Project Title

Seismic Gas Hydrate Quantification by Cumulative Attributes (CATTs)

Quarterly Progress Report

DE-FC26-06NT42961

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Date: July 30, 2007

Progress Report

Award No. DE-FC26-06NT42961

Seismic Gas Hydrate Quantification by Cumulative Attributes (CATTs)

Reporting Period: April 1, 2007 to June 30, 2007

Reporting Date: July 30, 2007

Executive Summary

During this period, we have narrowed our data selection to the Milne Point area of Prudhoe Bay, Alaska. We feel this data set offers the best combination of known hydrate occurrence and high quality log and seismic data. This data was obtained from the USGS and comprises 17 wells and approximately 180 sq. miles of 3D seismic data (see Figure 1 below for location of field data area). All data has been examined and loaded into our various software applications for processing and analysis. Results of this analysis are described below.

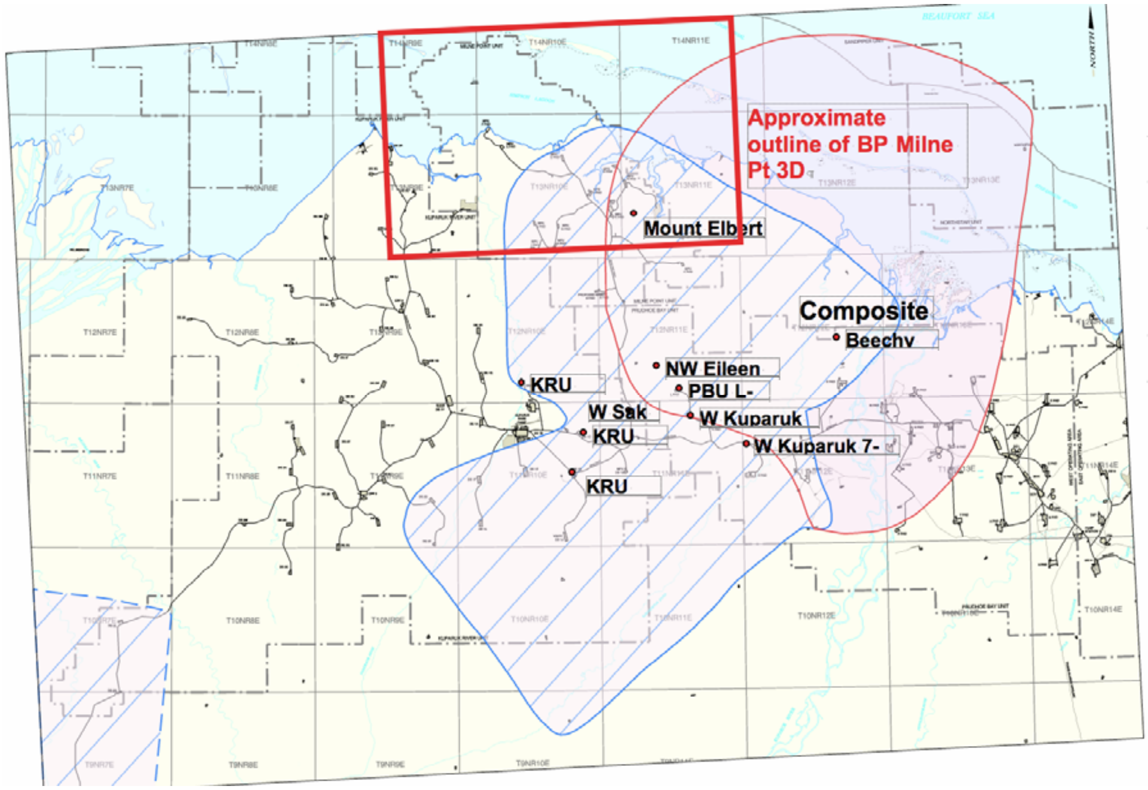

Figure 1: Field data is from Prudhoe Bay area of Alaska, in the Milne Point Unit operated by BP.

The seismic data quality for the Milne Pt area is acceptable to show in substantial detail the earth structure in the shallow subsurface where we expect to find hydrate accumulations (see Figure 2). Based on this and the similar acceptable quality of the well log data, we expect that our intended analysis methods will be successful.

