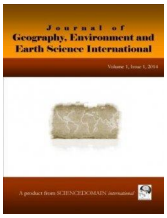

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Structural Features of Ajali Sandstone in the Western and Eastern Parts of River Niger, Southern Nigeria

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Author's contribution

The sole author designed, analyzed and interpreted and prepared the manuscript.

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ABSTRACT

The small-scale structural features identified in the field are original sedimentary structures. They were formed as direct results of sedimentation processes and are clearly preserved. The size, shape, and sorting of sedimentary structures within rocks may provide clues to the depositional environment that existed during their formation. They yield evidence of the top and bottom of individual beds and include graded bedding at Agola, current bedding at Fugar, ripple marks and sole marks at Fugar and Okigwe areas. The inclined beds are not due to secondary structures of tectonic origin, but the surfaces on which the original sediments were deposited. It varies from 4° SE at Ihube Okigwe to 7° S at Fugar, Edo state. The presence of Ophiomorha and Skolithos ichnofacies indicates marine environment although Ajali Sandstone is believed to be predominantly continental. Also it shows very poorly sorted and no graded bedding at Fugar, and this points to high-energy environment and current bedding. The Ajali Sandstone has several dome-shaped and circular highlands capped by laterites. The spring water that occurs at the contact between the Mamu – Ajali boundaries are structurally controlled.

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Keywords: Ajali Sandstone; small-scale geological structures; southern Nigeria.

1. INTRODUCTION

The Ajali Sandstone Formation lies between latitude 5° 30' to 7° 15' N and longitude 6° 00' to 8° 00' E in the southern part of Nigeria. The major towns in the study area include Agola, Fugar, Agenebode, west of River Niger, and Onitsha, Umunya, Enugu, Leru, Okigwe, Isikwuato and Ohafia areas, east of the River Niger. Four geologic formations have been identified in the area: the Nsukka Formation (Late Maastrichtian – Paleocene), the Ajali Sandstone and Mamu Formations (Maastrichtian), and the Campanian Nkporo Formation (Fig. 1). The Enugu escarpment is a prominent geologic feature in eastern Nigeria: it is formed by the Ajali Sandstone plus sandstone units of the Mamu Formation. Intense gullying characterize the area [1]. In the highlands between Fugar, Agola and Agenebode the Ajali Sandstone crops out. The Ajali Sandstone is located in the Anambra Basin hydrogeological province though outcrops are known in Imo, Cross River, Ogun and Osun hydrogeological basins [2,3].

1.1 Geological Setting

Investigations on the geology of the study area have been carried out earlier by [4-6], and more recently by [7-10]. The Mamu Formation contains shale and sandstone members which include carbonaceous shale, sandy shale, sandstone and siltstone. The fractured nature of these members renders them potential reservoir for aquifers. Planar or tabular cross-bedding structures can be observed on the sandstone units which are in places ferruginized

