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Research paper

Provenance Study of A Section of The Lokoja Sandstone, Southern Bida Basin, North-Central Nigeria

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Abstract

This study investigates the provenance and depositional environment of the Lokoja Sandstone in the Southern Bida Basin, North-Central Nigeria. The purpose is to determine the compositional maturity, textural characteristics, and source terrain of the sandstone using integrated granulometric and petrographic analyses. Four stratigraphic sections were logged along the Lokoja–Abuja expressway, with representative sandstone samples collected and analyzed. Grain size distribution was assessed through dry sieve analysis, and statistical parameters—mean size, sorting, skewness, and kurtosis were calculated. Thin-section petrography was conducted to evaluate mineral composition and sediment maturity.
The results show that the sandstone is predominantly coarse- to medium-grained, poorly sorted, and positively skewed, with kurtosis values ranging from mesokurtic to leptokurtic—characteristics typical of high-energy fluvial environments. Petrographic analysis reveals a dominance of monocrystalline quartz (87%), with moderate feldspar (12%) and trace muscovite (1%), classifying the sandstone as subarkosic. The presence of subangular grains and feldspar suggests limited chemical weathering.
In conclusion, the Lokoja Sandstone was deposited in a braided river system under variable flow conditions and sourced from the rounding Precambrian Basement Complex. These findings contribute to a better understanding of sediment dispersal and tectono-sedimentary evolution of the Southern Bida Basin.

Keywords: *Fluvial Deposition; Granulometric Analysis; Petrography; Subarkosic Sandstone; Sediment Provenance.*

1. Introduction

Siliciclastic sedimentary materials originate from complex processes involving transportation from their source areas to depositional basins. During burial and diagenesis, mineralogical changes may occur due to chemical interactions within pore fluids or other geological mechanisms. Consequently, provenance studies rely on a multidisciplinary approach, incorporating petrography, sedimentology, and geochronology to unravel the origin and evolution of sediments [1]. Each sediment layer comprises millions of detrital grains, each bearing a geological record. When these grains are systematically examined and interpreted, they provide a solid foundation for reconstructing sediment provenance [2].
Through detailed analysis of grain size distribution and petrographic characteristics, geologists can infer critical information about depositional settings, sediment maturity, and source rock types [3]. These parameters are essential not only for interpreting paleoenvironments but also for assessing the potential of sedimentary basins as reservoirs for natural resources such as hydrocarbons and groundwater [4 - 6]. The Lokoja Sandstone, located in the Southern Bida Basin of North-Central Nigeria (Fig. 1), presents an excellent opportunity for sedimentological investigation due to its extensive exposures, coarse clastic nature, and complex facies associations. Although previous studies have addressed the general stratigraphy and structural configuration of the basin [6 - 9], detailed quantitative data on the Lokoja Sandstone, particularly concerning grain size metrics and mineralogical composition, remain limited.
This study addresses that gap by systematically collecting samples from multiple outcrops along the Lokoja–Abuja expressway. We analyzed samples granulometrically to determine statistical textural parameters, and petrographic evaluation to identify mineral constituents and assess textural maturity. Combined, these techniques provide deeper insights into the depositional dynamics and origin of the Lokoja Sandstone, revealing patterns of sediment transport and contributing to the understanding of the tectonic and sedimentary development of the Southern Bida Basin.

1.1. Location of the study area

The study area is situated along the Lokoja–Abuja expressway in Kogi State, North-Central Nigeria (Fig. 2). The region is easily accessible by both motorable roads and footpaths, facilitating fieldwork and sampling activities. It lies within the tropical rainforest belt, characterized by dense, evergreen vegetation typical of the humid climate zone. Geographically, the area falls between latitudes 7°48'N and 7°57'N, and longitudes 6°42'E and 6°45'E, as mapped on Lokoja Sheet 247 NW

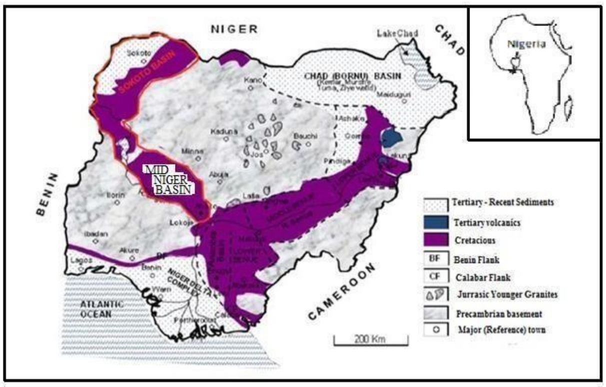


Fig. 1: Geological Map of Nigeria Showing Locations of Bida Basin [10].

