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Effects of Increased Sample Rate on Open Hole Well Logs: Implications for Accurately Determining Reservoir Parameters Using Conventional Well Log Data

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Summary

The determination of reservoir parameters in heterogeneous environments using conventional well log data is subject to substantial errors in log data values, and estimated bed thickness. This paper shows that conventional well logs can provide more accurate petrophysical data in reservoirs and thin beds, provided that the sample rate of the log data is increased beyond what is currently used to obtain normal main pass or high resolution logs.

Introduction

The Oil and Gas Industry relies on Open Hole Log data to provide a representation of the rock properties in order to determine reservoir properties and reserves determinations. The sample rate (number of data points per foot/meter) that has been used by the logging industry to provide this information has traditionally been 2 samples per foot, or 7 samples per meter. This has been sufficient in thick, homogenous formations that have been the target of conventional oil and gas exploration in the past, however as the easy targets get harder to find, the focus of conventional oil and gas exploration has been increasingly directed to thinner targets where standard well log data has not been entirely effective in determining reservoir parameters such as Bulk Density and bed boundaries and thicknesses.

High Resolution Logging has also been utilised by the logging industry to provide better log data resolution in interbedded or thin bed environments where normal logging sample rates proved to be ineffective in accurately determining Reservoir Parameters. The sample rate of High Resolution Well Logs varies from 28 – 40 samples meter (approximately 4 to 5 times greater than the typical sample rate of 'Main Pass' logs.

It has been industry convention that standard well logging tools are not capable of accurately resolving reservoir properties in heterogeneous environments, and that the industry would have to rely on Core and/or Image Logs if a better understanding of the reservoir was desired. It is the purpose of this paper to show that conventional well logs can be used to provide accurate Bulk Density and Bed Thicknesses for thin beds, provided that the sample rate of the log data is increased beyond what is considered normal for Main Pass or High Resolution Sample rates.

Theory and/or Method

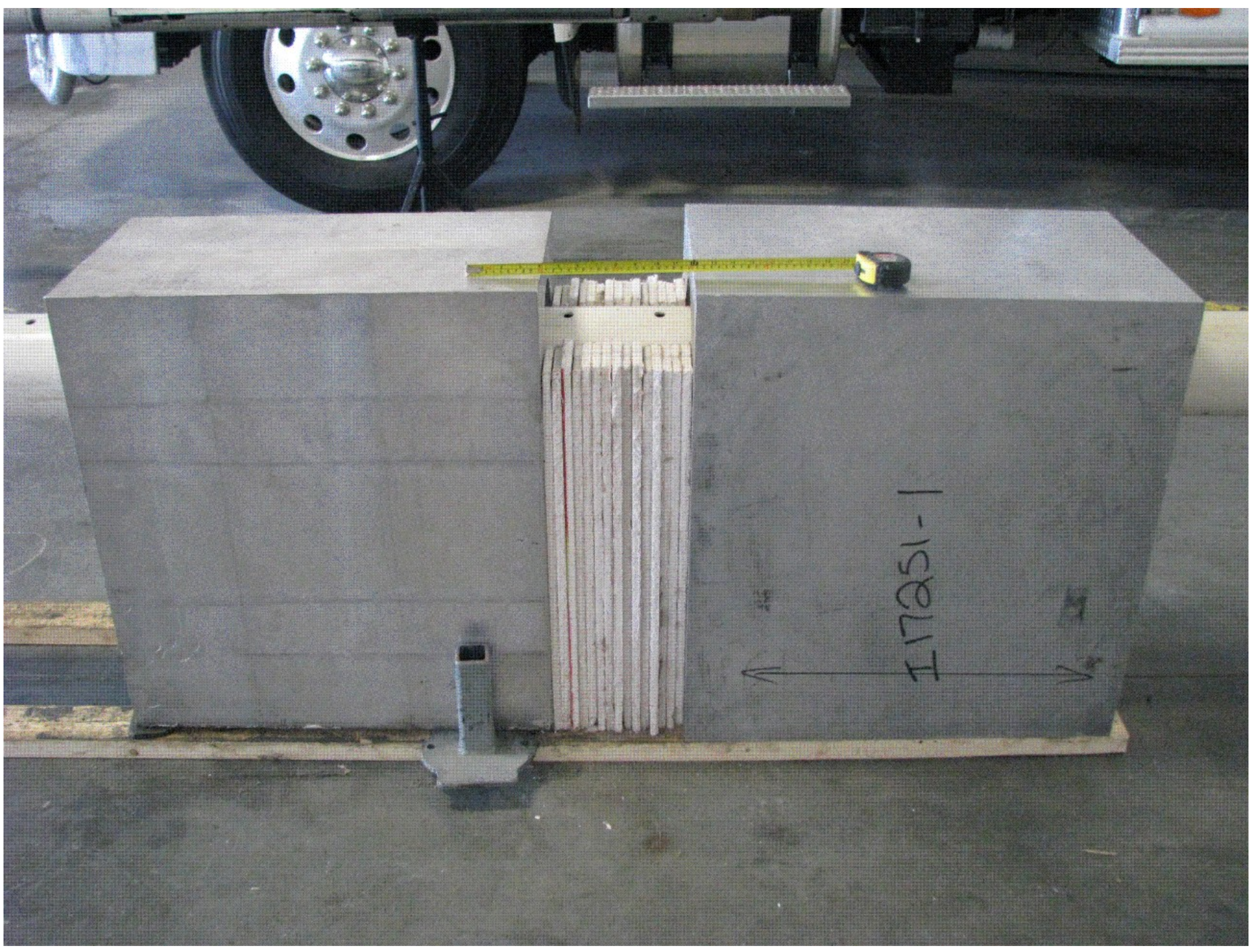
It has been shown that, when correlated to core, standard open hole well logs sampled at 132 samples per meter (40 samples per foot) are able to resolve thin beds of less than 25 cm (10 in.) (Seifert, Boutette, & Sloan, 2006). In order to quantify the accuracy of different sample rates in resolving the physical properties of thin beds, it was proposed that an experiment be conducted using materials of known physical properties in a controlled environment.

