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Sedimentology of a Basin-Margin Lacustrine Fan-Delta Depositional System in the Campano-Maastritchian Bida Formation, Bida Basin, Nigeria

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Abstract

Basin margin sedimentary deposits are increasingly recognized as holding significant potential for both hydrocarbon source and reservoir rocks, depending largely on the prevailing paleogeographic and depositional conditions. Despite their importance, the depositional environments of sedimentary successions along the eastern margin of the Bida Basin, particularly around Lapai, have not been systematically documented. This study addresses that gap by examining part of the eastern margin basin fill through detailed field investigations and facies analysis of relatively well-exposed outcrops. The analysis led to the recognition of seven lithofacies, which were further grouped into three genetically related facies associations: (i) offshore lacustrine, (ii) subaqueous fan-delta, and (iii) subaerial fan systems. The offshore lacustrine association is dominated by mudstone facies (Fm), massive sandstone (Sm), and normally graded gravelly sandstone (Sn). These facies are interpreted as the products of suspension settling, hyperconcentrated density flows, and turbidity currents, respectively. The subaqueous fan-delta association is characterized by the intercalation of debris-flow deposits (Facies Gmu, Sm, and Sn) with fine-grained mudstone and siltstone intervals (Fm), reflecting the interplay between mass-flow processes and background lacustrine sedimentation. In contrast, the subaerial fan association is represented predominantly by ungraded, matrix-supported conglomerates (Gmu) and pebbly to massive sandstones (Sm), with occasional trough cross-bedded conglomerates (Gt) and minor mudstone intercalations (Fm). The observed vertical stacking pattern of these associations indicates a progressive progradation of alluvial fan systems into the lacustrine environment, reflecting a dynamic interplay between tectonic activity, sediment supply, and lake-level fluctuations along the basin margin. From a petroleum system perspective, the subaqueous fan-delta association is interpreted as the most prospective target for conventional hydrocarbon reservoirs, owing to its textural heterogeneity and potential for sand-rich channelized deposits. Meanwhile, the offshore lacustrine facies association holds significant potential for unconventional hydrocarbon resources, especially as organic-rich fine-grained intervals could act as both source rocks and tight reservoirs. Overall, this work underscores the importance of integrating detailed outcrop-based facies analysis with paleoenvironmental reconstructions to generate robust conceptual paleogeographic models. Such models are invaluable in assessing the petroleum potential of basin-margin successions, particularly in underexplored frontier basins like the Bida Basin.

Keywords
Bida Basin,
Lapai,
Alluvial Fan,
Fan-Delta,
Debris Flow,
Hyperconcentrated Flow

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Introduction

Researches dealing with hydrocarbon exploration in basins dominated by continental deposits commonly focus on thick fluvial sedimentary successions deposited towards basin centres because basin margin deposits display poorer reservoir quality (Moscariello, 2005; Gao *et al.*, 2020). Published research papers highlighting the paleogeographic reconstruction of the northern part of Bida Basin which are helpful to hydrocarbon exploration have also focused more on the central part of the basin (e.g., Adeleye and Dessauvagie, 1972; Adekeye, 1974; Adeleye, 1989; Braide, 1992a; Braide, 1992b; Braide, 1992c; Akande *et al.*, 2005; Ojo and Akande, 2006; Ojo and Akande, 2008; Ojo, 2012; Okosun *et al.*, 2009: Obaje *et al.*, 2013; Obaje *et al.*, 2015; Goro *et al.*, 2014; Goro *et al.*, 2015; Goro *et al.*, 2017; Abdullahi *et al.*, 2020).

The basin margin areas are therefore understudied and underexplored as well. However, recent discoveries in basin margin alluvial fan deposits in several basins around the world suggests that these deposits have a lot of potentials for hydrocarbon (e.g., Howard *et al.*, 2003 and Moscariello, 2005).

The sedimentology of the alluvial fan to lacustrine deposits of the northern margin of Bida Basin was documented by Braide (1992a). However, the basin margin deposits of the eastern margin of the basin around Lapai (Fig. 1) have not been studied. The paleogeography of these deposits is crucial to hydrocarbon exploration in the basin because very thick laterally continuous sandstones and conglomerates that inter-finger with lacustrine mudstones offer good potentials for reservoir and source rocks.

The recent discovery of dark grey mudstone intervals beneath the regionally extensive Bida Formation near Lapai led the researchers to further explore the sedimentological characteristics of the basin margin succession around Lapai. The aim of the study is to produce a paleogeographic model of the studied interval through detailed lithofcaies analysis of the outcropping sedimentary succession. Specific objectives include identification of lithofacies, delineation of facies associations and determination of environment of deposition of the conglomerates, sandstones and mudstones exposed in the area.

