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# MINERALOGICAL AND GEOCHEMICAL STUDIES OF SANDSTONE IN IMOBI STUDY AREA AND ITS ENVIRONS, SOUTHWESTERN NIGERIA.

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**ABSTRACT**

The combination of mineralogical and geochemical data of sedimentary rock can reveal the nature of source rocks, the tectonic settings of the sedimentary basins and the Paleoclimatic conditions. The aim of this research is to determine the geochemistry and mineralogy of the Imobi sandstones and to infer the provenance and possible depositional environment for these sand stones.

Eight rock samples were collected from the study area, some portion were used for geochemical analysis to determine the chemical composition using X-ray fluorescence and the remaining portion were also used for mineralogical analysis to determine the mineralogical compositions and to estimate the modal percentages of minerals in the Imobi sandstone samples with the aid of the Petrological microscope.

From the geochemical analysis, sixteen (16) elements and oxides were revealed and they includes $SiO_2$, $Al_2O_3$, $Fe_2O_3$, CaO, $V_2O_5$, $ZrO_2$, $SO_3$, $K_2O$, Br, $P_2O_5$, CuO, $TiO_2$, MnO, $Rb_2O$, $As_2O_3$, $Cr_2O_3$, while the mineralogical study show the presence of three minerals along with accessory minerals, they include quartz, iron oxide, microcline and accessory minerals.

The presence of element and oxides like Br, $V_2O_5$, $ZrO_2$, CuO, $Rb_2O$, $As_2O_3$ and MnO (especially Br which occurred in a recognizable quantity of about 12%-27%) suggests the depositional environment of the Imobi sandstone to be a shallow marine or near marine environments. However the abundance

Of $Fe_2O_3$ infers the derivation of the sediments from a metamorphic source. The Petrography study reveals the presence of microcline, a feldspathic mineral commonly found in metamorphic rocks, and is consistent with the inference made from the geochemical composition that the provenance of these sandstones is from a metamorphic origin

**Key words:** Geochemical, Sandstone, Aluminum, Bromine, Marine, Quartz, Provenance.

## 1. INTRODUCTION

The knowledge of geochemical composition of clastic sediments and its distribution in the upper crust makes it possible to locate the provenance (Armstrong-Altrin, 2009; Etemad-Saeed et al., 2011). Even though, the distribution of sediments is controlled by the interaction between sediment, hydrodynamic processes and human intervention. The combination of petrography and geochemistry of sedimentary rocks can be able to reveal the nature of source rocks, the tectonic setting of a sedimentary basin and the paleoclimatic conditions. The main assumption behind sandstone provenance studies is that different tectonic settings consist their own rock type (Dickson and Suczek, 1979; Dickson 1985). Although some geochemical ratios can be altered during weathering through oxidation (McLennan 1985) or digenesis (Nesbit and Young 1989; Milodowski and Zalasiewicz, 1991), as long as the bulk chemical composition is not totally altered, hence the geochemical composition of sediments is a valuable tool in the study of provenance (Bakkiaraj *et al.,* 2010; McLennan, 1985, Bhatia, 1983). The major element tectonic setting discrimination diagrams of Bhatia (1983) have been traditionally used to discriminate the tectonic settings of sedimentary basins and was applied in the recent studies (e.g., Armstrong-Altrin *et al.,* 2004), although caution is required in their indiscriminate use (Armstrong-Altrin and Verma 2005). The most important clues for the tectonic setting of the basin comes from the relative depletion of oxides like CaO and $Na_2O$ (the most mobile elements), among others. The oxides are assumed to show enrichment or depletion of quartz, k-feldspars, micas and plagioclase. The ratio of the most immobile elements to the mobile ones increases towards the passive margin to the relative tectonic stability (Armstrong-Altrin *et al.,* 2004) and hence prolonged weathering. This research work is focused towards determining the geochemical distribution of elements in sediments of the study area, predicting the dispersal pattern of the elements, elucidating the dominant minerals present and subsequently inferring the provenance and possible effects of some of these elements on the environment, in addition to this the research is designed towards making appropriate recommendations from the interpreted result.

