IOSR Journal of Applied Geology and Geophysics (IOSR-JAGG)
e-ISSN: 2321–0990, p-ISSN: 2321–0982.Volume 4, Issue 5 Ver. III (Sep. - Oct. 2016), PP 24-28
www.iosrjournals.org

Source Rock Geochemistry of the Nsukka Formation in Arochukwu Area of Afikpo Basin, South–Eastern Nigeria

C Ameh[1], O Aina[1], K Ogbuwa[1], S Abrakasa[1,2] and R Ideozu[1]
[1]*Department of Geology, University of Port Harcourt, Rivers State, Nigeria.*
[2]*Centre for Petroleum Geosciences, IPS, University of Port Harcourt, Rivers State, Nigeria.*

Abstract: *A geochemical study on the evaluation of shale samples obtained from the Nsukka Formation in the Arochukwu area of Afikpo basin was undertaken. Samples from four sections of the studied area were analyzed using Rock Eval Pyrolysis.The results indicate that Total Organic Carbon (TOC) ranges from 0.5 wt%, to 0.88wt%. The hydrogen index (HI) values range from 3mgHC/TOC to 16mgHC/TOC. Samples show predominance of type III (gas–prone) and type IV (non- hydrocarbon potential) as indicated by the Van Krevelen diagram. The petroleum potential (PP) values range between 0.03–0.15mgHC/g and indicates a poor productive potential. The highest value of Net Expulsion obtained is 13.77%. The Van krevelen diagram indicates that samples were all deposited in fluvial deltaic environment. The Tmax values range from 354ºC to 464ºC shows that the source rocks in the area studied range were mostly immature.*

Keywords: *Afikpo Basin, Nsukka Formation, Rock Eval Pyrolysis, Petroleum potentials, Expulsion efficiency, Net expulsion.*

I. Introduction

The downturn in the petroleum market has made it imperative for the potential assessment of hydrocarbon reserves and possible evaluation for frontier exploration in other basins in Nigeria. Anambra and Afikpo basin are potential area. However, active petroleum systems have not been established in these basins. The source rock geochemistry of these basins has been under study and is still in progress. The source geochemistry includes the productive capacity of a source rock, depositional environment, and Volumetric of the source rock. The productive capacity of a source rock depends on the amount of organic matter present in the rock (volume), organic matter richness (kerogen type), and its thermal maturity. These are expressed as S1 –"free" or absorbed hydrocarbons from the sample, S2 (pyrolysate) the generated hydrocarbon embedded in the kerogen. These are determined by the quantity and quality of organic matter preserved and modified during the digenetic processes of source rock undergoes (Horsfeild and Rullkotter 1994).These transformations take place in a sedimentary rock usually called a source rock.

A source rock is a sedimentary unit (usually fine grained), hosting substantial amounts of fossilized organic matter, which is incorporated into the sediment at the time of deposition and which is capable of producing petroleum under exposure to intense heat and pressure over time (Hunt 1996). To determine the productivity of a sedimentary source rock, a laboratory analysis of the hydrocarbon contained in the rock is necessary. This study employs the use of TOC screening and the Rock Eval Pyrolysis. Expulsion efficiencies on the other hand, are the proportion of oil expelled from the source rock expressed as a percentage of total oil generated. In other words, it is a fraction of petroleum fluids formed in the source rock that has been expelled. It occurs as a result of the buildup of overpressure in the source rock as a consequence of hydrocarbon generation. It is very inefficient for a lean source rock, (McKenzie *et al.*, 1987). The objective of this study includes determination of the productive properties and expulsion efficiency, depositional environment and the organic matter type of the source rock.

Location of study area

The study area is located within the lower Benue Trough, and it covers Arochukwu Local Government Area of Abia state – South Eastern Nigeria (figure 1). The studied samples were obtained from different sections of outcrops bearing the Nsukka Formation. The area lies within longitude 070 54' 23.3"E to 070 49' 90.2"E and latitude 050 22' 40.1"N to 050 27' 81.5"N (figure 1) and it is accessible by road through Ikot Ekpene – Obotme axis, and also through Umuahia – Arochukwu axis.