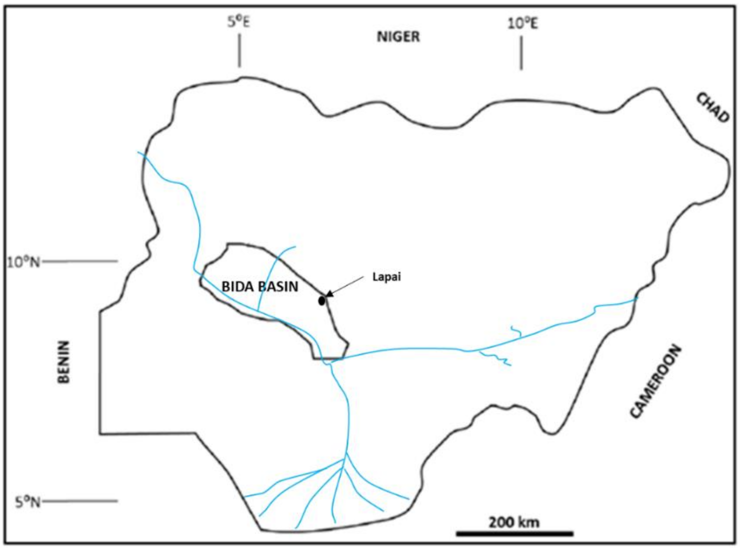

Figure 1. Map of Nigeria showing the approximate location of the study area

Geological Setting

The Bida Basin is a linear structure about 350km long and between 75-150 km wide trending NW-SE approximately orthogonally to Benue Trough (Zaborski, 1998) and situated between Sokoto and Anambra basins (Fig. 1). Various lines of evidence were given by different authors on the origin of this basin. A simple sag structure was proposed by Whiteman (1982). On the other hand, Braide (1990) postulated that it formed as a result of strike-slip tectonics. He divided the basin into three sub-basins each of which is characterised by proximal, mid and distal alluvial facies culminating in lacustrine and flood-basin deposits. Conversely, rift origin has been favoured by most works (e.g., Ojo & Ajakaiye, 1976, Ojo 1990, Genik, 1992, and Adegoke *et al.,* 2015).

This has been confirmed by recent subsurface seismic data acquired and interpreted by the Nigerian National Petroleum Company (NNPC). This basin is therefore better regionally understood to be part of the West and Central African Rift System.

The stratigraphic subdivision of the Bida Basin in the northern and southern parts are summarised in Figure 2. Recent subsurface data from NNPC revealed the presence of a marked angular unconformity separating the pre-Santonian from post-Santonian sedimentary successions of the basin. The Bida Formation is commonly described as composed of the older Doko Member overlain by the Jima Member. Around the central part of the basin, the typical Doko Member consists predominantly massive, poorly sorted medium to very coarse-grained sandstones which are pebbly and arkosic in part with localised crossing stratification. This member has been inferred to be deposited in braided river channel system (Adeleye, 1975); Okosun *et al.,* 2009; Goro *et al.,* 2014; 2015). The pebbles are mostly rounded to sub-rounded (e.g., Abdulahi *et al.,* 2020).

The sandstones of the Jima Member on the other hand are arenaceous, fine to coarse grained with widespread cross bedding interpreted to be deposited in meandering river system (Adeleye, 1975); Okosun *et al.,* 2009). The work of Braide (1992c), however observed that the Bida Formation at the margins of the basin do not conform to the general observations in the central area.

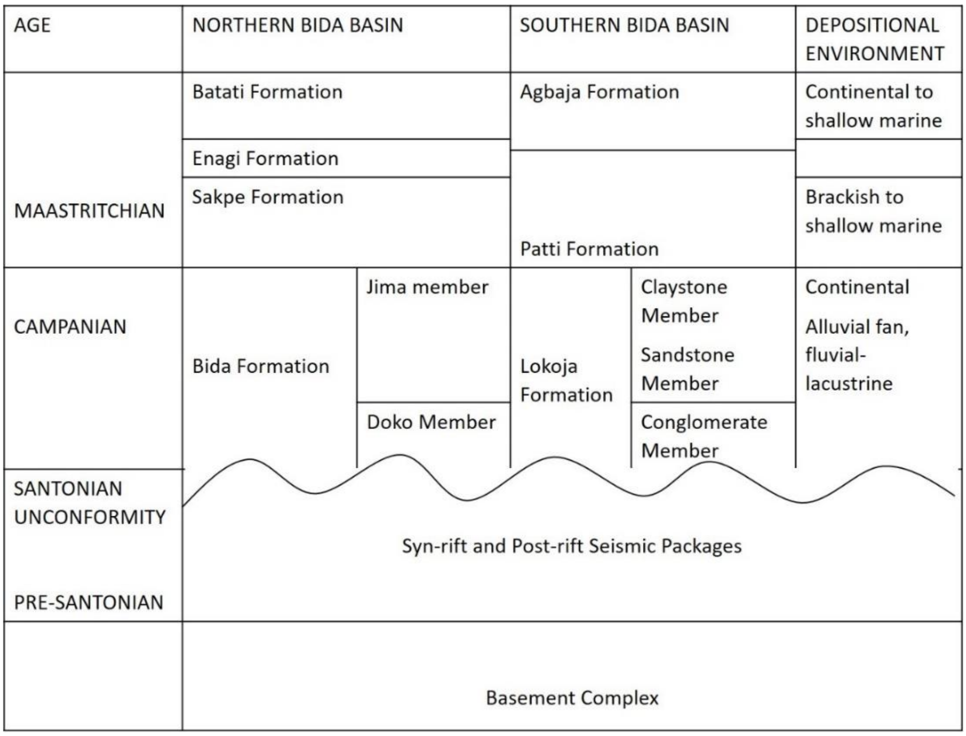

Figure 2. Lithostratigraphic subdivisions of the Bida Basin (Modified from Akande, 2003).

