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Organic Geophysics of Petroleum Source Rock and Depositional Environments in the Niger Delta, Nigeria

Dr. Benson Akinbode Olisa

Lecturer, Department of Applied Geophysics, Federal University of Technology, Akure, Nigeria

Matthew Ademola Adeniran

Graduate Assistant, Department of Geology, Ekiti University, Ado Ekiti, Nigeria

Abstract:

Seven wells regionally spread in the Niger Delta was used to analyze source rock potential in the Niger Delta. The total organic carbon (TOC) was calculated from well logs (sonic log). Highest TOC, up to 9.1 wt. %, occur in Agbada Formation in Abraka-001. The TOC range from 0.6 wt. % in Angalalei-001 to 36 wt. % in Olomoro-001. These indicate fair to good source rocks. Eocene TOC (1.8 - 7.8 wt. %) and Oligocene (2-39 wt. %) rocks show good source rock quality. Miocene rock contains (0.6 - 1.5 wt. %) and this indicates poor to good source rocks. Based on the resistivity (maturity indicator) and temperature (geothermal) map, the area is divided into low and high resistivity and temperatures values. Akata Formation has very high resistivity (158Ωm) around (Ameshi-001). This indicates that Ameshi-001 contains oil in the Eocene.

Keywords: Eocene, maturity, source-rock-potential, good-source-rock, resistivity

1. Introduction

1.1. Source Rock

A source rock is fine grained sediment rich in organic matter that could generate crude oil or natural gas after thermal alteration of kerogen in the Earth's crust, (Crain 2013). The oil or gas could then migrate from the source rock to more porous and permeable sediments, where ultimately the oil or gas could accumulate to make a commercial oil or gas reservoir.

If a source rock has not been exposed to temperatures of about 100 °C, it is termed a potential source rock. If generation and expulsion of oil or gas have occurred, it is termed an actual source rock. The terms immature and mature are commonly used to describe source rocks and also the current state of the kerogen contained in the rock.

1.2. Depositional Environments of Source Rocks and Kerogen Types

Gas-prone source rocks contain hydrogen poor organic matter (type III) and tend to occur predominantly in the delta plain/lagoonal environment.

Oil-prone source rocks comprise sediments that are rich in organic carbon and contain organic material sufficiently hydrogen-rich to convert mainly to oil during thermal maturation. The organic materials that are generally richest in hydrogen include marine plankton and anaerobic bacteria. All these materials are oil-prone and are classified as type I or type II kerogen, but they are usually deposited in different depositional environments (Creaney and Passey 1993).

1.3. Depositional Environments of the Niger Delta

The depositional environments of the Niger Delta are the Akata, Agbada and Benin Formations, Figure 1.

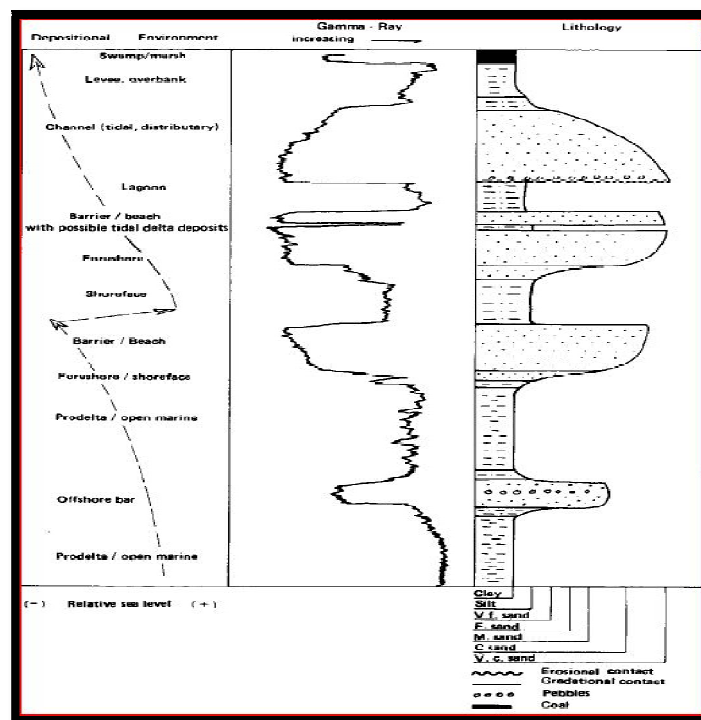


Figure 1: Depositional Environments of the Niger Delta (Bustin, 1988)

