Geochemical Assessment of Sandstone of Dumbulwa Member of the Pindiga Formation Exposed at Ashaka Quarry, Gongola Basin, Ne Nigera

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ABSTRACT

Detailed geological mapping coupled with sample collection of sandstone of Dumbulwa Member was carried out at the Ashaka Quarry in the Gongola Basin. The geological mapping showed that the dominant rocks outcropping within the study area are sandstone of the Dumbulwa and shale of the Kanawa Member. Geochemical analysis of sandstone oxides using X-ray Fluorescence (XRF) was carried out using six (6) samples and the investigation reveals the following results; SiO_2 range from 30.04% to 87.67% with an average of 57.80%, Al_2O_3 range from 2.50% to 28.50% with an average of 14.76%, Fe_2O_3 range from 0.48% 63.67% with an average of 19.03%, CaO range from 0.26% to 1.39% with an average of 0.88%, K_2O range from 0.15% to 10.79% with an average of 3.83%, P_2O_5 range from 0.325% to 0.725% with an average of 0.53%, MgO range from 0.00% to 1.20% with an average of 0.31% and MnO range from 0.02% to 1.67% with an average of 0.33%, Na_2O range from 0.00% to 0.00% with an average of 0.00%, TiO_2 range from 0.13% to 2.28% with an average of 1.09%, and lastly SO_3 range from 0.20% to 0.48% with an average of 0.36%. Enrichment of silica (quartz)- SiO_2 over Al_2O_3 (log SiO_2/ Al_2O_3<1.5) is a reflection of the duration and intensity of weathering and destruction of other minerals during transportation. This indicates that the sandstone samples of the study area have undergone long period of transportation and have been subjected to intense weathering resulting in the destruction of low temperature minerals like plagioclase and potassium feldspars during the phase of sedimentary cycle. The overall results showed that silica (SiO_2) enrichment over Al_2O_3 by chemical and mechanical processes indicates sandstones maturity. Lack of abundance Na_2O and K_2O characterized immature sandstones such as arkoses and greywackes. Fe_2O_3 and MgO enrichment and concentration is a net result of provenance and processes that concentrate and preserved detrital ferromagnesian minerals and their alteration products.

Keywords: Geochemical, Dumbulwa, Pindiga Formation, Ashaka Quarry, Gongola Basin

INTRODUCTION

Sandstones make up nearly one- quarter of the sedimentary rocks in the geologic record. They are common rocks in geologic system of all ages, although their abundance and composition vary from system to system. They are distributed throughout the continents of the Earth. Particle composition is also important aspect of these rocks; it is a fundamental physical property of sandstones and is the chief property used in their classification. This group of rocks is a fruitful topic for study for exploitation of economic materials within sandstones. Because there are often highly porous sandstones frequently regarded as major aquifer and petroleum reservoir. The aim of this research is to carry out a detail geological studies so as to collect samples from the field and subject them for major elemental studies and geochemically classify them on the basis of their enrichments.

Location of the Study Area and Geological Setting of the Gongola Basin

The study area being Ashaka Quarry is located in Ashaka Village, Funakaye L.G.A of Gombe State,

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northeastern Nigeria. The quarry lies between longitudes 11^0 26^I E to 11^0 29^I E and latitudes 10^0 54^I N to 10^0 57^I N. It covers an area of about $7km^2$ (Fig.1)

The Benue Trough of Nigeria is a rift basin in Central West Africa that extends NNE- SSW for about 800km in length and 150km in width. The trough contains up to 6000m of Cretaceous - Tertiary sediments with some pre- dating the mid- Santonian have been compressionally deformed, faulted and uplifted in several places (Obaje *et al*., 2006). Compressional folding occurred during the mid- Santonian tectonic episode affecting the whole of the Benue Trough and was quite intense, producing over 100 anticlines and synclines (Benkhelil 1989). The Gongola Basin is the northern portion of the Benue Trough which bifurcates in the N-S trending Gongola Arm.

