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Palynofacies and Kerogen Analyses of Upper Cretaceous (Campanian-Danian) Shales of Ugwueme Section of Anambra Basin, Southeastern Nigeria

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Abstract: Three samples of shale recovered from late Campanian to Danian sediments around Ugwueme area, Anambra Basin were studied for their particulate organic matter distribution and hydrocarbon potentials. Two major palynofacies were identified and designated palynofacies A and palynofacies B. Palynofacies A occupies the basal unit (Nkwe mudstone unit of Nkporo Shale) and the topmost unit; Umuaku shale unit of Nsukka Formation).Palynofacies A is dominated by abundant amorphous organic matter (AOM) and some phytoclastmaterials majorly of macerol marine exinite and some terrestrial influenced materials. Palynofacies B represents the middle unit bed (AcharaUgwueme shale unit of Mamu Formation) constitutes abundant phytoclasts with opaque debris of well-preserved terrestrial influenced plant fragments. The kerogen investigation result shows Nkwe mudstone unit of Nkporo Shale Formation and Umuaku shale unit of Nsukka Formation to be type II/III kerogens known to be oil-gas prone material. The study reveals that AcharaUgwueme shale unit of Mamu Formation is of type III kerogen known to be gas-prone. Estimation of the maturation stage of the samples using the exinecolours of pale-yellow to yellow, the sporomorphs shows (1+ to 2+)thermal alteration index(TAI) and reflectance values of 0.3% for both Nkwe mudstone and AcharaUgwume shale unit, thus are thermally immature to generate hydrocarbons while Umuaku shale unit with exinesporomorphscolour of yellow –light brown, (2to2+), thermal alteration index (TAI) and reflectance value of 0.5% to be thermally immature to early mature (early oil phase of hydrocarbon generation).

Keywords: Macerol Marine Exinite, Palynofacies, Phytoclast and Kerogen

Introduction

The study area lies within the Anambra Basin, Southeastern Nigeria, West Africa, latitudes $06^{0}00$' and $06^{0}07$N and longitudes $007^{0}21$'and $007^{0}28$E (fig. 1).Anambra Basin is a north-east-southwest heading syncline having a roughly triangular shape with a total sediment thickness of about 9km. Various authors have reviewed the origin, tectonic evolution, stratigraphy and geochemistry of the Benue Trough (Olade, 1975; Ekweozor**,** 1982; Nwachukwu, 1985 and 1988**).** Sedimentation in Benue Trough was controlled by three major tectonic phases and the first tectonic phase (Albian-Santonian resulted in the deposition of Asu River Group, Eze-Aku Group and Awgu Shale Formation within the Abakaliki-Benue Trough. The preferential rate of subsidence in the southern Benue Trough was very high during Turonian age and this was an important phase of platform subsidence (Ojo, 1990**).** The period of preferential high rate of subsidence of the Anambra Platform corresponds to the initiation of the Anambra Basin which started during the Conician and reached the peak at the Santonian thermo-tectonic event (compressive movement along northeast-southwest axis) which deformed existing strata and resulted in Santonian intensive magmatism, folding, uplift and faulting. The Abakaliki Anticlinorium later became a sediment dispersal centre from which mineralogical nature detritus washed into the newly formed Anambra Basin and Afikpo Synclines. Other sources of texturally matured sediments include Southeastern Nigeria Craton, crystalline basement areas of Oban Massif and Cameroon Basement granites which had undergone prolonged chemical weathering (Reijers, and Nwajide, 1998). The basin is characterized by environments of lithological heterogeneity in both lateral and vertical expansion derived from a range of paleo-environment settings (Akaogbobi, 2005).

The Anambra Basin sedimentary fill was deposited during one major transgression and a major regression in late Santonian (Campanian) to early Paleocene (Danian). The Companian Epoch marked the deposition of the Nkporo Group comprising Nkporo Shale, Owelli Sandstone and Enugu Shale. (Table1). Nkporo Group overlies the

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CompanianAwgu Group of the Southern Benue Trough. Slowing subsidence, followed by a major regression led to the formation of an expansive, low-lying coastal area with lagoons and swamps on which a thick succession of Coal Measures (Mamu Formation) and fresh water sandstone (Ajali Formation) were deposited during the Maastrichtian Epoch.