Methods

The study area is located in the eastern flank of the Bida Basin near Lapai in Niger State, Nigeria (Figure 1). It can be accessed through Paiko-Lapai road which is off Abuja-Minna Trunk "A". It can also be accessed off Lambata-Mokwa Trunk "A" road at Lapai. It is about five kilometres away from Lapai on Paiko-Lapai road.

Detailed outcrop facies analysis of the study area was conducted to evaluate the depositional history of the basin-margin conglomerates, sandstones and mudstones exposed in streams, gullies and road-cut sections. Sedimentological observations such as lithology, texture and structures were documented as graphic logs and a composite sedimentologic log was produced. Facies and facies associations were delineated from the lateral and vertical stacking of the sedimentary succession following the scheme of Dalrymple (2010). Lithofacies were identified and assigned codes based on Miall (1996; 2006) and Horton (1996). Processes of deposition were interpreted from the identified facies followed by analysis of facies associations from which related depositional processes within the ancient environments were evaluated to produce a depositional model for the sedimentary units.

4.0 Results and Discussion

Documentation of the detailed bed-to-bed characteristics of the study interval led to the identification of seven (7) sedimentary facies, from which three (3) genetically related facies associations were delineated. Evaluation of the spatio-temporal stacking of the facies associations suggests deposition of the study interval in ancient alluvial to fan-delta setting. Field observations are detailed in a composite sedimentological grahic log in Figure 3 and a summary of the characteristics of the facies are displayed in Table 1.

Table 1: Lithofacies of the outcropping parts of the Bida Formation in the eastern margin of the Bida Basin around Lapai

Facies	Facies Name	Description	Interpretation
Gmu	Ungraded matrix-supported conglomerate	Poorly sorted granule-pebble conglomerate, ungraded to crude inverse grading	Cohesive debris flow
Gcu	Ungraded clast-supported conglomerate	Poorly sorted granule-pebble conglomerate, ungraded	Cohessionless debris flows, Hyperconcentrated flows
Gcn	Normally graded clast-supported conglomerate	Moderately sorted granule-pebble conglomerate, normal grading (coarse tail), horizontal alignment of pebbles	Hyperconcentrated flows
Gt	Trough cross bedded conglomerate	Poorly sorted granule to pebble conglomerate, trough cross bedded	Gravel bar and bedform
Sm	Massive sandstone	Fine to very coarse grained sandstone, no grading, no stratification, scattered granule-pebble clasts, outsized gravel clasts	Hyperconcentrated flows, turbidity currents
Sn	Normally graded gravely sandstone	Fine to coarse grained sandstone with gravels, normal grading, no stratification. Basal gravel clasts	Hyperconcentrated flows, turbidity currents
St	Cross bedded sandstone	Fine to coarse grained sandstone, trough cross bedded	Migrating dunes
Fm	Mudstone	Mudstone, massive and laminated types, light grey to dark grey	Suspension settling, waning flood flow

4.1 Facies

4.1.1 Facies Gmu - Ungraded matrix-supported conglomerate

These facies consist of very poorly sorted matrix supported conglomerates having angular to sub-angular clasts with size ranging from 2-6mm. The clast do not show imbrication. Matrix is composed of muddy fine-grained sandstones. Thick, up to 0.5m beds occurs directly overlying the basement complex rock (Fig. 3, 4F.). Weak inverse grading may be discernable (Fig. 4F). Thinner units of this facies showing planar non-erosional contacts occur interbedded with Fm, Sm, Gcu facies in the middle part of the study interval (Fig. 3).

