FUDMA Journal of Sciences (FJS)
ISSN online: 2616-1370
ISSN print: 2645 - 2944
Vol. 10 No. 18, September, 2026, pp 331 – 337
DOI: https://doi.org/10.33003/fjs-2026-1018-5939

Lithofacies Architecture and Depositional Environment of the Lamja Formation, Yola Arm, Upper Benue Trough, Nigeria

***Njaka James Earnest and Valdon Yunis Boga**

Department of Geology, Modibbo Adama University, Yola, Adamawa State, Nigeria.

*Corresponding authors' email: earnest.n.james@gmail.com

ABSTRACT

The Lamja Formation records the terminal marine-influenced phase of the Cretaceous succession in the Yola Arm of the Upper Benue Trough, but its outcrop-scale facies architecture remains incompletely constrained. Four sections at Gwalura Village (LS1), Lamza Sama 1 (LS2), Lamza Sama 2 (LS3) and Lokoro (LS4) were measured and described using lithology, bed thickness, sedimentary structures, fossils and vertical contacts. The exposed measured intervals range from approximately 5.2 to 20.26 m. Gwalura is the thickest and most heterogeneous section, Lamza Sama 1 contains mudrock and sandstone beneath recent alluvium, Lamza Sama 2 records repeated mudrock-sandstone and marine-influenced intervals, and Lokoro is comparatively sand-rich. Five lithofacies groups were recognised: sandstone, shale, shale-mudstone intercalation, limestone and coal. Planar-bedded and planar-laminated fine sandstone records tractional deposition in relatively higher-energy settings, whereas fissile shale and intercalated mudrock indicate suspension settling in low-energy prodelta to offshore-transition environments. Thin fossiliferous limestone marks episodes of reduced siliciclastic supply and marine influence, while coal represents peat accumulation in waterlogged delta-plain swamps. Repeated mudrock-to-sandstone stacking records progradation, whereas renewed mudrock and limestone deposition records landward shoreline movement or marine flooding. The four investigated sections therefore document a shallow-marine to paralic deltaic system with recurring shifts among prodelta, delta-front, marine-influenced and delta-plain conditions. These observations are compatible with transgressive-regressive change, but formal sequence boundaries and maximum flooding surfaces require lateral correlation, independent age control and supporting geochemical or palynological evidence.

Received: 11 Sep. 2026
Accepted: 15 Sep. 2026
Published: 29 Sep. 2026

Keywords: Lamja Formation; lithofacies; Facies Architecture; Yola Arm; Upper Benue Trough

INTRODUCTION

The Upper Benue Trough preserves a Cretaceous sedimentary record produced by continental rifting, marine incursions, shoreline migration and renewed continental sediment supply. In the Yola Arm, the succession begins with continental Bima deposits and passes upward through transitional and marine units before terminating in the Lamja Formation. Recent regional syntheses emphasise the interaction of tectonic accommodation, sediment routing and episodic marine connection in controlling this architecture (Usman et al., 2021; Adamu et al., 2024; Didi et al., 2025). Comparable multi-parameter investigations show that Cretaceous basin reconstruction is strengthened when field relationships are tested against geochemical, palynological and subsurface evidence (Abubakar et al., 2021; Aigbadon et al., 2022; Oretade et al., 2024; Omietimi et al., 2025).

Facies studies in the Yola Arm have focused mainly on the Bima Formation, where vertical facies successions document changing fluvial, estuarine and shallow-marine processes (Finthan & Mamman, 2020; Finthan et al., 2023). A recent FUDMA Journal of Sciences study of the Bima Sandstone at Gurin further demonstrates the value of field-based lithofacies and depositional-environment analysis in the Yola Sub-Basin (Margimari et al., 2026). The broader northeastern Nigerian region is also experiencing rapid present-day environmental change; a Landsat- and NDVI-based study documented decadal vegetation change across Southern Taraba (Tijwun, 2025). That modern land-surface study is not used as evidence for the Cretaceous interpretation here, but it provides useful regional context for distinguishing present-day environmental processes from the ancient depositional record. The younger Lamja Formation is less fully documented even though its alternation of sandstone, mudrock, limestone and coal provides a direct record of the transition between marine-influenced and terrestrial environments. A multi-section comparison is needed because individual outcrops may record only a small part of a shoreline cycle. Studies from other Nigerian Cretaceous basins likewise use vertical facies associations to discriminate fluvial, deltaic, estuarine and shallow-marine successions (Alege et al., 2020, 2023, 2024; Boboye et al., 2021; Adamolekun et al., 2022).