1.4. The Akata Formation

The Akata Formation is characterized by a uniform shale development. The shale in general is dark grey, in some places sandy or silty, and contains, especially in the upper part of the Formation, plant remains and some mica. Toward the top of the formation where it grades into the overlying Agbada Formation, some thin sandstone lenses may occur. The fauna generally is very rich. Planktonic Foraminifera may make up more than 50 per cent of the microfauna. The benthic foraminiferal assemblages indicate deposition of the shale on a shallow-marine shelf, Bustin, (1988).

1.5. The Agbada Formation

The Agbada formation is characterized by the alternation of sandstone and sand bodies with shale layers. The sequence penetrated in Agbada-2 may be divided into two units: an upper one in which sandstone-shale alternations are abundant and shale intercalations relatively thin; and a lower unit in which the shale units become more prominent and in some places are thicker than the intercalated sandstone of sand bodies. The sandstone percentage ranges from 75 in the upper unit to 50 in the lower unit.

The shale beds are grey and dense at the base; they become markedly sandy and silty upward and grade into the overlying sand and sandstone bodies. Commonly they contain a microfauna which is best developed at the base of the shale units and becomes sparse or absent in the upper part. This indicates an increase in the rate of deposition in the front of the approaching delta, Short and Stauble, (1967).

1.6. The Benin Formation

The sequence penetrated by Elele-1 is predominantly (more than 90 %) sandy with few shale intercalation; these become more abundant toward the base. The sand and sandstone are coarse-grained, commonly very angular and pebbly to very fine-grained. In general they appear to be very poorly sorted. The grains are sub-angular to well-rounded. The sand and sandstone are white or, because of a limonite coating, yellowish brown. Lignite occurs in thin streaks or finely dispersed fragments; hematite grains and feldspars are common, Short and Stauble, (1967). The shale is greyish brown, sandy to silty, and contains some plant remains and dispersed lignite. Composition, structure, and grain size of the sequence indicate deposition in a continental, probably upper deltaic environment. The sand and sandstone may represent point-bar deposits, channel fills, or natural levees, whereas the shales may be interpreted as backswamp deposits and oxbow fills. The age of Benin Formation indicates an early Miocene to recent.

1.7. Source Rock Analysis

Source rock can be described by quantity of organic matter (TOC), the quality of organic matter and the maturity, Passey et al, (1990). Table 1 contains the data used to describe the source rock quantity, quality and maturity.

1.8. Quantity and Quality of Organic Matter

The TOC range from 0.6 wt. % in Angalalei-001 to 36 wt. % in Olomoro-001 (Tables 2). These indicate fair to good source rocks. Eocene TOC (1.8 - 7.8 wt. %) and Oligocene (2-39 wt. %) rocks show good source rock quality. Miocene rock contains (0.6 - 1.5 wt. %) indicates poor to good source rocks.

