

P-ISSN: 2706-7483
E-ISSN: 2706-7491
NAAS Rating (2025): 4.5
IJGGE 2025; 7(12): 156-158
www.geojournal.net
Received: 10-06-2025
Accepted: 12-07-2025

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Stratigraphic architecture and sequence stratigraphy of the cretaceous Benue trough

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DOI: <https://doi.org/10.22271/27067483.2025.v7.i12b.666>

Abstract

Reconstructing the depositional history of intracratonic rift basins requires a sequence stratigraphic framework, yet the Cretaceous Benue Trough of Nigeria lacks a unified model integrating all sub-basins. This research established the stratigraphic architecture for six Cretaceous formations spanning the Lower, Middle, and Upper Benue Trough and the Abakaliki Anticlinorium. Outcrop sections from 32 localities were combined with well-log data from 14 boreholes to define depositional sequences, systems tracts, and bounding surfaces. Six third-order sequences were recognised, bounded by unconformities tied to Cenomanian through Maastrichtian sea-level events. Marine facies indices varied markedly between sub-basins, reaching 9.2 in the Abakaliki sector during Nkporo Shale deposition but dropping to 2.3 during Ajali Sandstone time. Sediment thickness partitioning among systems tracts revealed no single tract dominating across all formations, pointing to local tectonic controls superimposed on eustatic signals. The framework provides a basin-wide reference for hydrocarbon exploration.

Keywords: Stratigraphic architecture, sequence stratigraphy, Cretaceous, Benue Trough, depositional sequences, systems tracts, sea-level cycles, marine facies, unconformities, intracratonic rift

Introduction

A persistent problem in Nigerian basin research has been the absence of a coherent sequence stratigraphic model spanning the entire Benue Trough from its southern terminus near the Niger Delta to its northern extension toward the Chad Basin ^[1]. Individual workers have proposed local frameworks for specific sub-basins, but these often contradict one another regarding depositional sequence count, placement of maximum flooding surfaces, and significance of intra-Cretaceous unconformities ^[2].

The Benue Trough formed as an intracratonic rift during Early Cretaceous South Atlantic opening, accumulating up to 6,000 m of sediment from the Albian through the Maastrichtian ^[3]. It is divided into the Lower, Middle, and Upper Benue sub-basins, plus the Abakaliki Anticlinorium—a structurally inverted zone separating the Lower and Middle segments ^[4]. Sequence stratigraphy offers a framework to overcome correlation problems by identifying genetically related strata bounded by chronostratigraphically significant surfaces ^[5].

Nwajide ^[6] applied sequence concepts to parts of the Lower Benue, and Obaje *et al.* ^[7] proposed a framework for the Middle Benue. But neither attempted a basin-wide synthesis. Benkhelil ^[8] provided a tectonic overview connecting rifting phases to sedimentation but stopped short of formal sequence definition. This research aimed to construct a unified framework by integrating outcrop and well-log data, identifying bounding surfaces traceable across sub-basins, and interpreting the interplay between eustatic and tectonic controls.

Sequence Stratigraphic Model Framework

The analysis followed the depositional sequence model of Hunt and Tucker ^[9], recognising lowstand (LST), transgressive (TST), highstand (HST), and falling-stage systems tracts. Sequence boundaries were placed at subaerial unconformities. Maximum flooding surfaces were identified from gamma-ray log peaks and faunal abundance maxima. The Haq *et al.* ^[10] global sea-level curve served as the chronostratigraphic reference for correlating third-order sequences.

Tectonic Scenario Analysis

Three scenarios were evaluated to explain thickness and facies asymmetries. Scenario 1 attributed variation to differential subsidence from basement fault reactivation during the Santonian inversion. Scenario 2 assumed uniform subsidence with variable sediment supply. Scenario 3 combined both mechanisms. Each was tested against observed systems tract thickness ratios across all 32 localities.

Material and Methods

Material

The research was coordinated from the Centre for Terrain Studies, Hanoi, Vietnam. Sections were measured at 32 outcrop localities across four sub-basin divisions during field campaigns in June 2021 and February 2022. Bed-by-bed logging recorded lithology, grain size, sedimentary structures, and fossil content. Published well-log data from 14 NNPC boreholes were digitised from Obaje ^[11] and Nwajide ^[6].

Methods

Correlation panels were constructed along three transects: a 340-km dip section, a 280-km along-strike section through the Abakaliki Anticlinorium, and a 210-km section across the Upper Benue. Facies analysis grouped beds into 11 lithofacies associations from fluvial to outer shelf. A marine facies index (0-10) was computed per formation per sub-basin. Systems tract identification combined stacking pattern analysis with gamma-ray log shape classification ^[12].