Borehole data from the southern parts of Anambra Basin used in reconstruction of the stratigraphic units revealed that the Nkporo Group and the Coal Measures (Mamu Formation; Ajali Formation and Nsukka Formation) appear to be steeply inclined dipping towards the western flank of Onitsha High and flattening out below the Imo Formation.

The petroleum geology and paleo-environmental deposition of Anambra Basin have been carried out by authors and researchers.

Hydrocarbon exploration in Anambra Basin was spear-headed by Shell D.ARCY during the 1930's following the notable stratigraphic setting and oil seepages, smells and stains observed at the foot of Enugu Cresta at Ugwueme, Southeast Nigeria. Since then, attention of the exploration and producing oil companies and several other workers have shifted to the basin in order to access the potential of the basin in accumulation of petroleum. However, several wildcat wells and such as Akukwa-1, Nzam-1 among others drilled within the basin by Multinationals and surface geologic by several workers in the basin showed little or no evidence of commercial hydrocarbons. Majority of the workers concluded that the source rocks within the Anambra Basin are not matured to generate hydrocarbons and that the oil seepage at Ugwueme does not indicate that it comes from the source rocks within Anambra Basin rather it was believed to have migrated from the pre-Santonian sediments underlying it. Other workers concluded that the basin does not accumulate oil but gas.

