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# Geochemical Assessment of Mudstone Member of the Gombe(Sandstone) Formation, Gombeand Environs, Gongola Basin

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***Abstract:*** *Detailed geologic mapping carried out within Gombe and environs, indicated thatthe major rock outcroppingin the area are basically Gombe Sandstone and Kerri-Kerri Formation. Geochemical analysis carried out for major oxides using X-ray fluorescence (XRF) for the three (3) rock samples of the mudstone member of Gombe Sandstone indicated that* $Si0_2$ *has an average percentage of 52.47% and range from 45.42 to 58.47%.* $Al_2O_3$ *has an average percentage of 15.78% and range from 13.42 to 17.21%.* $Fe_2O_3$ *has an average percentage of 3.22% and range from 2.46 to3.69%.* $Na_2O$ *has an average percentage of 2.93% and range from 2.48 to 3.25%. CaO has an average percentage of 1.98% and range from 1.11 to 2.90%.* $K_2O$ *has an average percentage of 1.57% and range from 0.89 to 2.74%. FeO has an average percentage of 1.09% and range from 0.81 to 1.32%.* $P_2O_5$ *has an average percentage of 0.65% and range from 0.14 to 1.00%. MgO has an average percentage of 0.122% and range from 0.064 to 0.18%. MnO has an average percentage of 0.04% and range from 0.02 to 0.06%. Loss of Ignition (LOI) has an average percentage of 10.09% and range from 7.91 to 12.16%. The Index of Compositional Variability (ICV) values of the mudstones of the study area in the southern part of Gombe shows that the source of the rock is from plutonic environment. Chemical Index of Alteration (CIA) value of the mudstone member of Gombe Sandstonein the study area showed intense chemical weathering of mudstone and the presence of minerals rich in compositionally mature alumina.*

***Keywords:*** *Geochemical Assessment, Chemical Index of Alteration, Mudstone, Gombe Formation, and Gongola Basin*

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## I. Introduction

The Gongola Basin(Upper Benue Trough or Northern Benue Trough) falls within the Benue Trough and is a linear stretch of sedimentary basin trending NE-SWdirection. TheUpper Benue Trough is made up of different Formations; Bima Sandstone, Yolde Formation, Pindiga Formation, Gombe Sandstone and Kerri-Kerri Formation.

This study area falling within the Upper Benue Trough and comprises of two (2) geologic Formations which are Gombe Sandstone (Cretaceous in age) and Kerri-Kerri Formation (Tertiary in age). The Gombe Sandstone overlies the Pindiga Formation unconformably and the Kerri-Kerri Formation overlies unconformably on Gombe Sandstone. From the mapping on the study area, thirty-two (32) rock samples were chipped with the help of topographic map and other field equipments and from which three (3) rock samples (mudstone member of Gombe Sandstone) were used for geochemical analysis of major elements oxides ($SiO_2$, $Al_2O_3$, $Fe_2O_3$, FeO, CaO, $K_2O$, $P_2O_5$, MgO, MnO and $Na_2O$) using X-ray fluorescence spectrometry (XRF) method and loss of ignition (LOI) using furnace. From the geochemical analysis result, it shows that $SiO_2$ has the highest percentage while MgO has the least percentage. Other parameters calculate are the Index of Compositional Variability (ICV), the Chemical Index of Alteration (CIA), $K_2O/Al_2O_3$ ratio, and $K2O/Na_2O$ ratio to ascertain provenance, tectonic setting, the degree of weathering of source rock and relative abundance of alkali feldspar versus plagioclase in the mudstone member of the study area.