Aluminum and magnesium calibration blocks with ½" thick pieces of gyprock (drywall, plasterboard, or sheet rock) between the blocks were used to simulate thin bed deposition. Several logging passes were made to determine the ability of the logging tools to accurately identify the individual bulk density and thickness of the "beds". Sample rates of 4, 10, 20, and 40 samples per foot were run and recorded.

The thickness of the gyprock "bed" was increased from 0" – 17", in ½" increments, to ascertain the minimum thickness that could be resolved by the logging tools at different sample rates. In all cases a fixed logging speed of 16 feet/minute was utilized to ensure consistent results.

The results of the experiment show the data collected at 40 samples per foot was able to accurately determine the bulk density of the aluminum and magnesium blocks, as well as differentiate a 1½" gyprock bed between the two blocks. Accurate bulk density values for the gyprock were able to be resolved at a minimum thickness of 10" at a rate of 40 samples per foot.

Standard main pass well log data was not able to resolve the gyprock bed at any thickness, and did not properly identify the thickness or Bulk Density value of either calibration block.



Picture 1: Calibration Blocks (Magnesium on Left) with ~190 mm Gyprock.

Properties of 'Formations' used in Experiment

Material	Thickness	Bulk Density	PE
Aluminum	**660 mm.**	**2,529 kg/m3**	**2.56**
Magnesium	**670 mm.**	**1,738 kg/m3**	
Gypsum (Wallboard)	**0 – 422 mm**	**900 kg/m3*****	

***** The bulk density of the gyprock was determined by weighing a single 4' X 8' x ½" sheet of gyprock and calculating the bulk density from this. The Bulk Density of pure Gypsum is 2,360 kg/m3.**

Examples

Based on the observations from well log data when correlated to core, it is shown that an increased sample rate does have a direct relation to the accuracy of the Bulk Density data and the ability to determine more precise bed thickness and boundary identification. The purpose of this talk is to show the extent to which increased sample rates can provide useful information in identifying and delineating thin beds

The thickness of each bed or interval (Aluminum, Magnesium, and Gyprock) was measured at the inflection point of the Rho-B curve and the Bulk Density of each 'bed' was determined from the average Rho-B value between the inflection points.

The example shown below has a 38 mm (1½ ") gyprock bed between the two calibration blocks, and is the thinnest interval where the density tool responded to the presence of the gyprock .

