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EVALUATION OF HYDROCARBON POTENTIAL OF SHALE OUTCROPS IN THE FLANKS OF ANAMBRA BASIN

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ABSTRACT

The research aim is to determine the organic productivity and hydrocarbon potential of the exposed shale lithology along Uzebba road and Bawa hills near Auchi, Southwest Nigeria.Twenty two (22) shale samples were acquired from the study area; twelve (12) from the outcropping section along Uzebba road, and the remaining ten (10) samples obtained from Bawa hills. The samples were then subjected to organic geochemical analysis using Total Organic Carbon (TOC) and Rock Eval Pyrolysis to evaluate the organic enrichment, organic quality and thermal maturity respectively.Total Organic Carbon (TOC) content of the twenty-two samples ranges from 3.42 – 4.88 wt. %, affirming a high organic enrichment. Shale samples from Uzebba segment and Bawa hills falls within the Type I and Type II Kerogen class respectively. The former is indicative of immature – sub mature organic matter with no hydrocarbon formation prospect whilst the latter exhibits great hydrocarbon (oil) generation potential Thermal maturation assessment for both samples apparently ranges from immature to mature organic matter. From the Rock-Eval pyrolysis result, all the twenty-two (22) samples were confirmed to be organically enriched. However, the type I kerogen of Bawa at favourable geothermal gradient can potentially serve as a suitable source rock for petroleum generation.

Keywords: maturation, organic matter, petroleum, rock-eval pyrolysis, source rock, maturation.

INTRODUCTION

The petroleum-generation assessment of prospective source rock speedily facilitates the location of hydrocarbon traps at the exploration stage (Samuel *et al*., 2015), and accurate depiction of source disposition on map can greatly reduce the exploration risk (Demaison, 1984). The hydrocarbon prospect of a source rock is fundamentally a function of its degree of organic enrichment, kerogen type and more importantly, thermal maturation, which according to Lecompte *et al*., 2010 is the determinant factor for oil or gas yield from the source. In other words, quantity and nature of petroleum generated depend on the quantity and type of the organic matter deposited in the source rock (Lafargue 1998). Thus, investigation of source rock characteristics as well as the level of appropriateness of geologic conditions (such as the chronology and geothermal gradient) is imperative for oil and gas production.

Various laboratory methods are applicable for source rock evaluation, but preferentially, Rock–Eval pyrolysis was aptly adopted due to its wide acceptability as a standard petroleum exploration technique for source rock characterization in the oil industry (Lafargue *et al*., 1998). It is an extensively used universal laboratory evaluation method for oil and gas exploration in sedimentary basins (Behar *et al*., 2001). Rock-Eval is the commonest employed device, but in this case, monitors the resulting gas evolution of samples, rather than the conventional weight measurement. It simulates in a transient period, the geological process (es) that had operated upon the rock at various depth. The present work is centered on the evaluation of hydrocarbon prospects of shale outcropping in the study area with a view to determining the organic enrichment, evaluating the petroleum potential as well as to ascertainthe thermal maturation stage of the rock.

Location of the Study Area

The study area lies between longitude 05° 48ᴵE to 06° 21ᴵE and latitude 06° 31ᴵ N to 07° 09ᴵN covering an area extent of about 150sq.km, with an elevation ranging between 243.9 to 426.6m above mean sea level (Fig. 1). It is readily accessible via a network of interconnected minor roads.

Noticeable topographic features in the area are hills and plains in its northern and southern part. The elevated northern portion is largely contorted by jagged hills at several places. Southerly towards the coastal area, the study area is approximately planar (coastal plain). Apparently, the relief of the area drops markedly from the northern portion in Akoko Edo to the coastal part of Ilaje (Ese Odo, less than 15m above sea level) in the south.

Drainage pattern is dendritic. The major rivers flow through the sedimentary rocks in deeply incised valley aligned in a north eastern – south western direction into the coastal lagoons. These rivers include the Owena, Oluwa, Oni, Ogbese and Ose. Geo-morphological units of the creek and riverine areas include sand ridges, lagoons, swamp flats, and creeks.

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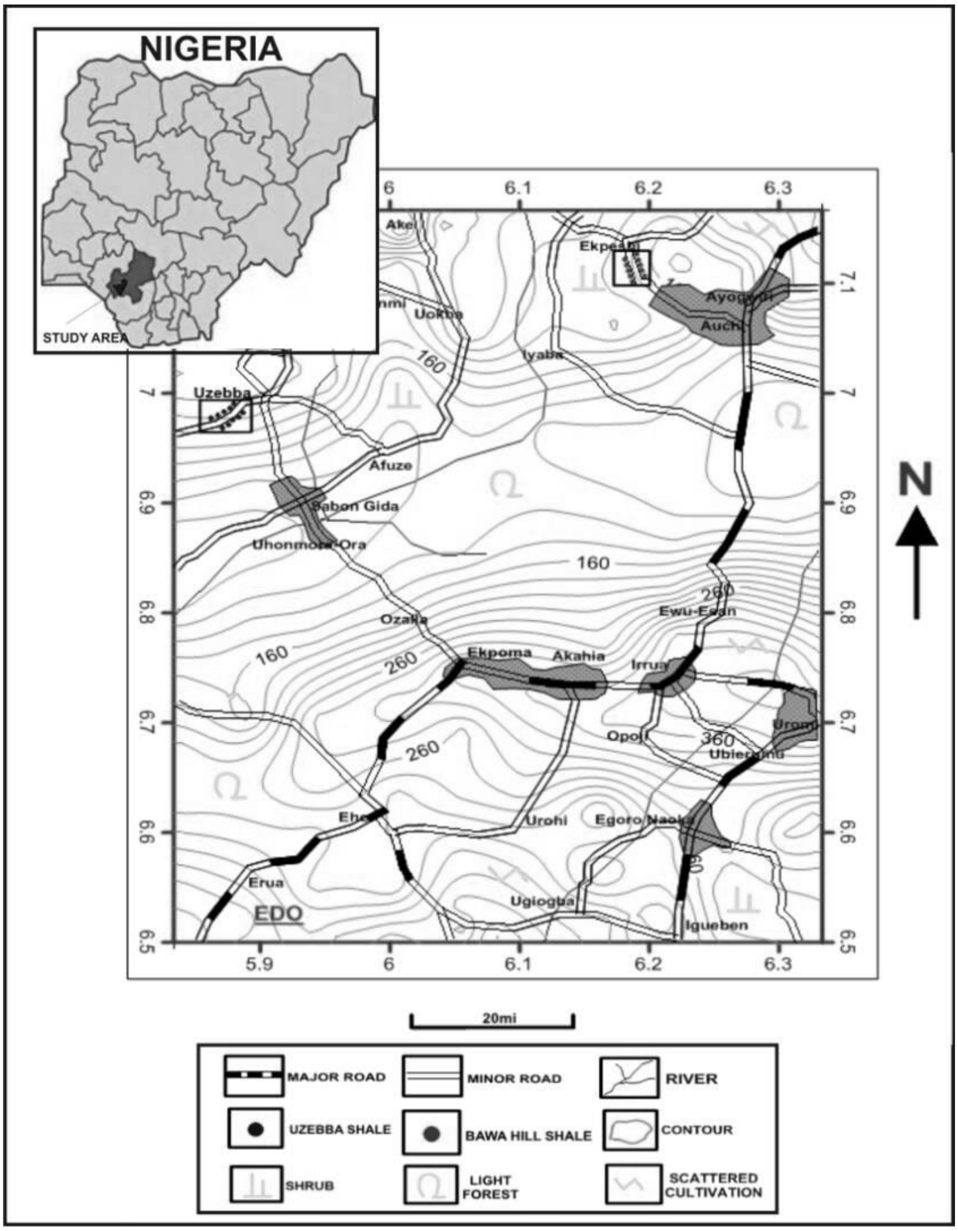