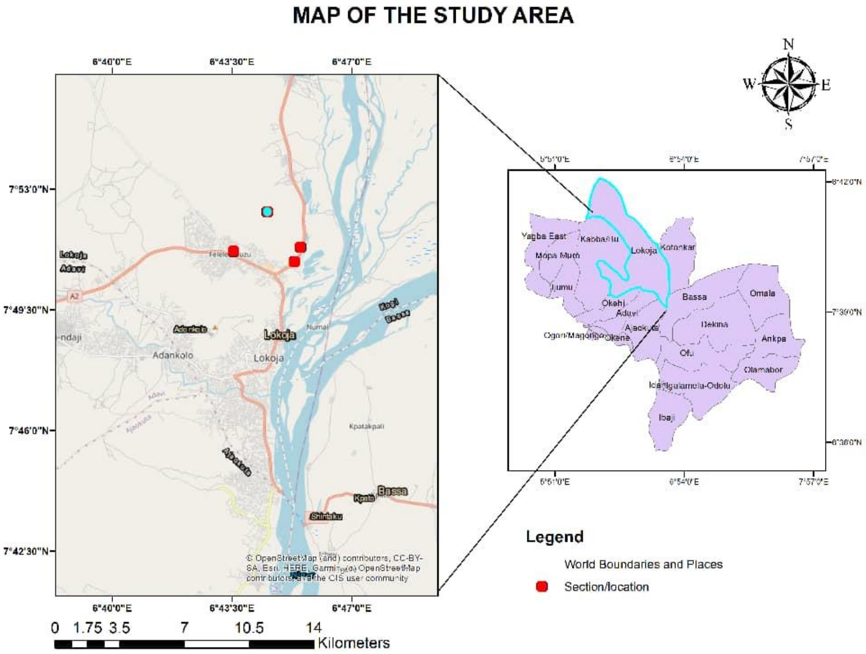


Fig. 2: Map of the Study Area.

1.2 Geology of the Bida basin

The Bida Basin is a narrow, intracratonic sedimentary basin that stretches across central Nigeria in a northwest–southeast orientation. It lies roughly perpendicular to the Benue Trough and is bounded in the west by a narrow strip of exposed crystalline basement, which separates it from the Sokoto Basin. To the east, it adjoins the Anambra Basin. The basin formed within a gently subsiding trough, likely associated with tectonic activities during the Santonian period that also significantly affected the Benue Trough and southeastern Nigeria [8].

The sedimentary fill of the basin dates to the late Cretaceous and is generally referred to as the Nupe Sandstone, which is further subdivided into four main lithostratigraphic units: the Bida Sandstone, Sakpe Ironstone, Enagi Siltstone, and Batati Ironstone [10]. These formations exhibit lateral facies variation across the basin. In the Lokoja region, the sequence is locally known as the Lokoja Sandstone, and the stratigraphy here differs somewhat from that of the Bida area. In the southern part of the basin, the key lithostratigraphic units include the Lokoja, Patti, and Agbaja Formations (Fig. 3) [11]

The Lokoja Formation is composed predominantly of conglomerates, coarse- to fine-grained sandstones, siltstones, and claystones. Its sediments include subangular to subrounded quartz grains, pebbles, granules, and cobbles embedded in a clayey matrix [12]. Both matrix-supported and grain-supported textures are observed, particularly at the base of sedimentary cycles. The sandstones are commonly cross-stratified and poorly sorted, consisting mainly of quartz and feldspar [13], and are considered texturally and mineralogically immature [13], [14].

The Patti Formation crops out between Koton-Karfi and Abaji and is characterized by fine- to medium-grained grey and white sandstones, interbedded with carbonaceous siltstones, shales, and oolitic ironstones [14], [15]. Trace fossils and plant remains are frequently observed, and the abundance of argillaceous sediments suggests deposition under low-energy conditions [16]

The Agbaja Formation, laterally equivalent to the Batati Formation in the northern basin, typically forms a capping unit over the Southern Bida Basin. It comprises sandstones and claystones interlayered with oolitic, massive, and concretionary ironstone beds, reflecting varied depositional processes within the uppermost units of the sedimentary succession.

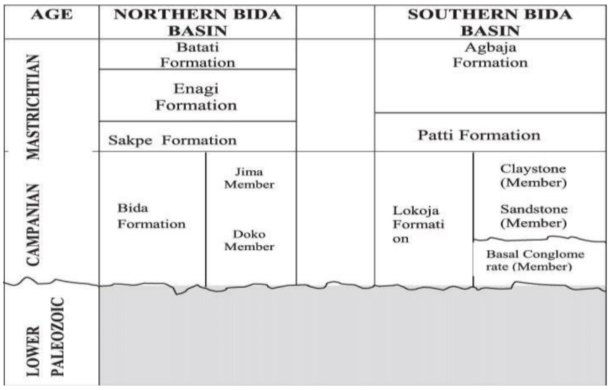


Fig. 3: Stratigraphic Succession Table of Formation in the Bida Basin [10].

