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Provenance and Tectonic Setting of Amasiri Sandstone (Turonian) in Ugep Area, Southern Benue Trough, Nigeria: Evidences from Petrography and Geochemistry

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Abstract - The petrographic and geochemical study of sandstones of Eze-Aku Formation (Turonian) outcropping in Ugep area southern Benue Trough Nigeria was carried out to ascertain the sandstone provenance and tectonic setting. Field studies show that the sandones occur in linear, parallel northeast-southwest trending ridges alternating with shale sequence. The sandstone facies show coarsening upward sequence, slightly bioturbated, cross-stratified, rippled bedded which infer foreshore to shallow marine below wave base. Petrographic studies show the occurrence of quartz, feldspar, rock fragments and muscovite. The calculated framework grains suggest feldsparthic (subarkosic) sandstone. The geochemical analysis of the major elements of the sandstones show that they are enriched in SiO2, TiO2, Al2O3 and Fe2O3 and depleted in K2O, Na2O, MgO and CaO. Tectonic setting discrimination plot diagrams based on major elements suggest the provenance for the sandstones to be of metamorphic and igneous rocks of Passive Continental Margin Basin. The results of petrographic and geochemical study suggest Oban Massif and Cameroon Basement as the source regions for the sandstone which are characterized by humid climate and low-relief during the Turonian.

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PROVENANCE AND TECTONIC SETTING OF AMASIRI SANDSTONE TURONIAN IN UGEP AREA, SOUTHERN BENUE TROUGH, NIGERIAEVIDENCES FROM PETROGRAPHY AND GEOCHEMISTRY

Strictly as per the compliance and regulations of :

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Abstract - The petrographic and geochemical study of sandstones of Eze-Aku Formation (Turonian) outcropping in Ugep area southern Benue Trough Nigeria was carried out to ascertain the sandstone provenance and tectonic setting. Field studies show that the sandones occur in linear, parallel northeast-southwest trending ridges alternating with shale sequence. The sandstone facies show coarsening upward sequence, slightly bioturbated, cross-stratified, rippled bedded which infer foreshore to shallow marine below wave base. Petrographic studies show the occurrence of quartz, feldspar, rock fragments and muscovite. The calculated framework grains suggest feldsparthic (subarkosic) sandstone. The geochemical analysis of the major elements of the sandstones show that they are enriched in SiO_2, TiO_2, Al_2O_3 and Fe_2O_3 and depleted in K_2O, Na_2O, MgO and CaO. Tectonic setting discrimination plot diagrams based on major elements suggest the provenance for the sandstones to be of metamorphic and igneous rocks of Passive Continental Margin Basin. The results of petrographic and geochemical study suggest Oban Massif and Cameroon Basement as the source regions for the sandstone which are characterized by humid climate and low-relief during the Turonian.

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I. Introduction

They have not been a sufficient work in the study area. However several geologic survey works have been conducted based on regional scales, noting that, the study area fall under the lower Benue Trough. The southern Nigeria sedimentary Basin which is housing the study area have been investigated by many researchers such as Reyment (1965) Cratchley and Jones (1965) and Offodile (1976). Murat (1972) attempted a paleogeographic description of the Cretaceous and lower Tertiary rocks in the southern Nigeria based on major depositional cycles resulting from three main tectonic episodes. Kogbe (1976) and Offodile (1976) have contributed to the recognition of the sedimentary units within the Benue trough.

The Turonian Eze-Aku Formation of the lower Benue Trough is dominated by shales and sandstones with subordinate limestones (Reyment, 1965). However, in the south eastern part of the trough, there are a number of northeastern-southwest trending sand bodies forming prominent sandstone ridges and are parallel to the axis of the Trough (Amajor, 1987). The stratigraphy and petrography of the sandstones have been carried out (Reyment, 1965; Banerjee, 1980; Amajor, 1987). The work of Reyment (1965) suggested that Eze-Aku sandstones were deposited in a shallow marine environment and possibly a tidal deposit (Banerijee, 1980). Amajor (1987) argued that sandstones of Eze-Aku Formation are storm dominated, not tide dominated base on facies analysis of the sandstones. Hoque (1977) and Amajor (1987) considered the sand bodies to be texturally and compositionally immature feldspathic Arenites, based on petrographic studies.