The Imobi study area is situated in eastern part of theDahomey basin ( latitude N $6^0$ 34'- N06$^0$ 43'and longitude E004$^0$ 08'- E004$^0$ 20') South western Nigeria. (Fig.1)

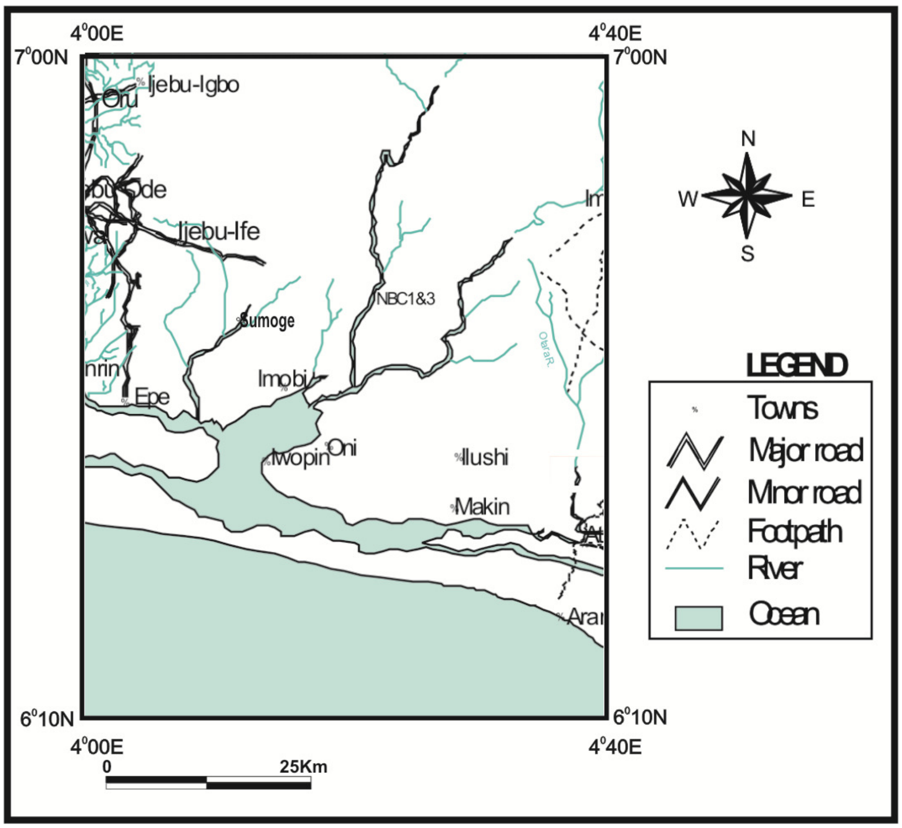



Fig 1: Accessibility Map of the Study Area

The area is accessible by major and minor road networks and the climatic condition is tropical as expressed in alternation of wet and dry seasons. These two regimes of tropical climate show a fairly wide seasonal and diurnal variation in temperature ranging between 35$^0$C during dry season and 25$^0$C during wet season (Akintola *et al*., 2011).

The period of wet with two rainfall peak from June-July and dry season have a remarkable effect on the vegetation of the area as trees and plant growth is controlled by this systematic seasonal changes. Therefore, during wet season plants exhibit fresh luxurious growth with green leaves and radiant flowers this disappears during the dry season as many trees shed their leaves. The area is characterized by moderate to low relief and the drainage is sub-dendritic as a result of numerous network of stream.

**2. GEOLOGIC SETTING**

The study area falls within the Nigeria sector of the Dahomey basin. The basin is a marginal pull-apart basin initiated during the Early Cretaceous separation of South American and African plates thereby constituting part of a system of west Africa pre-cratonic basins developed during the commencement of rifting, associated with the opening of the Gulf of Guinea in the Late Jurassic to Early Cretaceous (Adegoke, 1969). It extends from southeastern Ghana through Togo and Benin Republic on the west side to the Okitipupa ridge on the east side in the southern part of Nigeria. The basin consists of Cretaceous-Tertiary sequence, which outcrops in an arcuate belt roughly parallel to the ancient coastline. The Tertiary sediments thin out to the east and are partially cut off from the sediments of Niger Delta basin against the Okitipupa basement ridge.