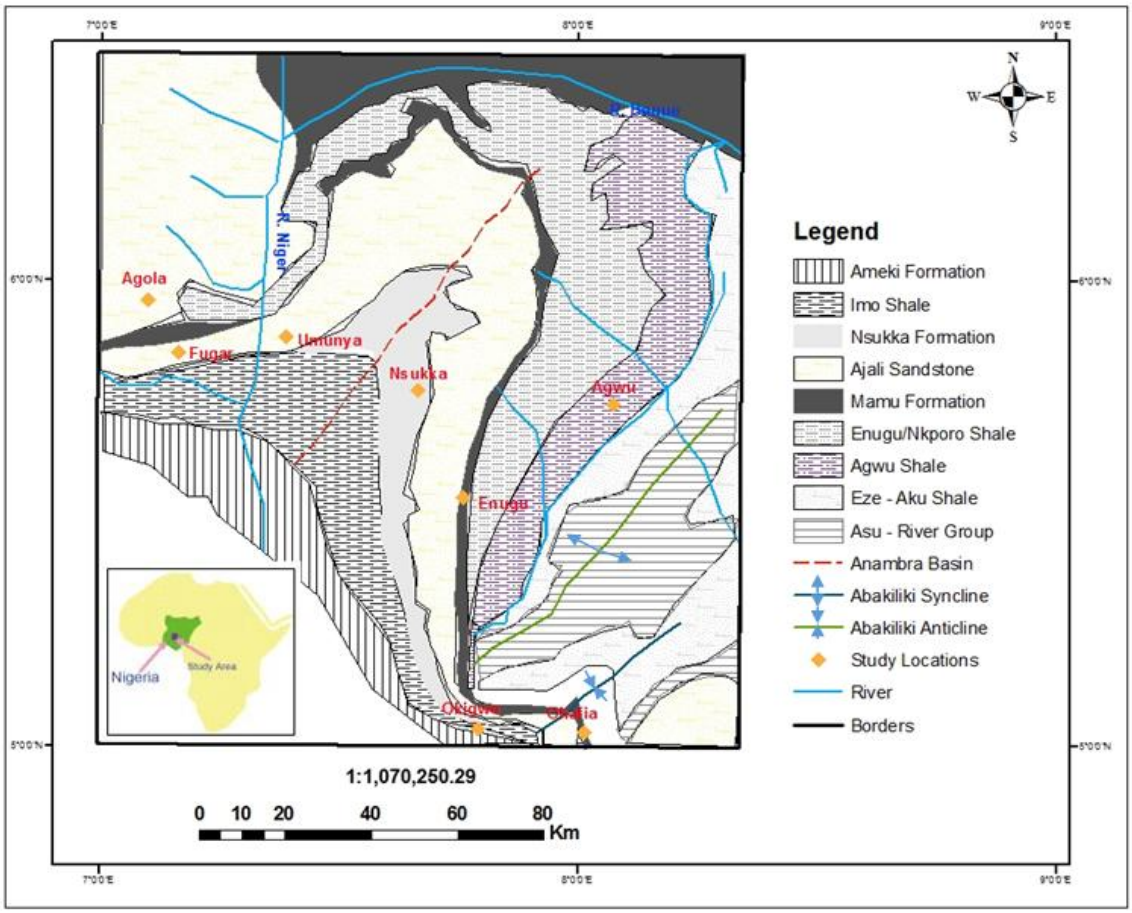


Fig. 1. Geological map of the study area in Southern Nigeria

sandstones, thickness 0.5 to 2.5 m and fine- to medium- grained. The formation is coaliferous: it was earlier mined at Enugu, Onyema and Okpara mines (but presently abandoned).

The Ajali Sandstone Formation is about 400m thick. It stretches from Fugar-Agola-Agenebode-Idah axis through the Nsukka-Enugu-Onitsha-Okigwe-Isikwuato to Ohafia areas. The thick sandstone members are medium-to coarse-grained, friable, poorly sorted and cemented, white to reddish brown coloured. At the boundary between sandstone units and Mamu Formation, there are clay draped features, bands and lenses of mudstone. Ajali Sandstone overlies the Mamu Formation conformably. The main angle of the foreset with the underlying major bedding range from 18° to 20° in a west-south-west direction. Some joints which are at various angle to the beds have been widen by erosion. The sandstone units are in places overlain by thick, red earth or superficial deposits where Nsukka Formation has been eroded away.

The study area is characterized by two types of landforms: residual hills and dry valleys. Such highlands and valleys are related to the rock type or geologic formation underlying the areas [11]. In southern parts of Ohafia area, the limestone units of Nsukka Formation are underlain by the ferruginous part of Ajali Sandstone, which [12] considered as a transitional zone between the predominantly marine sequence of the Nsukka Formation and predominantly continental Ajali Sandstone Formation.

The Nsukka Formation overlies the Ajali Sandstone conformably. The dip amount varies from north to south, with average of 3° in the north and greater values in the south. In the southern parts, exposure of Nsukka Formation are limited, they have been eroded and replaced with lateritic or superficial deposits. There are several outliers, some of which are above 130m from the ground surface in the northern parts. The residual hills are the remnants of Nsukka Formation that covered the area. According to [12], the area was uplifted during the Miocene–Pliocene and exposed to intense erosional activities. Five types of these hills are recognized, according to their shapes: domey, conical, ridges, flat-topped or mesa-like and cuesta-like. The lithology consists of sandstones, carbonaceous shale, clay, siltstone, and bands or lenses of impure coal.

The thick shale member consists of soft greyish, carbonaceous and pinkish shale with mudstone and siltstone inclusions. The shale exhibits characteristic lamination and bedding fissility. Concretions or heteroliths have been observed in the shales, while sandstone and siltstone are highly ferruginized. The sandstone are fine- to medium-grained, poorly consolidated and friable, and occasionally associated with lenses of greyish to whitish claystone, mudstone and siltstone. The Campanian Nkporo Formation overlies the Eze Aku Group facies. At Leru area, it marks the transition between Nkporo and Mamu Formations [13].

