS

Name: Ann Cook
Project Role: PI
Contribution: Managing student time, working on manuscript with Tost, developing block reports with Majumdar, developing models for JIP wells, assessing wells
Person Months: 1

Name: Brian Tost
Project Role: Graduate student/hourly summer worker
Contribution: Alaminos Canyon formation models, submitting URTEC paper, preparing journal article for publication
Funding Support: NSF fellowship/hourly on grant
Person Months: 1.5

Name: Urmi Majumdar
Project Roll: Graduate student
Contribution: Assessing wells in the Gulf of Mexico; preparing reports on East Breaks and Keathley Canyon
Person Months: 2

Name: Samyra Ismail
Project Roll: Undergraduate Hourly
Contribution: Well assessment
Person Months: ~3 weeks

COSTS

During Q3 charges to the project include graduate student tuition, undergraduate hourly pay, and partial travel for Majumdar and Cook to the Community Hydrate Meeting put on by the Consortium for Ocean Leadership. A prepurchase flight charge has been made to the grant for the upcoming URTEC presentation. A few things were ordered during the previous period that are only now reflected on the financial statements, such as undergraduate hourly pay and most of the DVD orders.

Department: **06560**
Principal Investigator: **Cook,Ann Elizabeth**
Sponsored Program Officer: **Port,Jared Austin**
Facilities & Administration Rate: **52.50 %**

The Ohio State University - Office of Sponsored Programs
Project Financial Summary
For the Month Ending: **JUN 30, 2013**
Project Period: ***10/01/2012*** to ***03/31/2014***

Project: **60036410**
Award: **GRT00028365**
Sponsor: **US Department of Energy**
Grant/Contract: **DE-FE0009949**

Project/Award Title: **New approach to understanding the occurrence and volume of natural gas hydrate in the northern Gulf of Mexico using petroleum industry well logs**

	Sponsor				
Category	**Budget**	**Expenses This Month**	**Expenses To Date**	**Commitments**	**Balance**
Salaries and Wages	52,030.00	2,191.72	12,253.92	10,300.43	29,475.65
Fringe Benefits	5,888.00	219.17	1,225.38	1,563.68	3,098.94
GA Tuition and Fees	23,256.00	0.00	5,852.00	14,700.00	2,704.00
Total Personnel Costs	81,174.00	2,410.89	19,331.30	26,564.11	35,278.59
Materials and Supplies	0.00	0.00	1,161.00	0.00	-1,161.00
Domestic Travel	10,000.00	1,471.32	1,471.32	0.00	8,528.68
Purchased Services	15,000.00	0.00	0.00	0.00	15,000.00
Total Direct Costs	106,174.00	3,882.21	21,963.62	26,564.11	57,646.27
Facilities and Administrative	43,532.00	2,038.18	8,458.64	6,228.66	28,844.70
Total	**149,706.00**	**5,920.39**	**30,422.26**	**32,792.77**	**86,490.97**

	Cost Share				
Category	**Budget**	**Expenses This Month**	**Expenses To Date**	**Commitments**	**Balance**
GA Tuition and Fees	0.00	0.00	8,656.00	0.00	-8,656.00
Total Personnel Costs	0.00	0.00	8,656.00	0.00	-8,656.00
Total Direct Costs	0.00	0.00	8,656.00	0.00	-8,656.00
Total	**0.00**	**0.00**	**8,656.00**	**0.00**	**-8,656.00**

	Third Party				
Category	**Budget**	**Expenses This Month**	**Expenses To Date**	**Commitments**	**Balance**
Other Direct Costs	22,500.00	0.00	0.00	0.00	22,500.00
Purchased Services	52,000.00	0.00	0.00	0.00	52,000.00
Total Direct Costs	74,500.00	0.00	0.00	0.00	74,500.00
Total	**74,500.00**	**0.00**	**0.00**	**0.00**	**74,500.00**

Table 2. Total costs through Q3.