Well	Formations	GR API	Resistivity (Ωm)	Sonic $\mu sec/ft$	Density Kgm^3	GR(TOC) wt %	Sonic(TOC) wt %	T ^o F	T ^o C
Polo-001	Benin	85		130	2.23	4.4	4.4	121	49
	Agbada	82	9.98	100.2	2.43	4.2	3.5	164	73
	Akata	78	2.83	100.1	2.5	4.16	3.3	190	88
Umut-002	Benin	94	29	118	2.23	3.17	3.74	135	57
	Agbada	88	14	97	2.32	3.18	3.08	143	61
	Akata	86	4.8	95	2.33	3.16	3.03	146	63
Okwe-001	Benin	83.5	15	-	2.19	4.31	-	-	-
	Agbada	87.4	13.6	-	2.28	4.5	-	160	71
	Akata	91	4.3	-	-	-	-	169	76
Abraka-001	Benin	70	16	-	-	-	-	-	-
	Agbada	83	59	-	-	9.1	-	173	78
	Akata	-	-	-	-	-	-	-	-
Ame-001	Benin	85	46.7	-	-	4.33	-		
	Agbada	90	76	-	-	4.5	-		
	Akata	75	158	-	-	4.04	-		
Angalalei-001	Benin	-	-	-	-	-	-		
	Agbada	45	31	-	-	-	-		
	Akata	-	-	-	-	-	-		
Olomoro-001	Benin								
	Agbada								
	Akata								

Table 1: Variation of TOC with Depositional Environments Data in the Wells

Map of TOC distribution in Akata Formation (Eocene rock) shows that TOC concentration is low in Umutu-002 and Abraka-001 and high around Pologbene-001 and Ameshi-001 (Figure 2). This indicates that there are good quality source rocks in Pologbene-001 and Ameshi-001.

Wells	TOC (wt%)	TOC Range (wt%)	Resistivity (Ωm)	Ωm Range (Ωm)	Sonic $\mu sec/ft$	Sonic Range $\mu sec/ft$	Density g/cm^3	Density Range g/cm^3	GR (API)	GR Range (API)
Good										
P480 Okw-1	11.6	1-77	1.1	0.7-2.2	ND	ND	2.2	1.8-2.4	81	35-145
P470 Okw-1	4.1	2.4-6	2	1.4-3	ND	ND	2.3	2.1-2.6	74	0.88-100
P580 Olomoro-001	36	12-50	21.6	12-48	109	99-119	0.82	0.76-0.9	50.8-101	84.7
Fair										
P720 Egw-1	0.55	0.53-0.57	ND	ND	131	85-150	ND	ND	76	48-87
Poor to good										
P680 Egw-1	1.8	0.4-5.8	3.7	3-5	126	90-140	ND	ND	91	29-106
Fair to good										
P670 Egw-1	0.77	0.66-1.1	2.5	1.5-9	114	106-122	ND	ND	ND	ND
Fair										
P740 Anga-1	0.6	0.5-0.7	ND	ND	87	70-100	ND	ND	30.8	28-34
Poor to fair										
P680 Anga-1	0.6	0.3-0.7	ND	ND	90	80-100	2.3	2.13-2.4	73	30-98

Table 2: Source Rock Anomalies and Well Log Data

The gamma ray (GR) is high around Okwefe-001, (Figure 3). Since concentration of GR corresponds to TOC concentration, there is a good quality source rock in Okwefe-001.

The structure contour map on top of Akata Formation closes around Okwefe-001 (Figure 4). This confirms that Okwefe-001 is a good prospective area for source rock.

Oligocene section is represented by the Agbada Formation. The GR (API) is very high in the Ameshi-001 (Figure 5). The GR (TOC) is high in the Abraka-001 (Figure 6).

The structure contour map on top of Agbada Formation closes on the Angalalei-001 and Abraka-001 (Figure 7). This shows that Abraka-001 contains very good quality source rock in the Oligocene.