2. METHODOLOGY

Remote sensing photograph [14] and field mapping were carried out in the area to identify ancient river channels in transitional depositional environment and recent geomorphic features in active river channel deposits (Fig. 2 and Plate1). The period of field visit to Nkisi River was at the peak of raining season, therefore the point bar and mouth bar areas were flooded. Original sedimentary structures were identified and measured in the east and west of River Niger where the Ajali Sandstone are exposed.

3. RESULTS AND DISCUSSION

The coal-bearing Mamu Formation are of poor water quality as indicated by the hydro-geochemistry of coaliferous aquifers in Enugu area. The acidity of the mine water is mainly due to sulphuric acid, probably from the oxidation of iron pyrites and/or other metallic sulphides with dissolved oxygen. Sulphur stains were equally observed on the surface of Nkporo Formation at Agola area (Plates 2 and 3). This can cause contamination of the spring water, which is being tapped from the lower section of the exposure on Plate 4.

Fig. 3 is a litholog of the Leru section of Nkporo Formation, which is comparable to Agola area, west of the River Niger. The palaeogeographic reconstruction of Environment of Deposition (EoD) is shown in Fig. 4 [15].

Vertical burrows of organisms like simple straight tubes example, Skolithos and branching dwelling burrow with pelleted walls Ophiomorpha, were observed at Fugar, Umunya, Uwani-Uboji and Okigwe areas (Plates 5-9). These points to the EoD as marine with tabular or cross beds and poorly sorted sands.

Fig. 2. River Niger showing braid bar, while Nkisi River showing point bar and mouth bar [14]

Plate 1. Field photograph on the Nkisi River bridge. The point bar is at the NE

Plate 2. Field photograph showing ancient river deposit: Point bar deposit at Agola west of the River Niger

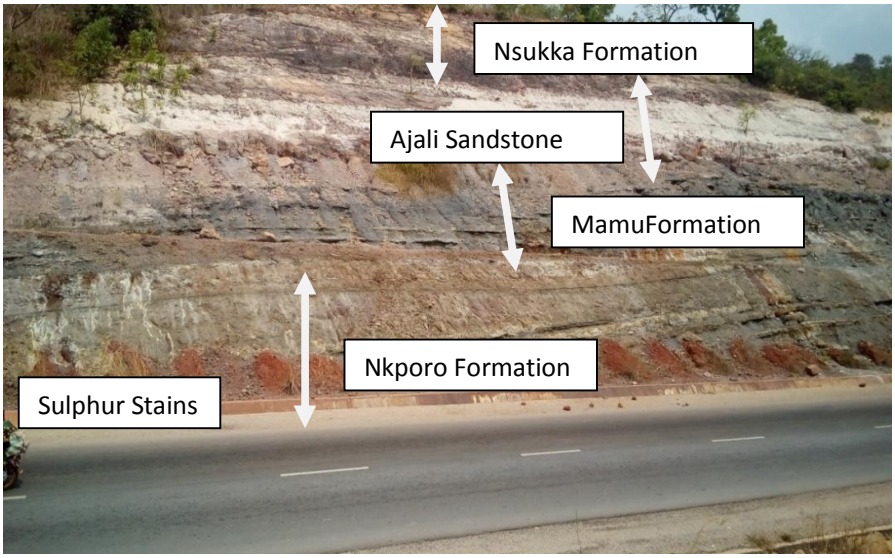


Plate 3. Field photograph showing Nkporo Formation (greyish-brown), Mamu Formation (greyish-black), Ajali Sandstone (white coloured) and Nsukka Formation (reddish-brown) on a road cut. The top of the Nkporo shows sulphur stains and pinch out at Agola area Edo State. The Ajali Sandstone showing graded bedding feature

The road cut exposure at Umunya, about 18 km from Onitsha, consists of heteroliths of fine-grained clayey tidal sandstone, claystone, poorly sorted fluvial sands and wave ripple laminated fine sandstone, indicating low energy environment at the top. The heteroliths on the upper section are composed of small-scale fine sandstone layers, rapidly alternating with white claystones of similar thickness (from 70 – 110 cm).The middle section is grey to off-white claystones, interbedded by two lenses of lensoid coarse, poorly sorted, ferruginous sandstone. There is heterolith on an erosion surface. The lower section shows physical and biogenic sedimentary structures indicating tidal/subtidal sedimentation.

