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PROVENANCE AND COMPOSITION OF THE BIMA GROUP EXPOSED AROUND WUYO VILLAGE, UPPER BENUE TROUGH N.E. NIGERIA

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ABSTRACT

Provenance study of Bima group of the Upper Benue Trough around Wuyo village was carried out on fresh representative samples. The petrographic results suggest the sandstones to be arkosic arenites, the average composition of the three rock forming minerals as observed are; 40% quartz, 46% feldspar and 3% rock fragments. The higher percentage of feldspar, the sphericity of the grain sizes which are largely sub-angular to sub-rounded and the poorly sorted nature of the sandstones as well as ZTR index of 60.3% from the heavy minerals analysis suggest immature sediments, they are deposited close to their source area. The coarse grain Sandstone in the study area were deposited by fluviatile system while the fine grain sandstone and clay were deposited in a lacustrine environment. The dominance of monocrystalline quartz as well as the Microscopic examination of the heavy minerals contained in the sandstones of the study area revealed that the sediments originated from dominantly granitic source and deposited by a moderate to high energy level shallow water continental conditions. The sutured contact, polycrystalline quartz crystals and the undulose extinction exhibited by some of the few quartz crystals in the petrographic studies is as a result of stress the sediment went through after deposition.

Keywords: Bima sandstone, Provenance, Upper Benue trough, Petrography, Heavy minerals

INTRODUCTION

The Benue Trough, situated in Nigeria, is a component of the intracratonic basin chain within the West and Central African Rift System, positioned in the intermediate zone between the Chad and Niger Delta Basins. The Benue Trough spans an impressive length of over 1000km, with a width ranging from 50-150km. It comprises a thick sequence of sediments from the Cretaceous-Tertiary period, totaling over 6000m associated with volcanics. Geographically, the basin is divided into three distinct segments; the Northern, Central and Southern. The Northern part is further divided into the Gongola and Yola arm (Dike, 2002).

The term Bima Sandstone refers to the oldest continental deposit that occurs in the chad Basin and the Upper Benue Trough of Nigeria. (Falconer 1911). The composition of Bima Sandstone, which ranges from arkose to quartz arenite has sparked widespread debate and discussions regarding its provenance and the depositional setting (Falconer, 1911; Jones, 1959; Carter *et al.*, 1963; Murat, 1972; Braide, 1990). The mineral or rock fragment within a sediment provide a trail of evidence leading back to their source, allowing us to trace the sediment`s journey, the paleoclimatic setting of the provenance (Suttner *et al.*, 1981; James *et al.*, 1981) and the mechanism of sediment transport and deposition that dispersed this grains across the bsin, shaping the final landscape (Breyer and Bart, 1978; Klein, 1977; Dovies and Ethridge, 1975; Swett *et al.*, 1971). The nature and amount of interstitial cement and matrix are largely controlled by the changes that occur during diagenesis.

One of the most important sedimentary basins in Nigeria is the Benue Trough which is a NE-SW trending sediment-filled depression (Cratchley and Jones, 1965; Burke *et al.*, 1971). Several research works have been carried out across the Basin. However, the provenance, composition and petrographic studies of the sediments in the study area are poorly known. Because most works around Wuyo was carried out on a regional scale. Hence, this necessitate the present study. The aim of this work is to study the provenance and composition of the Bima group around Wuyo village. (Haruna *et al.,* 2013), Bima Sandstone was derived from the borderlands during period of tectonic quiescence, low relief and in a humid tropical climate that enhanced rapid weathering of the rocks. The weathered products were worked by minor streams and piled in alluvial plains and fans, which were further reworked by meandering streams and intermittent shallow marine inundations at the central part of the trough. Bakari (2014) reported that the Bima Sandstone is continental in origin which is dominated by coarse grains and some fine to medium grains which indicates an evidence of change in depositional energy medium from moderate to high. The positive skewness values indicate fluvial process under high energy condition. Mustapha *et al.* (2019) reported that from the granulometric analysis and facies analysis, it is deduced that the sediments in this study area were deposited in a braided fluvial environment setting. In a separate research by Mustapha *et al*. (2019), the geochemical analysis showed that the Bima Sandstone studied at the Wuyo village formed on an active continental margin (ACM) setting and the Sandstone is classified as litharenite. Similar work was published in the sister Yola arm of the Upper Benue Trough by Sarki Yandoka *et al.* (2014), the facies and stratigraphy of the lower Bima Sandstone member reflected lacustrine and marginal lacustrine succession, alluvial fan and braided river succession all in Yola arm of the Upper Benue Trough. However, Sarki Yandoka's research is restricted to Lower Bima Sandstone. Some other authors that studied the Bima Sandstone include Shettima *et al.* (2017); Samaila *et al.* (2006) etc.

The geological map of the study area has been updated on a scale of 1:50,000, the provenance of the Bima Sandstone in the study area have been determined and the depositional environment of the Bima Sandstone in the study area has been established.

MATERIALS AND METHODS

The research area is located in Borno State, specifically within the Wuyo Sheet 153 NW, bounded by latitudes 10°15'N to 10°30'N and longitudes 11°30'E to 11°45'E (Figure 1). The terrain is generally hilly with some flat areas. The climate is semi-arid, with two distinct seasons: a dry season from November to April, characterized by high daytime temperatures (36-40°C) and cooler nighttime temperatures (10-17°C), and a rainy season from May to October, marked by warmer temperatures (20-31°C) and relative humidity ranging from 40-60%, with annual rainfall varying between 860-900 mm. Detailed geological field work was undertaken in the study area, the field work also involved locating and descriptions of outcrops, boundaries etc. Samples were gathered from various locations within the study area for laboratory examination. Two key laboratory tests were conducted: petrographic analysis and heavy mineral analysis. Both analyses are valuable tools for tracing the origin of sediments. Petrographic analysis, in particular, involves examining the optical properties of common minerals in rocks, such as their appearance and interaction with light, using a polarizing microscope (Tucker, 2001). This helps identify the source rock from which the sediments were derived. Heavy Mineral Analysis involves the selective identification of specific minerals that are resistant to physico-chemical alteration resulting from weathering, transportation, deposition, and digenesis. 1,1,2,2 Tetrabromoethane was used as the heavy fluid to separate the heavy minerals from the lighter ones and binocular microscope was used to identify the heavy minerals. Grid ocular method was use to count the minerals identified. Heavy minerals are key indicators of sediment provenance and geological events, with some linking to igneous sources and others to metamorphic rocks (Morton and Hallsworth, 1994; Mange and Wright, 2007; Nicholas, 2009; Pettijohn, 2002).

