Oil & Natural Gas Technology

DOE Award No.: DE-FE0009949

Quarterly Research Performance Progress Report (Period ending 9/30/2013)

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:
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National Energy Technology Laboratory

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. 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 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.

In the fourth quarter (July 1 – September 30, 2013) Majumdar continued working on assessments in the Gulf of Mexico, specifically focusing on Alaminos Canyon and Mississippi Canyon. The report for Alaminos Canyon can be found on pages 7-13 of this quarterly report. Mississippi Canyon will appear in the following quarter. Tost presented his work at the Unconvetional Resources technology conference. Tost and Cook continued to work on to work on the Alaminos Canyon Block 21 manuscript for submission to JGR. Anderson was able to fix the Schlumberger proprietary models, but we were not able to complete the resistivity formation models for GC955-H and WR313-G because of the delay. The target completion date for the resistivity models was moved to December 31, 2013.

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, and Alaminos Canyon in Q4. This subtask is on track to be completed in Q2 of this coming year 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. The completion date for this task was moved to December 31, 2013 due to problems with the proprietary Schlumberger code.

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. Originally, we hoped to have this paper in by August, but some errors were found in the calculations and took several weeks to revise. A draft manuscript is now complete and being reviewed by colleagues. It should be submitted in November.

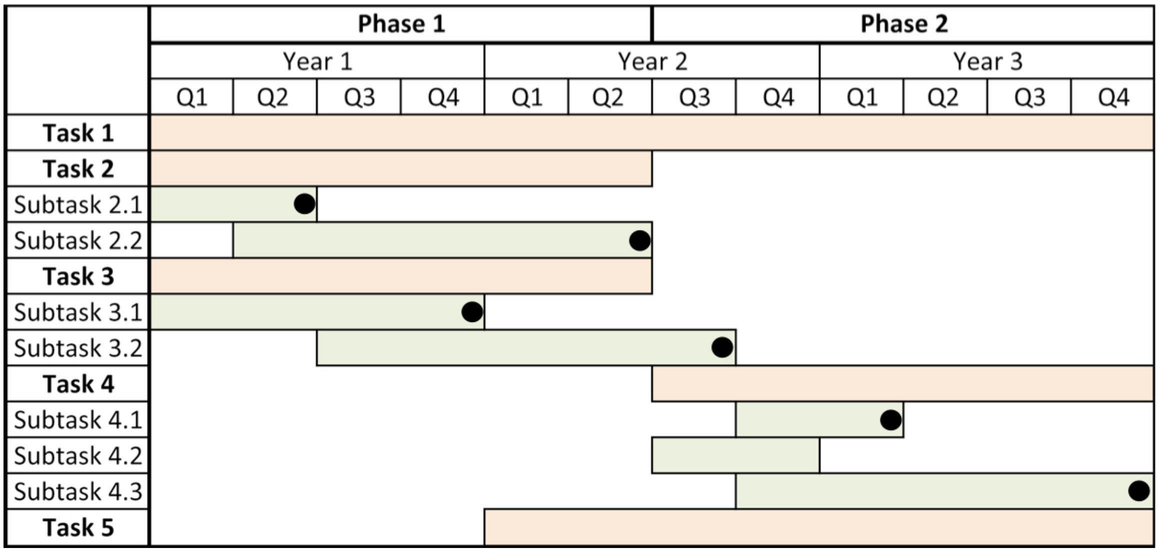

Table 1. Project timeline by task (tan bars) and subtask (green bars). Total project time is 2, 18 month-long phases (3 years). Subtask 2.1 has been completed and the first milestone was met. Milestones are indicated by a black dot.

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: 1.5

Name: Brian Tost
Project Role: hourly summer worker
Contribution: Alaminos Canyon formation models, presenting URTEC paper, preparing journal article for publication
Funding Support: hourly on grant
Person Months: 1

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

COSTS

During Q4 charges to the project include graduate student tuition, PI summer salary, hourly pay, and travel for Tost to the Unconventional Resources Conference.