Department: **06560**
Principal Investigator: **Cook,Ann Elizabeth**
Sponsored Program Officer: **Port,Jared Austin**

The Ohio State University - Office of Sponsored Programs
Detail of Expenses
For the Month Ending: **JUN 30, 2013**
Project Period: **10/01/2012** to **03/31/2014**

Project: **60036410**
Award: **GRT00028365**
Sponsor: **US Department of Energy**
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Account	Account Description	Sponsor Expense
60092	Graduate Research Associate	1,827.22
60131	Student (non-GA/non-FWSP)	364.50
	Salaries and Wages	2,191.72
60292	Bnft-Graduate Research Assoc	182.72
60331	Bnft-Student (non-GA/non-FWSP)	36.45
	Fringe Benefits	219.17
	Total Personnel Costs	2,410.89
63401	Ohio Travel - Univ Employee	542.99

Journal ID	Purchase Order	Voucher ID	Invoice ID	Vendor	Transaction Description	
AP03140168		13TRN70C	T000265409-1	COOK,ANN ELIZABETH	Reimb	$542.99

Account	Account Description	Sponsor Expense
63403	Ohio Travel - Students	428.45

Journal ID	Purchase Order	Voucher ID	Invoice ID	Vendor	Transaction Description	
AP03139157		13TRN6Q0	T000268429-1	MAJUMDAR,URMI	Reimb	$428.45

Account	Account Description	Sponsor Expense
63405	Out of State - Univ Employee	499.88

Journal ID	Purchase Order	Voucher ID	Invoice ID	Vendor	Transaction Description	
AP03133952		13YYN5IB	18788T269531	TRAVEL SOLUTIONS	AIRFARE T000269531 TOST	$499.88

Account	Account Description	Sponsor Expense
	Domestic Travel	1,471.32
	Total Direct Costs	3,882.21
66701	Indirect Costs	2,038.18
	Facilities and Administrative	2,038.18
	Total F&A Costs	2,038.18
	Total Project Costs This Month	**5,920.39**

Table 3. Detail of expenses through Q3.

Department: **06560**
Principal Investigator: **Cook,Ann Elizabeth**
Sponsored Program Officer: **Port,Jared Austin**

The Ohio State University - Office of Sponsored Programs
Detail of Payroll Expenses
For the Month Ending: **JUN 30, 2013**
Project Period: ***10/01/2012*** to ***03/31/2014***

Project: **60036410**
Award: **GRT00028365**
Sponsor: **US Department of Energy**
Grant/Contract: **DE-FE0009949**

Project/Award Title: **New approach to understanding the occurrence and volume of natural gas hydrate in the northern Gulf of Mexico using petroleum industry well logs**

	Employee						Sponsor Expenses
Account	ID	Name	Journal ID	Journal Date	Pay Type	Description	This Month
60092	200299301	Majumdar,Urmi		06/28/2013	HR Monthly	HR Payroll Expense	1,827.22
						Total for Account	1,827.22
60131	200208533	Ismail,Samrya A		06/14/2013	HR Bi-Weekly	HR Payroll Expense	175.50
60131	200208533	Ismail,Samrya A		06/28/2013	HR Bi-Weekly	HR Payroll Expense	189.00
						Total for Account	364.50
60292			BNRF700591	06/30/2013	Other	OSURF BENEFIT RATE 5	182.72
						Total for Account	182.72
60331			BNRF500446	06/30/2013	Other	OSURF BENEFIT RATE 5	36.45
						Total for Account	36.45
						Total for Project	**2,410.89**

Table 3. Detail of payroll expenses through Q3.

CONCLUSION

Currently, all project tasks are on track, however, the ANISBED modeling may be delayed due to changes with the proprietary Schlumberger model. It may not be completed by the end of Q4. There are no major changes from the PMP at this time.