Figure 1: Location Map of the study area

RESULTS AND DISCUSSION

A geological map of the study area was generated based on information gathered through field observations and mapping of the area.

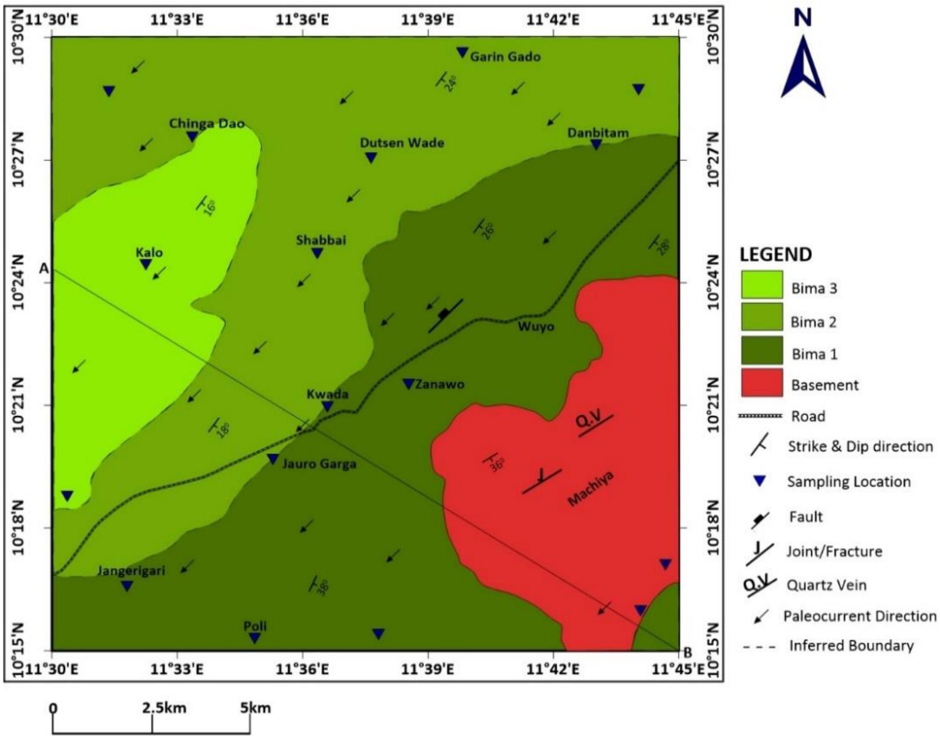


Figure 2: Geologic map of the Study area

Lower Bima Formation

The Lower Bima Sandstone member consist of coarse grained, feldspatic sandstone with Layers of purple and reddish clays and shales are interspersed with occasional horizons of pebbles (Carter et al., 1963). At Zanawo village, the section is composed of pebbly/cobbly sandstone with thickness of 0.9m at the base (with pebbles ranging in size from 1 mm to 50 cm) which is in contact with the basement non-conformably. Around Kwada village, a section of grayish clay with thickness of 2m overlain by brownish medium grain sandstone interbedded with clay, overlain by 1.9m thick brownish coarse grain sandstone were observed. The section ended with 0.6m mottled clay. Pebble imbrications, loadcast and sinistral strike slip fault were also observed on the Lower Bima Sandstone in the study area.

Middle Bima Sandstone

Middle Bima Sandstone section starts with 1.1m thick gray clay at the base, overlain by 0.7m fine grain sandstone, 0.6m clay 1.4m fine grain sandstone and 6.2m medium grain sandstone. At the base of this section sandstone and clay interbedding were observed and transit into units of sandstone. At Gari gado, the brownish medium grain sandstone is overlain by a bed of 6.2m whitish coarse grained tabular cross bedded sandstone.

Upper Bima Sandstone

The Upper Bima Sandstone is primarily composed of feldspathic sandstone with a medium to very coarse grain size, and a color range of whitish, cream, white-gray to buff (Carter et al., 1963). At Gama, the section observed is 5.5m thick medium grain sandstone with asymmetrical ripple marks. At Kalo, the section is whitish-purple coarse grain tabular cross-bedded sandstone. Poorly developed tabular cross-bedded sandstone was observed. Upper Bima Sandstone bed around Yaran Duwa and Jauro Ganga villages, are moderately sorted fine to medium grain massive sandstone.

