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Research Article

PETROLEUM POTENTIAL ASSESSMENT OF SOURCE ROCKS IN AFIKPO BASIN, SOUTHEASTERN, NIGERIA

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ABSTRACT

The results of petroleum potential assessment of source rocks in Afikpo Basin showed that the TOC values varied from 0.58-0.69wt% for samples analyzed from Obotme area, 0.60-0.61wt% for Nkana area, 0.67-0.71wt% for Okobo area, 0.68-0.78wt% and 7.36wt% for Amuvi and Ututu areas respectively. The average TOC value is 1.05wt% for all samples. SOM values varied from 100ppm to 375ppm with an average value of 203ppm. In the study area the results also showed that samples analyzed from Obotme area has Tmax values ranging from 4420C-4640C, indicating early to peak maturity. Tmax values of samples analyzed from Amuvi, Nkana and Ututu areas varied from 3640C-4290C, indicating thermal immaturity, samples analyzed from Okobo area indicate early thermal maturity with Tmax values ranging from 4270C-4480C.The average Tmax value for all sample is 4140C. The Tmax values in the study area shows that the sediments are immature and have not reached the oil generation phase, but are within the gas phase.

INTRODUCTION

This study focuses on the organic geochemical evaluation of Cretaceous shale which outcrops in parts of Afikpo Basin, Southeastern Nigeria, and reports the results of hydrocarbon source rock evaluation of Nsukka and Mamu Formations. Furthermore, it reviews the basics of accumulation and preservation of organic matter in sedimentary rocks, the generation of hydrocarbons, and the application of Rock-Eval/TOC pyrolysis techniques to the characterization of potential source rocks.

The results are based on the interpretation of Soluble Organic Matter (SOM) and Rock-Eval/TOC pyrolysis data. An example of the use of pyrolysis techniques is presented herein through the study of the organic matter content and maturity of the formations in Afikpo Basin. The potential and proven hydrocarbon source rock intervals of Cretaceous age are known throughout much of the Lower Benue Trough with most available data from the Anambra Basin portion of the trough, but with few data available pertaining to hydrocarbon source rock potential of the source beds in the study area. Moreover, hydrocarbon prospectivity hinges on the availability of oil and/or gas-proven source rock units that have generated and/or expelled hydrocarbons, meanwhile little is known of the thermal maturity of Post Santonian strata in this area and such information is critical for predicting what type of hydrocarbons, if any, may have been generated.

It is in this regard that the present work is aimed at evaluating the hydrocarbon potential, maturity and quality of shale rocks in the study area with a view to further understand the petroleum prospect of the Afikpo Basin.

LOCATION OF STUDY AREA:

The study area is located in Afikpo Basin, Southeastern part of Nigeria It stretches from longitude $07^0\ 54^1\ 23.3^{11}$E to $07^0\ 49^1\ 90.2^{11}$E and latitude $05^0\ 22^1\ 40.1^{11}$N to $05^0\ 27^1\ 81.5^{11}$N. The areas covered include Nkana and Obotme in Akwa Ibom State and Amuvi, Okobo, and Uturu in Arochukwu LGA of Abia State .

AIM AND OBJECTIVES OF STUDY:

The aim of this research work is to carry out petroleum potential assessment visa-vis geochemical investigation on shale sample s collected from the study area.

Location	Latitude	Longitude
1	05^0 25^1 35.8^{II}N	07^0 54^1 23.3^{II}E
2	05^0 25^1 35.05^{II}N	07^0 51^1 28.3^{II}E
3	05^0 25^1 51.82^{II}N	07^0 50^1 48.5^{II}E
4	05^0 261 14.38^{II}N	07^0 50^1 26.5^{II}E
5	05^0 27^1 81.5^{II}N	07^0 49^1 29.0^{II}E
6	05^0 22^1 4.04^{II}N	07^0 48^1 83.7^{II}E
7	05^0 22^1 8.10^{II}N	07^0 49^1 57.5^{II}E
8	05^0 22^1 7.10^{II}N	07^0 43^1 49.7^{II}E
9	05^0 $23^1$8. 32.6^{II}N	07^0 49^1 87.4^{II}E
10	05^0 23^1 39.4^{II}N	07^0 49^1 90.2^{II}E
11	05^0 23^1 34.1^{II}N	07^0 49^1 89.4^{II}E
12	05^0 23^1 33.4^{II}N	07^0 21^1 24.1^{II}E
13	05^0 23^1 29.9^{II}N	07^0 20^1 23.5^{II}E