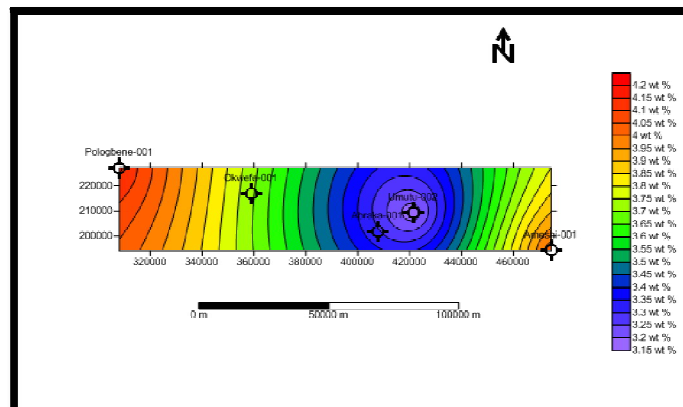


Figure 2: TOC Variations in Akata Formation

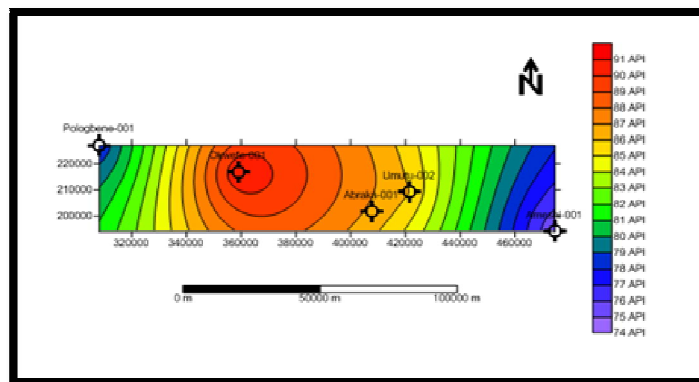


Figure 3: GR variations in Akata Formation

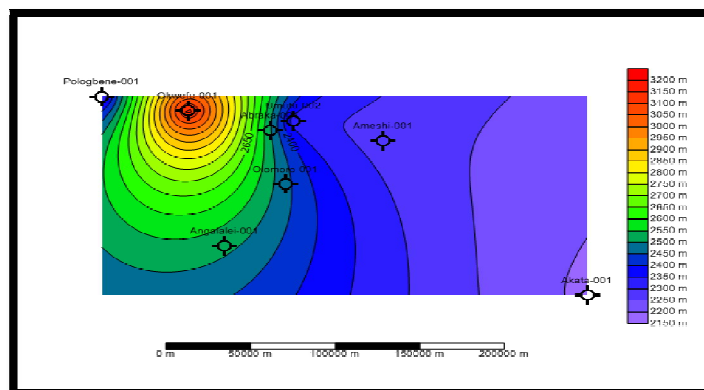


Figure 4: Map on Top of Akata Formation

1.9. Maturity of Source Rock

Based on the resistivity (maturity indicator) and temperature (geothermal) map, the area is divided into low and high Resistivity and temperatures values. Akata Formation has very high resistivity (158Ωm) around (Ameshi-001) (Figure 8). This indicates that Ameshi-001 contains oil in the Eocene.

In the Oligocene (Agbada Formation), the resistivity is highly concentrated in the Abraka-001 and Ameshi-001, 59Ωm and 76Ωm, respectively (Figure 9 and Table 1). The temperature variation indicates that Abraka-001 has very high geothermal temperature of 173°F (78°C). Even though these wells have very high resistivity, their temperatures are very low (below 100°C). This sediment is interpreted as immature (Figure 10).

