Petrographic and Sediment Logical Studies of Bima Sandstone Formation Outcroped at Lokoro area, Yola Arm of the Benue Trough, Northeastern Nigeria

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Abstract:
Petrographic and Sedimentological Studies of the Bima Formation which outcroped at Lokoro area of Guyuk was conducted. This was achieved after mapping the area on a scale of 1:25,000. Analyses on the textures, lithologies and the environment of deposition of the Bima sandstone is presented. The Bima Sandstone of Lokoro area of Guyuk are mostly medium to coarse grained, texturally and mineralogically matured quartz arenites. The formation shows lateral variation in thickness and consists of arkosic, clayed, medium to very coarse cross bedded sandstone. In the thin section the grains are predominantly quartz with many of the quartz floating in the cement while other grains exhibits point contacts. Some dark colour mineral grains, greyish and little brownish mineral grains were visible under the petrographic microscope. The petrographic studies also shows that sample is mainly silica in the form of quartz and iron oxides are predominantly the cementing materials for the Bima sandstone as seen in Figure #2, #3, #4 and #5. The grain sizes range from 1.36 – 1.83mm indicating a medium – coarse grained sandstone that is poorly sorted. This poorly sorted attribute noted is a disqualification of the Sandstone from being an ideal potential reservoir in the basin. The quartz present is sub-angular to subrounded with iron oxide induced reddish brown colouration.

Keywords: Bima sandstones, sedimentology, petrography, benue trough

1. Introduction

Sedimentology deals with the identification of source, transport and depositional processes and ultimately, the recognition of ancient sedimentary environments in the stratigraphic rock record. The recognition and palaeogeographic reconstruction of ancient sedimentary environments is achievable only through identifying thoroughly, the various sedimentation processes from their deposits, or sedimentary facies. Bima Sandstone is the name given to the continental intercalaire in the Chad Basin and Upper Benue Trough of Nigeria (Falconer 1911). Chronologically considered as the oldest sedimentary deposit in the basins. Compositionally, the Bima sandstone formation is averagely arkose to quartz arenite. The study area is located within the Yola Arm of the Upper Benue Trough. The study area has boundaries of latitude 9°48'N and 9°51'N and longitude 11°55'E and 11°58'E. The area is accessible by the major road to Guyuk and footpaths linking other localities and settlements around the area enabling easy access to the study area where the formation outcroped.
2. Literature Review

The Benue Trough is a linear shaped intra-cratonic sedimentary basin running from the present Niger-Delta to the Borno Basin in the Northeastern Nigeria. Many authors have put forward models on the tectonic origin and evolution of the Benue Trough, Burke et al., (1972), Olade (1975). It was envisaged that two arms of the RRF rift system each separated from the South Atlantic and third which was the failed arm represented by the Benue Trough. Benkhellil (1971) attributed its origin to the onshore extension of the equatorial oceanic fracture zone along the northwestern and southern margins of the trough. The Benue Trough was marked by permanent tectonic activities characterized by various stages of stress from tensional during the Aptian-Albian sub basin to compressional during the closure of the Trough. Thick sedimentary fillings occurred within the basin.

The Upper Benue Trough is subdivided into two major basins, the Gongola arm to the north and the Yola basin to the southeast, both partially separated by a near E–S–SW, Zambuk basement ridge. The sedimentation episode that occurred in Nigeria from Cretaceous time have been described Offodile and Rayment (1979). This episode gave rise to both thin and thick successions of sediments of varying stratigraphy and lithology (Guiraud, 1993).

The Upper Benue Trough is related to the transgression of the tethys sea from the north and the Atlantic from the South. During Cretaceous, other series of transgression and regression events were recorded in the trough and these brought different depositional cycles which resulted into the lithic fill of the trough. These sedimentary fills have a wedge-shaped geometry with varying thickness of mudrocks and sandstones with occurrence of carbonates and coal; deposited in a variety of continental and marine environments.

2.1. Stratigraphy

The study area being part of the Yola-arm of the Upper Benue trough, is covered with thick Continental to Marine Cretaceous (Aptian to early Santonian) deposits. These sequence of deposits includes the Bina, Yolde, Dukul, Jessu, Sukuliye, Numanha, Lamja and Volcanics. The stratigraphy of the Upper Benue Trough constituting the cretaceous and cenozoic sediments and tertiary volcanics in some areas is presented in table 1;
Table 1: Stratigraphic Succession of the Upper Benue Trough [Adapted from Uriah et al., 2018]

![Image](https://via.placeholder.com/150)

The study area (Lokoro) is part of the Yola Arm of the Upper Benue Trough, Northeastern Nigeria (fig. 1). The Yola Arm is covered by continental to marine Cretaceous (Aptian-Early Santonian) deposits with total thickness of 3-4km. The sedimentary sequences in the Yola Arm of the Upper Benue Trough are; Bima, Yolde, Dukul, Jessu, Sekuliye, Numanha and Lamja Formations (Carter et al., 1963).