2. Materials and methods

We conducted a four-day geological fieldwork in July 2024. The fieldwork focused on mapping lithostratigraphic sections and describing exposed sandstone outcrops along the Lokoja–Abuja expressway. Observations included essential sedimentological features such as grain size, texture, clast orientation, and primary sedimentary structures. Stratigraphic logging was performed bed-by-bed, and representative samples were collected systematically from four distinct stratigraphic sections within the Lokoja Formation.

Field investigations were conducted using standard geological tools, including a geological hammer, compass, clinometer, GPS device, measuring tapes, sample bags, field notebooks, markers, and both base and field maps for navigation and recording.

In the laboratory, grain size distribution was evaluated through dry sieve analysis, conducted at the Engineering Geology Laboratory, Department of Applied Geology, Federal University of Technology, Akure. Each sandstone sample was oven-dried at 105°C for approximately eight hours to remove residual moisture. About 200 grams of each dried sample was weighed and placed in a series of sieves with decreasing mesh sizes, ranging from 2.00 mm to 0.063 mm. These sieves were arranged vertically and mounted on a mechanical shaker, which was operated for 10 minutes.

The sediment retained on each sieve was collected, weighed, and the data recorded. Statistical grain size parameters, including mean size (Mz), sorting (σ1), skewness (Sk1), and kurtosis (Kg), were computed using the graphical methods based on the obtained weight distributions.

To investigate the mineralogical composition and textural maturity of the sandstones, thin sections were prepared. Samples were first oven-dried for 24 hours and then impregnated with a low-viscosity epoxy resin (Araldite A and B) while warm to ensure deep resin penetration. Once cured, the hardened samples were sliced into thin slabs (approximately 1–2 mm thick) and mounted on glass slides using adhesive resin. The mounted samples were ground and polished down to a thickness of ~30 microns using progressively finer abrasives.

Petrographic examinations were carried out using a polarizing microscope under both plane-polarized light (PPL) and cross-polarized light (XPL). Minerals were identified based on key optical properties such as relief, extinction angles, birefringence, and twinning. Particular attention was paid to identifying quartz, feldspar varieties (plagioclase and microcline), and accessory minerals such as muscovite. Modal analysis was done visually to estimate the relative abundance of each mineral, which was used to assess compositional maturity and sediment provenance.

3. Results

3.1. Description of the exposed lithologic sections

A total of six sandstone outcrops were studied and categorized into four main sections to streamline the description and interpretation process. Basic location data for these outcrops are presented in Table 1. Section 1 is located at Okumi village, Sections 2 and 3 lie within the Nataco Junction area in Felele, and Section 4 is positioned along the Lokoja–Abuja road corridor.

Table 1: Outcrop and Sample Locations. Section 1 = Okumi; Sections 2 & 3 = Nataco Junction, Felele; Section 4 = Lokoja-Abaji-Road

Location\ Section	Description of outcrop location	Latitude	Longitude	Retrieved Samples
1	Roadside exposure of massive sandstone located at Okumi village along the Lokoja-Abaji-Dawilko road.	N 7^0 51’9”	E 06^0 45’30”	LOK 1-LOK-04.
2	The locality is situated at the NATACO junction. It is situated opposite the NNPC fueling station.	N7^{0}50’54”	E 06^{0}45’20”	LOK-O5, LOK-06
3	Locality is Deeper life bible church, Felele district, along Lokoja-Abuja road.	N7^0 51’12”	E 06^{0}43’33”	LOK-07,LOK-08
4	Roadside exposure of sandstone along the Lokoja-Abaji road, beside UBA fast foods	N7^0 50’51”	E 06^{0}45’21”	LOK-09, LOK-10

The table above outlines the geographic coordinates and sample codes for each outcrop. At Okumi (Section 1), the outcrop is exposed by the roadside and reveals a well-developed fining-upward sequence. This sequence (Fig. 4) begins with a clast-supported conglomerate (Fig. 5a), overlain by conglomeratic sandstone featuring cross-bedding (Fig. 5b), and capped by a massive, medium- to coarse-grained sandstone beneath a lateritic overburden.

In the Nataco Junction area, the lithological expression is somewhat thinner. The outcrop here consists of coarse to medium-grained sandstone, with minor lateral changes and signs of ferruginization, pointing to localized oxidation and diagenetic alteration.

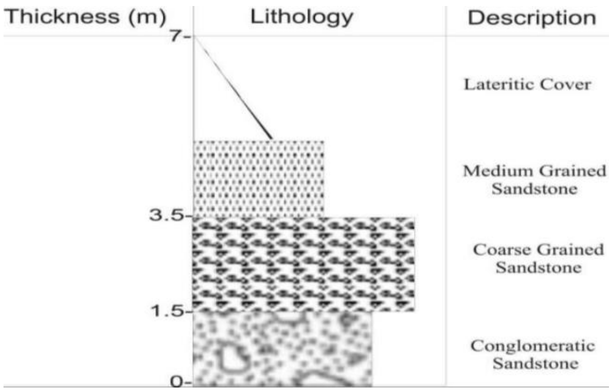


Fig. 4: Lithostratigraphic Section of the Lokoja Formation at Okumi village.