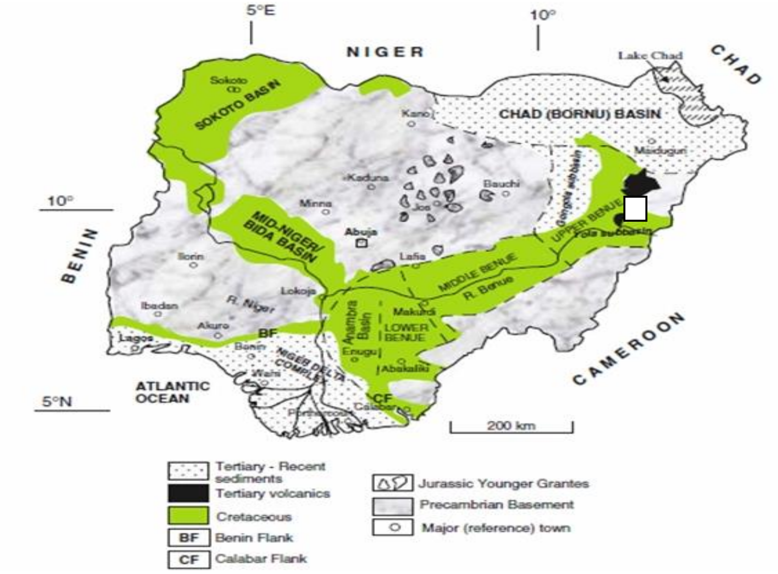

Fig. 1. Geological map of Nigeria showing the location of the study area (After Obaje, 2009)

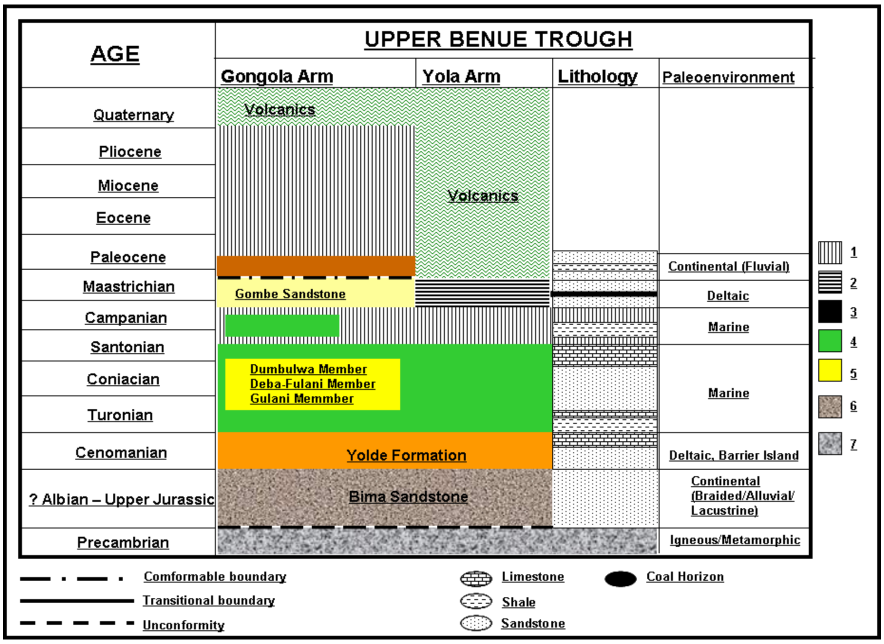

Figure 2: Lithostratigraphic subdivision of the Gongola Basin (After Zaborski *et al*., 1997)

Stratigraphycally; the Bima Group is the oldest sedimentary succession, continental in origin and directly overlies the crystalline Basement rocks. It is composed of three lithological formations, namely; Lower, Middle and Upper Bima Sandstones. The Lower Bima Sandstone is a highly variable unit with an overall thickness of 0 to 1500m and consists of conglomerates, alluvial fans/debris flow deposits. Is also consist of

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sandstones, clays, calcareous sandstones and shales, it is associated with volcanism. The Middle Bima Sandstone is a widely distributed, fairly uniform unit consisting of fining upward cycles (Fig.2)

It is characterized by trough and tabular cross- bedding, ripple lamination and contains mudstones. Its overall thickness is 500m (Guiraud, 1990). The Upper Bima Sandstone is fairly homogeneous, relatively matured, fine to coarse- grained sandstones characterized by tabular and convolute cross- beddings as well an overturned cross- bed. Its average thickness is 500m.