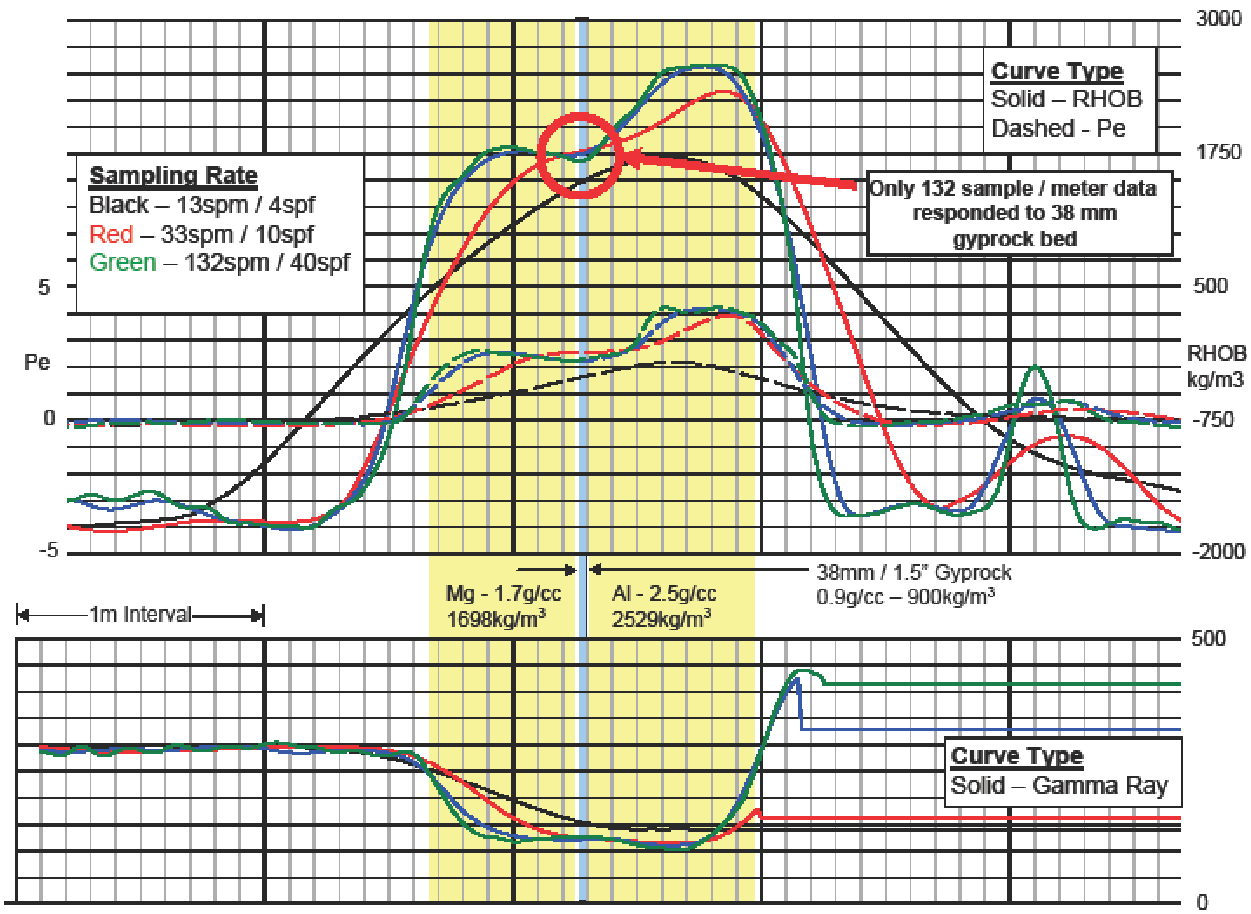


Figure 1: 38 mm Gyprock bed. Note response of 132 sample/m curve (green), this is the thinnest bed that the 132 sample/m data was able to resolve

	ACTUAL		13 Samples/meter				33 Samples/meter				132 Samples/meter			
			Thickness		Rho-B		Thickness		Rho-B		Thickness		Rho-B	
	Thickness (mm)	Rho-B (Kg/m3)	MM	% Error	Kg/m3	% Error	MM	% Error	Kg/m3	% Error	MM	% Error	Kg/m3	% Error
ALUMINUM	660	2,529	--	N/A	--	N/A	1,087	65	1,840	-27	815	21	2,179	-14
GYPROCK	38	900	--	N/A	--	N/A	--	N/A	--	N/A	181	376	1,713	-32
MAGNESIUM	670	1,738	--	N/A	--	N/A	513	-23	1,294	-26	529	-21	1,527	-12
TOTAL	**1,368**	**2096*** **	**1,700**	**24**	**1,256**	**-40**	**1,600**	**17**	**1,665**	**-21**	**1,525**	**11**	**1,908**	**-9**

***** WEIGHTED AVERAGE**

Table 1: 38 mm Gyprock bed. Tabular data from LAS file showing actual and apparent bed thicknesses and Rho-B for the test apparatus.

The actual and apparent bed thicknesses and Bulk Density are shown in tabular form and demonstrate the ability of the different sample rates at indentifying the 'reservoir properties' of the test materials.

Conclusions

It is obvious that the higher the sample rate, the more accurate the well logs will be. What was unforeseen is the amount of error observed on the main pass log data, especially when it is noted that the smallest sample rate used in this experiment is roughly double that of the industry standard main pass sample rate.

In order to obtain accurate reservoir properties and provide meaningful reserves estimates it is important to capture well log data at the highest sample rate possible. Not doing so may cause errors in the estimation of net pay thickness, missed thin bed responses that may be important to properly delineating and completing zones of interest, inaccurate Density (porosity) measurements; culminating in Reserves Estimates that may not accurately reflect the actual potential of the reserves at hand.

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References

Seifert, Boutette, & Sloan, 2006, Integration of Core and Ultra High Resolution Well Log Data to identify thin beds and bed boundaries: Implications for non-conventional reservoirs: CSPG-CSEG-CWLS 2006 JOINT CONVENTION