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: SEP 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	2,914.22	25,603.57	10,963.32	15,463.11
Fringe Benefits	5,888.00	367.19	3,173.27	1,381.37	1,333.36
GA Tuition and Fees	23,256.00	0.00	6,583.50	9,275.00	7,397.50
Total Personnel Costs	81,174.00	3,281.41	35,360.34	21,619.69	24,193.97
Materials and Supplies	0.00	0.00	1,161.00	0.00	-1,161.00
Domestic Travel	10,000.00	0.00	2,251.92	0.00	7,748.08
Purchased Services	15,000.00	0.00	0.00	0.00	15,000.00
Total Direct Costs	106,174.00	3,281.41	38,773.26	21,619.69	45,781.05
Facilities and Administrative	43,532.00	1,722.74	16,899.67	6,480.96	20,151.37
Total	**149,706.00**	**5,004.15**	**55,672.93**	**28,100.65**	**65,932.42**

	Cost Share				
Category	**Budget**	**Expenses This Month**	**Expenses To Date**	**Commitments**	**Balance**
GA Tuition and Fees	0.00	0.00	9,738.00	0.00	-9,738.00
Total Personnel Costs	0.00	0.00	9,738.00	0.00	-9,738.00
Total Direct Costs	0.00	0.00	9,738.00	0.00	-9,738.00
Facilities and Administrative	0.00	32.81	160.76	0.00	-160.76
Total	**0.00**	**32.81**	**9,898.76**	**0.00**	**-9,898.76**

	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 Year 1.

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: SEP 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**

Account	**Account Description**	**Sponsor Expense**
60092	Graduate Research Associate	1,827.22
60131	Student (non-GA/non-FWSP)	1,087.00
	Salaries and Wages	2,914.22
60292	Bnft-Graduate Research Assoc	230.23
60331	Bnft-Student (non-GA/non-FWSP)	136.96
	Fringe Benefits	367.19
	Total Personnel Costs	3,281.41
	Total Direct Costs	3,281.41
66701	Indirect Costs	1,722.74
	Facilities and Administrative	1,722.74
	Total F&A Costs	1,722.74
	Total Project Costs This Month	**5,004.15**

Account	**Account Description**	**Cost Share Expense**
66701	Indirect Costs	32.81
	Facilities and Administrative	32.81
	Total F&A Costs	32.81
	Total Project Costs This Month	**32.81**

Table 3. Detail of expenses in Q4.

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: **SEP 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		09/30/2013	HR Monthly	HR Payroll Expense	1,827.22
						Total for Account	1,827.22
60131	200208533	Ismail,Samrya A		09/06/2013	HR Bi-Weekly	HR Payroll Expense	207.00
60131	00099637	Tost,Brian C		09/06/2013	HR Bi-Weekly	HR Payroll Expense	880.00
						Total for Account	1,087.00
60292			BNRF700607	09/30/2013	Other	OSURF BENEFIT RATE 5	230.23
						Total for Account	230.23
60331			BNRF500456	09/30/2013	Other	OSURF BENEFIT RATE 5	136.96
						Total for Account	136.96
						Total for Project	**3,281.41**

Table 3. Detail of payroll expenses for Q4.

CONCLUSION

Currently, all project tasks are on track, however, the ANISBED modeling was delayed due to December 31, 2013. Otherwise, there are no major changes from the PMP at this time.

Gas hydrate prospects in Alaminos Canyon, Gulf of Mexico

Logging data from forty-six wells in the Alaminos Canyon in the Gulf of Mexico were analyzed to assess the presence of gas hydrate. Twenty out of those are likely to contain gas hydrate based on resistivity logging data. Water depths in those wells vary from 4808 fbsl to 10011 fbsl. The HSZ_Mean (mean statistical base of gas hydrate stability zone) varied from 6574 fbsl to 12443 fbsl, whereas HSZ_90 (90th percentile statistical base of gas hydrate stability zone) ranged from 7119 fbsl to 13066 fbsl in Alaminos Canyon. Statistical data on the gas hydrate stability zone for the Gulf of Mexico is based on Frye (2007) report. To distinguish multiple wells in the same block, letter designations have been assigned for quick referral.