The Yolde Formation is a transitional unit overlying the Bima Group. It is poorly exposed in most part of the Gongola Basin. The lower part consists of alternating Cenomanian sandstones and dark gray mudstones while the top consists of regularly bedded sandstones with argillaceous interbedding. Bioturbations is also common.

The Pindiga Formation overlie the Yolde Formation and has been revised by Zaborski *et al*. (1997) to consist of five (5) members, namely; the Kanawa, Deba Fulani, Gulani, Dumbulwa and Fika Members. The Kanawa Member is a sequence of shale intercalated with limestone outcropping around Kanawa east of Gombe. The Gulani Member has its complete section at Maliya Village and consists of three units with about 150m of gray, white and orange granules and coarse to very- coarse grained tabular cross- bedded pebbly sandstone with purple, gray and white mudstone.

The Deba Fulani Member is a sand bed recognized south of Jurare at Deba Fulani. It thrust upon Gombe Sandstone. It consists of thin red lateritic unit with regoliths. Pebble sized fragments of dense and flagging or vesicular nature are present. Thickness range from 15cm to 1m of silty sands and silty shales. Tabular and trough cross- bedding are present.

The Dumbulwa Member occurs around the Dumbulwa Hills consisting of coarse- grained feldspathic tabular cross- bedded sandstones. Channel fillings sandstone bodies cutting through sequences of thinly bedded, fine-grained sandstone. It reaches its greatest thickness to about 200m at the Dumbulwa Hills.

The Fika Member has no exposures of appreciable thickness (Zaborski *et al*.1997). The exposures that do occur mostly reveal shale/mudstones dark gray when fresh but light blue- green- gray when weathered.

The Gombe Sandstone is restricted to the western parts of the Gongola Basin. It represents the youngest Cretaceous sedimentation in the Gongola Arm. It consists of sequence of estuarine and deltaic sandstone, shale, siltstone, and ironstone which overlies the Pindiga Formation. The Kerri- Kerri Formation connects to the west with the Cretaceous sediments of the Gongola Basin and to the east by Biu Plateau (Zaborski *et al*., 1997). It is essentially flat lying to gently dipping to about 5^0. It predominantly consists of grits, and ferruginized sandstones, siltstones and claystones which are often kaolinitic with a maximum thickness of about 300- 320m (Dike, 1993).

MATERIALS AND METHODS

A detail geological field study was carried- out within the Ashaka Quarry site and sandstone samples belonging to the Dumbulwa Member were collected at different locations. Six samples were selected and used for X-ray fluorescence (XRF) analysis in order to determine the major oxides so as to investigate the major characteristics minerals dominant in the sandstones. The analysis of major and trace elements in geologic materials by XRF is made possible by the behavior of atoms when they interact with X- radiation. Bulk chemical analyses of Major oxides (SiO_2, TiO_2, Al_2O_3, Fe_2O_3, MnO, MgO, CaO, Na_2O, K_2O, P_2O_5, SO_3) in rocks was carried out. Detail description of the method has been described by (e.g. Rollinson, 1993; Fitton, 1997).

RESULTS AND DISCUSSIONS

Results of representative samples from different locations were selected and used for the investigation so as to establish a starting point for the experiment. An X-ray fluorescence (XRF) result of major oxides is presented in Table 1.

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The geochemical elements involved are SiO_2, TiO_2, Al_2O_3, Fe_2O_3, MnO, MgO, CaO, Na_2O, K_2O, P_2O_5, SO_3. Table 1 shows the bulk geochemical oxides of sandstones which provide information on the dominant oxides and those that occur in lesser amount.

Table 1 shows the results of the analyzed data reveals that SiO_2 range from 30.04 to 87.67% with an average of 57.80%, TiO_2 range from 0.13% to 2.28% with an average of 1.09%, Al_2O_3 range from 2.59 to 28.50% with an average of 14.76%, Fe_2O_3 range from 0.48 to 63.67% with an average of 19.03%, MnO range from 0.02 to 1.67% with an average of 0.33%, MgO range from 0.00 to 1.20% with an average of 0.13%, CaO range from 0.26 to 1.29% with an average of 0.88%,

Table 1: Geochemical analysis of major oxides obtained from sandstones of the Dumbulwa Member of the Pindiga Formation exposed at Ashaka Quarry (all in %)

