IMPACT: International Journal of Research in Applied, Natural and Social Sciences (IMPACT: IJRANSS)
ISSN(E): 2321-8851; ISSN(P): 2347-4580
Vol. 2, Issue 9, Sep 2014, 79-84

WELL LOG CORRELATION OF THREE VERTICAL WELLS IN THE NIGER DELTA

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ABSTRACT

This study presents correlation analysis of three wells in X-field in the Niger Delta, using three well logs namely Spontaneous Potential (SP), gamma ray (GR) and deep induction log (ILD). Two basic steps were followed in the correlation analysis. These steps are sand and shale correlation in the borehole. The sand and shales were first differentiated by the GR based on the relative occurrence of radioactivity in sand and shale. SP log differentiates permeable and impermeable beds based on differences in mud filtrate in the borehole and formation water. Three major sands were correlated. These sands are sand 1, sand 2 and sand 3 at 4800ft (1463m), 4950ft (1509m) and 5150ft (1570m) respectively at measured depths in all the wells. Sand 1, 4800 sand is in the same position in all the Wells. In Well A-2, radioactive sand was identified at 5000ft measured depth. This is equivalent to 4950ft sand in Wells A-1 and A-3. The shale correlation was done using Deep Induction Log (ILD). Three Shale Resistivity markers (SRM) were identified in the wells. These are SRM1, SRM 2 and SRM 3.

KEYWORDS: Spontaneous Potential, Gamma ray, Induction, Resistivity, Shale, Sand

INTRODUCTION

The Niger Delta is located on the Gulf of Guinea, between longitudes 5^0 E to 8^0 E and latitudes 3^0 N to 5^0 N. It is a mature petroleum province, Figure 1.

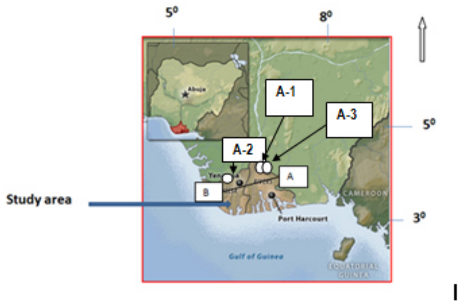

Figure 1: Location Map of Niger Delta, Nigeria (After Internet, 2013)

The structural style of Niger Delta is detached normal fault assemblages (growth faults). In this type of environment, it might be very difficult to map subsurface units and structures, Harding and Lowell, (1979). Correlation can be defined as the determination of structural or stratigraphic units that are equivalent in time, age, or stratigraphic position, Tearpock and Bischke, (1991). Correlation is very important for the purpose of preparing subsurface maps and cross sections. The two general sources of correlation data are electric wireline log and seismic sections. Fundamentally, electric well log curves are used to delineate the boundaries of subsurface units for the preparation of a variety of subsurface maps and cross sections. The subsurface units to be delineated and correlated in this study are the sands and shale units based on the principles of well logs.

The purpose of this paper is to use correlation guide lines to correlate two vertical wells in the Niger Delta.

GEOLOGIC SETTING OF THE NIGER DELTA

The Niger Delta consists of Tertiary deposits. It is underlain by continental crust (onshore) and oceanic crust (offshore), Figure 2.

There are three rock sequences in the Niger Delta in the ascending order, the Akata, Agbada and Benin Formations, Figure 2. The Akata Formation consists of a continuous shale section, high gamma ray on gamma ray (GR) log. The Agbada Formation consists of sands and shales intercalation and on the GR log, it is recognized by high GR values (shale beds) and low GR values (sand beds). The Benin Formation consists of a continuous sand sections and it is recognized on GR curve by continuous low GR values. The structural units are growth faults, synthetic and antithetic faults and rollover anticlines.

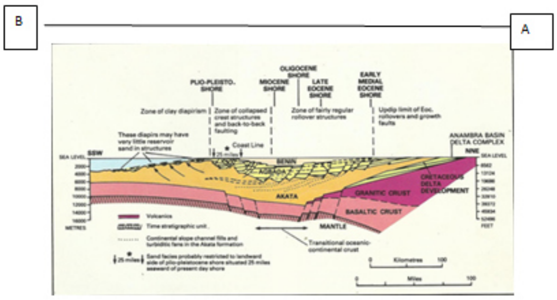

Figure 2: Cross Section of the Niger Delta, (Ablewhite 1986)

DATA DESCRIPTION

The data provided consist of three vertical wells A-2, A-1 and A-3 (Figure 3) located onshore, Niger delta, (Figure 1). The distance apart of Well A-2 from Well A-1 is 5664ft (1726m) and Well A-1 from Well A-3 is 2527ft (770m), Figure 3. The vertical scale is 1in (0.3ft) to 10ft (3m). GR and SP logs are located on the First panel of the wells. The Deep Induction Log (ILD) is located in the second panel of each well.

