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New Data on the Stratigraphy of the Ameki Group, Se Nigeria: Implications for the Eocene Stratigraphic Nomenclature

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Authors' contributions

This work was carried out in collaboration among all authors. Author GCO designed the study and wrote the protocol. Authors OASO and GO managed the analysis. Authors UCJ and OASO wrote the first draft of the manuscript. Author UCJ managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Detailed down-dip, bed-by-bed sedimentary logging of outcrops of the Ameki Group in the Awka-Onitsha area of south-eastern Nigeria, was performed to identify and characterize components of the Group in the area. Thirteen exposures were measured and analyzed for lithological changes, composition, sedimentary structures, trace fossils, and stratigraphic surfaces. Stratigraphic analysis shows that the Ameki Group in the study area consists of two stratigraphic components- a basal sandstone component (> 200m) and an overlying mud rock component (>20m). Facies analysis reveals that the sandstone component consists of two facies associations: (i) a tidally-influenced channel facies association comprising strongly ferruginized, pebbly- to medium grained, fining-upwards sandstone that is inter-bedded with kaolinitic claystone and ironstone of variable thickness and(ii) sand-rich heterolithic facies association that reflects sand flat sedimentation. The mud rock component of the Ameki Group also contains two facies associations: (i) clay-rich heterolithic facies association that reflects deposition in mixed flats and (ii) carbonaceous claystone-lignite facies association that reflects mudflats and swamp sedimentation. Field relations and facies analysis

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confirm that the contact between the channelized, basal sandy component of the Ameki Group and the underlying Imo Formation is defined by the upward transition from dark-coloured, fine grained marine facies, to coarse grained fluvial channel sandstone. Similarly, the contact between the of the muddy component of the Ameki Group and the overlying Ogwashi Asaba Formation is defined by the transition from dark coloured mud flats/swamp facies to light coloured pebbly-coarse grained coastal plain sandstone and lignite. These new information should serve as a major contribution toward the resolution of the problems of the stratigraphy and contact relations of the Ameki Group in this part of southern Nigeria.

Keywords: Ameki group; ogwashi-asaba formation; stratigraphic analysis; distributary channel; tidal fat sedimentation.

1. INTRODUCTION

The Eocene Ameki Group of south-eastern Nigeria, formerly referred to as the Bende-Ameki Series [1-7], has been described as consisting of the Ameki Formation, Nanka Formation, and Nsugbe Formation [8-10]. These lithologic components are described as lateral equivalents. The exact stratigraphic relationship among the components and with the overlying Ogwashi-Asaba Formation (the so called Lignite Series of [11] has remains poorly defined [12] had placed the contact between the Imo Group and Ameki Group at the transition from fossiliferous/calcareous shoreface facies at the upper levels of the Imo Formation, to the overlying coarse grained tidally-influenced fluvial sandstone that marks the base of the Ameki Group [10]. The overlying Ogwashi-Asaba Formation (Eocene-Oligocene) begins with coarse-grained tidally-influenced sandstone and passes upward into alternating lignite seams, and light coloured clays of continental origin [13,14]. The present research focused on accurate definition of (i) the contact between the Ameki Group and the younger Ogwashi-Asaba Formation and (ii) the stratigraphic relationship among the lithostratigraphic components of the Ameki Group. The study strategy involved (i) outcrop-based sedimentological descriptions and stratigraphic analysis of the Ameki Group outcropping in the Awka-Onitsha axis of Anambra State.

1.1 Study Area

The Ameki Group underlies over 70% of the land mass of Anambra State (Fig. 1) and hosts the bulk of the economic mineral wealth of the State. The Group and other Paleogene strata maintain a consistent SE-NW strike, with a corresponding dip to the south-west. The loosely-consolidated sandy component of the Group (the Nanka Sand), is largely responsible for the gullying erosion that has for long devastated the southeastern states of Nigeria. This study targeted the Awka-Onitsha axis of Anambra State (Fig. 1), where detailed down-dip outcrop descriptions and tracing of contacts are facilitated by several quarry sites, and road cuts.

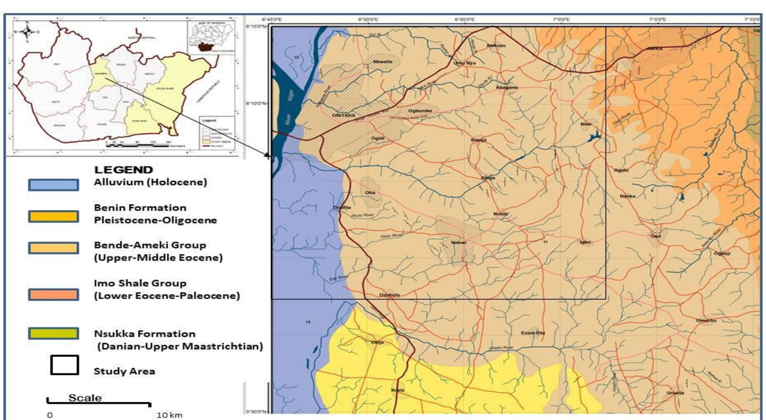

Fig. 1. Geological map of Anambra State showing the areal distribution of the Ameki Group. Strata dip is consistently towards the southwest (Modified after NGSA, 2013)

Fig. 1. Study area

2. REGIONAL STRATIGRAPHIC SETTING

Table 1 summarizes the late Cretaceous-Paleogene succession in southeastern Nigeria. The Paleogene succession is generally progradational and includes the Maastrichtian-Paleocene Nsukka Formation, the Paleocene Imo Formation, Ameki Group (Eocene), and the Oligocene Ogwashi-Asaba Formation [15,10]. The succession has an estimated composite thickness of about 3,500m [10]. The Nsukka Formation is composed of fluvio-deltaic sandstone, mudstone and thin limestone bands [16,14].