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II. Geologic Setting of the Area

Investigation on Benue Trough has always been a serious concern to most geologists, as its complex nature has resulted to varying theories on its origin.

Benue Trough has been described as a rift depression of up to 80km long and 90km wide on the average, in eastern Nigeria; composed of marine and fluvio-deltaic sediment that have undergone distortion by compressional folding (Cratchley and Jones, 1965). While some trace the origin of the Trough to be triple junction; one arm of which gave rise to Benue Basin (Wright, 1976). With the emergence of sea floor spreading tectonics hypotheses Burke, et al (1970) came up with a new theory for the origin of the trough. The authors contended that the Benue rift first opened, in the cretaceous, due to the spreading of a crustal ridge in the region of the present trough. This spreading, according to Burke,et al (1970), seized by late cretaceous and then was followed by a closing episode of the North Atlantic and South Atlantic African plates, in the Santonian. The resultant differential motion of the two parts of the African plate, in their view, resulted in the santoinan folds and gave them their unique parallel and sub-parallel structure along the trough. Nwachukwu (1972), apparently, disagreeing slightly, suggested that while the tectonic evolution of the Benue Trough may be reconstructed in terms of disruptive and convergent interactions of the two continental plates, under thrusting was not likely and crustal spreading therefore was minimal.

Nevertheless, the continuity of the sediments of the Benue Trough with the Nigeria Coastal Basin is not disputed as has been shown by Cratchley and Jones, (1965) to be marked by:

(1) The continuity of the paleontological zonation with the coastal marine formations
(2) The series of long narrow folds with East-Northeast-West-Southwest trend linked with the south-western folds of the Abakaliki sedimentary area.
(3) The narrow lead-zinc mineralization belt running from Abakaliki area to the north east part of the Basin.

The Benue Trough consist of a linear stretch of sedimentary basin running from about the present confluence of the Niger and the Benue rivers to the northeast, and bounded by the Basement Complex areas in the north and south of the River Benue. This elongate trough Basin is continuous with the Coastal Basin, has been described as the long arm of the Nigeria Coastal Basin (Reyment, 1965). Stratigraphically, the Benue Trough is arbitrarily subdivided into three regions; the upper or north-east regions; middle Benue region or the lafia-muri area; and the lower or southern Benue Trough (Obaje. et al; 2oo4), which is the area south and west of Markurdi.

The stratigraphy of southern Benue Trough is marked by a series of transgressive and regressive phases which affected the Benue Trough. According to (Reyment, 1965), description of the stratigraphy and palaeogeography of different sedimentary basins in Nigeria, the sediments of Benue Trough show markable variation in lithostratigraphy and Biostratigraphy. The various lithologies ranges from the Albian to the Maastrichtian age, with the oldest sediments been of Albian age.

The study area is of Turonian age (Eze-Aku Formation) deposited in the second transgressive phase in Nigeria (Simpson, 1955),. The type locality is the Eze-Aku River valley in southeastern Nigeria. The formation consists of hard grey to black shales and siltstones with frequent facies changes, to sandstones or sandy shales. The thickness varies, but may attain 100 meters in some places (Reyment, 1965). Locally, the outcrops of this sequence are seen at Amasiri "Amasiri Sandstone", Egede-Olu (South of Otukpo), Nkalagu, Ezillo, Ugep, with its lateral equivalence is the Markurdi Formation. The Eze-Aku formation is of shallow Marine deposit. The fossils consist mainly of vascoceratids, pelycypods, gastropods, echinoids, fish teeth, which indicate a basal Turorian age (Kogbe, 1989). The area is made ace-ssible by three major road network; the Abakaliki/ Afikpo road diversion in Abaomege area through Abaomege Ediba road to Ugep, Calabar/ Biase road to Ugep and Ikom/Obubra road to Ugep (Fig.1).