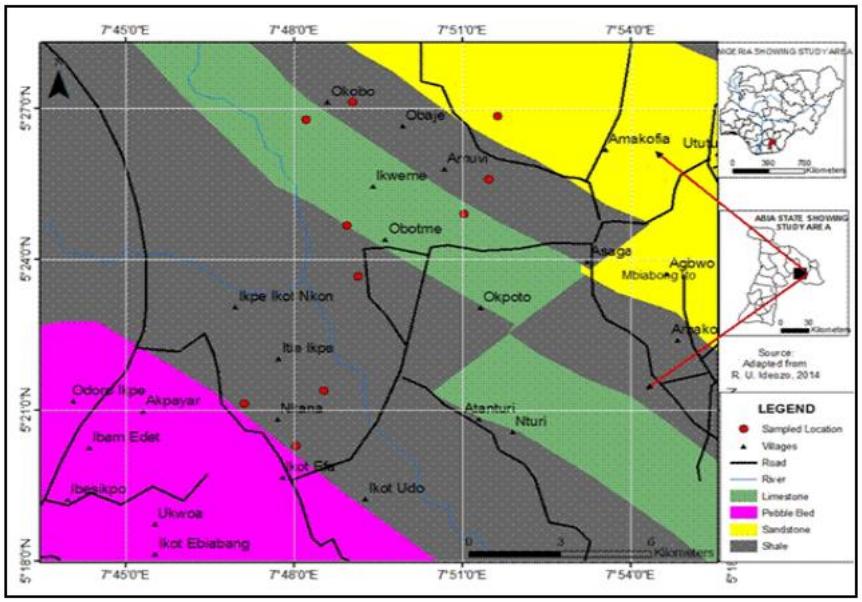

Figure 1: Geologic map of the study area showing the various sampling points (insert – Maps of Nigeria and Abia state**)** modified from Ideozu, 2014

II. Methodology

Sample Collection

A total of 16 fresh samples were collected from outcrops at variable depths in the various sample locations. These samples were collected in sample bags, and were properly labeled. Sample collection was carried out to cover part of the Nsukka Formation, which is the lithology of interest, and this collection was done by the use of a steel hand auger in order to obtain fresh samples, at depths, deep enough to avoid the effects of weathering or contaminated samples. Sample locations include;-Amuvi, Okobo, Nkana, and, Obotme sections of the studied area.

Sample Preparation and Analysis

The samples were air-dried for 72 hours at room temperature to remove all moisture. Thereafter, it was crushed using a HDEP (high densitypropylethylene) mortar and pestle. Crushed samples were sieved through the 0.2mm sieve, to obtain the clay fraction.1g of each sample was accurately weighed, properly packaged, labeled sent to the Petroleum Geochemistry Laboratory, Newcastle University United Kingdom for Rock Eval Pyrolysis.

III. Results

Table 1: Results on Rock Eval Pyrolysis

Sample Nos.	TOC WT%	S1	S2	NET EXP.	HI	PI	PP	Tmax
1	0.679	0.03	0.11	13.770	16	0.2142	0.14	423
2	0.777	0.04	0.09	9.852	12	0.3076	0.13	429
3	0.667	0.03	0.06	7.646	9	0.3333	0.09	448
4	0.714	0.04	0.04	4.765	6	0.5000	0.08	427
5	0.618	0.04	0.02	2.753	3	0.6667	0.06	364
6	0.597	0.03	0.02	2.848	3	0.6000	0.05	364
7	0.610	0.05	0.04	5.574	7	0.5556	0.09	354
8	0.624	0.09	0.06	8.173	10	0.6000	0.15	424
9	0.581	0.03	0.06	8.786	10	0.3333	0.09	460
10	0.622	0.01	0.02	2.735	3	0.3333	0.03	442
11	0.654	0.02	0.06	7.804	9	0.2500	0.08	456
12	0.667	0.03	0.04	5.102	6	0.4286	0.07	464
13	0.578	0.02	0.03	4.412	5	0.4000	0.05	372
14	0.880	0.02	0.04	3.864	5	0.3333	0.06	366
15	0.583	0.09	0.02	2.916	3	0.8182	0.11	405
16	0.693	0.03	0.05	6.132	7	0.3750	0.08	410