Sample ID %wt	**L 1**	**L 2**	**L 3**	**L 4**	**L 5**	**L 6**	**Average**
SiO_2	42.26	87.67	30.04	65.50	54.10	67.29	57.80
TiO_2	2.28	0.13	0.28	0.97	2.21	0.72	1.09
Al_2O_3	12.00	9.73	2.59	20.67	28.50	15.10	14.76
Fe_2O_3	36.72	0.48	63.67	1.08	9.39	2.89	19.03
MnO	1.69	0.02	0.16	0.02	0.06	0.05	0.33
MgO	0.69	0.00	0.00	0.00	1.20	0.00	0.31
CaO	0.59	0.26	1.38	1.09	0.51	1.39	0.88
Na_2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K_2O	0.79	0.15	0.31	8.65	2.32	10.79	3.83
P_2O_5	0.32	0.65	0.72	0.54	0.45	0.51	0.53
SO_3	0.25	0.48	0.20	0.40	0.40	0.44	0.36
Others	1.39	0.08	0.71	0.67	0.85	0.81	4.51
Total	99.98	99.67	99.99	99.59	99.99	99.99	99.86

Na_2O ranged from 0.00% to 0.00% with an average of 0.00%, K_2O ranged from 0.15 to 10.79% with an average 3.83%, P_2O_5 ranged from 0.32 to 0.72% with an average of 0.53%, SO_3 ranged from 0.20% to 0.48% with an average of 0.36%. Figure 3 shows the concentrations of major oxides with SiO_2 having the highest peaks except in sample L3 where Fe_2O_3 has the highest concentrations amongst the oxides. Al_2O_3 is the second most abundant oxide in terms of concentration values.

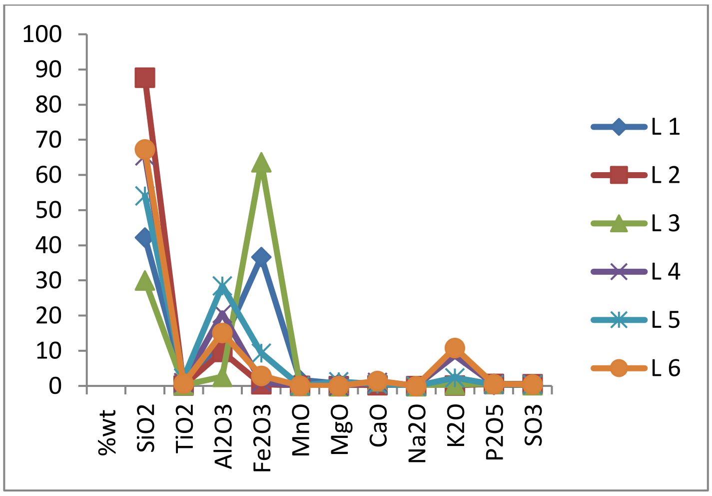

Fig. 3. Plot of major oxides concentrations percentage weight (%).

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Further Discussions

Lindsey (1999) reported that SiO_2 is a measure of sandstone materials, therefore, the enrichment of silica (quartz)- SiO_2 over Al_2O_3 (log SiO_2/ Al_2O_3<1.5) is a reflection of the duration and intensity of weathering and destruction of other minerals during transportation. This indicates that sandstones of the study area have undergone long period of transportation and abrasion, and have been subjected to intense weathering, resulting in the dissolution and destruction of low temperature weaker minerals such as plagioclase and potassium feldspars as well as biotite and muscovite (ferromagnesian) mica minerals.

The variation in SiO_2 content is probably due to textural variation and diagenesis. Al_2O_3 is the second most abundant oxide in the analyzed samples and results from weathering effects (Malpas *et al*., 2001), whereas the concentration of Fe_2O_3 ($FeTO_3$, total iron as Fe_2O_3) is the net result of provenance and processes that concentrate and preserved detrital ferromagnesian and iron minerals (amphibole, mica, illite, ilmenite, and magnetite) and their alteration products (chlorite, hematite and some clay varieties). SiO_2/Na_2O ratio showed very low correlation pattern due to none trace of Na_2O in all the analyzed samples and such is a result of poor contribution from clay minerals. Concentration of detrital ferromagnesian minerals reflects their abundance in source rock and is increased by hydraulic sorting and decreased by chemical destruction during weathering and diagenesis under oxidizing conditions. The low content of MgO in most of the studied samples indicates poor input from magnesian minerals, particularly biotite and muscovite (micas) and therefore low matrix contribution.

