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EVALUATION OF OIL SHALE POTENTIALS OF CARBONACEOUS SHALES IN THE TERTIARY OGWASHI-ASABA FORMATION, ANAMBRA BASIN, SOUTHEAST NIGERIA

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Abstract- *The oil shale potentials of carbonaceous shales in the Tertiary Ogwashi – Asaba Formation, Anambra basin (SE Nigeria) have been evaluated in this study. Samples were collected from three localities of Azagba Ogwashi (AZ), Oba (OB) and Ihioma (IH), where the Ogwashi Asaba Formation lithostratigraphic units are well exposed. Fieldwork studies reveal that the general lithologies in the studied localities consist of cyclic successions of lignite, carbonaceous shales, silty shales, mudstones, siltstones and sandstones, interpreted as deltaic deposits. Laboratory analyses include total organic carbon (TOC) determination and Rock – Eval pyrolysis studies of collected samples. TOC results indicate average values for AZ, OB and IH samples, to be respectively 12. 10wt.%, 5.01wt.% and 8.16wt.%. Rock – Eval pyrolysis studies include, Tmax, S2 and S2/TOC, calculated for Hydrogen Index (HI). Tmax average for AZ, OB and IH are 427°C, 418°C and 420°C respectively. Average S2 yields for AZ, OB and IH are respectively 24.42mgHC/g rock, 4.13mgHC/g rock and 8.53mgHC/g rock. Graphs of S2 vs TOC and Tmax vs HI show that the AZ samples plot within the fields of prolific, primary source rock, with the capability of yielding mixed oil and gas. The OB and IH samples plot within the fields of good, secondary and very good, primary source rocks respectively, with the capabilities of yielding gas only. Based on the obtained results, it is concluded that only the carbonaceous shale from the Azagba Ogwashi study locality has the potential for oil shale.*

Keywords: Oil shale, Carbonaceous shales, Ogwashi-Asaba Formation, Anambra Basin, Tertiary period, Southeast Nigeria

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1. INTRODUCTION

The onshore sedimentary basins of Nigeria comprise Cretaceous to Tertiary grabens which form part of a series of rift basins in central and west Africa. The Anambra basin, a sub-basin in the Benue trough, together with the neighbouring Abakaliki basin (anticlinorium) to the east (Fig. 1), contains formations with fossil energy units. Notable among these are the sub-bitumineous coal-bearing Mamu and Nsukka formations (Cretaceous) and the lignite-bearing Ogwashi -Asaba Formation (Tertiary).The focus of this study is on the carbonaceous shales in the Ogwashi-Asaba Formation. The Ogwashi Asaba Formation, generally, consists of lignite, carbonaceous shales, mudstone, shales, claystone, siltstones and cross-bedded sandstones (Okezie and Onuogu, 1985). It is the carbonaceous shales in the formation that are evaluated, in this study, for oil shale potential.

According to Eugster (1985), oil shales are fine-grained, organic rich sedimentary rocks, that are buried within shallow depths and are capable of yielding liquid oil-like hydrocarbons when exposed to temperatures of up to 500-600°C .The organic contents in oil shales are virtually insoluble in organic solvents but are responsible for yielding hydrocarbons when oil shales are exposed to the temperature range mentioned above. Ekweozor and Unomah (1990) reported the occurrence of oil shales in the Lokpanta town (Lokpanta oil shale) of the Abakaliki anticlinorium in the lower Benue trough. The occurrence of oil shale in neighbouring Abakaliki basin prompted the present investigation