GAS HYDRATE PROSPECTS IN EAST BREAKS, GULF OF MEXICO

The East Breaks (EB) block of the Gulf of Mexico has been drilled extensively by industry with a total of 410 wells, including many wild cat wells. Out of those, log data from only about 165 wells could be used to assess the presence of gas hydrates. These wells were logged from 1995 to 2008. The range of water depths in these wells are 1936 ft to 4918 ft. The mean estimated base of Hydrate Stability Zone (HSZ_Mean) varies from 1721 to 6654 fbsl (HSZ_90 from 1721to 7206 fbsl). Based on our assessments, 20 out of the 165 wells may contain gas hydrates. All the wells of interest are effectively vertical within the gas hydrate stability zone.

Table 1 shows the details of the most interesting wells with respect to occurrence of gas hydrates in the East Breaks.

The most interesting well is in Block EB 990 (API No. 608044023300), in which the top of logged interval (TLI) is 5150 fbsl. From 5700 fbsl to 6640 fbsl (which is also the HSZ_Mean) a consistent interval of clay (gamma ray measure ~75 GAPI) is encountered in well (Figure 1). Presence of gas hydrate is likely in intervals 5702-5716 fbsl, 5760-5766 fbsl, 5856-5860 fbsl and 5888-6430 fbsl in clay within the HSZ. The phase-shift resistivity log measures as high as 20 ohm*m in these gas hydrate intervals as opposed to the clay background resistivity measure of ~ 1 ohm*m. The propagation resistivity curve separation in EB 990 is characteristic of near-vertical gas hydrate filled fractures, where the deepest penetrating propagation resistivity logs measure the highest resistivity (Figure 1).

In EB 712 (API No. 608044021500), gas hydrate in a clay reservoir is likely present in intervals 4100-4120 fbsl and 4134-4220 fbsl as indicated by very high resistivity (more than 20 ohm*m at the resistivity curve peaks) and curve separation in the resistivity log. The background resistivity of the clay interval is more or less 1ohm*m. Figure 2 shows one of the clay intervals in well EB 712 likely containing gas hydrate.

EB 946 (API No. 608044016200) shows two small intervals of gas hydrate in 5530-5540 fbsl and 5680-5700 fbsl in clay. These gas hydrate intervals show higher resistivity measure (2 to 4 ohm*m) and curve separation as opposed to lower background resistivity of the clay interval (less than 2 ohm*m in the attenuation resistivity log).

EB 994 (API No.608044016500) shows an interval of washout sand from 5120 fbsl to 5580 fbsl. An interval of gas hydrate in sand to sandy clay is interpreted from 5580-5708 fbsl and 5738-5750 fbsl showing resistivity as high as 2 ohm*m in contrast to the background resistivity of the interval of about 1 ohm*m. However, if gas hydrate is present in these intervals in EB 994, it is present in very low in concentration disseminated in the sand constituent of the interval.

Gas hydrate may occur in EB 602 (API Nos. 608044020200, 608044019400, 608044019401, 608044019402, 608044019403, 608044019404, 608044019600, 608044019601, 608044018700 and 608044021600) in sand reservoir in small intervals as listed in Table 1, based on the resistivity curve separation and moderately high resistivity (about 2 ohm*m or higher) in ARC resistivity (attenuation and phase-shift) or EWR logs.

In EB 832 (API No. 608044020400), two small intervals of gas hydrate in clay (4760-4772 fbsl and 4800-4810 fbsl) may be interpreted due to moderately high resistivity (2 ohm*m in EWR)and resistivity curve separation.

A small interval 4456-4464 fbsl of gas hydrate possibly occurs in well EB 558 (API No. 608044021201) in clay from high EWR curve (3.5 ohm*m) in contrast to lower background resistivity (less than or equal to 1 ohm*m).

In EB 642 (API No. 608044024000), high resistivity and curve separation is encountered in EWR log in a clay interval within HSZ_90 from 5300-5430 fbsl. This interval may possibly contain gas hydrate as the interval is above the HSZ_90 (but below HSZ_Mean).