The stratigraphy have been well established by various workers (Jones and Hockey, 1964; Omatsola and Adegoke, 1981; Agagu, 1985; Enu, 1990), However, (Agagu, 1985) placed together the stratigraphy of eastern Dahomey basin from surface as well as subsurface data, deciphering that in most part of the basin, the stratigraphy is dominated by monotony of sand and shale alternations with minor proportion of limestone and clay. The stratigraphy of the Cretaceous to Tertiary sedimentary pile which unconformably overlies the basement complex includes the following lithostratigraphic units and is summarized in (Table 1). Abeokuta group is the oldest group of sediment in the basin, lying non-conformably on the basement (Jones and Hockey, 1964). Omatsola and Adegoke, (1981) on the lithostratigraphy of Dahomey basin recognized (3) formations belonging to the Abeokuta group based on lithologic homogeneity and similarity of origin. This group is the thickest sedimentary unit within the basin. The formations from oldest to youngest are Ise, Afowo and Araromi formation. Ise formation unconformably overlies the basement complex of Southwestern Nigeria, consisting of conglomerates and grits at the base which is in turn overlain by coarse to medium grained sands with interbeded kaolinite. The conglomerates are imbricated and at some locations where ironstones occur (Enu, 1990). An age range of Neocomian-Albian is assigned to this formation based on paleontological assemblages.

Afowo formation overlies the Ise formation, and composed of coarse to medium grained sandstone with variable but thick interbedded shale, siltstone and claystone. The sandy facies are tar-bearing while shales are organic-rich (Enu, 1990). Using palynological assemblage, a Turonian age is assigned to the lower part of this formation, while the upper part ranges into Maastrichtian.

The youngest Cretaceous formation in the group is Araromi formation, which conformably overlies the Afowo formation. It is composed of fine-medium grained sandstone at the base, overlain by shales, silt-stone with interbedded limestones, marl and lignite. (Omatsola and Adegoke, 1981) assigned a Maastrichtian to Paleocene age to this formation based on faunal content

Table 1: The stratigraphic units of Eastern Dahomey Basin.

| **Jones and Hockey (1964)** | | **Omatsola and Adegoke(1981)** | | | **Agagu (1985)** | |
|---|---|---|---|---|---|---|
| | **Age** | **Formation** | **Age** | **Formation** | **Age** | **Formation** |
| **Quaternary** | **Recent** | **Alluvium** | | | **Recent** | **Alluvium** |
| **Tertiary** | **Pleistocene - Oligocene<br>Eocene<br>Paleocene** | **Coastal plain sand<br>Ilaro<br>Ewekoro** | **Pleistocene-Oligocene<br>Eocene<br>Paleocene** | **Coastal Plain sand<br>Ilaro<br>Oshosun Akinbo<br>Ewekoro** | **Pleistocene-Oligocene<br>Eocene<br>Paleocene** | **Coastal Plain sands<br>Ilaro<br>Oshosun<br>Akinbo<br>Ewekoro** |
| **Cretaceous** | **Late Senonian** | **Abeokuta** | **Maastrichtian - Neocomian** | **Araromi<br>Afowo<br>Ise** | **Maastrichtian - Neocomian** | **Araromi<br>Afowo<br>Ise** |
| **Precambian Crystalline Basement Rocks** | | | | | | |

The Imo Group overlies the Abeokuta group and chronologically consists of two lithostratigraphic units which starts from the oldest to the youngest are Ewekoro and Akinbo formation. Ewekoro formation overlies the Araromi formation in the basin and is described by Adegoke (1977) as limestone unit intercalated with shale. This formation is an extensive limestone body, which is traceable over a distance of about 320km from Ghana in the west, towards the eastern margin of the Nigerian basin (Jones and Hockey, 1964). It is highly fossiliferous and Paleocene in age. Akinbo formation which is made up of shale and clay sequence overlies the Ewekoro formation (Ogbe, 1972). The claystones are concretionary and are predominantly kaolinite

The base of the formation is defined by the presence of glauconitic bands with lenses of limestone (Ogbe, 1972). Also based on faunal contents the formation is assigned as Paleocene-Eocene in age.

Oshosun formation overlies the Akinbo formation and consists of greenish-grey or beige clay and shale with interbeds of sandstones. The shale is thickly laminated and glauconitic. This formation is phosphate-bearing (Jones and Hockey, 1964). An Eocene age is assigned to this formation based on fossil content.