One drawback in the well log data is the absence of density and neutron porosity curves in the shallow methane hydrate intervals. We will overcome this problem by reconstructing these needed curves from sonic and resistivity and by using rock physics theory.

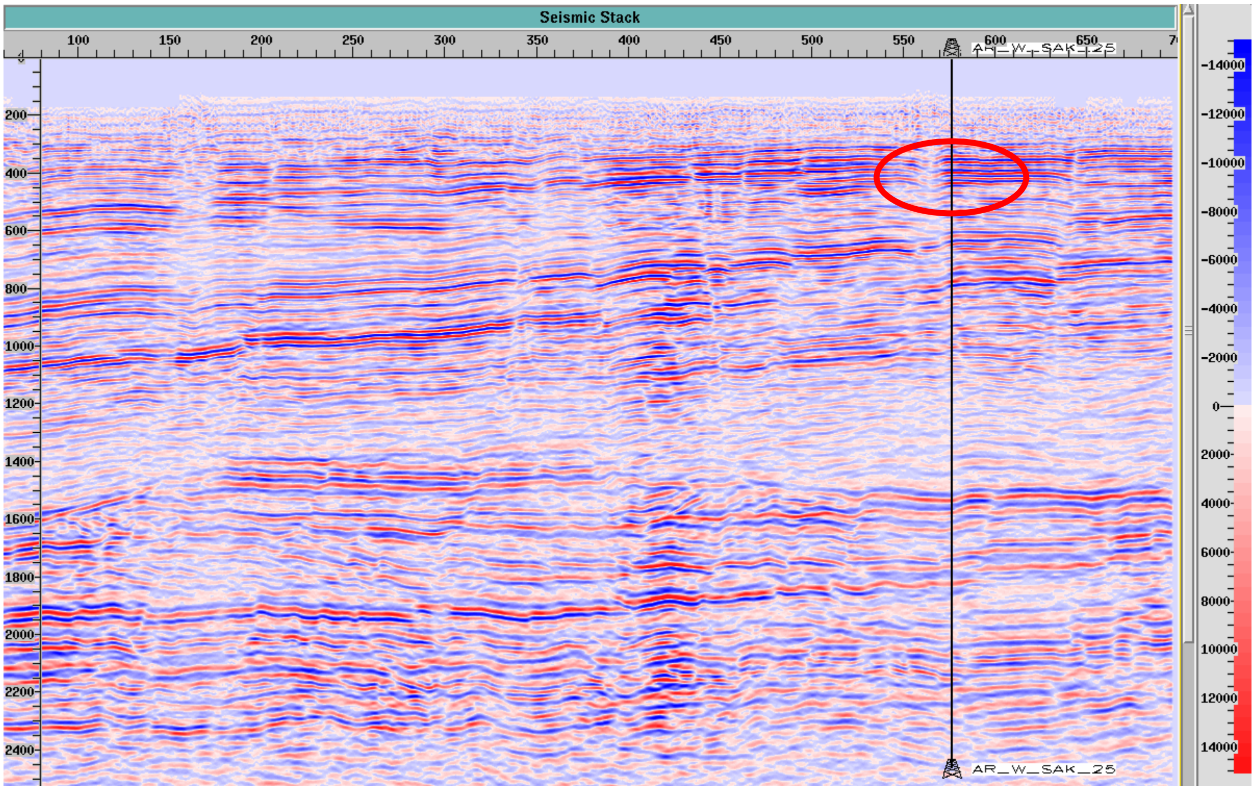

Figure 2: Inline # 561 through the AR-W-SAK25 well shows high quality seismic data and processing with good resolution in the hydrate stability zone (red oval).

Milestone Status Plan – progress was made toward analyzing and QC-ing the data; progress was made toward theoretical analysis that will serve as a basis for the proposed data treatment.

Actual or Anticipated Problems or Delays – none this period.

Technology Transfer – none this period.

Travel – none this period.