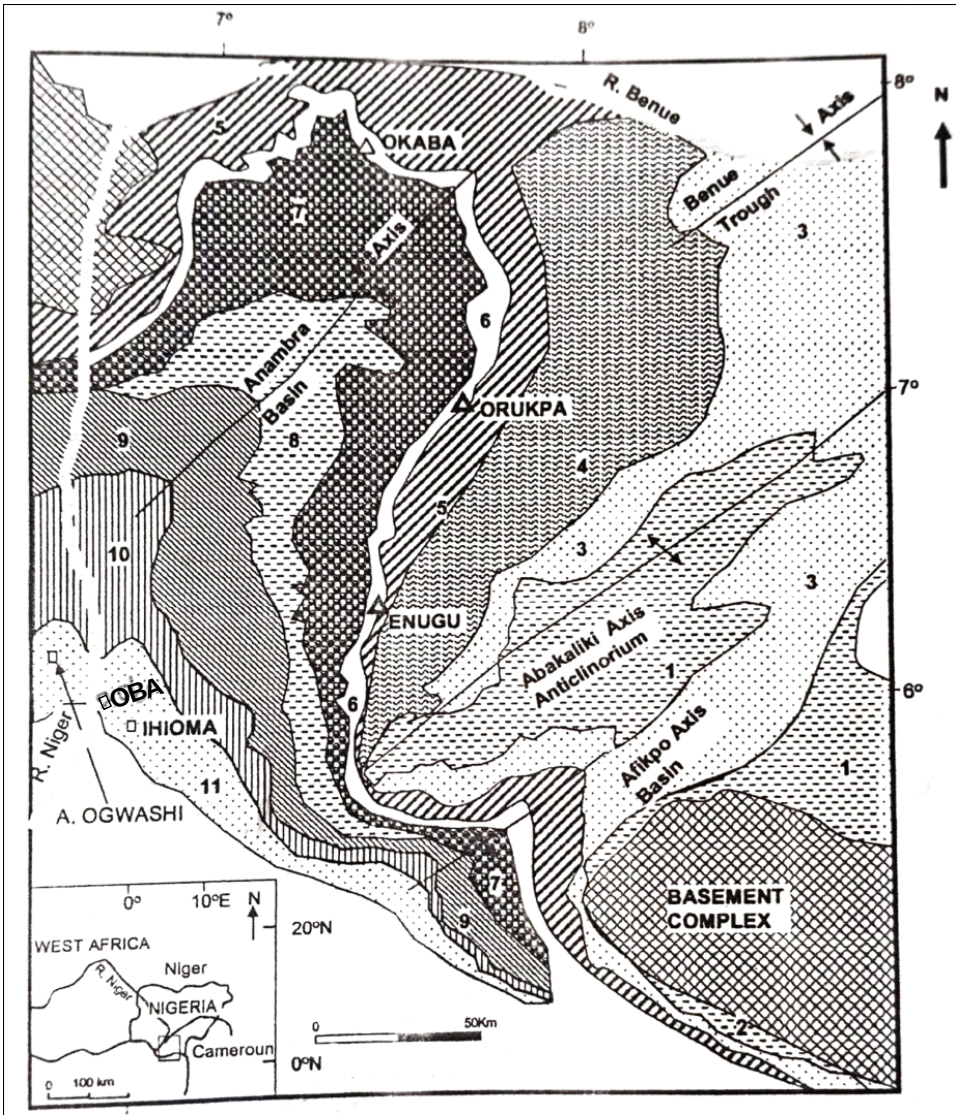


Fig. 1. Generalized geological map of SE Nigeria (boxed area of inset) showing the locations of the study areas (Azagba Ogwashi, Oba and Ihioma) within the Ogwashi-Asasba Formation(11).

2. LITERATURE REVIEW

The Anambra basin located in the southern part of Nigeria, is one of the sub-basins in the lower Benue trough. It covers an area of about 40,000km² and bounded in the north by part of the Precambrian basement complex, to the northwest by Bida basin, towards the southeast by the Abakaliki anticlinorium and to the south by the Tertiary Niger delta. The infilling of the Anambra basin occurred in two main sedimentary cycles (Petters, 1977).

The first cycle was an extremely short-lived event, commencing with the marine transgression during the Upper Campanian, when the Nkporo Shales were deposited with its equivalent the Enugu Shales. A major deltaic influence was developed at this stage, resulting in the deposition of the Owelli Sandstones. The regressive phase comprised the major Maastrichtian deltaic off lap sequences overlying the Nkporo Formation represented by the Mamu Formation (Lower Coal Measures), the Ajali Sandstones and the Nsukka Formation (Upper Coal Measures). These consist of shales, siltstones, sandstones and coal of fluvio - deltaic to fluvio –estuarine environments.

The second cycle started with an extensive Lower Palaeocene transgression, when the Imo Shales were deposited. The Eocene regressive phase includes the Ameki Formation, Nanka Formation and Nsugbe Formation, while the Olicene – Miocene regressive phase included the Ogwashi Asaba Formation (Reyment, 1965, Petters, 1977; Agagu and Adighije, 1983).