Table 1: Sampling Points where samples were collected

GEOLOGY OF THE STUDY AREA:

Benue Trough is believed to be an intercontinental Cretaceous Basin stretching in a NE-SW direction resting unconformably on the Precambrian basement. It formed as a failed arm of the triple junction (Olade, 1975, Amajor, 1985). It is divided into three domains; the Northern, Central and Southern Benue Trough. The trough is characterized by sediment reversal episodes as a result of eustatic sea level changes leading to regressive and transgressive activities of the ancient sea from the Albian to the Cenomanian times (Murat, 1972, Reijers 1996).

During the Santonian, the Pre-Santonian sedimentary units were affected by subsidence and uplift creating the following geologic structures, the Abakiliki-Okigwe Anticlinorium, the Anambra Basin to the west and Afikpo Basin to the east. The two depocenters created by the Santonian tectonism (Anambra and Afikpo Basins) received sediments from the thick sedimentary pile (Kogbe, 1976, Amajor, 1985). The Pre–Santonian units include the Asu River Group, Odukpani, Eze Aku Formation and Agwu Shale, while the Post-Santonian

units are Nkporo-Enugu Shale, Mamu, Ajali and Nsukka Formations (Simpson, 1954, Amajor, 1985).

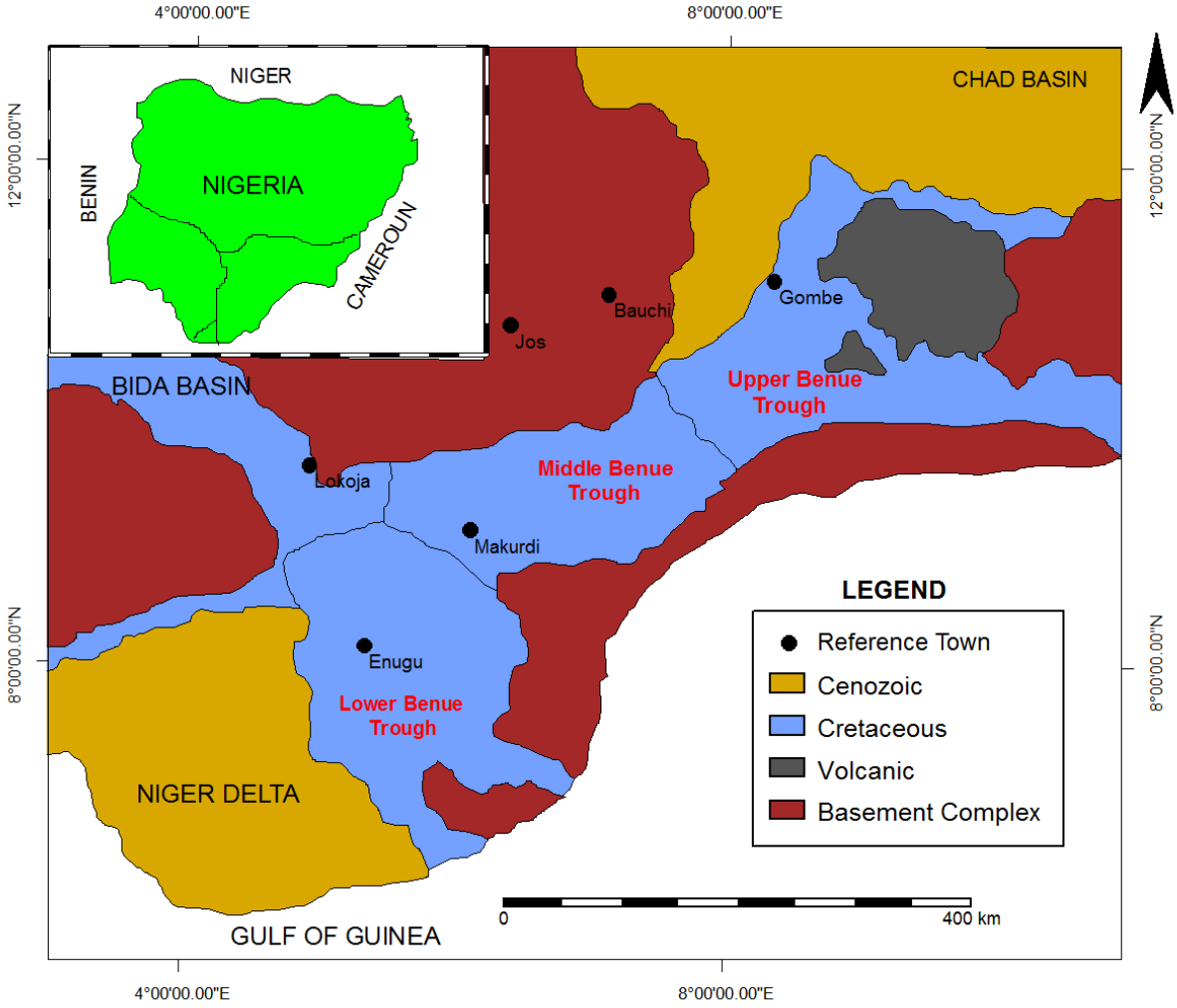

Figure1: Division of Benue Trough (Olade, 1975)

MATERIALS AND METHODS

SAMPLE COLLECTION:

The spot sampling (Davies *et al*, 1973) method was adopted for data collection during the field work. 17 samples were collected using steel hand-auger at different depths for vertical delineation of change in organic matter content as observed visually. All samples were put inside cellophane bags and labeled properly to avoid mix-up.

LABORATORY METHODS:

Standard laboratory methods as applied in petroleum potential studies were adopted. This involved analysis for Total Organic Carbon (TOC), Soluble Organic Carbon (SOM), Pyrolysis temperature (Tmax) and Free hydrocarbon (S1).The number of samples evaluated are seventeen.