Conformably overlying the Oshosun formation is the Ilaro formation and consists of massive, yellowish, poorly consolidated cross-bedded sandstone. The formation shows rapid lateral facies changes. The youngest stratigraphic sequence in the eastern Dahomey basin is the Benin formation. It is also known as the coastal plain sands (Jones and Hockey, 1964) and consists of poorly sorted sands with lenses of clays. The age is Oligocene to Recent.

## 3. METHODOLOGY

A thorough and careful traversing by foot was carried out and the study area and the locations of different rock types outcropping in the area were noted (Fig.2). This was achieved with the aid of a global positioning system *(G.P.S).*

However the field study involves visual observation of rocks exposed in the study area Description of outcrops such as texture, visible minerals, color as well as structural features were noted in the field note book. Fresh samples were taken for further study and properly labeled to avoid mix-up before keeping them in the sample bags. Eight samples ($Sst_1$, $Sst_2$, $Sst_3$, $Sst_4$, $Sst_5$, $Sst_6$, $Sst_7$, $Sst_{8}$), were collected (Table 2; Fig.2) and studied for both Petrography and geochemistry studies. Eight thin-sections were prepared for the petrographic study. The samples were cut into smaller sizes of about 2mm in thickness using the rock cutting machine. A lapping blade was then placed on the table with a mixture of little water and carborundum. The glass slide was then lapped on the surface until it became smooth. The slab was later displayed on the carborundum to make it smooth and air free. The glass slide and the slab were together heated on a hot plate to dryness before they were fixed together using Araldite. They were exposed to another grinding machine to give a thickness of 1mm and further lapped again to achieve a thickness of 0.3mm. The slides were observed under the petrologic microscope in order to ascertain the various mineral compositions and to estimate their modal percentages.

For the XRF analysis, the initial samples were reduced by splitting them into smaller size of about 30g before they were pulverized into a fine powder to create an XRF sample. The samples were then analyzed with ARL 9900 XP total cement analyzer, which is used to analyze cement and its raw materials and theses includes clay, gray shale, iron ore, alluvial sand and gypsum. The XRF analysis entails weighing of 5.0g of the pulverized sample into the drying dish or crucible and drying to a constant weight (± 0.01g) in the oven before cooling in the desiccators. This is then followed by preparation of fused bead (Drying of the crucible and the platinum mould in an oven at $110^0$C-$120^0$C for about thirty minutes)., 6.000 ±0.0001g of lithium tetraborate is weighed into another crucible and 1.000 ±0.0001g of sample is added followed by the addition of 0.0200g of lithium bromide using a clean small spatula or glass rod to mix properly before labeling and transferring of the fused bead into the X-ray analyzer's sample holder, ready for analysis.

Table 2: Showing locations of all the sampling points.

| Sampling points | Longitudes | Latitudes |
|---|---|---|
| Sst1 | 6° 34.760′ | 4° 19.311′ |
| Sst2 | 6° 35.760′ | 4°18.164′ |
| Sst3 | 6° 39.058′ | 4° 12.100′ |
| Sst4 | 6° 39.650′ | 4° 08.500′ |
| Sst5 | 6° 40.345′ | 4 °10.900′ |
| Sst6 | 6° 40.950′ | 4° 11.450′ |
| Sst7 | 6° 42.151′ | 4° 12.180′ |
| Sst8 | 6° 42.646′ | 4° 12.242′ |