The Ogwashi Asaba Formation, basically, consists of a succession of cross - bedded sandstones, grit, carbonaceous mudstones, shales and interbedded lignite seams (Okezie and Onuogu, 1985). The Ogwashi- Asaba Formation is underlain by the Eocene Ameki Group (comprising Nsugbe, Nanka and Ameki formations). The Ameki Group is underlain by the Palaeocene Imo Shale. The Imo Shale is underlain by the Danian Nsukka Formation.The Maastrichtian Ajali Sandstone and Mamu Formation underlay the Imo Shale and Nsukka Formation. The Campanian Nkporo/Enugu Shale form the basal unit (Regment, 1965) (Table 1).

Table 1. Stratigraphic succession in the Anambra, basin (modified Reyment, 1965; Akande et al., 1992 and Offodile, 2002)

BASIN	PERIOD	EPOCH	STRATIGRAPHY		SEA MOVEMENT
Anambra	Tertiary	Oligocene - Miocene	Ogwashi - Asaba		Regression
		Eocene	Ameki Group	Nsugbe Fm. Nanka Fm. Ameki Fm.	Transgression
		Palaeocene Danian	Imo Shales		
			Nsukka Fm		
	Cretaceous	Maastrichtian	Ajali Sandstones		Regression
			Mamu Fm		
		Campanian	Nkporo/Enugu Shales		Transgression

3. METHODOLOGY

3.1 Fieldwork

A total of fourteen (14) carbonaceons shales samples were collected from three (3) localities where the Ogwashi – Asaba Formation was exposed. The localities are Azagba Ogwashi (Ibaliba Stream valley, 6°31'E,6°14'N), Oba (Akpuchala Stream valley,6° 51'E, 6° 03'N) and Ihioma (Iyiokwu Stream valley, 7°01'E, 5°49'N) (Table 2)

Samples were taken from the bottom, middle and top parts of each exposed carbonaceous shale bed along the stream sections. Other lithologies that are interbedded with the carbonaceous shales were identified and noted accordingly. The lithostratigraphic section for each locality was prepared right in the field.

The above field procedures were carried out using measuring tape, chisel, hammer, hand shovel, masking tape, permanent marker, pencil, field notebook, sample bag, etc.

Table 2. Sample Number, formation, and location of samples collected

Sample No	Description	Formation	Locality	Longitude, Latitude
1H-03 T	Carbonaceous shales	Ogwashi-Asaba	Iyiokwu	7°01'E, 5°0 49'N
1H-03 M	''	''	Stream valley	
1H-03 B	''	''	Ihioma, Imo State	
1H-05 T	''	''		
1H-05 M	''	''		
1H-05 B	''	''		
OB-01	Carbonaceous shales	Ogwashi-Asaba	Akpuchala	6°51'E,6°03'N
OB-02	''	''	Stream valley	
OB-05T	''	''	Oba, Anambra	
OB-05M	''	''	State	
OB-05B	''	''		
			Ibaliba Stream	6°31'E,6°14'N
AZ-02T	Carbonaceous shales	Ogwashi-Asaba	valley, Azagba Ogwashi,	
AZ-02M	''	''	Delta State	
AZ-02B	''	''		

3.2 Laboratory work

The collected samples were evaluated in the laboratory for their total organic carbon (TOC) contents and hydrocarbon yields.

The TOC evaluation procedures involve crushing the samples into powdered form and weighing approximately 100mg of the crushed samples from each locality. The powdered and weighed samples were put into oven- sterilized crucibles where approximately 1ml of hydrochloric acid (HCl)

was added to each weighed sample to remove carbonates. The samples in the crucible were then allowed to drain off the HCl for about 6 hours before being transferred into an oven set at 60°C and left overnight following overnight drying TOC were then measured using LECO TOC analyzer instrument.

Rock – Eval pyroanalysers (Espitallie et al., 1984), was used to evaluate the hydrocarbon yields of the samples. The main Rock – Eval parameters evaluated were S1 and S2 yields and thermal maturity (Tmax). The Hydrogen Index (HI) values were calculated from S2/TOC

4. RESULTS AND DISCUSSION

4.1 RESULTS

Fieldwork

The results of the fieldwork at the three studied localities (Azagba Ogwashi, Oba and Ihioma) are as shown in the lithologic sections of Fig. 2 (a-c). The sections reveal that the three localities, consists of lignites, carbonaceous shale, mudstone, siltstones and fine-grained

sandstone. The Recent Benin Formation, which generally overlies the Ogwashi - Asaba Formation, consists of ferrugenized, poorly sorted, medium – coarse - grained sandstones.