The Benue Trough is a major northeast-southwest rift-related basin in Nigeria. Its Upper Benue segment includes the Gongola and Yola sub-basins. In the Yola Arm, Cretaceous strata unconformably overlie Precambrian basement and comprise the Bima, Yolde, Dukul, Jessu, Sekuliye, Numanha and Lamja formations. Regional palynostratigraphic and structural evidence links parts of this succession to changing connections between the Gulf of Guinea and the Tethyan realm (Usman et al., 2021; Adamu et al., 2024). The Lamja Formation conformably overlies the Numanha Formation and contains carbonaceous sandstone, siltstone, shale, limestone and thin coal seams. The upper contact was not investigated in the selected outcrops, so no overlying-unit relationship is inferred here. The formation is broadly Upper Cretaceous, but the sections investigated here were not independently dated; environmental interpretation is therefore based on observable facies relationships rather than a new chronostratigraphic assignment. Recent coal, sandstone and carbonate studies across the Benue Trough further document recurring terrestrial, marginal-marine and shallow-marine conditions (Akinyemi et al., 2020; Mangs et al., 2022; Aigbadon et al., 2024; Adamu et al., 2025; Ayinla et al., 2025).

This study characterises lithofacies architecture in four Lamja Formation sections, interprets the associated depositional processes and evaluates the degree to which vertical stacking supports a deltaic transgressive-regressive model. The selected sections are suitable for comparison because they expose contrasting mudrock-rich, sandstone-rich, carbonate-bearing and coal-bearing intervals within the mapped Lamja outcrop area. The study does not attempt a formation-wide correlation or a formal sequence-stratigraphic subdivision.

MATERIALS AND METHODS

Field Investigation

Reconnaissance and controlled traverses were completed across exposed Lamja Formation outcrops. Four sections were logged at bed scale, meaning that each distinguishable bed or bedset was described separately. For each exposure, lithology, grain size, colour, bed thickness, sedimentary structures, fossil content, stratigraphic contacts and position were recorded. A compass clinometer was used for structural observations, a handheld Global Positioning System receiver for location, and a measuring tape for bed thickness. The vertical depth values shown in Figure 2 were retained from the field logs. The thicknesses reported in the text are measured exposed section intervals; because the supplied field logs do not document bed-by-bed dip corrections, no post hoc structural correction was applied and apparent measured thickness is retained.

Representative lithologies were photographed, and field specimens were collected for lithologic reference. No laboratory analytical results are reported in this manuscript, so laboratory analysis is not used as an interpretive dataset. Photographs were selected to illustrate diagnostic lithologies and sedimentary structures present in the logged sections rather than to provide a statistical sample of the formation. The four localities are listed in Table 1 and shown in Figure 1.

Table 1: Locations of the Measured Lamja Formation Sections

Locality	Code	Latitude	Longitude	Elevation (m)
Gwalura Village	LS1	09°49'41.70"N	11°51'08.21"E	363
Lamza Sama 1	LS2	09°50'30.40"N	11°52'45.50"E	400
Lamza Sama 2	LS3	09°49'10.50"N	11°51'07.30"E	370
Lokoro	LS4	09°51'13.50"N	11°53'05.70"E	370

Note: Coordinates are reported in degrees-minutes-seconds (DMS) using the WGS 84 datum. LS1-LS4 are the section codes used throughout the manuscript; elevation is in metres above sea level.

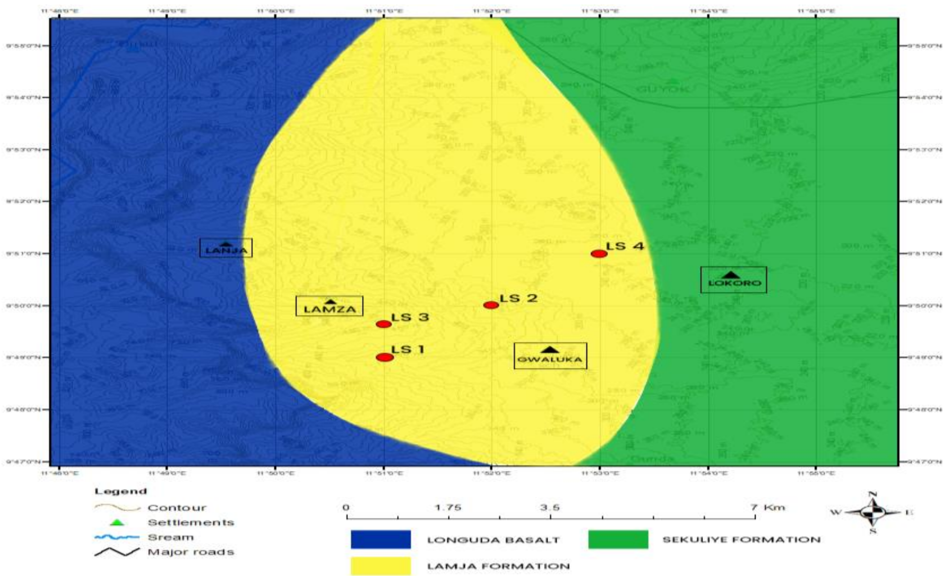

Figure 1: Study-area map showing the four measured Lamja Formation sections, coordinate graticules, mapped units, geographical features, north arrow and scale information