Results of Work This Period

Milne Point Well Data Analysis

Milne Point well dataset includes 15 wells. The logs have been delivered to RSI in disparate order: for the same well we often face a large number of curves sampled at different intervals. The original work on bringing this dataset to a manageable format form which the data could be exported into a spreadsheet, MATLAB, and iMOSS has been completed. We have also started a rock physics analysis of these data.

It appears that the intervals under investigation do contain substantial amounts of methane hydrate. Consider, for example, well AR-OLIKTOK-PT1 (Figure 1). The thick sand section above 0.5 km depth exhibits high (up to 4 km/s) *P*-wave velocity and high resistivity which are indicators of methane hydrate presence in the pore space of the host rock. Unfortunately, the density and neutron porosity curves are non-existent in the hydrate-filled section.

To estimate these important parameters, we will use rock physics models calibrated to the strata where all the required log curves are present. Figure 2 shows that such trends are present in the data.

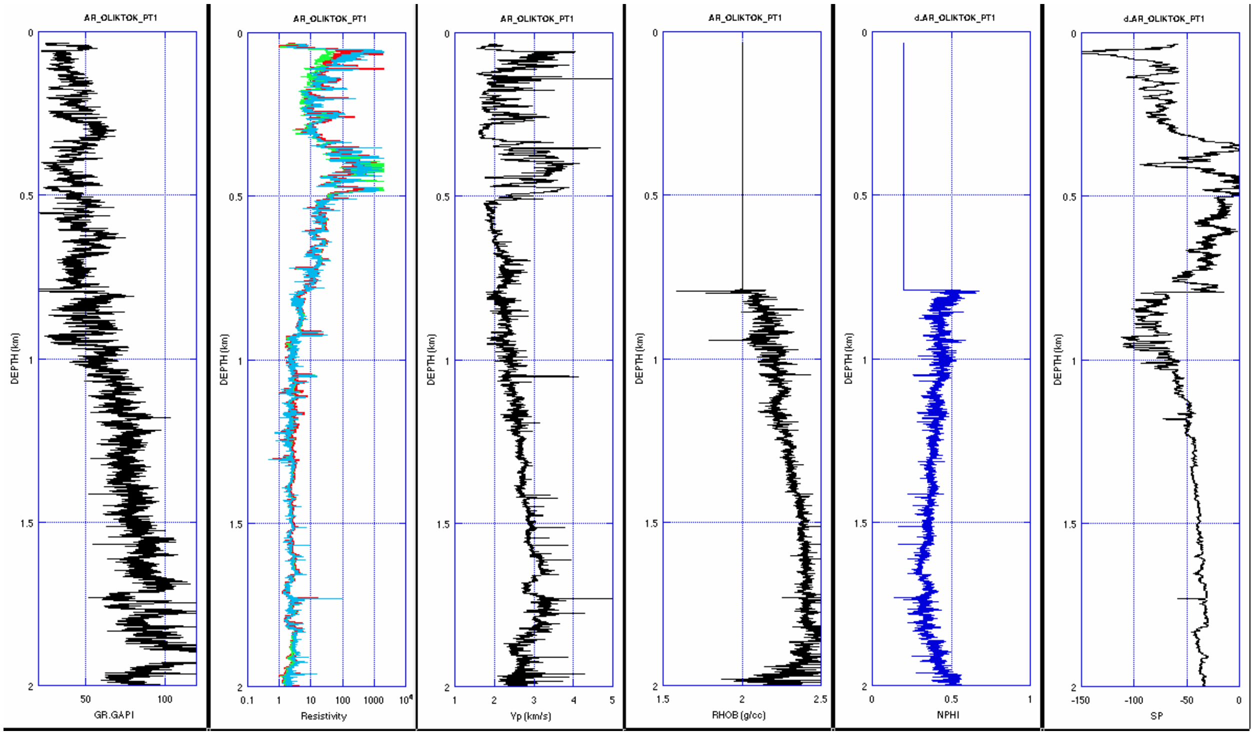

Figure 1. Milne Point well AR-OLIKTOK-PT1. From left to right: GR, resistivity, *P*-wave velocity, bulk density, neutron porosity, and spontaneous potential.