Fig. 5: Photograph Showing (A) a Conglomeratic Bed Present at Okumi, (B) Cross Stratification of Beds at Okumi.

At Felele,the outcrop(fig 6b) is characterized by a massive, reddish-brown, medium- to coarse-grained sandstone unit. The surface displays clear signs of ferruginization and oxidation features, such as mottling and nodules, which further support deposition in a fluvial setting under oxidizing conditions. The abundance of subrounded quartz grains, along with the absence of internal sedimentary structures, suggests rapid deposition events with little time for reworking.

Overall, these sections collectively exhibit sedimentary characteristics consistent with deposition in a high-energy, braided fluvial system. This interpretation is supported by features such as conglomeratic beds, cross-stratification, rapid facies transitions, and oxidized surfaces, all of which indicate episodic sediment influx, shifting channels, and exposure to weathering under continental conditions.

Fig. 6: (A) Photograph Showing the Entire Section of the Outcrop at Nataco Junction. (B) Photograph Showing the Entire Section of the Outcrop After Felele Junction, Lokoja.

3.2. Granulometric analysis

3.2.1. Univariate parameters

Grain size analysis serves as both a qualitative and quantitative tool for interpreting sedimentary environments, especially in dynamic systems such as river channels and coastal zones. It plays a vital role in understanding sediment transport dynamics and depositional processes [17]. In this study, grain size characteristics were interpreted using the classification schemes developed by Folk and Ward [18], with calculated parameters presented in Table 2.

Table 2: Granulometric Parameters of the Analyzed Samples, Along with Their Corresponding Interpretations

Sample Code	Mean (M_Z)	Standard Deviation ($\sigma 1$)	Skewness (sk_1)	Kurtosis (k_G)	Interpretation
LOK1	0.378	1.122	0.231	1.156	Coarse, poorly sorted, fine-skewed
LOK2	0.884	1.282	0.100	1.010	Coarse, poorly sorted, near symmetrical
LOK3	0.504	1.334	-0.049	1.677	Coarse, poorly sorted, leptokurtic
LOK4	0.657	1.190	0.099	1.084	Coarse, poorly sorted, mesokurtic

LOK6	0.364	1.170	0.303	1.218	Medium, poorly sorted, leptokurtic
LOK5	1.489	1.555	-0.058	0.808	Medium, poorly sorted, platykurtic
LOK7	0.818	1.291	0.225	1.075	Medium, poorly sorted, mesokurtic
LOK8	0.178	1.152	0.142	1.101	Fine, poorly sorted, mesokurtic
LOK9	0.105	1.138	0.250	1.314	Fine, poorly sorted, leptokurtic
LOK10	0.674	1.447	-0.008	1.051	Coarse, poorly sorted, mesokurtic

Mean Grain Size (Mz).

The geometric mean represents the average diameter of sediment particles and is largely influenced by the energy conditions during transport and deposition [16]. The mean grain size values for the studied samples range from 0.105Φ to 1.489Φ, classifying them as fine- to coarse-grained sandstones. Most of the samples fall into the coarse-grained category (Φ < 1.00), which is typical of high-energy depositional environments, such as braided river systems or proximal alluvial channels. A few samples, such as LOK8 and LOK9, exhibit finer textures, suggesting brief intervals of lower-energy conditions, possibly associated with floodplain or distal bar settings.

Sorting (Standard Deviation, σ1)

Sorting measures the uniformity of grain sizes within a sample and is a key indicator of textural maturity. It reflects both the energy variability and transportation history of the sediment [19]. All samples analyzed in this study are poorly sorted, with sorting values ranging between 1.122 and 1.555Φ. Such poor sorting implies a wide range of particle sizes, typically resulting from fluctuating energy conditions during sediment transport. These features are commonly observed in fluvial environments, where energy levels are inconsistent and sediment input is episodic.

Skewness (Sk1)

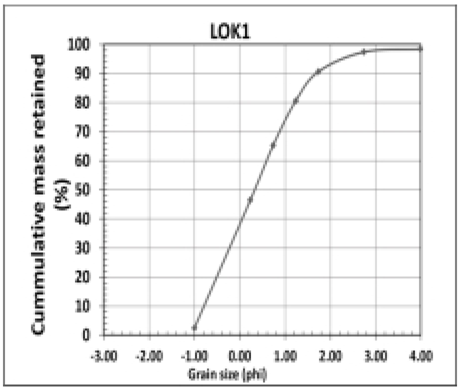
Skewness quantifies the symmetry of the grain size distribution and indicates whether fine or coarse particles dominate the sediment. The skewness values range from -0.008 to 0.303, with most samples displaying a slight positive skew. This suggests a predominance of finer grains, which may have settled during decreasing flow velocities. A few samples exhibit near-symmetrical or slightly negative skewness values, implying a more balanced distribution or relatively coarser sediment input, possibly linked to more consistent or higher-energy depositional conditions.

