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Sedimentary structures and depositional environment of the Amasiri sandstone (Turonian), in Akpoha, Southeastern Nigeria

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Abstract
Some physical sedimentary structures and trace fossils have been described from the Turonian Amasiri Sandstone outcropping in Akpoha area in the southern Benue Trough of Nigeria. The physical sedimentary structures are mainly parallel laminations and beddings, wavy/ripple laminations and beddings and planar cross beddings. The sediments are moderately to intensely bioturbated. The bioturbation structures consist of trace fossils represented by the *Cruziana - Zoophycons* ichnospecies of *Crosspodia*, *Monocraterion*, *Lorenzinia* and *Zoophycos.* The burrows are ichnofossil assemblages associated with shallow to deep-water marine settings. The cross bedding suggests deposition in moderate to high energy shallow marine shoreface environment above fairweather wave base. The wavy/ripple and parallel laminations and beddings are formed by traction and bottom current reworking in a low to moderate energy deep marine environment. The dominance and abundance of mainly deposit-feeding structures (*Cruziana*), sediment mining structures (*Zoophycos*) and absence of suspension feeding structures, the lithology, texture and physical sedimentary structures suggest a generally shallow to deep water environments. Paucity of the trace fossil assemblages in Amasiri Sandstone in some localities may be attributed to poor oxygenation of the sea bottom and salinity fluctuations in the environment.

1. Introduction

The Turonian Amasiri Sandstone represents the uppermost unit of Eze-Aku Group in the study area and overlain by Santonian uncomformity in the Afikpo Syclinorium (Table 1). The Eze-Aku Group was identified as a shallow marine sequence [20]-[16]. The sandstones consist of NE-SW trending ridges believed to be of subtidal origin alternating with marine shale (Fig 1.) [2]. Evidence of storm deposition was derived by [1] after a detailed study of the Amasiri Sandstone ridges. Reference [12] reported that the Akpoha Sandstone is of marginal marine origin. Trace fossils have been described and used in the paleoenvironmental interpretation of Cretaceous sediments of the Lower Benue Trough; such as the sediments of Turonian of Eze-Aku Group [10] and Campano-Maastrichtian Nkporo Group [13]-[3]. Apart from the trace fossils documented by these few workers, the physical sedimentary structures from the Amasiri Sandstone have been largely unreported. This paper therefore intends to interprete the depositional environments of Amasiri Sandstone using sedimentary structures. It is hoped and likened to stimulate interest and encourage further research on the sedimentary structures and depositional environments of the Amasiri Sandstone.

2. Description of Amasiri Sandstone in Akpoha

Two sandstone outcrops of this sandstone member of Amasiri Sandstone are studied. They are located in Akpoha, 3km from Abakaliki – Afikpo road and NW of Julius Berger quarry site. The sandstone outcrops occur on ridges trending in a NE - SW direction. The first locality studied occurs behind the Government Technical College, Akpoha. This lithologic section is bounded above and below by covered area (soil) which believably may represents another cyclic/repeated succession of sediments. The second locality studied is situated at the front of the Technical College, 60m from the old road leading to Akpoha market. It spans across the road to a swampy lowland where it is been quarried during dry season only. Fig. 1 is a geological map the study area.

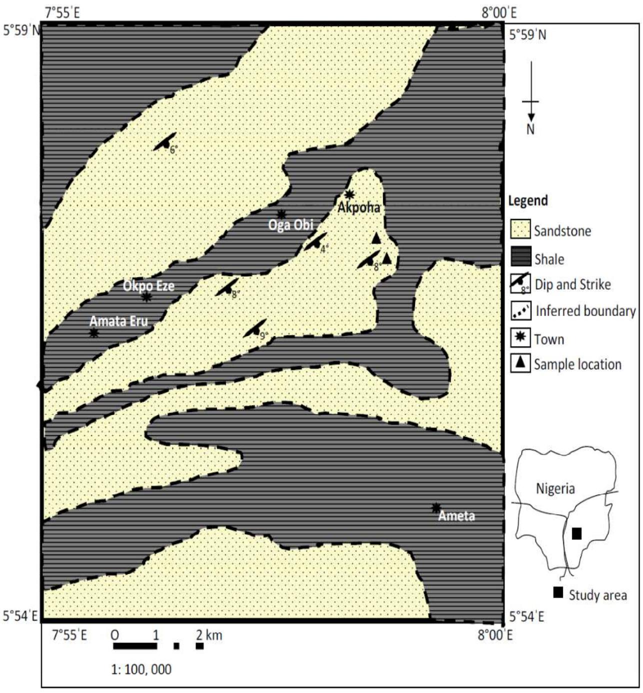

Fig. 1. Geological Map of the Area Showing Alternating Sequence of Sandstones and Shales

Although Amasiri Sandstone has been mapped and described elsewhere in Amasiri and adjoining villages by various authors [2]-[1]. The sandstones in Akpoha area show a typical and perculiar thin bedded lithology, rhythmically and cyclically deposited (Figs. 2 & 3). In addition to this thin bedding characteristics and cyclic nature, they show distinctive sedimentary structures and textures. All studies were carried out on exposed step-like surfaces or vertical sections along the ridges.