Facies Analysis

Facies were defined from recurring combinations of lithology, grain size, bedding, lamination, fissility, fossils, carbonaceous material, bed geometry and vertical association. Five group-level lithofacies codes were used to make the classification reproducible: S for sandstone, Sh for shale, Sm for shale-mudstone intercalation, L for limestone and C for coal. A group was assigned only where the lithology and its diagnostic characteristics recurred in the measured sections. The group-level scheme reflects the discontinuous nature of the exposures and is not intended to imply a higher-resolution facies subdivision than the field evidence supports. Process interpretations follow current sedimentological criteria for traction transport, suspension settling, shoreline progradation, marine flooding and peat accumulation (Nichols, 2023; Levell, 2026). Environmental assignments were made from facies associations rather than from a single structure. Sequence-stratigraphic terms were used cautiously because the outcrops are discontinuous and lack independent correlation surfaces (Catuneanu, 2022). This association-based procedure is consistent with Nigerian sandstone studies that combine facies analysis, petrography, mineralogy and geochemistry rather than assigning environments from isolated sedimentary structures (Adepoju et al., 2020, 2021, 2024; Ojo et al., 2021; Margimari et al., 2026).

RESULTS AND DISCUSSION

Measured Section Architecture

The four measured intervals are compared in Table 2 and Figure 2. Gwalura Village (LS1) exposes 20.26 m of dark brown to grey shale, shale-mudstone intercalation, fine-grained carbonaceous sandstone, limestone, coal and planar-laminated to planar-bedded sandstone. Lamza Sama 1 (LS2) covers approximately 12.5 m and contains basal fissile shale and interbedded mudrock overlain by fine sandstone, with limestone and coal beneath recent alluvium. Lamza Sama 2 (LS3) covers approximately 9.2 m and contains mudrock, a 2.5 m planar-bedded sandstone, shale-limestone-shale, coal and an upper shale-to-sandstone transition. Lokoro (LS4) covers approximately 5.2 m and is sand-rich, with thick fine-grained sandstone and subordinate shale, limestone and coal. These are exposed measured intervals, not formation thicknesses.

Table 2: Comparative lithofacies architecture and depositional interpretation of the four measured sections.

Section	Measured interval (m)	Dominant architecture	Principal process signal	Environmental implication
Gwalura (LS1)	20.26	Alternating mudrock, sandstone, limestone and coal	Repeated energy and salinity change	Prodelta/delta front with marine and delta-plain intervals
Lamza Sama 1 (LS2)	Approx. 12.5	Basal mudrock passing to sandstone; limestone and coal	Shallowing followed by renewed flooding and emergence	Marine-influenced deltaic succession
Lamza Sama 2 (LS3)	Approx. 9.2	Mudrock-sandstone, shale-limestone-shale, coal and upper sandstone	Two progradational phases separated by marine influence	Prodelta to delta front, marine interval and delta plain
Lokoro (LS4)	Approx. 5.2	Thick sandstone with subordinate shale, limestone and coal	High sand supply interrupted by lower-energy deposition	Sand-rich delta front with prodelta and delta-plain components

Note: LS1-LS4 are defined in Table 1. The measured intervals refer only to the exposed sections shown in Figure 2 and should not be interpreted as the total thickness of the Lamja Formation.

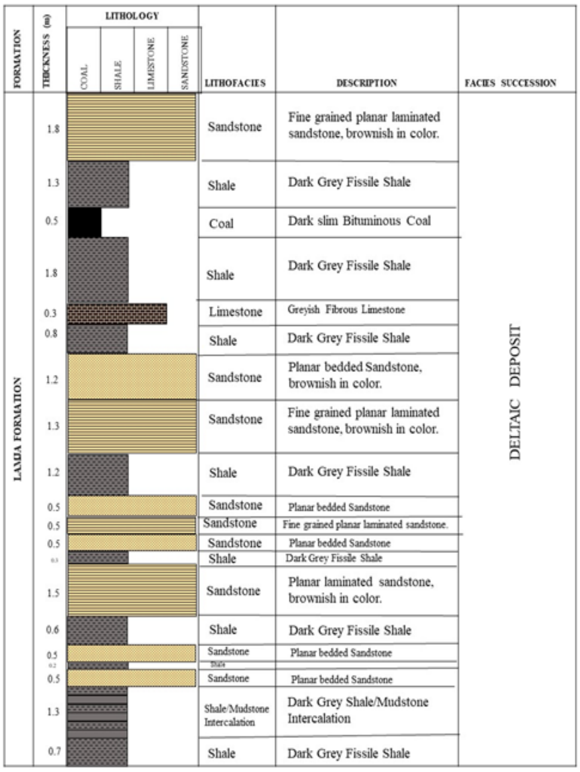

Figure 2a: Gwalura Village (LS1)