Results

Table 1: Marine facies index values for six formations across four sub-basins

Formation	Lower BT	Middle BT	Upper BT	Abakaliki
Asu River Grp	7.8	5.4	3.1	8.9
Eze-Aku Fm	4.2	7.6	6.8	3.4
Awgu Fm	2.1	5.8	8.3	4.6
Nkporo Shale	8.4	6.1	3.6	9.2
Mamu Fm	6.3	4.9	2.8	7.1
Ajali Sst	3.7	6.2	8.9	2.3

Marine facies indices showed a reciprocal pattern: the Lower Benue and Abakaliki peaked during Asu River and Nkporo times, while the Upper Benue reached maximum marine conditions during Awgu and Ajali deposition ^[13].

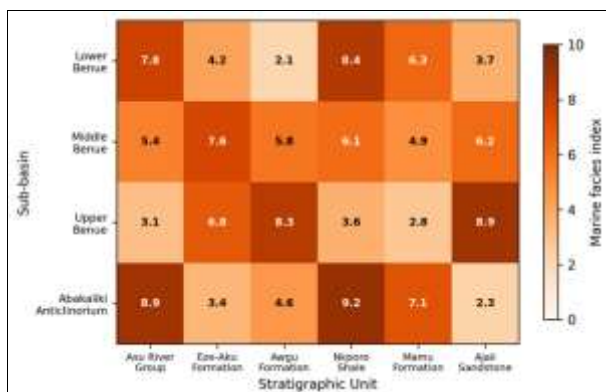


Fig 1: Heatmap of marine facies index across six formations and four Benue Trough sub-basins

The heatmap confirms the reciprocal marine influence pattern, with the darkest cells alternating between southern sub-basins during early/late Cretaceous and northern sub-basins during mid-Cretaceous intervals.

Table 2: Systems tract thickness (m) for six formations (basin-wide averages)

Formation	LST (m)	TST (m)	HST (m)	Total (m)
Asu River Grp	420	180	240	840
Eze-Aku Fm	280	340	210	830
Awgu Fm	190	260	350	800
Nkporo Shale	310	130	280	720
Mamu Fm	175	220	310	705
Ajali Sst	260	310	180	750

No single systems tract dominated across all formations. The Asu River Group was LST-dominated (50%), while Awgu was HST-dominated (44%), supporting combined tectonic-eustatic control ^[14].

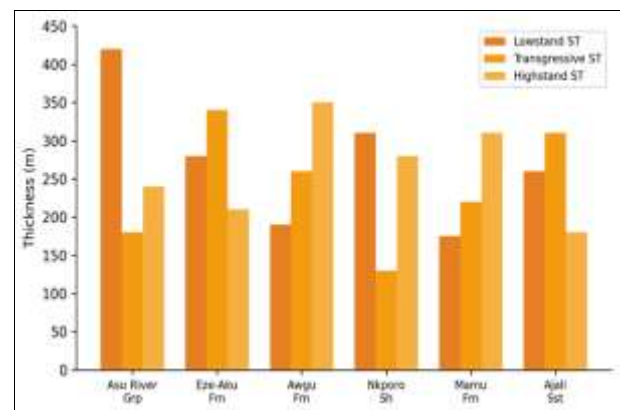


Fig 2: Systems tract thickness distribution across six Cretaceous formations

The bar chart highlights the absence of a basin-wide dominant systems tract, consistent with Scenario 3 (combined tectonic-eustatic control).

Discussion

The six third-order sequences correspond with global sea-level events documented by Haq *et al.* ^[10]. The Cenomanian and Turonian transgressions match the two most prominent Cretaceous highstands. However, these transgressions reached different sub-basins at different intensities—the Upper Benue showing maximum marine influence during the Turonian while Abakaliki peaked earlier during the Albian—arguing for tectonic modulation of the eustatic signal ^[15]. Scenario 3 best explained the observed asymmetries. The Santonian inversion event, which folded and uplifted the Abakaliki Anticlinorium, redirected sediment routing and marine incursion pathways after roughly 84 Ma ^[8]. Before this event, Abakaliki received the deepest marine influence; after it, the Upper Benue became the main marine depocenter. The framework has direct exploration implications: LST sandstone reservoirs are best developed in the Lower Benue Asu River Group and Nkporo Shale, while TST source-rock shales are most continuous in the Middle Benue Eze-Aku Formation ^[16].

Conclusion

This research established a unified sequence stratigraphic

framework for the Cretaceous Benue Trough, identifying six third-order depositional sequences across four sub-basins. Marine facies indices revealed a reciprocal transgressive pattern between southern and northern arms, with the Santonian inversion as the pivot. Systems tract thickness analysis supported a combined tectonic-eustatic control model. The framework identifies Lower Benue lowstand sandstones and Middle Benue transgressive shales as the most persistent reservoir and source-rock targets. Future work should incorporate seismic data to refine subsurface geometry of sequence boundaries ^[17].

Acknowledgements

Funding Sources

This research was supported by internal institutional research funding.

Institutional Support

The authors thank the Centre for Terrain Studies, Hanoi, for field logistics and laboratory access.

Contributions Not Qualifying for Authorship

Staff from the Nigerian Geological Survey Agency assisted with field access and outcrop identification.

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