Δ log R technique in quantitative estimation of source rock in Ameshi-001 well, Niger Delta

Benson Akinbode Olisa
Department of Applied Geophysics,
The Federal University of Technology, Akure
(akinbode7@yahoo.com)

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Abstract: Total organic matter (TOC) estimation in the Niger Delta employed laboratory methods which gives elements of uncertainty because analyses were not done insitu. In addition, laboratory analysis is time consuming and very costly. The purpose of this analysis is to test if Δ log R technique could be applicable in the analysis of organic rich rocks in the Niger Delta. Four basic quantitative methods for determination of total organic carbon (TOC) from well logs are available, which include, directly from regression of core TOC versus core bulk density, Δ log R technique, based on the petro physical response model and an artificial neural network. Δ log R technique is employed in this study to identify source rock and estimate TOC. The reservoir interval was removed by gamma ray (GR) log curves. Carefully scaled resistivity and sonic curves were placed in the same track in log panels. In organic lean rocks (sandstone), the two curves are on top of each other, but in organic rich rocks (shale) the two curves are separated. Results shows that out of twelve sampling points, six calculated TOC were comparable with the laboratory results at corresponding depths.

Keywords: Δ log R, gamma ray (GR), organic-rich-rocks, Total organic matter (TOC), estimation.

I. INTRODUCTION

Ameshi-001 well is located on longitude 6^0 13' and latitude 4^0 02' in the Niger Delta, Fig. 1.

The Formations found in the Niger Delta are mostly unconsolidated sand and shale Fig. 2, in which it is often not possible to take cores or to make drill stem tests (Ablewhite *et al.* 1985).

Source, reservoir and cap rocks are essential elements in hydrocarbon exploration (Dow 1974). The source rock is estimated by measuring the amount of total organic carbon (TOC) present in shale. In the laboratory, methods of Rock-eval analysis, visual kerogen inspection and gas chromatography are used among others to estimate the TOC. The TOC estimated in the laboratory has an element of uncertainty, because it cannot be determined insitu. Besides these, sampling of the core or sidewall samples is very costly. Well logs for analysis are readily available and samples could be analyzed insitu.

The four basic quantitative methods for determination of total organic carbon (TOC) from well logs are directly from regression of core TOC versus core bulk density, ΔlogR technique presented by Passey (1990), based on the petrophysical response model and an artificial neural network, Liu et al. (2013).

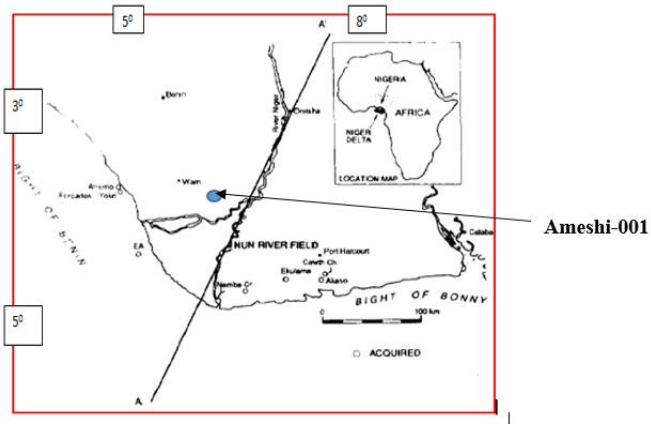

Figure 1: Location of Ameshi-001 in the Niger Delta.

Passey *et al.* (1990) developed a method for the estimation of TOC using Resistivity/porosity log overlay refer to as Δ Log R. This method is adopted to estimate TOC values for shale of an interval in Ameshi-001(Eocene section), Fig. 2, and using Table 1 obtained from borehole data of Ameshi-001 in the Niger Delta.

Table 1: Rock-Eval and geophysical data of Ameshi-001.

Depth (ft)	Pzone	TOC Wt %	Resistivity Ωm	Sonic µsec/ft	ρ Kg/cm³	GR API
7237	F5700	2.0	18.8	106.2	18.9	18.8
7376	F5700	1.2	18.8	116.8	26.1	26.1
7596	F5700	1.9	163.9	97.9	164	163.9
8276	F5700	2.6	45.8	99.6	44.7	44.6
8674	F5700	2.4	21.1	104.8	21.2	21.1
8744	F5700	3.1	15.4	121.6	15.4	15.4
9142	F5700	2.3	13.5	114.5	13.6	13.5
9191	F5700	1.9	15.0	105.3	15	15.0

II. Materials and Methods

Material

The Eocene section (Fig. 2 and Table 1) of Amesh-001, coincides with biostratigraphic zone F5700. It ranges from 7239-9191ft. in the well. Rock-Eval data as well as geophysical logs, resistivity, sonic and gamma ray values obtained from borehole logging were also incorporated in the data.