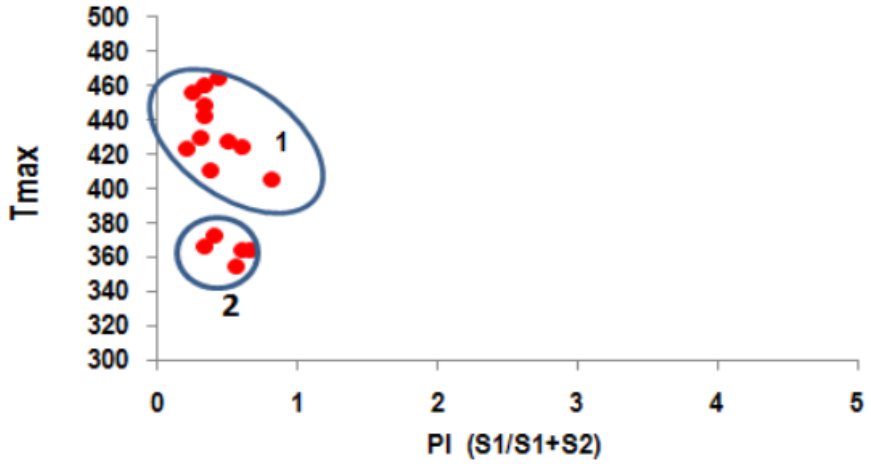

Figure 2: A plot of maximum temperature against production index, (Tmax vs. PI) showing the productivity level with respect to maximum temperature of various samples