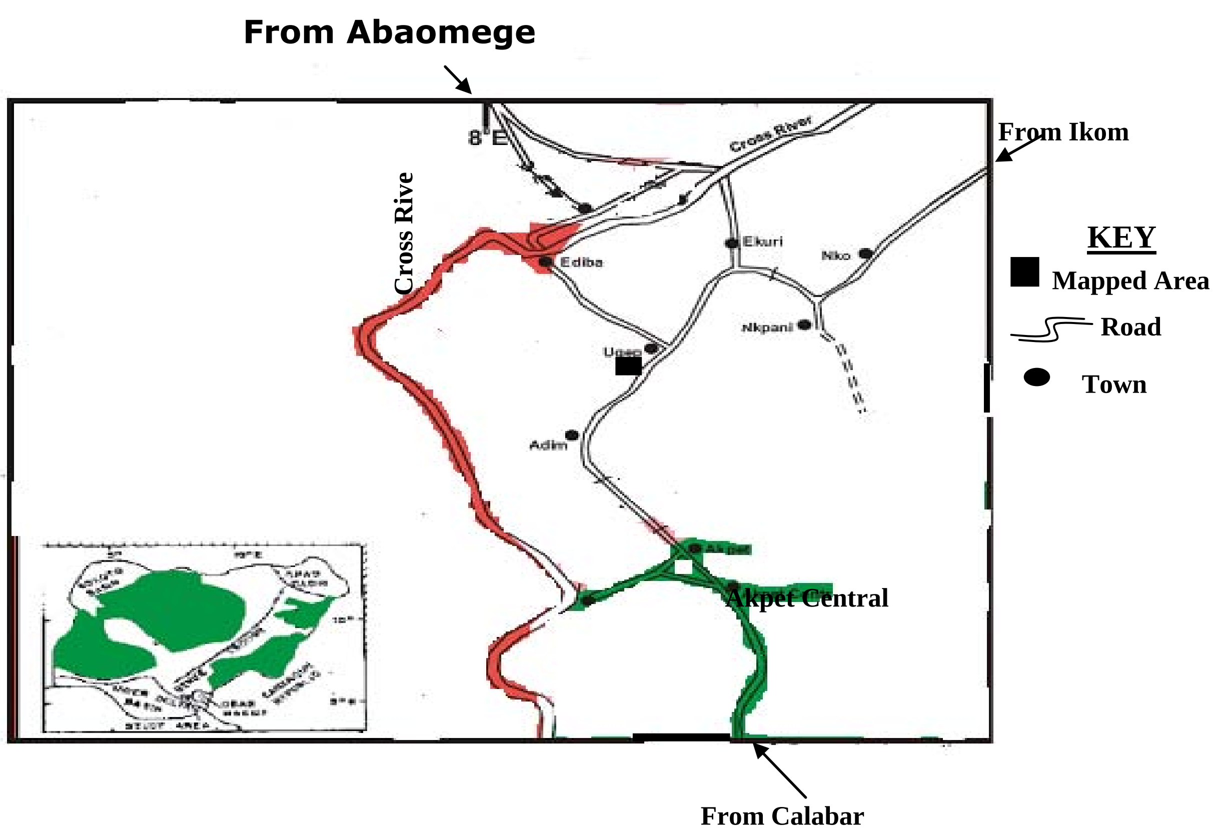

Figure 1 : Accessibility Map of the Study Area (Adapted from, Ogungbesan, G.O. and Akaegbobi, I.M, 2011)

III. Method of Study

The sandstones outcropping in places Ekpanti farm Road along Idomi major Road, Kebur stream in Iabokem Idomi village, Akpepon Ntiefoli Road Ugep, Akpepon farm Road Ugep, Epanipaniti, along park Road Ugep, Ementi along Idomi major Road, Egeiti farm Road in Ugep, Yidobiti farm Road, Kiwel stream along stadium Road, Omilakwa oil filling station along Ikom Calabar major Road and Ntankpo Areas, were studied and described. Five thin sections were prepared from the collected samples. The produced thin section slides were studied using petrographic microscope for minerals identification, the photomicrograph taken (Fig.2) the modal composition (Table 1) and the recalculated modal analysis data (Table2) generated. Petrographic classification was done using quartz (Q), feldspar (F) and rock fragment (RF), after Dott (1964). The mineral maturity calculated using the mineralogical maturity index (IMM) of Nwajide and Hoque (1985).