Fig. 1: Location Map of the Study Area

REGIONAL AND LOCAL GEOLOGY

The rift hypothesis proposed for the evolution of major sedimentary basins in West Africa (Fig. 2) are supported by several reputable scholars, notably Cratchley and Jones, 1965; McConnell, 1969 and Hospers, 1971; establishing the Benue trough as the failed arm of Y-shaped R-R-R junction rift. Anambra basin, situated on the southwestern extreme of the Benue trough, originated in response to the later stresses associated with the rifting of Gondwana in the Cretaceous –an event that resulted in separation of African and South America plates, and the opening of South Atlantic (Burke, *et al.*, 1972)..The formation of the basin is widely believed to be initiated during the Santonian by a stress-induced regional block displacement (subsidence) in the Lower Benue trough. During this orogenic period, the depocentres in the Abakaliki region were concurrently translocated, deformed and uplifted (Okogbue, 2005).

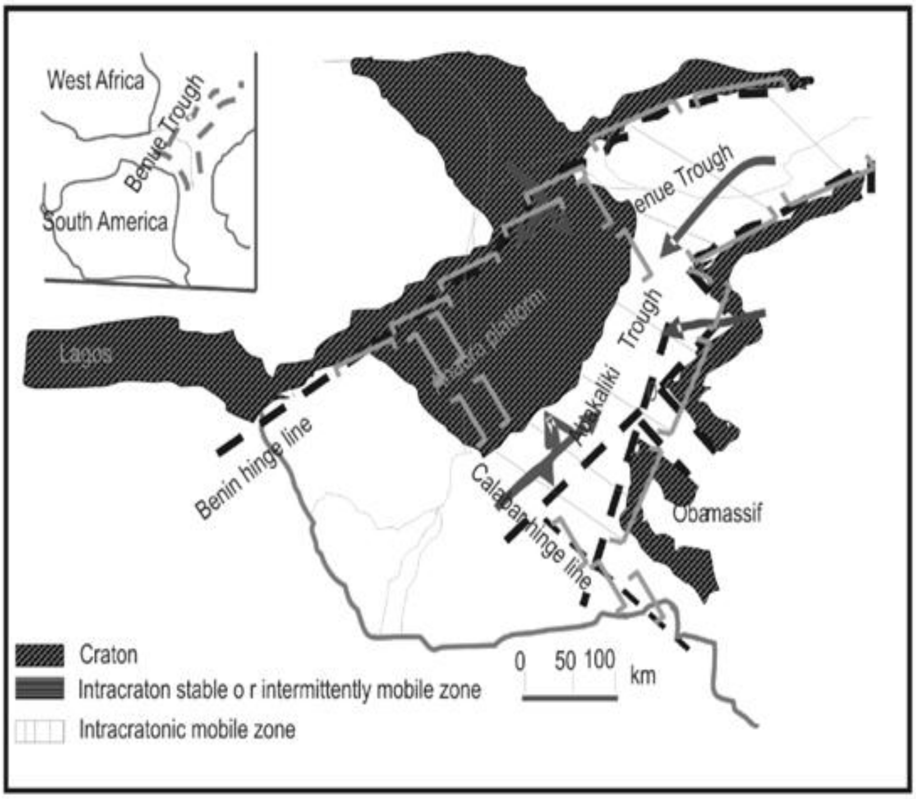

Fig 2: Megatectonic Rame and Controls on Sedimentation in the Anambra Basin in the Campanian-Eocene Time (after Murat, 1972).

The major sources of grits supply into Anambra basin are the bordering Abakaliki anticlinorium and the folded Benue belt. Sedimentary pile varies spatially within the basin, with a maximum delineated thickness of approximately 4800m which is broadly packaged into two lithostratigraphic units (Table 1), namely; Nkporo group and the coal measures which accompanied a major transgressive and regressive depositional phase respectively. Nkporo group is largely constituted by prodeltaic shales with relatively lesser
occurrence of sands and limestones. The fluvio-deltaic and marginal marine deposits accommodated within the coal measures exhibit a cyclothermic progradational sedimentation pattern (Nwajide, 2006). Another major trangressive episode in the Paleocene deposited deltaic sediment that leveled the basin with an extensive pro deltaic facies onlap over its southern end.Thereafter, an extensive offlap wedge (Niger-delta) was amassed by the succeeding regression in the Cenozoic. The lithostratigraphic succession of Anambra basin is summarily presented using the table below.

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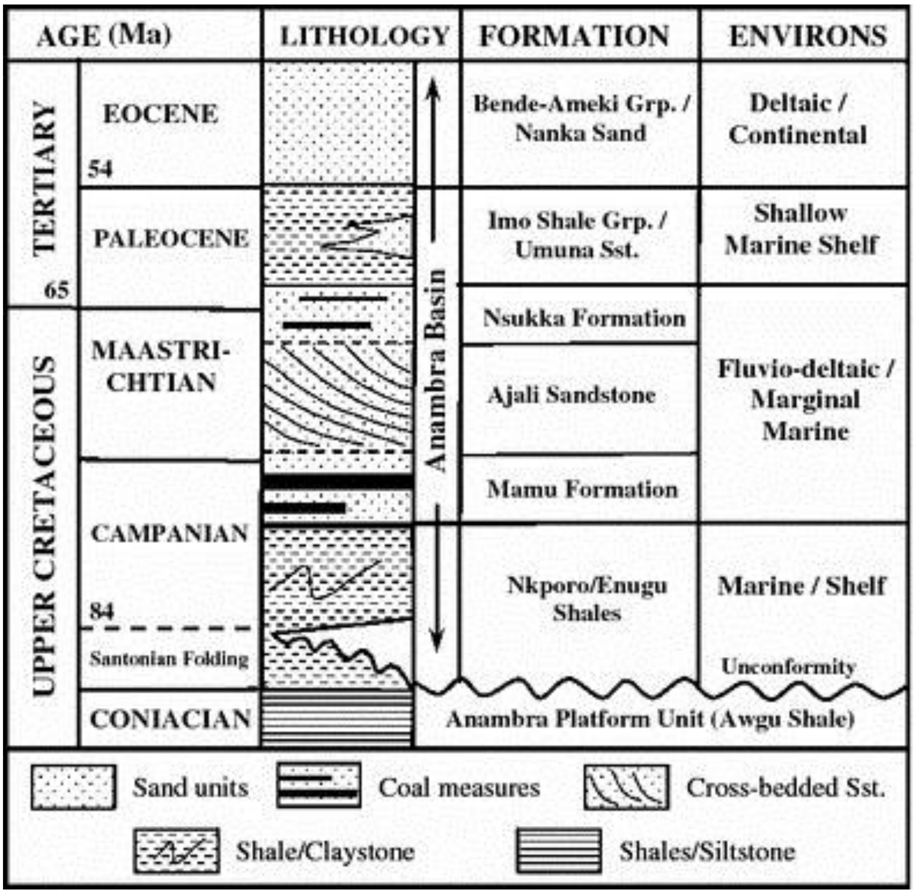
Table 1: Lithostratigraphic Succession in the Anambra and the Niger Delta Basins. (After Reyment, 1965: Short and Stauble, 1967; Maron, 1969.)