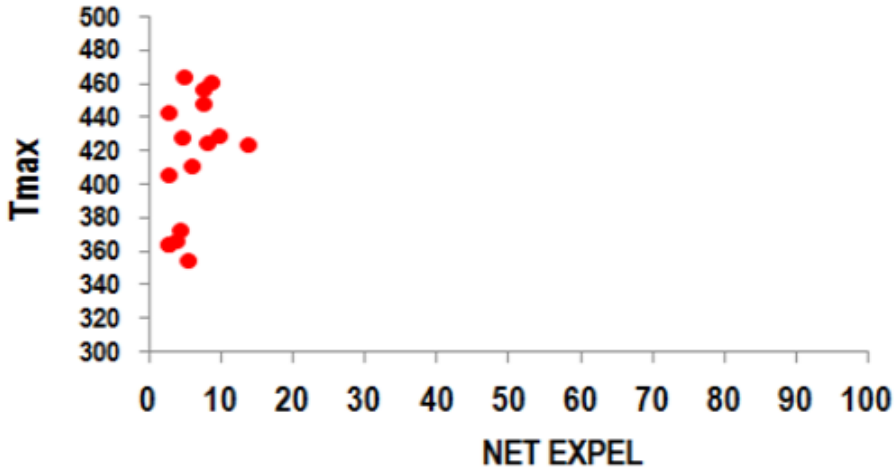

Figure 3: A graph of Tmax vs Net Expulsion

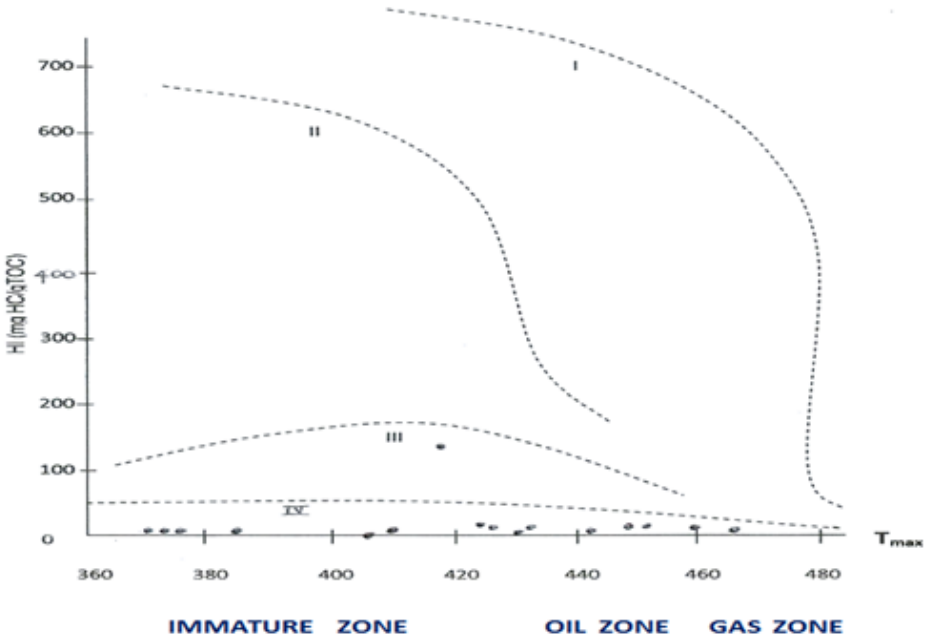

Figure 4: Van Krevelen diagram showing the result of the plot of (HI) against Tmax

IV. Discussion

Petroleum Potential

Petroleum source potential (PP) represents the maximum quantity of hydrocarbon that a sufficiently matured source rock might generate; and is given as (S1+S2). It is a measure of genetic potential (Tissot and Welte, 1984) or the total amount of petroleum that might be generated from a rock. It therefore accounts for the quantity of hydrocarbons that the rock has already expelled (S1) and hydrocarbon embedded in the kerogen (S2). Rock Eval Pyrolysis revealed that the total generation potential (S1+S2) of the studied samples ranges between 0.03 mgHC/g rock–0.15mgHC/g rock (table 1) with a mean value of 0.085mgHC/g. S1 represents free hydrocarbon liberated by volatilization at 300 $^{\circ}$C and S2 is the quantity of hydrocarbon produced from cracking of kerogen.These values fall below the 2mgHC/g rockindicating little or no potential for liquidhydrocarbon, but some potential for gas. Another criterion for determination of the organic matter richness of source rocks is the use of total organic carbon content (TOC), which is the total amount of organic material (kerogen) present in the rock, expressed as a percentage by weight (TOC wt.%). The TOC values for the Nsukka formation studied ranges between 0.55%–0.88%. However, higher TOC values represent better chance and potential for hydrocarbon generation. According to Hunt (1995), the TOC values between 0.5 and 1.0% indicate a fair source-rock generative potential, TOC values varying from 1.0% to 2.0% reflects a good generative potential whilst values between 2.0% and 4.0% infers a very good generative potential, and source rocks with TOC greater than 4.0% are considered to have excellent generative potential. The Hunt (1996) scale infers that the Nsukka formation does not have potential for oil but probably for gas.

