IOSR Journal of Applied Geology and Geophysics (IOSR-JAGG)
e-ISSN: 2321–0990, p-ISSN: 2321–0982.Volume 6, Issue 2 Ver. I (Mar. – Apr. 2018), PP 70-85
www.iosrjournals.org

Source Rock Analysis Using Well Logs In Western Niger Delta

Kaka Abiodun[1], Saleh .A. Saleh[2,] Eze Stanley*[3], William Sampson[4]
[1]*Department of Earth Sciences, Federal University of Petroleum Resources, Effurun, Nigeria.*
[2]*Department of Petroleum Engineering and Geoscience, Petroleum Training Institute, Effurun, Nigeria.*
[3,4]*Department of Geology, University of Port Harcourt, PMB 5323, Choba, Port Harcourt, Nigeria.*
Corresponding Author: Kaka Abiodun

Abstract: *Well logs have been calibrated for the determination of Total Organic Carbon (TOC wt%), amount of hydrocarbon yield through thermal cracking (mg/g) S2 and Hydrogen Index (HI) for analysis of source rock in pologbene 002 well in western Niger Delta Nigeria. The EXXON method was used to determine the Total Organic Carbon Content of the source using well log data such as gamma-ray (GR), density (RHOB), sonic (DT), resistivity (LLD), and neutron (NPHI), which are the commonly used wireline logs to identify and quantify source rock. The geologic window for organic rich shales in the well was defined using a combination of GR, density-porosity/resistivity overlay and within 7840-8000ft. Results of TOC estimated from well logs show that at 7840ft, TOC is about 6.6433wt%, and this value keeps increasing with level of organic maturity (LOM), and vitrinite reflectance (Ro). TOC generated from well logs was compared to that of the geochemical logs and results show that TOC from both data (well log and geochemical log) averages at 9wt% and 3wt% respectively within the defined window. The deviation of the results was calculated using their mean and standard deviation and the results show standard deviation* ***(S)*** *of 3.14 for well log derived TOC and 1.12 for TOC from geochemical logs. Though a comparison of the results show some margin of differences between TOC derived from well logs and that from geochemical logs, the method was still able to predict that the hydrocarbon yield from source rock in pologbene 002 well is gas dominant and the well is a dry gas producing area.*

Keywords*: Source Rock, Total Organic Carbon, Level of organic Maturity, Hydrogen index, Well-Logs.*

Date of Submission: 15-03-2018 Date of acceptance: 31-03-2018

I. Introduction

Petroleum is generated from organic-rich sediments (source rocks) containing organic matter originating from biological materials. Source rocks results from a convergence of physical, biochemical and geologic processes, which occurs during burial of sediments. These processes results in a series of geochemical reactions which transforms biopolymers to geopolymers, often collectively called kerogen, which are the precursors of petroleum (peters, 1986).

In petroleum geology, source rock refers to rocks from which hydrocarbons have been generated or are capable of being generated. They form one of the necessary elements of a working petroleum system. They are organic-rich sediments that may have been deposited in a variety of environments including deep water, lacustrine and deltaic environment (Stacher 1995). According to Bustin (1988), the amount, type and composition of petroleum generated from a source rock depends on the nature and geological history of the source rock, which includes the environmental conditions that supports biological activities that produces large quantities of organic matter, where the depositional conditions concentrate this matter, and where post depositional conditions permits its preservation. The key parameters that determines the composition of petroleum generated from a source rock are the organic content of the source rock. Organic content is controlled largely by biologic productivity, sediments mineralogy and oxygenation of the water column and sediments. The mechanisms by which oil and gas are generated from a matured source rock vary from basin to basin depending on sedimentary facies, time-temperature/burial history, tectonics and other geologic processes (Anders 1991).

The initial stages of an exploration programme is to evaluate the source rock, which is the central component to the success of each well, together with the hydrocarbon potential of the source rock and integrate these data with the geological development of the basin to enhance predictions of where and when hydrocarbon generation and accumulation have occurred (Bardsley 1963; Bustin 1988). Geoscientists employ a variety of techniques to evaluate the hydrocarbon generating capacity of source rocks. Geochemical testing of outcrop samples, formation cuttings, sidewall cores, and conventional cores, can help determine the amount, type and thermal maturity of organic matter present in the rock (Bob 2011).

These techniques are diagnostic in ascertaining how much, when and what kind of petroleum might have been generated in the source rock; however they require laboratory analysis which is quite expensive and time consuming. To compensate for this, several models have been developed which uses the conventional wireline logs for evaluating the thermal maturity of source rocks and calculating the total organic carbon (TOC) content.

One of these models is that used by (Passey et al., 1990 and Heidarifard, 2011); **EXXON technique**. This technique was designed for use in shales, and the model has been modified to create a baseline conditions through the full range of clean sand to shale. Deviations from the baseline conditions can be used to identify both source rocks and hydrocarbon reservoirs. The use of well logs in source rock analysis is an efficient, economical and "quick-look" method of source rock analysis without calibration to core data and can be performed at once at the drill site. When correlated to the geochemical data of the well, the result gives more detailed and reliable information about its maturation.

The aim of this study is to determine the total organic carbon (TOC) content in organic-rich rocks in Pologbene well (002) located western Niger delta offshore using well log analysis and by implication determine its dominant hydrocarbon type. Gamma ray, density, sonic, resistivity and neutron logs were used to identify and quantify the source rock. The results, when compared with the results of TOC from geochemical data, show that cautions must be taken into consideration when applying these model because the model is empirical and their validation takes place under certain conditions. The study is significant since it offers a direct correlation of Total Organic Carbon (TOC) Content computed using wireline logs with that from geochemical analysis.

II. Geologic Setting

The well under study pologbene well (002) is located in western Niger delta offshore. The Niger Delta is situated in the Gulf of Guinea in the West coast of Africa. It is located at the southeastern end of Nigeria, bordering the Atlantic Ocean and extends from Latitude 4^0 to 6^0 North and Longitude 3^0 to 9^0 East. The tectonic framework of the Niger Delta is related to the stresses that accompanied the separation of the African and South American plates which led to the opening of the South Atlantic. The Niger Delta Basin is the largest sedimentary Basin in Africa with an area of about 75,000km^2, and a clastic fill of about 9,000 to 12,000m (30,000 to 40,000ft) and terminates at different intervals by transgressive sequences (Stacher, 1995). The proto Delta developed in the Northern part of the Basin during the Campanian transgression and ended with the Paleocene transgression. Stratigraphic evolution of the Tertiary Niger Delta and underlying Cretaceous strata is described by Short and Stauble (1967). The three major lithostratigraphic units defined in the subsurface of the Niger Delta includes: (a) the basal Paleocene to Recent pro-delta facies of the Akata Formation. (b) Eocene to Recent paralic facies of the Agbada Formation and (c) Oligocene to Recent, fluvial facies of the Benin Formation (Short and Stauble, 1967; Evamy et al, 1978). These formations became progressively younger basinward, recording long-term progradation (seaward movement) of depositional environments of the Niger Delta into the Atlantic Ocean Passive Margin. The stratigraphy of the Niger Delta is complicated by the syn-depositional collapse of the clastic wedge as shale of the Akata Formation mobilized under the load of prograding deltaic Agbada and fluvial Benin Formation (Allen 1970). Stratigraphic equivalent units to these three formations are exposed in southern Nigeria (Short and Stauble, 1967). The formations reflect a gross coarsening-upward progradational clastic wedge (Short and Stauble, 1967), deposited in marine, deltaic, and fluvial environments (Weber and Daukoru, 1975).