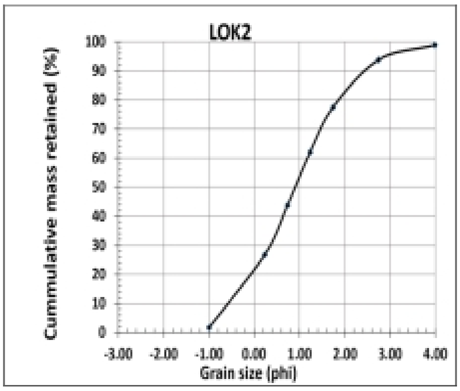
Kurtosis (Kg)

Kurtosis assesses the "peakedness" or concentration of grain sizes around the mean. The kurtosis values obtained range from 0.808 to 1.677, classifying the samples as mesokurtic to leptokurtic. Mesokurtic distributions reflect normal spreading of grain sizes, whereas leptokurtic patterns indicate higher concentration around the mean size [21]. These results suggest a moderate to high level of textural consistency in the central portion of the grain size distribution, which aligns with fluvial depositional systems that experience periodic sediment reworking.

Collectively, these univariate grain size parameters support the interpretation that the Lokoja Sandstone was deposited in a high-energy fluvial environment, likely characterized by variable flow conditions and episodic sediment supply. The cumulative weight percent curves for grain size distribution of the retrieved samples across different stratigraphic sections are shown in Figures 7a-j below.

a) Cumulative weight percent curve for Sample LOK1, showing a steep gradient and coarse-grain size distribution. This pattern is characteristic of rapid deposition under high-energy fluvial conditions.
b) Cumulative weight percent curve for Sample LOK2, indicating moderately coarse grains with a relatively sharp slope. The curve supports deposition in a strong but slightly waning energy regime.
c) Cumulative weight percent curve for Sample LOK3, with a distinct inflection and leptokurtic distribution. This suggests selective deposition under fluctuating high-energy conditions within a proximal braided stream.
d) Cumulative curve for Sample LOK4, showing moderate coarseness and a mesokurtic pattern. This reflects sediment deposition under moderately variable fluvial energy conditions.
e) Cumulative weight percent curve for Sample LOK5, showing a broader, more gradual slope with platykurtic distribution. This is indicative of lower sedimentary energy and greater textural diversity.
f) Cumulative curve for Sample LOK6, illustrating a leptokurtic distribution with a moderately steep slope. It reflects grain size concentration around the mean, consistent with steady fluvial currents.
g) Cumulative weight percent curve for Sample LOK7, indicating medium to coarse grains and a uniform slope. This is consistent with moderately high-energy fluvial deposition.
h) Cumulative curve for Sample LOK8, representing finer grain sizes and a gentle slope. The textural trend suggests deposition in a relatively low-energy environment such as a floodplain or overbank setting.