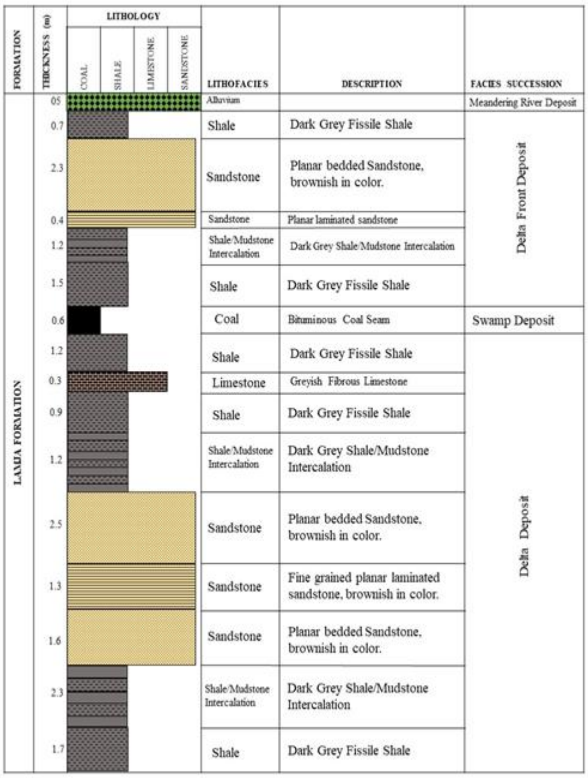

Figure 2b: Lamza Sama 1 (LS2)

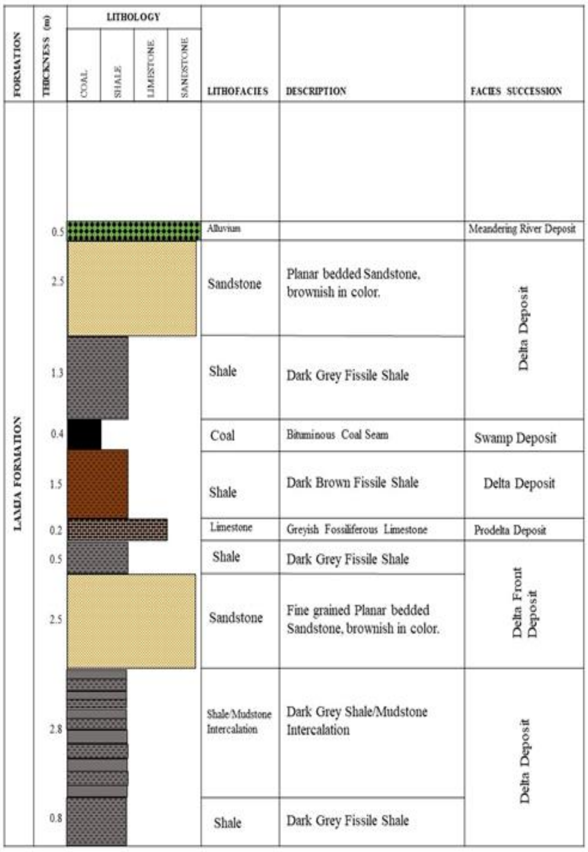

Figure 2c: Lamza Sama 2 (LS3)

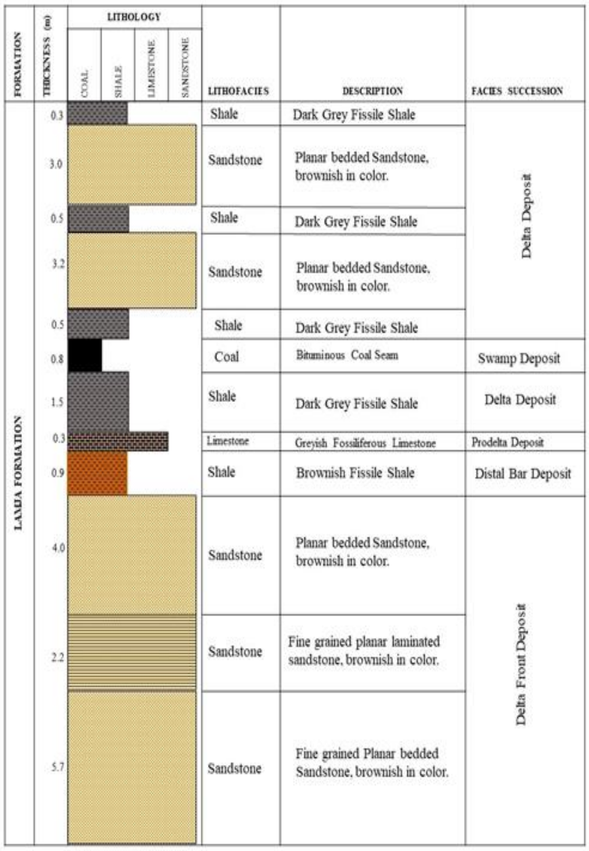

Figure 2d: Lokoro (LS4)