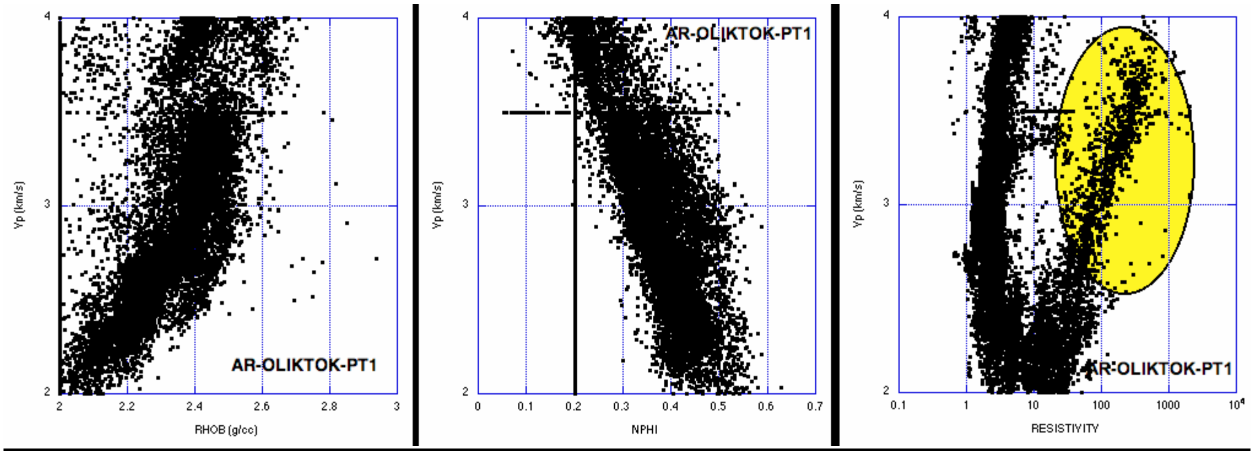

Figure 2. Milne Point well AR-OLIKTOK-PT1. From left to right: velocity versus bulk density, neutron porosity, and resistivity. The yellow ellipsis in the third frame highlights the hydrate sand interval.

Well CO-NW-MILNE1 exhibits a similar behavior (Figure 3). The hydrate interval here is thinner than in the first well which fits our purposes of forecasting hydrate reserves in seismic-subresolution intervals.