AC 857 is the most interesting block in the Alaminos Canyon with possible gas hydrate shows in eleven wells (API#s 6080540-01800 (A), 6080540-01801 (B), 6080540-02000 (C), 6080540-02300 (D), 6080540-02301 (E), 6080540-02900 (F), 6080540-03100 (G), 6080540-06402 (H), 6080540-06500 (I), 6080540-06600 (J) and 6080540-06700 (K)). These wells were drilled by various operators from 1997 to 2009. The shallowest depth of gas hydrate show is at 8410 fbsl in well I.

Large intervals of gas hydrate in clay is encountered from 10276-10320 fbsl, 10348-10460 fbsl and 10512-10580 fbsl (all deeper than HSZ_Mean but within the HSZ_90) in wells AC 857-A (Figure 1), B and C as indicated by the very high resistivity reading and resistivity curve separation. The resistivity measurement in the resistivity log (deep phase EWR, medium phase EWR, shallow phase EWR and Ext shallow phase EWR) in the intervals predicted to contain gas hydrate is in the order of 20 ohm*m against the background resistivity of 1 ohm*m.

In well AC 857-D, thick intervals of gas hydrate in clay occurs from 10242-10290 fbsl, 10340-10390 fbsl, 10474-10726 fbsl and 10858-10884 fbsl. The resistivity reading (deep phase EWR, medium phase EWR, shallow phase EWR and Ext shallow phase EWR) in these intervals is very high (about 20 ohm*m) compared to the background resistivity of about 1 ohm*m. The resistivity log at these intervals also show curve separation.

Gas hydrate may also occur in well AC 857-E in multiple intervals of clay in 10142-10164 fbsl, 10180-10184 fbsl, 10240-10390 fbsl, 10450-10726 fbsl and 10860-10884 fbsl. The resistivity at these intervals is high (as high as 20 ohm*m against background resistivity of 1 ohm*m) and resistivity curve separation is also seen in the high resistivity peaks.

Multiple intervals of gas hydrate may also be present in well AC 857-F. The intervals that may contain gas hydrate are 9400-9540 fbsl, 9778-9784 fbsl, 10114-10270 fbsl, 10350-10632 fbsl and 10738-10760 fbsl. Gas hydrate in the interval 9400-9540 fbsl is suggested by the high phase shift resistivity (about 5 ohm*m) compared to 1 ohm*m background resistivity and resistivity curve separation. The reservoir is sand-clay mix. The phase shift resistivity is 20 ohm*m in the intervals 10114-10270 fbsl and 10350-10632 fbsl where gas hydrate may occur in clay. Resistivity curve separation is visible at resistivity peaks. 10738-10760 fbsl and 9778-9784 fbsl are minor intervals of gas hydrate in clay as indicated by the high resistivity.

Well AC 857- G has multiple possible small intervals of gas hydrate. All the intervals 9406-9420 fbsl, 97046-9710 fbsl and 9800-10500 fbsl are intervals of clay but a bit sandier or less radioactive than the background clay interval. The first two intervals show higher resistivity (about 5 ohm*m) than the background resistivity (1 ohm*m) while resistivity in the third interval varies from 1.5 to 6 ohm*m. The density log trend and the neutron porosity log trend in opposite directions, that is , the density increases and the neutron porosity decreases in the intervals. However, this trend is less defined in the third interval.

Well AC 857- H has five possible gas hydrate intervals -- 9400-9530 fbsl, 9960-9980 fbsl, 10000-10050 fbsl, 10064-10078 fbsl and 10170-10330 fbsl. The last interval extends slightly deeper than HSZ_mean (10271 fbsl). Gas hydrate may be present in low concentration in the sand interval 9400-9530 fbsl. In interval 9960-9980 fbsl, possibility of presence of gas hydrate is determined by the high EWR (4 ohm*m) and resistivity curve separation. The reservoir is clay. The resistivity is more than 20 ohm*m in the last three clay intervals. Resistivity curve separation is very prominent in the interval 10000-10050 fbsl while not so well defined in the other two intervals.