***Table 1.** Stratigraphic Sequence Showing the Position of Eze-Aku Group Relative to Other Formations in Southeastern Nigeria*

Age		Stratigraphic Sequence	Basin/Cycle
Eocene		Ameki Group/Nanka Fm	Anambra - Afikpo Basin (Second Sedimentary Cycle)
Paleocene		Imo Shale	
Upper Cretaceous	Danian	Nsukka	
	MAASTRICHTI	Ajali SS	
		Mamu Fm	
	Campanian	Nkporo Group/ Enugu Shale	
	Santonian		Uplifting/ Folding
	Coniacian	Awgu Fm	Anambra Basin (First sedimentary Cycle)
	Turonian	Eze-Aku Group / Amasiri Ss	
	Cenomanian	Odukpani FM	
Lower CRETA.	Albian	Asu River Group	
PRE CAMBRIAN		BASEMENT COMPLEX	

2.1. Outcrop 1: Ridge Section Behind Government College Akpoha

This section covers a lateral extent of about 1.4km along the ridge, and has a thickness of 15m. This outcrop is composed of light to grey, very fine to fine to medium grained, moderately to well sorted, thin bedded sandstone with parallel, wavy/ripple laminations/beddings and dirty brown mudstone with bioturbation and burrows bounded above and below by massive, fine to medium grained, poorly to moderately sorted sandstone with irregular shaped and chaotic limestone rip-up clasts (Figs 2 & 3). At the bottom section, these rip-up clasts are randomly distributed; they are oblate, oval or elliptical in shape. The sizes of the limestone clasts vary from 10 – 40cm in diameter. Some of the clasts are dissolving out while some have completely dissolved leaving open potholes. Lateral mapping of this outcrop showed that the sandstone bodies that represent the bottom section are poorly exposed in most other parts of the lower outcrop section of the sandstone ridge.

Mid-way up, from the bottom part of the outcrop, fine to medium grained, well sorted, thin bedded sandstone with parallel lamination occur (Fig 5b). Tool casts; load and fluid escape structures occur in this section of the outcrop particularly on the bedding plane surface. This sandstone is calcareous with erosional bedding contacts, load casts, flute casts and occasional burrows. At about 5.5m up the section of this outcrop, dirty white to light grey, very fine to fine grained, moderately to well sorted thinly and wavy/ripple bedded sandstone overlie the parallel bedded sandstones (Figs. 2 & 3). There is alternation of fine and very fine grain size within some of the main beds but they exhibit fining upward character. There are also some mudstone interlamination/interbeddings with occasional burrowing and bioturbation. The burrows are mainly horizontal burrows. Mudstone constitutes about 20% of this section. The mudstone laminations/beds appear wavy or ripple laminated. The finer grained beds have more mudstone laminations/interlaminations which appear continuous but, however appear discontinuous except where they are distorted by bioturbations. In some beds where the sandstone is cleaner and less muddy, the mudstone lamination becomes discontinuous and thin-out within the sandstone bed. Towards the top, the sandstone gets muddier (about 30%), more distinctly bioturbated and burrowed. The topmost bed of this section of is rippled, with very low amplitude and high wavelengths. The bedding planes appear wavy but may also be erosional (Fig. 4b). From about 7.5m up section, intensely burrowed and bioturbated mudstone overlies the rippled sandstones. The beds appear thick and massive possibly due to burrowing and bioturbation. They have thicknesses range from 15-60cm and comprise of dominantly siltstones and clays. Above this section, fine grained moderately sorted massive sandstones occur. Above and overlying this section chaotic sandstone with rip-up clasts occurs. This section is capped by overburden (soil) which the villagers are farming on despite the height of this outcrop.