Petrographic Studies

Lower Bima Sandstone

(a) XPL (b) PPL

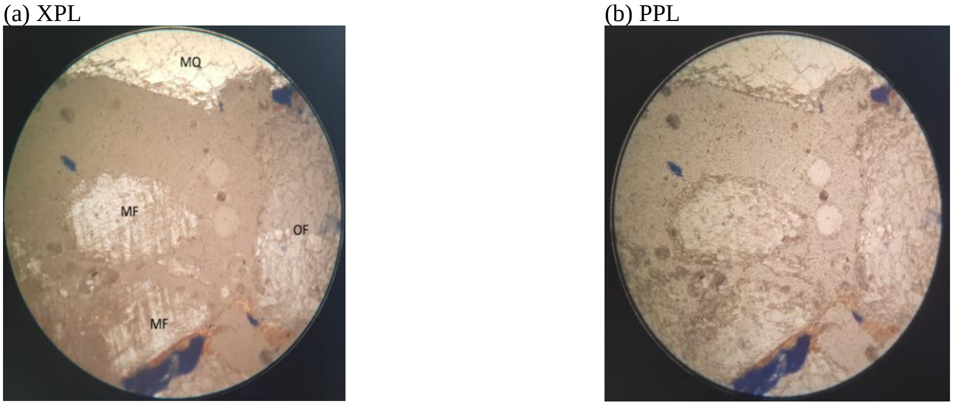


Plate 1: Photomicrographs of Sandstone and Clay interbedded from Lower Bima Sandstone as observed under the microscope. Magnification x10

(a) XPL (b) PPL

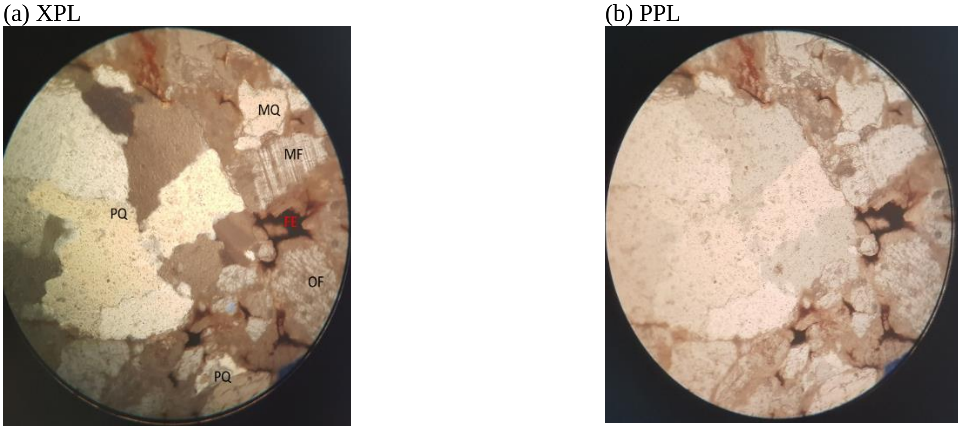


Plate 2: Photomicrographs of Massive Sandstone from Lower Bima Sandstone as observed under the microscope. Magnification x10

(a) XPL (b) PPL

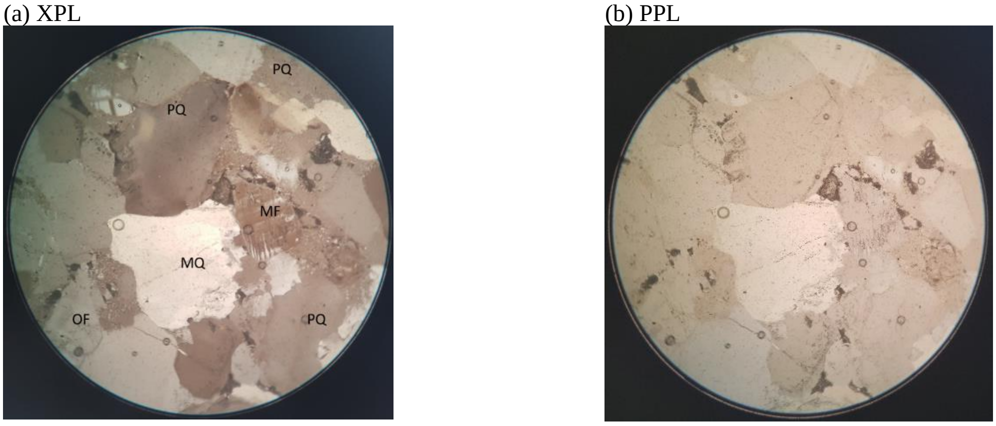


Plate 3: Photomicrographs of Pebbly/cobbly Sandstone from Lower Bima Sandstone as observed under the microscope. Magnification x10

(a) XPL (b) PPL

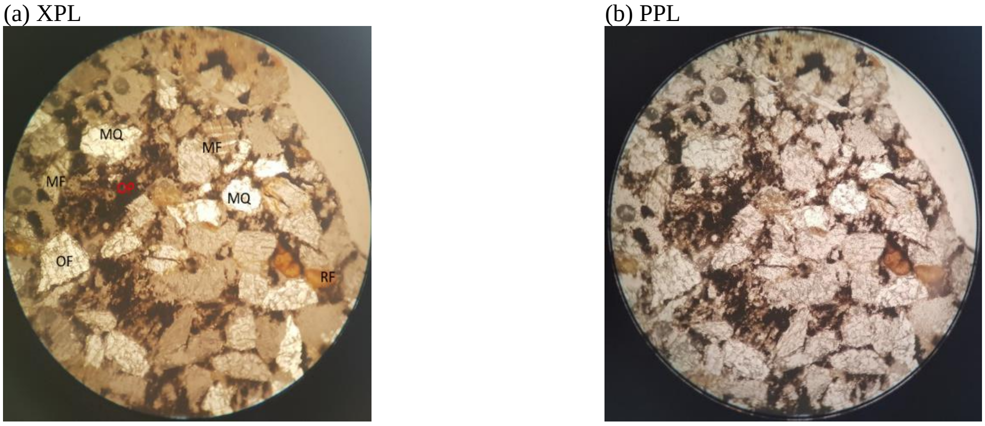
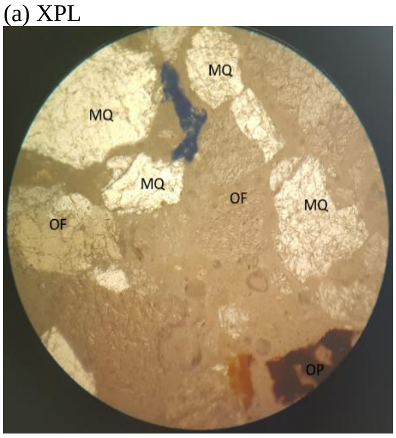