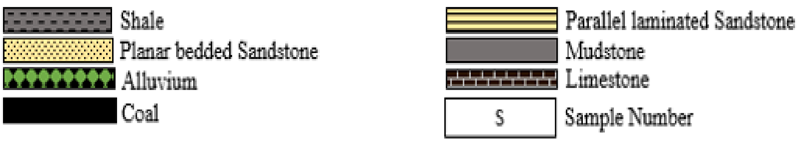

Figure 2: Measured lithostratigraphic sections of the Lamja Formation. Panels (a)-(d) show Gwalura Village, Lamza Sama 1, Lamza Sama 2 and Lokoro, respectively. The lithologic legend and sample-number key are integrated below panel (d). Horizontal panel width is standardized; the original depth ranges are retained for each section

Lithofacies Groups

The five lithofacies groups identified in the four sections are summarized in Table 3. Representative field photographs are shown in Figure 3. The classifications are association-based: dark shale alone does not demonstrate anoxia, and thin limestone alone does not establish a maximum flooding surface.

Table 3: Lithofacies groups, diagnostic characteristics, processes and interpreted depositional environments.

Code	Lithofacies Group	Diagnostic characteristics	Process interpretation	Preferred environment
S	Sandstone	Fine-grained, brownish, planar-bedded to planar-laminated; 0.5-5.7 m	Traction transport under moderate energy; locally coarsening upward	Delta front or mouth-bar association
Sh	Shale	Dark grey to brownish, fissile, locally interbedded with sandstone	Suspension settling and compaction in quiet water	Prodelta to offshore transition
Sm	Shale-mudstone intercalation	Alternating laminated or fissile fine beds	Variable fine-sediment supply and settling	Low-energy prodelta/offshore transition
L	Limestone	Thin grey fibrous to fossiliferous beds	Reduced siliciclastic input and carbonate accumulation	Marine-influenced or flooding interval
C	Coal	Thin discontinuous black seams within mudrock	Peat accumulation under persistent waterlogging	Delta-plain swamp

Note: S, Sh, Sm, L and C are group-level lithofacies codes. LS1-LS4 are section codes, not facies codes. Environmental interpretations are based on associations rather than on isolated lithologies.

Figure 3. Representative Lamja Formation lithofacies observed in the measured sections. Panels are labelled (a)-(f); geological hammers and the visible object in panel (a) provide approximate visual scale where present, but no calibrated scale length was recorded

Discussion

Deltaic Process Framework

The recurring mudrock-sandstone associations provide the clearest evidence for shoreline mobility. Mudrock records fine-grained suspension fallout in relatively quiet water, whereas overlying planar-bedded sandstone records an increase in tractional transport and sediment supply. Where the relationship is coarsening upward, it is consistent with progradation from prodelta or offshore-transition conditions towards the delta front. The interpretation is supported by repetition across several sections rather than by planar bedding alone (Nichols, 2023; Levell, 2026). Recent reservoir-scale studies also demonstrate that facies architecture and diagenesis should be evaluated together when interpreting marginal- to shallow-marine sandstone bodies (Bello et al., 2022, 2023, 2024, 2025).

Coal and limestone constrain the environmental range of the succession. Coal requires terrestrial plant production, waterlogging and limited oxidation, which are compatible with delta-plain swamps. Fossiliferous limestone demonstrates marine influence and reduced clastic dilution. Their occurrence within the same broad succession shows that the depositional system repeatedly shifted between terrestrial and marine-influenced states. Organic-matter studies similarly relate preserved terrestrial debris and coal to waterlogged, low-oxidation settings on or near delta plains (Aggarwal, 2022; Mangs et al., 2022; Ayinla et al., 2025).

Transgressive-Regressive Significance

The sections record repeated landward and basinward shifts in shoreline position. Sandstone progradation may reflect basinward shoreline advance, increased sediment supply or reduced accommodation, whereas renewed mudrock and fossiliferous limestone may reflect lower-energy conditions, marine influence or renewed accommodation. A mudrock-to-sandstone stacking pattern therefore does not uniquely demonstrate a relative sea-level fall. Tectonic subsidence, sediment supply, channel migration, compaction and local accommodation can generate similar vertical architecture. The observed stacking is compatible with transgressive-regressive cycles, but the discontinuous outcrops do not justify naming systems tracts, parasequences or maximum flooding surfaces. Those designations require regional correlation, chronostratigraphic control and evidence that candidate surfaces are laterally persistent (Catuneanu, 2022). Palynofacies-based studies in Nigeria likewise show that shoreline trends are most defensible when lithologic stacking is supported by changes in terrestrial and marine organic-matter input (Valdon & Maigari, 2022; Omietimi et al., 2025).