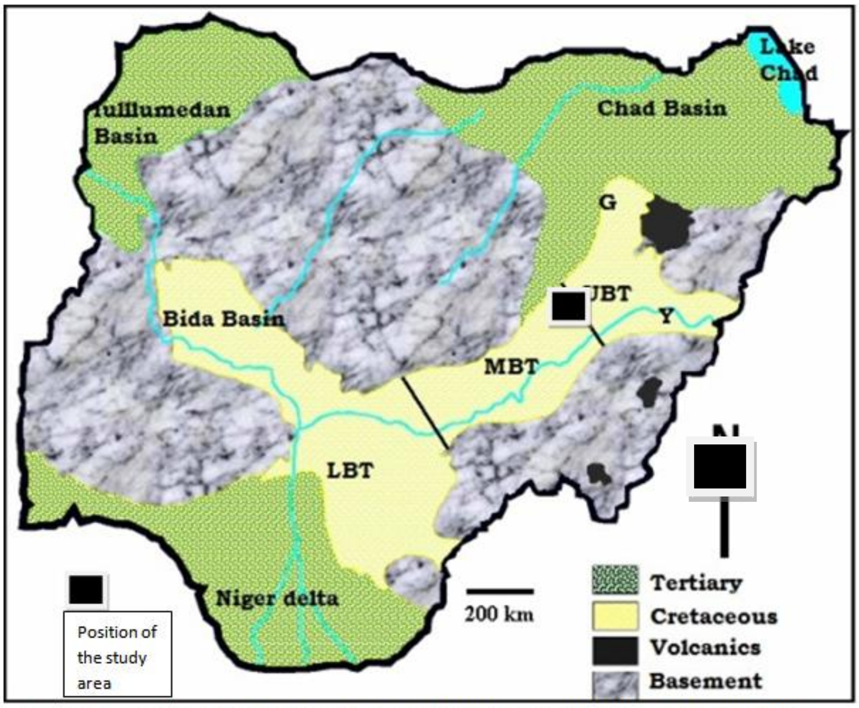


Figure 1: Geological map of Nigeria showing the location of the study area (Modified from Oboe *et al.*, 1999)

## II. Geological Setting

Regionally, the geology of the study area falls within the Benue Trough which is linear stretch of sedimentary basin trending NE-SE direction. It stretches from Niger-Delta around Onitsha through Makurdi following the course River Benue up to Gombe and Yola areas (Kogbe, 1976). The trough is flank to the west and east by basement complex bounded on the SW and SE respectively by the Benin and Calabar flank. In the north, it is separated from Chad Basin by Zambuk ridge.

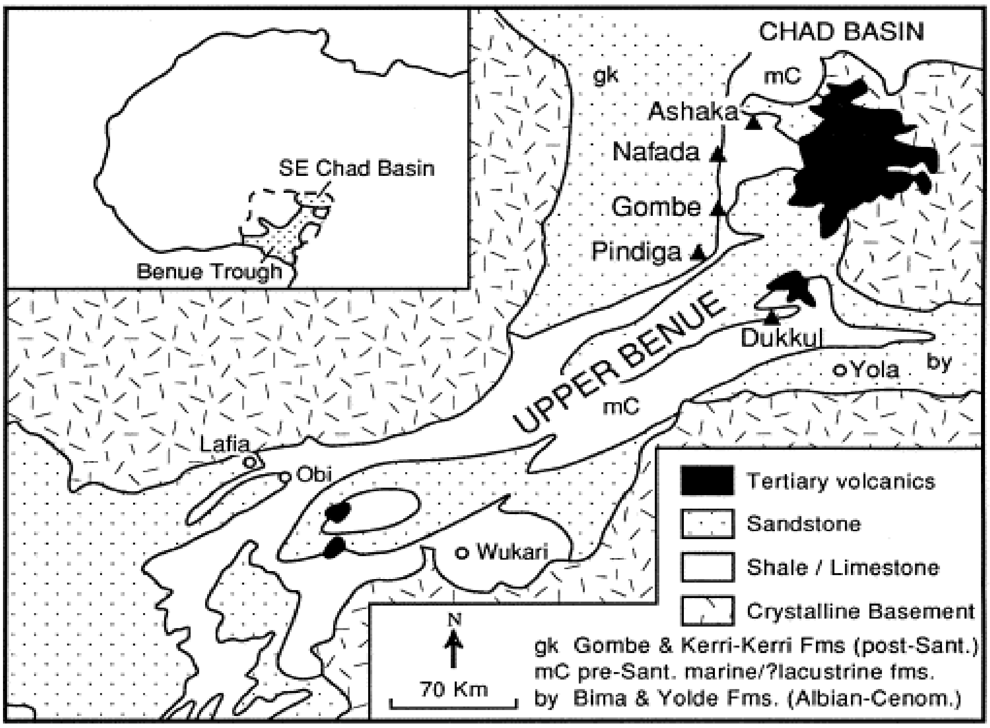


Figure 2: Geographical location of the Upper Benue Trough and Gombe in Nigeria (After Obaje *et al*. 1999)