Plate 4: Photomicrographs of Massive Sandstone from Lower Bima Sandstone as observed under the microscope. Magnification x10

Middle Bima Sandstone

(a) XPL



(b) PPL

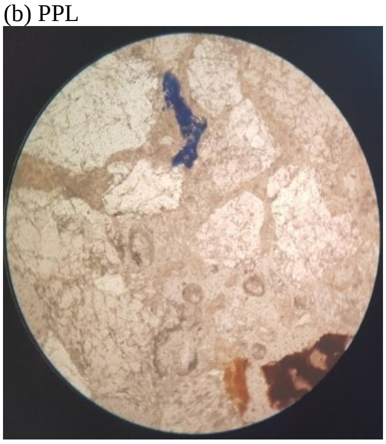
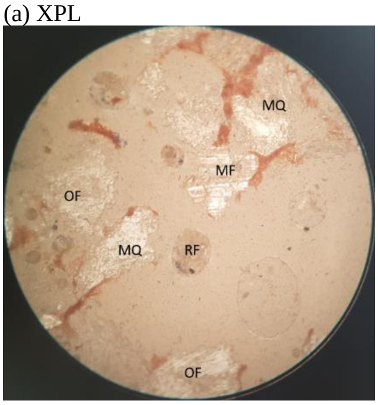


Plate 5: Photomicrographs of Sandstone and Clay interbedded from Middle Bima Sandstone as observed under the microscope. Magnification x10

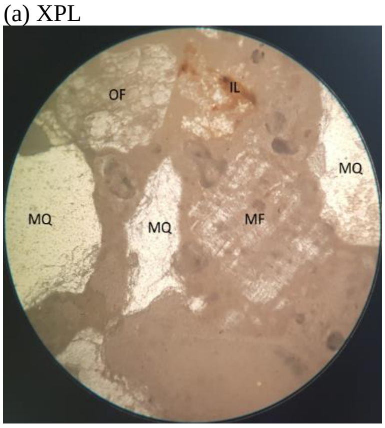
(a) XPL



(b) PPL

Plate 6: Photomicrographs of Tabular cross-bedded Sandstone from Middle Bima Sandstone as observed under the microscope. Magnification x10

(a) XPL



(b) PPL

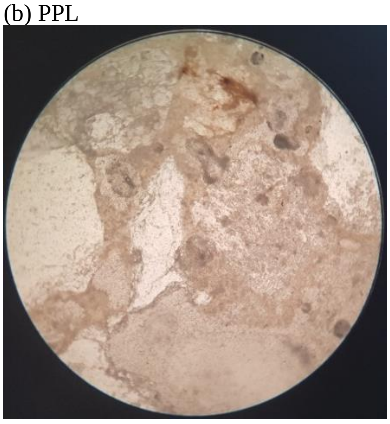


Plate 7: Photomicrographs of Sandstone and Clay interbedded from Middle Bima Sandstone as observed under the microscope. Magnification x10

Upper Bima Sandstone

(a) XPL (b) PPL

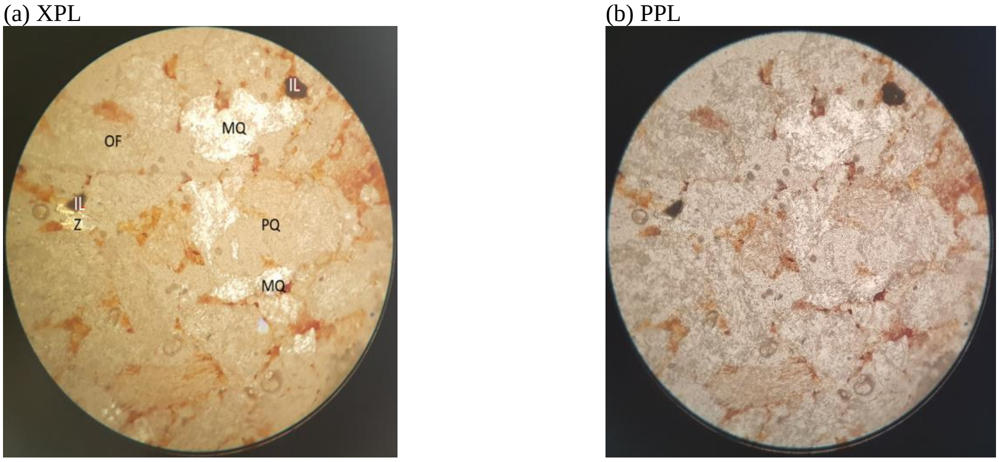


Plate 8: Photomicrographs of Massive Sandstone from Upper Bima Sandstone as observed under the microscope. Magnification x10

(a) XPL (b) PPL

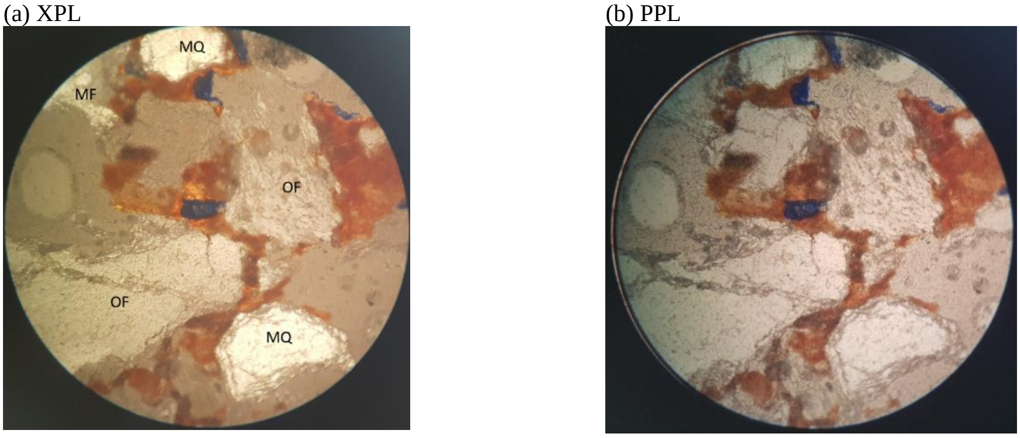


Plate 9: Photomicrographs of Ripple Mark Sandstone from Upper Bima Sandstone as observed under the microscope. Magnification x10