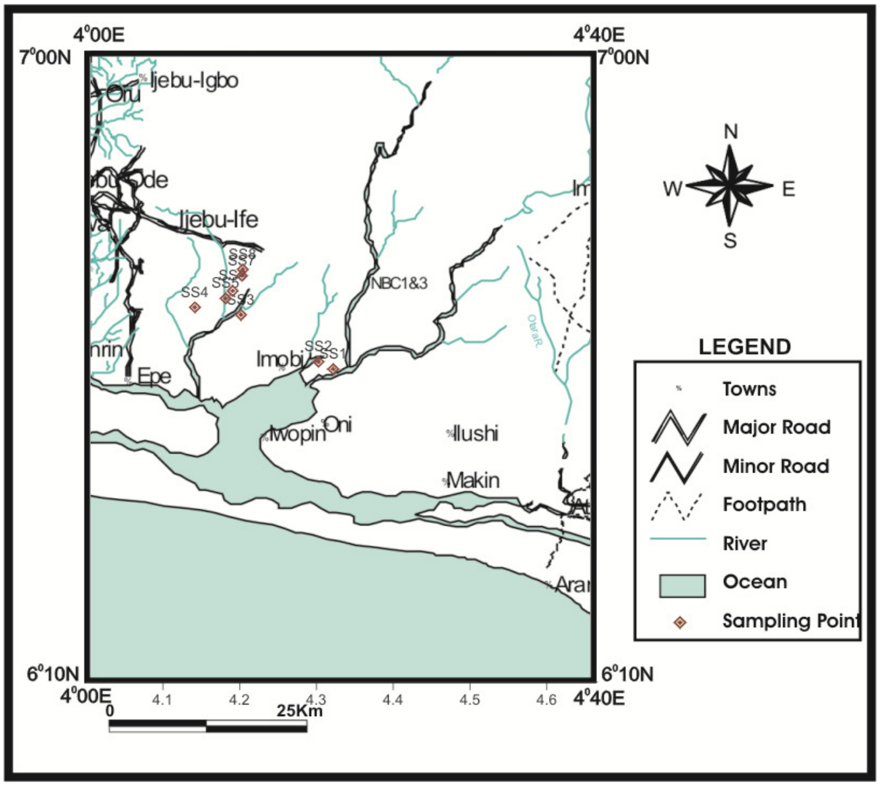



Fig 2: Location Map Showing the Sampling Points

## 4. RESULT AND DISCUSSIONS

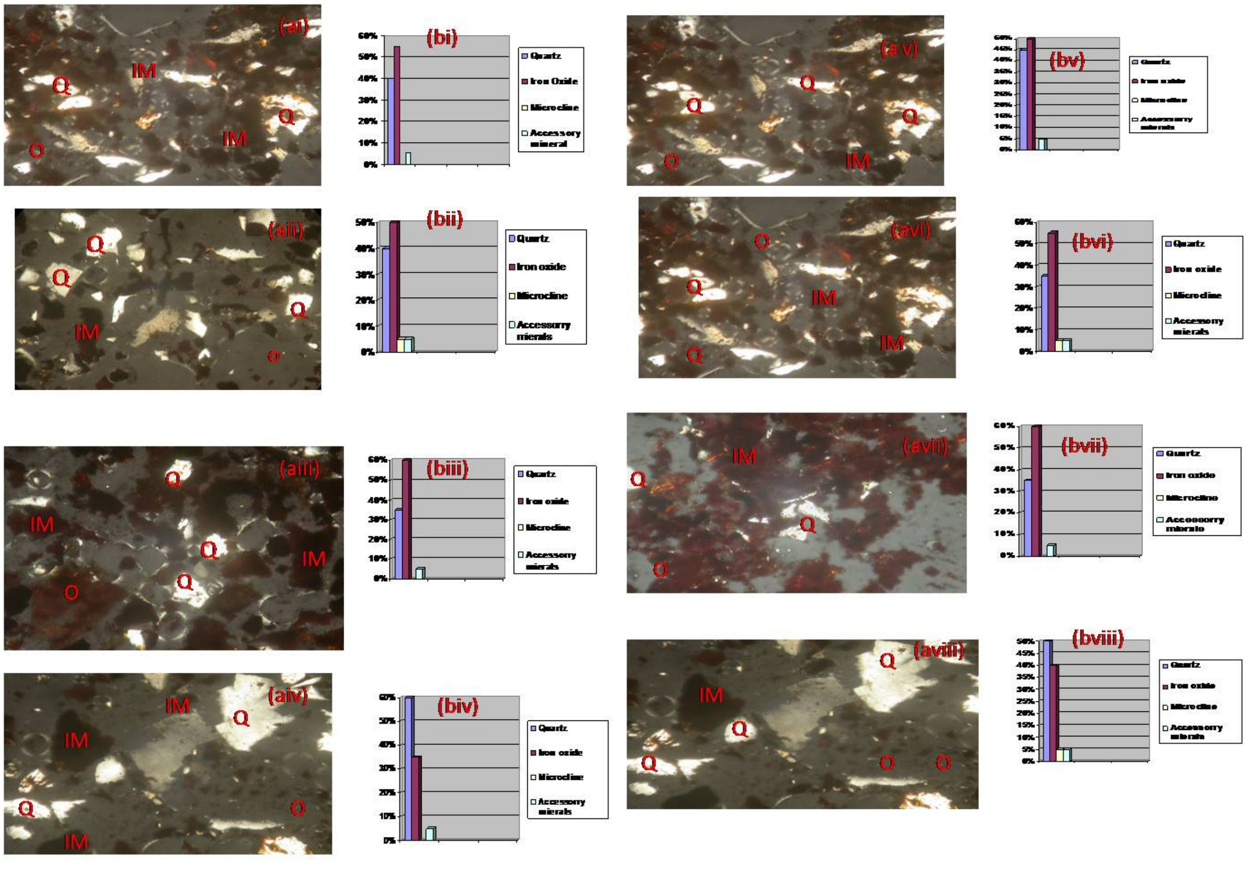
Petrographic studies of the Imobi Sandstone show that they contain mainly quartz, iron oxide minerals with microcline, zircon and others as accessory minerals (Table 3).