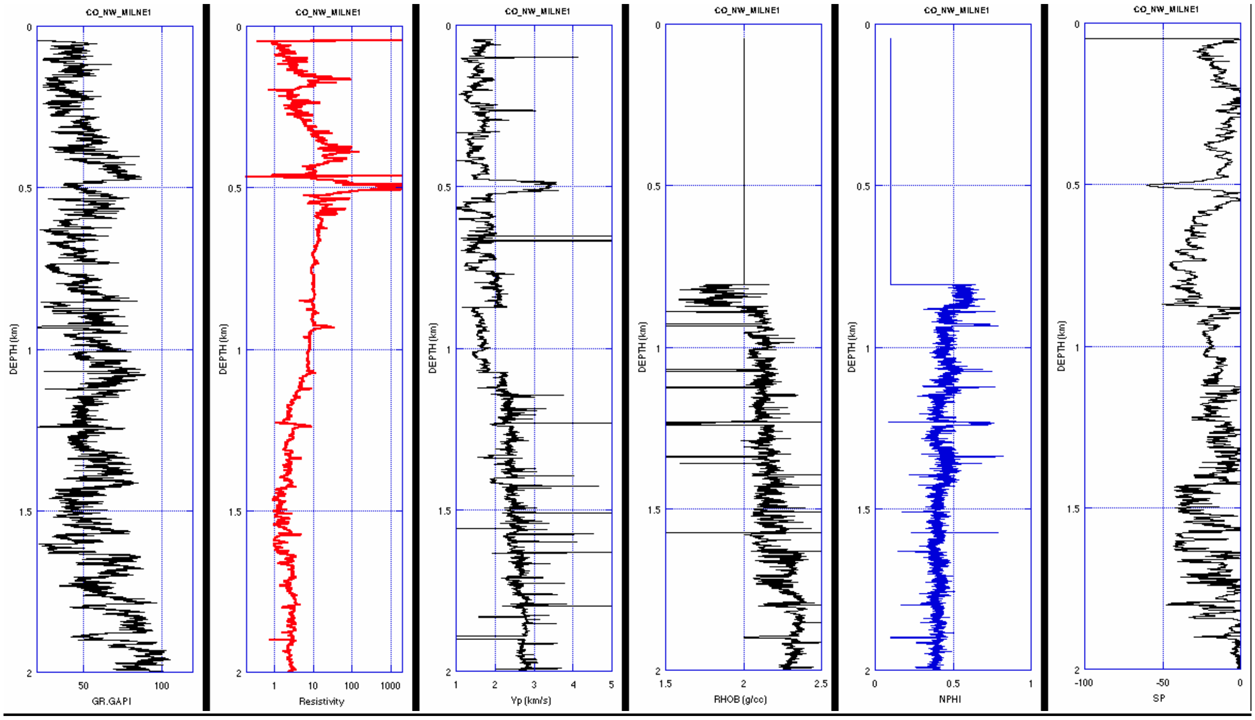

Figure 3. Milne Point well CO-NW-MILNE1. From left to right: GR, resistivity, *P*-wave velocity, bulk density, neutron porosity, and spontaneous potential.

Once again, the density data are absent in the interval of interest but rock physics trends do exist in the rest of the well which will be used to restore the missing parts of the required curves (Figure 4).

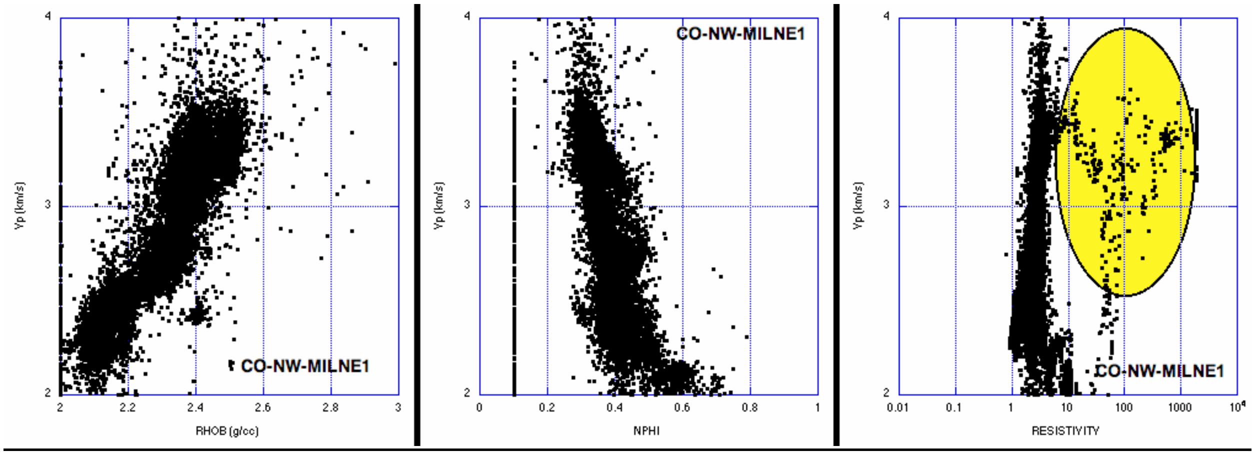

Figure 4. Milne Point well CO-NW-MILNE1. From left to right: velocity versus bulk density, neutron porosity, and resistivity. The yellow ellipsis in the third frame highlights the hydrate sand interval.

Theoretical Analysis

The main purpose of investigation during the reported period was the sensitivity of the *P*-wave impedance to the bulk properties of the methane hydrate reservoir, namely the hydrate saturation of the pore space, total porosity of the host rock, and clay content in the host rock.

This investigation has been carried out by means of forward modeling of the impedance with the inputs covering predefined ranges in these input parameters.