SOLUBLE ORGANIC MATTER (SOM):

The analysis for Soluble Organic Matter (SOM) was carried out in the Plant Anatomy and Physiology Research Laboratory, University of Port Harcourt. This was to determine the petroleum potential of the shales which make up the Nsukka and Mamu Formations. The methodology used for acquiring data for the SOM is the Magnetic Agitation Method (magnetic extraction). The reagents and equipment used include chloroform, conical flask, meter balance, spatula, graduated cylinder, boiling tube, aluminium foil, filter paper, spectro-photometer, magnetic stirrer and funnel.

PROCEDURE:

The following standard procedure was adopted for the magnetic extraction method.

1. 2.0g of each of the 17 pulverized samples initially dried for 24 hours were measured and put in separate 100ml conical flasks into which 10ml of the organic solvent (chloroform) was poured.
2. A magnetic stirrer was placed in each of the 100ml conical flasks containing 10ml of the organic solvent and the pulverized samples, placed on a hot plate and stirred for six minutes to a temperature of 37^0C. In addition, aluminium foil was used to cover the mouth of the conical flasks containing the mixture, to prevent evaporation because chloroform is very volatile and evaporates easily when exposed.
3. The contents of the conical flask were allowed to settle in order to decant the filtrates which were transferred to a volumetric flask using a glass funnel.
4. The filtrate was poured into a graduated glass cylinder and made up to a mark using chloroform .
5. The absorbance (Abs) values were obtained by multiplying with the slope of the calibrated curve (Figure 3.2)

ROCKS-EVAL PYROLYSIS/TOC ANALYSIS:

Rock-Eval pyrolysis technique was applied in this work and is based on the methodology described by Espitalié *et al* (1977). This was carried out in the Civil Engineering and Geosciences Laboratory, Newcastle University. This technique provided data on the quantity, quality, and thermal maturity of the associated organic matter.