Quartz percentage ranges from 35% to 60%, iron oxide ranges from 35% to 60%, and microcline ranges from 0 to 5% while zircon and other accessory minerals range from 0 to 5%. (Figs 3a and 3b).

| Location | Mineral Composition | Estimated modal composition (%) |
|---|---|---|
| $Sst_1$ | Quartz | 40 |
| | Iron oxide | 55 |
| | Accessory minerals | 5 |
| $Sst_2$ | Quartz | 40 |
| | Iron Oxide | 50 |
| | Microcline | 5 |
| | Accessory minerals | 5 |
| $Sst_3$ | Quartz | 35 |
| | Iron Oxide | 60 |
| | Accessory minerals | 5 |
| $Sst_4$ | Quartz | 60 |
| | Iron Oxide | 35 |
| | Accessory minerals | 5 |
| $Sst_5$ | Quartz | 45 |
| | Iron Oxide | 50 |
| | Accessory minerals | 5 |
| $Sst_6$ | Quartz | 35 |
| | Iron Oxide | 55 |
| | Microcline | 5 |
| | Accessory minerals(zircon and others) | 5 |
| $Sst_7$ | Quartz | 35 |
| | Iron Oxide | 60 |
| | Accessory minerals | 5 |
| $Sst_8$ | Quartz | 50 |
| | Iron Oxide | 40 |
| | Microcline | 5 |
| | Accessory minerals | 5 |

Table 3: Average modal composition (%) of minerals in Imobi study Area.




Bar scale = 20mm    Magnification: X40    Resolution: (150 dpi)

Figure 3a(i-viii): Photomicrograph of Imobi Sandstones in transmitted light showing Quartz( Q), Iron minerals (IM) and Other Accessory Minerals (O).and 3b(i-viii) Modal distribution of estimated minerals in Imobi Sandstones.

Results of the XRF analysis (Table 4) reveal a total number of sixteen (16) elements and oxides which includes $SiO_2$, $Al_2O_3$, $Fe_2O_3$, CaO, $V_2O_5$, $ZrO_2$, $K_2O$, $SO_3$, Br, $P_2O_5$, CuO, $TiO_2$, MnO, $Rb_2O$, $As_2O_3$, and $Cr_2O_3$. The chemical analysis reveals that the studied sandstones are depleted in major elements like $SiO_2$, $Fe_2O_3$ and $Al_2O_3$ The geochemistry of Imobi sandstones are compared with the Lead and Mead's, 1915 average sandstone composition (Table 5) It is observed that the composition is varying among the sandstone samples studied

Some oxides like FeO, MgO, $Na_2O$, $H_2O$, $SO_2$, BaO were absent in some samples. However concentrations of other elements are enriched for example bromine, which varies from 12% to

27 % (Fig. 4)

Petrography study reveals that quartz and iron oxide are the main mineral constituents present in the Imobi sandstones. The presence of microcline "a feldspathic mineral that occurs in metamorphic rocks" infers that the Imobi sandstone was probably derived from metamorphic source rocks.