In Figure 5 we plot the input hydrate saturation versus the calculated impedance and color-code the graph by the total porosity. The clay content is fixed zero. The total-porosity range in the left-hand frame is from 0.35 to 0.4. We observe that within this porosity range, the estimate of hydrate saturation from impedance has small uncertainty, especially at high hydrate saturation. For example, impedance 6 km/s g/cc may correspond to hydrate saturation between 0.65 and 0.75.

The total-porosity range in the middle frame is from 0.30 to 0.35. The uncertainty of the hydrate saturation estimate in this range is also small. For example, impedance 6 km/s g/cc may correspond to hydrate saturation between 0.50 and 0.60.

However, if we input the entire porosity range from 0.30 to 0.40 (the right-hand frame), the uncertainty increases. For example, impedance 6 km/s g/cc may now correspond to hydrate saturation between 0.50 and 0.70.

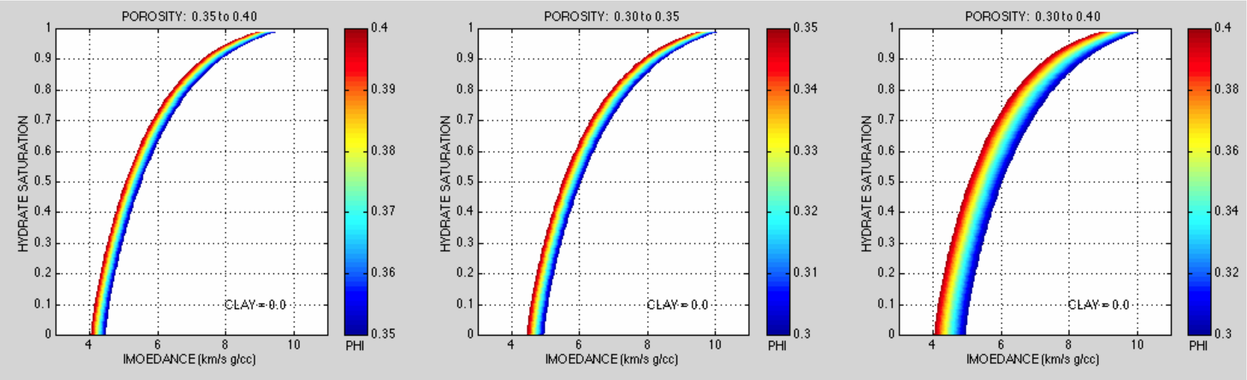

Figure 5. Hydrate saturation versus impedance at fixed clay content zero color-coded by the total porosity of the host sediment. The porosity range used in this modeling is shown in the title above each frame.

This accuracy of hydrate saturation estimate remains essentially the same if we use clay content 0.3 instead of zero as in the first example. For example, at clay content 0.3, impedance

6 km/s g/cc for porosity range between 0.35 and 0.4 may correspond to hydrate saturation between 0.70 and 0.80 (Figure 6, left-hand frame). At the same impedance and in porosity range between 0.30 and 0.35, the hydrate saturation is between 0.60 and 0.70 (Figure 6, middle frame). Finally, at the same impedance and in porosity range between 0.30 and 0.40, the hydrate saturation is between 0.60 and 0.80.

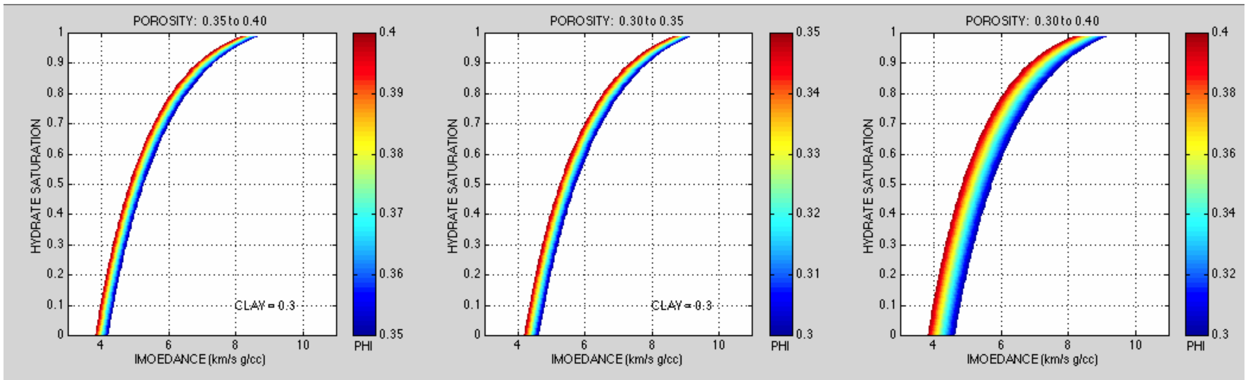

Figure 6. Same as Figure 1 but with clay content 0.30.