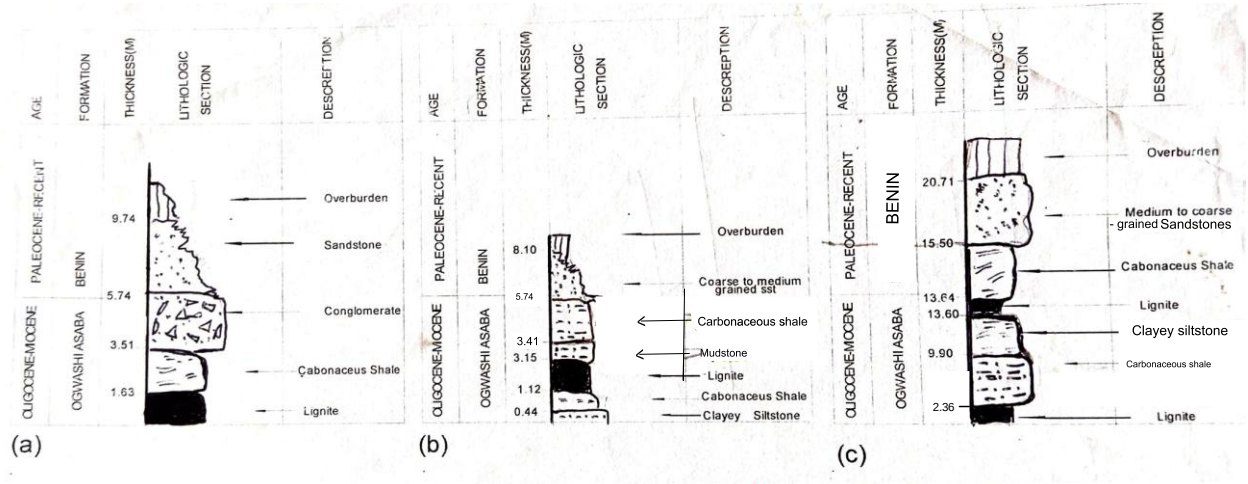


Fig 2 (a) Lithostratigraphic succession of Azagba Ogwashi study locality

(b) Lithostratigraphic succession of Oba study locality

(c) Lithostratigraphic succession of Ihioma study locality

Total Organic Carbon

The total organic carbon (TOC) results for the analysed samples, generally range from 4.97 to 12.12wt% (mean=7.88wt.%). The average TOC values of the samples from Azagba Ogwashi, Oba and Ihioma are respectively 12.10wt.%, 5.01wt.% and 8.16wt.%

Rock – Eval Pyrolysis

Rock – eval pyrolysis results reveal that the Tmax values for the analysed samples range from 414 to 428°C (mean=421°C). The average Tmax values for the Azagba Ogwashi, Oba and Ihioma samples are 427°C, 418°C and 420°C respectively. S1 yields values range from 0.76 to 2.61 mgHC/g rock (mean=(.43mgHC/g rock). S2 yields range from 4.06 to 24. 43mgHC/g rock (mean=10.37mgHC/g rock). Hydrogen Index (HI) values range from 80.08 to 201. 90mgHC/g TOC (mean=117.16mgHC/g TOC).These results are presented in Table 3.

Table 3. Total organic carbon (TOC) and Rock – Eval pyrolysis results for the studied samples

S/NO	Sample	location	TOC (wt.%)	Tmax (°C)	S1 (mgHC/g rock)	S2 (mgHC/g rock)	HI (mgHC/g TOC)
1	AZ-02T	Azagba	12.12	426	2.61	24.41	201.80
2	AZ-02M	Ogwashi	12.10	428	2.59	24.43	201.90
3	AZ-02B		12.09	427	2.57	24.41	201.90
4	OB-01		5.01	414	0.79	4.14	82.47
5	OB-02	O	4.99	418	0.78	4.18	83.76
6	OB-05T	B	4.97	420	0.76	4.18	84.10
7	OB-05M	A	5.07	419	0.82	4.06	80.08
8	OB-05B		5.01	418	0.80	4.07	81.24
9	IH-03T	I	8.14	420	8.52	9.91	104.67
10	IH-03M	H	8.11	422	8.61	9.97	106.17
11	IH-03B	I	8.12	419	8.49	9.90	103.92
12	IH-05T	O	8.21	422	8.44	9.82	102.80
13	IH-05M	M	8.16	421	8.69	10.02	106.50
14	IH-05B	A	8.18	417	8.62	9.89	102.93

4.2 DISCUSSION

Fieldwork

The exposed lithofacies in the Ogwashi Asaba Formation, as examined in the studied localities, is essentially a cyclic succession of lignite, carbonaceous shale, mudstone, siltstones and sandstone [Fig.2 (a-c)]. This indicates that the Ogwashi Asaba Formation is a sequence of cyclothern (= a repetitive coal - bearing sequence). It (the formation) is also interpreted as deltaic deposits.