The formation is succeeded by the marine Imo Formation comprising blue-grey clays, shallow marine shale, limestone and calcareous sandstone [17].

Regression during the Eocene led to the accumulation of Ameki Group which [10] described as comprising Ameki Formation (open marine facies), Nanka Sand, and Nsugbe Formation (both of tidal origin). The Nanka Formation is reported to be of tidal origin and composed of unconsolidated, flaser-bedded, planar and trough cross-stratified and lenticular-bedded sandstone containing a few mud bands [8,9]. The sand is free from feldspars, contains sub-rounded to sub-angular gains with > 5% clay content and enriched in ultra-stable heavy minerals. The sand is thus texturally sub-mature and compositionally highly mature [8,9]. The Nsugbe Formation on the other hand consists of flat-bedded and wave ripple laminated, medium grained and conglomeratic sandstone interpreted to be of beach origin [8]. The exact stratigraphic relationship of the Nanka and Nsugbe Formations is unclear and needs further clarification.

The Ameki Formation in the Umuahia-Bende area has been described as being composed of fossiliferous shale and limestone rich in mollusks, foraminifera, corals, nautiloids and chunks of amber [18,19,20]. These rocks have been variously interpreted to be of open marine-near shore (barrier ridge-lagoonal complex) environments [21,22].

The Ogwashi-Asaba Formation which overlies the Ameki Group has been described as coastal plain deposit comprising alternation of coarse-grained sandstone, light-coloured clays and lignite seams [10].

Table 1. Correlation of Early Cretaceous-Paleogene Strata in SE Nigeria (modified after 10)

AGE			SOUTH-EASTERN NIGERIA	
30 my	Oligocene	PALEOGENE	Ogwashi-Asaba Formation	NIGER DELTA
54.9 my	Eocene		Ameki/Nanka Formation/Nsugbe Sandstone	
65 my	Paleocene		Imo Formation	
	Maastrichtian		Nsukka Formation	ANAMBRA BASIN
			Ajali Sandstone	
73 my			Mamu Formation	
83 my	Campanian		Nkporo/ Oweli Formation/Afikpo Sandstone/Enugu Shale	
87.5 my	Santonian		Erosion/ Non-deposition	SOUTHERN BENUE TROUGH
88.5my	Coniacian		Awgu Group (Agbani Sandstone/Awgu Shale)	
93 my	Turonian		Ezeaku Group)	
100 my	Cenomanian- Albian		Asu River Group ... Asu River Gr	
119 my	Aptian Barremian Hauterivian		Un-named Units	
Precambrian			Basement Complex	

3. METHODS OF STUDY

Detailed bed-by-bed sedimentary logging was carried out at thirteen outcrops located along two down-dip routes: (i) the Ifite Ukpo-Awkuzu-Onitsha highway (route C-A-B) and (ii) the Ifite Ukpo-Neni-Nnewi-Ozubulu (route C-D-E; Fig. 2). Over two hundred and fifty meters of section were logged at 1:50 scale. The exposures were measured and examined for lithological changes, composition, sedimentologic structures, trace fossils, and stratigraphic surfaces. The profiles of the outcrops were drawn and backed-up with high resolution photographs.

4. RESULTS AND DISCUSSION

4.1 Sedimentary Facies of the Ameki Group

Facies analysis of the measured outcrop sections shows that the Ameki Group in the study area is composed of two stratigraphic components: a basal sandstone and an overlying mud rock units. The aerial distribution of the components is shown in Fig. 3.

4.1.1 Sandstone unit

The Sandstone Unit is topographically expressed as a SE-NW trending ridge that passes through Nanka, Abagana, Awkuzu and beyond. The ridge forms a drainage divide that separates the NE-flowing Awdaw River system and the westerly Nkisi, Idemmili and the Orashi Rivers that empty direct into the Niger River (Fig. 3).

At localities where the base of the sandstone unit was exposed, it rests on a ferruginized erosional surface and consists of strongly ferruginized, pebbly- to medium grained fining-upwards sandstone and ironstone with intercalations of kaolinitic claystone of variable thickness. Two facies associations were identified namely:

(i) Cross-bedded sandstone facies association, with less than 20% clay content and
(ii) Sand-rich heterolithic association, with 20%-50% clay (Table 2).

The cross-bedded sandstone facies association includes five distinct lithofacies, namely:

(a) Pebbly Sandstone (PS) comprising interbedded, pebbly-coarse grained and poorly to moderately sorted sandstone. At the Ugwuakpi section (Location 4; Figs. 2 and 4a), the facies is over 5m in thickness, cross bedded and contains extra-formational clasts and liesegang rings (Fig. 5),