The GR log is calibrated in API unit, the SP and ILD logs are calibrated in millivolts and ohms meter (Ωm) respectively. The scales of GR and SP are linear while ILD is graduated in decades of resistivity. Two well tops present are aa-1.3 and AA-1.6.

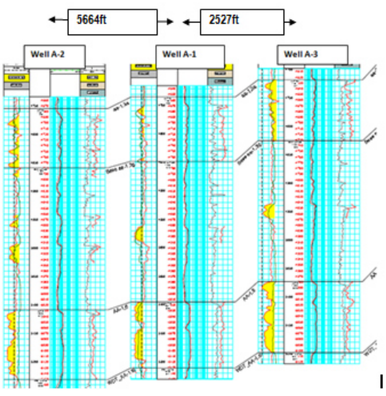

Figure 3: Wells A-2, A-1 and A-3 Un-Interpreted Log Segments

Methodology and Principles of Well Log Analysis

Three steps were used in the correlation analysis. The first step is lithologic analysis to differentiate sand and shale. The second step is sand correlation and the third step is shale correlation.

Lithology Analysis

The lithology logs are the Spontaneous Potential (SP) and Gamma ray (GR) logs, Figure 4.

SP Log

The SP log differentiates between permeable and impermeable beds based on the relationships between mud filtrate and formation water. SP curve calibrated in millivolt is a recording of the natural potential diffence between a point in the borehole and the surface, Rider, (2002). The salinity of the Formation water is greater than that of mud filtrate. This causes the potential opposite the premeable sand bed to be negative with respect to the potential opposite the shale bed. The SP curve (panel 1) is green coloured. The permeable beds are indicated in yellow colouration, Figure 4.

GR Log

The GR log differentiates between sand and shale sequences based on the relative presence of radioative materials. Generally, the shales has more concentration of radioactive material than sands. The GR curve calibrated in API is a measure of the Formations natural radioactivity. Sandstone is on the whole, less radioactive than shale. This causes the GR readings to be lower in sand than in shale. The GR curve differentiates between sands and shales. The GR curve is red colour in track 1 in Figure 4.

RESULTS

Sand Analysis and Correlation

Sand 1

The results show that at Well A-2, the sand 1 is located between depths 4795-4689ft (true vertical depth subsea (TVDSS)) (106ft, 32m thick). The GR curve is low and SP curve is negative deflection. This sand is nicknamed 4800 sand because it occurred at this depth, measured depth (MD) in Well A-2. At Well A-1, the sand is located between depths 4770ft-4670ft TVDSS (100ft, 30m thick). This sand is also nicknamed 4800 sand because it occurred at this depth, measured depth (MD) in Well A-1. In Well A-3, the same sand is located between 4735ft-4625ft TVDSS (110ft, 34m) thick. Sand 1 is thickest in Well A-3 (Table 1). Figure 4 shows sand 1 correlation line.

Table 1: Sand Analysis of Wells A-2, A-1 and A-3

	Well A-2				Well A-1				Well A-3			
	Top (ft)	Base (ft)	Thick (ft)	Thick (m)	Top (ft)	Base (ft)	Thick (ft)	Thick (m)	Top (ft)	Base (ft)	Thick (ft)	Thick (m)
Sand 1@MD 4800	4689	4795	106	32	4670	4770	100	30	4625	4735	110	34
Sand 2*@MD 4950	4860	4885	25	8	4880	4910	30	9	4845	4870	25	8
Sand 2@MD 5000	4910	4945	35	11	-	-	-		-	-	-	
Sand 3@ 5150	5030	5145	115	35	5015	5120	105	32	4982	6108	1126	342

Sand 2

At Well A-2, sand 2 is located between depths 4945ft-4910ft TVDSS (35ft, 11m thick), Table 1. The GR curve is low and SP curve is negative deflection. This sand is nicknamed 5000 sand because it occurred at this depth, measured depth (MD) in Well A-2. A variety of this sand (Sand 2* occurs at 4950ft, 1509m (MD). This sand is between 4885ft -4860ft TVDSS (25ft, 8m thick). It has low GR curve and positive SP deflection. It is suspected that Sand 2* in A-2 is a fake sand. It is radioactive (red). It is treated as shale and it is part of shale resistivity marker (SRM 2) of Well A-2 in Figure 5, Table 2. At Well A-1, Sand 2 is located between 4910ft-4880ft (30ft, 9m thick). This sand occurs at 4950 ft, 1509m measured depth (MD) in well A-1. At Well A-3, Sand 2 is located between 4870ft-4845ft (25ft, 8m thick). The sand occurs at 4950ft (MD). Sand thickness decreases from Well A-2 to Well A-3. The 5000ft sand of Well A-2 is equivalent to the 4950 sands of Wells A-1 and A-3.