Source rocks in the Niger Delta might include marine interbedded shale in the Agbada Formation, marine Akata Formation shales and underlying Cretaceous shales (Evamy et al, 1978; Ejedawe 1981; Lambert-Aikhionbare and Ibe, 1984; Bustin, 1988; Doust and Omatsola, 1990). Reservoir intervals in the Agbada Formation have been interpreted to be deposits of high stand and transgressive systems tracts in proximal shallow ramp settings (Evamy et al, 1978). Most primary reservoirs were thought to be Miocene-aged paralic sandstones with 40% porosity, 2darcy permeability, and thickness of about 300 feet. Reservoirs may thicken toward down-thrown sides of growth faults (Weber and Daukoru, 1975). Reservoir units vary in grain size; fluvial sandstones tend to be coarser than the delta front sandstones. Point bar deposits fine upward; barrier bar sandstones tend to have the best grain sorting. Kulke (1995) reported that most sandstones are unconsolidated with only minor argillaceous and siliceous cement.

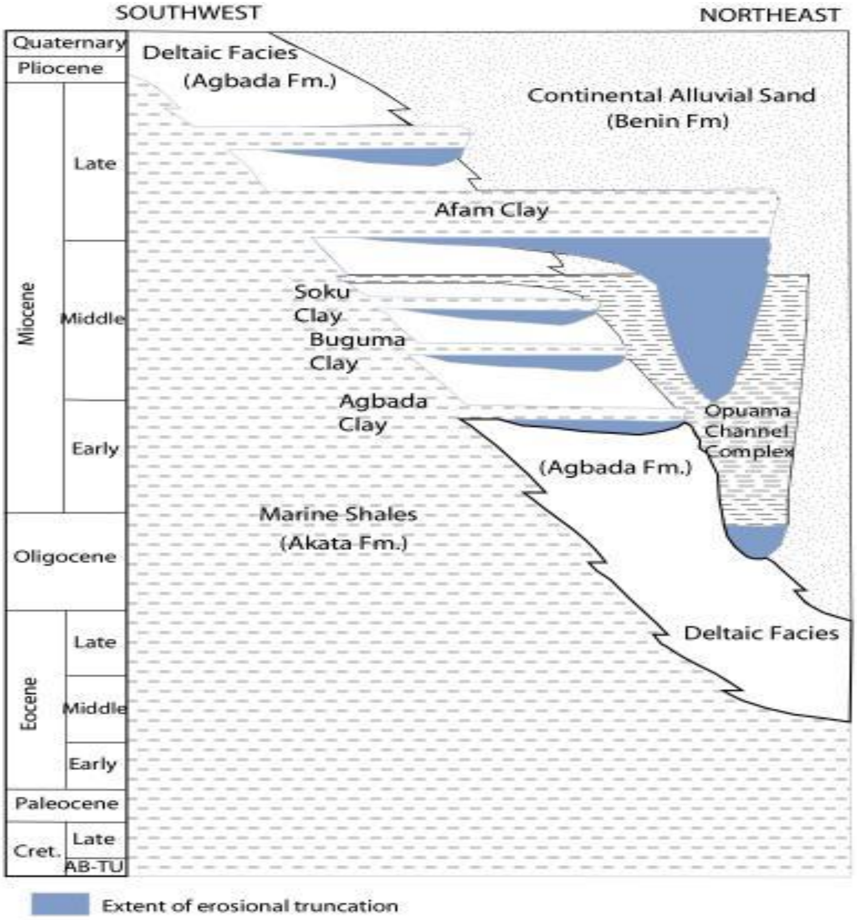


Figure 1: Stratigraphic column of the Niger Delta (Modified from Doust and Omatsola, 1989).

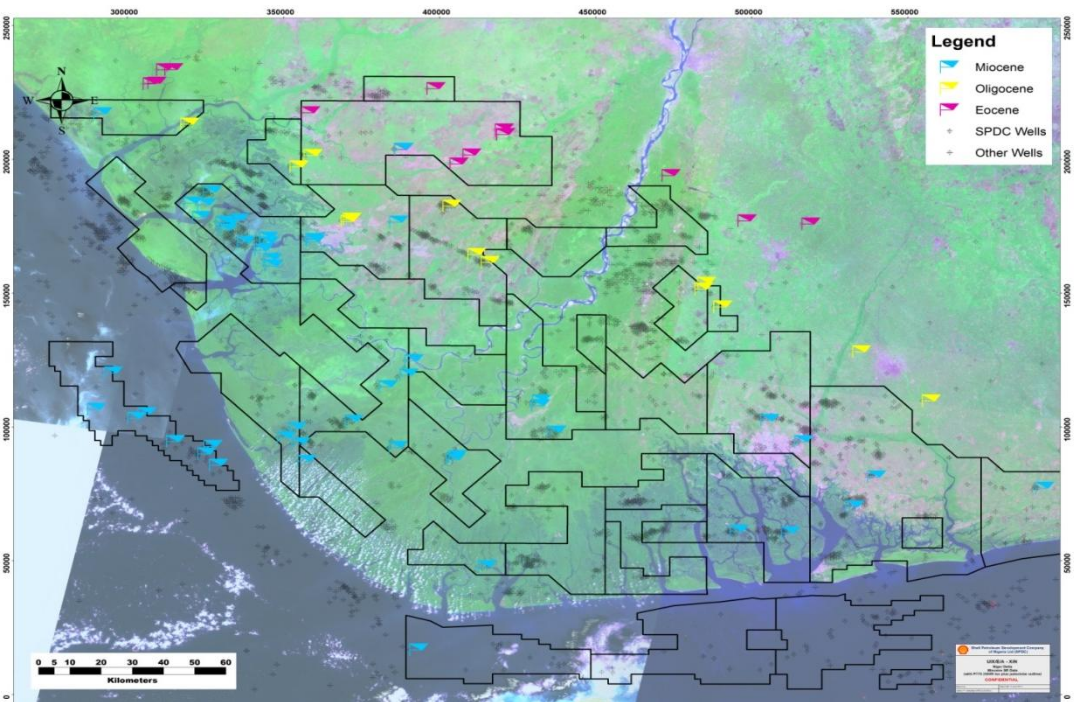


Figure 2: Base map of Western Niger Delta showing co-ordinate X- 305131 and Y- 228287. (SPDC Warri Geoservice Department) 2012.

III. Theory

In this study, the model used to calculate TOC (Total Organic Carbon) content from well logs within the defined window is the **EXXON method** published by(Passey et al., 1990; and Heidarifard, 2011) given as:

$\Delta \log R = log_{10} \left({}^{R}/_{R_{ns}} \right) + K * (P - P_{ns})(1)$

Where, ΔlogR, is the curve separation, R is the measured formation resistivity, P is the porosity log reading, while Rns and Pns are their values within fine grained non-source rocks and K is a scale factor depending on the porosity log unit.

So, TOC can be estimated through the equation;

$TOC = \Delta logR * 10^{(2.297 - 0.1688 * LOM)}(2)$

Where; TOC is total organic carbon content in wt%, and LOM is the level of organic maturity.

Also, the Hydrogen Index (HI) and the S_2 (amount of hydrocarbon the source rock can yield through diagenetic changes at its Oil generating window) can be determined from the LOM and TOC values respectively using the following equations shown below:

$HI=0.2914*LOM^4 - 11.6LOM^3+169.57LOM^2 - 1099LOM+ 2863.2(3)$

Where;

LOM = Level of Organic Maturity

HI = Hydrogen Index (for gas prone source rock, passey et al., 1990) and,

$HI = \frac{100 * S_2}{TOC\%}(4)$

From which S2 can be determined using known values of HI and TOC%.

The **EXXON method** was designed for use in shales. The model has been modified to create a baseline conditions for the full range of clean sand to shale. However deviations from the baseline conditions can be used to identify both source rocks and hydrocarbon reservoirs.Equation (2) predicts zero (0) TOC where there is no curve separation (baseline conditions). In practice, however, all shales have some organic carbon content, so it is necessary to add 0.2 to 1.6 (wt%) to TOC values calculated by this technique (Passey et. al., 1990). The baseline TOC content of shales is usually determined from laboratory measurements or using local knowledge. However it is rare to have both TOC laboratory measurements and reliable organic maturity data, in these situations it is possible to choose a value for LOM that will result in a match with available TOC data.