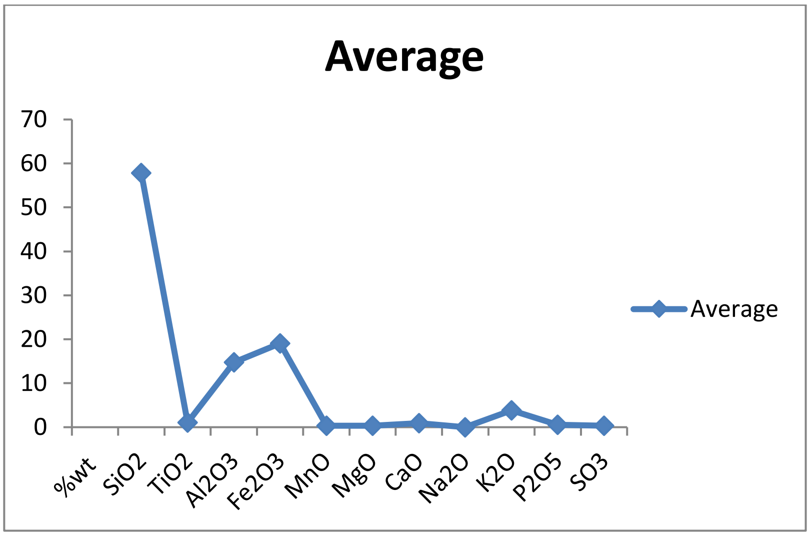

Fig. 4. Average concentrations of major oxides of the Dumbulwa Member

Figure 4 above shows the average concentrations of major oxides of Dumbulwa Member with silica (SiO_2) having the highest peak in all the analyzed samples, this is followed by Fe_2O_3, silica dominance in majority of the samples is an indication that it is the bulk dominant mineral in most sandstones. There are relatively very low concentrations of SO_3, CaO, P_2O_5, K_2O, MgO and MnO. This can be attributed to low calcite feldspar (plagioclase and alkali) and other detrital minerals contributions.

However, there is positive correlation between K_2O and Al_2O_3 which implies that the concentrations of K-bearing minerals have significant influence on aluminium distribution and suggests relative abundance of these elements is primarily controlled by the content of clay minerals (McLennan *et al*., 1983). The overall results showed that silica (SiO_2) enrichment over Al_2O_3 by chemical and mechanical processes is an indication of sandstone maturity, lack of abundant Na_2O and K_2O characterize immature sandstones (e.g. arkosic and greywacke. Fe_2O_3 and MgO enrichment and concentration is a net result of provenance and processes that accompanied the presence of detrital ferromagnesian minerals and their alteration products. It can further be stated that, the sandstones can be classified on the basis of their silica contents; samples L_1 and L_3 as lithic-arenites because of the abundance of rock fragments which are greater than 25%, samples L_2, L_4, L_5 and L_6 are classified as subarkose/arkose on the bases of their relatively high proportion of feldspathic minerals and their oxide products.

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Therefore, it can be stated that majority of the sandstones are subarkose or arkose while two others are lithic-arenites with no presence of quartz- arenites in the six analyzed samples. Sample L_3 is ferruginous sandstone that has noticeable amount iron (Fe_2O_3), this is presented Table 1.

CONCLUSION

Geochemical investigation of major oxides of sandstones of the Dumbulwa Member was carried in the Gongola Basin in order to classify the sandstones and understand their maturity levels. The

Information obtained reveals that silica enrichment (quartz) – SiO_2 over Al_2O_3 ($logSi0_2/Al_20_3<1.5$) is a reflection of the duration and intensity of weathering and destruction of other minerals during transportation. The overall results showed that silica (SiO_2) enrichment over Al_2O_3 through chemical and mechanical processes indicates sandstone maturity. Lack of abundance of K_2O and Na_2O characterized immature sandstones such as arkose. Fe_2O_3 and MgO enrichment and concentration is a net result of provenance and processes that concentrate and preserved detrital ferromagnesian minerals and their alteration products.

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