The Upper Benue Trough bifurcates into E-W trending Yola Arm and N-S trending Gongola Arm. These two are separated by an area structurally dominated by four major NE-SW trending sinistral strike-slip faults; Gombe, Bima- Teli, Kaltungo and Burashika faults (Zaborski *et al*., 1998).

Stratigraphic description of sediments in the Upper Benue Trough (Gongola Basin) have been discuss in some details by (Carter *et al.*,1963; Benkhelil, 1989; Popoff *et al*., 1986; Guiraud, 1993; Gebhardt, 1997; and Zaborski *et al*., 1998; and Zaborski, 1998).

The continental Bima Group comprises of the oldest sediments in the Upper Benue Trough which directly overlie the crystalline basement rocks. The principal reference section is at Lamurde Anticline, where Carter *et al*. (1963) and Allix (1983)gave the description of the sequences exposed and recognized a three subdivision. Further description of the Bima Group was also presented by Popoff *et al*. (1986), but comprehensive description of the Bima Group was done by Guiraud (1990a; and 1990b) into three as:

---- the "Upper Bima Sandstone" ("$B^3$"), fairly arenaceous relatively mature, fine to coarse- grained sandstone with planar, convolute, and overturned cross- beds.

---- the "Middle Bima Sandstone" ("$B^2$"), widely distributed, trough and tabular cross- bedding characterizes the sandstones, while clays and palaeosols also occur in the loos of individual cycles with overall thickness in some beds from 100m to 500m (Zaborski, 1998).

---- the "Lower Bima Sandstone" ("$B^1$"), highly variable with an overall thickness of 0 to over 1500m, lacustrine deposits with interbedded clays, fine- grained sandstones and calcareous sandstones.

The continental Bima Group was succeeded by Yolde Formation (Carter *et al*., 1963). These "transitional beds" were recognized earlier by Falconer (1911) between the Bima Group and Pindiga Formation. A type section was designated in the Yolde Stream, western part of Yola arm. Zaborski *et al*. (1998) reported that the Yolde Formation gives rise to a subdued topography often with a sparse vegetation cover. The formation has feldspathic sandstones mostly coarse- grained and cross- bedded and grey mudstones. Bioturbations (Planolites) is common towards the top while groove marks are present on some beds (Zaborski *et al*., 1998).

This is followed by the Pindiga Formation which makes up the greater part of the Upper Cretaceous deposits in the Upper Benue Trough. Carter *et al*. (1963) referred age- equivalent beds in Gongola Basin to the "Gongila Formation" which is made up of a lower limestone- shale member and an upper sandstone- shale member, and to the "Fika Shales" for the overlying argillaceous beds. Zaborski *et al*. (1998) have characteristically described the Pindiga Formation to be best understood as consisting five members;

----- above, Fika Member, being the equivalent of the "Fika Shales" of Carter *et al*. (1963) and upper, shaly part of the Pindiga Formation.

----- the Dumbulwa Member, being probable equivalent of the upper, sandstone- shale member of the "Gongila Formation" of Carter *et al*. (1963).

----- the Deba Fulani Member, a previously unrecognized unit.

----- the Gulani Member, being the "Gulani Sandstone" of Carter *et al.* (1963).

----- below, the Kanawa Member, being the "Kanawa Formation" of Thompson (1958) and the lower, shale- limestone members of the "Pindiga Formation" and "Gongila Formation" of Carter *et al*. (1963).

The Gombe Sandstone represents the youngest Cretaceous sedimentation in the basin and is restricted to the western part of the Gongola Basin. It weathers to produce a ferruginous capping. The formation comprises of claystone at its base that passes upward to sandstone beds which becomes become more persistent and make up the greater part of what is termed the "bedded facies" (Zaborski et al., 1997).