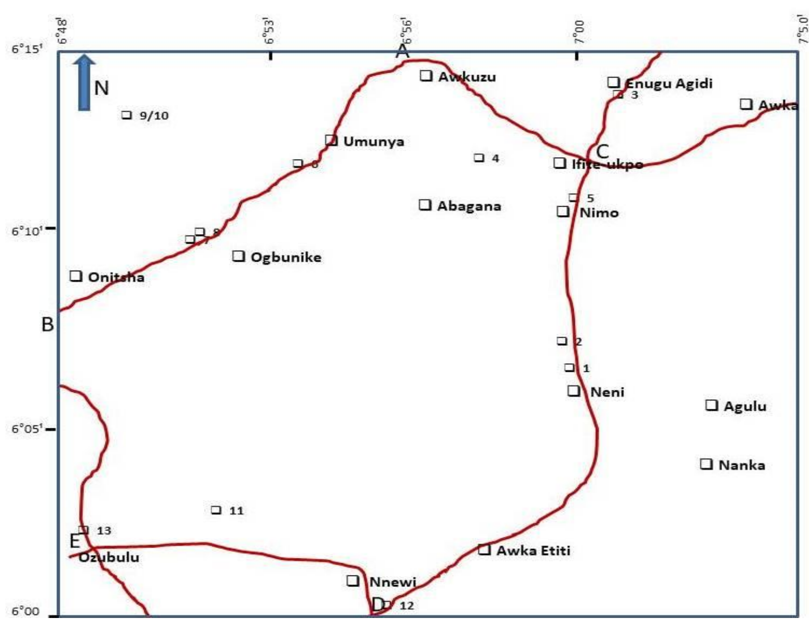

Fig. 2. Outcrop map of the study area showing traverse routes (C-A-B and C-D-E) and outcrop locations

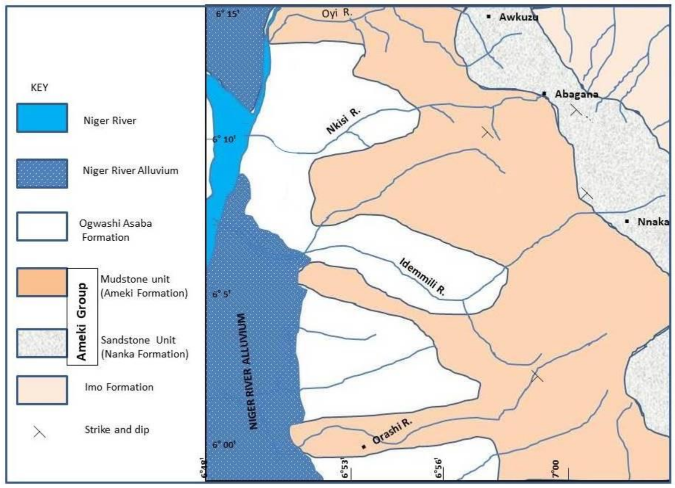

Fig. 3. Geological map of the study area showing the areal distribution of facies of the Ameki Group and the adjacent formations

Table 2. Sedimentary facies of the ameki group

Lithologic Units	Facies Associations	Facies Description	Code
Mud Rock	Carbonaceous Claystone (>80% clay)	Bedded/massive mudstone	MB/Mm
		Sideritic, bedded mudstone	Msd
	Clay-rich heteroliths (50-80% clay)	Bioturbated muddy heterolith	Msb
		Lens-bedded, muddy heterolith	Mst
Sandstone	Sand-rich heteroliths (20-50% clay)	Wavy-bedded sandy heterolith	SMw
		Bioturbated sandy heterolith	SMb
		Glacuonitic/fossiliferous clayey sandstone	SMshg
	Cross-bedded Sandstone (<20% clay)	Bioturbated sandstone	Sb
		Fine-very fine grained, mm-scale lamination, clay drapes	Sc
		Very fine grained, cm-scale laminated	Sl
		Fine-coarse grained sandstone, with cm-scale cross bed	Sx
		Pebbly sandstone	Ps

(b) Very-fine-grained cm-scale laminated sandstone (Sl), characterized by mud-draped low angle cross sets (in which pebbles, ferruginized bands and disseminated plant matter occur at various levels), Teichichnus, Paleophycus, and Chondrites (Fig. 7). Bivalve shell fragments also occur locally.

(c) Very-fine-grained mm-scale laminated sandstone, with clay drapes (Sc) and

(d) Bioturbated sandstone (Sb) containing Ophiomorpha, liesegang rings and extra-formational clasts. At the Ugwuakpi locality this interval is over 5m in thickness. (Fig. 6).

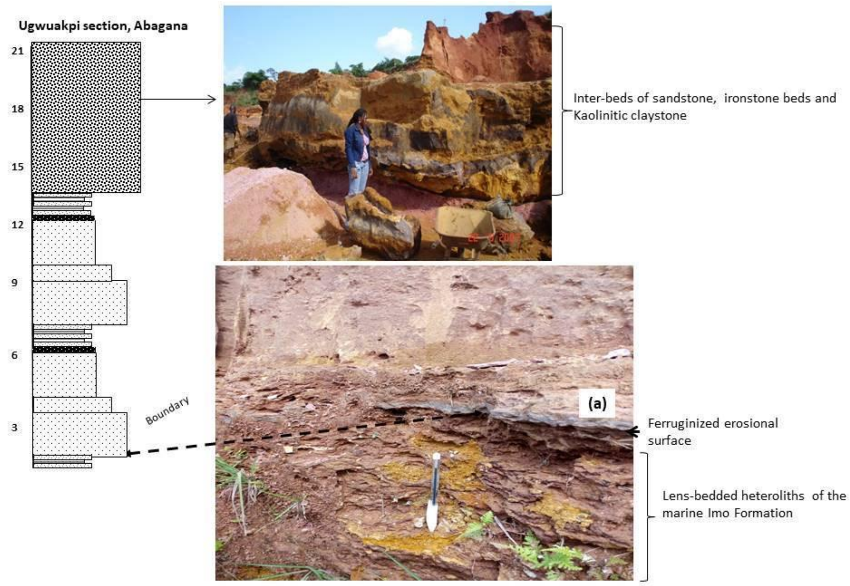

Fig. 4a. Profile of the Sandstone unit at Ugwuaki uarry, Abagana showing the basal ironstone (a) that seperates the unit from underlying lens-bedded heteroliths