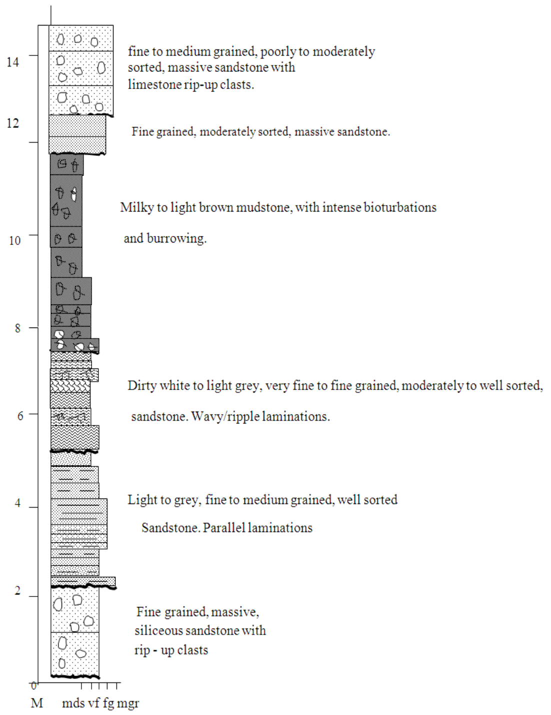

Fig. 2. *Litholog Section of Outcrop 1 Behind Government College Akpoha*

Fig. 3. *Outcrop 1 Behind Government College (GTC) Akpoha*

Fig. 4a & b. *Wavy/Ripple Laminations/Beds in Amasiri Sandstone in Akpoha.*

2.2. Outcrop 2: Akpoha Roadside Section

This section is located within the premises and in the front of the Government Technical College, Akpoha, It extends across the road to the swampy lowland where it is quarried by the local indigenes for economic purposes. It is light grey to dirty white in colour, fine to medium grained and moderately to well sorted sandstone. This outcrop displays both erosional and planar bedding contacts. The middle and upper sections are characterized by planar cross beddings. Some of the cross beds are deformed. This sandstone has occasional *Cruziana* burrows.

3. Sedimentary Structures

3.1. Wavy/ Ripple Lamination and Bedding

These sedimentary structures occur in the Wavy/ripple bedded lithofacies in the sandstone outcrop behind G.T.C Akpoha. They are irregular/wavy and ripple laminations (Figs. 4a & b). The topmost beds of this facies have rippled/wavy contacts (Fig. 4b). This ripples are are very low amplitude ripples. Some ripples are draped with mudstone interlaminations while flaser beds represent starved ripples. There is a vertical distribution grading from plane parallel lamination which occur in parallel bedded sandstone lithofacies to wavy to ripple drift laminations. The occurrences of these discrete traction structures in the sequences indicate bottom current reworking [18].

3.2. Parallel Lamination

The Parallel bedded Sandstone lithofacies in Amasiri Sandstone behind G.T.C Akpoha are characterized by parallel laminations/beddings (Fig. 5a & b). This may be defined by distinct planar and continuous laminae as evident in the outcrop.

3.3. Cross Stratification

The lower to middle part of the sandstone body consists of distinctive planar cross stratified beds (Fig 6.), 2.6m thick and 10m across. The cross beds are deformed at the middle section. The lower and middle contact is erosional and in some places gradational into the overlying planar tabular cross stratified beds overlain by bioturbated beds.

3.4. Trace Fossils

The trace fossils observed in Amasiri Sandstone on course of this study belong to two ichnofacies viz: *Cruziana* and *Zoophycos. Monocraterion*, *Crosspodia* are ichnospecies of *Cruziana* ichnofacies while Zoophycos ichnofacies are represented by *Lorenzinia* and *Zoophycos* ichnospecies.

Fig. 5a & b. *Parallel Laminations/Beds in Amasiri Sandstone in Akpoha*

3.4.1. *Cruziana* Ichnofacies

Monocretarion burrows occur in the very fine to fine grained sandstone (middle section) of outcrop 1 (Fig. 7a). These sandstones are occasionally bioturbated with discrete burrows believed to be *Monocreterion isp* of *Cruziana* ichnofacies [14]. They are mainly produced by deposit feeders foraging for food in the muddy substrates. The *Crosspodia* ichnofacies are documented in the bioturbated beds of locality 2 (Fig. 7b).

3.4.2. *Zoophycos* Ichnofacies

Lorenzinia isp and *Zoophycos isp* burrows of *Zoophycos* ichnofacies [14] (Fig. 8) occur in the fine to medium grained sandstone (lower section), and bioturbated mudstone (upper section) of outcrop 1 respectively. References [9]-[14] described this ichnofacies as sediment - mining organisms; characteristic of deep marine environment where oxygen is low and nutrient supply more sparse.