2.2. Bima Sandstone

The Bima sandstone is the oldest sedimentary rock in the region, is extensively exposed particularly in the northern and eastern borders of the Gongola basin. The over 3000m of formation consists of arkosic, kaolinitic, medium to very coarse cross bedded conglomeratic sandstone. It has been subdivided into lower, middle and upper members and grades southwards into the contemporaneous muri, Keana and Makurdi sandstone in the middle Benue. The lower Bima appears to be upper Jurassic to early cretaceous, latest Jurassic to early Cretaceous, associated with lava flows of the same age to late Aptian and late Albian for the middle and upper Bima respectively. The typically massive medium to coarse and pebbly felspathic sandstones is presumed to rest unconformable on the basement complex rocks.

3. Methodology

The method of study includes field work and laboratory analysis. The field work involves detailed mapping of the formation, locating good outcrop sections, description of lithology and measurements. During this period, detailed description of lithology, measurement of thickness, dip and strike of sedimentary structures were carefully carried out. 20 Samples were taking for both sieve and petrographic analyses.

The laboratory work involves the thin section preparation and petrographic examination of rock specimens using polarizing microscope and also the granulometric analysis with the aid of sieve.

3.1. Petrographic Analysis

The important aspect of petrographic studies involves the practical aspect of rock description and identification based on their mineral content which can easily be identified from the optical properties under a polarizing microscope or from hand specimen base on its texture, and mineral composition. The instruments used in these studies is the polarizing microscope. Five (5) representative samples were selected and a slides was prepared from each sample, numering #1 to #5. The slides were mounted on polarizing microscope were mineral grains description was conducted in addition to the production of five photomicrographs one for each.

3.2. Sieve Analysis

Three samples were analyzed, collected from different points as representative samples within the study area which are labeled as sample #1, #3 and #5 respectively. For the textural analysis, 200g of each of the three samples were measured using electronic balance before sieving. Samples were then collected, disaggregated with the use of pestle and mortar; care was taken to avoid breaking the original size of the sediment. The sieves were arranged in downward decreasing mesh diameters, which range from 2.00mm, 1.00mm, 0.25mm, 0.125mm, 0.063mm and <0.063 (pan). The sieves were mechanically vibrated for 2 minutes with sieve shaker. The weight of sediments retained on each sieve were measured with the use of electronic balance and converted into a percentage of the total sediment of each of the sample.

4. Results and Discussion

Petrography of Sandstone is dependent to a large extent on the composition of the source rock especially in immature sandstone. The relative abundance of the five (5) principal ingredients (quartz grains, lithic grain, feldspar grain...
matrix and cement) of sandstone in any sandstone deposits is a relative of the provenance of the materials. The photomicrographs for the five (5) samples studied are presented in Figure 1 to 5 for both under crossed polarized light and plane polarized light.

In the thin section the grains are predominantly quartz with many of the quartz floating in the cement while other grains exhibits point contacts. Some dark colour mineral grains, greyish and little brownish mineral grains are visible under the petrographic microscope. The available minerals observed in the Bima Sandstone are quartz, feldspar (both plagioclase and microcline), and iron oxide.

![Figure 1: Cross Polarization, Plane Polarization Photomicrograph of Sample No 1 with MAG-X40](image1)

![Figure 2: A. Under Cross Polarization B. Under Plane Polarization Photomicrograph of Sample No 2 with MAG-X40](image2)

![Figure 3: A. Under Cross Polarization B. Under Plane Polarization Photomicrograph of Sample No 3 with MAG-X40](image3)
4.1. Petrological Description of Samples

The petrographic study shows quartz as the dominant mineral. Quartz enrichment is a measure of sandstone maturity and is a reflection of the duration and intensity of weathering and destruction of other minerals during transportation. It can be deduced from the thin section that the Bima Sandstone in the study area has undergone long period of transportation and have been subjected to intense weathering resulting in the destruction of other minerals such as feldspars. The petrographic studies also shows that the Bima sandstones is mainly silica in the form of quartz and felspars predominate the cementing materials as seen in Figure #2, #3, #4 and #5. The grain sizes range from 1.36 – 1.83mm indicating a medium – coarse grained sandstone that is poorly sorted. In all the thin sections studied, the quartz present is sub-angular to subrounded with iron oxide induced reddish brown colouration.