(a) XPL (b) PPL

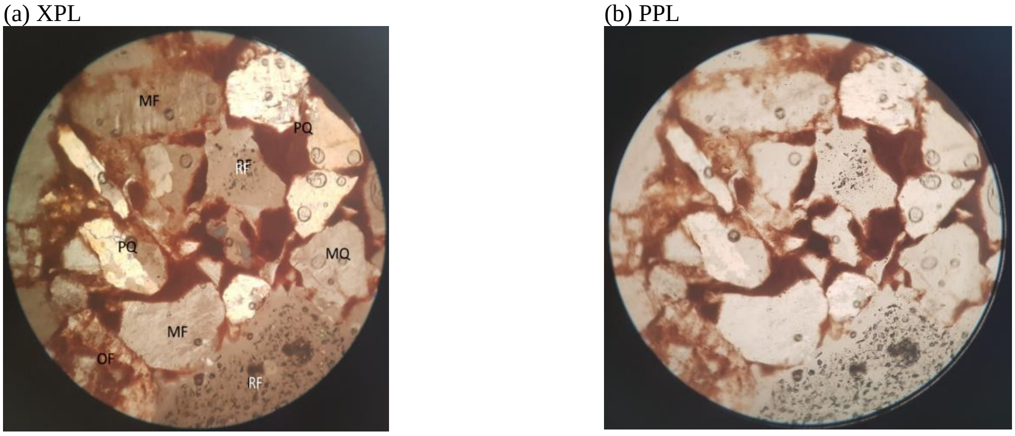


Plate 10: Photomicrographs of Massive Sandstone from Upper Bima Sandstone as observed under the microscope. Magnification x10

Table 1: Distribution of minerals percentage by number in the study area

Minerals	S1	S2	S4	S6	S7	S9	S10	S12	S13	S17	Total	%
Quartz	11	19	13	23	26	15	13	12	15	14	161	40.04
Feldspar	14	15	18	22	17	13	20	24	30	12	185	46.01
Rock fragment	0	0	0	3	5	0	0	0	2	0	10	2.48
Others	1	8	5	3	19	2	0	3	2	3	46	11.44

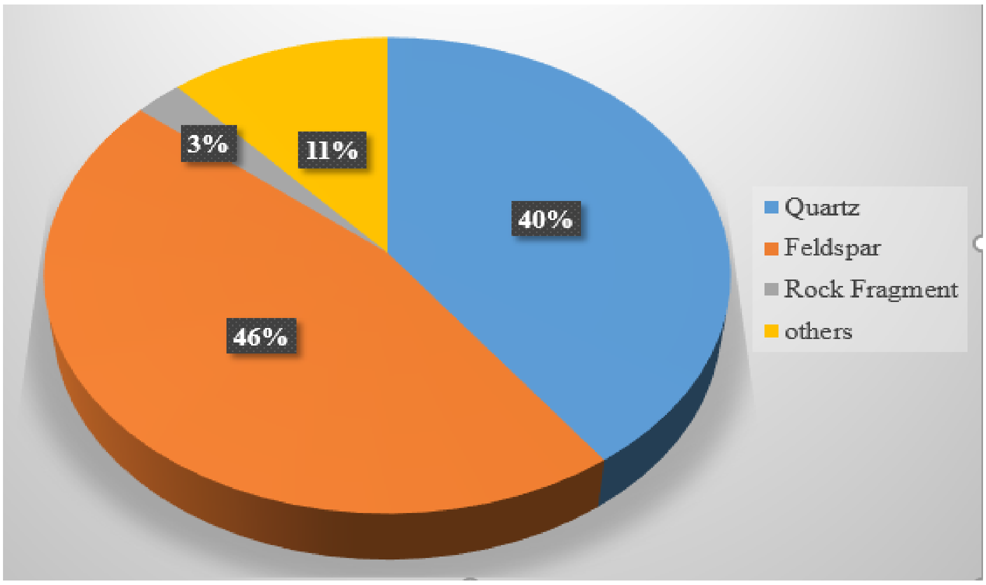


Figure 3: Distribution of minerals in the study area

Heavy Minerals Analysis
These minerals are more resistance to weathering, hence survive a greater distances of fluvial transport. Analyzing heavy minerals provides valuable insights into the source area's history and events. To gain these insights, heavy minerals were examined and counted using a grid ocular method.