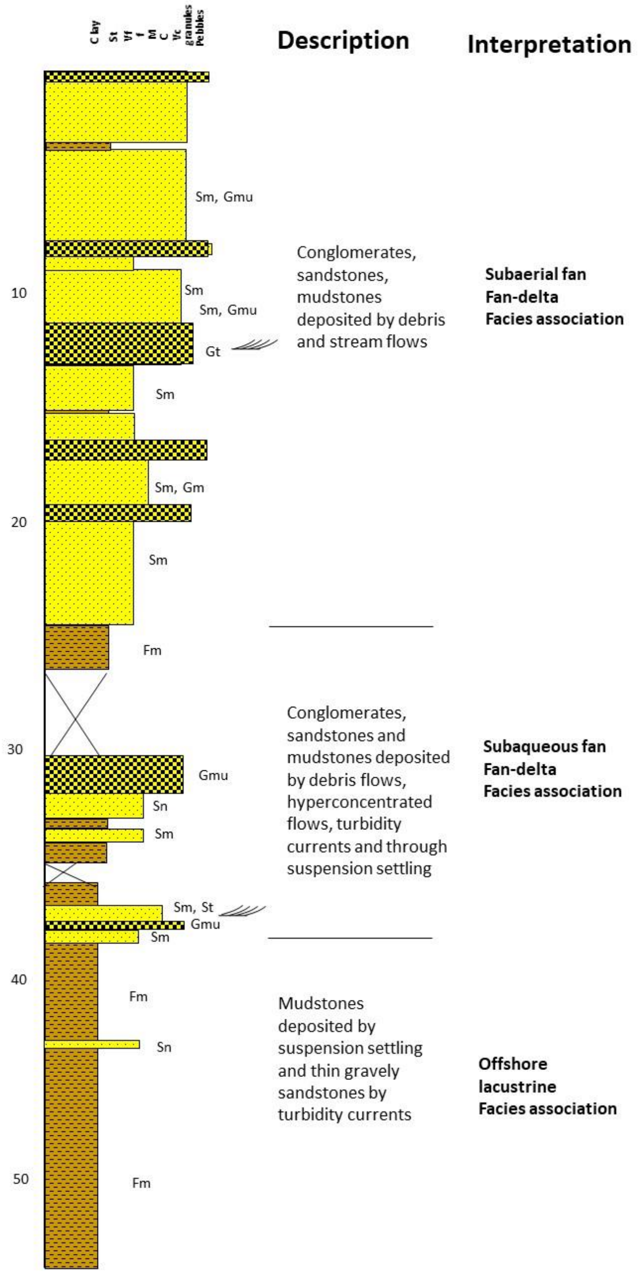

Figure 3. Interpreted sedimentological graphic log of basin margin deposits around Lapai, Bida Basin, Nigeria

Interpretation

This facies is interpreted as product of deposition by either subaerieal or subaqueous plastic debris flows (Gloppen and Steel, 1981; Ghibaudo, 1992). Non erosional contact and lack of imbrication is indicative of deposition by non-turbulent, laminar flow (Enos, 1977).

4.1.2 Facies Gcu - Ungraded clast - supported conglomerate

This facies is composed of massive, matrix rich, clast-supported conglomerate (Fig. 4H). The moderately sorted gravels range from granule to pebble size and display subangular to subrounded shapes while the matrix is muddy sand occurring commonly surrounding the clasts. The clasts do not show imbrication. Beds are 5-20cm thick and display planar, non-erosive basal contacts. This facies is interbedded with Gmu, Sm, Fm in the middle part of the study interval while in the upper part, it occurs overlying lenticular scour surfaces or associated with thickly bedded facies Sm beds (Fig. 3.)

Interpretation

Subaerial clast-rich, plastic debris flows have been invoked to have deposited this facies (e.g., Warensback and Turbeville, 1990). Similar facies with granule-pebble clasts, and rich in matrix has been interpreted as product of subaerieal hyperconcentrated flows (Horton, 1996). Both matrix strength and buoyancy due to clast rich nature combine to provide support mechanism for the sediments (Lowe, 1982).

4.1.3 Facies Gcn – Normally graded clast-supported conglomerate

Facies Gcn consists of moderately to poorly sorted, clast-supported conglomerates with normal grading. The grading is coarse tail type and the gravel clasts range from granule to pebble sizes. The beds do not show stratification nor clast imbrication but horizontally aligned pebbles are often seen. The facies is associated with Gmu, Gcu, and Sm facies in the upper part of the study interval. Beds display non-erosional boundaries often marked by sharp grain size differences (Fig. 4G).

Interpretation

This facies is interpreted to be deposited by hyperconcentrated flows (Waresback and Turbeville, 1990; Horton, 1996). The matrix rich, massive nature of these deposits further indicate turbulence inherent in hyperconcentrated flows where dispersive pressure and buoyancy combined with turbulence play a vital role in sediment support (Smith, 1986)

4.1.4 Facies Gt – Trough cross bedded conglomerate

This facies consists of trough cross stratified matrix rich gravel bed (Fig. 4C). The matrix is sandy while the clasts are granule to pebbly. It is associated with facies Gm and Sm and displays wedge shape (Fig. 3; 4C). This facies is a minor facies at the studied locality and is described from only one bed. The bed boundary is not clear but appear to be flat.

Interpretation

The facies Gt represent gravel bars and bedforms which are commonly the infill of minor channels or product of migration of curve-crested transverse bars (Miall, 1996).

4.1.5 Facies Sm – Massive sandstone

Facies Sm consists of massive, moderately to poorly sorted, medium to very coarse grained sandstones most of which contain scattered gravels (commonly granule to pebble sized). Some beds show outsized pebble clasts. This facies occurs as lens to sheet bodies with thicknesses ranging from 0.5cm in the lower portion of the study interval to more than 1m in the upper half (Fig. 3; 4B, D). Indistinct boundaries between amalgamated units may develop up to 4m thick units. A common feature in this facies is discontinues lenses of clast-supported, 2-5cm thick conglomerates which may be traced for few meters horizontally.

Interpretation

Lowe (1982) and Smith (1986) interpreted Sm facies as resulting from rapid deposition from turbulent suspension. The absence of internal stratification is attributable to lack of enough time to develop bedforms.