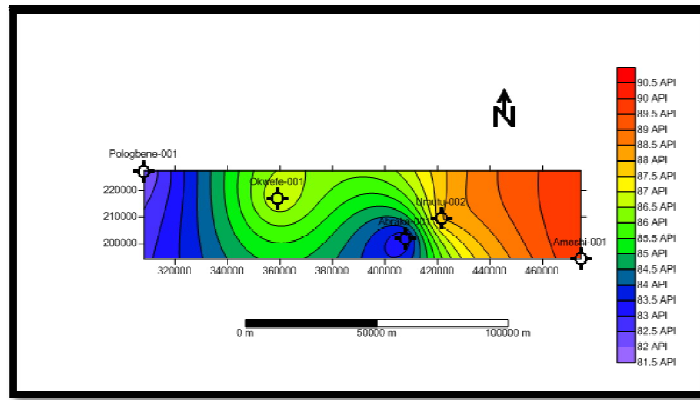


Figure 5: GR Variations in Agbada Formation

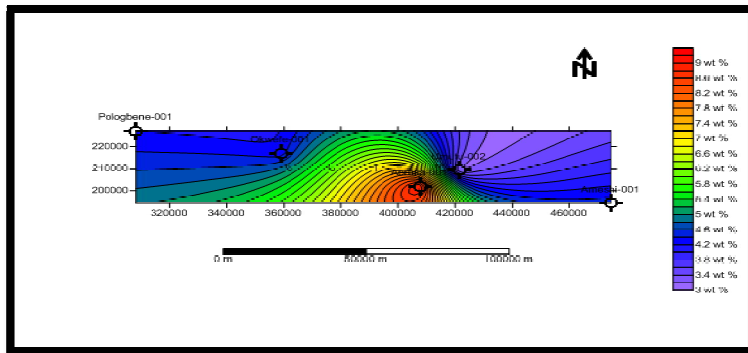


Figure 6: GR (TOC) Variations in Agbada Formation

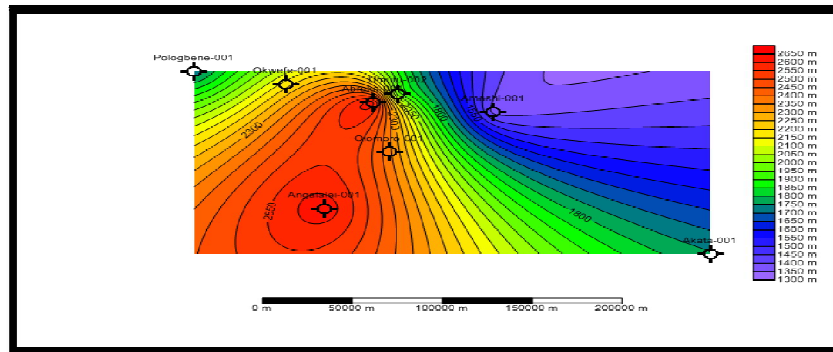


Figure 7: Map on Top of Agbada Formation

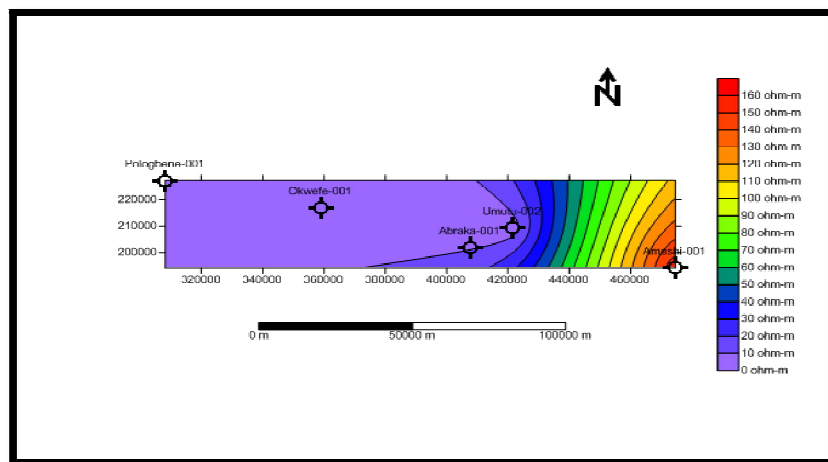


Figure 8: Resistivity Variations in Akata Formation

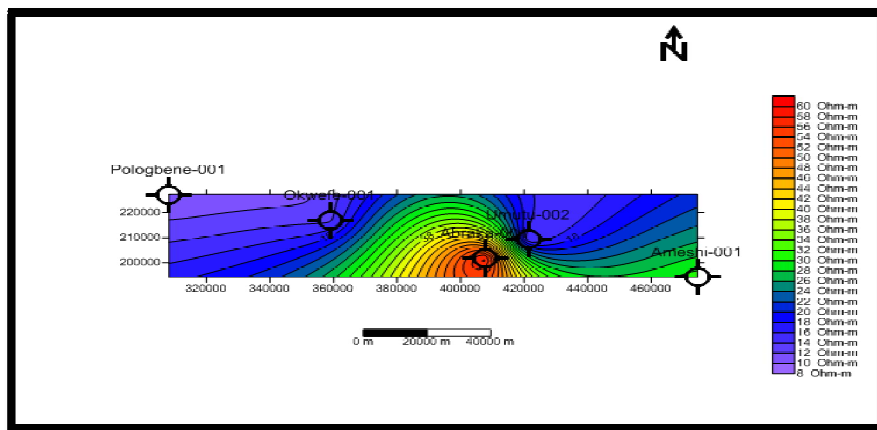


Figure 9: Resistivity Variations in Agbada Formation

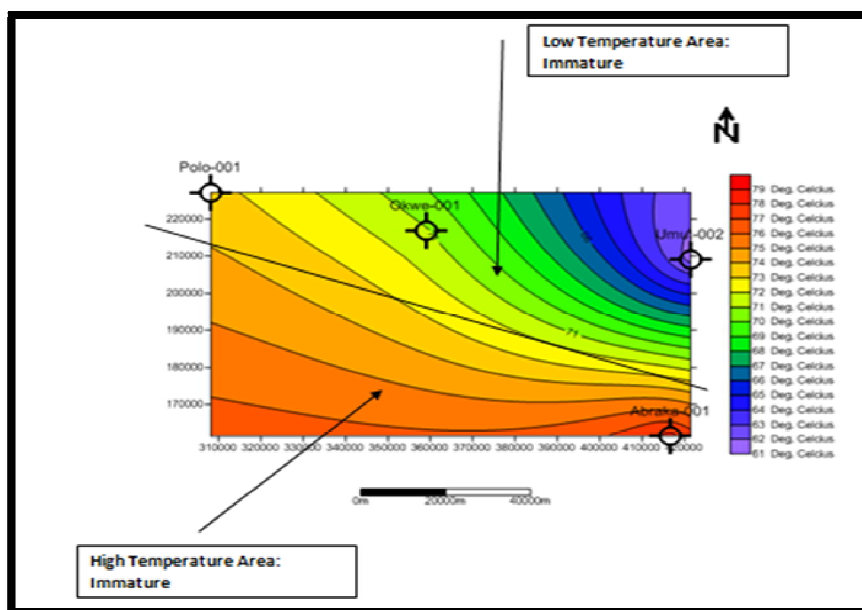


Figure 10: Temperature Variations in Agbada Formation

2. Conclusion

Organic geophysics of the Niger Delta source rocks indicates that the area is a major hydrocarbon generation. In some intervals, fair to poor source rocks do exist. Source rock quality, assessed on the total organic carbon content, is good, but fair to poor quality source rocks do exist in some intervals. Paleo-temperature data (Borehole temperature, BHT) data indicate that temperature in the basin have been relatively cool. Temperature up to 176°F (78°C) were reached in the source beds, an indication that kerogen would have reached early stages of hydrocarbon generation. Akata Formation has very high resistivity (158Ωm) around (Ameshi-001). This indicates that Ameshi-001 contains oil in the Eocene.

3. References

- i. Crain (2013), Cain geophysical handbook, <https://spec2000.net>.
- ii. Creaney S. and Q. R. Passey, (1993), Recurring Patterns of Total Organic Carbon and Source Rock Quality within a Sequence Stratigraphic Framework: Bulletin American Association Petroleum Geologists v. 77, p. 386-401
- iii. Bustin, R. M., (1988), Sedimentology and Characteristics of Dispersed Organic Matter in Tertiary Niger Delta: Origin of Source Rocks in a Deltaic Environment: Bulletin American Association Petroleum Geologists v. 72, p. 277-298.
- iv. Short, k. C., and A. J. Stauble, (1967), Bulletin American Association Petroleum Geologists V. 51, P. 761-779.
- v. Passey Q. R., S. Creaney, J. B. Kulla, F. J. Moretti and J. D. Stroud, (1990), A Practical Model for Organic-Richness from Porosity and Resistivity Logs: Bulletin American Association Petroleum Geologistsv. 74, no. 12, p. 1777-1794.