Sand 3

This sand occurs in all the wells at 5150ft, 1570m (MD). At Well A-2 and Well A-1, Sand 3 ranges in depth between 5145ft-5030ft (115ft, 35m) and 5120ft-5015ft (105ft) TVDSS respectively. At Well A-3 Sand 3 occurs at (6108ft-4982ft (1126ft, 342m) TVDSS. Sand 3 is thickest in Well A-3.

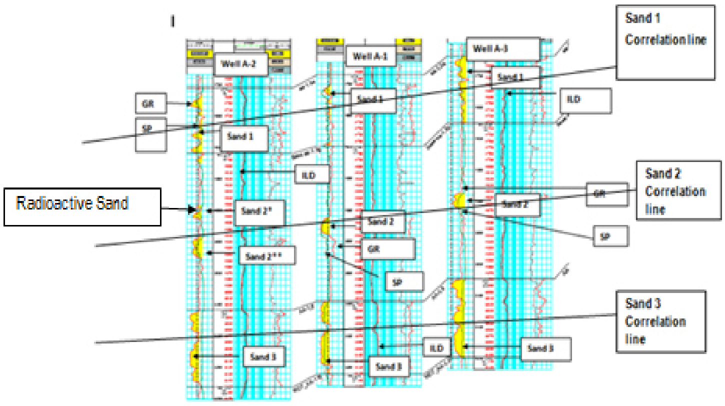

Figure 4: Sand Analysis and Sand Correlation

Shale Correlation

The analysis is carried out using Deep Induction Log (ILD). There are three shale resistivity markers in Wells A-2, A-1 and A-3, Figure 5, Table 2. In Well A-2, Shale Resistivity Marker (SRM-1) is at depth 4860-4795ft true vertical depth subsea (TVDSS) (65ft thick). It is equivalent to SRM-1 of Wells A-1 and A-3 at 4840-4770ft TVDSS (70ft thick) and 4800-4735ft TVDSS (65ft) respectively. This means that Shale is thickest in Well A-1 and equivalent in Wells A-2 and A-3.

In wells A-2 and A-1, SRM-2 are at depths 4910-4860ft TVDSS (65ft thick) and 4880-4840ft TVDSS (40ft thick) respectively, while SRM-2 in Well A-3 is at depth 4845-4800ft TVDSS (65ft). Shale is thickest in Well A-2 and shortest is Well A-1.

SRM-3 is at depths of 5030-4945ft TVDSS (85ft thick) and 5015-4910ft TVDSS (105ft) in Wells A-2 and A-1 respectively. At Well A-3, SRM-3 is at a depth range of 4982-4870ft TVDSS (112ft). Shale thickness increases from Well A-2 to Well A-3.

Table 2: Shale Correlation

	Well A-2				Well A-1				Well A-3			
	Top (ft)	Base (ft)	Thick (ft)	Thick (m)	Top (ft)	Base (ft)	Thick (ft)	Thick (m)	Top (ft)	Base (ft)	Thick (ft)	Thick (m)
SRM 1	4795	4860	65	20	4770	4840	70	21	4735	4800	65	20
SRM 2	4860	4910	50	15	4840	4880	40	12	4800	4845	45	14
SRM 3	4945	5030	85	26	4910	5015	105	32	4870	4982	112	34

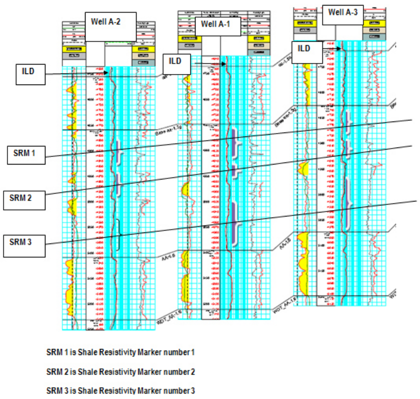

Figure 5: Shale Correlation

CONCLUSIONS

There are three sand units correlated in the area with gamma ray (GR) and Spontaneous Potential (SP) logs. The sands are Sand 1, Sand 2 and Sand 3 at 4800 ft, 4950ft and 5150ft measured depth respectively. The shales are SRM 1, SRM 2 and SRM 3 identified with Deep Induction (ILD) log. Sand 1 is thickest in Well A-3. Sand 2 decreases in thickness from west to East (Well A-2 to A-3). Sand 3 is thickest in Well A-3 (1126ft).

SRM 1 is 65ft in Well A-2 and A-3. SRM 2 is thickest in Well A-2 and SRM 3 increases in thickness from west to east (85ft in Well A-2 to 112ft in A-3).

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