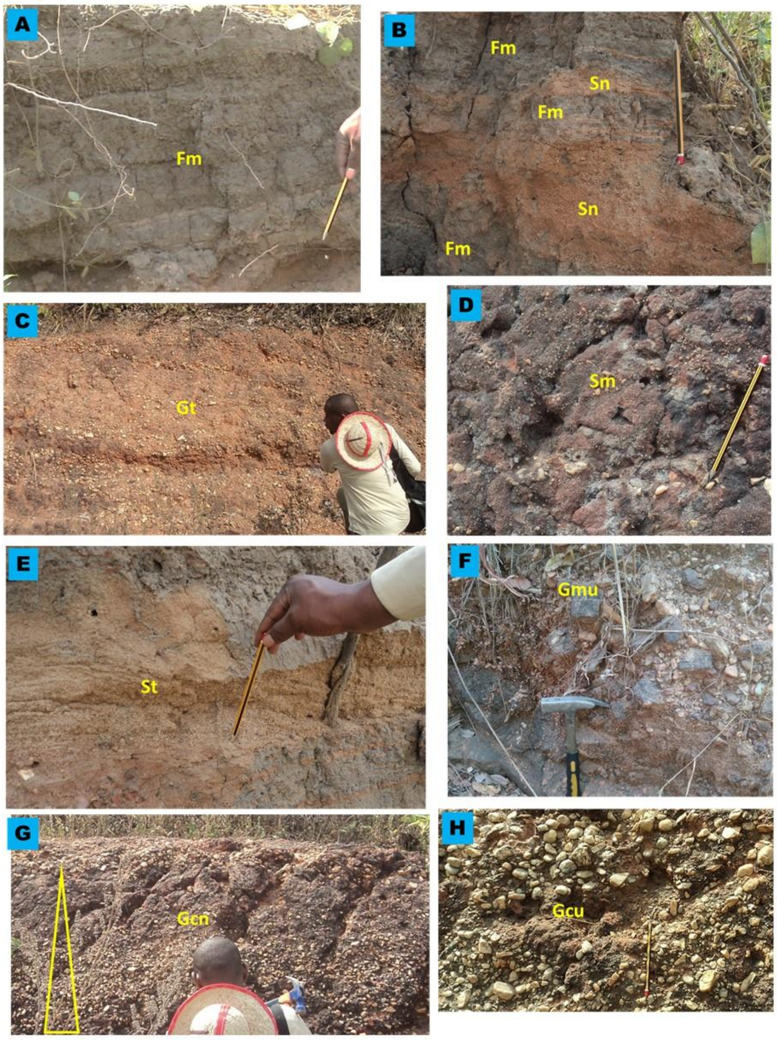

Figure 4 Lithofacies types [A] Facies Fm; [B] Facies Sn (Normally graded sandstone) interbedded with Facies Fm Mudstone); [C] Facies Gt (Trough cross bedded conglomerate); [D] Facies Sm (Massive sandstone); [E] Facies St (Trough cross bedded sandstone); [F] Facies Gmu (Ungraded matrix supported conglomerate); [G] Facies Gcn (Normally graded clast-supported conglomerate); [G] Facies Gcu (Ungraded clast-supported conglomerate).

4.1.6 Facies St – Trough cross bedded sandstone

This facies is characterised by trough cross bedding (Fig. 4E) and it is a rare facies in the study interval. It is associated with the upper parts of Sm and Sn facies occurring within interbedded mudstones of facies Fm in the middle part of the study interval (Fig. 3).

Interpretation

Facies St is interpreted as product of migration of 3D dunes (Miall, 1996). Its association with facies Fm suggest deposition in subaqueous environment.

4.1.7 Facies Fm – Mudstone

This Fm facies consists of mudstone lithology and may display massive or laminated structure. It occurs as massive, light grey to dirty white thin laterally discontinuous beds associated with Sm, Gcn, Gmn facies in the upper part of the study interval. It also occurs as dark to dark grey, very thickly bedded intervals in the lower stratigraphic portion of the study interval (Fig. 3; 4A, B). Here the beds displays either massive or laminated structure and may be contorted. In the middle part of the study interval, this facies is associated with thin bedded gravely sandstones of facies Sm, Sn and St (Fig. 3).

Interpretation

This facies represent suspension sedimentation in quiet water environment of waning flow deposits (e.g., Horton, 1996).

4.2 Facies Associations

4.2.1 Offshore lacustrine

This facies association is dominated by thick beds of facies Fm with subordinate occurrence of thin beds of facies Sn and Sm, some of which are gravelly (Fig. 5). The predominance of grey mudstones and lack of marine indicators suggest deposition by suspension settling of mudstones in generally low energy offshore lacustrine accompanied by intermitted turbidity currents depositing the thin sandy layers (e.g., Horton, 1996). Up to 20 m of this association is encountered in boreholes around the study area.