IV. Methodology

In this study, well log analysis for identifying and calculating Total Organic Carbon (TOC) Content in organic-rich rocks at Pologbene002 well at depth between 7350– 8100ft was carried out. The method employs the overlaying of a properly scaled porosity log (derived from sonic transit time) on the resistivity log track. In water saturated organic-clean rocks, the two tracks lie parallel to each other and can be overlain, since both logs respond to variations in formation porosity; however, in hydrocarbon reservoir rocks or organic rich non-reservoir rocks, a separation between the tracks occurs. The two tracks separates in organic-rich intervals due to two reasons: (a) the porosity log respond to the presence of low-density, low velocity kerogen, and (b) the resistivity log responds to the formation fluid.

In an immature organic-rich rock, where no hydrocarbons have been generated, the observed log track separation is solely due to the porosity log response. In mature source rocks, in addition to the porosity log response, the resistivity log increases because of the presence of generated hydrocarbons within. The magnitude of the track separation in non-reservoirs is calibrated to total organic carbon and maturity, and allows for depth profiling of organic richness in the presence of sample data. This method allows organic richness to be accurately assessed in wide varieties of lithologies and dominant fluid present in maturated source rock using well logs.

PROCEDURE / WORKFLOW

The research design usedforthisworkis summarized in the flow chart (Fig 3).

The analysis was done within Hampson Russell Software (HRS) application. Hampson Russell Software consists of several modules, some of which includes the Geoview module, which serves as a starting point of any Hampson Russell program. Well log data were imported and loaded into Geoview well data base through the Well Explorer file to display log signatures and tracks for analysis.

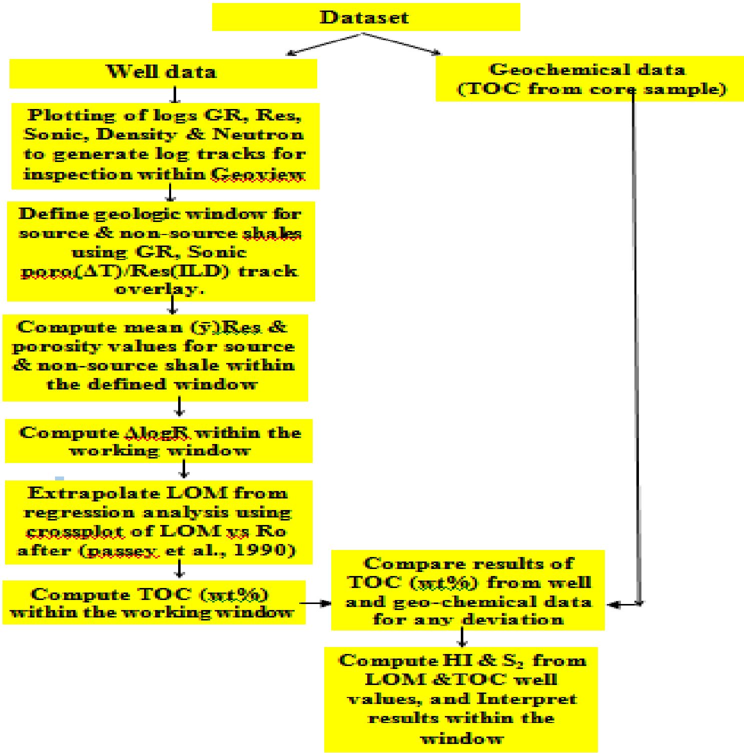


Figure 3: Flow chart showing the research workflow.

V. Results

The various logs provided were loaded into the E-log modelling tool within Hampson-Russell software application to produce the wiggles for all the well logs for analysis.

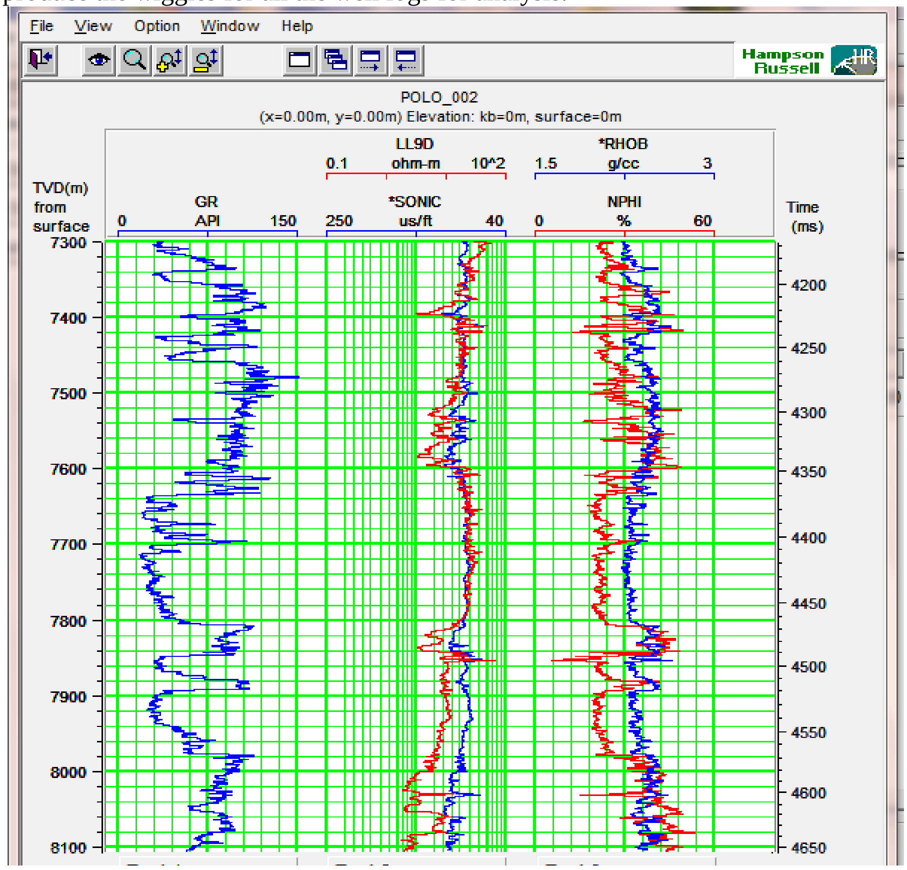


Figure 4: Composite log plot in Geoview showing the wiggles (track) display for all the well logs.

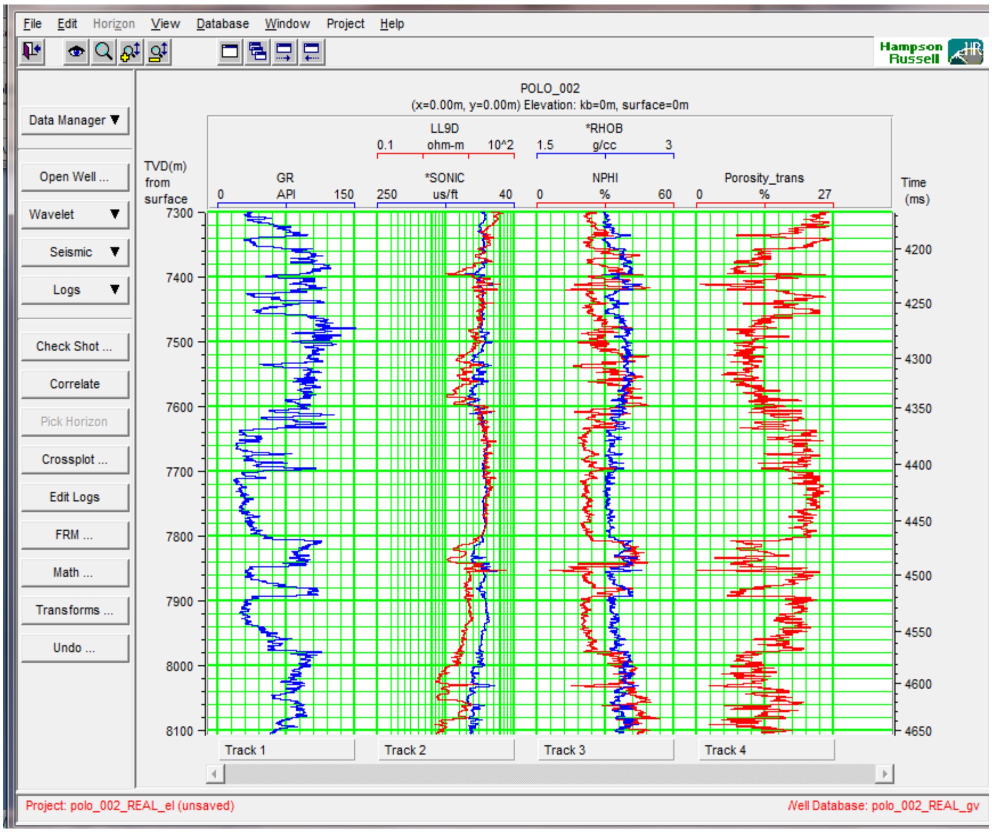


Figure 5: Composite log track showing porosity log (track 4) derived from density. The red circle shows the curve separation (ΔlogR) or Sonic-resistivity overlay at a depth of 7820 – 7840(ft).

