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Reseach Article

Sedimentological Evolution and Depositional Environments of the Afikpo Basin and Southern Benue Trough: A Comprehensive Review

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ABSTRACT

The Afikpo Basin and Southern Benue Trough preserve a critical Cretaceous sedimentary record, yet existing interpretations remain dispersed across tectonic, stratigraphic, sedimentological, ichnological, provenance, and geophysical studies. This fragmentation limits a unified explanation of how Santonian inversion, sea-level fluctuation, sediment supply, and depositional energy-controlled basin evolution, facies distribution, paleogeography, and sediment-routing systems. This review synthesizes published evidence on the tectonic framework, lithostratigraphic succession, depositional facies, sedimentary structures, trace fossils, transgression-regression cycles, paleocurrent indicators, provenance signatures, and emerging digital reconstruction methods in the Afikpo Basin and Southern Benue Trough. The analysis integrates field-based facies descriptions, ichnofacies interpretation, petrographic and QFL data, grain-size indicators, aeromagnetic and radar-derived structural information, reservoir-property evidence, and basin-modelling implications to develop a coherent tectono-sedimentary interpretation. The synthesis shows that Early Cretaceous rifting-initiated accommodation, while Santonian compression uplifted the Abakaliki Anticlinorium and shifted depocenters into the Afikpo and Anambra basins. Sediment thickness ranges from 513.9 m to more than 3469.6 m, with post-Santonian clastics sourced largely from uplifted hinterlands. Cross-bedding, ripple lamination, mud cracks, flaser bedding, herringbone structures, basal lag deposits, and bioturbated heteroliths indicate fluvial, deltaic, estuarine, tidal-flat, shoreface, and shelf systems. Skolithos, Ophiomorpha, Cruziana, Planolites, Chondrites, and Thalassinoides confirm variable energy, salinity, oxygenation, substrate consistency, and marine influence. Provenance evidence includes Akpoha quartz of 55-64%, feldspar of 22-30%, rock fragments of 1-9%, Eze-Aku Q90F10L0 composition, and mature to supermature Ajali Sandstone. The review supports integrated facies-ichnology-sequence stratigraphy, GIS paleogeographic mapping, digital outcrop analysis, and basin modelling for future studies.

1. Introduction

1.1 Geological Background of the Afikpo Basin and Southern Benue Trough

The Afikpo Basin forms part of the Southern Benue Trough, a major intracratonic sedimentary basin in southeastern Nigeria that developed during the Early Cretaceous opening of the South Atlantic Ocean (Amobi et al., 2019; Momta, 2018; Obioha & Mbonu, 2021). The Benue Trough extends in a northeast-southwest orientation and represents a rift structure formed through crustal extension and subsequent sediment accumulation (Dim et al., 2018; Okoro et al., 2020). The Afikpo Basin occupies the southeastern segment of this system, created after the Santonian tectonic inversion folded and uplifted the Abakaliki Anticlinorium, forming the Afikpo Synclinorium on its southeastern flank and the Anambra Basin on its northwestern flank (Agibe et al., 2019; Okolo et al., 2020; Nwamekwe et al., 2025). The basin preserves thick sedimentary successions of sandstone, shale, siltstone, and heterolithic units deposited under continental, transitional, and marine conditions (Momta, 2018; Odigi & Momta, 2019).

The tectonic evolution of the Benue Trough controlled depositional architecture within the Afikpo Basin. Structural deformation, subsidence, and Santonian compressional uplift displaced the depocenter from the Abakaliki Basin, creating new accommodation space in the Afikpo and Anambra basins (Agibe et al., 2019; Amobi et al., 2019). Sediment thicknesses of 2.0 to 3.98 km have been recorded in the Afikpo Basin (Dim et al., 2018). The sedimentary fill consists of three tectono-stratigraphic mega-sequences: the Asu River Group, Eze-Aku Group, and proto-Niger Delta succession (Dim et al., 2018; Odigi & Momta, 2019). Transgressive-regressive depositional cycles, controlled by eustatic sea-level changes and local tectonism, shaped facies distribution and sediment dispersal pathways (Okolo et al., 2020; Okpoli, 2019). The basin therefore provides an important geological record for understanding Cretaceous basin evolution and paleoenvironmental dynamics in tropical sedimentary settings (Momta, 2018; Okoro et al., 2020).

1.2 Scientific Importance of the Basin

The Afikpo Basin holds considerable stratigraphic and paleoenvironmental significance. The basin preserves sedimentary successions of fluvial, deltaic, and shallow marine origin, recording multiple transgressive-regressive cycles from the Albian through the Maastrichtian (Amobi et al., 2019; Obioha & Mbonu, 2021). Sedimentary structures and trace fossil assemblages, including Ophiomorpha, Skolithos, and Cruziana ichnofacies, provide direct evidence for reconstructing depositional energy conditions and water depth (Momta, 2018; Okoro et al., 2020). Facies analysis across the basin has identified estuarine, tidal flat, shoreface, and shelf depositional systems (Agibe et al., 2019; Dim et al., 2018). The basin also carries regional significance for hydrocarbon exploration. The Afikpo Sandstone shows porosity values of 0.485 to 0.499 and permeability of 26.03 to 42.64 md, indicating good reservoir potential (Dim et al., 2018). Source rock evaluation of the Nkporo Shale at Mgbom section yielded TOC values of 0.51 to 1.02 wt%, exceeding the minimum threshold for a potential source rock (Okolo et al., 2020). Oil seeps and shows have been reported in the Nguzu and Amangwu Edda areas (Dim et al., 2018). The Eze-Aku sandstones retain good reservoir properties with average porosity of 22.7% and permeability of 745.43 mD (Nwamekwe et al., 2025). Sediment thicknesses in the basin range from 513.9 m to over 3469.6 m (Odigi & Momta, 2019). Despite this documented scientific value, the Afikpo Basin remains comparatively underrepresented in global sedimentological syntheses relative to other Cretaceous sedimentary systems.

1.3 Need for an Integrated Sedimentological Review

Existing studies within the Afikpo Basin are fragmented into separate tectonic (Okpoli, 2019), stratigraphic (Okoro et al., 2020), sedimentological (Amobi et al., 2019; Dim et al., 2018), ichnological (Momta, 2018; Okoro et al., 2020), petrographic (Okolo et al., 2020; Nwamekwe et al., 2026), and geochemical investigations (Okolo et al., 2020). Dim et al. (2018) focused on facies and reservoir potential of the Afikpo Sandstone. Okolo et al. (Momta, 2018) addressed lithofacies and grain size of the Eze-Aku Group. Ejeh and Odigi (Nwamekwe et al., 2025) examined reservoir characterization through SEM and petrography. Ohaegbulem et al. (Okolo et al., 2020) studied sedimentary structures and provenance at Akpoha. Odigi and Okpoli (2019) applied radar imagery to tectonic and structural analysis. Each of these studies addressed specific aspects of the basin in isolation. This separation limits a comprehensive understanding of the relationships among tectonic evolution, depositional systems, sediment dispersal, and paleoenvironmental reconstruction. An integrated sedimentological review is necessary to unify evidence from facies analysis, ichnology, paleocurrent interpretation, provenance studies, and tectonic history into a single basin-evolution framework. Such integration provides a stronger basis for interpreting depositional environments and regional sedimentary evolution within the Southern Benue Trough, and for linking the Afikpo Basin record to broader Cretaceous paleogeographic and paleoceanographic patterns across West Africa (Obioha & Mbonu, 2021; Okoro et al., 2020).