Interval 9420-9560 fbsl is a sand interval in the wells AC 857- I, J and K which may contain disseminated gas hydrate in it. Well J also consists of a shallower sand interval 9226-9238 fbsl which may contain gas hydrate as indicated by the slightly higher resistivity (about 3 ohm*m) compared to 1 ohm*m background resistivity.

Block AC 557 (API#s 6080540-01301 (A) and 6080540-01302 (B)) shows quite a thick interval (about 100 feet) of possible gas hydrate in clay. This interval from 9024-9120 fbsl shows a high resistivity in the EWR log and resistivity curve separation (Figure 2). The resistivity in this interval is around 10 ohm*m and as high as 20 ohm*m at the peak of the curve against a background resistivity of 1 ohm*m or even lower.

Block 818 (API# 6080540-02500) contains two thick intervals of gas hydrate in volcanic sand (Boswell et al. 2009). The phase shift resistivity of interval 10436-10506 fbsl is about 2.5 ohm*m and that of interval 10530-10600 fbsl is as high as 70 ohm*m against the background resistivity of 1.5 ohm*m (Figure 3). Resistivity curve separation is also noted in these intervals.

Low concentration of gas hydrate possibly exists in Wells AC 856 -A (API# 6080540-03300) and B (API# 6080540-03301) in the sand interval of 8424-8570 fbsl. Phase shift resistivity here is about 2 ohm*m which is comparatively higher than the background resistivity of 1 ohm*m. Slight resistivity curve separation is also evident here.

Well AC 815-A (API# 6080540-06101) might have an interval of gas hydrate in clay from 11330-11510 fbsl. If gas hydrate is present here, it is present in very low concentration as predicted from the resistivity log reading (phase shift resistivity of about 2 ohm*m compared to background resistivity of 1 ohm*m). However, no sign of gas hydrate is present in Well B (API# 6080540-03000).

Both the wells AC 21- A (API# 6080540-07000) and B (API# 6080540-07001) are predicted to have multiple intervals of gas hydrate (Lee et al., 2012: Lee, 2012). The first two intervals that might contain gas hydrate - 5482-5494 fbsl and 5520-5570 fbsl are sand intervals. The phase shift resistivity in these intervals is only slightly greater (2 to 2.5 ohm*m) than the background resistivity of 1 ohm*m and the delta T compressional log hardly shows any deviation in these intervals (Figure 4). Intervals 5750-6094 fbsl and 6240-6600 fbsl may also contain gas hydrate. These are clay intervals and thicker than the first two intervals. The phase shift resistivity is about 2 ohm*m and delta T compressional log also show a decrease which makes the possibility of the presence of gas hydrate in these two intervals stronger.

References

Boswell, R., D. Shelander, M. Lee, T. Latham, T. Collett, G. Guerin, G. Moridis, M. Reagan, and D. Goldberg, 2009, Occurrence of gas hydrate in Oligocene Frio sand: Alaminos Canyon Block 818: Northern Gulf of Mexico, *Mar. Petrol. Geol*., 26(8), 1499–1512, doi: 10.1016/j.marpetgeo.2009.03.005.

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Lee, M.W, 2012, Anisotropic and Borehole Washout Analyses in Gulf of Mexico Gas Hydrate Joint Industry Project Leg II, Alaminos Canyon Well 21-A, Geological Survey Scientific Investigations Report 2012-5046, 23 p.