From the well data, the average values of resistivity and porosity log for source and non-source shales werecomputed within the window 7355-7800ft and results presented in table 2 below.

Table 1: Showingparameters for computing curve separation.

R/Rns(average)	K – factor	P-Pns(average)	K (P-Pns)	R/Rns+K(P-Pns)	$Log_{10}R$
10.61824/ 21.61078	2.5	19.11441-18.88124	2.5(19.11441-18.88124)	(10.61824/ 21.61078)+2.5(19.11441-18.88124)	
0.49133	**2.5**	**0.2328**	**0.582**	**1.07333**	**0.03073**

Therefore from the above table;

ΔlogR = 0.03073

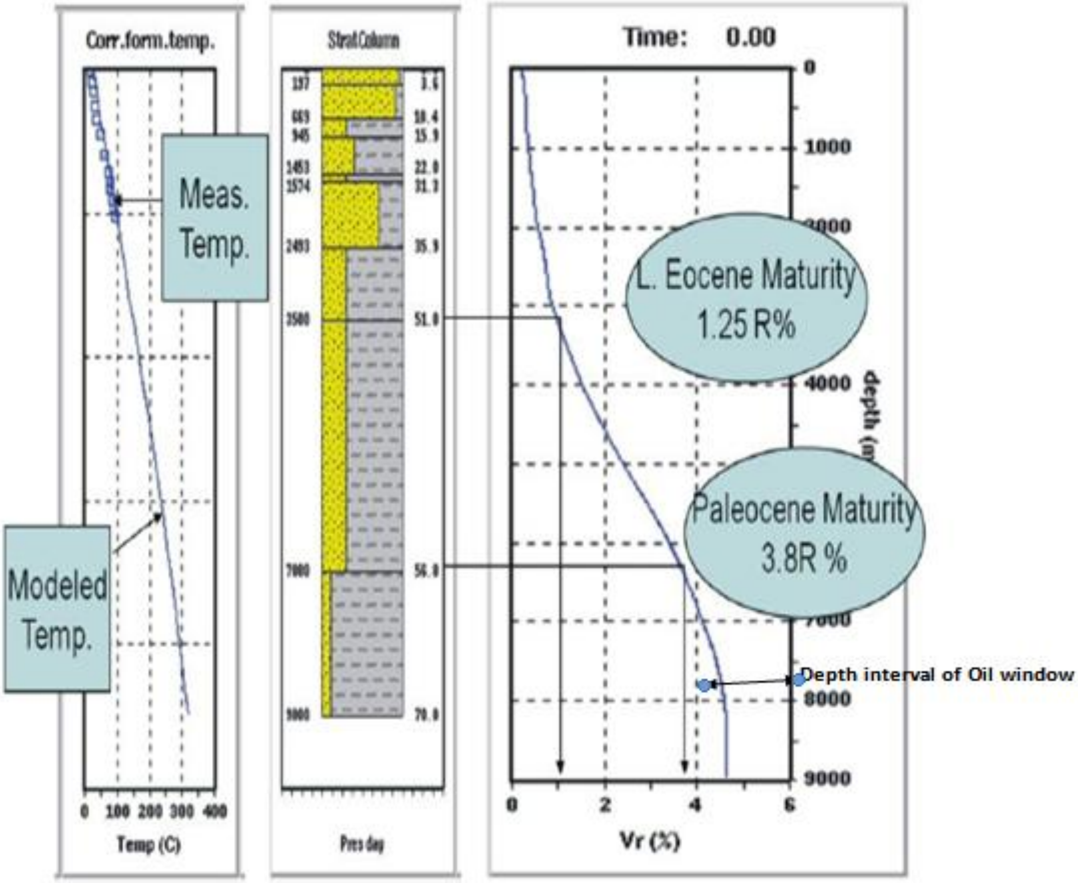
Also recall that Total Organic Carbon (TOC) can be estimated through the equation;

$$TOC = \Delta logR * 10^{(2.297-0.1688*LOM)}$$

Where LOM is the level of organic maturity which was estimated from the LOM vs vitrinite reflectance (Ro) crossplot, at a known value of Ro. The Vitrinite reflectance (Ro) value used in this study to estimate LOM within the window (7355-8000ft) was inferred from the temperature model table in Pologbene-002 well (after Ojo et al., 2012).

Within the geologic window, the Vitrinite reflectance (Ro) value inferred at depth 7355 ft is about 4.20%, and this was used for LOM and TOC estimation.

Table 2: Temperature and modeled Vitrinite Reflectance with depth in Pologbene-002 well (Adapted from Ojo et al., 2012).



With the known value of the Vitrinite Reflectance (Ro) inferred above, the Level of Organic Maturity LOM was obtained from the crossplot of Level of Organic Maturity vs Vitrinite Reflectance in figure 6 below. From the crossplot the highest value of vitrinite reflectance (Ro) is 3%, but the inferred value of Ro within the geologic window is 4.20% (not depicted in the crossplot) regression statistical method was used to extrapolate the LOM values at Ro values not shown on the crossplot.

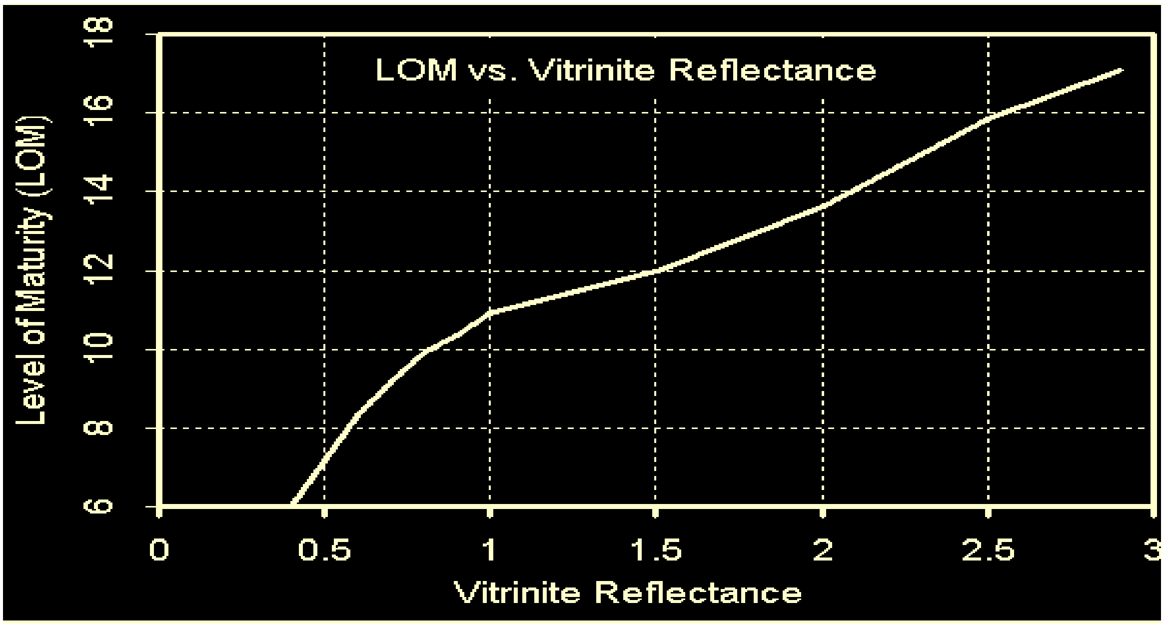


Figure 6: Crossplot of LOM vs. Vitrinite reflectance (Ro), (after passey et al., 1990).