Sedimentation in Enugu and environs began with the non-conformable deposition of the Albian (Lower Cretaceous) fluvio group – consisting of shales, sandstones and siltstones, but however became severely deformed during the Santonian thermo-tectonic event, resulting in partial uplift (Abakaliki anticlinorium) and subsidence (Afikpo synclinorium) of this stratigraphic group.

In the Upper Campanian to Early Maastrichtian, the synclinorium accommodates Enugu shales and Awgu sandstones along the same area which are collectively classified as Mamu formation.This Formation consists of coarse sandstones with shale intercalation and fragments of ironstones, ferruginized shales and sandstones.

The upliftment of the Tertiary sequence gave rise to the Enugu – Okigwe escarpment. The approximately 1000m shale and clay dominated Paleocene formation conformably overlie the upper coal measure within the Enugu area.The prototype outcrop of investigation is underlain by two formations: The Enugu Shale (Campano-Maastrichtian) and the Mamu Formation (Maastrichtian).

Materials and Methods

Field mapping exercise conducted in the study area was complemented by a follow-up laboratory analyses for research aim accomplishment. The mapping phase involved the collection of twenty two shale samples in the area from both the exposed sections in Bawahills (Fig. 3)and near

Uzebba (Fig. 4)at a lateral and vertical interval of 5m and 3m (Fig. 5 and 6) respectively.

Fig 3: Shale facies exposed at Bawa Hills, near Auchi

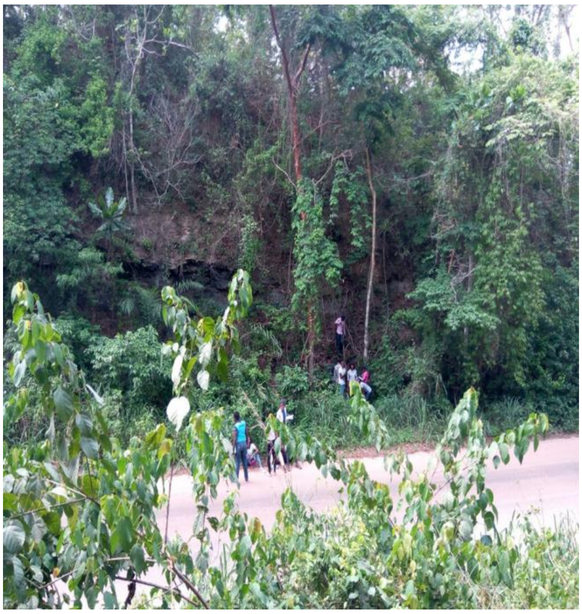


Fig 4: The Shale outcropping along Uzebba road

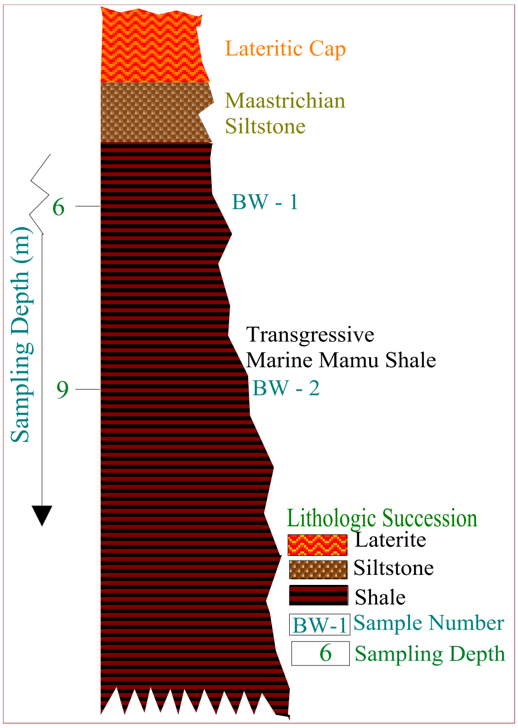


Fig. 5: Lithostratigraphic succession of the Bawa Hills Shale Sampled at an Interval of 3m

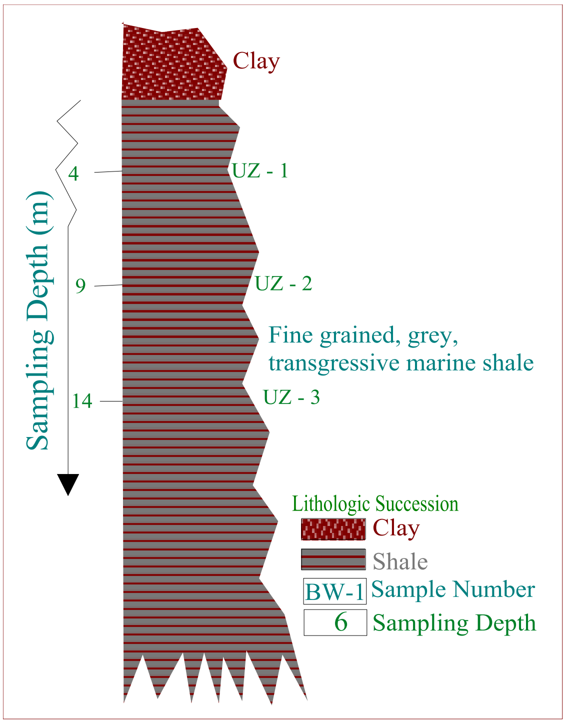


Fig. 6: Lithostratigraphic succession of the Uzebba Shale Sampled at an Interval of 5m

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The acquired samples were subjected to organic geochemical analysis using Total Organic Carbon (TOC) to determine the organic enrichment factor of the source rock via the use of Rock Eval pyrolysis technique.

100g of each sample was prepared, washed, air dried at a temperature below 40^{O}C for sanitization. Lithology of these prepared samples was then briefly processed prior to pulverization; with the resulting streak sieved and analyzed for total organic carbon content (TOC) and pyrolysis yield. Evaluation of organic richness assessment value (Law, 1999) for TOC of the studied shale (Table 2) was done in line with the established guideline by Law (1999).

Table 2: Guideline for Organic Richness Assessment (Law, 1999)

Generation Potential	**Wt.% TOC, Shales**
Poor	0.0-0.5
Fair	0.5-1.0
Good	1.0-2.0
Very good	2.0-5.0
Excellent	>5.0

An assertion of high T.O.C weighing over 0.5wt% in each sample further propelled the subjection of the samples to Rock-Eval analysis.

Rock-Eval Pyrolysis Analysis

The entire samples rate above 0.5wt% of TOC, and thus were subjected to Rock Eval Pyrolysis using the IFP-Fina Rock-Eval apparatus. 100mg of crushed, whole rock from picked lithology was weighed accurately into a crucible and introduced into a furnace at 250°C in order to volatilize the free hydrocarbons which was quantified by flame ionization detector (FID) to give the first peak (S1, ppm). Furnace temperature was subsequently increased to 550°C at 25°C per minute; and within this range, the kerogens cracked to yield hydrocarbons and carbon dioxide - measured by FID and thermal conductivity detector (TCD) to give the second (S2, ppm) and third Peak (S3> ppm) correspondingly. Temperature at the maximum rate of evolution of cracked volatiles (Tmax) was measured automatically using standard calibration on daily basis, and at regular interval. Crucible blanks are run as routine.