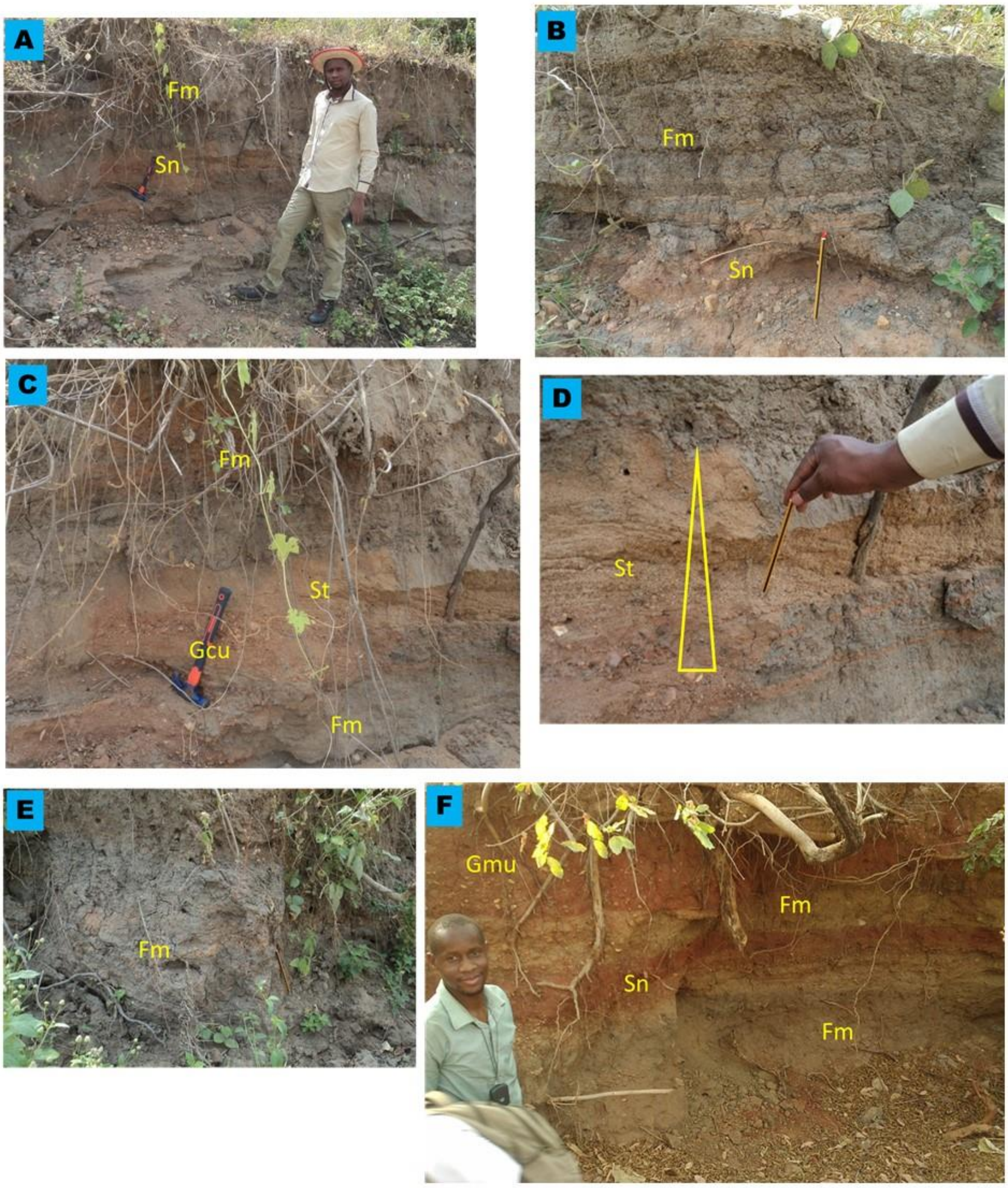

Figure 5: Subaqueous facies association [A] Facies Fm (massive type interbedded with facies Sn; [B] Facies Fm (Laminated type) interbedded with Sn; [C] Facies Gcu overlain by St occurring within thick facies Fm; [D] Close-up view of facies St; [E] Contorted mudstone (Fm) interval; [F] Facies Fm interbedded with facies Sn and Gmu.

4.2.2 Subaqueous fan-delta facies association

The features of debris flow deposits associated with subaqueous environments is similar to those deposited in subaerieal environments. However, notable subtle differences have been documented to distinguish subaerieal from subaqueous debris flow deposits (e.g., Nemec and Steel, 1984). These authors observed that subaqueous fan-delta deposits are commonly distinguished by the the following features: association of debris flow deposits with turbidites interbedded with fossiliferous layers, bioturbation, and presence of wave-generated structures interlaying or at least common presence of mud/silt interbeds or partings, upwards gradual increase in matrix content in graded beds as against sharp contrasts in subaerieal debris flow deposits, interbedding of debris flow deposits with mudstone/siltstone as well as sandstone beds, the presence of deformed mudstone layers.

In the present study, the subaqueous fan delta facies association is recognised by the interbedding of debris flow deposits (Facies Gmu, Sm, and Sn) with mudstone/siltstone (Facies Fm) (Figs. 3, 5A, B, C, F); the presence of deformed mudstone layers (contorted beds of facies Fm, Fig. 5E); the generally, better internal organization of sedimentary structures (grading, fining-up, cross stratification Fig. 5). The better internal organisation of the sedimentary structures in this FA reflects the tendency for evolution of the debris flows into turbidity currents. This commonly happens in the subaqueous environment when the flow loses strength. This phenomenon often leads to the deposition of sand rich beds by suspension settling or traction sedimentation of high density turbidites as indicated by the fining-upwards from facies Gcu to St (Fig. 5C, D) and facies Sn (Fig. 5A, F). Rapid deposition of the facies Sn and Sm might have prevented the development of complete Bourma Sequence in these turbidites (Horton, 1996). Also, within the thick mudstone lower interval of this section (Fig. 3), the sharp based, isolated, discontinuous sand rich gravelly beds may indicate beds deposited by distal splitting of debris flows. This happens where initially thick non-cohesive, debris flows splits in more distal positions into smaller beds that are commonly embedded within thick lacustrine mudstones (Nemec and Steel, 1984).