Geochemistry analyses (major elements) of seven samples were performed by x-ray difraction technique **(Minipal 4ED Version).** The required filters for each element were selected accordingly and probed. The initial results of concentration of the elements selected were shown in diffractions, which were then converted to concentration in weight percentage of the major oxide of the elements in question. The results are shown in Table 3.

IV. Results and Discusion

a) *Lithostratigraphy*

Based on field observations the sandstones are divided into two units; Unit A (Idomi sandstone) and Unit B(Ugep sandstone).

Idomi sandstone Unit covers the North-eastern and south-eastern part of the mapped area. The sandstones exposures are massive, vary in thickness, about 10 to 34cm, silty, well consolidated, poorly bedded and show little or no laminations. The grain sizes are very fine to fine, angular to sub-rounded, and well sorted. The attitude of the beds shows NW-SE strike direction generally with dip amount between 8^{o} and 14^{o}NE. It is dirty white to whitish in colour. The minerals composition include; quartz, feldspar and muscovite.

Ugep sandstone Unit covers more than half of the mapped area .The sandstones are mostly whitish, yellowish and brownish in colour. In some locations, the rocks occur in colour bands from yellow to reddish brown coloration which is attributed to the effect of iron oxide in the cement. The mineral composition observed include; quartz, feldspar, muscovite. The sandstone show a coarsening upward grain size gradient, which ranges from fine to very coarse sandstone indicating upper and middle shore face depositional environment. The sandstones exposures are massive, non calcareous, friable and ranging in thickness between 3m and 22m from ground level and a lateral extent up to 350m. The beds are less distinct in some areas and others are thin and range between 30cm to 65cm in thickness. The grains are angular to sub-rounded, and poorly to moderately sorted. The general strike direction of the beds is NW-SE with dip amount between 3^{o} and 20^{o}NE. The sandstones are characterized by nodules and few rip clast, less resistance and bioturbations with calcite and iron oxide been the main cementing materials.

b) *Petrology*

The detrital frame work grains of the Ugep sandstone include quarts, feldspar, and muscovite. Quartz has been the dominating framework grain in the studied thin section (Table 1). The percentage range of quartz is 64 to 84%. The monocrystalline and polycrystalline grains have straight to strongly undulose extinction (Fig.2). The quartz grains are subangular to subsurrounded. Feldspar constitutes 6 to 14% of the detrital grains of the sandstones. Rock fragment about 4 to 15%. The muscovite is present in minor amounts. Matrix is between 4 to 8% of the detrital fraction. Cementing materials of about 3 to 7%. From the plot of the framework composition of quartz, feldspars and rock fragments for sandstone classification after Dott (1964) (Fig.3), all the samples plotted in the subarkose field; the sandstones are therefore classified as subarkosic sandstones.

The plot of the compositional framework grain data after Suttner *et al.,* (1981) diagram (Fig.4) suggest both metamorphic and igneous source rocks for the Ugep sandstones. In the QFR ternary diagram of Dickinson *et al.,* (1983), the compositional framework grain data plot in the Craton interior and recycled Orogen fields (Fig.5). These sandstones plotted in the Craton interior field are mature sandstones derived from relatively low-lying granitoid and gneissic sources, supplemented by recycled sands from associated platform or Passive Margin Basins (Dickinson *et al.,* 1983). This low relief and short transport distance gave rise to typically quartzo-feldsparthic sandstones of classic subarkosic character.