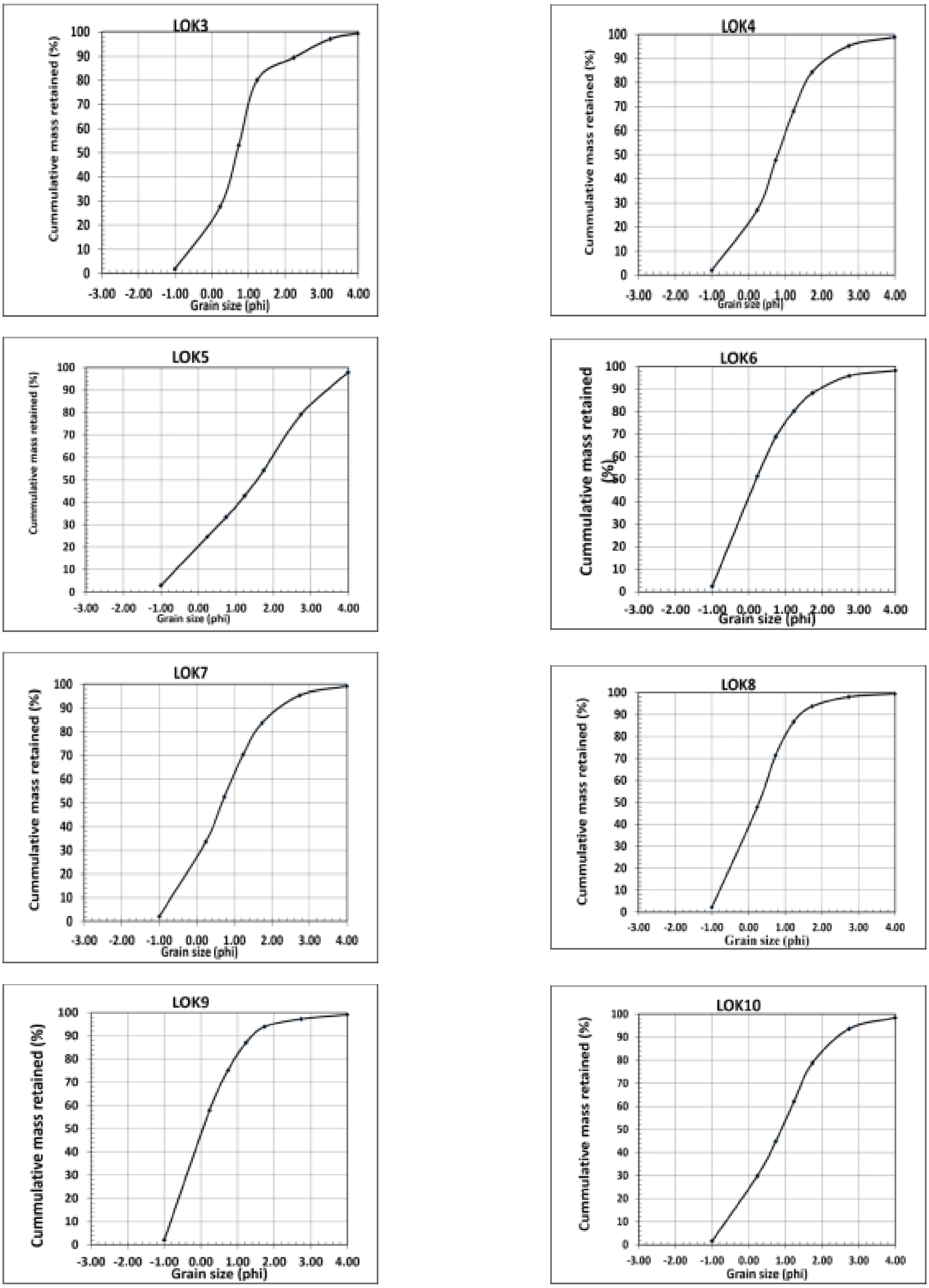


Fig. 7: Cumulative of the Individual Weight Percent of the Sediments (This Study).

3.2.2. Bivariate parameters

Bivariate analysis of grain size parameters is a useful method for distinguishing between closely related depositional environments. It enhances the interpretive power of granulometric data by revealing trends not evident in univariate statistics alone [17], [19], [21]. In this study, plots of mean grain size versus standard deviation (Fig. 8) were utilized to differentiate between fluvial and beach sedimentary settings.

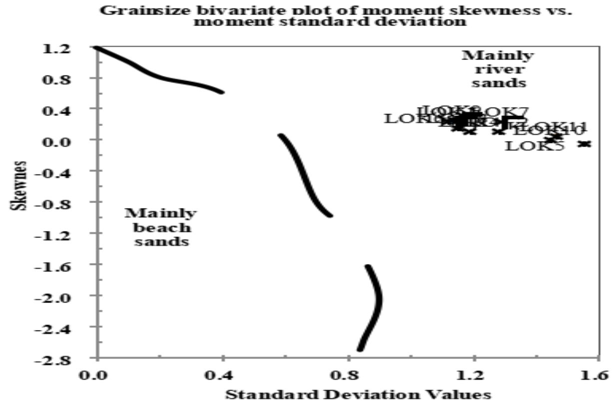


Fig. 8: Bivariate Plots of Mean Size Versus Sorting.

The graphical plots (Fig. 8) clearly position most of the samples within the river sand domain, indicating that the sediments were predominantly deposited by fluvial processes. The data points reflect a consistent association with poorly sorted, medium- to coarse-grained sediments—features characteristic of braided river systems, where variable flow conditions produce a wide range of grain sizes. This pattern confirms the univariate interpretations and strengthens the conclusion that the Lokoja Sandstone was formed under the influence of high-energy, continental river environments.

These bivariate relationships further support the classification of the Lokoja Sandstone as a fluvial deposit, emphasizing the role of episodic discharge and sediment influx in shaping its granulometric signature.

3.3. Petrographic analysis

Petrographic examination was carried out to determine the mineral composition, textural features, and provenance of the Sandstone samples from the Lokoja Formation. A total of ten thin sections were studied using a polarizing microscope to identify key mineral constituents, assess the maturity of the grains, and interpret the depositional history.

The sandstones are largely composed of quartz, with minor contributions from feldspar (both microcline and plagioclase) and muscovite. Quartz appears as the predominant framework grain across all samples, typically occurring as monocrystalline crystals. These grains are mostly subhedral, displaying features such as wavy extinction, low relief, and low birefringence, which are consistent with stable quartz under polarized light (fig. 9).