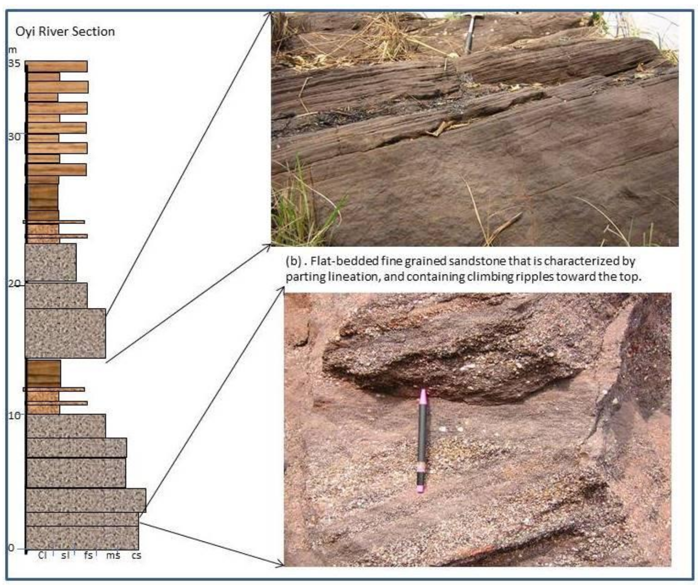

Fig. 4b. Strongly ferrugnized, pebbly sandstone facies (PS) exposed at the Oyi River section

The Sandstone unit continues upward into an interval of erosive-based sand-rich heterolithic facies association (Table 2). This facies association was encountered in sections at Umunya (Location 6), Oyi River (Location 9) and at Anthill (location 12; Fig. 2), where it consists of alternation of (i) bioturbated sandy heteroliths (SMb; Fig. 7a) containing *Paleophycus, Ophiomorpha, Skolithos* and *Diplocraterion*, and (ii) fine-grained wavy-bedded sandstone (SMw) characterized by clay-draped sub-parallel lamination (Fig. 7b). The interval shows a consistent upwards decreases in bed thickness and grain size.

Evidence from water boreholes sited in the study area shows that the subsurface thickness of the sandstone unit is in excess of 200m.

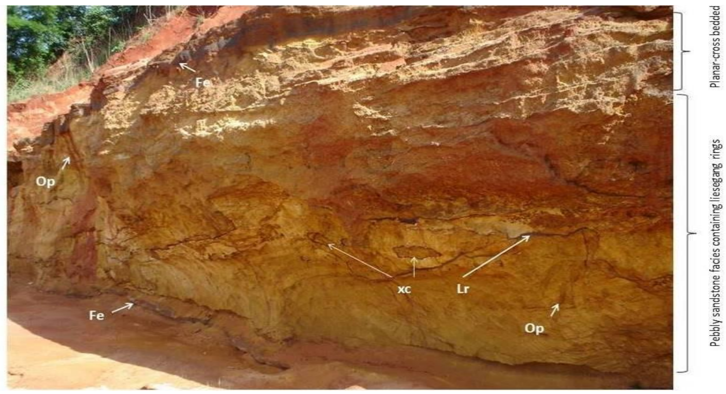

Fig. 5. Close-up on pebbly sandstone facies Ugwuakpi section resting on ferruginized surface (Fe) and characterized by extra-formational clasts (c), liesegang rings (Lr) and Ophiomorpha (op), planar cross bed occurs toward the top

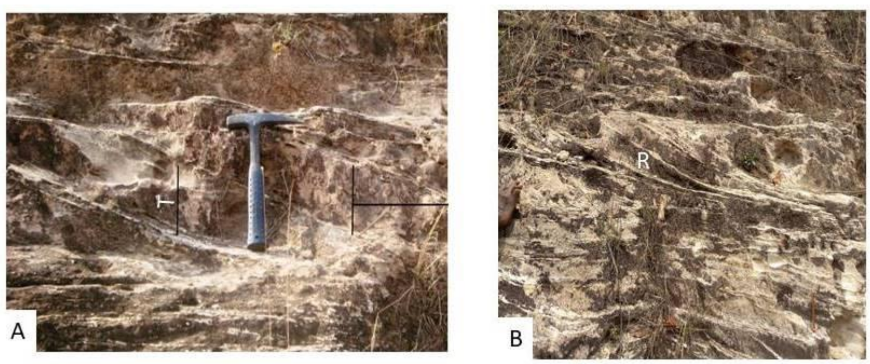

Fig. 6. Cm-cross bedded facies at Umunya showing (A) large-scale planar cross stratification arranged in tidal bundles (T) and (B) reactivation surfaces (R)

Interpretation: The gross sedimentary characteristics of the sandstone unit indicate that it accumulated in a channel that was initially fluvial, but became increasingly tidally-influenced. The observed general fining-upward grain-size motif, presence of herringbone cross-stratification, flaser bedding and mud drapes, are typical of tidally-influenced fluvial channel sedimentation [23-26]. The presence of trace suites of the *Skolithos* and the *Glossifungites* ichnofacies associations indicates sandy high energy setting [27,14]. Herringbone cross bedding, mud drapes and tidal bundling probably relate to ebb-flood tidal cycles [28-30].