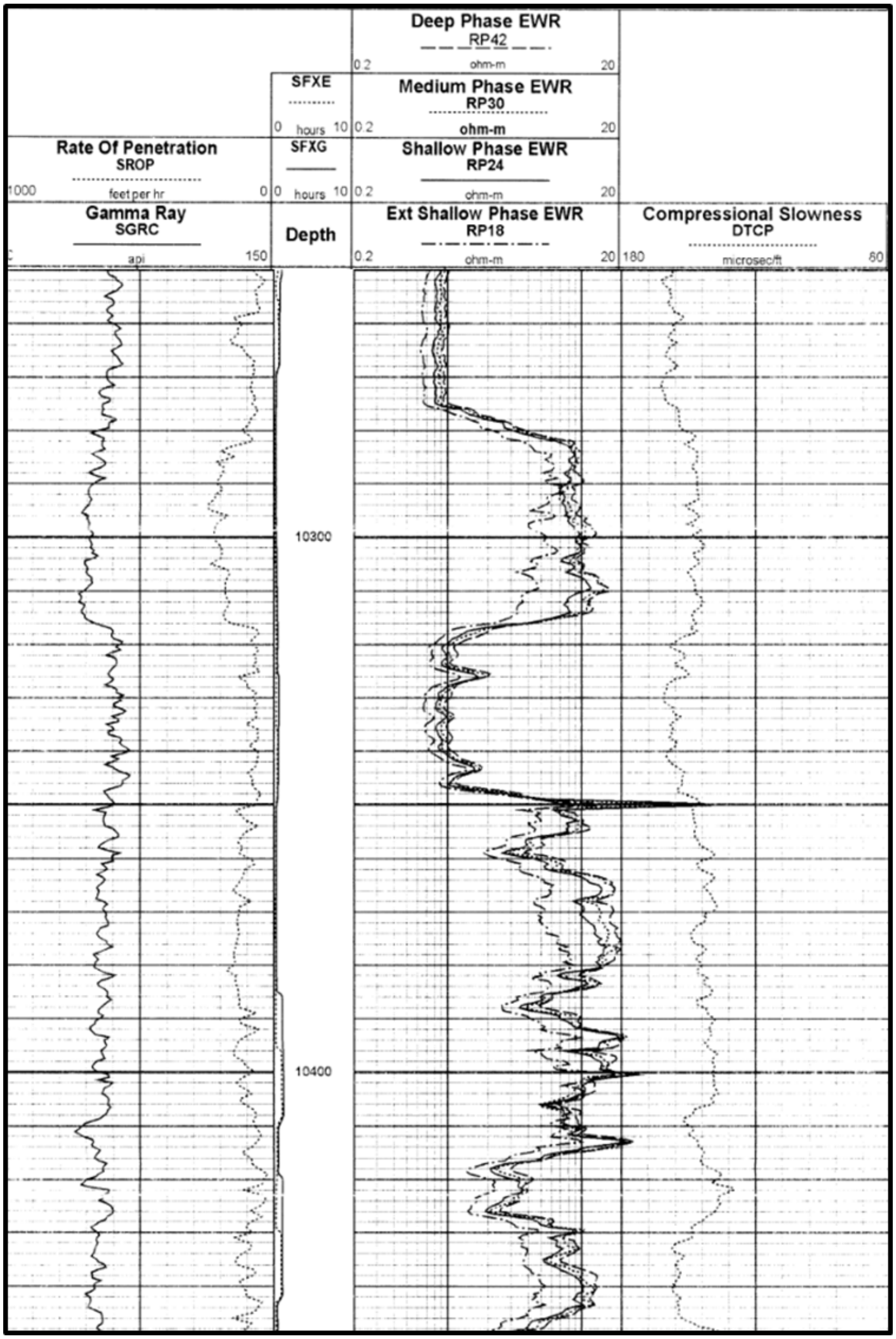

Figure 1: A section a log from well AC 857- A (API# 6080540-01800). Clay interval 10276-10320 fbsl and a portion of clay interval 10348-10460 fbsl is represented. EWR in these intervals are as high as 20 ohm*m in these intervals compared to background resistivity of 1 ohm*m.