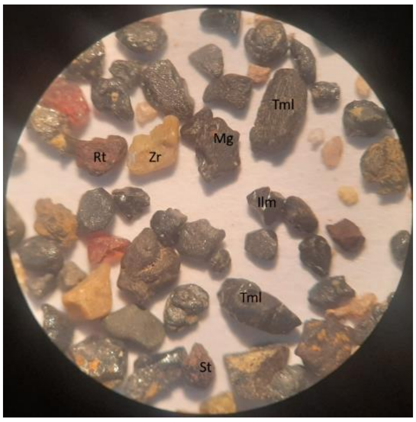


Plate 11: Photomicrograph of heavy mineral around Kwada village Sample ID: Kwada S2 from Lower Bima Sandstone

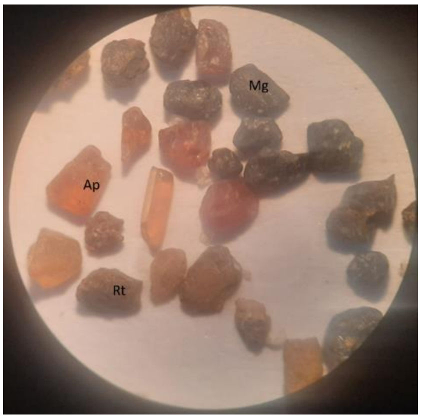


Plate 12: Photomicrograph of heavy mineral around Shabbai village Sample ID: Shabbai S5 from Middle Bima Sandstone

Plate 13: Photomicrograph of heavy mineral around Kalo village Sample ID: Kalo S12 from Middle Bima Sandstone

Table 2: Distribution of heavy minerals percentage by number in the study area

Sample ID	Ilmenite	Apatite	Staurolite	Zircon	Tourmaline	Rutile	Total	ZTR	ZTR index %	Opaque
Kwada S2	10	11	2	23	32	26	104	81	58.3	35
Adada S4	14	17	7	38	21	22	119	81	55.5	27
Shabbai S5	11	14	2	31	24	31	113	89	65.9	22
Kuldum S9	9	11	6	42	19	24	111	85	59.9	31
Kalo S12	13	15	8	39	37	27	139	103	61.7	28
Total	57	68	25	173	133	130		439		143
Average	11.4	13.6	5.0	34.6	26.6	26.0		87.5	60.3	28.6

Table 3: Heavy minerals composition in percentage by number

Sample ID	Ilmenite %	Apatite %	Staurolite %	Zircon %	Tourmaline %	Rutile %	Total
Kwada S2	9.6	10.6	1.9	22.1	30.8	25.0	100
Adada S4	11.8	14.3	5.9	31.9	17.6	18.5	100
Shabbai S5	9.7	12.4	1.8	27.4	21.2	27.4	100
Kuldum S9	8.1	9.9	5.4	37.8	17.1	21.6	100
Kalo S12	9.6	10.8	5.8	28.1	26.6	19.4	100
Total	9.8	11.6	4.2	29.5	22.7	22.4	100

Petrography

The petrography of the samples in the study area revealed similar mineral compositions across the Lower, Middle and Upper Bima Sandstone, these includes quartz, orthoclase, microcline, zircon, ilmenite, iron oxide, opaque minerals and very few rock fragments. However, ilmenite and zircon are peculiar to the Upper Bima Sandstone. The results of petrographic study indicate dominance of feldspar (46.01%) (Figure 3). The Sandstone in the study area is Arenite because the matrix content is less than 15% (2.48%) and falls under Arkosic Arenite sub-class because feldspar is more than 25% (46.01%) and is much more than the rock fragment (3%) (Figure 3). The dominance of feldspar also implies The grains were either eroded rapidly from a high-relief source area or came from a source area with limited chemical weathering due to an arid or cold climate. The quartz crystals from the Lower and Upper Bima Sandstone ranging from medium to coarse grains are dominated by monocrystalline crystals, the crystals lack sutured intra-grain boundaries, characteristics of igneous rocks (Pettijohn, et al., 1972; Blatt, et al., 1972). Additionally, most grains have iron oxide rims on their edges. Quartz is the primary silicate mineral serving as cement, although iron-oxide cement is also present in patches. These cements are chemically bonded to the crystal lattice of existing quartz grains, forming rims. Iron oxide appears reddish in colour, suggestive of hematite/ilmenite occur as clots and coatings around grains, often in areas with no grain-to-grain contact, indicating diagenetic formation. The grains of the Middle and Upper Bima Sandstones are poorly sorted while the Lower Bima Sandstone is moderately sorted suggesting that the Bima Sandstone in the study area is close to the source and this indicates that it is texturally and mineralogically immature (Folk, 1968; Friedman, 1967). The quartz crystals are anhedral, meaning they lack well-defined crystal faces, and exhibit parallel extinction. In contrast, the orthoclase mineral grains have subhedral crystal forms, which are partially bounded by crystal faces. The boundaries between grains are primarily characterized by floating contacts, with only a few concavo-convex contacts present. However, the boundaries between Lower and Upper Bima Sandstone grains show few sutured contacts, indicating that diagenetic processes occurred after deposition. Quartz and microcline feldspar have a very high relief across both the Lower, Middle and Upper Bima Sandstone and orthoclase have a low relief and appear in anhedral form. The grains are mostly angular across the Middle and Upper Bima Sandstone and sub-rounded in the Lower Bima Sandstone suggesting closeness to source area. In summary, the sandstone is composed of a mixture of quartz, orthoclase, microcline, and iron oxide, with quartz and feldspars (orthoclase and microcline) being the main components, and a small amount of rock fragments present. The quartz crystals are dominantly monocrystalline typical of igneous rock provenance, grains are poorly sorted, texturally and mineralogically immature, deposited close to the source area. The Bima Sandstone is classified as arkosic arenites (Pettijohn, 1973), indicating a sandstone rich in feldspar.

Heavy Minerals Suite

Heavy minerals have long been used as indices of provenance (Nicholas, 2009, Pettijohn, 2002). The ultra-stable group of heavy minerals, comprising zircon, tourmaline, and rutile, are exceptionally resistant to weathering and abrasion. Zircon and tourmaline, in particular, are highly durable and chemically unreactive, enabling them to withstand multiple cycles of erosion and transportation without breaking down. Opaque minerals, in as much as they have relatively high iron content, generally have a very high specific gravity. The study area shows presence of tourmaline and magnetite among other heavy minerals. Tourmaline indicates the derivation of sediments from granitic and pegmatitic rocks (Krynine**,** 1946). The presence of magnetite, ilmenite, apatite, zircon and rutile in the studied samples also indicates that The sediments came from igneous sources, having been eroded and transported from their original igneous rock formation. (Nicholas, 2009, Pettijohn, 2002). The overall studies of the heavy mineral suite of the Lower, Middle and Upper Bima Sandstone in the study area suggest their derivation from igneous sources and stable heavy minerals indicate moderate energy conditions at the site of deposition. It can be concluded that the sediments have a short distance of transportation from the source area to the site of deposition.