A natural question is how we can reduce this uncertainty. It can possibly be reduced if we know (or can assume) depositional reasons for porosity variation within the sediment volume under investigation. For example, one of such reasons is shale variation in the sand. The more shale the less the total porosity.

This porosity reduction mechanism may work to our advantage in reducing the uncertainty because the clay content and porosity have opposite effects on the impedance: the smaller the porosity at fixed clay content and hydrate saturation the higher the impedance and, conversely, the higher the clay content at fixed porosity the smaller the impedance. This effect is illustrated in Figure 7 where we (a) calculate the impedance versus hydrate saturation in the porosity range between 0.35 and 0.40 and fixed clay content zero and (b) calculate the impedance versus hydrate saturation in the porosity range between 0.30 and 0.35 and fixed clay content 0.3.

We observe when we combine (a) and (b) that the uncertainty of hydrate saturation estimate from impedance improves. For example (Figure 7, right-hand frame) that at impedance 6 km/s g/cc, the hydrate saturation range is from 0.70 to 0.80 which is only 0.10 saturation uncertainty range instead of from the 0.20 uncertainty range as observed in Figure 5 and 6.

Finally, it is important to remember that in order to estimate reserves in a methane hydrate reservoir, we have to know both the porosity and hydrate saturation. The value that is needed is, in fact, the product of porosity and hydrate saturation which we call *hydrate concentration*. The question is then whether we can estimate hydrate concentration from impedance.

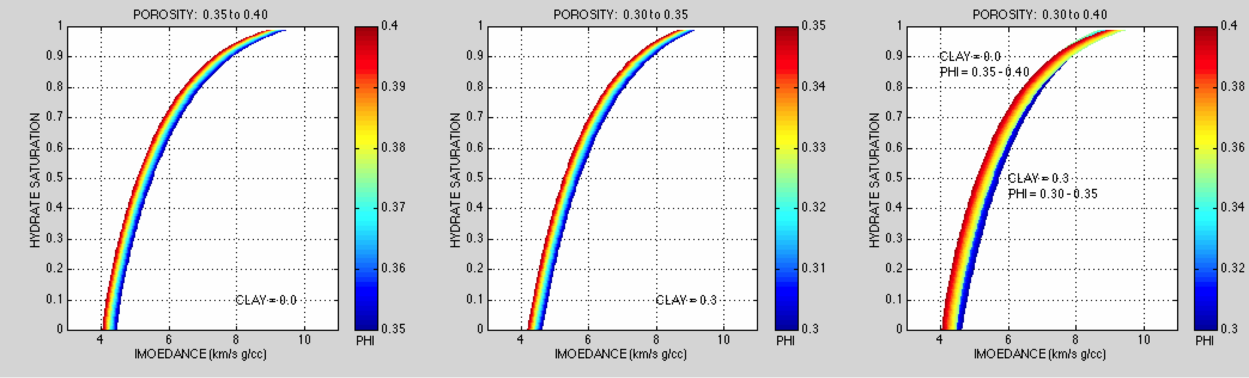

Figure 7. Same as Figure 5 and 6 but with clay content and porosity varying simultaneously, as marked on the plots.

Finally, it is important to remember that in order to estimate reserves in a methane hydrate reservoir, we have to know both the porosity and hydrate saturation. The value that is needed is, in fact, the product of porosity and hydrate saturation which we call *hydrate concentration*. The question is then whether we can estimate hydrate concentration from impedance.