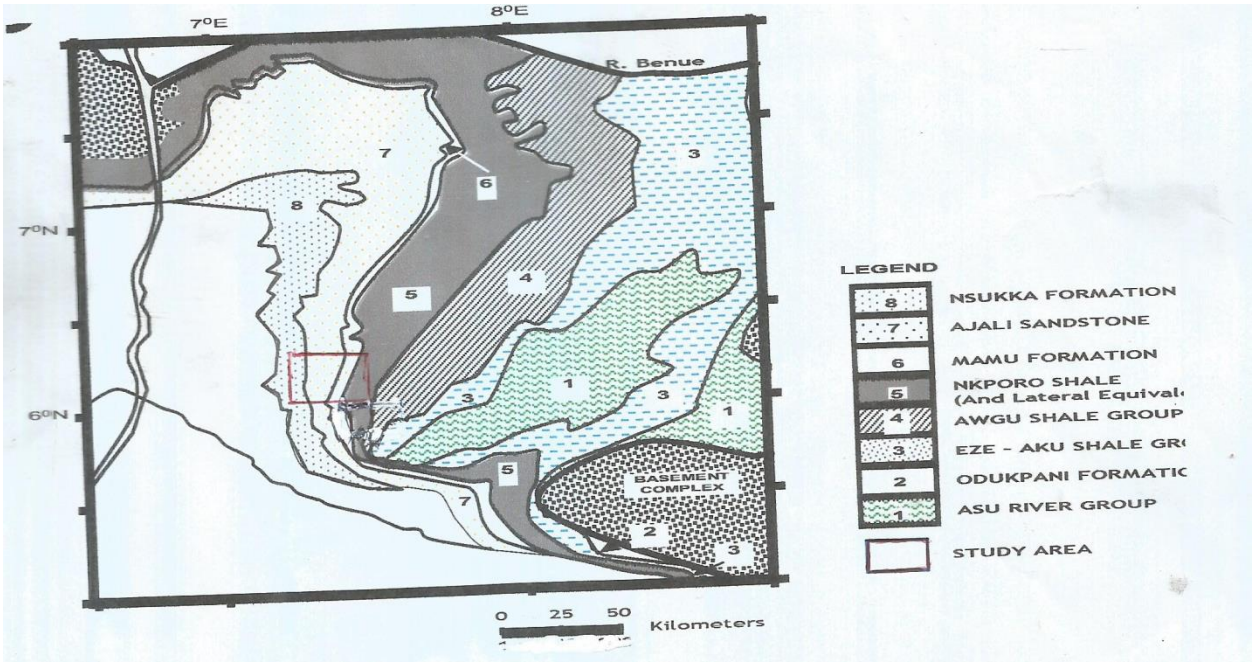


Figure 1: Geologic Map Of Anambra Basin Showing Study Area

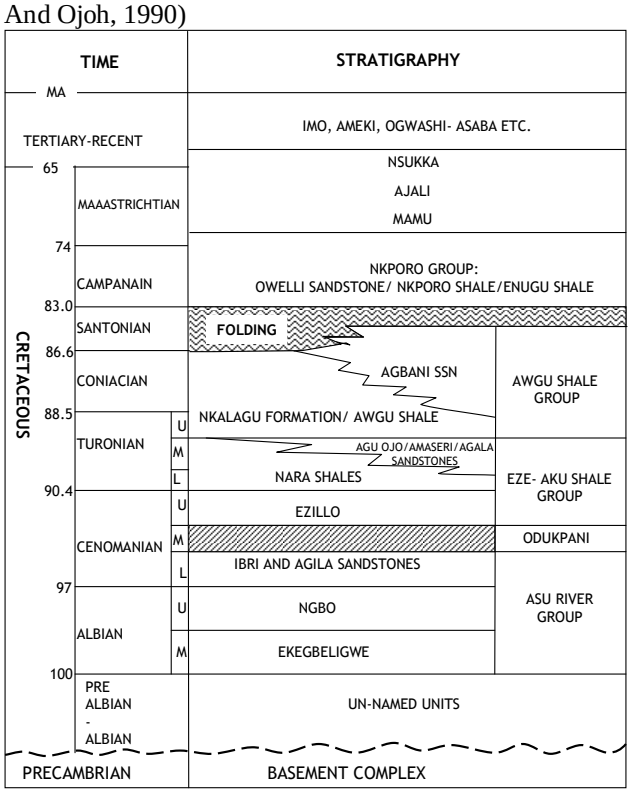
Whiteman (1982), places Anambra Platform as having good to very good prospects for oil and gas. Agagu and Ekweozor(1982), indicated that the Awgu and NkporoShales constitute the main source and seal rocks in Anambra Basin. Ekwuozor and Gormy(1983) described Nkporo Shale as an example of a marine source rock composed of type II/III kerogen with low but consistent contribution from marine organic matter. Unomah and Ekweozor(1993) reported that the organic facies of the Nkporo Shale are provincial with the Calabar Flank having the highest oil potential while those in the Anambra Basin and Afikpo Synclines are gas prone. Adeigbe and Salufu(2010) established that Enugu Shale, Mamu Formation and Nsukka Formation ; all in Anambra Basin are all potential source rocks but only that of Mamu Formation has reached oil generating window. They established a predominant gas prone basin for Anambra Basin. Chiaghanam et al. (2013) in their study concluded that Enugu Shale and Mamu

Formation are gas-prone (type III kerogen) and immature.

The Enugu and Lafia-Obi Coals (Mamu Formation) have been consistence with kerogen II/III derived from terrestrial plant with low marine organic matter found within oil and oil-gas generative windows (Nwajide, 2013). Nwajide, 2013 suggested that the coal facies have been source rocks. In the light of the foregoing, this paper focuses on using palynofacies and kerogen analyses as proxy to evaluate and assess the palnofacie type, kerogen type as well as the degree of thermal maturation of the studied samples within Ugwueme, Anambra Basin.

These controversial issues form part of the reasons for the study. Therefore, knowing the true geology and assessing the source rocks within Ugwueme and environs within Anambra Basin for possible petroleum generation potential is essential.