Regional Context and Limitations

The marine-influenced deltaic interpretation agrees with recent work showing that the Yola Arm experienced alternating continental, transitional and marine conditions during the Cretaceous (Usman et al., 2021; Adamu et al., 2024). It also complements facies studies of older Yola Arm units that demonstrate repeated changes in accommodation and sediment supply (Finthan & Mamman, 2020; Finthan et al., 2023). Bima-related studies generally emphasise continental to transitional facies, whereas the four Lamja sections examined here include recurring mudrock-sandstone associations together with fossiliferous limestone and coal. The comparison is process-based and does not imply direct lateral correlation or age equivalence. The present sections extend that process-based framework to the younger Lamja Formation.

Three limitations define the strength of the conclusions. First, exposure is discontinuous, so direct lateral correlation is not possible. Second, the study did not obtain absolute ages or formal palynostratigraphic zonation. Third, no redox-sensitive or carbonate geochemistry was available. Consequently, environmental interpretations are robust at the facies-association scale, while precise sequence rank, age, bottom-water oxygenation and the relative contribution of eustasy, tectonics and sediment supply remain unresolved.

CONCLUSION

The four investigated Lamja Formation sections at Gwalura Village, Lamza Sama 1, Lamza Sama 2 and Lokoro comprise five recurring lithofacies groups: sandstone, shale, shale-mudstone intercalation, limestone and coal. Within these outcrops, their vertical associations record alternation among traction-dominated delta-front deposition, quiet-water prodelta to offshore-transition settling, marine-influenced carbonate deposition and waterlogged delta-plain peat accumulation. Repeated mudrock-to-sandstone stacking indicates progradation, whereas renewed mudrock and limestone indicate landward shoreline movement or marine flooding. These observations support a shallow-marine to paralic deltaic interpretation for the four measured sections, but they should not be extrapolated to the entire Lamja Formation without lateral correlation. Future work should correlate additional sections, obtain independent age control through palynological or biostratigraphic investigation, and integrate redox and carbonate geochemistry before assigning formal sequence surfaces.

REFERENCES

Abubakar, U., Usman, M. B., Aliyuda, K., Dalha, A., Bello, A. M., & Linus, L. N. (2021). Major and trace element geochemistry of the shales of Sekuliye Formation, Yola Sub-Basin, Northern Benue Trough, Nigeria: Implications for provenance, weathering intensity, and tectonic setting. Journal of Sedimentary Environments, 6(3), 473-484. https://doi.org/10.1007/s43217-021-00067-2

Adamolekun, O. J., Busch, B., Molenaar, N., Suess, M. P., & Hilgers, C. (2022). Petrography and reservoir quality controls in shallow transitional marine Cretaceous-Paleogene deposits in the Dahomey Basin, Nigeria. Journal of African Earth Sciences, 186, 104437. https://doi.org/10.1016/j.jafrearsci.2021.104437

Adamu, L. M., Fatoye, F. B., Alege, T. S., Odoma, A. N., Obaje, N. G., Isaac, B. O., Ohiemi, A. F., Ebeh, A., Ochu, G. D., Umar, M. U., Etukudo, N. J., & Adesina, D. E. (2025). Palynofacies signatures and maturation pathways of Cretaceous shales in Nigeria's Middle Benue Trough: Reconstructing rift-controlled marine-deltaic palaeoenvironments. Journal of Mining and Geology, 61(1), 117-132.

Adamu, L. M., Obaje, N. G., Adeoye, J. A., Oladimeji, R. G., & Yusuf, I. (2024). Trans-Saharan seaway connection between the South Atlantic and the Tethys Sea during the Coniacian-Turonian: Evidence from bibliographical synthesis, field mapping, and seismic interpretation. Geosystems and Geoenvironment, 3(2), 100243. https://doi.org/10.1016/j.geogeo.2023.100243

Adepoju, S. A., Ojo, O. J., Akande, S. O., & Sreenivas, B. (2020). Provenance of the Campanian-Maastrichtian sandstone, northern Bida Basin: Evidence from facies analysis, detrital zircon morphology and whole-rock geochemistry. NAPE Bulletin, 29(1), 59-81.

Adepoju, S. A., Ojo, O. J., Akande, S. O., & Sreenivas, B. (2021). Petrographic and geochemical constraints on petrofacies, provenance and tectonic setting of the Upper Cretaceous sandstones, northern Bida Basin, north-central Nigeria. Journal of African Earth Sciences, 174, 104041. https://doi.org/10.1016/j.jafrearsci.2020.104041

Adepoju, S. A., Ojo, O. J., Akande, S. O., Sreenivas, B., Babu, E. V. S. S. K., & Vijaya Kumar, T. (2024). Reconstruction of weathering history and paleoclimatic conditions of the Campano-Maastrichtian sandstones in the Northern Bida Basin, Nigeria. Discover Geoscience, 2, 102. https://doi.org/10.1007/s44288-024-00101-6

Aggarwal, N. (2022). Sedimentary organic matter as a proficient tool for the palaeoenvironmental and palaeodepositional settings of Gondwana coal deposits. Journal of Petroleum Exploration and Production Technology, 12, 257-278. https://doi.org/10.1007/s13202-021-01331-x