The Cretaceous Gongola Basin is concealed to the west by the Kerri- Kerri Formation and to the extreme east by the Biu Plateau Basalts (Zaborski *et al*., 1998). It consists of coarse grained arkosic sands and grits with interbeds of sandy gravel, minor clays, silts and fine- grained members also occur (Thompson, 1958).

## III. Methodology

**GEOCHEMICAL ANALYSIS**

In geochemical analysis, the samples were crushed and pulverized (powder form). X-Ray fluorescence spectrometry (XRF) was used as an analytical technique in the determination of major oxides of the mudstone member of the Gombe Sandstone. X-ray fluorescence spectrometry is based upon the excitation of a sample by X-ray. A primary X-ray beam excites secondary X-ray which have wavelengths characteristic of the elements present in the sample. The intensity of the secondary X-ray is used to determine the concentrations of the elements present by reference to the calibration standards of (Potts *et al.,* 1990).

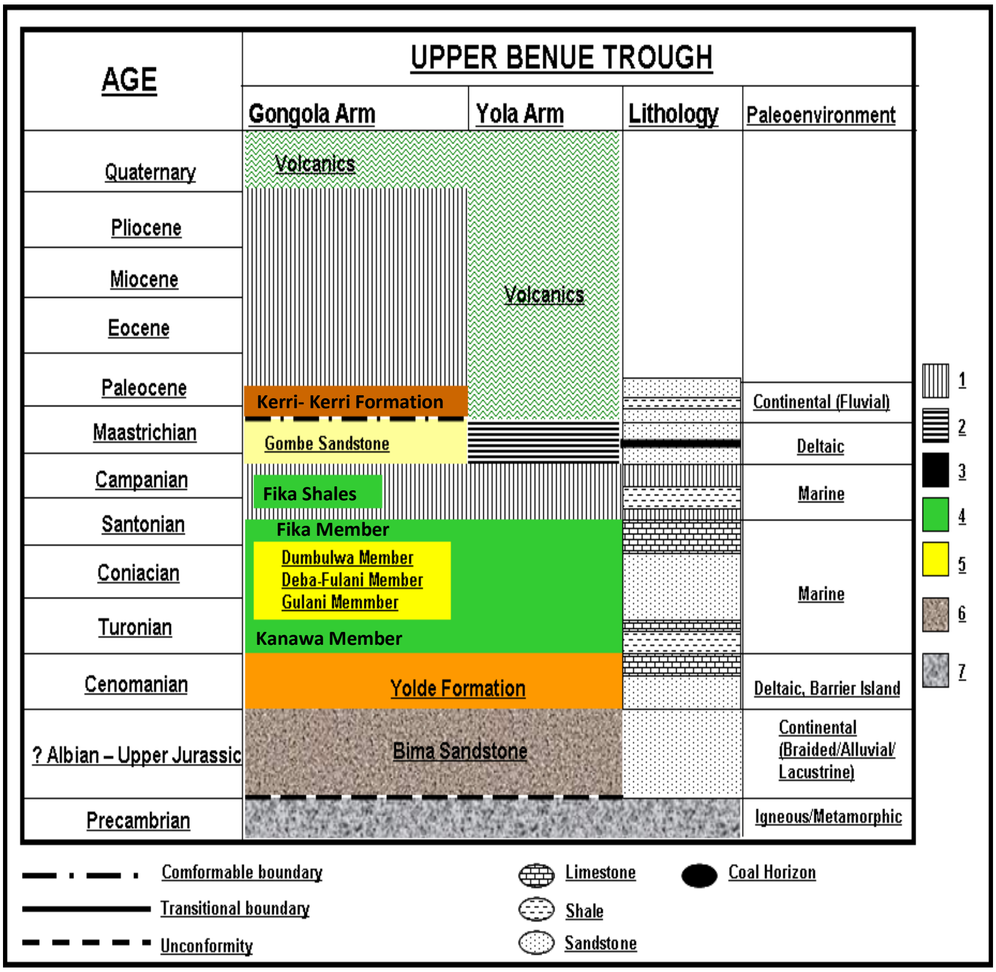


Figure 3: Lithostratigraphic subdivision of the Gongola Basin (Modified after Zaborski *et al*., 1998)