Microcline feldspar is the most common feldspar present, recognized by its characteristic cross-hatch twinning and subhedral form. Some signs of alteration are observed, especially in microcline grains. Plagioclase feldspar is present in smaller amounts. Muscovite, though only seen in trace amounts, is easily identified by its colorless flakes, moderate relief, and high birefringence, along with straight extinction under polarized light.

The quantitative composition of each mineral type in the individual samples is presented in Table 3, while Table 4 summarizes the average modal composition. On average, the framework grains consist of approximately 87% quartz, 11.2% feldspar, and 1% muscovite and lithic fragments. This mineral assemblage provides insight into the textural and compositional maturity of the sandstone, as well as its likely source rock [6].

Table 3: Percentage (%) Mineral Composition of the Sandstone Samples from the Study Area

Sample no.	Quartz		Feldspar	Muscovite
		Microcline	Plagioclase	
LOK 1	79.4	13.2	7	
LOK2	85.7	12	2	
LOK 3	85	10	3.9	
LOK 4	75	21	3.8	
LOK 5	93.	2.7	4	
LOK 6	76.	15	7.7	
LOK 7	93	2	2	2
LOK 8	80	20	-	
LOK 9	79	10.3	10.3	
LOK 10	100		-	

Table 4: Average Framework Composition of the Lokoja Formation

Minerals	Percentage Abundance
Quartz: Monocrystalline	87.%
Feldspar: Microcline & Plagioclase	11.2%
Muscovite and other lithic fragment	1%

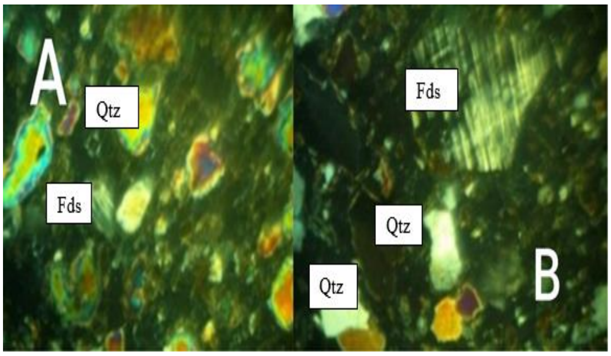


Fig. 9: Photomicrographs of the Detrital Components of the Siliciclastic Sandstone. The two Images Are in Xpl. Abbreviations: Qtz = Quartz, Fds = Feldspar.

3.3.1. Compositional maturity and sandstone classification

The sandstone samples exhibit a high level of both textural and compositional maturity, largely due to the dominance of quartz, which makes up approximately 87% of the framework grains. This high quartz content suggests the sediments have undergone significant weathering and reworking, during which less stable minerals such as feldspars and lithic fragments were largely eliminated [22]. The QFL ternary diagram (fig. 10) of Dickinson [23], which relates sediment provenance to the tectonic environments, was also used in characterising the sediment clasts from the study area. Nevertheless, the presence of about 11% feldspar indicates that the sandstone has not reached the extreme maturity typical of quartz arenites, and instead fits into the subarkose classification.
This moderate feldspar content points to relatively short transport distances or reduced chemical alteration, implying that the sediments originated from nearby granitic rocks. Additionally, the small proportion of other minerals (~1%) supports the conclusion that the sediment was deposited in an environment where persistent sorting and abrasion led to the dominance of durable grains like quartz.

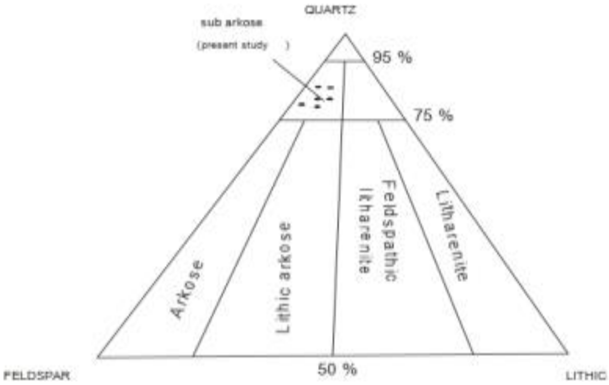


Fig. 10: Classification of Lokoja Sandstone Using the QFL Ternary Diagram (Modified after Dickinson [23]) Q = Quartz, F = Feldspar, L = Lithic.

Framework grain modal percentages for quartz (Q), feldspar (F), and lithic fragments (L) were recalculated to sum to 100%, following the standard Gazzi–Dickinson point-counting method, where each grain is classified by its mineral identity regardless of grain size. Quartz was subdivided into monocrystalline and polycrystalline varieties, while feldspar counts included both plagioclase and microcline. Lithic fragments encompassed all rock fragments excluding chert. These recalculated values were then plotted on a QFL ternary diagram using the provenance fields defined by Dickinson [23], which relate modal composition to tectonic setting (e.g., continental block, magmatic arc, recycled orogen). Plotting was performed manually using a ternary template, ensuring that the plotted position for each sample reflected its normalized QFL percentages. This approach allows direct comparison with published sandstone provenance datasets from other basins.