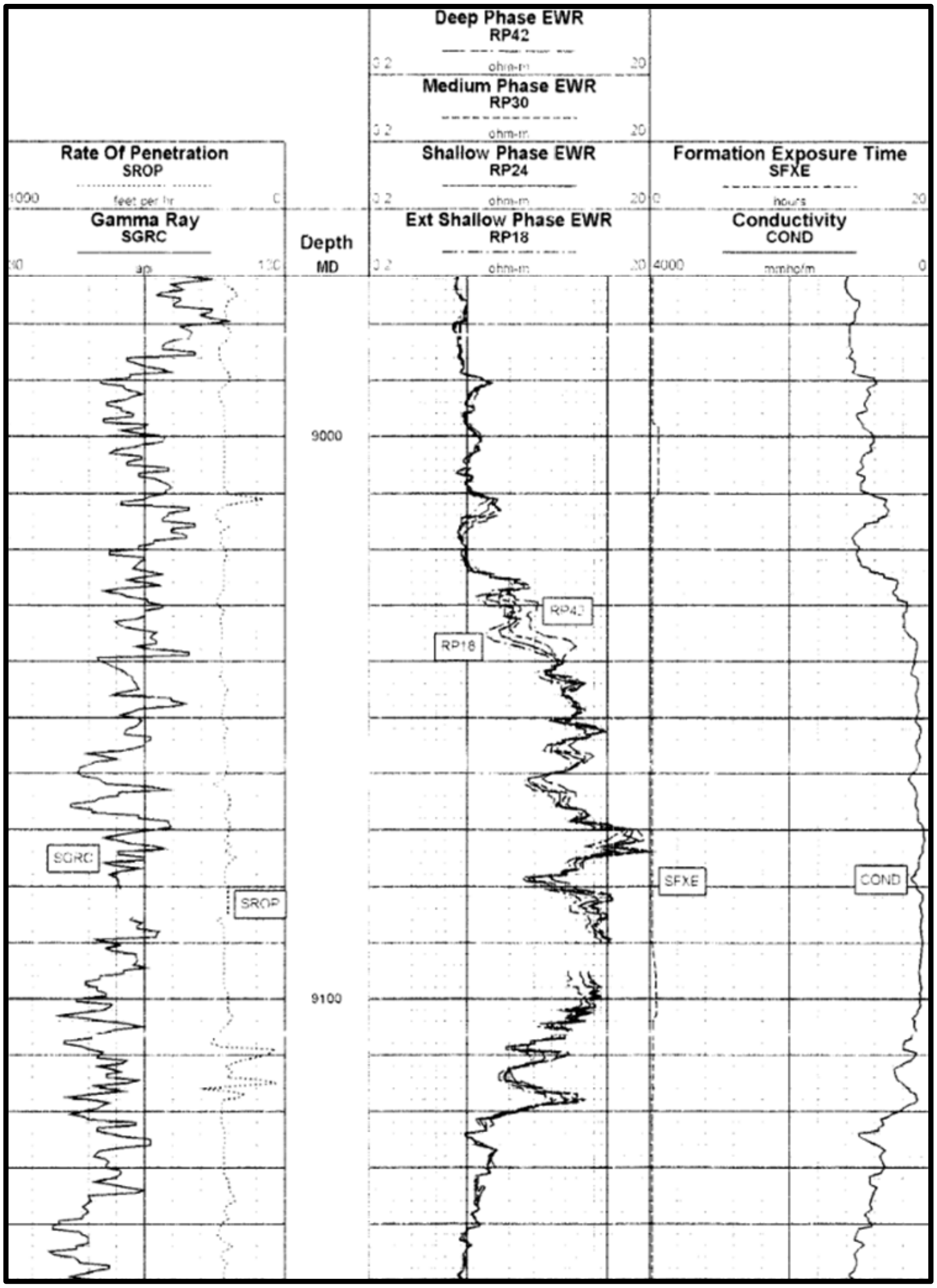

Figure 2: A section a log from AC 557-A (API# 6080540-01301). Interval 9024-9120 fbsl is a thick clay interval possibly containing gas hydrate. EWR in this interval is high (about 10 ohm*m) compared to background resistivity of 1 ohm*m.