Total Organic Carbon

The total organic carbon (TOC) of a sedimentary rock is a direct measurement of its organic richness. Sufficient quantity of organic matter (OM) must be present in a sedimentary rock before it can qualify as a potential petroleum source rock. The common prerequisite TOC value for a source rock is 0.5 TOC (wt.%) (Tissot and Welte, 1984; Petters and Cassa, 1994).

From the results of the average TOC values of the samples from the three localities the sample from Azagba Ogwashi study locality has the highest Average TOC content

(12.10wt.%). This reveals that the Azagba Ogwashi carbonaceous shale has the potential to yield good quantity of oil - like hydrocarbons. However all the analysed samples gave TOC values that fall within the class of excellent source rock (>4 TOC wt.%)

Rock – Eval Pyrolysis

Rock – Eval pyrolysis is routinely used to estimate the hydrocarbon generation potentials of prospective source rocks by providing information about their thermal maturity, organic matter type and quantity (Petters, 1986). The thermal maturity of a potential source bed is a factor which assesses the ability of the rock to generate or expel hydrocarbon. Tmax is the temperature that corresponds to the maximum hydrocarbon generation (S2) during pyrolysis.

From the results of the studied samples, the average Tmax of 427°C, 418°C and 420°C for Azagba Ogwashi, Oba and Ihioma respectively, reveal that the Azagba Ogwashi carbonaceous shale is slightly more mature than those of Oba and Ihioma. This implies that larger quantities of Hydrocarbon can be extracted from the Azagba Ogwashi carbonaceous shales than for the Oba and Ihioma samples.

Source quality determination on graph of S2 against TOC reveal that the carbonaceous shales samples from the Azagba Ogwashi study locality are prolific source rocks (Fig.3). The Oba and Ihioma samples plots on the S2 against TOC graphs reveal that they are good, secondary source rock and marginally very good, primary source rock respectively (Fig.3). Plots of Tmax against HI reveal that the Azagba Ogwashi samples marginally yield mixed oil and gas, while the Oba and Ihioma samples yield gas only (Fig. 4).