Regression is a statistical tool used for assessing the association between two variables, to find the relationship between them.

Regression Equation (y) = a + bx where;

Slope (b) = (NΣXY - (ΣX) (ΣY)) / (NΣX^2 - (ΣX)^2)

Intercept (a) = (ΣY - b(ΣX)) / N

The regression Parameters were obtained from the crossplot above (figure 6). The X co-ordinates are the Ro values, while the Y co-ordinates were the LOM values.

Table 3: Showing the regression Parameters obtained from figure 6, for estimating LOM at Ro value of 4.20%.

	X	Y	X.Y	X.X	where N = 7
	0	6	0	0	
	0.5	8	4	0.25	
	1	10	10	1	
	1.5	12	18	2.25	
	2	14	28	4	
	2.5	16	40	6.25	
	3	18	54	9	
∑(summation)	**10.5**	**84**	**154**	**22.75**	

From the regression equation defined above;

$$b = \frac{7(154) - (10.5*84)}{7(22.5) - (10.5)^2}$$

$$\frac{1078 - 882}{157.5 - 110.25}$$

$$\frac{196}{47.25}$$

$$b = 4.15$$

and;

$$a = \frac{84 - 4.15(10.5)}{7}$$

$$\frac{84 - 43.56}{7}$$

$$\frac{40.444}{7}$$

$$a = 5.78$$

therefore; y = 5.78 + 4.15x is the regression equation.

From the regression equation, the Level of organic maturity (LOM) was estimated for Vitrinite reflectance (Ro) value of 4.20 % at depth of 7355feet.

Then the LOM is:

$$y = 5.78 + 4.15(4.20)$$
$$= 5.78 + 17.513$$

= 23.21

Therefore at Vitrinite reflectance 4.20%, Level of Organic Maturity = **23.21.**

The same analysis was done for all depth intervals taken for this study and in each case Ro, LOM, and TOC were determined and the result obtained is presented in the table below:

Table 4: TOC determined from well logs, at known values of Ro, and LOM.

DEPTH FT	Ro	LOM	ΔLogR	TOC(calculated)
7355	4.20	23.21	0.03	3.84579
7360	4.21	23.23	0.03	3.92971
7365	4.21	23.23	0.03	3.92971
7370	4.21	23.23	0.03	3.92971
7375	4.21	23.23	0.03	3.92971
7380	4.21	23.23	0.03	3.92971
7385	4.21	23.25	0.03	4.01527
7390	4.21	23.26	0.03	4.04996
7395	4.21	23.26	0.03	4.04996
7400	4.21	23.26	0.03	4.04996
7405	4.21	23.26	0.03	4.04996
7410	4.21	23.26	0.03	4.04996

7410	4.21	23.26	0.03	4.04996
7415	4.21	23.27	0.03	4.08493
7420	4.22	23.27	0.03	4.10251
7425	4.22	23.27	0.03	4.10251
7430	4.22	23.27	0.03	4.10251
7435	4.22	23.27	0.03	4.10251
7440	4.22	23.27	0.03	4.10251
7445	4.25	23.40	0.03	4.66272
7450	4.25	23.40	0.03	4.66272
7455	4.25	23.40	0.03	4.66272
7460	4.25	23.40	0.03	4.66272
7465	4.25	23.40	0.03	4.66272
7470	4.25	23.40	0.03	4.66272
7475	4.25	23.42	0.03	4.7625
7480	4.25	23.42	0.03	4.7625
7485	4.25	23.42	0.03	4.7625
7490	4.25	23.42	0.03	4.7625
7495	4.25	23.42	0.03	4.7625
7500	4.25	23.42	0.03	4.7625
7505	4.30	23.63	0.03	5.8714
7510	4.30	23.63	0.03	5.8714
7515	4.30	23.63	0.03	5.8714
7520	4.30	23.63	0.03	5.8714
7525	4.30	23.63	0.03	5.8714
7530	4.30	23.63	0.03	5.8714
7535	4.33	23.75	0.03	6.64333
7540	4.33	23.75	0.03	6.64333
7545	4.33	23.75	0.03	6.64333
7550	4.33	23.75	0.03	6.64333
7555	4.33	23.75	0.03	6.64333
7560	4.33	23.75	0.03	6.64333
7565	4.36	23.87	0.03	7.50543
7570	4.36	23.87	0.03	7.50543
7575	4.36	23.87	0.03	7.50543
7580	4.36	23.87	0.03	7.50543
7585	4.36	23.87	0.03	7.50543
7590	4.36	23.87	0.03	7.50543
7595	4.40	24.04	0.03	8.81125
7600	4.40	24.04	0.03	8.81125
7605	4.40	24.04	0.03	8.81125
7610	4.40	24.04	0.03	8.81125
7615	4.40	24.04	0.03	8.81125
7620	4.40	24.04	0.03	8.81125
7625	4.40	24.04	0.03	8.81125
7630	4.40	24.04	0.03	8.81125
7635	4.40	24.04	0.03	8.81125
7640	4.40	24.04	0.03	8.81125
7645	4.40	24.04	0.03	8.81125
7650	4.40	24.04	0.03	8.81125
7655	4.41	24.08	0.03	9.16811
7660	4.41	24.08	0.03	9.16811
7665	4.41	24.08	0.03	9.16811
7670	4.41	24.08	0.03	9.16811
7675	4.41	24.08	0.03	9.16811
7680	4.41	24.08	0.03	9.16811
7685	4.41	24.08	0.03	9.16811
7690	4.41	24.08	0.03	9.16811
7695	4.41	24.08	0.03	9.16811
7700	4.41	24.08	0.03	9.16811
7705	4.41	24.08	0.03	9.16811
7710	4.41	24.08	0.03	9.16811
7715	4.43	24.16	0.03	9.92112
7720	4.43	24.16	0.03	9.92112
7725	4.43	24.16	0.03	9.92112
7730	4.43	24.16	0.03	9.92112
7735	4.43	24.16	0.03	9.92112
7740	4.43	24.16	0.03	9.92112
7745	4.43	24.16	0.03	9.92112
7750	4.43	24.16	0.03	9.92112
7755	4.43	24.16	0.03	9.92112