Rock-Eval Pyrolysis Parameters

Significant mathematical relationships exist between Rock-Eval pyrolysis parameters; a few important derivations are listed below:

Hydrogen Index (H.I) = S2/ (T.O.C* 100)
ProductionIndex (P.I) = S1/S1+S2
Oxygen Index = S3/ (T.O.C*100)
QualityIndex (Q.I) = S2/S3
Petroleum Potential = S1+S2
Saturation Index= S1/TOC

Definitions

S1*= Free hydrocarbons (comparable to extractable hydrocarbons) thermally distilled to a 300^{O}C isotherm*

S2*= Hydrocarbons released during the pyrolysis of kerogen between 300 ^{O}C and*

550 ^{O}C or 600^{O}C with a linear temperature gradient usually between 25^{O}C and 30^{O}C per minute

***S3**= Organic carbon dioxide released between 300 ^{O}C and 390 ^{O}C.*

***T max**= Temperature at which the maximum rate of yield of S2 hydrocarbons is obtained during pyrolysis*

***T.O.C**= Total Organic Carbon in weight percent.*

Organic Matter Quality

Organic matter quality of the samples was evaluated using the Rock-Eval HI and Tmaxplot.The plot will reveals the stage of evolution of organic matter (maturity) and the type(s) of kerogen dominating the source material. Kerogen types are distinctively three (3); which are Type I, TypeII and Type III. Irrespective of the kerogen type, the organic matter must be thermally matured to yield oil or gas.

Generating Potentialities

The source rock capability to generate hydrocarbon would be determined using the bi-logarithmic plot of Hydrogen Index (HI) against Total Organic Carbon (TOC). The plot categorizes the shale samples into different subgroups from which varying degree of hydrocarbon potential capabilities can be recognized (Espitalie *et al*., 1977). Subgroups include Gas Source, Gas/Oil source, Fair Oil source- Good Oil Source and Excellent Source

Thermal Maturation

The degree of thermal metamorphism of the organic matter in shale sample was another critical consideration for evaluation of petroleum generation.As a matter of fact, the thermal history (depth of burial and age) coupled with the quality of organic matter dictate to a very large extent hydrocarbon concentration and distribution of a particular source sample (Tissot and Welte 1984 and Longford and Blanc-Valleron 1990).The inverse relationship between hydrocarbon production and the hydrogen index of the source rock is an important concept used for the analysis of maturation level; since the greater the maturity, the lower the amount of hydrogen and the greater the saturation required for hydrocarbon expulsion. Thus, Tmax is a critical index for thermal maturation.

Determination of thermal maturity level of the source rocks in the present study was attained via the plotting of certain Rock–Eval geochemical pyrolysis parameter, which are: plot of Pyrolysis Production Index “PI” against temperature pyrolysis ‘‘Tmax’’ (Hunt 1996), plot of Hydrogen Index “HI” against “Tmax”, reverse plot of “Tmax” against “HI” and the plot of “Tmax” against “PI”. The classification standards by Espitalie et al.,(1985); Peters (1986) and Hakimi *et al*., 2010 were adopted for the study; which reported the initiation of ***oil*** generation from source rocks at Tmax range of 435°C – 465°C, and at a production index ‘‘PI’’ between 0.2 and 0.4. At a ‘‘Tmax’’ of 470°C, and a production index ‘‘PI’’ greater than 0.4, the hydrocarbon begins to evolve from oil to ***gas***. However at a‘‘Tmax’’ value less than 435°C, and ‘‘PI’’ less than 0.2, the source rocks are said to be ***immature***.

Source Rock Quality

The quality of the organic matter in the matrix of the shale samples was evaluated via the plot of S1 against TOC. The plots enabled the discrimination between non-indigenous/migratory (allochthonous) and

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indigenous (autochthonous) hydrocarbons. TOC was used as a quality variation determinant within the source rock through fluid expulsion. A complementary bi-logarithmic plot of S2 against TOC was also construction for quality assessment.

Hydrocarbon Migration

The proposition by Jin and Sonnenberg (2012) about the prediction of hydrocarbon migration into source rock was also modeled in this research to elucidate more on the possible migration tendency into the shale formation under investigation using the bi-logarithmic plot of S1 against the Total Organic Carbon (TOC).

Descriptive Statistics

Computed statistical parameters include Mean, Median, Std. Deviation, Variance, Range, Minimum, Maximum and Sum for TOC, Tmax, HI, OI, PI, S1, S2, S3, PP, QI and MI. Pearson correlation was also analyzed to ascertain the relationship between the individual parameters using the conventional classification below (Table 3).

Table 3: Pearson correlation ranges class and indications

Range	Indication
0	No Liner Correlation
0-0.25	Negligible Positive Correlation
>0.25-0.5	Weak Correlation
>5.0-0.75	Moderate Positive Correlations
>0.75	Very strong positive correlation

RESULTS AND DISCUSSION

Total Organic Content and Rock Eval Pyrolysis analyses of the weighted samples from study area (Table 4) furnished the following results tabulated below. The percentage organic carbon in the samples ranges from 3.52% - 3.677% in Bawa to 4.48% - 4.88% in Uzebba. The Hydrogen Index (H.I), Oxygen Index (O.I), Production Index (P.I) and Production Yield ranges between 476-488, 17-21, 0.03-0.06 and 1000-2020 respectively for Uzebba while it ranges between 328-376, 11-16, 0.03 – 0.07 and 1000 – 2018 respectively for Bawa (Table 3).

Table 4: Laboratory Rock Eval Pyrolysis Result

Location	Sample	Organic Carbon (%)	Pyrolysis Temp (^{0}C)	Pyrolysis Hydrogen Index (HI)	Pyrolysis Oxygen Index (OI)	Pyrolysis Production Index (PI)	Pyrolysis Potential Yield (Ppm)
Uzebba (UZ)	UZ1	4.46	442	476	17	0.06	1000-2009
	UZ2	4.48	446	480	17	0.04	1000-2011
	UZ3	4.83	448	484	17	0.03	1000-2021
	UZ4	4.72	448	468	19	0.03	1000-2012
	UZ5	4.66	436	484	21	0.04	1000-2000
	UZ6	4.58	446	484	16	0.04	1000-2016

	UZ7	4.68	447	486	19	0.05	1000-2014
	UZ8	4.66	444	486	17	0.03	1000-2007
	UZ9	4.69	446	482	19	0.04	1000-2008
	UZ10	4.77	444	478	17	0.06	1000-2015
	UZ11	4.88	444	476	19	0.04	1000-2020
	UZ12	4.66	445	488	17	0.06	1000-2019
BAWA (BW)	BW1	3.68	426	358	16	0.05	1000-2005
	BW2	3.42	428	328	13	0.05	1000-2010
	BW3	3.55	426	376	11	0.03	1000-2002
	BW4	3.68	424	366	13	0.07	1000-2004
	BW5	3.62	448	346	13	0.05	1000-2001
	BW6	3.48	422	345	11	0.04	1000-2006
	BW7	3.77	438	346	16	0.06	1000-2003
	BW8	3.74	426	348	11	0.05	1000-2018
	BW9	3.52	428	364	13	0.03	1000-2017
	BW10	3.74	436	362	13	0.07	1000-2013

More significantly depicted in Fig. 7 and 8 are the Rock Eval parameters of the studied samples. The S1 value-range of the shale samples is 0.40 – 1.46; more specifically between 0.72 – 1.46 and 0.40 – 1.02 in Uzebba and Bawa samples respectively. S2 value of the samples ranges from 11.22 – 23.38; within the Uzebba shale, the range is 22.77 – 23.38 but in Bawa samples range from 11.22 – 13.54.