Net Expulsion

The proportion of oil expelled from the source rock expressed as a percentage of total oil generated is called expulsion efficiency. Expulsion efficiency increases with the maturation process, that is, the more oil generated in the source rock, the more that can be effectively expelled from it.Expulsion efficiency is intimately related to the degree of hydrocarbon saturation of the pore system. The expulsion efficiencies are higher for a rich, oil prone source rock unit compared to a poorer quality source rock, which may not have rich organic matter and very much dependent on S2. Net Expulsion efficiencies range from 3% to 14% of the samples studied.Expulsion should be about 60% for good source rocks (Cools *et al.,* 1985). Net Expulsion is S1 expressed as carbon, relative to the TOC. The productive index depends on S1, and both parameters are affected by the expulsion (Rullkotter *et al.,* 1988). From the plot of Net Expulsion Efficiency vs. Tmax, (figure 3)the studied samples showed low expulsion rates (below 20% for all samples). McKenzie *et al.*, (1987) proposed that a good quality source rock at its peak generation potential reaches Expulsion Efficiency between 50-70%, and the studied samples showed a very low percentage below 20%. Though the source characteristics portray low TOC values and immature; expulsion may not have started or probably no oil generated enough to be expelled.

Organic Matter Type

The type of organic matter that makes up the shales of the Nsukka formation could be inferred from figure 4 which is the Van Krevelen diagram. The Van Krevelen diagram shows that most of the samples are in the type III and IV zones. The samples in these categories are made up mostly from epicuticular waxes of vascular land plant materials. These organic materials are mostly gas prone, they have little or no oil potential (Hunt, 1996). They may also have a high content of degraded planktonic organic material or high phytoclast inputs (unoxizised woody materials).

Depositional Environment

The Paleo depositional environment of source rock also determines the preservation and productivity of the organic matter deposited. Organic matter deposited in oxic environment could be exposed to microbial degradation.Organic matter deposited in marine environment are mostly algal rich materials, while those deposited in deltaic environment are mostly from epicuticular waxes of vascular landplant materials (Hunt, 1996, Tissot and Welt 1984). Figure 4, indicates that all samples from the Nsukka formation in this study are type III and IV, this shows that their corresponding depositional environment is fluvial–deltaic and are mostly rich in epicuticular waxes of vascular landplant materials (Hunt, 1996, Tissot and Welt 1984). These samples are not oil prone, but could be gas prone.The Nsukka formation was deposited in a marginal marine (low marine) environment with terrigenous influx of organic matter into nearshore and distal environments. Hence organic matter could be mostly land plant materials and could have been exposed to microbial degradation which is fostered by oxic or suboxic environments.

V. Conclusion

The samples from the Nsukka formation showed TOC values in the range of 0.55% to 0.88%, this is within the lower limits for potential source rocks and source rocks. The petroleum potential values range from 0.03–0.15mgHC/g rock, but falls below 2.0mgHC/g rock for good source rocks.The petroleum potential is a sensitive parameter and very much expresses the viability of the source rock. The Net Expulsion values are very low, generally below 20%, good source rock has hydrocarbon expulsion in the range of 50% to 70%.Net Expulsion is the S1 expressed as carbon relative to the TOC. The Van Krevelen diagram indicates that the samples are made up of organic matter from vascular land plant materials, the organic materials are not oil prone, but has potential for gas. The depositional environment for the source rock isinferred to be deltaic, sources in deltaic environments are mostly gas prone.

References

[1] Adegoke O.S., Omatsola M.E. and Coker S.J.L., 1991 The Geology of the Nigerian Tar Sands, InMeyer, R.F., Ed., 5thUnitar International Conference on Heavy Crude and Tar Sands: AOSTRA, Technical Reports, pages 369-3385

[2] Akinmosin, A, Omosanya, K.O, Ariyo, S.O, Folorunsho, A.F, and Aiyeola, S.O. 2011. Structural Control For Bitumen Seepages in Imeri, SouthWestern Nigeria. International Journal of Basic & Applied Sciences. 11 No: 01, 61-68.

[3] Akintola A. I., Ikhane P. R. and Adeola O. 2013. Heavy mineral and grain size characterization of bitumen seeps exposed at Ogbere, SouthWestern. Nigeria. International Research Journal of Geology and Mining. 3(2) pp. 82-101

[4] Ako B.J., 2003. Exploration strategies for bitumen saturated sands in Nigeria:Prospects for investment in mineral resources of southwestern Nigeria. In Elueze, A.A. (Ed). 2008, Nigeria Mining and Geosciences Society (N.M.G.S) 61-66

[5] Algeo, T.J., Maynard, J.B., 2004, Trace-element behavior and redox facies in core shales of Upper Pennsylvanian Kansas-type cyclothems, Chemical Geology, 206, 289-318.