7760	4.43	24.16	0.03	9.92112
7765	4.43	24.16	0.03	9.92112
7770	4.44	24.19	0.03	10.1179
7775	4.44	24.19	0.03	10.1179
7780	4.44	24.19	0.03	10.1179
7785	4.44	24.19	0.03	10.1179
7790	4.44	24.19	0.03	10.1179
7795	4.44	24.19	0.03	10.1179
7800	4.44	24.19	0.03	10.1179
7805	4.44	24.19	0.03	10.1179
7810	4.44	24.19	0.03	10.1179
7815	4.44	24.19	0.03	10.1179
7820	4.44	24.19	0.03	10.1179
7825	4.44	24.19	0.03	10.1179
7830	4.44	24.19	0.03	10.1179
7835	4.45	24.24	0.03	10.6044
7840	4.45	24.24	0.03	10.6044
7845	4.45	24.24	0.03	10.6044
7850	4.45	24.24	0.03	10.6044
7855	4.45	24.24	0.03	10.6044
7860	4.45	24.24	0.03	10.6044
7865	4.48	24.37	0.03	12.053
7870	4.48	24.37	0.03	12.053
7875	4.48	24.37	0.03	12.053
7880	4.48	24.37	0.03	12.053
7885	4.48	24.37	0.03	12.053
7890	4.48	24.37	0.03	12.053
7895	4.48	24.37	0.03	12.053
7900	4.48	24.37	0.03	12.053
7905	4.48	24.37	0.03	12.053
7910	4.48	24.37	0.03	12.053
7915	4.48	24.37	0.03	12.053
7920	4.48	24.37	0.03	12.053
7925	4.48	24.37	0.03	12.053
7930	4.48	24.37	0.03	12.053
7935	4.48	24.37	0.03	12.053
7940	4.48	24.37	0.03	12.053
7945	4.48	24.37	0.03	12.053
7950	4.48	24.37	0.03	12.053
7955	4.50	24.46	0.03	13.0153
7960	4.50	24.46	0.03	13.0153
7965	4.50	24.46	0.03	13.0153
7970	4.50	24.46	0.03	13.0153
7975	4.50	24.46	0.03	13.0153
7980	4.50	24.46	0.03	13.0153
7985	4.50	24.46	0.03	13.0153
7990	4.50	24.46	0.03	13.0153
7995	4.50	24.46	0.03	13.0153
8000	4.50	24.46	0.03	13.0153
8005	4.50	24.46	0.03	13.0153
8010	4.50	24.46	0.03	13.0153
8015	4.50	24.46	0.03	13.0153
8020	4.50	24.46	0.03	13.0153
8025	4.50	24.46	0.03	13.0153
8030	4.50	24.46	0.03	13.0153
8035	4.50	24.46	0.03	13.0153
8040	4.50	24.46	0.03	13.0153
8045	4.50	24.46	0.03	13.0153
8050	4.50	24.46	0.03	13.0153
8055	4.50	24.46	0.03	13.0153
8060	4.50	24.46	0.03	13.0153
8065	4.50	24.46	0.03	13.0153
8070	4.50	24.46	0.03	13.0153
8075	4.50	24.46	0.03	13.0153
8080	4.50	24.46	0.03	13.0153
8085	4.50	24.46	0.03	13.0153
8090	4.50	24.46	0.03	13.0153
8095	4.50	24.46	0.03	13.0153
8100	4.50	24.46	0.03	13.0153

A crossplot of LOM values vs Vitrinite reflectance (Ro) obtained from the regression analysis was plotted to show their relationship.

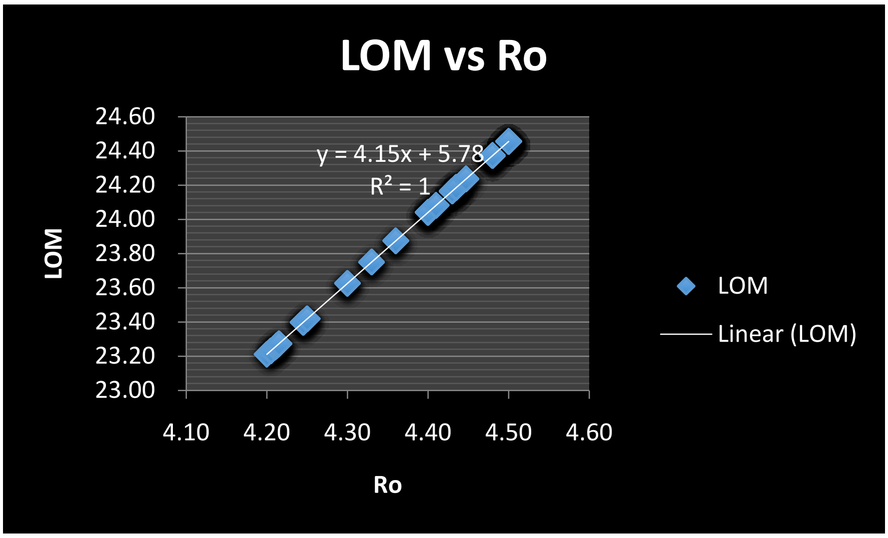


Figure 7: Showing crossplot of LOM vs Vitrinite Reflectance (Ro) obtained from regression analysis.

The crossplot shows a linear relationship between LOM and Ro which agrees with that after passey et al., 1990.

The above analysis was done with well logs using the **EXXON METHOD**. Total Organic Carbon (TOC) from geochemical logs (core sample analysis) was compared with the Total Organic Carbon (TOC) estimated from well logs within the same geologic window. The result is presented below:

Table 5: Showing TOC from geochemical logs and well logs (derived)

DEPTH FT	TOC from geochemical log wt%	TOC from well logs wt%
7355	2.708	3.84579
7360	2.7	3.92971
7365	2.7	3.92971
7370	2.7	3.92971
7375	2.7	3.92971
7380	2.7	3.92971
7385	2.324	4.01527
7390	2.3	4.04996
7395	2.3	4.04996
7400	2.3	4.04996
7405	2.3	4.04996
7410	2.3	4.04996
7415	2.024	4.08493
7420	2	4.10251
7425	2	4.10251
7430	2	4.10251
7435	2	4.10251
7440	2	4.10251
7445	2.184	4.66272
7450	2.2	4.66272
7455	2.2	4.66272
7460	2.2	4.66272
7465	2.2	4.66272
7470	2.2	4.66272
7475	2.568	4.7625
7480	2.6	4.7625
7485	2.6	4.7625
7490	2.6	4.7625
7495	2.6	4.7625
7500	2.6	4.7625
7505	2.508	5.8714
7510	2.5	5.8714
7515	2.5	5.8714
7520	2.5	5.8714
7525	2.5	5.8714

7530	2.5	5.8714
7535	1.856	6.64333
7540	1.8	6.64333
7545	1.8	6.64333
7550	1.8	6.64333
7555	1.8	6.64333
7560	1.8	6.64333
7565	2.26	7.50543
7570	2.3	7.50543
7575	2.3	7.50543
7580	2.3	7.50543
7585	2.3	7.50543
7590	2.3	7.50543
7595	2.668	8.81125
7600	2.7	8.81125
7605	2.7	8.81125
7610	2.7	8.81125
7615	2.7	8.81125
7620	2.7	8.81125
7625	3.16	8.81125
7630	3.2	8.81125
7635	3.2	8.81125
7640	3.2	8.81125
7645	3.2	8.81125
7650	3.2	8.81125
7655	4.212	9.16811
7660	4.3	9.16811
7665	4.3	9.16811
7670	4.3	9.16811
7675	4.3	9.16811
7680	4.3	9.16811
7685	3.564	9.16811
7690	3.5	9.16811
7695	3.5	9.16811
7700	3.5	9.16811
7705	3.5	9.16811
7710	3.5	9.16811
7715	3.132	9.92112
7720	3.132	9.92112
7725	3.132	9.92112
7730	3.132	9.92112
7735	3.132	9.92112
7740	3.132	9.92112
7745	4.48	9.92112
7750	4.6	9.92112
7755	4.6	9.92112
7760	4.6	9.92112
7765	4.6	9.92112
7770	4.6	10.1179
7775	3.2	10.1179
7780	3.2	10.1179
7785	3.2	10.1179
7790	3.2	10.1179
7795	3.2	10.1179
7800	3.2	10.1179
7805	3.016	10.1179
7810	3	10.1179
7815	3	10.1179
7820	3	10.1179
7825	3	10.1179
7830	3	10.1179
7835	3	10.6044
7840	3	10.6044
7845	3	10.6044
7850	3	10.6044
7855	3	10.6044
7860	3	10.6044
7865	3.092	12.053
7870	3.1	12.053
7875	3.1	12.053

7880	3.1	12.053
7885	3.1	12.053
7890	3.1	12.053
7895	3.008	12.053
7900	3	12.053
7905	3	12.053
7910	3	12.053
7915	3	12.053
7920	3	12.053
7925	3.092	12.053
7930	3.1	12.053
7935	3.1	12.053
7940	3.1	12.053
7945	3.1	12.053
7950	3.1	12.053
7955	3.1	13.0153
7960	3.1	13.0153
7965	3.1	13.0153
7970	3.1	13.0153
7975	3.1	13.0153
7980	3.1	13.0153
7985	2.64	13.0153
7990	2.6	13.0153
7995	2.6	13.0153
8000	2.6	13.0153
8005	2.6	13.0153
8010	2.6	13.0153
8015	2.6	13.0153
8020	2.6	13.0153
8025	2.6	13.0153
8030	2.6	13.0153
8035	2.6	13.0153
8040	2.6	13.0153
8045	3.52	13.0153
8050	3.6	13.0153
8055	3.6	13.0153
8060	3.6	13.0153
8065	3.6	13.0153
8070	3.6	13.0153
8075	3.876	13.0153
8080	3.9	13.0153
8085	3.9	13.0153
8090	3.9	13.0153
8095	3.9	13.0153
8100	3.9	13.0153