1.4 Aim and Scope of the Review

This review synthesizes the sedimentological evolution and depositional history of the Afikpo Basin and Southern Benue Trough by integrating tectonics, stratigraphy, sedimentology, ichnology, paleogeography, and provenance interpretation. The review specifically focuses on:

1. tectonic evolution of the Benue Trough;
2. Santonian tectonic inversion;
3. lithostratigraphic succession;
4. depositional facies and sedimentary structures;
5. trace fossils and ichnofacies interpretation;
6. marine transgression-regression cycles;
7. paleocurrent systems and sediment dispersal; and
8. regional basin-evolution models.

2. Tectonic Framework and Basin Evolution

2.1 Origin and Evolution of the Benue Trough

The Benue Trough originated during the Early Cretaceous as part of the tectonic processes linked to the separation of the African and South American plates during South Atlantic opening (Ekwok et al., 2021; Odigi & Momta, 2019). The trough represents a failed arm of a rift-rift-rift triple junction system connected to the breakup of Gondwana, reactivating pre-existing weaknesses within the Pan-African Basement Complex (Nwamekwe and Chikwendu, 2025; Ekwok et al., 2021; Onuoha. et al., 2020). Wrench movements along these basement fractures produced block faulting and formed several sedimentary basins (Odigi & Momta, 2019). The trough extends in a northeast-southwest orientation and contains up to 6000 m of Cretaceous sedimentary, minor intrusive, and extrusive rocks (Odigi & Momta, 2019). Structurally, the Benue Trough subdivides into the Northern, Central, and Southern Benue segments, each with distinct tectonic histories and depositional styles (Igbokwe and Nwamekwe et al., 2025; Odigi & Momta, 2019). The Southern Benue Trough, which contains the Afikpo Basin, accumulated both continental and marine sediments ranging in age from Early Cretaceous to Santonian (Onuigbo et al., 2020). The earliest sediments deposited in the southern portion were Aptian-Albian pyroclastics (Nkiru et al., 2021). A transgressive depositional phase during the Middle to Late Albian resulted in deposition of the Asu River Group under prolonged shelf and deep basin conditions (Agibe et al., 2019; Igbokwe et al., 2025). Sedimentation proceeded through repeated transgressive-regressive cycles influenced by eustatic sea-level changes, basin tectonics, and local diastrophism (Ekwok et al., 2021). The Cenomanian to Turonian interval represented the main phase of rifting, evidenced by rapid subsidence rates averaging 44 m/Mya and reaching 169.75 m/Mya (Amobi et al., 2019).

2.2 Santonian Tectonic Inversion and Basin Reconfiguration

The Santonian tectonic event represents the most significant deformational phase within the Benue Trough. Compressional stress produced intense folding, faulting, uplift, and regional structural reorganization of all pre-Santonian sediments (Nkiru et al., 2021; Ohaegbulem et al., 2024; Okolo et al., 2020). Horizontal stresses generated parallel to sub-parallel folds trending northeast-southwest (Nkiru et al., 2021). This compressional episode uplifted the axial part of the Benue Trough into the Abakaliki Anticlinorium, creating two flanking depressions: the Anambra Basin to the northwest and the Afikpo Syncline to the southeast (Amobi et al., 2019; Okoro et al., 2020; Onuigbo et al., 2020). The deformation displaced the depocenter from the Abakaliki Basin to these new structural lows (Amobi et al., 2019; Okeagu et al., 2024). Erosion and non-deposition followed in the Abakaliki

Basin, raising previously buried source rocks such as the Lokpanta Shale above the oil generative window (Amobi et al., 2019). The Santonian inversion also triggered magmatism and emplacement of intermediate igneous rocks, including dolerites and diorites, into the sedimentary succession (Obioha & Mbonu, 2021; Igbokwe et al., 2025). Structural features produced during this event, including fractures, faults, and folds, controlled subsequent mineralization patterns across the Southern Benue Trough (Ekwok et al., 2021; Igbokwe et al., 2025). The Afikpo Syncline and Anambra Basin became the principal depocenters for all post-Santonian sedimentation (Vitalis et al., 2024; Okolo et al., 2020; Onuigbo et al., 2020).

2.3 Post-Santonian Basin Subsidence and Sedimentation

Following Santonian tectonic inversion, renewed subsidence promoted widespread sediment accumulation in the Afikpo and Anambra basins. Renewed sedimentation began in the Campanian as sagging occurred due to sediment loading (Amobi et al., 2019). The Maastrichtian recorded subsidence rates of 168.28 m/Mya, comparable to the Cenomanian-Turonian rifting phase, reflecting rapid erosion and unroofing of the structurally inverted Benue Trough (Amobi et al., 2019). Over 2000 metres of sediments deposited in the Afikpo Sub-Basin and Anambra Basin were sourced from the uplifted Abakaliki Anticlinorium (Igbokwe et al., 2024; Ohaegbulem et al., 2024). Aeromagnetic studies indicate sediment thicknesses in the Afikpo Basin ranging from 513.9 m to over 3469.6 m, with the thickest units located around Bende (Nkiru et al., 2021). The sedimentary fill in the Afikpo Basin consists of the Nkporo Group, Mamu, Ajali, and Nsukka formations (Agibe et al., 2019; Okoro et al., 2020). The Campanian-Maastrichtian transgression deposited marine sediments under shallow-marine, deltaic, estuarine, and tidal conditions (Okoro et al., 2020; Sunday & Chijioke, 2018). The Afikpo Sandstone, a basal unit of the Nkporo Group, records deposition during the late Campanian to early Maastrichtian in a high-energy fluvio-marine setting with estuarine and subtidal sand ridge facies associations (Okoro et al., 2020). Trace fossil assemblages of Skolithos-Cruziana ichnogenera confirm shallow-water, high-energy conditions during this post-Santonian depositional phase (Okolo et al., 2020; Okoro et al., 2020). The Late Campanian to Middle Miocene phase produced rapid subsidence and uplift in alternation, with subsequent progradation of a delta system that eventually led to the formation of the Niger Delta (Nkiru et al., 2021).

Figure 1: Tectono-sedimentary evolution model of the Afikpo Basin and Southern Benue Trough from pre-Santonian to post-Santonian stages.

Figure 1 summarizes the basin evolution from Early Cretaceous rifting through Albian transgression, Cenomanian-Turonian subsidence, Santonian inversion, and post-Santonian sedimentation. It shows how tectonic uplift, depocenter migration, accommodation creation, sea-level change, and sediment supply shaped facies distribution, paleogeography, and sediment-routing architecture across the Afikpo Basin and Southern Benue Trough system.