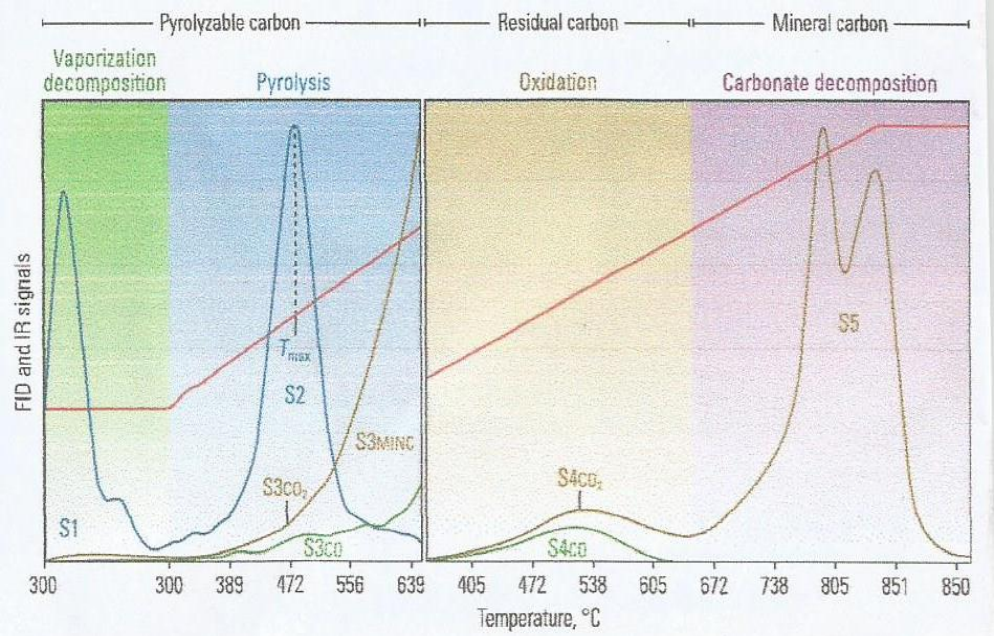

Figure 2: Response of Organic Carbon to controlled heating during pyrolysis

(Adapted fron Vinci technology, 2011)

RESULTS AND DISCUSSION

LITHOLOGIC DESCRIPTION:

The lithologic description of location 1 from the fieldwork is presented below.

Location 1 Ututu.

Depth (m)	Lithologic description (Figure 1)
1	Top soil; consist of medium grained sand
2.5	Fine to medium grained ferruginous sandstone. They are reddish.
7	Medium grained sand with clasts. They are whitish.
15	Well bedded clay. They are brownish.
20	Shale, dark to gray.