3.4. Provenance deduction

The angular to subrounded grain textures, coupled with the moderate feldspar content (~11%) and trace muscovite, indicate derivation from a nearby granitic source terrain. In fluvial sandstone provenance studies, the survival of relatively unstable minerals such as microcline and plagioclase is widely interpreted as evidence for short transport distances and limited chemical alteration [24,25]. These features, along with the subarkosic composition, align closely with findings from other intracratonic basins sourced from Precambrian basement complexes, such as the Parnaíba Basin [26] and parts of the Amazon Basin [27], where granitic uplands provide a steady influx of coarse detritus into braided river systems. The Lokoja Sandstone's compositional and textural maturity pattern thus supports a proximal continental-block provenance, most plausibly from the adjacent Nigerian Shield.

4. Discussion

The combined results from granulometric and petrographic analyses strongly suggest that the Lokoja Sandstone was deposited in a dominantly fluvial setting, with sediments derived from a continental granitic source area. The grain size data show that the sandstones are generally coarse- to medium-grained, poorly sorted, and positively skewed, with kurtosis values ranging from leptokurtic to platykurtic—features characteristic of deposition in high-energy, variable-flow environments such as braided rivers [28].
Petrographic evidence corroborates these interpretations. The sandstones are mainly composed of monocrystalline quartz (87%), with lesser amounts of feldspars (11%) and trace muscovite (1%). This mineralogical composition places the rocks within the subarkose category and reflects moderate compositional maturity.

Altogether, the sedimentological and mineralogical features indicate that the Lokoja Sandstone was deposited in a proximal braided river system, likely adjacent to uplifted crystalline basement terrains, such as those of the Nigerian Shield. This tectonic setting and sediment source are also supported by the sandstone's position within the Continental Block provenance field on the QFL ternary diagram [17].
Modern provenance studies should therefore couple traditional petrography with higher-resolution tools such as detrital zircon U–Pb geochronology, heavy-mineral suites, and whole-rock geochemistry to disentangle multi-stage sediment routing and to resolve intrabasin provenance heterogeneity that modal analysis alone can miss. For example, detrital zircon studies in cratonic basins, e.g., the Michigan Basin and several South American intracratonic basins, reveal temporal changes in sediment sources and intrabasin variability that are invisible in simple QFL fields [29,30]. These advances emphasise that provenance interpretations of fluvial successions should integrate multiple proxies.
Braided and ephemeral fluvial systems- the depositional analogue invoked for the Lokoja Sandstone produced characteristic granulometric and modal signatures, which are generally coarser mean grain sizes, poor sorting, frequent positive skewness, and rapid lateral/vertical facies shifts. Recent process-based studies of dryland braided rivers and source-to-sink work show how autogenic channel dynamics and episodic sediment pulses can strongly influence grain-size distributions and local mineral preservation, complicating direct one-to-one mapping between grain types and source lithologies [31], [32]. Thus, granulometric patterns (mean, sorting, skewness, kurtosis) are powerful for reconstructing depositional energy but must be tied to petrography and provenance tracers to robustly infer source area lithology and distance.
Comparative studies of intracratonic basins worldwide provide useful analogues for the Lokoja Sandstone. For example, the Parnaíba Basin in Brazil and other South American intracratonic basins show dominantly continental-block signatures in QFL space but record mixing and temporal shifts revealed by detrital zircon and geochemical data [33]. Similarly, studies of the Sherwood Sandstone Group in NW Europe indicate that long-distance recycling and climatic weathering regimes can greatly alter modal compositions while preserving zircon age spectra that reflect source provinces [34]. These basin studies collectively demonstrate that a continental-block QFL signal (as observed in Lokoja's subarkosic composition) often reflects proximity to crystalline basement sources, but that the full story requires multi-proxy confirmation. Applying these multi-proxy approaches to the Lokoja Sandstone would strengthen the inference of a proximal Precambrian basement source and help quantify any contributions from recycled or more distal sources.

5. Conclusion

This study employed granulometric and petrographic methods to assess the provenance and depositional environment of the Lokoja Sandstone in the Southern Bida Basin, North-Central Nigeria. The findings contribute valuable insights into the sedimentary history and source characteristics of this Cretaceous clastic unit, enhancing the geological understanding of the basin's evolution.
Grain size analysis revealed that the sandstone is primarily coarse- to medium-grained, poorly sorted, and positively skewed, with varying kurtosis values. These sedimentary features suggest deposition under high-energy fluvial conditions, likely within a braided river system.

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Conflict of interest

The authors agree that this research was conducted in the absence of any self-benefits, commercial or financial conflicts, and declare the absence of conflicting interests

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