Aigbadon, G. O., Igbinigie, N. S., Obasi, A. I., Akudo, E. O., Christopher, S. D., Ocheli, A., Igwe, D. O., Francis, A. J., Joseph, G. E., & Akor, D. J. (2024). Microfacies and mineralogical analyses of the Late Cretaceous carbonate rocks from the Central Benue Trough, Nigeria. Ife Journal of Science, 26(1), 101-118. https://doi.org/10.4314/ijs.v26i1.8

Aigbadon, G. O., Odoma, A. N., Obasi, I., Christopher, S., Changde, N., Muawiya, B. A., & Akakuru, O. (2022). Hydrocarbon prospectivity of the southern Bida and northern Anambra basins, Nigeria using palynological and geochemical studies. Geosystems and Geoenvironment, 1, 100103. https://doi.org/10.1016/j.geogeo.2022.100103

Akinyemi, S. A., Adebayo, O. F., & Nyakuma, B. B. (2020). Petrology, physicochemical and thermal analyses of selected Cretaceous coals from the Benue Trough Basin in Nigeria. International Journal of Coal Science & Technology, 7(1). https://doi.org/10.1007/s40789-020-00303-6

Alege, T. S., Tella, T. O., & Aigbadon, G. O. (2024). Lithofacies, bio-sequence stratigraphy and paleoenvironment of the Cretaceous-Neogene at the BG-1 well, offshore Eastern Dahomey Basin, Nigeria: Implications for future exploration and development efforts. Carbonates and Evaporites, 39, 49. https://doi.org/10.1007/s13146-024-00953-6

Alege, T. S., Tella, T. O., Aigbadon, G. O., & Omada, J. I. (2023). Sedimentary facies and palynological studies of Ajali Sandstones Formation outcropping in Idah, Northern Anambra Basin, Nigeria. Journal of Applied Sciences and Environmental Management, 27(6), 1207-1215.

Alege, T., Lukman, A., & Odoma, A. N. (2020). Sedimentology, lithofacies, palynofacies and sequence stratigraphy of the Campano-Maastrichtian successions within the southern Bida Basin, Nigeria. Minna Journal of Geosciences, 4, 122-142.

Ayinla, H. A., Abdullah, W. H., Makeen, Y. M., Ayok, J., Abdulbariu, I., Sanni, Z., & Toyin, A. (2025). Palynofacies and predictions for hydrocarbon generation potential of the Upper Cretaceous lignite from Maiganga Coalfield, Northern Benue Trough, Nigeria. Journal of Pure and Applied Sciences (Science Forum), 23(1), 447-468.

Bello, A. M., Usman, M. B., Abubakar, U., Al-Ramadan, K., Babalola, L. O., Amao, A. O., Sarki Yandoka, B. M., Kachalla, A., Kwami, I. A., Ismail, M. A., Umar, U. S., & Kimayim, A. (2022). Role of diagenetic alterations on porosity evolution in the Cretaceous (Albian-Aptian) Bima Sandstone, northern Benue Trough, NE Nigeria. Marine and Petroleum Geology, 145, 105851. https://doi.org/10.1016/j.marpetgeo.2022.105851

Bello, A. M., Usman, M. B., Amao, A. O., Al-Ramadan, K., Al-Hashem, M., Kachalla, A., Abubakar, U., Salisu, A. M., Mukkafa, S., Kwami, I. A., Aro, O. E., Butt, M. N., Maigari, A. S., Yusuf, A., Chiroma, L. U., & Akinsanpe, O. T. (2024). Diagenesis and reservoir quality evolution of estuarine sandstones: Insights from the Cenomanian-Turonian Yolde Formation, northern Benue Trough, NE Nigeria. Marine and Petroleum Geology, 169, 107073. https://doi.org/10.1016/j.marpetgeo.2024.107073

Bello, A. M., Usman, M. B., Amao, A. O., Salisu, A. M., Al-Ramadan, K.,Abubakar, U., Mukkafa, S., Kwami, I. A., Chiroma, L. U., Al-Hashem, M., Yusuf, A., Maigari, A. S., Kachalla, A., Aro, O. E., Ismai'l, M. A., Umar, U. S., & Akinsanpe, O. T. (2025). Linking provenance and diagenesis to reservoir quality evolution of sandstones: The Paleocene-Eocene Kerri-Kerri Formation, northeastern Nigeria. Marine and Petroleum Geology, 172, 107227. https://doi.org/10.1016/j.marpetgeo.2024.107227

Bello, A. M., Usman, M. B., Ismail, M. A., Mukkafa, S., Abubakar, U., Kwami, I. A., Al-Ramadan, K., Amao, A. O., Al-Hashem, M., Salisu, A. M., Kachalla, A., Abubakar, M. B., Maigari, A. S., & Chiroma, L. U. (2023). Linking diagenesis and reservoir quality to depositional facies in marginal to shallow marine sequence: An example from the Campano-Maastrichtian Gombe Sandstone, Northern Benue Trough, NE Nigeria. Marine and Petroleum Geology, 155, 106386. https://doi.org/10.1016/j.marpetgeo.2023.106386

Boboye, O. A., Jaiyeoba, O. K., & Okon, E. E. (2021). Sedimentological characteristics and mineralogical studies of some Cretaceous sandstones in Nigeria: Implications for depositional environment and provenance. Journal of Sedimentary Environments, 6, 531- 550. https://doi.org/10.1007/s43217-021-00066-3

Catuneanu, O. (2022). Principles of sequence stratigraphy (2nd ed.). Elsevier.