Similarly, the presence of oxides like $V_2O_5$, $ZrO_2$, Br, CuO, $Rb_2O$, $As_2O_3$, $Cr_2O_3$ with the abundance of Bromine (Br) suggests that the depositional environment is a shallow marine or near marine environment. $Fe_2O_3$ is being incorporated into the environment by oxidation process and it can be inferred to have originated from the country rocks which are derived from metamorphic origin. This result is consistent with the petrography study

Table 4: showing the elements and oxides of Imobi Sandstones samples in (Wt %)

| Elements and oxides | % | % | % | % | % | % | % | % |
|---|---|---|---|---|---|---|---|---|
| **Sample #** | Loc $Sst_1$ | Loc $Sst_2$ | Loc $Sst_3$ | Loc $Sst_4$ | Loc $Sst_5$ | Loc $Sst_6$ | Loc $Sst_7$ | Loc $Sst_8$ |
| $SiO_2$ | 37.94 | 36.13 | 38.49 | 51.41 | 37.24 | 21.78 | 16.10 | 43.06 |
| $Al_2O_3$ | 1.70 | 2.36 | 2.70 | 3.02 | 9.64 | 8.73 | 8.04 | 9.40 |
| $Fe_2O_3$ | 44.05 | 46.93 | 41.84 | 22.27 | 31.14 | 48.60 | 53.01 | 17.09 |
| CaO | 0.78 | 0.68 | 0.44 | 0.81 | 0.64 | 0.38 | 0.85 | 0.48 |
| $V_2O_5$ | | | | 0.06 | 0.25 | 0.73 | 0.46 | 0.21 |
| $ZrO_2$ | | | 0.09 | 0.48 | 0.15 | 0.19 | 0.11 | 0.20 |
| $SO_3$ | | 0.29 | 0.34 | | 0.13 | 0.13 | 0.23 | |
| $K_2O$ | 0.44 | 0.44 | 0.19 | | 0.79 | | 0.57 | 0.88 |
| Br | 14.09 | 12.53 | 14.90 | 20.10 | 18.06 | 17.37 | 18.55 | 26.36 |
| $P_2O_5$ | 0.64 | 0.50 | 0.18 | | 0.27 | | 0.41 | 0.64 |
| CuO | | | | | | | | 0.01 |
| TiO2 | 0.25 | 0.15 | 0.80 | 1.57 | 1.52 | 1.90 | 1.44 | 1.45 |
| MnO | | | | 0.05 | 0.03 | 0.04 | 0.02 | 0.02 |
| $Rb_2O$ | 0.01 | 0.01 | | 0.01 | | 0.02 | 0.01 | 0.01 |
| $As_2O_3$ | 0.07 | | 0.04 | 0.10 | 0.05 | 0.01 | 0.09 | 0.15 |
| $Cr_2O_3$ | 0.05 | | | 0.07 | 0.10 | 0.11 | 0.11 | 0.05 |
| SUM | 100.02 | 100.02 | 100.01 | 99.96 | 100.01 | 99.99 | 100.00 | 100.01 |

Where: Loc = Location

# = Number

Table 5: Average major element composition of sandstone after Leith and Mead's (1915).

| Oxides | Percentage (%) |
|---|---|
| $SiO_2$ | 78.30 |
| $TiO_2$ | 0.25 |
| $Al_2O_3$ | 4.77 |
| $Fe_2O_3$ | 1.07 |
| FeO | 0.30 |
| MgO | 1.16 |
| CaO | 5.50 |
| $Na_2O$ | 0.45 |
| $K_2O$ | 1.31 |
| $H_2O$ | 1.63 |
| $P_2O_5$ | 0.68 |
| $CO_2$ | 5.03 |
| $SO_2$ | 0.07 |
| $Ba_2O$ | 0.05 |