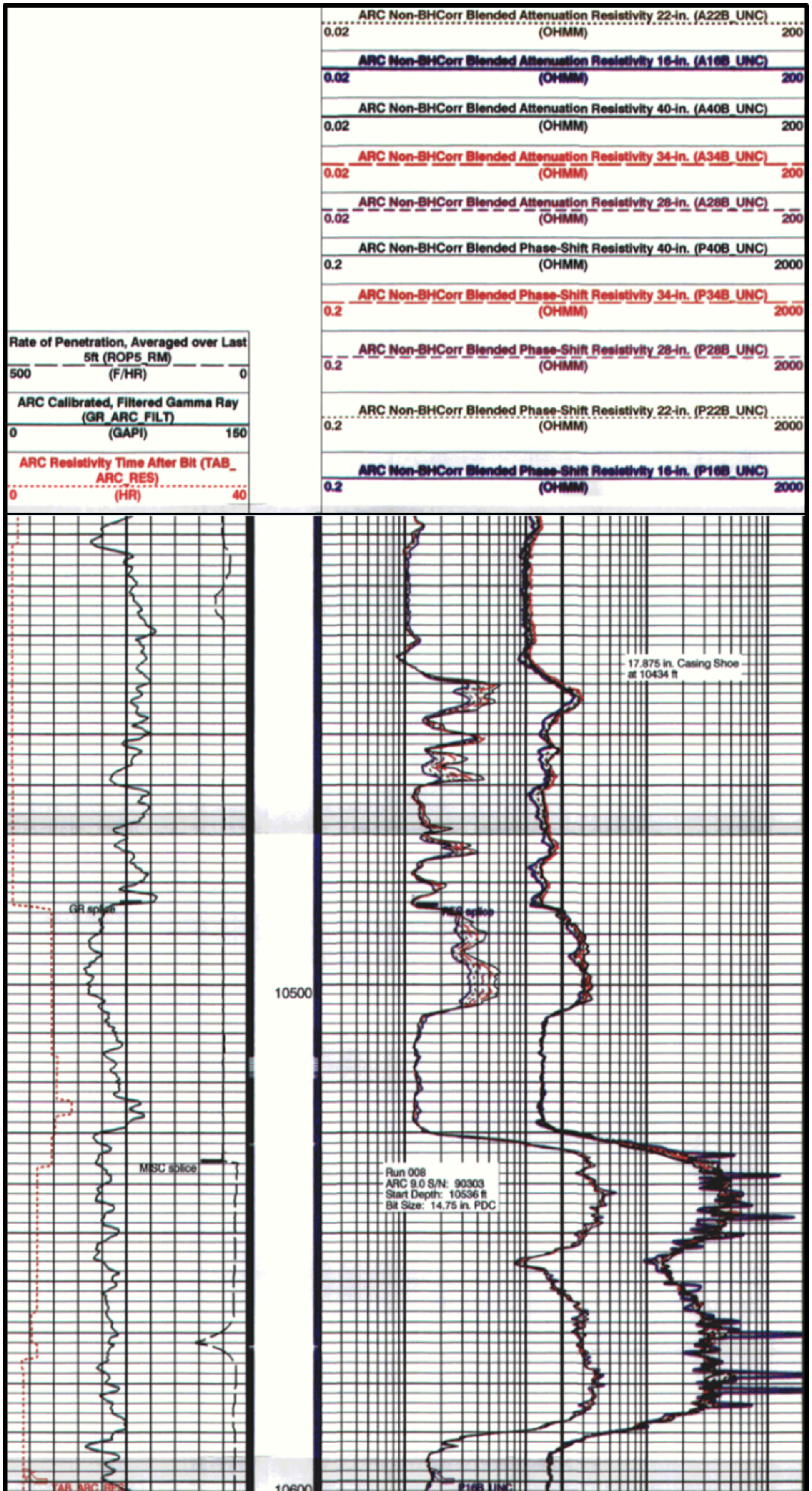

Figure 3: A section a log from AC 818 (API# 6080540-02500). Intervals 10436-10506 fbsl and 10530-10600 fbsl may be clay intervals containing gas hydrate. The phase shift resistivity is as high as 70 ohm*m in the second interval.