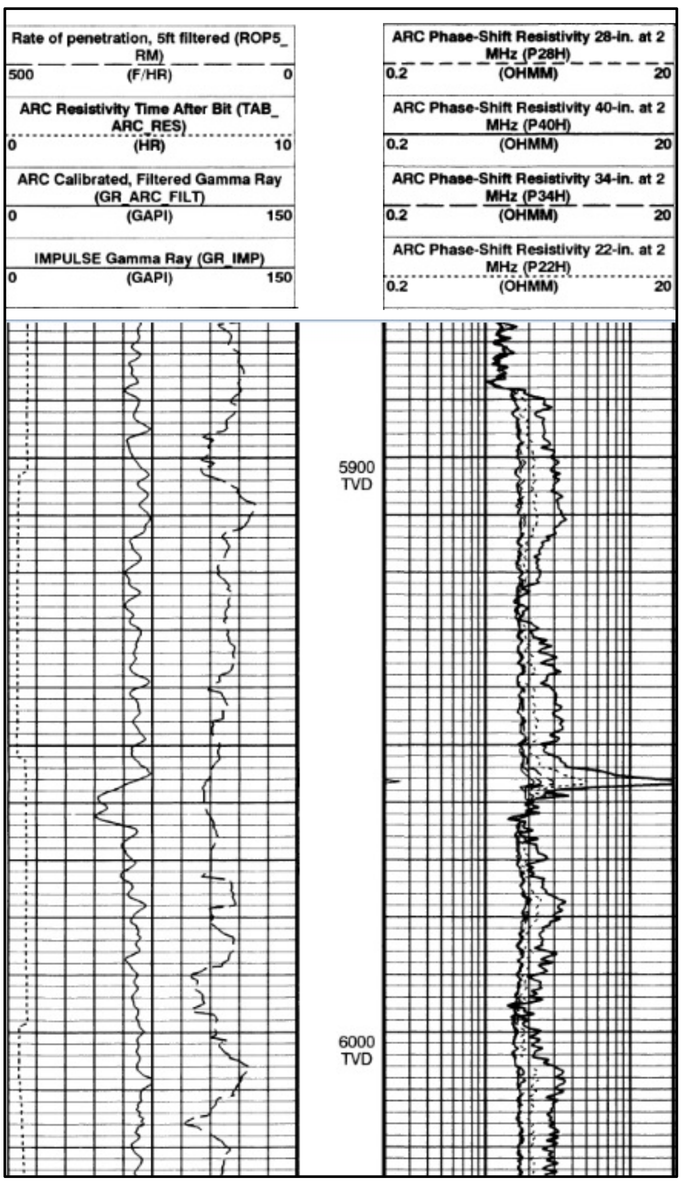

Figure 1: A section of well EB 990 likely containing gas hydrate. The interval possibly containing gas hydrate has high resistivity (more or less 2-3 ohm*m) against lower background resistivity. Resistivity curve separation is also noted.