3. Stratigraphy and Depositional Systems

3.1 Stratigraphic Framework of the Afikpo Basin

The stratigraphic architecture of the Afikpo Basin consists of three tectono-stratigraphic mega-sequences: the Asu River Group, the Eze-Aku Group, and the proto-Niger Delta succession (Odigi & Momta, 2019). The Asu River Group occupies the basal unit and consists of alternating shale, siltstone, and sandstone deposited during the Albian under prolonged shelf and deep basin conditions, with a maximum thickness of 1000 m (Agibe et al., 2019). The Eze-Aku Group, deposited during the Cenomanian to Turonian, represents the most extensive clastic deposition within the lower Benue Trough and consists of dark grey to black calcareous shales interbedded with limestone lenses, calcareous sandstones, and NE-SW trending sandstone ridges (Ejeh & Odigi, 2022; Okolo et al., 2020). The Amasiri Sandstone, a lateral equivalent within this group, forms a massive outcrop with lateral extent exceeding 8 kilometers (Momta, 2018). Following the Santonian unconformity, the post-Santonian succession includes the Nkporo Group (containing the Afikpo Sandstone and Nkporo Shale), the Mamu Formation, the Ajali Formation, and the Nsukka Formation (Agibe et al., 2019; Nwamekwe et al., 2025). The Afikpo Sandstone overlies an angular unconformity above the Eze-Aku Group near Ozizza and Amasiri and comprises thick successions of cross-bedded and bioturbated sandstones, sandy heteroliths, coal stringers, and muddy heteroliths (Okoro et al., 2020). The Ajali Sandstone at Igbere-Abiriba is friable, ranges from white to reddish brown, and shows cross-bedding with fining-upward sequences (Chidiebube et al., 2025). Maastrichtian sediments of the Nsukka Formation contain sand, silt, shale, and clay fractions (Agibe et al., 2019). Sediment thicknesses in the basin range from 513.9 m to over 3469.6 m (Nkiru et al., 2021).

3.2 Depositional Facies and Sedimentary Structures

Sedimentary structures preserved within the Afikpo Basin provide direct evidence for interpreting depositional processes and paleoflow conditions. At Akpoha, the major structures identified include wavy/ripple lamination, mud cracks, parallel lamination, fissility, cross-bedding, and bioturbation (Ohaegbulem et al., 2024). The Eze-Aku sandstones display basal lag deposits with fining-upward successions and planar cross-bedding (Ejeh & Odigi, 2022). Wave and tide generated structures dominate the Eze-Aku Group at Itigidi-Ediba, including trough cross-beds interpreted as products of migrating sinuous-crested dunes in the lower flow regime (Okolo et al., 2020). The Afikpo Sandstone on Macgregor Hill preserves eight lithofacies: planar cross-stratified sandstone, bioturbated sandstone, trough cross-stratified sandstone, parallel laminated sandstone, bioturbated cross-stratified sandstone, sandy bioturbated heterolith, conglomerate, and laminated mudstone (Okoro et al., 2020). Herringbone structures and clay-draped foresets within the bioturbated cross-stratified lithofacies indicate bidirectional tidal currents (Okoro et al., 2020). Wavy ripple laminations and flaser beddings characterize the sandy heterolith lithofacies (Okoro et al., 2020). The Ajali Sandstone at Igbere-Abiriba exhibits tabular and planar cross-bedding, horizontally laminated sands, mud clasts, and bioturbated beddings reflecting tidal influence (Chidiebube et al., 2025). Trace fossil assemblages consisting of Ophiomorpha, Skolithos, and Cruziana ichnofacies occur across multiple stratigraphic levels and indicate moderate to high energy shallow-water conditions (Okolo et al., 2020; Okoro et al., 2020). Horizontal burrows such as Planolites and Chondrites occur locally in heterolithic facies with moderate bioturbation intensity (Okoro et al., 2020). The abundance of well-preserved sedimentary structures at Akpoha indicates prolonged tectonic quiescence after deposition (Ohaegbulem et al., 2024).

3.3 Depositional Environment Interpretation

The sedimentary facies preserved within the Afikpo Basin record complex interaction among fluvial, deltaic, estuarine, tidal-flat, and shallow-marine depositional systems. The Afikpo Sandstone on Macgregor Hill shows estuarine lithofacies associations with tripartite subdivision into mudflat deposits, fluvio-estuarine sandstones in bayhead delta environments, and central estuarine deposits dominated by intertidal bayfill and lagoonal muddy sediments (Okoro et al., 2020). Textural analysis using multivariate discriminant functions confirms deposition in a high-energy fluvio-marine setting (Okoro et al., 2020). The Eze-Aku Group at Itigidi-Ediba records five facies' associations indicating deposition across proximal submarine fan, shelf edge/submarine fan, distal shelf, shallow to deep marine, and shoreface/foreshore sub-environments (Okolo et al., 2020). The Eze-Aku sandstones have internal characteristics similar to barrier island shoreface-foreshore sand ridges (Ejeh & Odigi, 2022). At Akpoha, the occurrence of irregular/wavy and ripple laminations with low amplitude suggests some lithofacies formed in a low-energy deep marine environment, while others reflect different regressive and transgressive episodes (Ohaegbulem et al., 2024). The Cretaceous exposures at Afikpo Town contain fluvial deposits as braided stream and point-bar channel sedimentary units, deltaic deposits as mouth-bars at Akpoha, and shallow marine regressive barrier bars at Amasiri (Momta, 2018). The sedimentary environment of the Ajali Sandstone at Igbere-Abiriba is a tidally influenced fluvial-deltaic as revealed by textural and sedimentary features (Chidiebube et al., 2025; Onyemaechi et al, 2025). The presence of shale intervals in the marine environment indicates low energy depositional environment of the Marine, while the presence of ripple-marked and bioturbated sandstone units in the marine section suggest shallow-marine depositional environment with tidal and wave process (Ejeh & Odigi, 2022; Okolo et al., 2020).

3.4 Marine Transgression and Regression Cycles

The stratigraphic record of the Afikpo Basin preserves evidence of repeated marine transgression and regression cycles tied to eustatic sea-level changes and basin tectonics (Agibe et al., 2019; Nkiru et al., 2021). The first transgressive-regressive cycle during the Albian deposited the Asu River Group under marine shelf conditions (Agibe et al., 2019). A second transgressive phase during the Upper Cenomanian to Middle Turonian deposited the Eze-Aku shale and its lateral equivalents, including the Amasiri Sandstone (Nwamekwe et al., 2025). A third cycle from the Upper Turonian to Lower Santonian deposited the Awgu Shale, with the Turonian transgression believed to have commenced from the Gulf of Guinea through the Anambra Basin to the Benue Trough (Nwamekwe et al., 2025). The Santonian tectonic event terminated pre-Santonian deposition through folding and uplift (Agibe et al., 2019). A fourth sedimentary cycle during the Campanian-Maastrichtian transgressive phase deposited the Nkporo Shales, Afikpo Sandstones, Mamu Formation, Ajali Sandstones, and Nsukka Formation (Nwamekwe et al., 2020). The shallow marine regressive Amasiri Sandstone, underlain by marine shales, records a clear regression event with barrier bars exceeding 70 m in thickness and running parallel to the paleo-coastline (Momta, 2018). At Akpoha, the sandstones represent products of different regressive and transgressive episodes (Ohaegbulem et al., 2024). The stratigraphy of the region reflects these transgressive and regressive periods, with the flexural inversion of the trough forming the Afikpo Basin from the Ikpe Platform (Ezeh et al., 2022). Facies migration patterns and vertical lithologic transitions across these cycles collectively indicate dynamic depositional conditions controlled by the interplay of tectonism and eustasy throughout basin evolution (Nkiru et al., 2021; Odigi & Momta, 2019).