The claystones are overlain by channelled sandstone with clay-draped foresets, reactivation surfaces and burrows, becoming flat-bedded and increasingly clayey upwards. Claystone overlain by channelled sandstone, clay-draped foresets, reactivation surfaces and burrows. The litholog of the exposure is shown in Fig. 5.

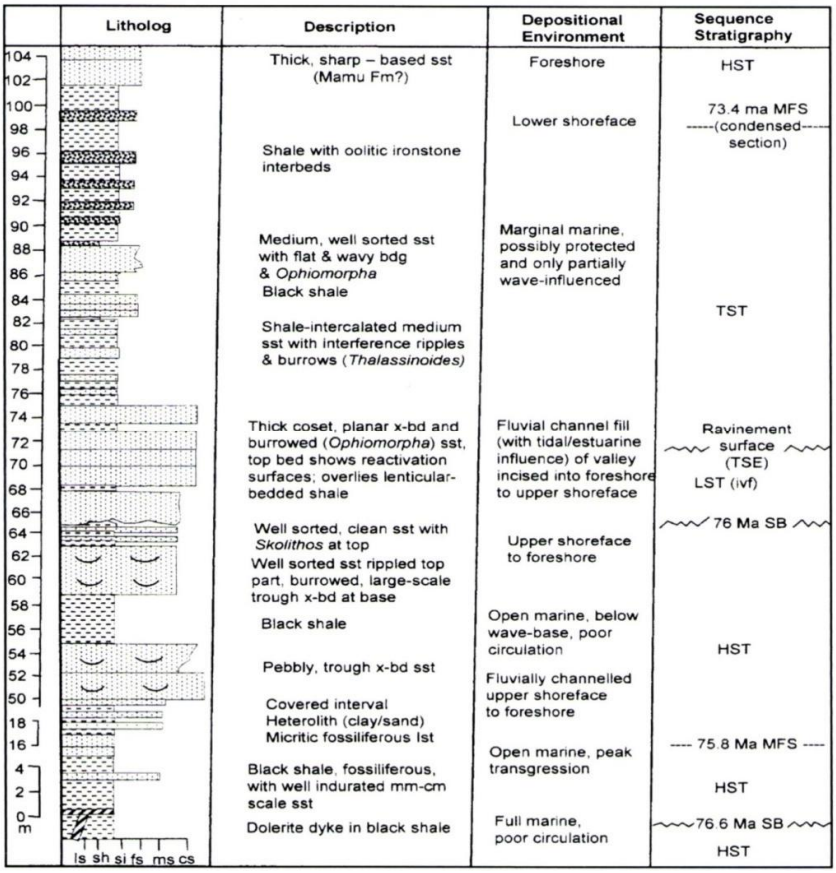
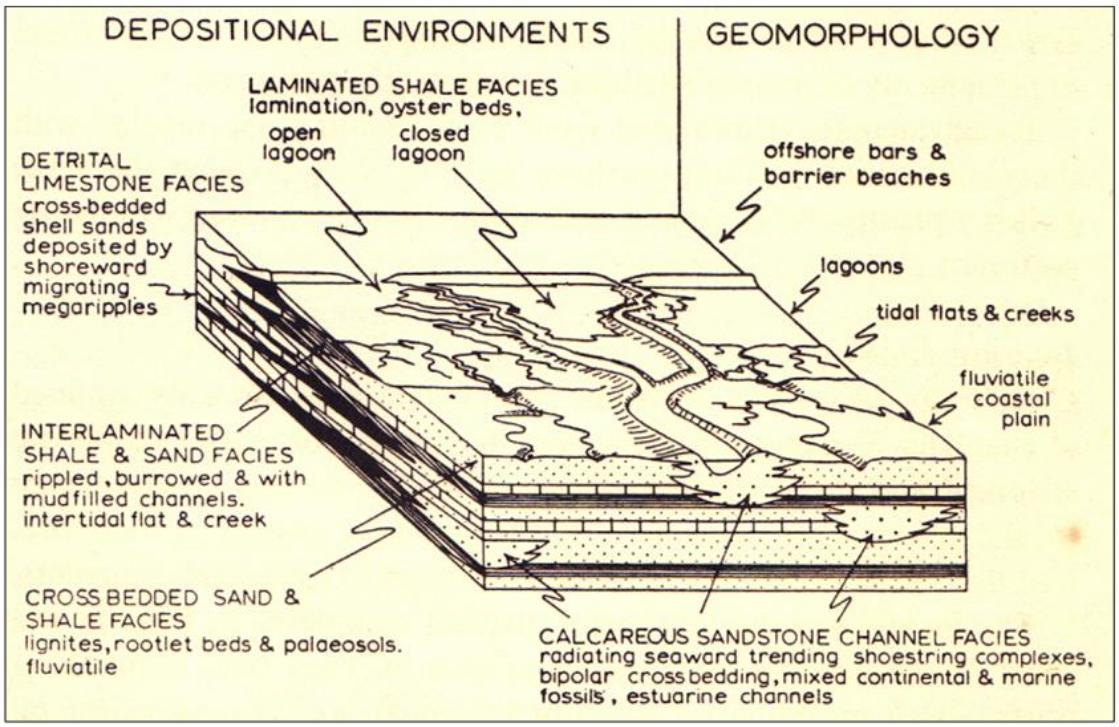