Unfortunately, the uncertainty of this estimate is greater than that of hydrate saturation. Figure 8 is equivalent to Figure 7 barred the fact that the vertical axis now is the product of the total porosity and hydrate saturation, i.e., hydrate concentration.

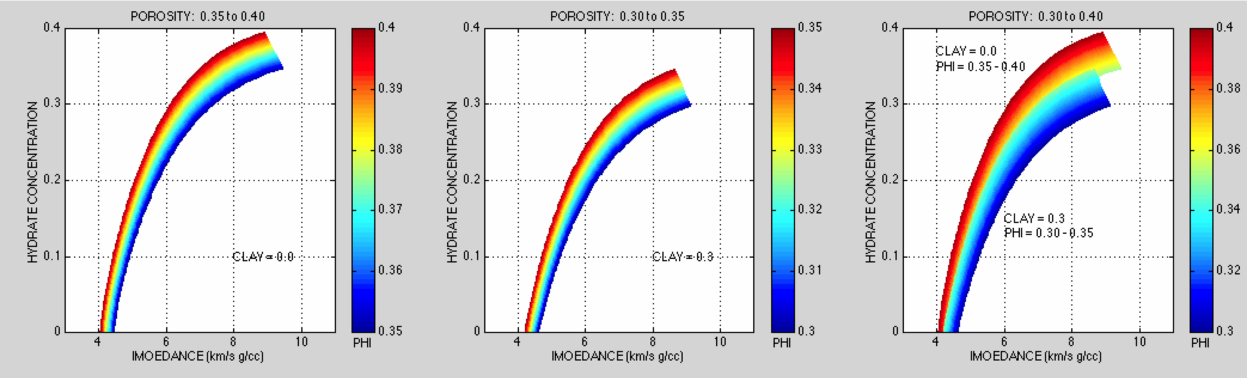

Figure 8. Same as Figure 3 but with hydrate concentration as vertical axis instead of hydrate saturation.

Cost Plan/Status

	Year 1 Start: October 31, 2006 End:September 30, 2007				Year 2 Start: October 31, 2007 End: September 30, 2008			
Baseline Reporting Quarter	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	**Q8**
Basline Cost Plan **(from SF-424A)**								
Federal Share	67,025	104,467	92,976	84,619	217,987	221,019	84,423	86,364
Non-Federal Share	16,756	26,117	23,244	21,155	54,497	55,255	21,106	21,591
Total Planned	83,781	130,584	116,220	105,774	272,484	276,274	105,529	107,955
(Federal and non-Federal) Cumulative Baseline Cost	83,781	214,365	330,585	436,359	708,843	985,117	1,090,646	1,198,601
Actual Incurred Costs								
Federal Share	67,615	91,180	95,238					
Non-Federal Share	16,904	22,795	23,810					
Total Incurred Costs - Quarterly	84,518	113,974	119,048	-	-	-	-	-
(Federal and non-Federal) Cumulative Incurred Costs	84,518	198,493	317,540					
Variance								
Federal Share	(590)	13,288	(2,262)					
Non-Federal Share	(148)	3,322	(566)					
Total Variance-Quarterly	(737)	16,610	(2,828)					
(Federal and non-Federal) Cumulative Variance	(737)	15,872	13,045					

Disclaimer

"This report was prepared with support of the U.S. Department of Energy under Award No. DE-FC26-06NT42961. However any opinions, findings, conclusions, or recommendations expressed herein are those of the authors and do not necessarily reflect the views of the DOE."

Milestone Plan/Status Report

6/30/2007

Task/Subtask #	Critical Path Project Milestone Description*	Project Duration - Start: October 1, 2006 End: September 30, 2008								Planned Start Date	Planned End Date	Actual Start Date	Actual End Date	Comments (notes explanation of deviation from baseline plan)
		Project Year (PY) 1				Project Year (PY) 2								
		Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8					
#3 Data Select	Find suitable field data		X	X						1/1/2007	6/30/2007	1/1/2007	6/30/2007	completed
#4 Design	Demonstrate CATT method			X	X	X				3/1/2007	9/31/07	3/1/2007		on Schedule
# 5 Upscaling														
#6 Calibration														

*No Fewer than two (2) milestones shall be identified per calendar year