Didi, C. N., Osinowo, O. O., Akpunonu, O. E., & Usman, M. B. (2025). Re-evaluation of the stratigraphy, structural, and depositional environment of Kolmani field, Gongola Sub-basin, northeast Nigeria using outcrop data, ditch-cutting data, and well-log data for enhanced hydrocarbon exploration. Discover Geoscience, 3, 95. https://doi.org/10.1007/s44288-025-00207-5

Finthan, B., & Mamman, Y. D. (2020). The lithofacies and depositional palaeoenvironment of the Bima Sandstone in Girei and environs, Yola Arm, Upper Benue Trough, northeastern Nigeria. Journal of African Earth Sciences, 169, 103863. https://doi.org/10.1016/j.jafrearsci.2020.103863

Finthan, B., Mamman, Y. D., & Valdon, Y. B. (2023). Facies association and sequence-stratigraphic analysis of the Lower Cretaceous Bima Formation in the Yola Arm of the Upper Benue Trough, northeastern Nigeria. Journal of African Earth Sciences, 198, 104773. https://doi.org/10.1016/j.jafrearsci.2022.104773

Levell, B. (2026). Reading's sedimentary environments: Processes, facies and stratigraphy (4th ed.). Wiley-Blackwell.
Mangs, A. D., Wagner, N. J., Moroeng, O. M., & Lar, U. A. (2022). Petrographic composition of coal within the Benue Trough, Nigeria and a consideration of the paleodepositional setting. International Journal of Coal Science & Technology, 9(1), 35. https://doi.org/10.1007/s40789-022-00500-5

Margimari, U. J., Mamman, Y. D., Valdon, Y. B., & Adeniyi, A. (2026). Lithofacies study of Bima Sandstone in Gurin and its environs, Yola Sub-Basin, Northern Benue Trough, Nigeria. FUDMA Journal of Sciences, 10(5), 15-22. https://doi.org/10.33003/fjs-2026-1005-4950

Nichols, G. (2023). Sedimentology and stratigraphy (3rd ed.). Wiley.

Ojo, O. J., Adepoju, S. A., Awe, A., & Adeoye, M. O. (2021). Mineralogy and geochemistry of the sandstone facies of Campanian Lokoja Formation in the Southern Bida Basin, Nigeria: Implications for provenance and weathering history. Heliyon, 7(12), e08564. https://doi.org/10.1016/j.heliyon.2021.e08564

Omietimi, E. J., Lenhardt, N., Yang, R., Götz, A. E., Edegbai, A. J., & Bumby, A. J. (2025). Multi-parameter investigation of Cretaceous to Palaeocene sedimentary sequences in the Anambra and Niger Delta basins, Nigeria: Organic matter characterisation, palynofacies and implications for palaeoclimate and sea-level changes. Geological Journal, 60(1), 196- 222. https://doi.org/10.1002/gj.5084

Oretade, B. S., Adepehin, E. J., & Ola, P. S. (2024). Palynostratigraphy of Late Cretaceous subsurface sediment of southern Bornu Basin, Nigeria: Implications for depositional environments and palaeoclimatic predictions. Journal of African Earth Sciences, 212, 105192. https://doi.org/10.1016/j.jafrearsci.2024.105192

Tijwun, E. S. (2025). Decadal spatio-temporal dynamics of vegetation change across ecological gradients in Southern Taraba, Nigeria (2014-2024). International Journal of Innovative Science and Research Technology, 10(9), 2486-2490. https://doi.org/10.38124/ijisrt/25sep1401

Usman, M. B., Brasier, A. T., Jolley, D. W., Abubakar, U., & Mukkafa, S. (2021). Did the Benue Trough connect the Gulf of Guinea with the Tethys Ocean in the Cenomanian? New evidence from the palynostratigraphy of the Yola Sub-basin. Cretaceous Research, 119, 104683. https://doi.org/10.1016/j.cretres.2020.104683

Valdon, Y. B., & Maigari, S. A. (2022). Palynofacies and sea-level changes in the Upper Cretaceous of the Yola Basin, Northern Benue Trough, northeastern Nigeria. Dutse Journal of Pure and Applied Sciences, 8(3b), 184-195. https://doi.org/10.4314/dujopas.v8i3b.18