4.2.3 FA3 – Subaerial fan-delta facies association

This facies association consists of facies Gmu, Gt, Sm and Fm. The Fm and Gt facies are minor components while the Gmu and Sm facies predominate. The association of Gt, Gmu and Sm facies indicate the combination of gravel bars and bedforms and sediment gravity flows (GB and SB architectural element, of Miall, (1985), this strongly suggests deposition in subaerieal alluvial fan environment. The association of GB and SG elements as as well as facies Gcn in the upper portion of the study interval (Fig. 3, 6) is a common feature of the upstream part of alluvial fan depositions setting (Miall, 1985; Miall, 1996). The laterally restricted, rare facies Fm in this association represent abandoned channel fills (e.g., Miall, 1985; 2006) (Fig. 6B, C).

Figure 6. Subaerial facies association [A] Facies Sm interbedded with facies Gcu; [B] Facies Sm interbedded with are facies Fm; [C] interpreted view of B showing laterally restricted facies Fm; [D] Upward fining from gravel to sandstone in facies Gcn; [E] Facies Gcu on curved erosional base; [F] Gravel lenses within massive sandstones.

The upward fining from clast-supported conglomerates to coarse grained sandstone observed in facies Gcn (Fig. 6D) are probably resultant from gradual abandonment of sediments of braided alluvial system (Rust and Koster, 1984) or they may represent simple waning of very large floods which are common to these areas (Nemec and Steel, 1984). Bedload deposition from stream flows have been attributed to similar units (e.g., Reading and Collinson, 1996). Facies Gcu overlying lenticular erosional surfaces (Fig. 6E) record debris flows with clast-support fabric deposited in small ephemeral distributary channels or gully fills associated with subaerieal fan depositional setting (Horton, 1996).

The common occurrence of thin gravel lenses within the facies Sm (Fig.6F) may represent products of elutriation due to water escape during compaction of the water rich hyperconcentrated flows that deposited them. Deposition in fluvial fan settings are attributable to migration of permanent and intermitted channelised streams due to random channel shifting, crevassing and bar development within the channels as indicated the interaction of these processes by this facies association (e.g., Reading, 1996).

Discussion

Depositional Model

The vertical stacking of the facies associations from offshore lacustrine to subaqueous fan delta to subaerieal fan-delta provide key evidences for deposition of the study interval in a fan-delta depositional setting. Leeder (1999) described fan deltas as alluvial fan bodies prograding into and interacting with standing body of water which could be lake or marine. In the study area, the alluvial fan developed in normal fault bounded margin of the Bida Basin near Takuti village and prograded southwestward into a Cretaceous lake located around Lapai and beyond (Fig. model). The facies stacking pattern depicted by this study suggests that the alluvial fan dominated by subaerieal debris flow and stream flow deposits (Gcu, Gt, Gmn, Sm) prograded from the Basement rocks around Takuti depositing the subaerieal fan facies association. However, at Gada-Biyu area, the occurrence of subaqueous fan facies association record the interaction of debris flow and suspension fallout sedimentation in the ancient lake (Fig.).

This model indicates that the subaqueous fan delta was the transition between subaerieal fan and offshore lacustrine environment with the subaqueous fan delta representing the phase of progradation of subaerieal fan into the lake. The contorted bedding observed in the subaqueous facies association is indicative of rapid deposition inherent delta front environment (Postma, 1983). Studies by Larsen and Steel (1978) and Pivnik (1990) documented facies associations with similar attributes. The direct transition from subaqueous facies association to subaerieal facies association without and intervening nearshore deposits suggests that the ancient lake was either shallow or the gradient between the basin margin and the lacustrine environment was gentle preventing large waves from reworking the sediments at the nearshore (e.g., Horton, 1996).