VI. Result Interpretation and Discussion

At depth 7355 ft, the TOC from geochemical logs shows 2.708wt%, while that of well logs shows a TOC of 3.84579wt%, at depth range of 7360ft – 7380ft, TOC from well logs shows 2.7wt% while that of geochemical logs shows 3.92971wt% which shows a steady increase in the TOC calculated from well logs. At depth of *7540 ft* TOC from geochemical logs shows 1.8wt%, while that from well logs shows 6.6433wt% , this shows that irrespective of the TOC source (from geochemical logs or well logs) for pologbene 002 well at different depth interval, as long as the vitrinite reflectance increases, so will the LOM increases, subsequently the TOC will increases (table 4).

Vitrinite reflectance values less than 0.8% are considered immature, while between 0.8 and 1.0% is the oil zone. The condensate / mixed zone is between 1.0 and 1.4% and greater than 1.4% is the dry gas window. These windows are used as indicators of likely production. Mixed production is possible as well as local variations in the relationship between vitrinite maturity, and hydrocarbon production (Hood’s et al 1975). Lower Eocene source rock maturity is about 1.25 Ro%, while Paleocene maturity is about 3.8 Ro %. (Temperature and modeled vitrinite reflectance with depth after Ojo et al., 2012). Inferring from these data the Pologbene 002 well could be tagged as a dry gas window well since it has the same characteristic as the Paleocene source rock maturity. Therefore the hydrocarbon content of the well is gas dominant rather than oil.

Since the source rock is gas dominant, the Hydrogen Index (HI) for a gas prone source rock and S2 was estimated from well logs using (eqns 3 and 4) for known values of LOM.

Also from the result shown in Table 6, there is some level of deviation in the TOC estimated from well logs to that determined using geochemical logs. The mean and standard deviation of the results from TOC estimated from well logs to that of geochemical logs were estimated from the available data within our working interval using equations 5 and 6.

$\bar{x} = 1/n\ (x + x + ... + x)$ (5)

Standard Deviation = $\left\{\sqrt{\frac{\sigma^2}{n1}+\frac{\sigma^2}{n2}}\right\}$ (6)

Where

σ = variance of the two set of values i:e TOC from well log and geochemical data

x = each of the values

$\bar{x}$ = mean of the given values

The mean and standard deviation for the data of both TOC sources was done using statistical software called statgraphics

Standard deviation for TOC calculated from well log is **3.14,** while that for TOC calculated from geochemical logs is **1.12.** The graphs below are regression crossplots of the various parameters derived from well logs and from geochemical data.

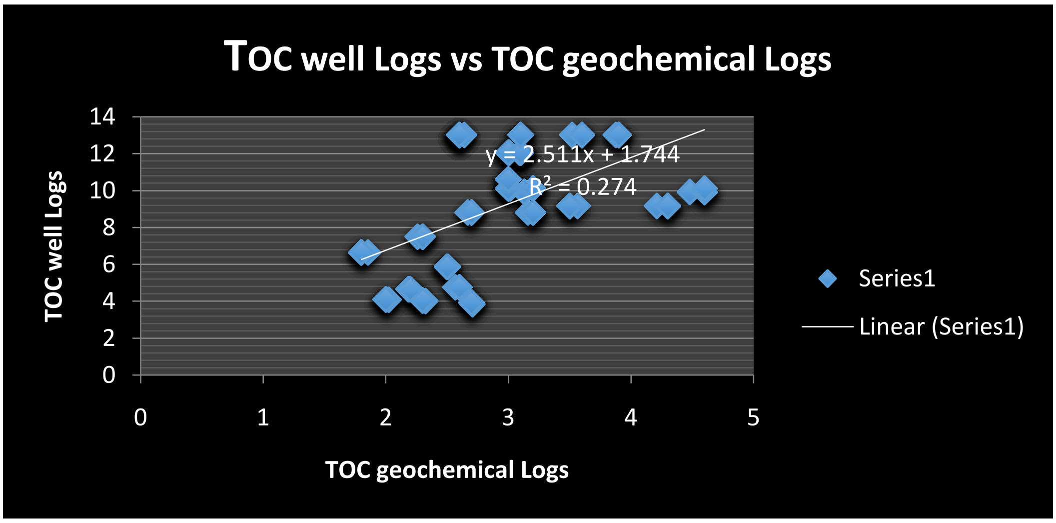


Figure 8:TOC well Logs vs TOC geochemical Logs. The graph shows the level of deviation between the two data set, however the deviation level is still within acceptable limits of error, hence the TOC estimated from well log is reliable

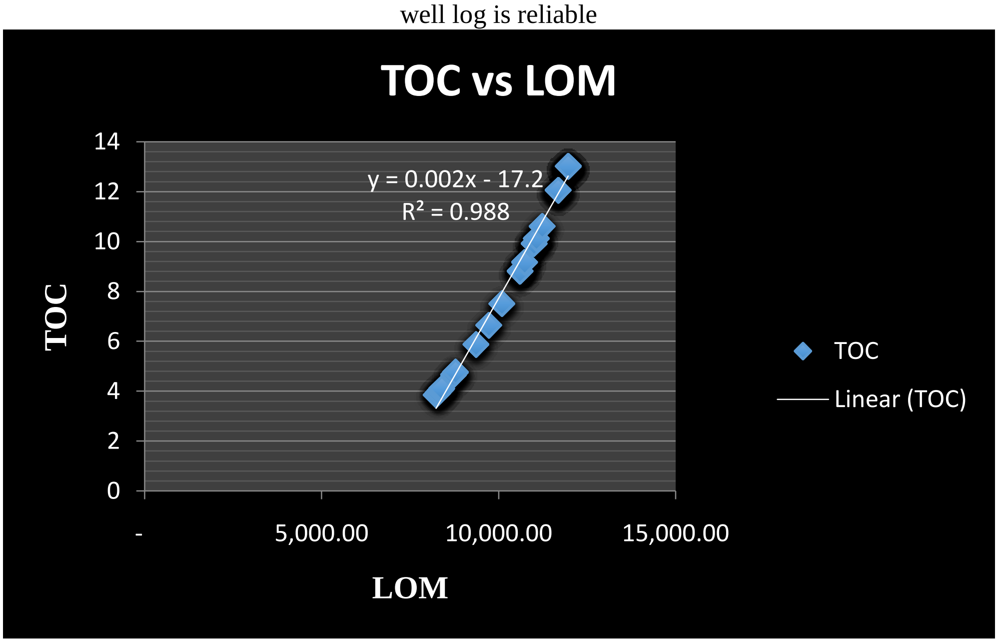


Figure 9: TOC vs LOM from Well Logs data. The graph shows a linera relationship between the two dataset