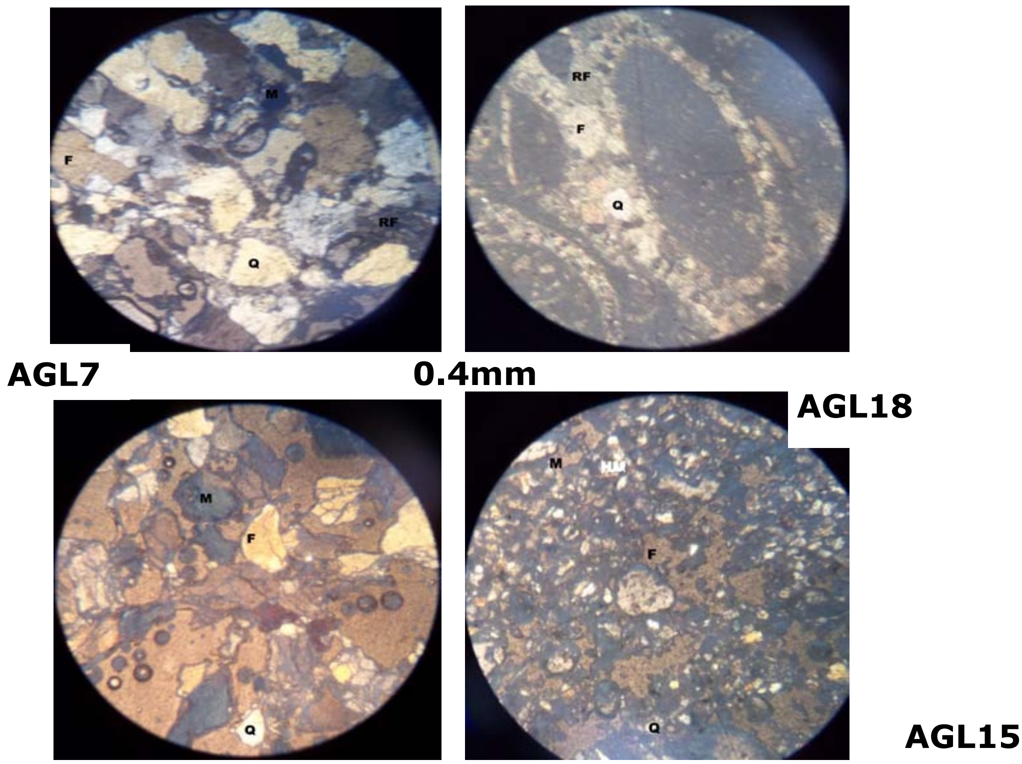

Figure 2 : Photomicrograph showing Q; Quarts grain; F; Feldspar; R.F; Rock Fragment; M; Heavy metals