Table1. Summarized Stratigraphy Of The Benue Trough And Anambra Basin (After Reyment, 1965 And Ojoh, 1990)



Materials and Method:

Three samples belonging to Nkporo Formation, Mamu Formation and Nsukka Formation of upper Cretaceous sediments exposed at Nkwe, AcharaUgwueme and Umuaku villages within Ugwueme and environs were obtained for the analysis. Three kerogen slides were prepared from the samples using conventional method of acid maceration. Each slide was examined using the transmitted light microscopy at x10 and 40 magnifications for qualitative and quantitative analysis of the Particulate Organic Matter (POM), determination of the palynofacies association and kerogen types, spore/pollen colouration and estimation of thermal alteration index (TAI), vitrinite reflectance (R_O%) and organic thermal maturation. Each slide was counted for its (POM) content, in which the first 200 particles were counted in terms of *abundant* (>35 %), *frequent* (16-35 %), *common* (5-15 %) and *rare* (<5 %).

Result and Intrpretations:

The particulate organic matters identified are polynomorphs, phytoclasts, opaques and amorphous organic matter (Table 2).

Table 2. Percentage Distribution of Particulate Organic Matter (POM) Among the Studied Samples

SAMPLE NO.	PHYTOCLAST	AOM	OPAQUES	PALYNOMORPHS
Umuaku Shale (NsukkaFm)	30 %	50 %	15 %	5 %
AcharaUgwume Shale (MamuFm)	65 %	7 %	25 %	3 %
Nkwe Mudstone (Nkporo Shale Fm)	30 %	55 %	10 %	5 %

Table 3. Verbal Interpretation Of Percentage Abundance Of Pom - Where A-Abundance, F-Frequent, C- Common And R-Rare

Sample No.	Formation	Phytoclast	AOM	Opaque	Palynomorphs
Umuakwu shale	Nsukka Formation	F	A	C	C
Achara Shale	Mamu Formation	A	C	F	R
Nkwe Mud	Nkporo Shale	F	A	C	C

The percentage distribution of the particulate organic matter is represented alphabetically by abundant -A (> 35%), frequent-F (16-35%), common-C (5-15%), and rare-R (>5%)**(**table 3).Using the values above as an interpretative guide, the distribution of particulate organic matter throughout the studied sequence shows a clear organic facie shift from mixed marine-terrestrial influenced facies to strongly terrestrial dominant facie. Thus, the studied sedimentary sections were subdivided into two main palynofacies units: palynofacies A and palynofacies B. Palynofacies A comprises of the lower Nkwe Shale Unit of Nkporo Formation and upper Umuaku Mudstone Unit of Nsukka Formation.

Palynofacie A has abundant organic matters (AOM), common opaques, frequent phytoclasts and rare palynomorphs. The amorphous organic matter (AOM) of this palynofacie is composed majorly of maceral marine exinite such as dinoflagellate and also some palynomorphs and stem cuticles.The AcharaUgwueme unit of Mamu Formation being classified as palynofacie B is exceptionally characterized with a high terrestrial derived particulate organic matter with abundant phytoclasts (up to 65%), common (7%), frequent opaques (25%) and rare palynomorphs (3%). The phytoclast is composed of well-preserved structured terrestrial plant fragment, mainly of tracheids.

Table 4. Summary Of Kerogen Assessment and Interpretation

SAMPLE NO	PALYNOFACIES ASSOCIATION	S/P COLOUR	TAL	VITRINITE REFLECTANCE(Ro%)	THERMAL MATURATION	KEROGEN TYPE	HYDROCARBON TYPE
Umuaku shale	Mostly amorphous organic matter (AOM) followed by Phytoclasts. **(A)**	Yellow to light brown	2 to 2+	0.5%	Immature to mature	Type II/ III	Oil- Gas Prone
Achara shale	Mostly Phytoclasts followed by Opaque Debris. **(B)**	Pale yellow to yellow	1+ to 2-	0.3%	Immature	Type III	Gas Prone
Nkwe mudstone	Mostly amorphous organic matter (AOM) followed by Phytoclasts. **(A)**	Pale yellow to yellow	1+ to 2-	0.3%	Immature	Type II / III	Oil - Gas Prone