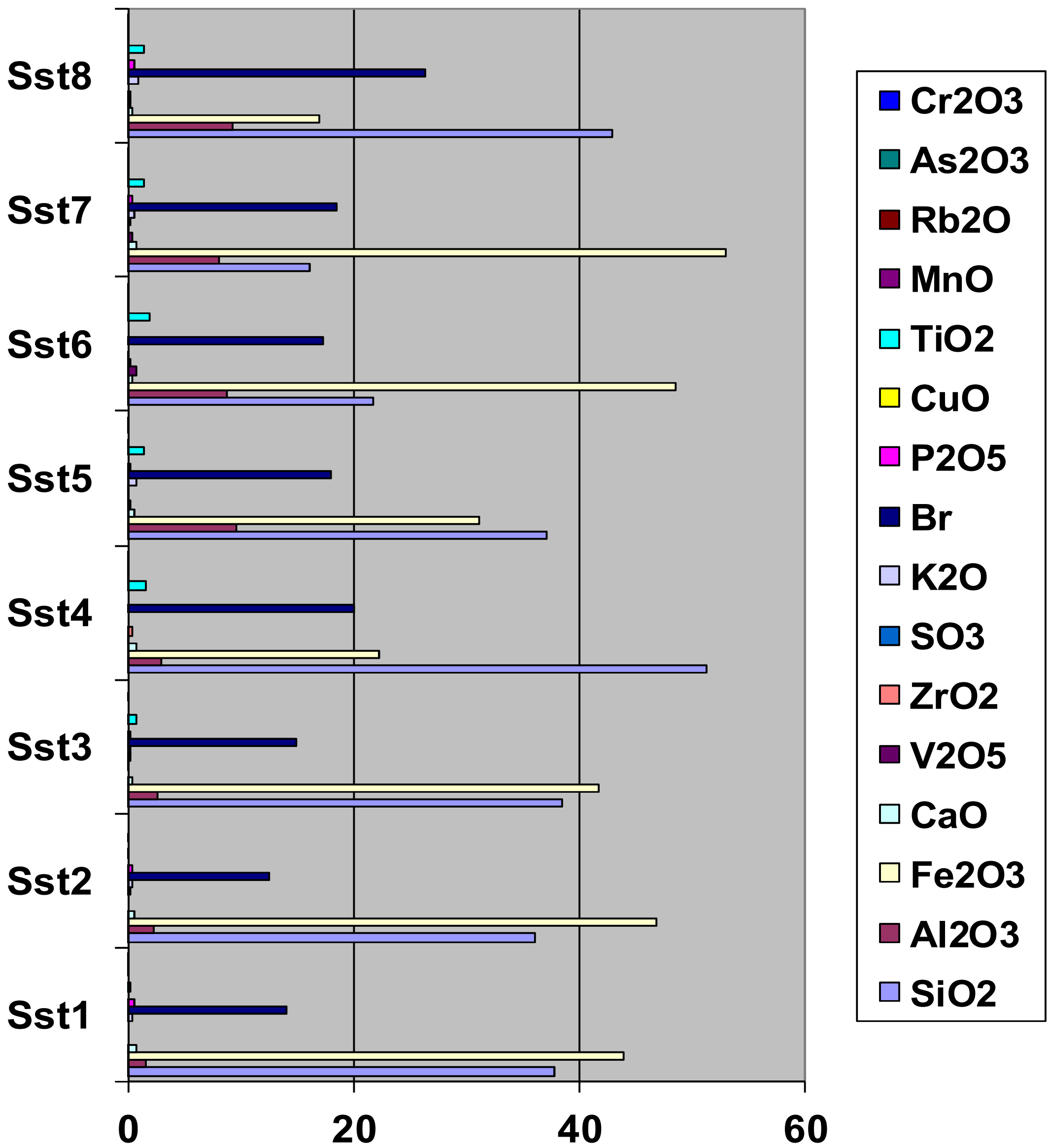



Figure 4: Showing the Bar chart of all the chemical compositions of the Imobi sandstone Samples

## 4. CONCLUSION

The petrography and geochemistry results are in consistent with each other. Petrography results show the presence of quartz, iron oxide minerals and microcline with accessory minerals like zircon. The presence of microcline, in the Imobi sandstones supports the metamorphic source rocks. When compared to Lead's and Mead's (1915) average chemical composition, elements and oxides like Br, $V_2O_5$, $ZrO_2$, CuO, $Rb_2O$, $AS_2O_3$, MnO suggests the depositional environment to be a shallow marine or near marine environment. The abundance of $Fe_2O_3$ in most of the samples confirms them to be ferruginized sandstone and their source to be of metamorphic origin.

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