The inter-bedded thin, light-coloured mudstone and sand-rich heteroliths represent sand flats /floodplain/overbank facies. The presence of the *Skolithos* and the *Glossifungites* associations confirms that sedimentation occurred under brackish water conditions [31-34].

4.1.2 The mud rock unit

The mud rock unit of the Ameki Group consistently tracks the sandstone component in the down-dip direction, covering the largest part of the study area (Fig. 3). Typical sections were described at Umunya (Location 6), Ogbunike (Toll-gate section, Location 7), Oyi River (Location 9), and in the Nnewi area (Locations 12 and 13; Figs. 2 and 8).

Facies analysis shows that the mud rock component of the Ameki Group contains two facies associations, (i) clay-rich heterolithic association, with 50%-80% clay (Fig. 9), and (ii) carbonaceous claystone association (with more than 80% clay; Table 2).

The clay-rich facies association consists of lens-bedded muddy heteroliths (Mst) inter-bedded with grey, bioturbated muddy heterolithic facies

(Msb) that locally contains *Skolithos* and *Paleophycus* (Fig. 10).

The Claystone Association is represented by intervals of light grey, bedded kaolinitic and carbonaceous mudstone (Mb/mm) interbedded with lignite and bioturbated clay-rich heteroliths (Msd) containing *Diplocraterion, Planolites* and *Paleophycus* (Fig. 11).

Interpretation: The Mud Rock Unit is recognized as a product of tidal flat sedimentation based on the overall sedimentary characteristics and stratigraphic relationship with the underlying tidally-influenced channel facies. Sub-environments within the tidal flats that are identified include (i) the mixed flats and (ii) mud flats/swamps.

The clay-rich facies *association* is interpreted as product of mixed flat sedimentation based on the mode of 35, while intervals of grey carbonaceous mudstone and lignite are interpreted as fresh water to brackish water, low-energy swamp deposits. Brackish water conditions are reflected by the presence of the *Skolithos* ichnofacies [35,36,37].

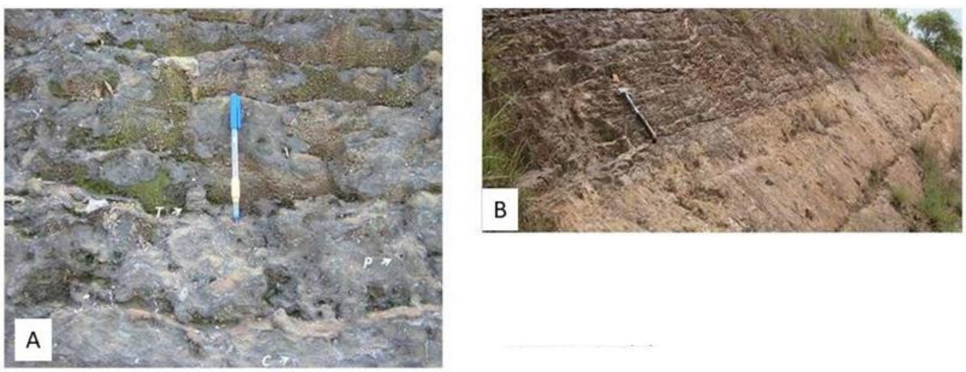

Fig.7. Laminated sandstone facies (Sl) at (A) the Oyi R.section containing *Teichichnus (T), Paleophycus (P) and Chondrites (C)*; (B) the Umunya section overlain by very fine grained mm-scale laminated facies (Sc)

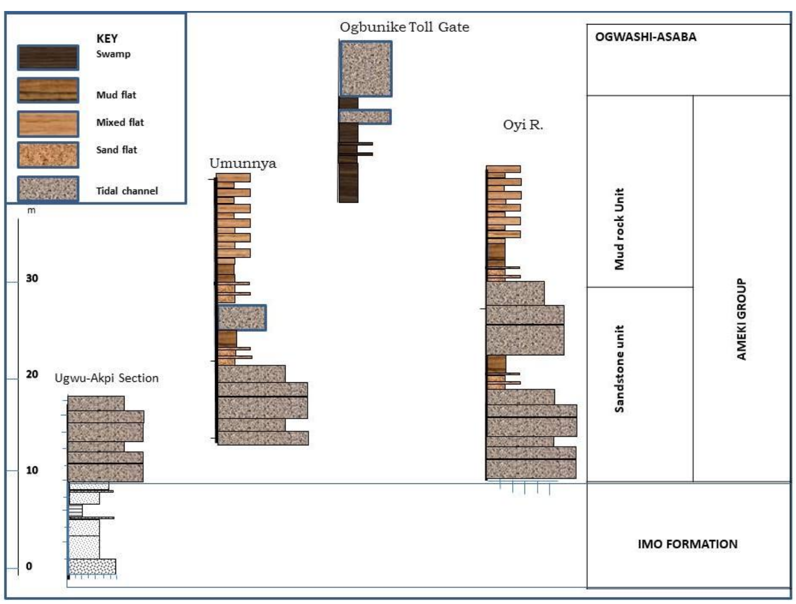

Fig. 8a. Down-dip facies differentiation along abagana-umunya-ogbunike traverse route. the ameki group contains two lithostratigraphic units: sandstone and mud rock