## IV. Result and Interpretation

Three rock samples were selected amongst the 10 identified facies from the study area and were for geochemical analysis of major oxides using X-ray fluorescence (XRF). The result is presented in the table 1 below:

Table 1: Result of geochemical analysis of Gombe Sandstone (mudstone member)

| Oxides/parameters | L4S4B | L15S15 | L19S19 | Average | Range |
|---|---|---|---|---|---|
| $SiO_2$ | 58.47 | 45.42 | 53.21 | 52.37 | 45.42-58.47 |
| $Al_2O_3$ | 13.42 | 16.70 | 17.21 | 15.78 | 13.42-17.21 |
| $Fe_2O_3$ | 2.46 | 3.51 | 3.69 | 3.22 | 2.46-3.69 |
| $Na_2O$ | 3.25 | 2.48 | 3.06 | 2.93 | 2.48 -3.25 |
| CaO | 2.90 | 1.93 | 1.11 | 1.98 | 1.11-2.90 |
| $K_2O$ | 2.74 | 0.89 | 1.11 | 1.57 | 0.89-2.74 |
| FeO | 1.13 | 0.81 | 1.32 | 1.09 | 0.81-1.32 |
| $P_2O_5$ | 0.14 | 1.00 | 0.81 | 0.65 | 0.14-1.00 |
| MgO | 0.122 | 0.18 | 0.064 | 0.122 | 0.064-0.18 |
| MnO | 0.02 | 0.06 | 0.05 | 0.04 | 0.02-0.06 |
| LOI | 7.91 | 10.21 | 12.16 | 10.09 | 7.91-12.16 |

Table 2: Some parameters calculated from the major oxides

| Oxides/parameters | L4S4B | L15S15 | L19S19 | Average | Range |
|---|---|---|---|---|---|
| $K_2O/Al_2O_3$ | 0.204 | 0.053 | 0.064 | 0.107 | 0.053-0.204 |
| CIA | 60.15 | 75.91 | 76.52 | 70.80 | 60.15-76.52 |
| ICV | 0.65 | 0.49 | 0.46 | 0.53 | 0.46-0.65 |
| $K_2O/Na_2O$ | 0.84 | 0.36 | 0.36 | 0.56 | 0.36-0.84 |

The major oxides obtained are $Si0_2$, $Al_2O_3$, $Fe_2O_3$, $Na_2O$, CaO, $K_2O$, FeO, $P_2O_5$, MgO, and MnO, and loss of ignition (LOI).

The oxides average percentage range as follows: $Si0_2$ has an average percentage of 52.47% and range from 45.42 to 58.47%. $Al_2O_3$ has an average percentage of 15.78% and range from 13.42 to 17.21%. $Fe_2O_3$ has an average percentage of 3.22% and range from 2.46 to3.69%. $Na_2O$ has an average percentage of 2.93% and range from 2.48 to 3.25%. CaO has an average percentage of 1.98% and range from 1.11 to 2.90%. $K_2O$ has an average percentage of 1.57% and range from 0.89 to 2.74%. FeO has an average percentage of 1.09% and range from 0.81 to 1.32%. $P_2O_5$ has an average percentage of 0.65% and range from 0.14 to 1.00%. MgO has an average percentage of 0.122% and range from 0.064 to 0.18%. MnO has an average percentage of 0.04% and range from 0.02 to 0.06%. LOI has an average percentage of 10.09% and range from 7.91 to 12.16%. And other parameters calculated are $K_2O/Al_2O_3$ has an average percentage of 0.107% and ranges from 0.053 to 0.204%. CIA has an average percentage of 70.80% and ranges from 60.15 to 76.52%. And ICV has an average percentage of 0.53% and range from 0.46 to 0.65%. $Si0_2$ has the highest percentage of 58.47% in L4S4B and lowest percentage of 45.42% in L15S15. $Al_2O_3$ has the highest percentage of 17.21% in L19S19 and lowest percentage of 13.42% in L4S4B. $Fe_2O_3$ has the highest percentage of 3.69% in L19S19 and lowest percentage of 2.46% in L4S4B. $Na_2O$ has the highest percentage of 3.25% in L4S4B and lowest percentage of 2.48% in L15S15. CaO has the highest percentage of 2.90% in L4S4B and lowest percentage of 1.11% in L19S19. $K_2O$ has the highest percentage of 2.74% in L4S4B and lowest percentage of 0.89% in L15S15. FeO has the highest percentage of 1.32% in L19S19 and lowest percentage of 0.81% in L15S15. $P_2O_5$ has the highest percentage of 1.00% in L15S15 and lowest percentage of 0.14% in L4S4B. MgO has the highest percentage of 0.18% in L15S15 and lowest percentage of 0.064% in L19S19. MnO has the highest percentage of 0.06% in L15S15 and lowest percentage of 0.02% in L4S4B.