The respective value-range of S3 within the entire whole, Uzebba samples and Bawa samples are 0.38-0.98, 0.73-0.98 and 0.38-0.60 respectively. Petroleum Potential value of the shale samples range from 11.81 – 24.94; district value for Uzebba and Bawa shale ranges between 22.40 – 24.26 and 11.81-14.56 respectively. Quality Index value ranges from 21.63 – 34.18, 23.05 – 30.25 and 21.63 – 34.18 for the entire shale samples, Uzebba samples and Bawa samples respectively while the migration/saturation–indexrange is 0.11-0.31 for all studied Samples, while 0.14-0.31 for Uzebba and 0.11-0.28 for Bawa Hills.

Average value of S1, S2, S3, Petroleum Potential, Quality Index and Migration Index is 0.84, 17.79, 0.66, 18.64, 27.07 and 0.20 respectively.

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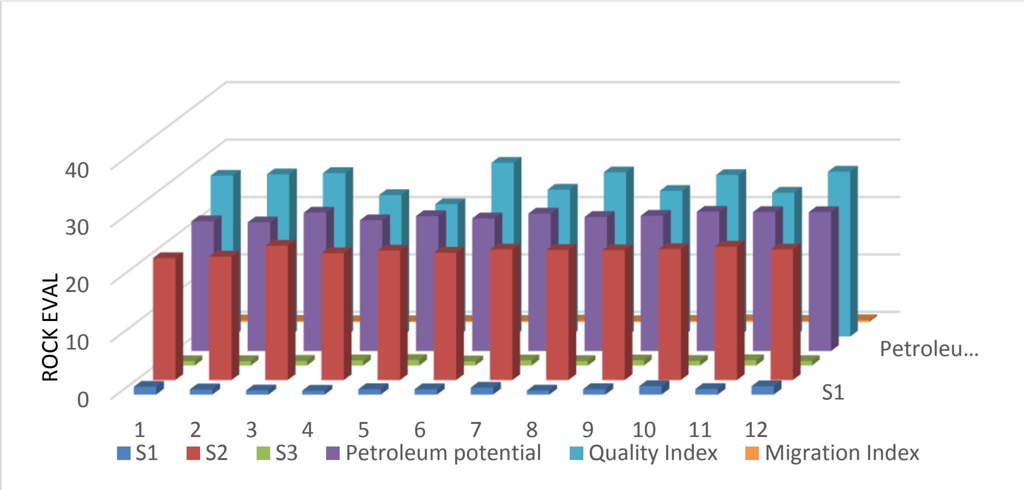

Fig. 7: Rock-Eval Parameter Values for Uzebba Samples

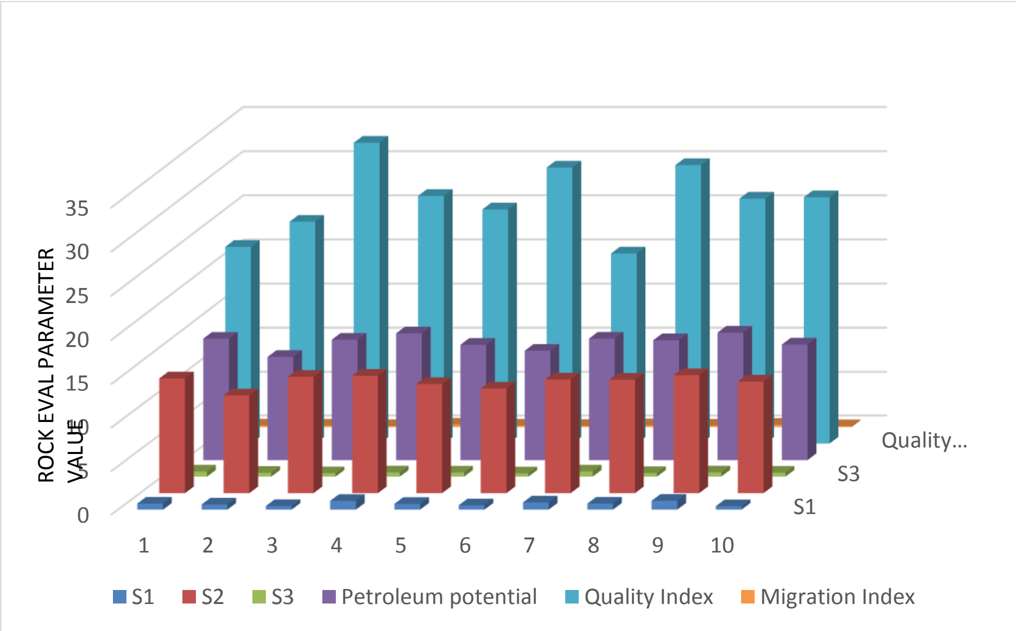

Fig. 8: Rock-Eval Parameter Values for Bawa Samples

Organic Enrichment Level

The Total Organic Carbon content ranges between 3.42 wt. % and 4.88 wt. % in the studied shale samples (Fig. 9) but comparatively richer in Uzebba samples (4.46 wt.% -4.88 wt.%) than Bawa samples (3.42-3.77 wt.%) .Samples rating samples, according to the Organic Richness Assessment (Law, 1999) Guideline, fall within the 'very good' class – indicative of very good organic richness in both shale samples acquired from the two formations.

Fig 9:- Scatter Plots of the shale sample rating in relation to Guideline for Organic Richness Assessment (Law, 1999).

Organic Matter Quality

Plot of hydrogen index (HI) against maximum temperature (Tmax) (modified van Krevelen diagram) categorizes the twenty-two samples (Fig. 10) within the ***Type-I*** and ***Type-II kerogen*** classes(Espitalie *et al*., 1987, Tissot, and Welte 1984). Several meaningful connotations can be drawn from the HI-Tmax diagram of the area, which include;

1. The prevalence of immature Type-II kerogen in Bawa shale; and by the virtue of its immaturity lacks hydrocarbon generating capability.
2. Complete presence of Type-1 kerogen in Uzebba samples with good oil generation potential.This kerogen type is essentially algal and terrestrialbacteria derivative (Baudin *et al*., 2007, Tissot, and Welte, 1978); probably dominated by the cyanophyceae (blue-green algal) identified by (Brunet, *et al*. 1988) in the basin as the main organic matter constituents.
3. Depositional environment is inferentially anoxic (anaerobic) lacustrine setting.