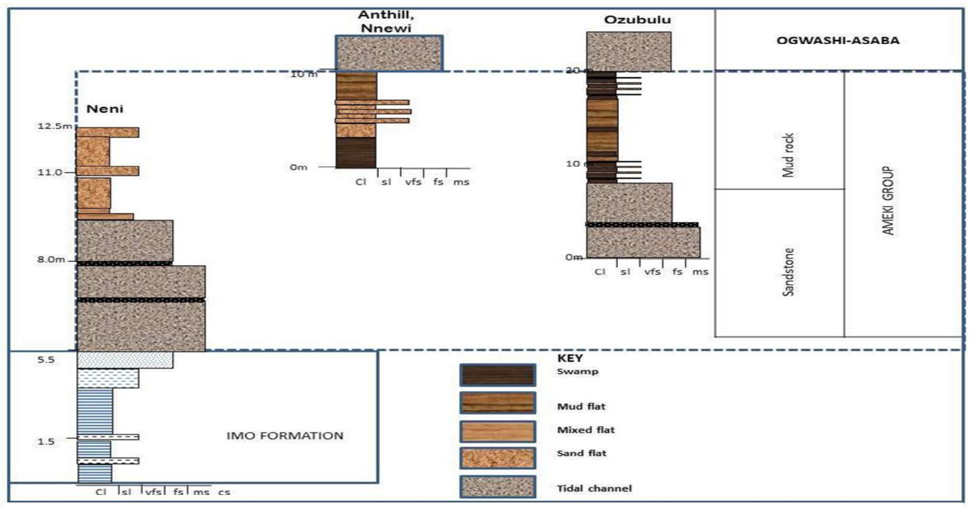

Fig. 8b. Down-dip facies differentiation along Neni-Nnewi-Ozubulu traverse route. The Ameki Group consistently contains two lithostratigraphic units: sandstone and mud rock

Fig. 9. Clay-rich heterolithic facies of the Ameki Group eposed at Umunya (A) and Nnewi (B)

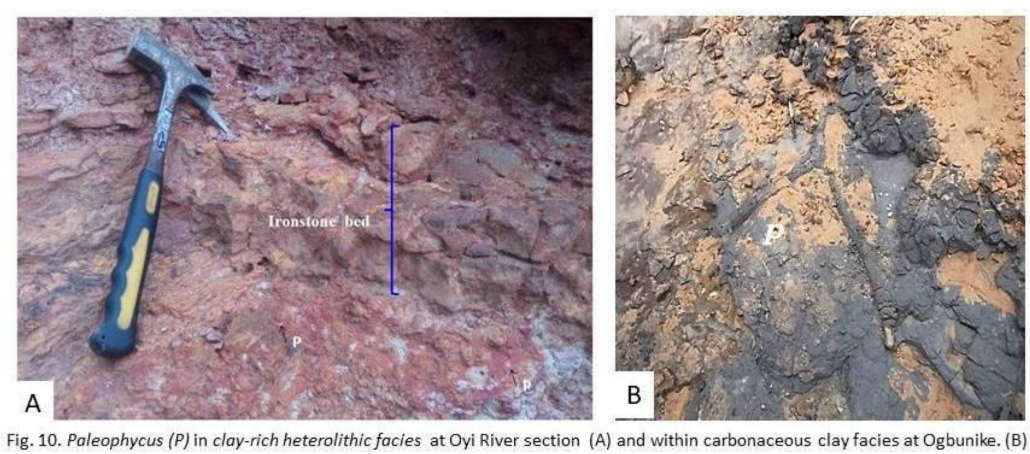

Fig. 10. *Paleophycus* (P) in *clay-rich heterolithic facies* at Oyi River section (A) and within carbonaceous clay facies at Ogbunike (B)

Fig. 11. Carbonaceous claystone facies at Ogbunike (A) and lignite at the Nnewi section (B)

4.2 Contact Relations and Stratigraphic Nomenclature of the Ameki Group

According to 8, 14 and 17, the base of the Ameki Group which in this region is represented by the Nanka Sand, is dominated by coarse grained, tidally-influenced fluvial clastics. The contact between the Imo Formation and the Ameki Group in the study area has earlier been located in the Ugwuakpi (Abagana) section [17], where shoreface facies marking the upper levels of the Imo Formation is directly overlain by coarse-grained, tidally-influenced fluvial distributary sandstone deposit. 17 identified this contact as a type-1 sequence boundary (56.5 my), reflecting a significant landward shift in facies.

Above this contact the Ameki facies continues upwards, beginning with tidally-influenced distributary channel and sub-tidal channel facies, and into coastal plain facies.

The Ogwashi-Asaba Formation comprises alternation of coarse-grained sandstone, lignite seams, and light colored clays of continental origin [13,14]. The basal units of the Ogwashi-Asaba Formation in south-eastern Nigeria is composed of alternation of thickly-bedded conglomerates, coarse-grained sandstone and lignite seams of fluvial distributary channel origin and overbank kaolinitic mud rocks . According to [14], these beds represent non-marine/coastal plain aggradation portion of the Ogwashi-Asaba transgressive systems tract. In the present study area, the thick coarse grained, ferruginized sandstone containing thin intervals of lignite seams, which sharply overlies grey, tidal flat/coastal plain mud rocks at the top of the Ameki succession at Ogbunike (Fig. 12), is here assigned to the basal units of the Ogwashi-Asaba Formation.