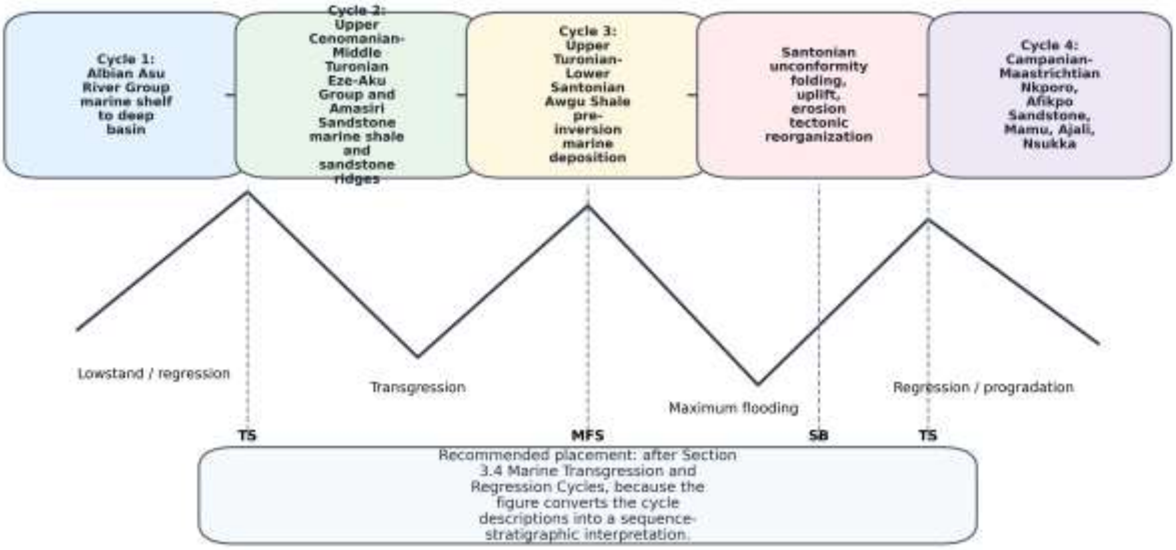

Figure 2: Sequence Stratigraphic Model of Transgression-Regression Cycles and Key Stratigraphic Surfaces in the Afikpo Basin

Figure 2 presents a sequence stratigraphic model of the Afikpo Basin using transgressive-regressive cycles and key stratigraphic surfaces. It connects Albian, Cenomanian-Turonian, Turonian-Santonian, and Campanian-Maastrichtian deposition to transgressive surfaces, maximum flooding surfaces, sequence boundaries, Santonian unconformity, facies migration, shoreline movement, and post-inversion accommodation development through time stages clearly. Robustly.

Table 1: Major lithofacies, sedimentary structures, depositional interpretation, and paleoenvironmental significance within the Afikpo Basin

Major lithofacies	Diagnostic sedimentary structures	Representative formation or locality	Depositional interpretation	Paleoenvironmental significance
Planar cross-stratified sandstone	Planar cross-bedding, fining-upward sandstone, basal lag where present	Afikpo Sandstone; Eze-Aku sandstone; Ajali Sandstone	Migration of straight-crested dunes and bars under traction-current flow	Records fluvial to tidally influenced channelized sand bodies and directional sediment transport
Trough cross-stratified sandstone	Trough cross-beds produced by sinuous-crested dunes	Afikpo Sandstone on Macgregor Hill; Eze-Aku Group at Itigidi-Ediba	Lower-flow-regime migration of three-dimensional dunes	Indicates moderate to high energy current activity within fluvial, estuarine, or shoreface settings
Bioturbated sandstone	Skolithos, Ophiomorpha, Cruziana ichnogenera, moderate to high burrow intensity	Afikpo Sandstone; Eze-Aku Group	Colonization of sandy substrates under marine to marginal-marine influence	Confirms oxygenated shallow-water conditions and variable biological reworking

Sandy bioturbated heterolith	Wavy ripple lamination, flaser bedding, mud drapes, horizontal burrows	Afikpo Sandstone estuarine lithofacies	Alternation of sand and mud deposition under tidal energy fluctuation	Represents intertidal bayfill, lagoonal, and central estuarine deposits
Laminated mudstone and shale	Fissility, parallel lamination, low-energy mud accumulation	Asu River Group, Eze-Aku shale, Nkporo Shale	Suspension settling in shelf, prodelta, lagoonal, or deeper marine settings	Provides evidence for marine flooding, low-energy conditions, and possible source-rock intervals
Conglomerate and basal lag deposits	Coarse lag, erosional bases, channel-fill architecture	Eze-Aku sandstones and Afikpo Sandstone facies	High-energy channel incision and reworking during relative sea-level or discharge change	Marks erosional surfaces, channel bases, and sequence-boundary-related deposits
Mud cracks and ripple-marked beds	Desiccation cracks, ripple marks, wavy lamination	Akpoha and other shallow marginal facies	Alternating subaqueous and subaerial exposure in tidal-flat or shoreline settings	Indicates environmental fluctuation during regression and tidal-flat emergence

Table 1 integrates the major lithofacies, diagnostic sedimentary structures, depositional meanings, and paleoenvironmental implications recorded across the Afikpo Basin succession. It links cross-stratified sandstone, heteroliths, mudstone, shale, conglomerate, mud cracks, ripple marks, and bioturbated facies to fluvial, estuarine, tidal-flat, shoreface, shelf, and deeper-marine depositional settings within the basin evolution. framework

4. Ichnology and Paleoenvironmental Reconstruction

4.1 Trace Fossils and Bioturbation Structures

Trace fossils preserved within the Afikpo Basin provide direct evidence for reconstructing paleoenvironmental conditions and depositional-energy regimes. The Eze-Aku Group at Itigidi-Ediba contains trace fossil assemblages consisting of Ophiomorpha, Skolithos, and Cruziana ichnofacies, suggestive of a moderately disturbed environment (Okolo et al., 2020). The Afikpo Sandstone on Macgregor Hill records Skolithos-Cruziana ichnogenera within bioturbated lithofacies, showing moderate to high intensity of bioturbation with dominantly and intermittently distributed feeding structures (Okoro et al., 2020). Vertical burrows of Skolithos indicate high-energy sandy substrates associated with shoreface and shallow-marine conditions (Okpala et al., 2025; Okoro et al., 2020). Ophiomorpha reflects active burrowing within marginal-marine and nearshore environments and is a common trace fossil in Mesozoic and Cenozoic sedimentary rocks deposited in shallow and marginal marine settings (Okpala et al., 2025). Thalassinoides, documented in the Upper Benue Trough equivalents, is associated with low to moderate energy marine settings characterized by stable substrates (Okpala et al., 2024). At Akpoha, burrows and bioturbation structures occur within the Eze-Aku sandstones, supporting deposition in a shallow marine oxygenated environment

(Ohaegbulem et al., 2024). Horizontal burrows such as Planolites occur locally in heterolithic facies of the Afikpo Sandstone (Okoro et al., 2020). The Ogbunike succession in the Niger Delta Basin, stratigraphically linked to the Benue Trough evolution, also records Skolithos-Cruziana ichnofacies within bioturbated sandstone and ripple laminated lithofacies (Onuigbo et al., 2020). Miocene deposits in the eastern Niger Delta preserve twelve ichnogenera including Asterosoma, Bergaueria, Chondrites, Gyrolithes, Thalassinoides, Lockeia, Palaeophycus, Planolites, Siphonichnus, Skolithos, and Diplocraterion, providing a broader regional context for understanding trace fossil distribution across the Southern Benue Trough and its successor basins (Ezeh et al., 2018).