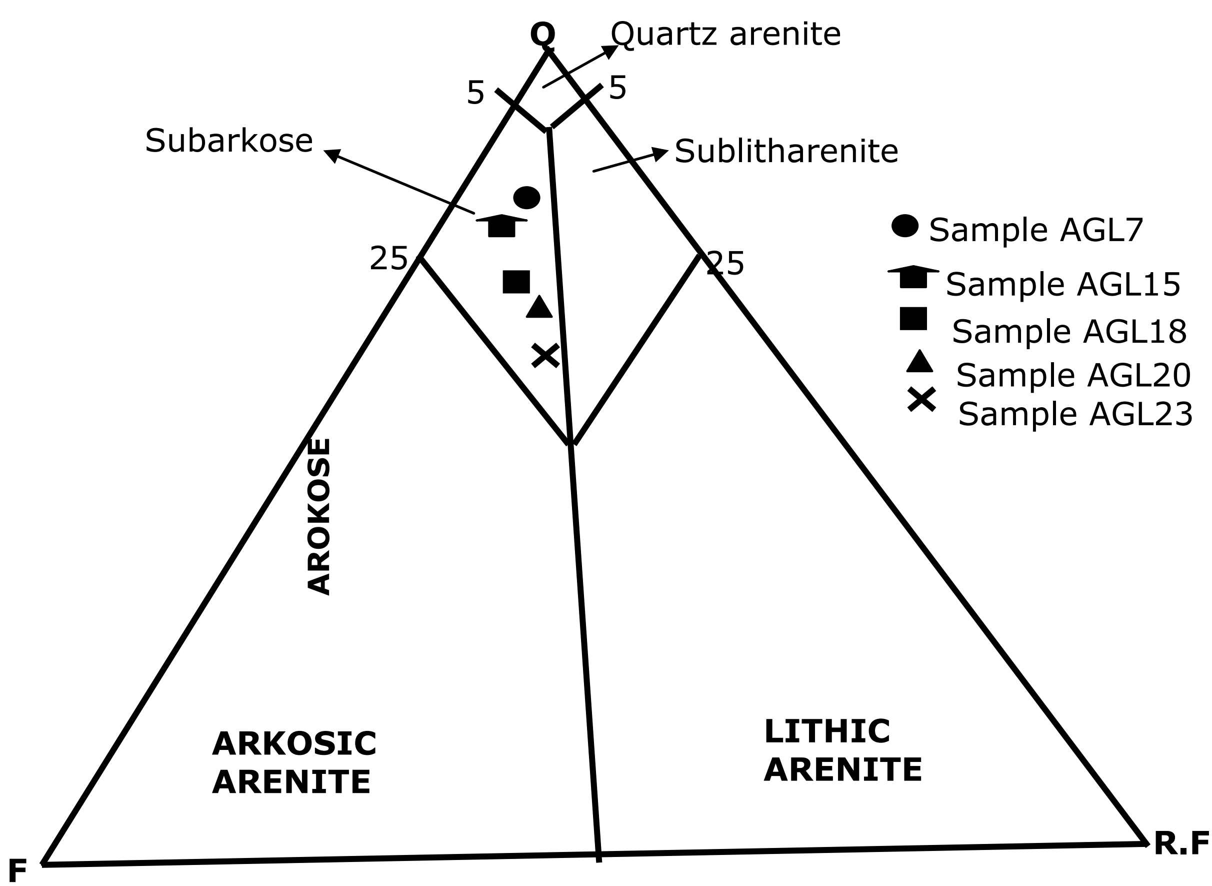

Figure 3 : Classification of terrigenous sandstones of Ugep using Dott, 1964 diagram

Table 1 : Petrographic Analysis Data

Sample No	Quartz	Feldspar	Rock Fragment	Muscovite	Matrix	Cement	Unfilled Void
AGL7	74	10	4	-	5	5	2
AGL15	62	8	9	3	7	9	2
AGL18	59	11	15	-	7	5	3
AGL20	49	14	13	5	9	8	2
AGL23	69	10	4	6	5	4	2

Table 2 : Re-calculated petrographic Analysis data

Sample No	Quartz	Feldspar	Rock Fragment
AGL7	84	11	4
AGL15	79	10	11
AGL18	69	13	18
AGL20	64	18	17
AGL23	83	12	5