Methodology

Resistivity/Sonic logs Overlay

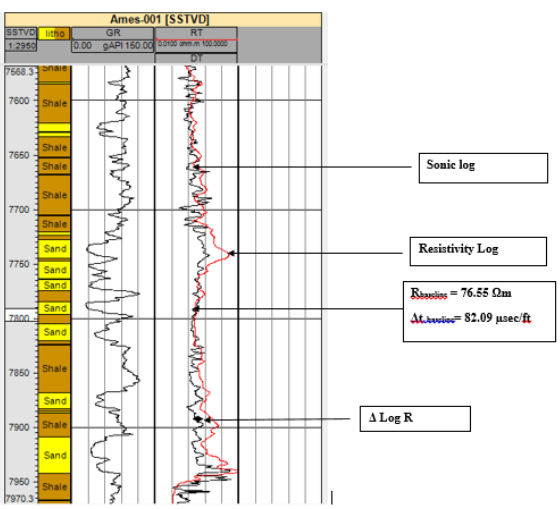

Figure 2: Ameshi-001 well.

Δ Log R technique requires logs overlay (Fig. 2) and availability of maturity data (vitrinite reflectance). Organic matter is concentrated in the shale sections. To estimate TOC from Resistivity/Sonic logs overlay, gamma ray (GR) curve was used to separate the shale from sand (Track 1). Then in track 2 the resistivity log (black curve) was overlaid on the sonic log (red curve). There are two areas in the curves. Those areas where the curves are separated indicated source rocks (organic rich shale) and those areas where they meet were the non-source rocks (sand).

R_t and Δt were obtained where the curves were separated, and $R_{baseline}$, and $\Delta t_{baseline}$ were obtained where the curves coincide.

TOC calculations followed two steps, Passey *et al*. (1990). The first is calculation of Δ Log R from equation 1 at each sampling point in the well.

$$\Delta \text{ Log } R = \log_{10} (R/R_{baseline}) + 0.05*(\Delta t - \Delta t_{baseline}) \quad \ldots\ldots 1$$

0.05 is the relative scaling of the two curves.

The value of $R_{baseline}$ and $\Delta t_{baseline,}$ are 76.55 Ωm and 82.09 µsec/ft respectively, estimated at depth 9040ft (2755m).

The second step is calculation of TOC from equation 2

$$TOC = \Delta \log R * 10^{(2.297-0.1688*LOM)} \quad \ldots\ldots 2$$

The maturity indicator is LOM (Level of organic metamorphism), which is (vitrinite reflectance). Vitrinite reflectance data were not available. Therefore assumptions were made for the vitrinite reflectance, Table 2 in (Passey *et al.*, 1990). By substituting LOM 1, 2……..11, 12, 13 in equation 2, the best LOM that describes the data in Table 2 is LOM 2 and was therefore used for its computation, confirming the source rock in the Niger delta as immature.

Table 2: Maturity Analysis (Passey *et al.* 1990)

Level of organic metamorphism (LOM)	Interpretation
1-5	Immature
6-10	Mature
Above 10	Gas producing

III. RESULTS AND DISCUSSION

The calculated TOC ranges from 1.96- 3.54wt%.
Based on the shape of the resistivity and sonic logs, the source rock resembles a mature source rock. The resistivity and sonic curves show increase in values (Passey *et al.* 1990), Table 3. The result confirmed the values obtained from the laboratory. Bustin (1988) gave an average values of 2.5wt% in the Niger Delta Eocene section.

Table 3: Estimated TOC at Ameshi-001 well.

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Depth (ft)	R_t (Ωm)	Δt (µsec/ft)	TOC(LOM=10) (wt%)
7237	18.8	106.2	2.06
7376	18.8	116.8	2.59
7596	163.9	97.9	3.54
8276	45.8	99.6	2.08
8674	21.1	104.8	2.02
8744	15.4	121.6	2.78
9142	13.5	114.5	2.40
9191	15.0	105.3	1.96

IV. RESULT VALIDATION

Eight sampling points were available for analysis based on the rock-eval data (Tables 1 and 3). Five points showed good result with the calculated data corresponding to the measured data (7237ft, 8674ft, 8744ft, 9142ft and 9191ft). The other data points did not correlate (Table 4). The results show that there is need to test other methods of TOC analysis in the Niger Delta.

Table 4: Validation of calculated TOC result of Ameshi-001

Depth (ft)	Resistivity R_t (Ωm)	Sonic Δt (µsec/ft)	TOC(LOM=10) wt%	Rock-eval (Lab TOC) wt%
7237	18.88	106.28	2.065136185	2.01
7376	18.88	116.88	2.595136185	1.21
7596	163.9	97.94	3.542584259	1.99
8276	45.82	99.62	2.084063031	2.61
8674	21.19	104.82	2.022312541	2.49
8744	15.4	121.64	2.787675702	3.1
9142	13.59	114.52	2.408031025	2.32
9191	15	105.31	1.965950359	1.92

V. CONCLUSION

Δ log R technique could be used to quantitatively estimate source rock in the Niger Delta. The method is very fast and cost effective. Out of eight tested sampling points, results obtained from five points showed corresponding values between the calculated result and the laboratory result. It is hereby recommended that Δ log R technique should be used to estimate TOC in the Niger Delta, because it faster and cheaper than the laboratory methods.

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