4.2 Ichnofacies Interpretation

Ichnofacies analysis provides information on substrate consistency, oxygenation, salinity variation, and depositional stress within the Afikpo Basin. The Afikpo Sandstone records ichnofossils of Skolithos-Cruziana ichnofacies, representing shallow water ichnofacies where vertical burrows indicate shallower water and horizontal and patterned burrows occur in deeper water (Okoro et al., 2020). The Skolithos Ichnofacies is recognized by a low diversity of abundant vertical domichnia burrows including Skolithos, Diplocraterion, and Arenicolites, along with fodinichnia such as Ophiomorpha, recording preferential colonization by suspension feeders in high-energy settings (Okpala et al., 2025; Emeka et al., 2025). The proximal Cruziana Ichnofacies is dominated by epigenic and horizontal endogenic structures produced by deposit feeders, reflecting deposition in comparatively lower-energy environments (Emeka et al., 2025). The occurrence of mixed Skolithos-Cruziana ichnofacies within the Afikpo Basin indicates fluctuating depositional energy and transitional environmental conditions between marine and marginal-marine systems (Okolo et al., 2020; Okoro et al., 2020). At Itigidi-Ediba, the trace fossil assemblages within wave and tide generated sedimentary structures confirm a moderately disturbed environment with alternating energy conditions (Okolo et al., 2020). In the Niger Delta Miocene deposits, trace fossil associations within recurring ichnoassociations reflect the re-establishment of particular environmental conditions throughout deposition, with each ichnoassociation providing clues about the nature of the depositional environment (Ezeh et al., 2018). The degree of bioturbation, assessed using ichnofabric indices, varies across facies and correlates with changes in sedimentary facies and depositional energy (Ezeh et al., 2018; Ezeanyim et al., 2025).

4.3 Paleoenvironmental Implications of Trace Fossils

Trace fossils within the Afikpo Basin provide strong evidence for shallow-marine, tidal, estuarine, and marginal-marine depositional conditions. The coexistence of bioturbation structures with ripple marks, cross-bedding, and mud cracks at Akpoha demonstrates repeated environmental fluctuation between subaqueous and subaerial conditions (Ohaegbulem et al., 2024). The Eze-Aku Group trace fossil assemblages at Itigidi-Ediba, combined with wave and tide generated sedimentary structures, indicate deposition in a tidal shallow shelf to deep marine environment under moderate to high energy conditions with fluvial influence (Okolo et al., 2020). The estuarine lithofacies of the Afikpo Sandstone show tripartite subdivision into mudflat deposits, fluvio-estuarine sandstones in bayhead delta environments, and central estuarine deposits dominated by intertidal bayfill and lagoonal muddy sediments, with trace fossils confirming these environmental interpretations (Okoro et al., 2020). The Gombe Formation in the Upper Benue Trough preserves trace fossil assemblages associated with coastal and shallow marine depositional systems of the Campanian-Maastrichtian, providing a regional comparison for the Afikpo Basin ichnological record (Okpala et al., 2024). In the Niger Delta, all trace fossil assemblages illustrate deposition in nearshore, restricted settings, with low diversity and monotypical nature indicative of brackish-water environments (Ezeh et al., 2018). The activity of organisms at the water-sediment interface is controlled by depositional energy conditions, substrate consistencies, depositional rates, oxygenation, water turbidity, and salinity

(Singh et al., 2025). These ichnological features across the basin and its regional equivalents indicate variable salinity, oxygenation, and hydrodynamic conditions during sediment deposition (Ezeh et al., 2018; Okolo et al., 2020; Okoro et al., 2020).

4.4 Integration of Sedimentology and Ichnology

The integration of facies analysis and ichnology improves depositional-environment interpretation because sedimentary structures alone do not fully capture substrate conditions and biological activity. Integrated sedimentological and ichnological studies provide identification of facies and the inter-relationship between organisms at the sediment-water interface and paleo-depositional affinities (Singh et al., 2025). At Macgregor Hill, the combination of eight lithofacies with Skolithos-Cruziana ichnogenera allowed Okoro et al. (Okoro et al., 2020) to interpret the Afikpo Sandstone paleoenvironment using lithofacies characteristics, textural analysis, and ichnofossils together. Okolo et al., (2020) integrated lithofacies analysis and trace fossil assemblage to reconstruct the paleodepositional environment of the Eze-Aku Group from Itigidi-Ediba, which were divided into five facies associations that span from the proximal to the submarine fan-to-shoreface/foreshore sub-environments. The intensity of bioturbation is correlated with the variation in the sedimentary facies and the highest bioturbation intensity is associated with the facies that record depositional environments in the nearshore environment (Ezeanyim et al., 2025; Nwokolo et al, 2022). The Ogbunike succession demonstrates how lithofacies and biofacies analyses, when integrated, allow delineation of lower shoreface to inner neritic, fluvial channel, lagoonal/mixed flat, and subtidal sandwave associations (Onuigbo et al., 2020). In the Niger Delta Miocene deposits, ichnological and sedimentological criteria were combined to recognize brackish-water deposits and formulate integrated facies models (Ezeh et al., 2018). Combined sedimentological and ichnological evidence therefore provides a more reliable framework for reconstructing paleoenvironments and basin evolution across the Afikpo Basin and the broader Southern Benue Trough system (Okolo et al., 2020; Okoro et al., 2020; Singh et al., 2025).

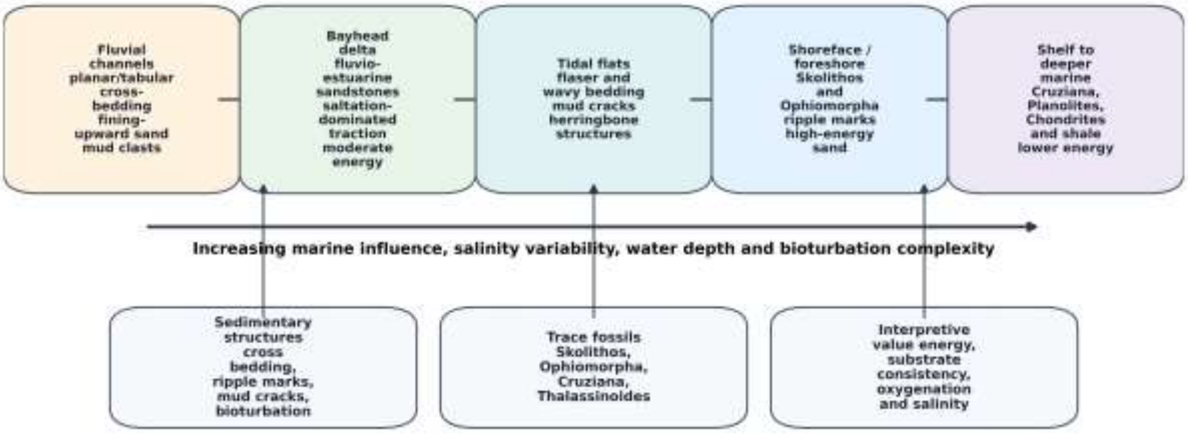

Figure 3: Integrated facies-ichnology model showing depositional environments and paleoenvironmental gradients within the Afikpo Basin.