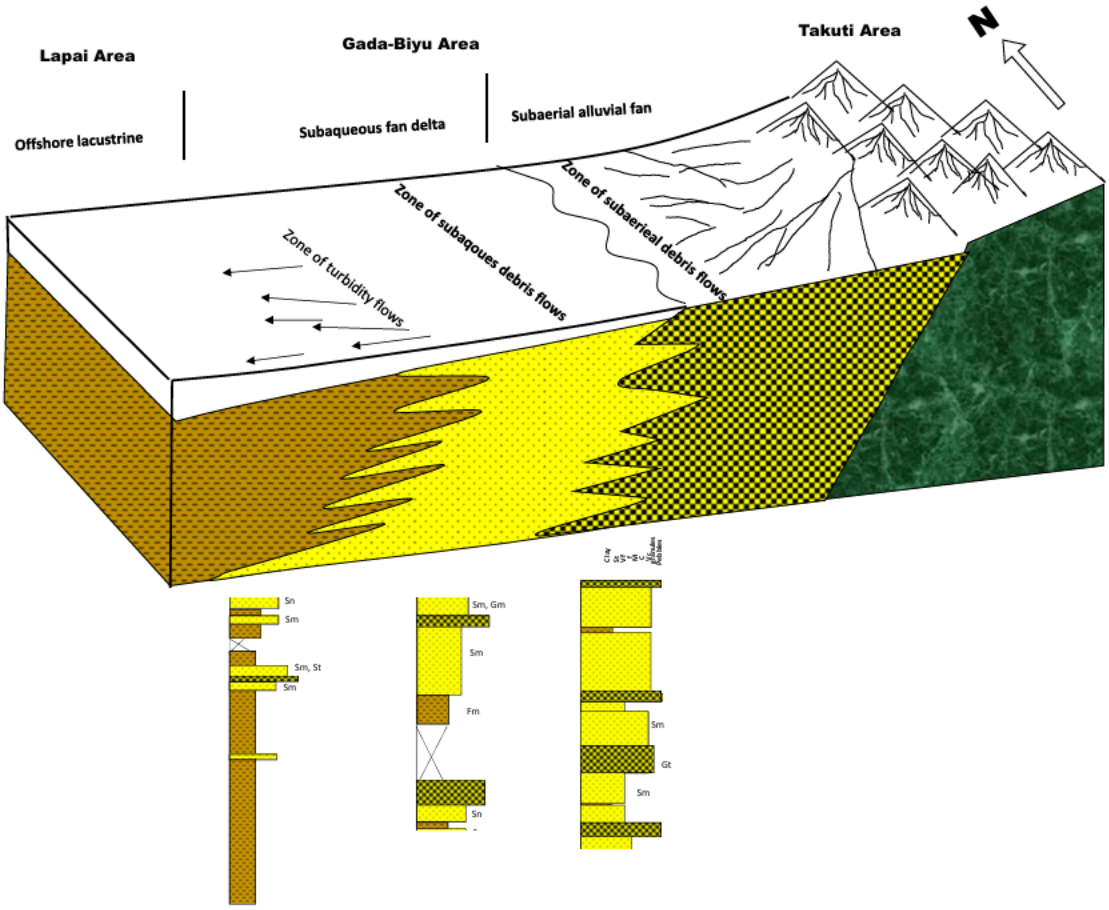

Figure 7. [A] Paleoenvironmental reconstruction and approximate position of logged sections of basin-margin deposits around Lapai, Bida Basin, Nigeria.

The occurrence of pebbly sandstone units of Doko Member of Bida Formation stratigraphically above the study interval as indicated by field relations and the work of Olawoki *et al.* (2022) demonstrates the progressive downstream reduction in grain size and change from upstream sedimentation at the fan head to downstream sedimentation in subaerial alluvial fan setting (Miall., 1985; Reading, 1996). The internal architecture of the sandy braided river deposits of Bida Formation is detailed in Goro *et al.* (2014). These sandstone dominated interval unit and compound bars built by longitudinal and transverse dunes deposited in braid plain setting of fluvial fan (e.g., Boothroyd and Ashley; Okosun *et al.*, 2007 and Goro *et al.*, 2014).

Hydrocarbon implication

Exploration strategies in the alluvial fan to lacustrine deposits of the study interval and the overlying fluvial (braided river) dominated succession of the Doko Member of Bida Formation are expected to be different because the former is laterally restricted in its occurrence while the later has basin-wide occurrence. Mascarillo (2015) noted that very thick alluvial-lacustrine sedimentary successions (similar to the study interval) are commonly well preserved due to high subsidence rates in fault bounded rift basins with great potential for hydrocarbon gas but are commonly not more than 15 km in extend. Potentials, therefore, exist for both conventional and non-conventional hydrocarbon resources in the study interval. For conventional hydrocarbon, potential reservoir rocks and stratigraphic traps are offered by gravelly to sandy turbidites (Facies Gmu, Sn, Sm, St) encased within lacustrine mudstones (Fm) of the subaqueous fan delta and offshore lacustrine facies associations while good source rock potentials are offered by the lacustrine mudstones at deeper levels.

Good, potential intra-formational seal rocks may be provided by the lacustrine shales. In the overlying subaerieal debris flow facies association, however, good reservoir potentials are offered by gravelly stream and hyperconcentrated flow deposits but rare seal lithologies offer potential risk for conventional hydrocarbon exploration. Nonetheless, great potentials exist for oil-shale (non-conventional hydrocarbon) in the thick grey lacustrine mudstones of the study area. Similar occurrence with oil-shale rich lacustrine mudstones have been documented by Glenmie (1998).

Conclusions

Recent hydrocarbon discoveries in basin-margin areas globally has led to increased exploration interest in these areas. The good prospectively for both source and reservoir elements inherent in theses deposits depends on the paleogeographic condition of deposition. This study evaluated the paleoenvironmental conditions of deposition of basin-margin sedimentary succession exposed near Lapai at the eastern margin of Bida Basin. Detailed facies analysis of fairly good exposures seen on stream and road cuts reveal the presence of conglomerates, sandstones and mudstones deposited by debris flows, stream flows and suspension fallout in subaerieal and subaqueous alluvial to lacustrine environment. A fan-delta depositional setting was inferred from the vertical stacking of the offshore lacustrine to subaqueous fan-delta to subaerieal fan-delta facies associations delineated at the study area. The proposed depositional model offer important insights into the role these deposits would play in terms of exploration for conventional and non-conventional hydrocarbon. Potentials exist for source, reservoir and seal rocks especially within the offshore to subaqueous fan delta associations but potential exploration risks are associated with the subaerieal fan deposits due to lack of seal lithologies. Great potentials however exist for oil-shale provided by the thick grey lacustrine mudstones.

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