Fig. 6a & b. *Low Angle Planar Cross Beds in Amasiri Sandstone Behind Catholic Church Akpoha.*

Fig. 7 a & b. *Monocraterion and Crosspodia Ichnospecies of Cruziana in Outcrop 1 in Akpoha/*

Fig. 8a. *Zoophycos Ichnospecies in Amasiri Sandstone Outcropping Behind Government Technical College, Akpoha.*

Fig. 8b. *Lorenzinia Ichnospecies in Amasiri Sandstone Outcropping Behind Government Technical College, Akpoha.*

4. Discussion

Fossil assemblages and physical sedimentary structures evident on Trace Amasiri Sandstone are useful in determining the depositional environments. Ichnofossils have considerable application in paleoecology, and environmental reconstruction [6]-[17]. The ichnofacies concept pioneered by [17] is based upon the observation that certain ichnofossil assemblages tend to occur in particular sets of environmental conditions which I have mentioned in this work. Although the *Skolithons - Cruziana - Zoophycons - Nereites* ichnofacies succession generally aids in reconstructing shallow to deep water sedimentary sequences [17]. It is known that bathymetry only is not the controlling factor in determining ichnofacies. Reference [10] opined that ichnofossil assemblages are only related to bathymetry where particular sets of environmental factors can be correlated with bathymetry. Therefore in modern ichnofacies, analysis of all available evidence (physical sedimentary structures, stratigraphic position, body fossils etc.) must be evaluated and used in interpretation [6]-[8].

Ichnofossil assemblages from the Amasiri Sandstone consist of dominantly horizontal trace fossils assigned to the *Cruziana* and *Zoophycos* ichnofacies. The depositional environments for the Amasiri Sandstone using the interpretation of the associated sedimentary structures as revealed by this study are discussed below

4.1. Wavy/Ripple Lamination/Bedding

The wavy/ripple lamination/bedding is interpreted to have been deposited in a low energy deep marine environment [22]-[21]. The depositional process is dominated by traction and bottom current reworking in the lower flow regime. The ripple-laminated/bedded sandstone represents traction deposits, and thin rippled divisions are interpreted to be products of short-lived traction processes [4]-[24]. The unusual thick rippled beds which he noted are product of long-lived traction processes is absent in the Amasiri Sandstone. Such traction deposits in deep-water environments have been ascribed to bottom-current reworking. References [19]-[4]-[15]-[23] routinely classified such rippled beds as thin-bedded turbidites without regard for their true origin.

4.2. Parallel Lamination/Bedding

The parallel laminations/bedding suggests that this lithofacies was deposited in moderate energy deep marine environment [21]. The environment was dominated by bottom current reworking with transition from lower flow to upper flow regime [19]. The texture and the planar cross stratifications suggest deposition in shallow shoreface environment dominated by storm events [19].

4.3. Cruziana Ichnofacies

Cruziana ichnofacies which are mainly produced by deposit feeders foraging for food in the muddy substrates are characteristic of shallow to deep water sedimentation [17]-[14] The sediments of the study area associated with this ichnofacies evolve from shallow to deep water settings.

4.4. Zoophycos Ichnofacies

Reference [19]-[14] described the *Zoophycos isp* as sediment - mining organisms characteristic of deep marine environment where oxygen is low and nutrient supply more sparse. The dominance of *Zoophycos isp* of the *Zoophycos* ichnofacies and lack of primary sedimentary structures in the lithofacies hosting this ichnofacies due to flocculation without traction and possible ponding. Reference [11] suggest that this sediment was deposited in a very low energy marine environment (basin plain), possibly by relatively low density turbidity currents in deep-water hemipelagic settling [14]-[15].

5. Conclusion

The sedimentary structures in Amasiri Sandstone indicate depositional environments which evolve from shallow marine shoreface environment through moderate to low energy deep water marine environment into very low energy deep water environment (basin plain). The planar cross stratifications are interpreted as shallow marine shoreface deposits. The massive bedding indicate moderate to high energy sedimentation (high turbidity current). The parallel lamination/bedding is interpreted as moderate energy deep marine environment. The wavy/ripple lamination is interpreted as low energy deep marine environment. The ichnofossil assemblges in the sediments represented by *Cruziana – Zoophycos* ichnospecies of *Arthrophycus, Monocreterion, Crosspodia, Lorenzinia* and *Zoophycos* corroborate deposition of sediments in shallow to deep-water environments.

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