Provenance

Petrographic and heavy mineral analyses are significant in deducing provenance. The relationship of quartz, feldspar, and rock fragments in sandstone indicates both compositional maturity and provenance, distinguishing between deep-seated and surface-level sources (Pettijohn, 1975). Additional clues about the origin of sandstone can be found in the characteristics of quartz grains, including their crystalline structure (whether monocrystalline or polycrystalline) and their optical properties when viewed under cross-polarized light, such as their extinction behavior (Tucker, 1981). The dominance of monocrystalline quartz suggests that the sandstone originated from granitic rocks. The sutured contact, polycrystalline quartz crystals and the undulose extinction exhibited by some of the few quartz crystals in the petrographic studies is as a result of stress the sediments went through after deposition. The absence of volcanic rock fragments in the samples indicate a non-volcanic source (Tucker, 1981). The study of the heavy minerals also gives useful information on provenance and events in the source area. Common non-opaque heavy minerals grains are apatite, epidote, garnet, rutile, staurolite, tourmaline and zircon. The common opaque detrital minerals are the hematite and magnetite. Specific heavy minerals like garnets, epidote, and staurolite originate from metamorphic terranes, whereas others like rutile, apatite, and tourmaline are indicative of igneous source rocks (Adam et al., 1984). Microscopic examination of the heavy minerals contained in the sandstones of the study area revealed both opaque and non-opaque minerals. The opaque minerals are made up of about 19.60% while the non-opaque minerals consist of about 9.80% ilmenite, 11.60% apatite, 4.20% staurolite, 29.5% zircon, 22.7% tourmaline, 24.2% rutile. According to Friedman, (1979), Pettijohn (1984), these heavy mineral assemblages in any sandstone suggest igneous parent rocks. This shows that the sediments are derived from dominantly granitic source and deposited under shallow water continental conditions. The sub-rounded to sub-angular-angular shapes of the grains is an indication of short distance of transportation from the source area.

CONCLUSION

Standard field practice, petrography, heavy mineral analyses are analytical tools used for the study. The results of this work shows that the Bima Sandstone are derived dominantly from igneous source and deposited under fluvial and lacustrine environment. The cementing materials are mainly iron oxide and silica. The grains are sub-rounded to sub-angular to angular shape, coarse to medium grained, and moderately to poorly sorted. These suggest short distance of transportation or closeness to the source area. Sandstones with such characteristics indicate an arkosic sandstones as supported by the petrographic analysis which shows higher percentage of feldspar than quartz. The concentration of feldspar and the poorly sorted nature of the sandstones, as well as the ZTR (Zircon Tourmaline Rutile) index value of $<75\%$ shows that the Bima Sandstone in the study area is both texturally and mineralogically immature.

REFERENCES

Adams, A.E., W.S. MacKenzie and C. Guilford, (1984). Atlas of sedimentary rocks under the microscope. *English language book society Longman Scientfiic and Technical Longman Group UK Ltd* p .231.

Bakari, A. (2014) Granulometric Analysis Of Bima Sandstone Around Chekole In Gombe Sub Basin Of The Upper Benue Trough, Nigeria. International Journal of Scientific & Technology Research Volume 3, ISSN 2277-8616

Burke, K. Dessanvagie, T.F and Whiteman, A. J (1971): Opening of the Gulf of Guinea and Geological history of the Benue Depression and Niger Delta. Natune 233, P.51-55.

Braide, S. (1990): Tectonic origin of preconsolidation deformation, Bima Sandstone, Yola Basin, Benue Trough. *Bulletin Nigerian Association Petroleum Explorationists7*, P. 39-45.

Breyer J.A, Bart H.A (1978). The Composition of fluvial sands in a Temperate Semi - Arid Region. *Journal of Sed. Petrology* V.48, P.1311 - 1320.

Blatt, H., Middleton, G.V. & Murray, R.C. (1972) Origin of Sedimentary Rocks (2nd edition). *Prentice-Hall, Englewood Cliffs*, New Jersey.

Carter J. D., Barber W. E.A and Jones G.P (1963): The Geology of parts of Adamawa, Bauchi, and Borno Province in Northeastern Nigeria. *Bulletin Geological Survey Nigeria* 30, P. 1-99.

Cratchley, C.R and Jones, G.P. (1965): An interpretation of the geology and gravity anomalies of the Benue Valley, Nigeria. *Overseas Geological surveys Geophysical paper* I, pp. 1-26.

Dike, E.F.C. (2002): Sedimentation and tectonic evolution of the Upper Benue Trough and Bornu Basin, Northeastern Nigeria. *Nigerian Mining and Geosci. Soc. 38th Annual and international conference Port Harcourt 2002 (NMGS/ELF award winning paper) Abstr.* Vol.1 45p.

Davis D.K, Ethridge F.G (1975): Sandstone Composition and Depositional Environment. *Bulletin American Associationof Petroleum Geologist,* 59. P. 239 - 264.

Falconer, J. D (1911): The Geology and Geography of Northern Nigeria. MacMillan London, P.295 1911. *Universal Journal of Geoscience.* 2 (3): 93-103.

Folk RL (1968): Petrology of Sedimentary Rocks, *1st Ed., Hemphills, Austin*, Texas. P.170.

Friedman GM (1967): Dynamic Processes and Statistical Parameters Compared for size frequency distribution of beach and river sands. *Journal of Sed. Petrology V.37*, p.327-354.

Friedman, G.M., (1979): Differences in size distributions of populations of particles among sands of various origins. *Journal of Sed. Petrology* 26: 3-32.