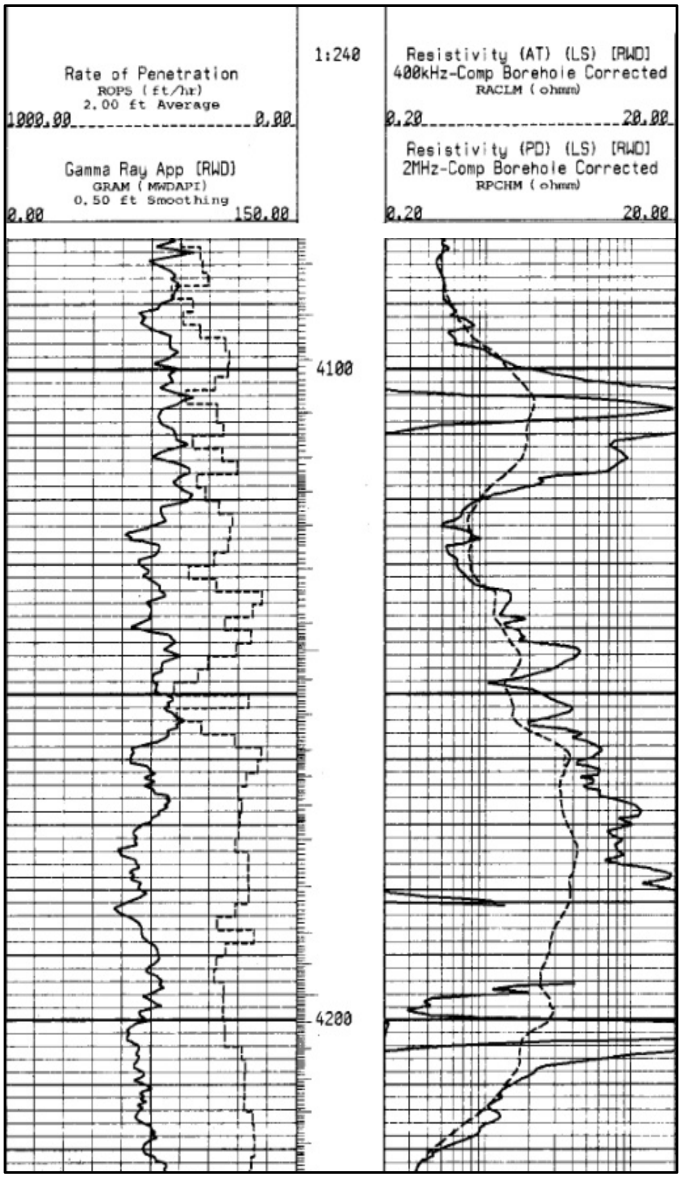

Figure 2: A section of well EB 712 likely containing gas hydrate. The background resistivity of this clay interval is as low as 1.5 ohm*m while the section of the interval likely containing gas hydrate has very high resistivity (higher than 20 ohm*m at the high resistivity peaks) and resistivity curve

Gas Hydrate Prospects in Keathley Canyon, Gulf of Mexico

Forty-eight wells from the Keathley Canyon block in the Gulf of Mexico were analyzed to assess the presence of gas hydrates. Out of these only 2 wells (KC 151 and KC 291) likely contain gas hydrate. Schlumberger logged the two wells in the year 2005 and 2009 respectively. The water depths in these wells are 4337 feet and 5765 feet. While the bases of hydrate stability zone (HSZ_Mean) are 6053 fbsl and 7403 fbsl (HSZ_90 are 6617 fbsl and 7978 fbsl).

Table 2 lists the wells in Keathley Canyon that might possibly contain gas hydrate.

The well with the most potential in terms of gas hydrate is KC 151 (API No. 608084000800), originally drilled by Gulf of Mexico Gas Hydrate Joint Industry Project (JIP). Drilled with seawater, the well has large intervals of clay from 5100-5200 fbsl and 5240-5362 fbsl (Figure 3) that contain gas hydrate. High resistivity (2 ohm*m to as high as 5 ohm*m compared to background resistivity of 1 ohm*m) as well as resistivity curve separations are shown in the intervals. Gas hydrate filled fractures are clearly visible on the LWD images.

KC 291 (API No. 608084001700) is another interesting well in the Keathley Canyon block. It contains a number of intervals likely to contain gas hydrate. An interval from 7100-7110 fbsl is a sandy clay interval showing high resistivity (as high as 7 ohm*m) in contrast to the much lower background resistivity (0.4 ohm*m). Interval 7138- 7144 fbsl is a more clayey interval showing resistivity as high as 3 ohm*m (Figure 4). Clay gas hydrate reservoirs are possibly encountered in intervals 7262-7274 fbsl (Figure 2), 7340-7360 fbsl, 7366-7376 fbsl and 7392-7396 fbsl. Interval 7262-7274 fbsl shows resistivity high of 3 ohm*m compared to a background resistivity of 0.5 ohm*m. Resistivity is as high as 6 ohm*m in interval 7340-7360 fbsl, and 2 ohm*m both in intervals 7366-7373 fbsl and 7392-7396 fbsl (background resistivity 0.5 ohm*m). Resistivity curve separation is also shown by all these possible gas hydrate intervals. There are 4 more intervals in KC 291, below the HSZ_Mean but within the HSZ_90 which shows high resistivity (2.5 ohm*m to 9 ohm*m) in contrast to background resistivity of 0.4-0.5 ohm*m. These are clay intervals at 7484-7490 fbsl, 7498-7505 fbsl and 7656-7664 fbsl. These intervals could also contain gas hydrate.