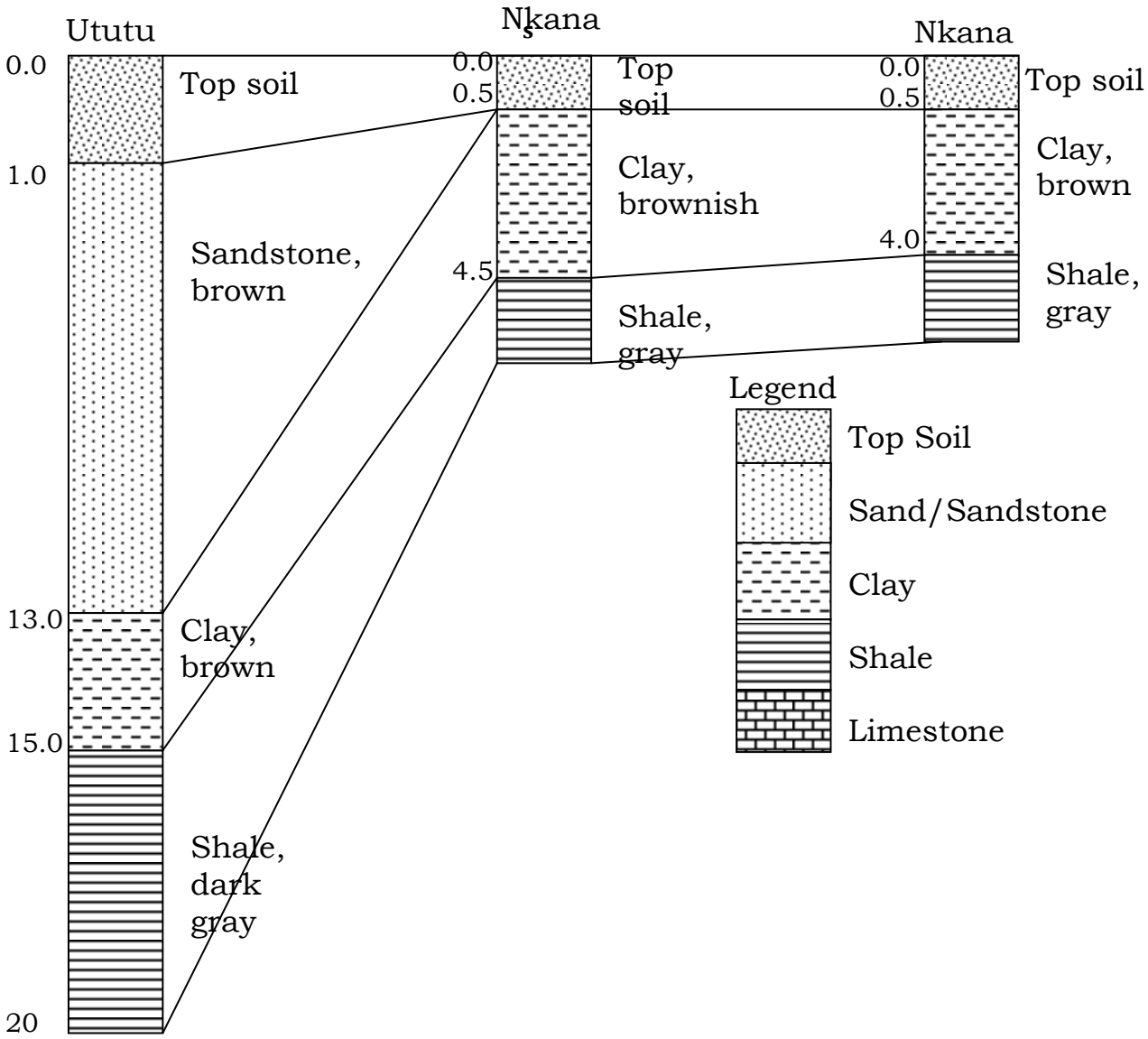

Figure 3: Summary of lithological logs of location 1,6 and 7 (Ututu-Nkana area).