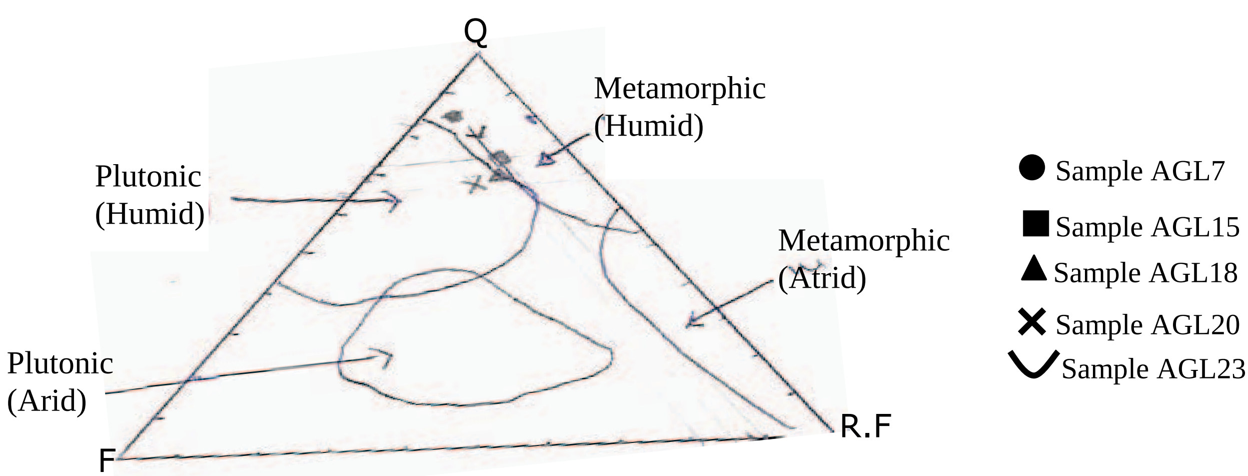

Figure 4 : The effect of source rock on composition of Ugep sandstone using suttner *et al.*, (1981) diagram

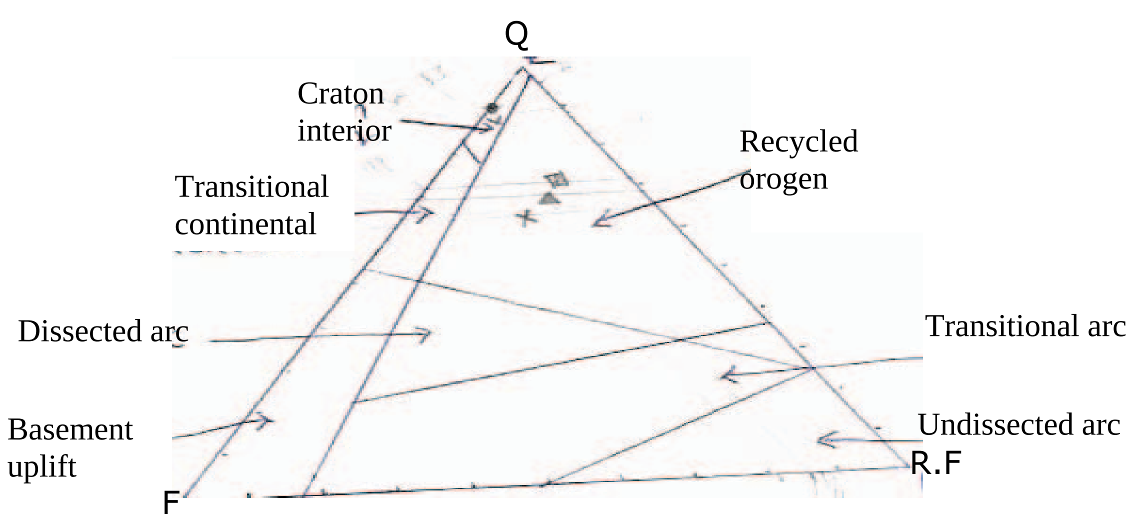

Figure 5 : QFRF Ternary diagram for the Ugep sandstone, after Dickinson *et al.*, (1983)

c) Mineralogical Maturity

The mineral maturity is calculated using the mineralogical maturity index (IMM) of Nwajide and Hoque(1985), given as;

$$IMM = \frac{\text{Proportion of Q}}{\text{Proportion of F} + \text{Proportion of R.F}}$$

From (Table 2), the mineralogical maturity Index is calculated thus;

$$IMM = \frac{75.8}{12.8 + 11} = \frac{75.8}{23.8} = 3.18$$

Since IMM value is less than 9 but greater than 3 as calculated above; hence the Sandstone is said to be mineralogically submature (Nwajide and Hoque, 19885). See table 3.