## V. Discussions

More mature mudstone with mostly clay minerals ought to display lower Index of Compositional Variability (ICV) values that are <1.0 as reported by (Cox *et al*., 1995). Such mudstones are derived from cratonic (plutonic) environments (Weaver, 1989), where recycling and weathering processes predominate. In addition, mudstone displaying ICV values less than 1 have also been found in some intensely weathered first cycle sediments (Barshad, 1966). The ICV value is derived from the formula ($Fe_2\,O_3$ + $Na_2O$ + CaO + MgO + $TiO_2$)/$Al_2O_3$ indicating that the mudstones of the study area in the southern part of Gombe area range from 0.46 to 0.65% with an average of 0.53% (Table 3). This may suggest that the mudstones may have been sourced fromcratonic (plutonic) environment.

$K_2O/Al_2O_3$ ratio indicates relative abundance of alkali feldspar versus plagioclase and clays in mudstone. $K_2O/Al_2O_3$ ratios of the alkali feldspar ranges from 0.4 to 1, illite approximately 0.3 and other clay minerals nearly zero, such results have been reported by (Cox *et al*., 1995). $K_2O/Al_2O_3$ ratio greater than 0.5, suggests dominance of alkali feldspar as compared to other minerals in the original mudstone. In contrast, those having $K_2O/Al_2O_3$ of less than 0.4 suggest minimal alkali feldspar in the original mudstone. The $K_2O/Al_2O_3$ ratio in mudstone of the study area ranges from 0.053 to 0.204% with an average of 0.107%. It suggests that mudstone have minimal K-feldspar (Table 3).

The Chemical Index of Alteration (CIA) is used to infer the degree of weathering of the source rocks and is calculated by using the following formula (Nesbitt and Young, 1982):

$$\text{The Chemical Index of Alteration (CIA)} = \frac{\text{Al2O3}}{\text{Al2O3+CaO +K2O+Na2O}} \times 100.$$

The CIA value of mudstone member of Gombe Sandstone of the study area range from 60.15 to 76.52% and average of 70.80% (Table 2), which indicate intense chemical weathering of mudstone and presence of minerals rich in compositionally mature alumina. Low $K_2O/Al_2O_3$ ratios and average CIA values (70.80%) of the mudstone samples suggest some reduction of feldspar in source area. CIA also shows that mudstones passed through intense chemical weathering and transportation.

$SiO_2$ percentage is highest in the mudstone because of its resistance to weathering and low temperature nature. Others are depleted because they can easily weather during weathering, transportation and diagenesis. Most important factor responsible for the reduction of feldspar is diagenesis.

## VI. Conclusion

Geochemical analysis carried out on the mudstone member of Gombe Sandstone using major oxides shows that the rock samples has $SiO_2$ as the highest percentage oxide and MnO the lowest. The $K_2O/Al_2O_3$ ratio in mudstone of the study area ranges from 0.053 to 0.204% with an average of 0.107%, suggesting that mudstone have minimal K-feldspar. The CIA value of mudstone member of Gombe Sandstone of the study area range from 60.15 to 76.52% and average of 70.80% indicate intense chemical weathering of mudstone and presence of minerals rich in compositionally mature alumina. The ICV values of the mudstones of the study area in the southern part of Gombe state indicate that it's from cratonic (plutonic) environment.

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