Fig. 12. Contact between the ameki group and the overlying ogwashi-asaba formation. arrow is marked where coarse grained, ferruginized sandstone sharply overlies grey tidal flat/coastal plain mud rocks on top of the ameki succession at ogbunike

Table 3. New eocene stratigraphic nomenclature for the anambra basin

Age	Nwajide (2013)		Uduezue et al., 2021	
Oligocene	Ogwashi Asaba Formation	Niger Delta Basin	Ogwashi Asaba Formation	Niger Delta Basin
Eocene	Ameki/Nanka/Nsugbe		Ameki Formation	
			Nanka sand	Anambra Basin
Paleocene	Imo Formation		Imo Formation	

4.3 Stratigraphic Nomenclature of the Ameki Group

The Ameki Group of south-eastern Nigeria has been extensively studied, especially in the Umuahia-Bende axis of southeastern Nigeria, but these studies, as observed by [10] did not clearly distinguish the component formations. For example, [38] described the Group as being composed of two distinct, sandy sub-facies: a basal planar cross-bedded, fine to coarse grained sandstone with intercalations of shale and thin shelly limestone, and upper, planar cross-bedded, coarse grained sandstone, with bands of fine grained sandstone and sandy clay. 39 also described the Ameki Formation (a component of the Ameki Group) as consisting of highly fossiliferous grey-green sandy clays with calcareous and white clayey sands. 19 worked in the same region as 39 and described the Ameki Formation as being composed of four stratigraphic units, namely (i) pebbly sandstone, (ii) argillaceous sandstone, (iii) shale and (iv) clay.

8 and 9 nominated three *laterally equivalent* components within the Group, to include the Ameki Formation, the Nanka Formation and the Nsugbe Formation, but did not explain the relative positions of these components in space and time. To complicate matters, 10 (pp.383, Fig. 11.38b) stated that the Nanka Formation is stratigraphically situated between the underlying marine Imo Formation (Paleocene) and the overlying paralic Ogwashi-Asaba Formation (Middle Eocene). This left unanswered, the question of the stratigraphic status/positions of the components of the Ameki Group.

In the present study, the tidally-influenced distributary channel sandstone unit which erosively overlies the marine Imo Formation is recognized as the basal unit of the Ameki Group, equivalent to the Nanka Formation of 8, 9 and 10, while the overlying tidal flat facies (the mud rock unit of this study) represents the up-dip equivalent of the shallow marine Ameki Formation of 39. The slight modification in the Eocene stratigraphic nomenclature suggested in this work is shown in Table 3.

5. CONCLUSIONS

This study has shown that the Ameki Group in the study area contains two lithostratigraphic components: (i) a basal sandstone component equivalent to the Nanka Formation and (ii) an overlying mud rock component equivalent to the Ameki Formation.

The sandstone component (Nanka Formation) contains two major facies associations namely: cross-bedded sandstone and wave ripple laminated sandy heteroliths. These facies associations document deposition in tidally-influenced distributary channel and sand flats respectively. The mud rock component (Ameki Formation) also contains two facies associations that include a clay-rich heterolithic association and a carbonaceous mud rock association. The sedimentary associations and vertical arrangement of the two facies associations and the presence of lignite, reflect deposition in mud flats and marsh/swamp environments respectively. The gross sedimentary characteristics and facies relationships of the facies associations within the Ameki Group reflect tidal flat progradation in a shoreline and coastal plain setting.

The stratigraphic components of the Ameki Group are therefore not stratigraphically equivalent as reported by previous researchers. The stratigraphic status of 9 and 10 Nsugbe Formation is a matter that needs further clarification.

The coarse grained, ferruginized sandstone containing thin intervals of lignite seams, which sharply overlies grey, tidal flat/coastal plain mud rock unit of the Ameki Group at Ogbunike is here interpreted to mark the contact between the Ameki Group and the Ogwashi-Asaba Formation in this region. The new stratigraphic information presented in this work should help to resolve the question of the stratigraphic architecture of the