Table 3 : Maturity scale of Sandstone by Nwajide and Hoque (1985)

Limiting % of Q and (F + RF)	MI and maturity stage
Q =≥ 95% (F + RF) = 50%	MI = ≥ 19 suppermature
Q =95-90% (F + RF) = 5-10%	MI = 19- 9.0 submature
Q = 90-75% (F + RF) =10-25%	MI =9.0-3.0 submature
Q =75-5O% (F + RF) = 25-50%	MI =3.0-1.O immature
Q = < 50%	MI ≤ 1
(F + RF) > 50%	Extremely immature

d) Geochemistry

From (table 4) below ,the result shows a slight variation in element composition of all the samples analysed, reflecting homogeneity of all the sediment suit and indicating constancy of provenance and sedimentary environment of the rock. This variation reflects changes in the chemical and mineralogical composition of the sediment, especially in the quartz-feldspar ratio. SiO_2 abundance ranges from 55.56% to 71.78%; TiO_2 ranges from 0.05 to 0.18%; Al_2O_3 ranges from 13.83 to 25.22%; Fe_2O_3 ranges from 0.42 to 1.32%; Mno_2 NiL; MgO ranges from 0.07 to 0.32%; Na_2O ranges from 0.17 to 4.2%; CaO ranges from 0.22 to 0.41% and K_2O ranges from 4.66 to 6.14%.

The Ugep sandstone is enriched in SiO_2, TiO_2, Al_2O_3 and Fe_2O_3 and depleted in K_2O, Na_2O, MgO, CaO and absent of MnO_2. Mineralogical studies revealed that SiO_2 is mainly present as quarts and Al is mainly held in the clay mineral lattice as an essential constituent.

Characterizing the tectonic setting of the depositional basin, the geochemistry data of the Ugep sandstone samples are plotted on discrimination digram after Kroonenberg (1994). The diagram show that Ugep sandstone was deposited in a Passive Continental Margin as most of the plotted points shows in the Fig.6.

Table 4 : Major Element Composition in Percentage

Sample No	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2	TiO_2	SO_2	LO_1	Fe_2O_3+MgO	Al_2O_3/SiO_2	K_2O/Na_2O	$Al_2O_3/(Ca+Na_2O)$	K_2O+Na_2O	TiO_2+Na_2O	$SiO_2/20$
AGL7	55.78	25.76	1.13	0.12	0.27	4.63	0.13	0.06	0.01	11.95	1.40	0.46	35.61	103.04	4.76	1.46	2.79
AGL13	60.81	21.25	0.44	0.22	0.3	6.14	0.19	0.05	0.01	10.53	0.74	0.35	32.32	51.83	6.33	0.79	3.04
AGL14	57.88	24.21	1.14	0.19	0.27	5.01	0.15	0.07	0.02	10.93	1.41	0.42	33.40	71.21	5.16	1.48	2.89
AGL16	60.17	21.34	0.43	0.24	0.28	5.98	0.21	0.07	0.01	10.44	0.71	0.35	28.48	47.42	6.15	0.78	3.01
AGL18	55.56	25.22	1.04	0.41	0.2	5.34	0.17	0.05	0.01	12.00	1.24	0.45	31.41	43.48	5.15	1.29	2.78
AGL20	71.78	13.83	0.69	0.23	0.07	4.66	4.2	0.18	0.19	3.99	0.76	0.19	1.11	3.09	8.86	0.94	3.59
AGL23	60.57	21.1	0.48	0.39	0.32	5.12	0.21	0.06	0.02	11.7	0.87	0.35	24.38	35.2	5.33	0.86	3.03

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V. Conclusions

The Turonian sandstone of Ugep is made up of medium to coarse grain, poorly to moderately sorted, subarkosic Sandstones occur in fairly parallel, linear, Northeast-Southwest trending ridges characterized by a coarsening upward textural sequence.

The field relationship revealed that the sandstone is deposited in lower foreshore to shallow marine environment. The sandstone is texturally and mineralogically sub-mature and indicates a relatively short distance of transportation.

The petrographic and geochemical analysed suggest basement igneous and metamorphic rocks as the source rock, probably from Oban Massif and the Cameroon Basement which are under humid climatic setting. The major elements abundance also suggests a Passive Margin tectonic setting for the sandstones of the study area.

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