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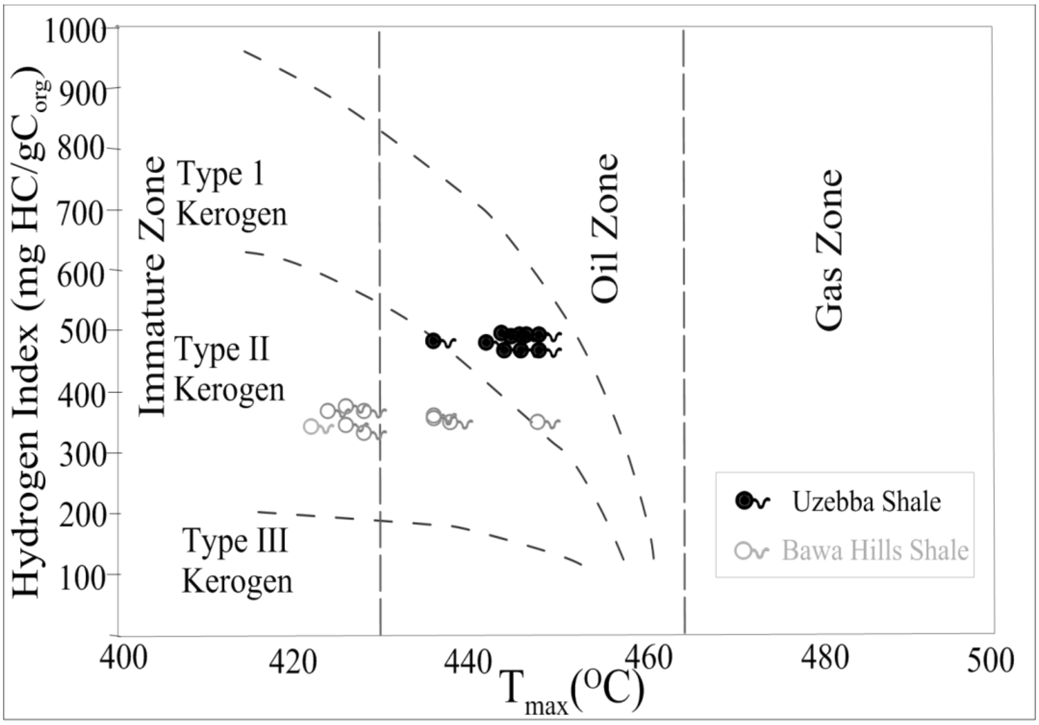

Fig.10:- Relationship between HI and Tmax.

Shale samples from the both formations fall within the ***Fair Oil Source*** (Fig. 11) – an indication that the shale samples have slight or modest petroleum generation potential, and hence must not be considered as a viable hydrocarbon source.

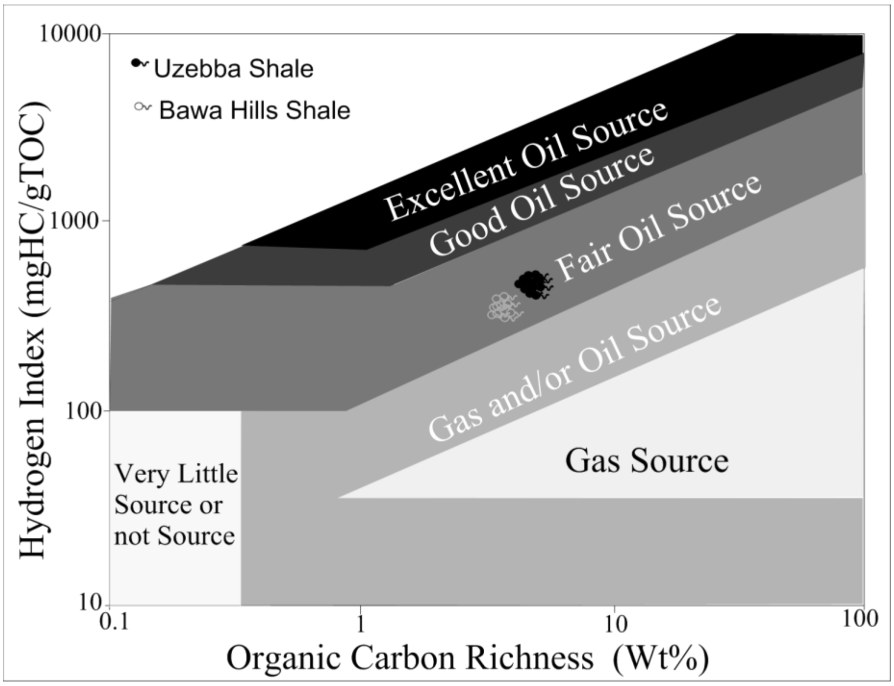

Fig. 11:- Plot of HI mg/g versus TOC (wt%)

Several kerogen classification charts were constructed to explain the pyrolysis data of the study area. The PI versus Tmax plot (Fig. 12) depicts the thermal maturation stage of shale samples which observably rangesfrom immature (with low level of conversion) to mature (with intensive generation expulsion) for Bawa and Uzebba samples respectively. This observation implies incapability of the Bawa shales to generate petroleum but however explains the potentiality of Uzebba shales which falls within the oil window.

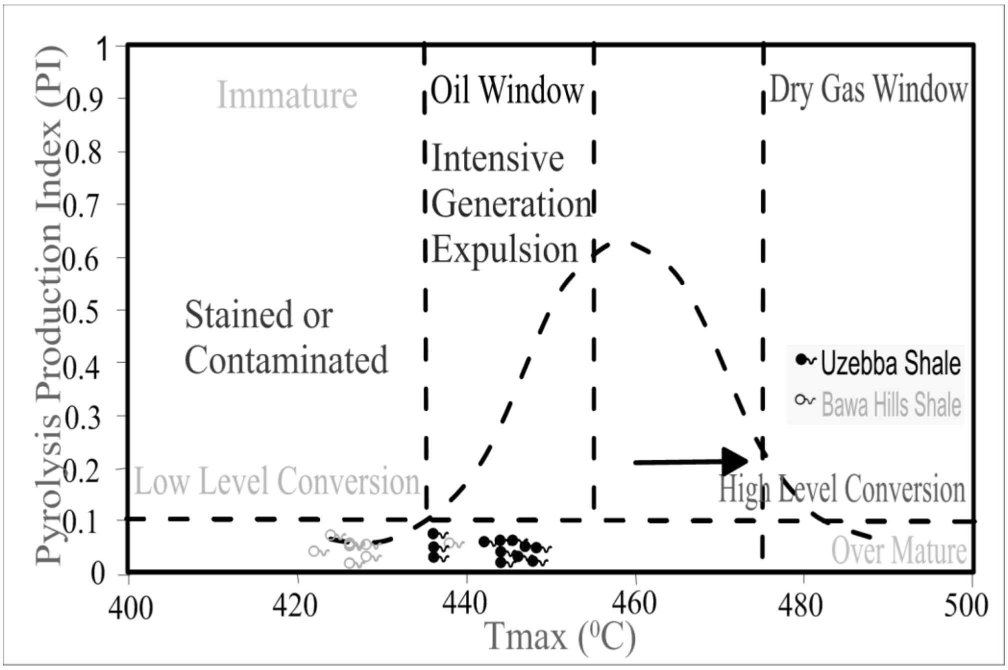

Fig. 12:- Plot of PI vs Tmax.

Another useful chart analyzing the maturation of the shale is the HI – T_{max} plot (Espitalié *et al.*, 1985) which also affirms the dominance of immature organic matter in Bawa samples but contrary wise has attained a significant level of maturity in Uzebba samples (Fig. 13).