Ameki Group and the contact relation with the overlying Ogwashi-Asaba Formation.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Wilson RC, Bain ADN. The Nigerian coalfield, section II, parts of onitsha and owerri provinces. With an Appendix by Spath, L.F., on the Albian Ammonoidea of Nigeria. Bull. Geol. Survey of Nigeria. 1928;12:54.
2. Tattam CM. A review of Nigerian stratigraphy. Report of the Geological Survey of Nigeria. 1944;27-46.
3. Du Preez JW. Further observations on lignite of Onitsha Province. Ann Rpt of Geol. Survey of Nigeria. 1946;25-26.
4. Jones B. The sedimentary rocks of sokoto province. Bull. Geol. Survey of Nigeria. 1948;18:75.
5. Groove AT. Land use and soil conservation in parts of onitsha and owerri provinces. Geol. Survey of Nigerial Bull. 1951;21.
6. Simpson A. The Nigerian coalfield: The geology of parts of Onitsha, Owerri and Benue Provinces. Bull. Geol. Survey of Nigeria. 1955;24:85.
7. Reyment RA, Barber WM. Nigeria and Cameroons. In Lexique Stratigraphique International. 1956;4:35-39.
8. Nwajide CS. A lithostratigraphic analysis of the Nanka Sands, southeastern Nigeria. Journal of Mining and Geology. 1979;16:103-109.
9. Nwajide CS. Eocene tidal sedimentation in the Anambra Basin, Southern Nigeria. Sediment, Geology. 1980;25:189-207.
10. Nwajide CS. Geology of Nigeria's sedimentary basins. Css Press. 2013;565.
11. Parkinson J. The post cretaceous stratigraphy of southern Nigeria. Q.J. Geol. Soc. London. 1907;63:311-320.
12. Odunze SO, Obi GC. Depositional process of the ebenebe sandstone and the implication for the paleogene evolution of Southeastern Nigeria sedimentary basin. Presented at 19th International Sedimentological Congress at Geneva, Switzerland; 2014.
13. Kogbe CA. The 'Continental Intercalaire' in northwestern Nigeria. J. Min. Geol. 1976;13:45-50.
14. Oboh-Ikuenobe FE, Obi GC, Jaramillo CA. Lithofacies, palynofacies and sequence stratigraphy of Paleogene strata in southeastern Nigeria: Journal of African Earth Sciences. 2005;41:79-102.
15. Odunze OS, Obi GC. New perspectives on the lithostratigraphy and depositional environments of the imo formation in southern benue trough. 2007 NAPE International Conference, Abuja, Nigeria; 2007.
16. Obi GC. Depositional model for the campanian-maastrichtian Anambra Basin, Southern Nigeria. PhD Thesis, University of Nigeria, Nsukka. 2000;286.
17. Odunze OS, Obi GC. Sequence Stratigraphic framework of the imo formation in the Southern Benue Trough. Journal of Mining and Geology. 2011;47/2:135-146.
18. Adegoke OS, Arua I, Oyegoke O. The new Nautiloids from the Imo Shale, (Paleocene) and ameki formation (Middle Eocene), Anambra state Nigeria. Journal Mining and Geology. 1980;17:85-89
19. Arua I. First record of typhine gastropods from Eocene of southeastern Nigeria. Geol Mijnb. 1981;60:277-280.
20. Anyanwu NPC, Arua I. Ichnofossils from the imo formation and their paleoenvironmental significance. Journal of Mining and Geology. 1990;26:1-4.
21. Ekwenye OC, Nichols G, Collinson A, Nwajide M, CS, Obi GC. paleogeographic model for the Sandstone members of the Imo Shale, SE Nigeria. Journal of African Earth Sciences. 2014;96:190-211.
22. Fayose EA, Ola PS. Radiolarian occurrence in the Ameki type section, Eastern Nigeria. Journal of Mining and Geology. 1990;26/1:75-80.
23. Nilsen TH. (Ed.). Fluvial sedimentation and related tectonic framework, Western North America. Sedimentary Geology. 1982;36:523.
24. Archer AW, Kvale EP. Seasonal and yearly cycles within tidally laminated sediments;

an example from the Pennsylvanian in Kentucky, Indiana, and Illinois: Indiana Geological Survey, Illinois Basin Consortium. 1989;1:45-46.
25. Miall AD. Alluvial deposits. In: Walker, R.G., James, N.P. (Eds.), Facies Models: Response to Sea Level Change. Geological Association of Canada. 1992;119-142.
26. Hettinger RD. Sedimentological descriptions and depositional interpretation in sequence stratigraphic context, of two 300-meter cores from upper cretaceous straight cliffs formation kaiparowits Plateau, Kane County, Utah. United States Geological Survey Bulletin. 1995;2115-A:32p.
27. Pemberton SG, MacEachern JA, Frey RW. Trace fossil facies models: Environmental and allostratigraphic significance. In: Walker R.G. and James, N.P. (Eds.), Facies Models: Response to Sea Level Change. Geological Association of Canada. 1992;47-72.
28. Yang CS, Nio SD. The estimation of paleohydrodynamic processes from sub tidal deposits using time series analysis methods. Sedimentology. 1985;32:41-57.
29. Leckie DA, Singh C. Estuarine deposits of the Albian paddy member (peace river formation) and lowermost shaftsbury formation, Alberta, Canada. Journal of Sedimentary Petrology. 1991;61:825-849.
30. Shanley KW, McCabe PJ, Hettinger RD. Tidal influence in Cretaceous fluvial strata from Utah, U.S.A.—A key to sequence stratigraphic interpretation: Sedimentology. 1992;39:905-930.
31. Buatois LA, Mángano MG. Ichnology: Organism-substrate interactions in space and time. New York, Cambridge University Press. 2011;358.
32. Buatois LA, Gingras MK, MacEachern J, Mángano MG, Zonneveld JP, Pemberton SG, Netto RG, Martin AJ. Colonization of brackish-water systems through time: Evidence from the trace-fossil record. Palaios. 2005;20:321-347.
33. Martinius A, Hegner J, Kaas I, Bejarano C, Mathieu X, Mjøs R. Sedimentology and depositional model for the Early Miocene Oficina Formation in the Petrocedeno Field (Orinoco heavy-oil belt, Venezuela). Mar. Pet. Geol. 2012;35:354–380.
34. Solórzano E. Sedimentology, ichnology, biostratigraphy, and sequence stratigraphy of the middle miocene oficina formation, orinoco oil belt, Venezuela. PhD Thesis, University of Saskatchewan. 2018;159.
35. Kamola DL. Trace fossils from the marginal-marine facies of the spring canyon member, blackhawk formation (upper cretaceous), east-central Utah. Journal of Paleontology. 1984;58: 529-541.
36. Allen GP. An introduction to estuarine lithesome and their controls. In: V.P. Wright (Ed.), Sedimentology Review. Blackwell Scientific Publications, Oxford. 1993;1:123-138.
37. Allen GP, Posamentier HW. Sequence stratigraphy and facies model of an Incised valley fill: the Gironde estuary, France. Journal of Sedimentary Petrology. 1993;63:378-391.
38. Reyment RA. Aspects of the geology of Nigeria. Ibadan University Press. 1965;145.

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