Haruna I.V., Dio C.J., Maunde A. and Raji A.S. (2013) Provenance and Paleoenvironmental Study of Bima Sandstone in the Upper Benue trough, N.E., Nigeria. *International Research Journal of Earth Sciences* Vol. 1(2) ISSN 2321–2527

Ingersoll R. V and Suezek, C. A. (1979): Petrology and Provenance of Neogene sand from Nicobar and Bengal Fans, DSDP sites 211 and 218. *Journal of Sed. Petrology* V.49, p.1217 - 1228.

Jones G.P (1959): Sedimentary Structures in the Bima Sandstone, Records of the Geological survey of Nigeria. *Bulletin Geological Survey Nigeria* V.6, p.5 - 14.

Jones P.D (1972): Quartz arenita and Lithoarenite Facies in the Fluvial Foreland Deposits of Trenchard Group (West-Phalian) Forest of Dean, Ebgland, *Journal Sed. of Geology* P.177-198.

J
ames C.W, Nack G.H and Suttner L.J (1981): Relative Alteration of Microcline and Sodic Plagioclase in Semi-arid and Humid climates. *Journal of Sed. of Petrology* V.51, P.151 - 164.

Krynine, W.C. and Sloss, L.L. (1946): Stratigraphy and sedimentation (2nd Ed.) *Freeman, San Francico*, P. 660.

Klein D.V (1977): Clastic Tidal Facies, Champaign IL CEPCO. *Journal of Sed. Petrology* Illinoisp.149.

Mustapha, I. M., Sa'ad A. S., Muhyideen, H. and Abubakar T. M. (2019). Granulometric Analysis Indices as Signatures of The Depositional Environment of The Bima (I) Formation At Wuyo Area, Part of Gongola Sub-Basin, Upper Benue Trough, Northeastern Nigeria. *International Journal of Scientific Research in Multidisciplinary Studies Vol.5, Issue.12, pp.43-51* E-ISSN: 2454-9312

Mustapha, I. M., Shettima, B., Sa'ad A. S., Maibeti, U., Muhyideen, H. and Abubakar T. M. (2019). Facie Analysis and Geochemical Characteristics of Bima Formation at Wuyo, Part of Gongola Sub-Basin, Upper Benue Trough, Northeastern Nigeria: Implications for Provenance, Paleoenvironment and Tectonic History. *International Journal of Scientific Research in Physics and Applied Sciences Vol.7, Issue.6, pp.01-12.* E-ISSN: 2348-3423

Murat RC (1972): Stratigraphy and Paleogragraphy of the Cretaceous and Lower Tertiary in southern Nigeria. In: African Geology Dessauvagie, T.F.J. and Whiteman, A.J. (eds), *Ibadan Univ. Press, Ibadan*, Nigeria p.251-276.

Morton A.C and Hallsworth C (1994) Identifying provenance-specific features of detrital heavy mineral assemblages in sandstones. SedimentaryGeology90, 241–56.

Mange A and Wright D.T (2007) Heavy Minerals in Use. Developments in Sedimentology 58. Amsterdam: Elsevier Science.

Nichols, G. J. (2009): Sedimentology and Stratigraphy. *John Wiley and Sons, New York*, P. 452

Pettijohn, F. J. (1973). Sand and Sandstones (2nd Ed). Springer- Verlag, 407p

Pettijohn's FJ (1975). Sedimentary Rocks, 3rd ed., *Harper & Raw New York*, p.1- 628.

Pettijohn, F.J., (1984). Sedimentary Rocks. 3rd Edit., *CBS Publication and Distribution Delhi*. P628.

Pettijohn, F.J. (2002): Sedimentary Rock, a review of braided river depositional environment *Earth Science Revision*. 13 pp.1-16.

Sarki Yandoka, B. M., Abubakar, M. B., Hasiah, A. W., Hassana, M. H. A., Adamu, B. U., John, S. J., Abdulkarim, H. A. and Adegoke, A. K. (2014). Facies analysis palaeoenvironmental reconstruction and stratigraphic development of the early cretaceous sediments (lower Bima member) in the Yola sub-basin, northern Benue trough, N.E Nigeria. J. Afr. Earth Sci. 96, 168-179 2014.

Samaila, N. K., Abubakar, M. B., Dike, E. F. C. and Obaje, N. G. (2006) Description of soft sediment deformation structures in the cretaceous Bima Sandstone from the Yola arm, upper Benue trough, and Northeastern Nigeria. Journal of African Earth Sciences 44, 66-74

Shettima, B., Abubakar, M. B., Kuku, A. and Haruna, A. I. (2017). Facies analysis, depositional environments and Paleoclimate of the Cretaceous Bima Formation in the Gongola Sub – Basin, Northern Benue Trough, NE Nigeria, Journal of African Earth Sciences, doi: 10.1016/ j.jafrearsci.2017.10.001

Suttner LJ, Basu A, Mach GH (1981): Climate and the origin of Quartz Arenites, *Journal Set. Petrology* V. 51, P. 1235 – 1246.

Swett K, Klein G, De V, Smith DE (1971): A Cambrian Tidal Sandbodyand eriboll sandstone of Northwest Scotland, 'An Ancient - Recent Analog. *Journal of Geol.* V.79, p.400-415.

Tucker, M. E. (1981): Sedimentary Petrology: An introduction, *Geoscience Texts v.3, Lackwell Scientific Publications, Oxford*, p.10-75.

Tucker, M E. (Ed.) (2001) sedimentary Petrology, an introduction to the origin of Sedimentary rocks. Blackwell Scientific Publication, Oxford, 394 pp

Young SW (1976): Petrographic Textures of Detrital Polycrystalline Quartz as an Aid to Interpreting Crystalline Source Rocks; *Journal Sed. Petrology* V.46, P.395-603.