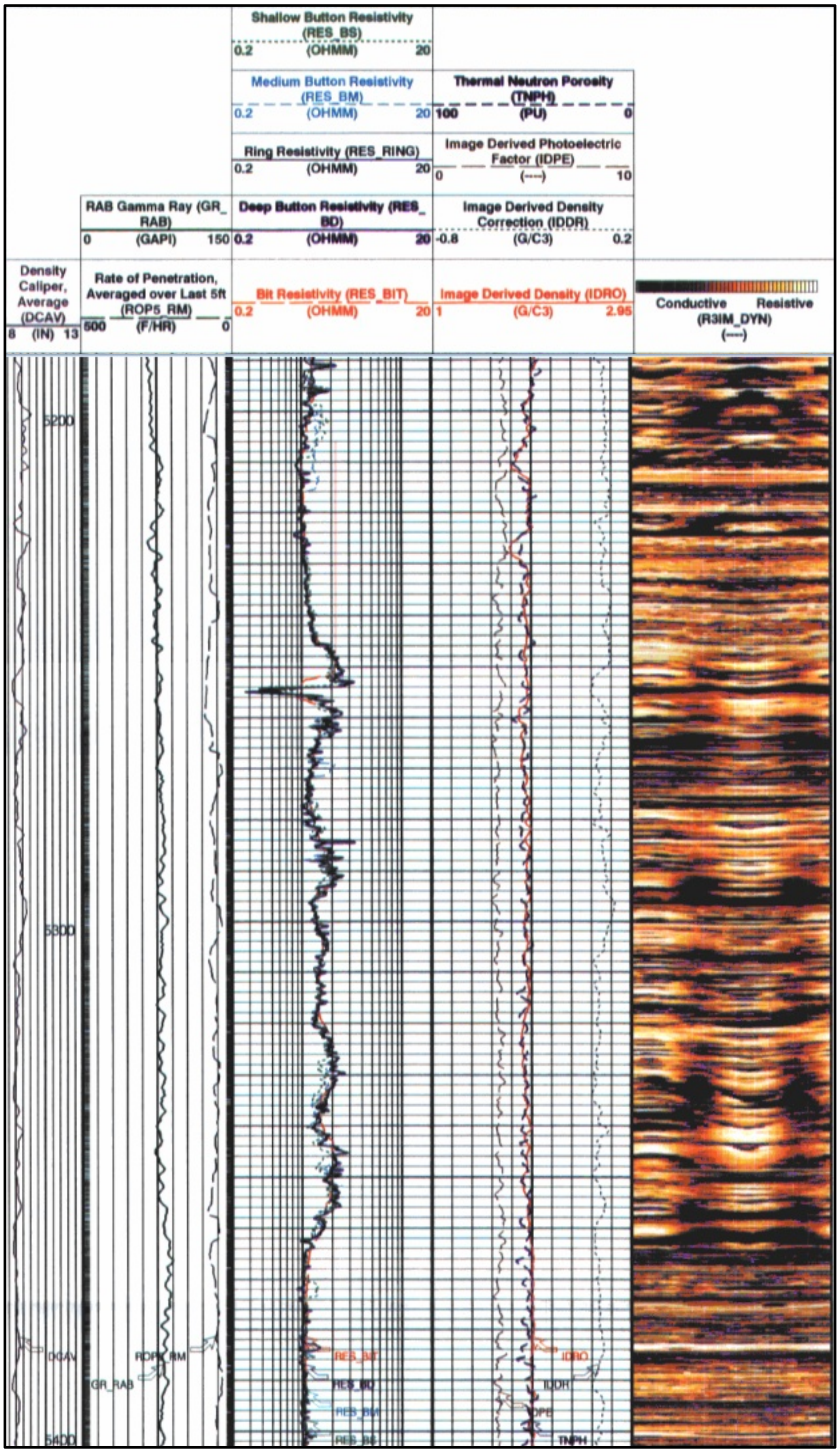

Figure 3: Interval from 5240-5362 fbsl in well KC 151 contains gas hydrate as indicated by the high resistivity measure in the resistivity logs and also characteristic resistivity image.