Figure 3 integrates sedimentary facies and trace-fossil evidence across fluvial, bayhead delta, tidal-flat, shoreface, and shelf environments. It shows how structures such as cross bedding, flaser bedding, ripple marks, mud cracks, and ichnogenera including Skolithos, Ophiomorpha, Cruziana, Planolites, and Chondrites constrain energy, salinity, oxygenation, and marine influence patterns clearly. overall

5. Provenance, Paleocurrents, and Sediment Dispersal Systems

5.1 Provenance Controls on Sediment Composition

Sediment composition within the Afikpo Basin reflects contributions from surrounding basement terrains and uplifted sedimentary sources. Petrographic modal analysis of sandstones at Akpoha shows quartz (55-64%), feldspar (22-30%), and rock fragments (1-9%) (Ohaegbulem et al., 2024). The high feldspar content (>25%) indicates immature arkosic/feldspathic sandstones with a short transport history from provenance, likely the Oban Massif of the southeastern Nigeria basement complex (Ohaegbulem et al., 2024). The Eze-Aku sandstones have an average Q90F10L0 modal composition and are classified as sub-arkose, indicating a more mature sediment supply compared to the Akpoha sandstones (Ejeh & Odigi, 2022). The Afikpo Sandstone on Macgregor Hill consists of quartz with subordinate weathered feldspar and metamorphic rock fragments as framework elements (Okoro et al., 2020). The Ajali Sandstone at Igbere-Abiriba has a Mineral Maturity Index of 24-49, falling within the mature to super mature class, with high quartz content and insignificant feldspar and rock fragments suggesting substantial reworking and removal of ferromagnesian minerals (Nwamekwe et al., 2024). The Ajali Formation sediments were sourced from the post-Santonian Abakaliki Anticlinorium (Nwamekwe et al., 2024). Over 2000 metres of sediments deposited in the Afikpo Sub-Basin were eroded from the uplifted Abakaliki Anticlinorium (Ohaegbulem et al., 2024). The Southern Benue Trough is enriched with industrial minerals of both sedimentary and magmatic origin, including ferruginized sandstone, calcareous sandstones, carbonaceous sandstones, kaolinite, hematite, feldspar, mica, and quartz (Onwualu-John & Nwosu, 2019). Diagenetic processes modified sediment texture and reservoir properties. The Eze-Aku sandstones show cement in the form of quartz overgrowths, authigenic clays, and feldspar, where feldspar dissolution produced silica and aluminium precipitated as quartz overgrowths and kaolinite respectively (Ejeh & Odigi, 2022). Smectite identified in Maastrichtian sediments of the Afikpo Basin is of hydrothermal or deuteric origin, inherited from weathered granitic basement rocks (Agibe et al., 2019). The Mamfe Basin, a southeastern branch of the Lower Benue Trough extending into Cameroon, records similar provenance patterns with sediments derived from the Oban and Obudu Massifs (Onyeka et al., 2024).

5.2 Paleocurrent Systems and Sediment Transport

Cross-bedding orientation and ripple asymmetry provide evidence of dominant paleoflow directions and sediment transport pathways within the Afikpo Basin. The Eze-Aku sandstones display basal lag deposits with fining-upward successions and planar cross-bedding, indicating unidirectional current transport (Ejeh & Odigi, 2022). The Afikpo Sandstone preserves planar cross-stratified and trough cross-stratified sandstone lithofacies, with trough cross-beds reflecting migrating sinuous-crested dunes under lower flow regime conditions (Okoro et al., 2020). Herringbone structures within the bioturbated cross-stratified lithofacies indicate bidirectional tidal currents, confirming tidal influence on sediment transport (Okoro et al., 2020). The Ajali Sandstone at Igbere-Abiriba exhibits tabular and planar cross-bedding with fining-upward sequences, and bivariate plots from grain size parameter combinations indicate a fluvial-river system dominated sedimentary process (Nwamekwe et al., 2024). At Akpoha, the sandstone outcrops are poorly to moderately sorted with angular to sub-angular grain shapes, giving clear indication of high-energy sediment deposition and short transport distance from provenance (Ohaegbulem et al., 2024). The NE-SW trending sandstone ridges of the Eze-Aku Group at Itigidi-Ediba, alternating with shale swales, reflect structurally controlled sediment dispersal patterns (Ejeh & Odigi, 2022; Ohaegbulem et al., 2024). Grain size analysis of the Eze-Aku Group shows moderate to poorly sorted sediments, positively skewed and mesokurtic to leptokurtic, deposited under moderate to high energy conditions with fluvial influence (Ejeh & Odigi, 2022). The cumulative frequency curves of the Ajali Sandstone show sediment populations dominated by saltation, confirming transport by traction currents (Nwamekwe et al., 2024). Paleocurrent systems were strongly influenced by tectonic uplift of the Abakaliki Anticlinorium, basin subsidence, and shoreline migration during transgressive-regressive cycles (Nkiru et al., 2021; Okoro et al., 2020). The Afikpo River serves as a modern analogue, functioning as a major conduit transporting sediments from the basin to the offshore area of the eastern Niger Delta (Okoro et al., 2020).

5.3 Regional Sediment Routing and Basin Connectivity

Regional sediment dispersal within the Afikpo Basin was controlled by tectonic relief, paleodrainage systems, and marine connectivity. The Santonian tectonic inversion uplifted the Abakaliki Anticlinorium and simultaneously created the Anambra Basin and Afikpo Sub-Basin as flanking depressions, establishing the primary sediment routing framework for post-Santonian deposition (Ohaegbulem et al., 2024; Onuigbo et al., 2020). Sediment thicknesses in the Afikpo Basin range from 513.9 m to over 3469.6 m, with the thickest units located around Bende, indicating preferential sediment accumulation in structurally controlled depocenters (Nkiru et al., 2021). The basin is partly sandwiched between the Southern Benue Trough and the Niger Delta Basin, establishing direct connectivity between these sedimentary systems (Okoro et al., 2020). The Afikpo River channel currently transports sediments from the basin to the offshore eastern Niger Delta, and similar fluvial conduits operated during the Cretaceous (Okoro et al., 2020). The Campano-Maastrichtian beds represent the third and terminal Cretaceous marine depositional cycle in the basins, with sediments constituting the pro-Niger Delta succession (Nkiru et al., 2021). The Mamfe Basin in southwest Cameroon forms a southeastern branch of the Lower Benue Trough and shares structural and sedimentary connectivity with the Afikpo Basin through the broader West and Central African Rift System (Onyeka and Emeka, 2025). Lineament analysis from radar imagery reveals NW-SE and NE-SW trending lineaments in the Afikpo Basin, with some rivers aligned along these regional lineaments, indicating structural control on drainage and sediment routing (Okoro et al., 2020). The interaction between fluvial sediment supply from the uplifted Abakaliki hinterland and marine reworking during transgressive phases influenced facies distribution and depositional architecture across the basin (Agibe et al., 2019; Onwualu-John & Nwosu, 2019). The repetitive transgressive-regressive sedimentary cycles in the Southern Benue Trough resulted in massive deposition of sediments of both continental and marine origin (Onuigbo et al., 2020; Onwualu-John & Nwosu, 2019). The northern Anambra Basin, connected to the Afikpo Sub-Basin through the broader Anambra system, received similar post-Santonian sedimentary fill including the Nkporo Group and Coal Measures (Obasi et al., 2024).

Table 2: Provenance indicators, paleocurrent evidence, sediment transport mechanisms, and tectono-sedimentary interpretation.