The palynomorphs standard colour calibration of the facies ranges from pale-yellow to yellow in accordance with Traverse (1988) for both Nkwe Mudstone (Nkporo Formation) and AcharaUgwueme Shale (Mamu Formation). For Umuaku Shale (Nsukka Formation), the colour ranges from yellow to light brown. The thermal alteration values of Nkwe Mudstone (Nkporo Formation) and that of AcharaUgwueme Shale (Mamu Formation) ranges from 1+ to 2- while thermal alteration of Umuaku Shale (Nsukka Formation) was2+. The change in kerogen type within the sequence may be attributed to the variation in paleo-geographical setting ofCampanian-Maastrichtian sea level across the basin. The vitrinite reflectance (Ro%)value for both Nkwe mudstone unit (Nkporo Shale Formation) and AcharaUgwueme shale unit (Mamu Formation) is 0.3%, while that of Umuaku shale unit (Nsukka Formation) is 0.5%.

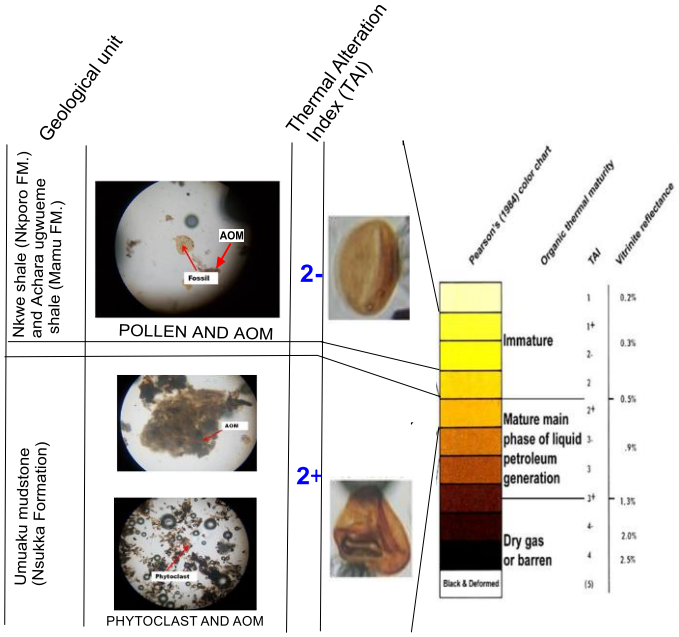


Figure 2. Composite Chart of Studied Sequence showing the Thermal Maturity of Samples and their Particulate Organic Matter

From the above results, it can be said that NkweMudstoneUnit and AcharaUgwuemeShale unit which are predominantly of amorphous organic matter (AOM) followed by phytoclasts are as a result of marine and terrestrial influences, these are compose of type II/III kerogenmaceral marine exinite and stem cuticles that are oil-gas prone. The Umuaku shale unit is predominantly composed of phytoclasts followed by opaque debris materials suggesting strong influence from terrestrial materials which consists type III kerogen known to be gas prone. The pale yellow to yellow colour of both Nkwe mudstone Unit (Nkporo Formation)and AcharaUgwueme shale unit (Mamu Formation) indicates that they are still in diagenetic phase of maturation showing immaturity of the organic matters, while the yellow-light brown colour of Umuaku shale unit shows an early maturity of catagenetic phase of maturation. The thermal alternation index values of 2 to 2t and vitrinite reflectance value (Ro%) of 0.3 for both Nkwe mudstone unit and AcharaUgwueme shale unit indicates that the organic matter for both units are immature, while the TAI values of 1+ to 2- and vitrinite reflectance (Ro%) 0.5 of Umuaku shale unit indicate immature to early maturity of organic matter.

Conclusion:

From the particulate organic matter distribution analysis, it was established that the area of study has two major palynofacies units: palynofacies A and palynofacies B. Though the studied area is predominantly gas prone, Nkwe mudstone unit of Nkporo Shale Formation, AcharaUgwueme shale unit of Mamu Formation and Umuaku shale unit of Nsukka Formation all in Ugwueme section of Anambra Basin are potential hydrocarbon source rocks but only Umuaku shale unit of Nsukka Formation has reached early stage of oil generating window probably due to its radioactive elements that emit heat energy.

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