[6] Bailey, J., Jobson, M. & Rogers, M. 1973. Bacterial degradation of crude oil: comparison of field and experimental data. chemical geology, 11, 203 – 221.

[7] Barwise, A.J.G. 1990. Role of Nickel and Vanadium in Petroleum Classification. Energyand Fuels. 4, 647 – 652.

[8] Brekke, H. and Evoy, R. 2004. Use of dipmeter data in the definition of the internal architecture of point bar deposits in the Athabasca Oilsands: implications for the Middle McMurray Formation in the Hangingstone Area, Alberta, abstract, Annual AAPG Conference, Dallas.

[9] Brooks, P. W., Fowler, M. G., and Macqueen, R. W., 1988, Biological Marker and Conventional Organic Geochemistry of Oil Sands Heavy Oils, Western Canada Basin, Organic Geochemistry, 2, pp 519-538.

[10] Derro, G., Powell, McGrossan, R.G. and Der, E., 1974. Geochemistry of the Heavy Oils in Alberta, Oil Sands Fuel of the Future. Canadian Society of Petroleum Geologists, Memoir3, pp 148 – 167.

[11] Head, I. M. Jones, D. M. Larter S. R. 2003. Biological Activity in the Deep Subsurface and the Origin of Heavy Oil. Nature, 426, 344-352 Ideozu, R. U. 2014.Sedimentology of Post Santonian sediments in parts of Afikpo basin, south Eastern Nigeria. Unpublished PhD Dissertation, Geology Department, University of Port Harcourt. Pp 428.

[12] Larter, S., A. Wilhelms, I. Head, M. Koopmans, A. Aplin, R. Di Primio, C.Zwach, M. Erdmann, and N. Telnaes, 2003, The controls on the composition of biodegraded oils in the deep subsurface part 1: biodegradation rates in petroleum reservoirs: Organic Geochemistry,34, p. 601-613.

[13] Lewan, M.D., Maynard, J.B., 1982. Factors controlling the enrichment of vanadium and nickel in the bitumen of organic sedimentary rocks. Geochim Cosmochim. Acta,46, 2547–2560.

[14] Muwais, W., and Smith, D. G., 1990. Types of channel fills interpreted from dipmeter logs in the McMurray Formation, northeast Alberta. Bulletin of Canadian Petroleum Geology, 39, p. 53-63.

[15] Nurkowski, J. R., 1985. Coal quality and rank variation within upper Cretaceous and Tertiary sediments, Alberta plains region. Alberta Research Council, Earth Science Report85-1, 39 p.

[16] Obianjuwa and Nwachukwu J.I., 2008 Characterization of Nigerian Oil Sands by TXRF Spectrometry, Petroleum Science and Technology, 26(1), 29–39

[17] Pelet, R., Béhar, F., Monin, J.C., (1986). Resins and asphaltenes in the generation and migration of petroleum. Organic Geochemistry,10 (1-3), 481-498.

[18] Peters, K. E. & Moldowan, J. M. (1993). The Biomarker Guide: Interpreting Molecular Fossils in Petroleum and Ancient Sediments. Prentice Hall, Englewood Cliffs, New Jersey, 363pp.

[19] Udoh, O.T., Ekwere, S. and Abrakasa, S. 1988. Concentration and distribution of some trace metals in Nigerian crude oils and Asphaltene. 24th Annual conference of the Nigerian Mining and Geosciences, 7th March, Lagos.

[20] Udoh, O.T., Ekwere, S. and Abrakasa, S. 1992. Some trace metals in selected Niger Delta crude oils: Application in oil-oil correlation studies. Journal of Mining and Geology, 28, 289–292.