Provenance indicator	**Evidence from reviewed studies**	**Sediment transport mechanism**	**Tectono-sedimentary interpretation**	**Research significance**
Quartz, feldspar and rock-fragment proportions	Akpoha sandstones contain quartz 55-64%, feldspar 22-30%, and rock fragments 1-9%	Short-distance transport from nearby basement or uplifted sedimentary sources	Immature arkosic or feldspathic input reflects active relief and limited sediment recycling	Supports linkage between provenance maturity and basin-margin uplift
QFL modal composition	Eze-Aku sandstone average Q90F10L0 and sub-arkose classification	More mature sand delivery and partial reworking before deposition	Indicates progressive sediment sorting and textural maturation during basin filling	Useful for comparing reservoir quality across stratigraphic intervals

Mineral Maturity Index	Ajali Sandstone maturity index of 24-49, mature to supermature class	Longer reworking and removal of unstable ferromagnesian minerals	Signals high quartz enrichment and advanced sediment recycling	Supports interpretation of post-Santonian sediment recycling from uplifted hinterlands
Cross-bedding and ripple asymmetry	Planar, tabular and trough cross-bedding with fining-upward sequences	Traction-current transport through fluvial channels, estuarine currents, and migrating dunes	Records paleoflow organization and sediment-routing direction	Provides field-scale evidence for paleocurrent reconstruction
Herringbone structures and clay-draped foresets	Bidirectional tidal structures in Afikpo Sandstone lithofacies	Alternating flood and ebb tidal currents	Confirms tidal modulation of marginal-marine sand bodies	Strengthens estuarine and tidal-flat interpretation
Sediment thickness and depocenter distribution	Thicknesses from 513.9 m to more than 3469.6 m, with thickest units near Bende	Preferential accumulation in structurally controlled subsiding zones	Shows post-Santonian accommodation and depocenter migration	Connects tectonic inversion to sediment preservation
Lineaments and drainage alignment	NW-SE and NE-SW lineaments; rivers locally aligned along structural trends	Structure-guided drainage and sediment dispersal	Reveals structural control on paleodrainage and basin connectivity	Supports GIS-based paleogeographic reconstruction
Reservoir and petroleum-system indicators	Porosity 22.7% and permeability 745.43 mD in Eze-Aku sandstone; TOC values above source-rock threshold in Nkporo Shale	Depositional sorting, diagenesis, and burial history control reservoir and source potential	Links sediment routing, facies distribution, and petroleum-system development	Guides basin modelling and hydrocarbon prediction

Table 2 synthesizes provenance indicators, paleocurrent evidence, sediment transport mechanisms, and tectono-sedimentary interpretations. It relates quartz-feldspar-rock fragment proportions, QFL composition, maturity indices, cross-bedding, herringbone structures, sediment thickness, lineaments, and petroleum-system indicators to source terrain, transport distance, tidal influence, depocenter migration, and basin connectivity in post-Santonian sediment-routing models regionally. regional synthesis.

6. Emerging Perspectives and Research Gaps

6.1 Limited Integrated Basin-Scale Sedimentological Models

Most studies within the Afikpo Basin remain localized and lack basin-wide depositional synthesis. Okoro et al. (Okoro et al., 2020) focused on facies and reservoir potential of the Afikpo Sandstone at Macgregor Hill. Okolo et al. (Okolo et al., 2020) addressed lithofacies and grain size of the Eze-Aku Group at Itigidi-Ediba. Ejeh and Odigi (Ejeh & Odigi, 2022) examined reservoir characterization of the Eze-Aku sandstones through SEM and petrography. Ohaegbulem et al. (Ohaegbulem et al., 2024) studied sedimentary structures and provenance at Akpoha. Each of these studies addressed specific localities and specific stratigraphic intervals without connecting their findings into a coherent basin-scale depositional model. The sedimentology and reservoir quality of only two out of the three main sequences of the Afikpo Basin, the Asu River and Nkporo Groups, have received detailed study, while the Eze-Aku Group remains comparatively less integrated (Ejeh & Odigi, 2022). The tectonic setting, depositional facies, burial depths, mineralogical composition, basin fluids composition, and flow patterns all control diagenetic patterns and reservoir-quality evolution pathways (Ejeh & Odigi, 2022), yet no single study has synthesized these controls across the entire basin fill. Odigi and Momta (Odigi & Momta, 2019) applied radar imagery to tectonic and structural analysis of the basin, identifying lineaments, folds, and geomorphological units, but did not integrate these structural observations with sedimentological facies data. The Afikpo Sub-basin covers about 1000 km2 with a total sedimentary thickness of about 3 km (Okoro et al., 2020), and sediment thicknesses range from 513.9 m to over 3469.6 m based on aeromagnetic data (Ezeh et al., 2022). A basin of this scale and complexity demands an integrated depositional model linking tectonics, facies architecture, ichnology, and provenance across all three mega-sequences.

6.2 Weak Coupling Between Ichnology and Sequence Stratigraphy

Ichnological evidence remains underused in regional sequence-stratigraphic interpretation within the Southern Benue Trough. Trace fossil assemblages of Ophiomorpha, Skolithos, and Cruziana ichnofacies have been documented in the Eze-Aku Group at Itigidi-Ediba (Okolo et al., 2020) and Skolithos-Cruziana ichnogenera in the Afikpo Sandstone at Macgregor Hill (Okoro et al., 2020). These ichnofacies carry direct information about water depth, substrate energy, salinity, and oxygenation conditions that are essential for identifying systems tracts and key stratigraphic surfaces. The estuarine lithofacies associations of the Afikpo Sandstone show tripartite subdivision into mudflat, bayhead delta, and central estuarine deposits (Okoro et al., 2020), a pattern consistent with transgressive estuarine fill models used in sequence stratigraphy. The transgressive-regressive cycles documented in the Benue Trough (Nwamekwe et al., 2025) provide a framework within which ichnofacies data should be systematically placed. Trace fossils at Akpoha record different regressive and transgressive episodes (Ohaegbulem et al., 2024), yet these observations have not been tied to formal sequence boundaries or flooding surfaces. The bioturbation structures observed in the Ajali Sandstone at Igbere-Abiriba indicate tidal influence (Okoro et al., 2020), but no study has linked these ichnological signatures to specific parasequence stacking patterns. Future work should systematically integrate ichnofacies with vertical facies successions to define maximum flooding surfaces, transgressive surfaces, and sequence boundaries across the basin.

6.3 Need for High-Resolution Paleogeographic Reconstruction

High-resolution paleogeographic reconstruction of the Afikpo Basin remains absent from the published literature. Existing paleocurrent data are scattered across individual studies. The Amasiri Sandstone at Abini records a paleocurrent direction toward the SE (Nwamekwe and Nwabunwanne, 2025). The Ajali Sandstone at Igbere-Abiriba shows fining-upward sequences with cross-bedding indicating fluvial-river dominated transport (Okoro et al., 2020). The Eze-Aku sandstone ridges trend NE-SW (Ohaegbulem et al., 2024; Nwamekwe and Igbokwe, 2024), reflecting structurally controlled depositional geometries. Radar imagery identified NW-SE and NE-SW lineaments in the Afikpo Basin, with rivers aligned along regional lineaments (Odigi & Momta, 2019). Aeromagnetic studies revealed basement topography variations with sedimentary thicknesses between 2.3 and 3.2 km (Ezeh et al., 2022) and depths to centroid between 5.02 and 10.65 km (Ezeh et al., 2022). These datasets, when combined with stratigraphic correlation and paleocurrent mapping, would support digital paleogeographic reconstruction of the basin through successive time slices from the Albian to the

Maastrichtian. The Afikpo Basin connects structurally to the Anambra Basin through the broader post-Santonian depocenter system (Igbokwe et al., 2024), and paleogeographic models should capture this connectivity. Future studies should integrate all available paleocurrent, provenance, facies, and geophysical data into GIS-based paleogeographic maps for each depositional cycle.