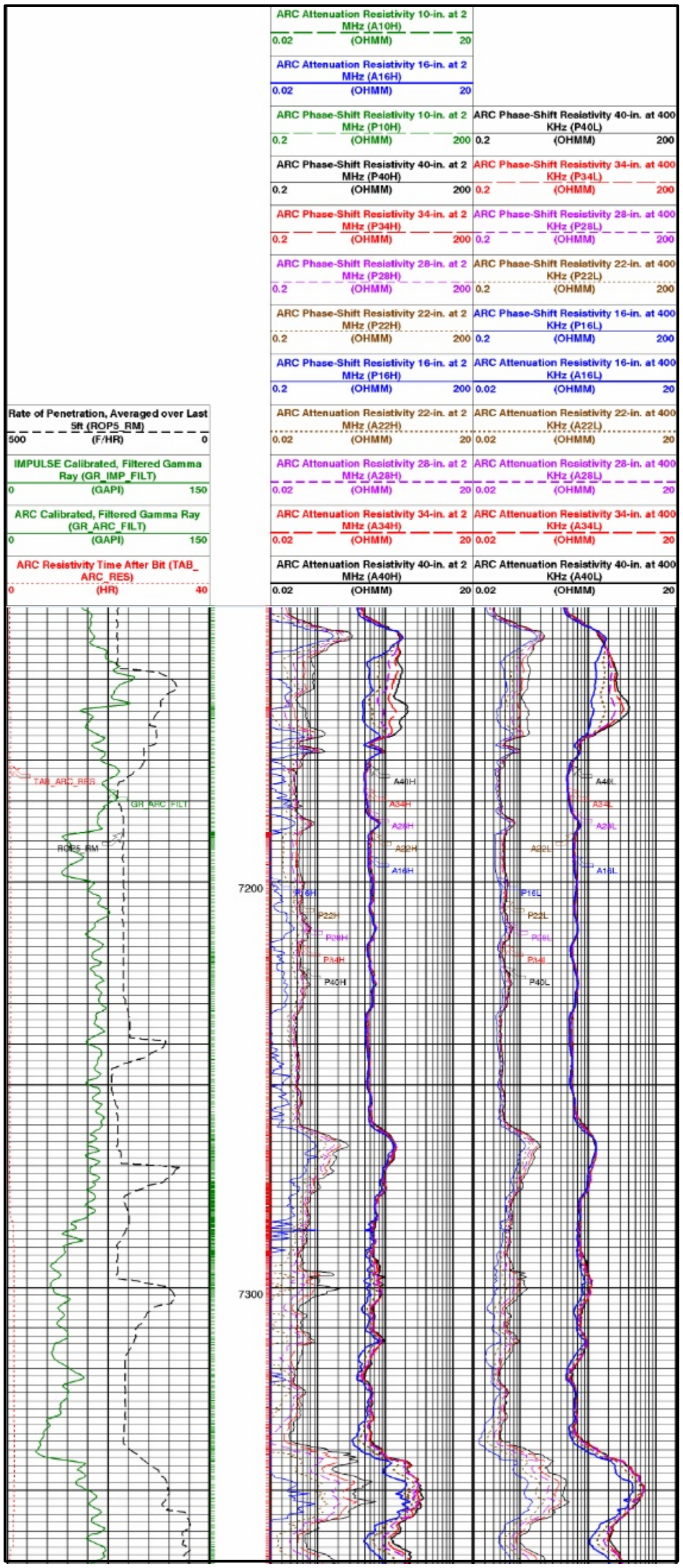

Figure 4: A section of a log of well KC 291 showing the likelihood of presence of gas hydrate in intervals 7138-7144 fbsl and 7262-7274 fbsl as indicated by high phase shift and attenuation resistivity measurements and resistivity curve separation.