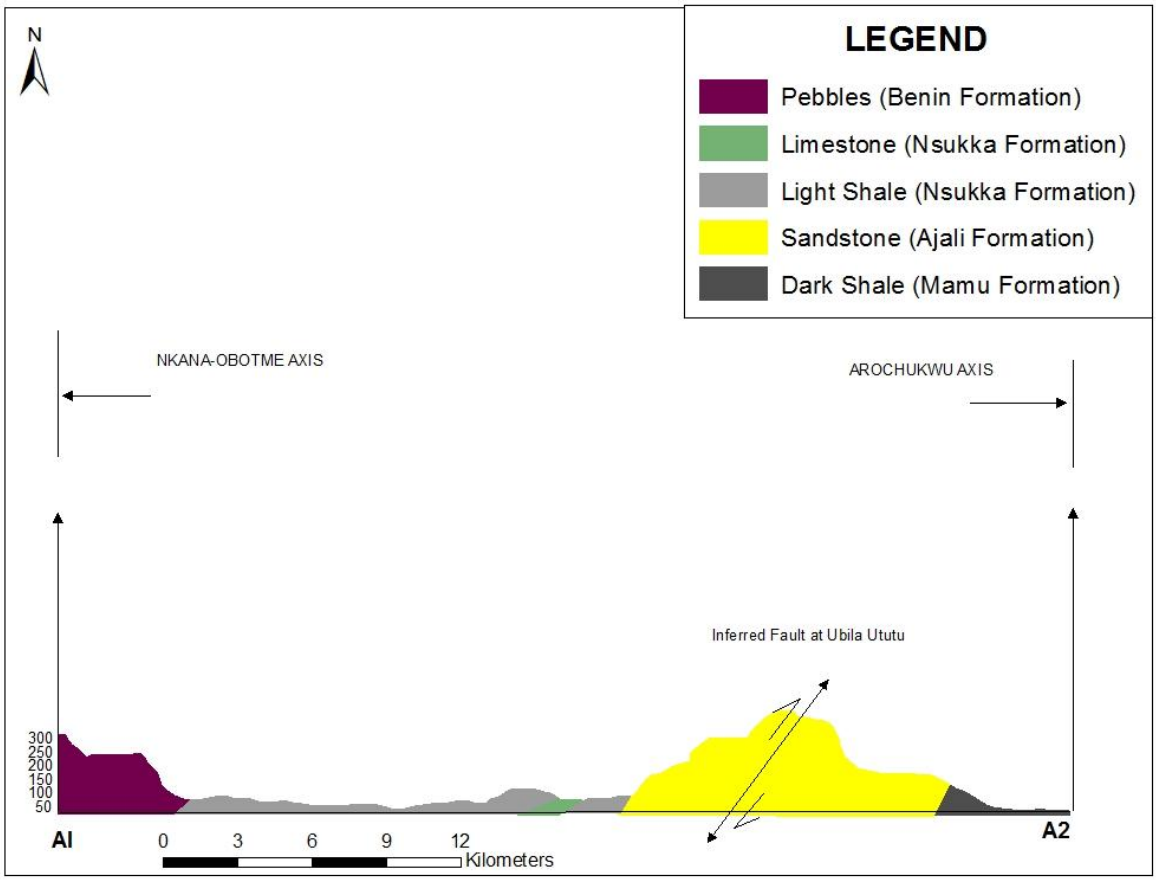

Figure 4: Cross section along A1-A2

(Modified after Ideozu, 2014)

Depth (m)	Lithology	Location	Formation	SOM (ppm)	TOC (wt%)	$S_{1(mg/g)}$	Tmax
13	Shale	Ututu	Mamu	300	7.36	0.21	424
0.2	Shale	Amuvi	Nsukka	150	0.68	0.20	423
1.0	Shale	Amuvi	Nsukka	160	0.78	0.04	429
1.0	Shale	Okobo	Nsukka	375	0.67	0.03	448
5.5	Shale	Okobo	Nsukka	375	0.71	0.04	427
4.5	Shale	Nkana	Mamu	300	0.62	0.04	364
4.0	Shale	Nkana	Mamu	375	0.60	0.03	364
1.0	Shale	Obotme	Nsukka	150	0.61	0.05	354
1.5	Shale	Obotme	Nsukka	120	0.62	0.09	424
0.5	Shale	Obotme	Nsukka	150	0.58	0.03	460
1.0	Shale	Obotme	Nsukka	200	0.62	0.01	442
0.5	Shale	Obotme	Nsukka	150	0.65	0.02	456
1.0	Shale	Obotme	Nsukka	180	0.67	0.03	464
2.0	Shale	Obotme	Nsukka	175	0.58	0.02	372
2.0	Shale	Obotme	Nsukka	175	0.88	0.02	366
0.5	Shale	Obotme	Nsukka	120	0.58	0.09	405
1.0	Shale	Obotme	Nsukka	100	0.69	0.03	410