6.4 Potential for GIS, Remote Sensing, and Digital Outcrop Analysis

Spatial technologies offer direct applications for improving depositional modeling, facies mapping, and structural interpretation in the Afikpo Basin. Odigi and Momta (Odigi & Momta, 2019) demonstrated the application of radar imagery to identify geological features including drainage patterns, geomorphological units, mega-lithostratigraphic units, lineaments, and structures not imaged by traditional ground field mapping. Their study mapped 280 lineaments in the Afikpo Basin and 415 in the adjacent Oban Massif (Odigi & Momta, 2019). Aeromagnetic data processing using reduction to equator, analytical signal, first vertical derivative, upward continuation, and 3D Euler deconvolution has been applied to evaluate subsurface structures and sediment thickness across the Southern Benue Trough (Ezeh et al., 2022). Spectral analysis of aeromagnetic data identified two distinct depth sources: shallower sources at 1.09 to 1.6 km and deeper sources at 1.61 to 4.90 km (Ezeh et al., 2022). These remote sensing and geophysical approaches should be extended to include digital outcrop modelling using LiDAR and photogrammetry, which would allow three-dimensional characterization of facies geometries, bedding architecture, and lateral facies transitions across the extensive sandstone ridges and shale swales of the basin. The Amasiri Sandstone alone extends over 8 km laterally (Okoro et al., 2020) and presents an ideal target for digital outcrop analysis. GIS-based integration of field data, remote sensing outputs, and geophysical models would strengthen facies mapping and structural interpretation across the basin.

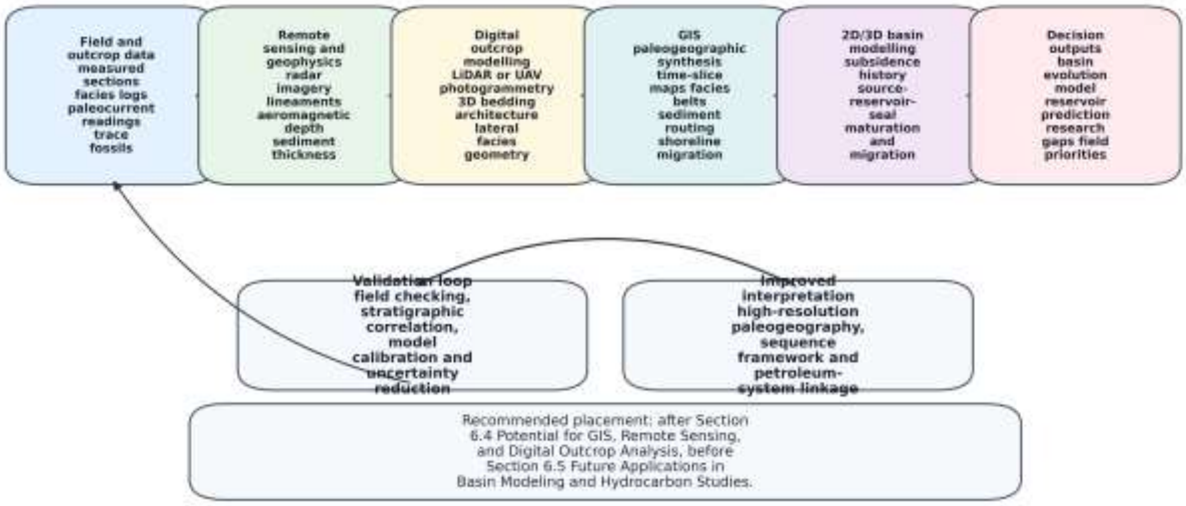

Figure 4: GIS, Remote Sensing, Digital Outcrop and Basin-Modelling Workflow for High-Resolution Afikpo Basin Reconstruction

Figure 4 proposes a digital workflow for high-resolution Afikpo Basin reconstruction. It integrates field logging, facies measurement, ichnology, paleocurrent data, radar imagery, aeromagnetic interpretation, digital outcrop modelling, GIS time-slice mapping, and 2D/3D basin modelling to improve paleogeographic reconstruction, sediment-routing prediction, reservoir characterization, and future research prioritization strategies robustly. Applications.

6.5 Future Applications in Basin Modeling and Hydrocarbon Studies

Integrated sedimentological models hold direct value for improving reservoir prediction and hydrocarbon exploration within the Southern Benue Trough. The Eze-Aku sandstones retain good reservoir properties with average porosity of 22.7% and permeability of 745.43 mD (Ejeh & Odigi, 2022). The Afikpo Sandstone shows porosity of 0.485 to 0.499 and permeability of 26.03 to 42.64 md (Okoro et al., 2020). The Nkporo Shale at Mgbom section has TOC values of 0.51 to 1.02 wt%, exceeding the minimum threshold for a potential source rock (Sunday & Chijioke, 2018). The Lokpanta Shale, the key petroleum source rock for the basin, shows vitrinite reflectance values of 1.87 to 4.78% Ro, indicating mature to overmature conditions (Okoro et al., 2020). Basin modelling by Amobi et al. revealed subsidence rates of 169.75 m/Mya during the Cenomanian-Turonian and 168.28 m/Mya during the Maastrichtian (Okoro et al., 2020). The southern Anambra Basin flank at Imiegba shows sandstone permeability of 307.18 to 724.85 Md and TOC values of 0.17 to 1.42 wt% (Igbokwe et al., 2024). The Dim et al. (2018) study identified signatures of source, reservoir, and seal rocks with structural and stratigraphic traps in the Anambra Basin (Okoro et al., 2020). Future basin modelling efforts should integrate these sedimentological, geochemical, and geophysical datasets into 2D and 3D models to predict reservoir distribution, source rock maturation, and migration pathways across the Afikpo Basin and its connection to the Niger Delta petroleum system.

7. Conclusion

This review establishes that the Afikpo Basin and Southern Benue Trough evolved through a tightly coupled tectono-sedimentary system in which rifting, Santonian inversion, post-inversion subsidence, sea-level fluctuation, and sediment supply jointly controlled basin architecture. The evidence shows that the Santonian compressional event was the main turning point. It uplifted the Abakaliki Anticlinorium, shifted depocenters into the Afikpo and Anambra basins, and created the accommodation space that later received thick post-Santonian clastic successions. The sedimentological record confirms a transition from marine shelf and deeper basin sedimentation to fluvial, deltaic, estuarine, tidal-flat, shoreface, and shallow-marine systems. Cross-bedding, ripple lamination, mud cracks, flaser bedding, herringbone structures, basal lag deposits, and bioturbated heteroliths collectively show repeated changes in current direction, water depth, sediment supply, and shoreline position. These structures support the interpretation of a basin repeatedly shaped by transgression, regression, tidal modulation, and fluvial sediment input. The ichnological evidence strengthens this reconstruction. Skolithos, Ophiomorpha, Cruziana, Planolites, Chondrites, and Thalassinoides indicate variable substrate consistency, oxygenation, salinity, energy level, and marine influence. Their association with cross-stratified and heterolithic facies confirms that biological and physical sedimentary signals must be interpreted together, especially in marginal-marine successions. Provenance and sediment-routing evidence further indicate active sediment supply from uplifted basement and sedimentary source areas, especially the Abakaliki Anticlinorium and adjoining massifs. Quartz-feldspar-rock fragment proportions, QFL maturity patterns, paleocurrent indicators, NE-SW sandstone ridges, and structurally guided drainage systems show that tectonic relief strongly controlled sediment dispersal and basin connectivity. The major contribution of this review is the integration of tectonics, stratigraphy, facies analysis, ichnology, provenance, paleocurrents, sequence stratigraphy, and digital basin-modelling needs into a unified framework for interpreting the Afikpo Basin. Future work should prioritize basin-wide facies correlation, ichnology-guided sequence stratigraphy, GIS-based paleogeographic mapping, digital outcrop analysis, and 2D or 3D basin modelling to refine depositional architecture, reservoir prediction, and regional sediment-routing history.

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