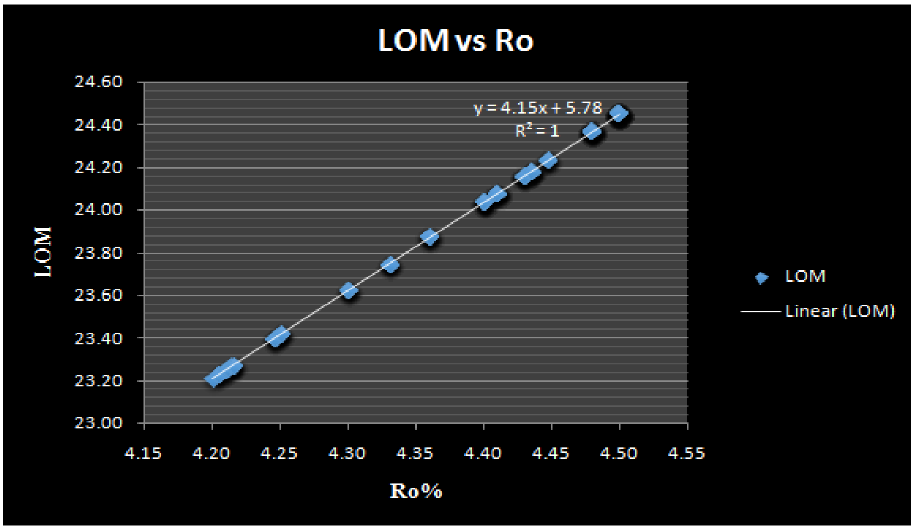


Figure 10: LOM vs Ro% (Well Log data)

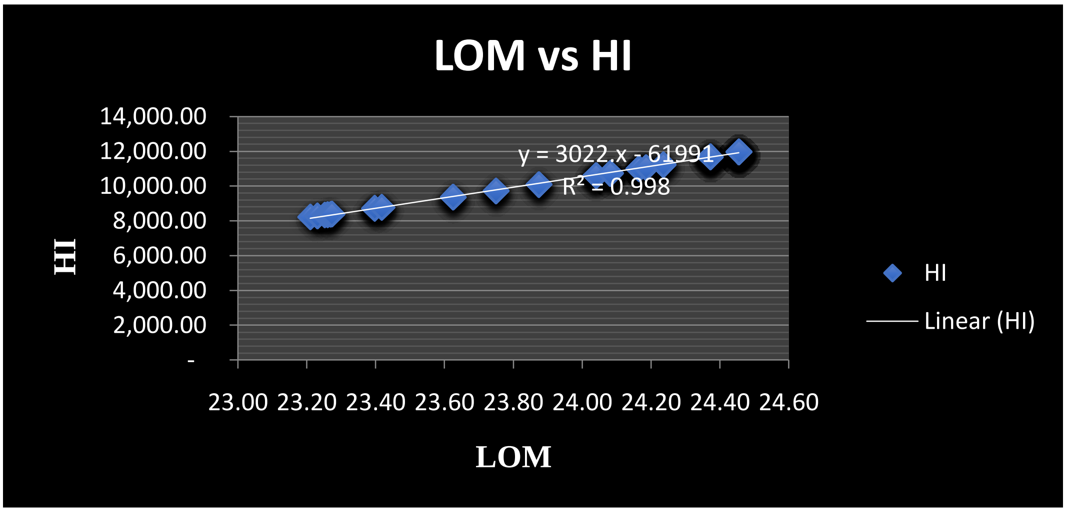


Figure 11: LOM vs HI (Well Log data). Graph shows that level of organic maturity (LOM) increases with the hydrogen index (HI) content, and vice versa.

VII. Conclusion

We have estimated TOC content from source rock in pologbene 002 well using well logs, and computed other parameters like Level of organic maturity (LOM), hydrogen index (HI) and amount of hydrocarbon yield through pyrolysis (S2). A comparison of the TOC estimated from well logs was compared to that of geochemical logs show that TOC from well logs shows a steady increase with increase in LOM, which implies that as LOM increases, TOC increases and this is a function of the increase in vitrinite reflectance within the interval. This method of TOC estimation, can be used to calculate TOC in real time from wire line logs on a well site as drilling is being done; this will serves as a faster method in reducing time analysis and help reduce cost if done appropriately.

References

[1] Allen, D., (1970). "Sediments of the modern Niger Delta: A summary and review". Society of Economic Paleontologists and mineralogists (SEPM): Special Publication, no. 15, p. 138 – 151.

[2] Anders D., (1991). "Geochemical Exploration Methods in Merrill RK (ed): Source and Migration Processes and Evaluation Techniques. Tulsa: AAPG 89-95.

[3] Bardsley, S.R., and Algermissen, S.T., (1963). "Evaluating oil shale by log analysis. Jpt 81 -84. Trans AIME 228".

[4] Bob Cluff., (2011). "Practical use of core data for shale petrophysics".

[5] Burke, K. C. B., Dessauvagie T.F., and Whiteman A. J., (1971). "The Opening of the Gulf of Guinea and the Geological History of the Benue Depression and Niger Delta". Nature phys. sci. Vol. 233, no.38, p. 51 – 55.

[6] Bustin, R. M., (1988). "Sedimentology and characteristics of dispersed organic matter in Tertiary Niger Delta: Origin of source rocks in a deltaic environment. AAPG Bulletin, Vol. 72, p. 277 – 298.

[7] Doust, H., and E. Omatsola., (1989). "Geology of the Niger delta". AAPG Memoir 48; p. 201-238.

[8] Doust, H. and Omatsola, E., (1990). "Niger Delta, in Edwards, J.D, and Santogrossi, P.A., eds"; Divergent/passive Margin basins; AAPG Memoir 45; p. 239–248.

[9] Ejedawe, J.E.,(1981). "Patterns of incidence of oil reserves in Niger Delta Basin". AAPG Bulletin, Vol. 65, p. 1574-1585.

[10] Evamy, B.D., Haremboure J., Kammerling R., Knaap W.A., Molloy F.A., and Rowlands P.H., (1978). "Hydrocarbon habitat of tertiary Niger Delta". AAPG Bulletin; Vol.62, no.1, p. 1 – 39.

[11] Heidarrifard, M., (2011). "TOC prediction from well logs using Δlog R method and neural network technique in the northern Dezful, Embayment" Zagros, Iran. The 2nd South Asian Geoscience Conference and Exhibition.

[12] Hood et al (1975). "Organic Metamorphism and the generation of Petroleum", The American Association of Petroleum Geologist. Bulletin vol 59, Pg 6.

[13] Kulke, H., (1995)."Regional petroleum geology of the world Part II": Africa, America, Australia and Antarctica: Berlin, Gebruder Borntraeger, p.143-172.

[14] Lambert-Aikhionbare, D.O. and Ibe, A.C., (1984). "Petroleum source-bed evaluation of the Tertiary Niger Delta: discussion". AAPG Bulletin, Vol. 68, p. 387-394.

[15] Oomkens, E., (1974). "Lithofacies relations in late Quaternary Niger delta complex. Sedimentology, Vol.21, p. 195-222.

[16] Ojo, J.I., Akpabio, I. and Frielings dosf, J, (2012). "Burial and Thermal History modeling and petroleum potential evaluation of the northwestern Niger Delta, Nigeria", Communicacoes Geologica's 99, 2, 53 – 59.

[17] Peters K.E., (1986). "Guidelines for evaluating Petroleum Source rock using programmed pyrolysis," AAPG Bulletin 70, no 3, 318-329.

[18] Passey, Q.R., Creaney S., Kulla J.B., Moretti F.J., Stroud J.D., (1990). "A practical model for organic richness from porosity and resistivity logs". AAPG Bull., Dec.

[19] Short, K. C. and Stauble A.J., (1967). "Outline of geology of Niger Delta". AAPG Bulletin, Vol. 51, no.5, p. 761 - 779.

[20] SPDC Warri Geoservice Department 2012.

[21] Stacher, P., (1995). "Present understanding of the Niger Delta hydrocarbon habitat". In: M.N. Oti and G.Postma (eds), Geology of deltas; A.A.Balkema, Rotterdam; p. 257 – 267.

[22] Weber, K.J. and Daukoru, E.M., (1975). "Petroleum Geology of the Niger Delta". Proceedings of the 9th World Petroleum Congress, Tokyo, Vol. 2.

IOSR Journal of Applied Geology and Geophysics (IOSR-JAGG) is UGC approved Journal with Sl. No. 5021, Journal no. 49115.

Kaka Abiodun "Source Rock Analysis Using Well Logs In Western Niger Delta." IOSR Journal of Applied Geology and Geophysics (IOSR-JAGG) 6.2 (2018): 70-85.