Legend

Immature

Early Mature to peak mature

Late mature

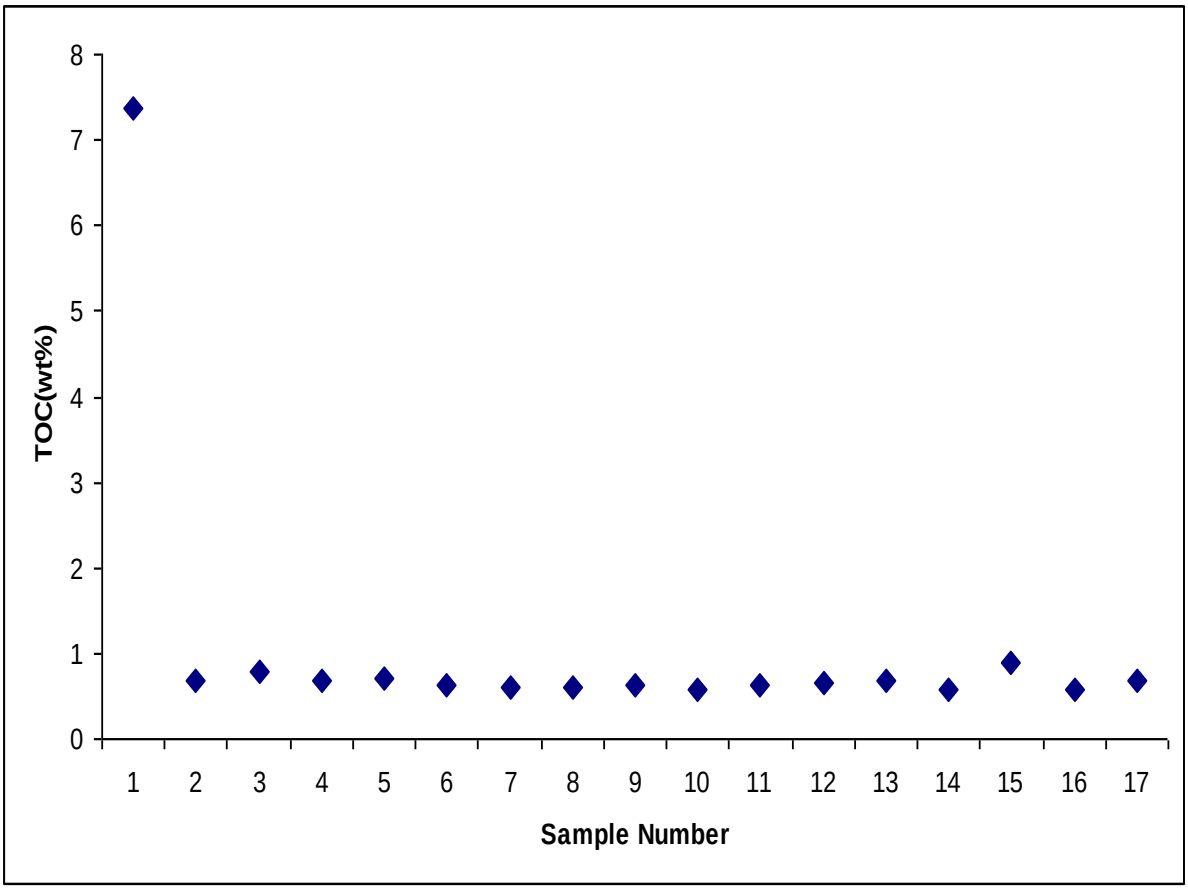

Figure 5: The results of the geochemical analysis; the following parameters were determined: Total Organic Matter (TOC), Soluble Organic Matter (SOM), Tmax and S1.

SOLUBLE ORGANIC MATTER:

Seventeen shale samples yielded organic extract in the range of 100ppm-375ppm with an average value of 209ppm (see table 4.2) for all the samples analyzed. The results showed that the SOM value varied from 100-200ppm for samples collected from Obotme area, 300-375ppm for samples collected from Nkana area, 375ppm for samples collected from Okobo area, 150-160ppm and 300ppm for samples collected from Amuvi and Ututu sections respectively. The Nsukka Formation has an SOM range of 100-375ppm with an average value of 184ppm, while the Mamu Formation has SOM range of 300-375ppm with an average value of 325ppm. The work of Deroo *et al* (1977), relates the SOM contents to source rock potential. These values are greater than 50ppm and it indicates that the source rocks have adequate organic matter to generate hydrocarbon.

RESIDUAL HYDROCARBON (S1):

The S1 values (see tabe4.4) varied from 0.01-0.09mg/g for samples collected from Obotme area, 0.03-0.04mg/g for samples collected from Nkana area, 0.03-0.04mg/g for samples collected from Okobo area, 0.02-0.04mg/g and 0.02mg/g for samples collected from Amuvi and Ututu areas respectively. The Nsukka Formation has an S1 range of 0.01-0.09mg/g with an average value of 0.04mg/g, while the Mamu Formation has S1 range of 0.02-0.04mg/g with an average value of 0.03mg/g. The results shows that only little amount of hydrocarbon might have been generated by the rocks in the subsurface.

Based on the results of geochemical analysis, the organic matter content of the samples is adequate for hydrocarbon generation. The samples analyzed from Obotme, Nkana, Okobo and Amuvi are classified as poor, while the sample analyzed from Ututu area is classified as very good. There is contrasting levels of thermal maturity in the study area. Maturity variation in the study area is due to presence of high temperature associated with tectonism. The results indicate an oil and gas source possibility in Nsukka Formation, while Mamu Formation in the study area has potential for gas only.

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