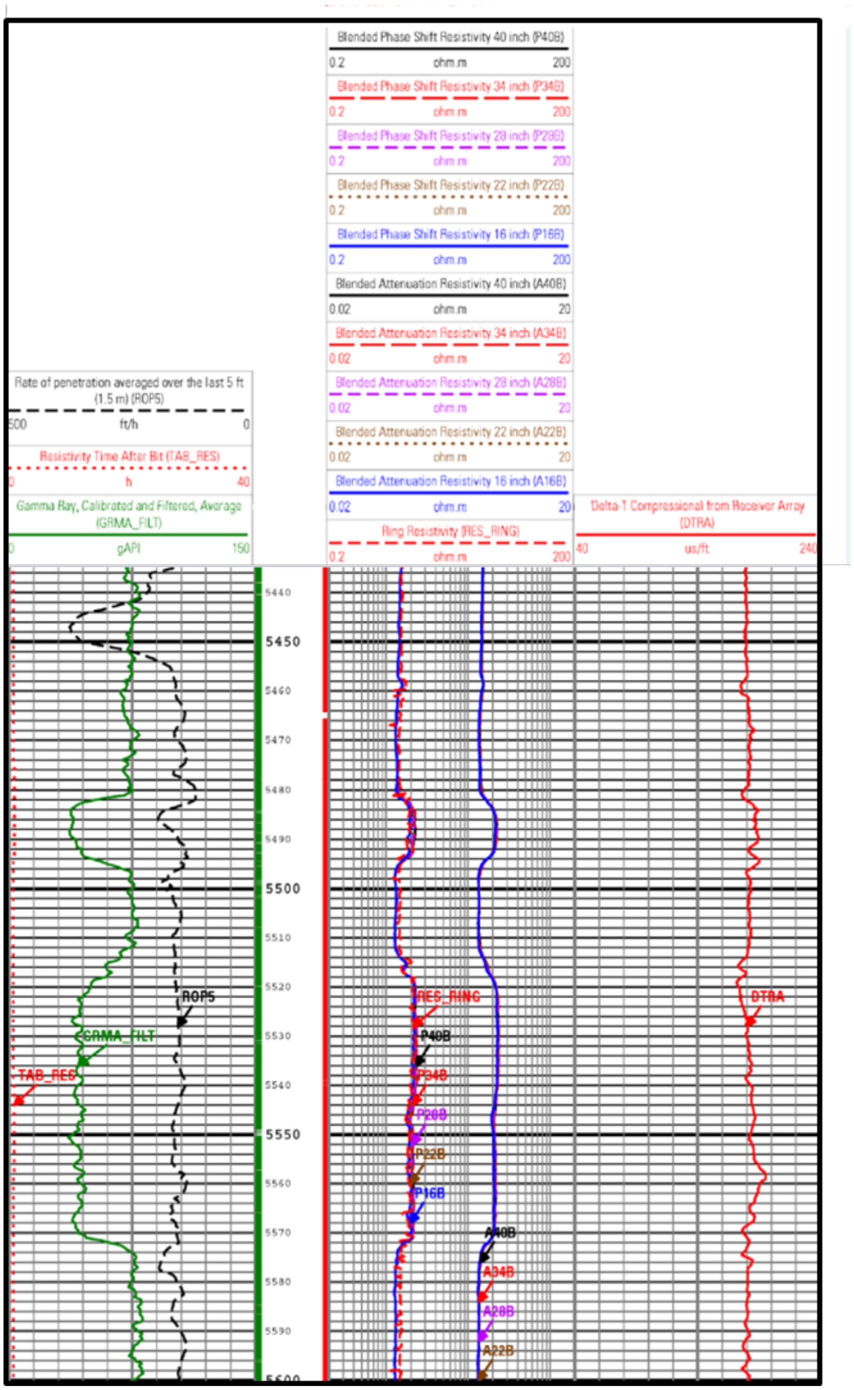

Figure 4: A section a log from well AC 21-A (API# 6080540-07000). Intervals 5482-5494 fbsl and 5520-5570 fbsl may contain gas hydrate. Phase shift resistivity in these intervals are about 2-2.5 ohm*m as opposed to background resistivity of 1-1.5 ohm*m. Almost no deviation is noted in the delta T compression log.