4.2. Sieve Analysis Results

The results of three representative samples within the study area labeled as sample #1, #3 and #5 respectively are presented in Table 2, 3b and 3c.

| Mesh size (mm) | Mesh Size (Φ) | Mid Mφ | Raw Weight (g) | Raw Weight (%) | Cumulative Weight (%) |
|----------------|---------------|--------|----------------|----------------|-----------------------|
| 2              | -1            | -1.5   | 0.9            | 0.45           | 0.45                  |
| 1              | 0             | 0.50   | 7.90           | 3.96           | 4.41                  |
| 0.5            | 1             | 0.50   | 77.50          | 38.86          | 43.27                 |
| 0.25           | 2             | 1.50   | 63.90          | 32.05          | 75.32                 |
| 0.125          | 3             | 2.50   | 31.00          | 15.54          | 90.86                 |
| 0.063          | 4             | 3.50   | 11.60          | 5.82           | 96.68                 |
| <0.063         | 5             | 4.50   | 6.60           | 3.31           | 99.99                 |

199.40

Table 2: Result of Sieve Analysis of Sample #1
Table 3: Result of Sieve Analysis of Sample #3

| Mesh size (mm) | Mesh size (Φ) | Mid MΦ | Raw Weight(g) | Raw weight (%) | Cumulative Weight (%) |
|---------------|---------------|--------|---------------|----------------|-----------------------|
| 2             | -1            | -1.5   | 1.00          | 0.50           | 0.50                  |
| 1             | 0             | 0.50   | 11.3          | 5.66           | 6.16                  |
| 0.5           | 1             | 0.50   | 118.1         | 59.11          | 65.27                 |
| 0.25          | 2             | 1.50   | 31.00         | 15.52          | 80.79                 |
| 0.125         | 3             | 2.50   | 28.00         | 14.01          | 94.8                  |
| 0.063         | 4             | 3.50   | 8.30          | 4.15           | 98.95                 |
| <0.063        | 5             | 4.50   | 2.10          | 1.05           | 100                   |
|               |               |        |               |                | 199.80                |

Table 4: Result of Sieve Analysis of Sample #5

| Mesh size (mm) | Mesh size (Φ) | Mid MΦ | Raw Weight(g) | Raw weight (%) | Cumulative Weight (%) |
|---------------|---------------|--------|---------------|----------------|-----------------------|
| 2             | -1            | -1.5   | 2.7           | 1.35           | 1.35                  |
| 1             | 0             | 0.50   | 15.80         | 7.91           | 9.26                  |
| 0.5           | 1             | 0.50   | 30.80         | 15.41          | 24.67                 |
| 0.25          | 2             | 1.50   | 51.50         | 25.77          | 50.44                 |
| 0.125         | 3             | 2.50   | 73.50         | 36.78          | 87.22                 |
| 0.063         | 4             | 3.50   | 19.00         | 9.51           | 96.73                 |
| <0.063        | 5             | 4.50   | 6.50          | 3.25           | 99.98                 |
|               |               |        |               |                | 199.80                |

Table 5: Summary of Percentiles from Cumulative Frequency Curve Samples #1, #3, and #5

| Percentile | Sample #1 | Sample #3 | Sample #5 |
|------------|-----------|-----------|-----------|
| Φ55        | 0.1       | 0.4       | 0.05      |
| Φ16        | 0.4       | 0.4       | 0.6       |
| Φ25        | 0.6       | 0.5       | 1         |
| Φ50        | 1.2       | 0.7       | 2         |
| Φ75        | 2         | 1.6       | 2.6       |
| Φ84        | 2.5       | 2.3       | 2.9       |
| Φ95        | 3.8       | 2.7       | 3.8       |

Table 6: Result of Mean, Standard Deviation, Skewness and Kurtosis of Samples #1, #3, And #5 Using Graphical Method

| Sample #1          | Sample #3          | Sample #5          |
|--------------------|--------------------|--------------------|
| MEAN               | 1.36               | 1.16               | 1.83               |
| Medium Sand        | Medium Sand        | Medium Sand        |
| SORTING            | 1.08Poorly Sorted  | 1.13Poorly Sorted  | 1.14Poorly Sorted  |
| Coarsely Skewed    | 0.29               | 0.33               | -0.13              |
| Strongly Coarse Skewed | 1.08               | 1.67               | 2.34               |
| Mesokurtic         | Very Leptokurtic   | Very Leptokurtic   |

The sections is composed of mainly of medium – coarse grain, moderately sorted sandstone parallel laminated of 5cm thick.

4.3. Condition of Deposition

Visual studies of the three samples indicates that the sediments are medium to coarse grains within the study area, is indicative of fast running water, therefore, the condition of deposition of Bima Sandstone in Lokoro area is progradational deposits. On the basis of petrography, the sandstone composed of about 95% quartz, feldspar and iron oxide make up the other constituents minerals.

5. Conclusion

The Bima Sand Stone Formation outcropped at Lokoro area has been found to be texturally coarse-medium grained, scarcely cemented and poorly sorted thereby rendering the segment not a good potential reservoir in the basin. Extensive weathering of the feldspar within the inclusion of some opaque minerals could possibly be an answer to why clay occurrence is reported in sample No. #5.
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