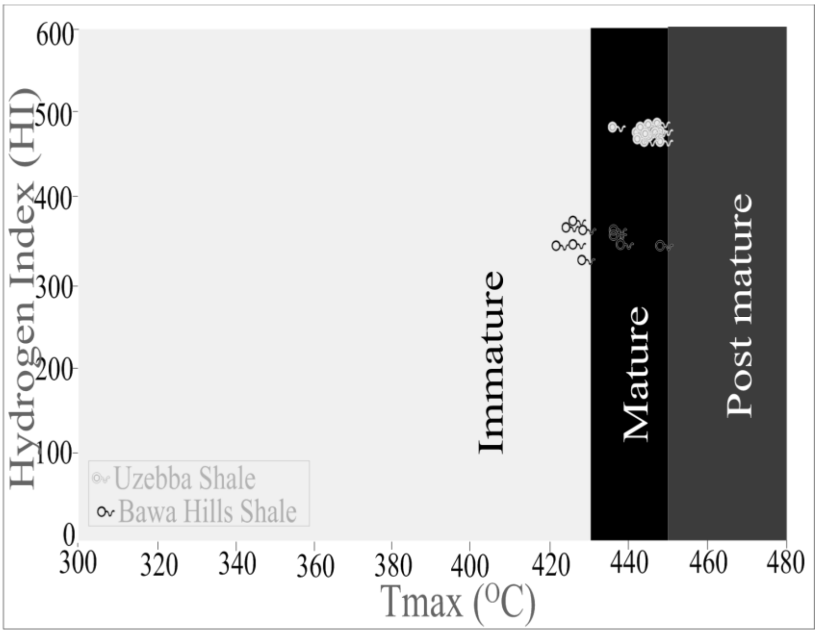

Fig. 13: HI versus Tmax plot in block diagram

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Shown in Fig. 14 is the reserve plot of Tmax against Hydrogen Index; depicting the distribution of the samples away from the hydrocarbon block. With the exception of a Bawa sample which falls within the oil and gas block, all other samples fall out of grid – indicative of poor prospect for hydrocarbon yield.

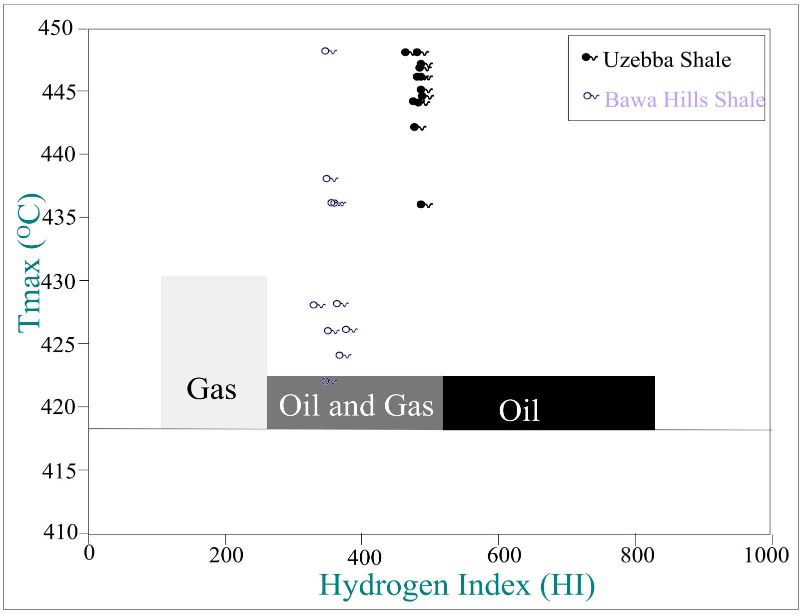

Fig. 14:Reverse plot of Tmax vs HI

Tmax versus P.I plot of the examined samples (Hakimi *et al*., 2010) reveals the occurrence of the entire sample within the ***inert carbon group***, very close to the hydrocarbon generation group (Fig. 15), and perhaps could be inferred as immature to sub-mature source rock, incompetent for hydrocarbon generation.

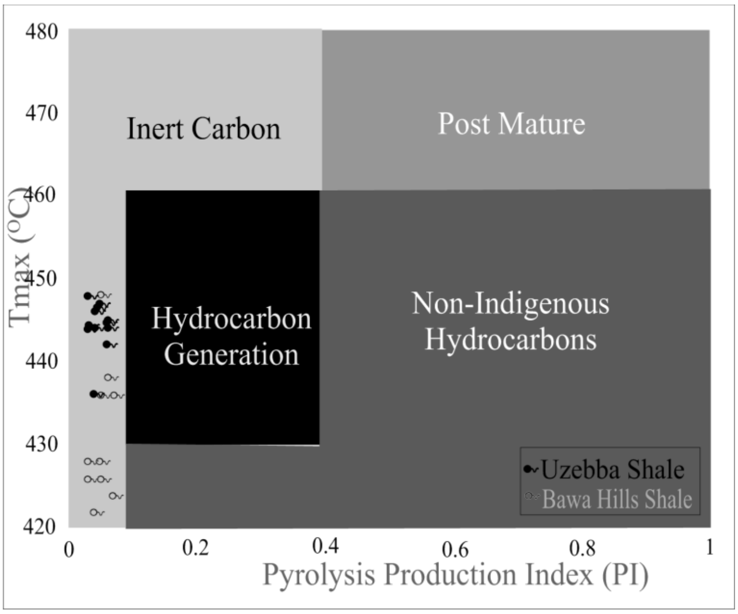

Fig. 15: Plot of Tmax versus Production Index showing the hydrocarbon-generation zone in block (Hakimi *et al*., 2010).

Fig. 16 is a plot of S1 against TOC revealing the preponderance of authochonous hydrocarbon in both shale samples with minor influx of non-indigenous hydrocarbon from other sources.

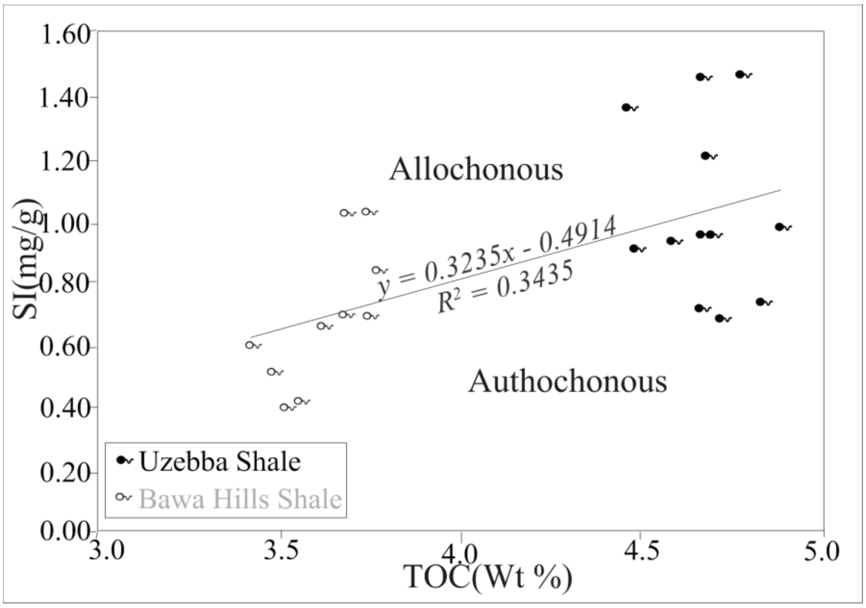

Fig. 16: The plot of S1 against TOC.

As a complement, Fig. 17 depicts the bi-logarithmic plot of S2 against TOC; disclosing a respective poor to fair source quality at Bawa and Uzebba.