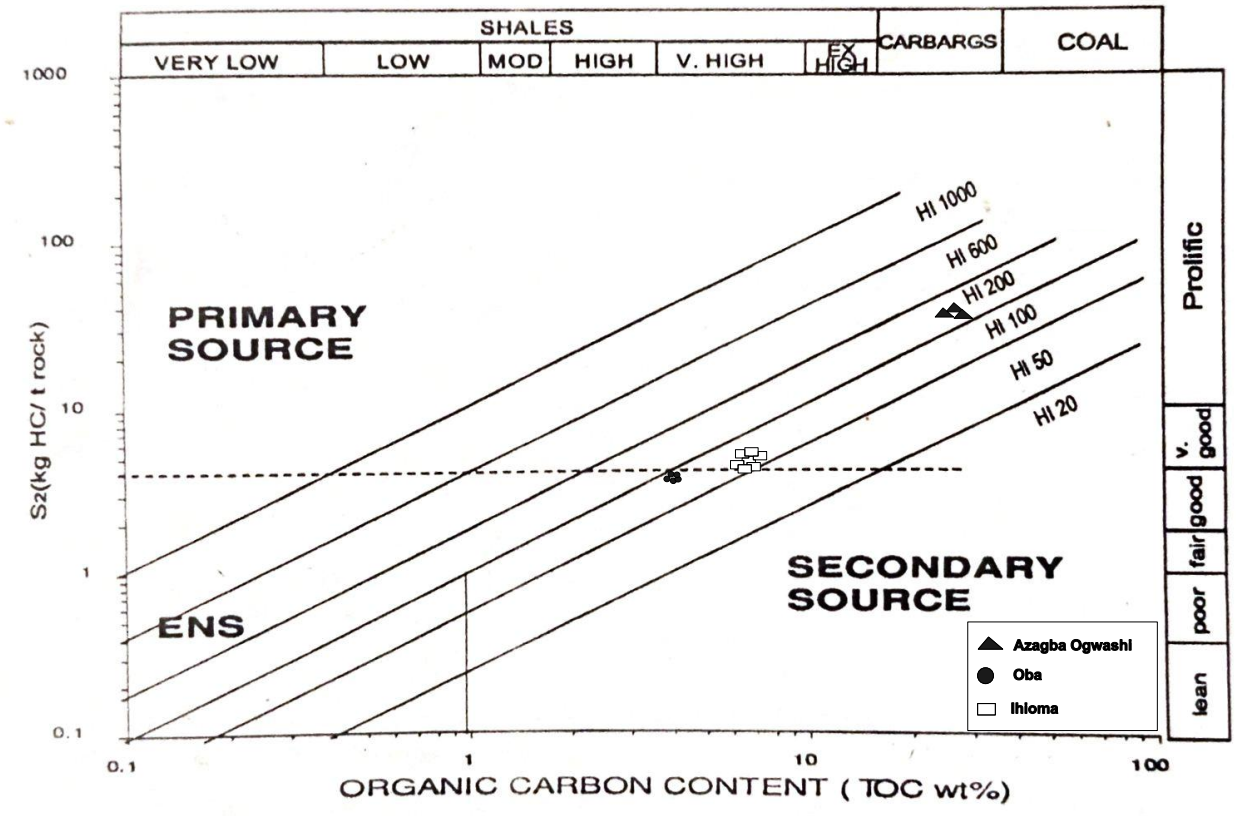


Fig. 3. Source rock quality information on the basis of S2 yields (kg HC/t rock) versus TOC (wt %) for the AzagbaOgwashi Oba and Ihioma carbonaceous shales. Modified after Burwood *et al*., 1995).

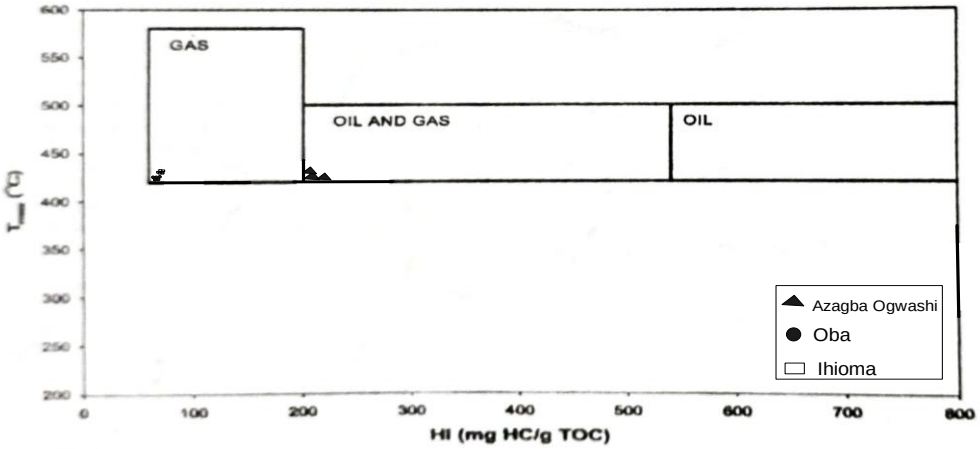


Fig 4. Plot of Tmax against Hydrogen Index (HI) for carbonaceous shales of Ogwashi Asaba Fm. The plot shows that only the Azagba Ogwashi carbonaceous shales yield mixed oil and gas while the Ihioma and Oba shales yield gas only

5 CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

The carbonaceous shale samples from the Azagba Ogwashi study locality, marginally yield mixed oil and gas, while the Oba and Ihioma samples yield gas only. Based on these results, it is concluded that only the Azagba Ogwashi study locality of the Ogwashi - Asaba Formation has carbonaceous shale of potential oil shale quality.

5.2 RECOMMENDATIONS

Based on the result of this research work, I recommend that large-scale exploration for potential oil shale deposits, within the Anambra basin, be embarked upon by the Federal Government of Nigeria. This is because it is my earnest hope that this study should stimulate inquiries that may eventually lead to exploration for oil shale deposits within the Anambra basin; which if discovered in exploitable quantity, and under favorable environmental and economic conditions, may culminate in their exploitation.

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