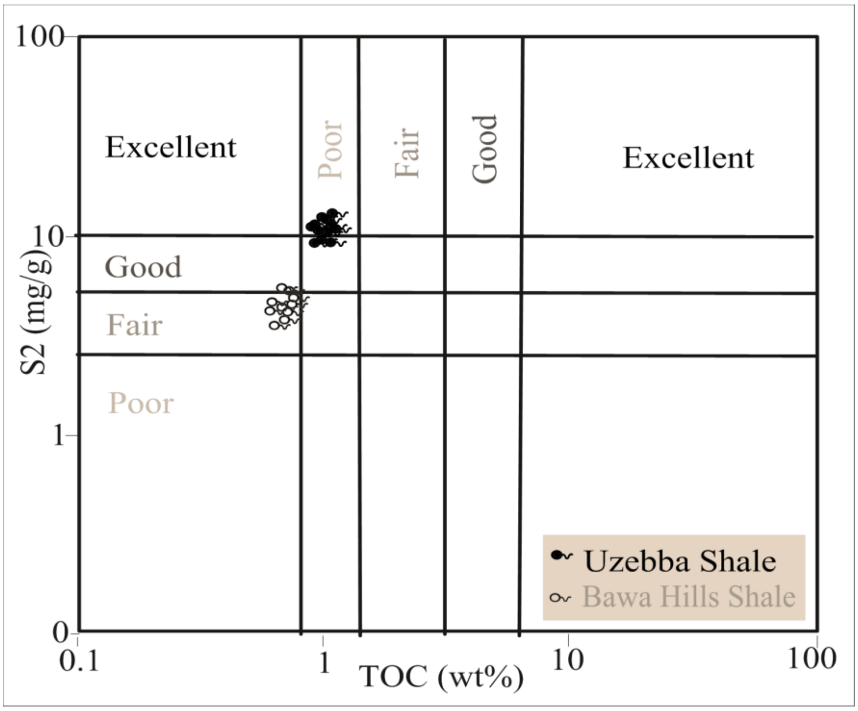

Fig. 17: The plot of S2 against TOC.

The bi-logarithmic plot of SI against TOC (Fig. 18) suggests no hydrocarbon migration, as the hydrocarbon contents are indigenous the sampled shale formations; falling within the oil expulsion and low hydrocarbon range, far below the migration line.

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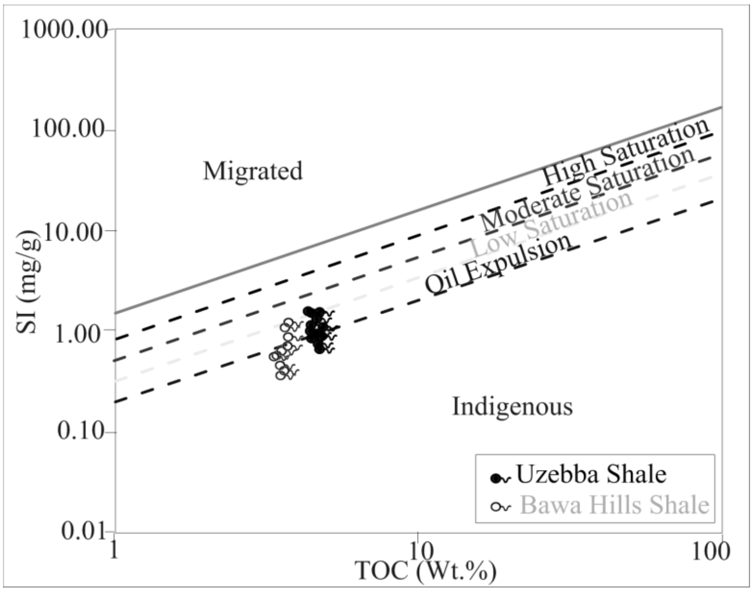

Fig. 18:Logarithmic Plot of S1 against TOC for Migration plot of Hydrocarbon determination.

TOC in the studied sample has a mean value of 4.19, median value of 4.47, standard deviation of 0.55, variance of 0.3, range of 1.46, minimum value of 3.42, maximum value of 4.88 and sum of 92.27. Statistical analysis of the entire Rock-Eval parameters, and their correlation relationships are summarized below in Tables 5 and 6.

Table 5: Statistical Analysis of Rock – Eval Parameters in the StudiedSamples.

Parameters	Mean	Median	Standard Deviation	Varianc e	Range	Minimu m	Maximu m	Sum
Toc	4.19	4.47	0.55	0.3	1.46	3.42	4.88	92.27
Tmax	438.6	443	8.97	80.55	26	422	488	9648
HI	423.2	472	65.54	4295	160	328	488	9311
OI	15.68	16.5	2.97	8.8	10	11	21	345
PI	0.05	0.05	0.01	0	0.04	0.03	0.07	1.02
SI	0.87	0.87	0.3	0.09	1.06	0.4	1.46	19.04
S2	18.08	21.37	4.97	24.67	12.16	11.22	23.38	397.9
S3	0.67	0.75	0.2	0.04	0.6	0.38	0.98	14.76
PP	18.95	22.49	5.15	26.5	12.45	11.81	24.26	416.9
Q1	27.32	28	3.07	9.43	12.55	21.63	34.18	601.1
MI	0.2	0.2	0.06	0	0.2	0.11	0.31	4.48

Table 6: Pearson Correlation of the collected samples

	TOC	TMAX	HI	OI	PI	SI	S2	S3	PP	QI	MI
Toc	1										
Tmax	0.79	1									
HI	0.97	0.74	1								
OI	0.87	0.74	0.82	1							
PI	-0.2	-0.1	-0.3	-0.2	1						

SI	0.59	0.47	0.57	0.51	0.62	1					
S2	0.99	0.77	0.99	0.85	-0.3	0.58	1				
S3	0.95	0.77	0.91	0.98	-0.2	0.55	0.94	1			
PP	0.99	0.77	0.99	0.85	-0.2	0.62	1	0.94	1		
Q1	-0.2	-0.3	-0.1	-0.6	-0.2	-0.2	-0.1	-0.4	-0.1	1	
MI	0.29	0.25	0.28	0.27	0.84	0.94	0.28	0.27	0.33	-0.2	1

The correlation tables 5 and 6 clearly reveal diverse degree of relationship between randomly selected parameters. Apparently, very strong positive relationships exist between most of these parameters, and thus suggest origination from same source rock.

CONCLUSION

The hydrocarbon potential of the Bawa and Uzebba samples has been comprehensively evaluated using TOC analysis and Rock-Eval pyrolysis technique. Major findings of this research are enumerated below:

1. The shale samples have a very good organic richness rating.
2. Rock-Eval Pyrolysis of the samples for S1, S2, S3, Petroleum potential, Quality Index and Migration Index revealed an average value of 0.84, 17.79, 0.66, 18.64, 27.07 and 0.20 respectively.
3. Assessment of organic matter quality revealed different maturation levels for the samples which are observed as between the immature to sub mature Type-II kerogen for Bawa shales and the mature Type-1 kerogen for Uzebba shales; the ‘former’ lacks the capability to generate either oil or gas while the ‘later’exhibits the tendency for oil generation.
4. Generating potentialities of the entire samples (Uzebba and Bawa) falls within the ***poor*** to ***fair*** oil source with minimal petroleum prospects, and as such should be given no consideration as an oil source formation.
5. Thermal maturation assessment of the shale samples also affirms the immaturity and maturity of Bawa and Uzebba samples respectively.
6. The shale samples from both formations are largely composed of autochthonous hydrocarbon with a relatively lesser proportion of allochthonous hydrocarbon.
7. The analyzed parameters exhibit a very strong correlation; indicative of same source origination

   Substantial oil and gas generation prospects from both formations are presently unlikely. Moreover, generation of appreciable temperature and pressure at greater depth could enhance the maturity ofthe samples for oil and gas production.

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