Fig. 3. Litholog of Leru section, similar to the lower section of Agola area, west of River Niger

Plate 4. Field photograph showing spring water from the contact between fractured sandstone members of Ajali and Mamu formations, at Agola, west of River Niger



Illustrating paleogeographic reconstruction : 3D model incorporating the EoDs & the geomorphic setting (after Selley, 1996); recall Walther's Law

Fig. 4. A sketch (not to scale) showing paleogeographic reconstruction [15]

Plate 5. Field photograph showing Ajali Sandstone white-colured, tabular or planar cross beds, separated by reddish clay layer at Fugar, Edo state west of the River Niger. This is a current bedding feature

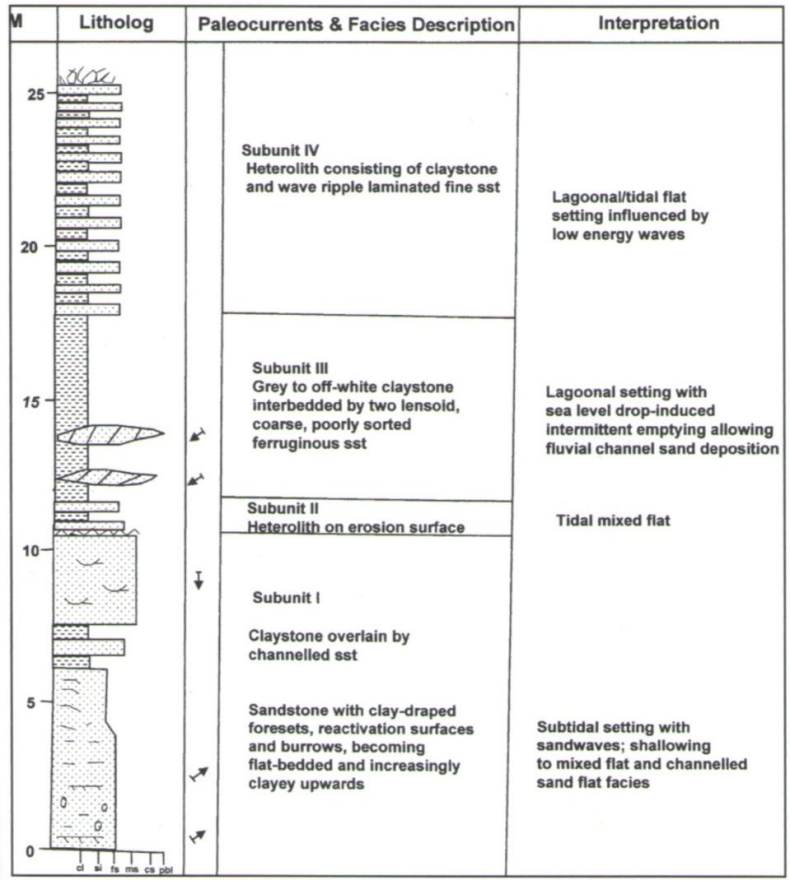


Fig. 5. Litholog of a section of the Umunya road cut exposure

Plate 6. Field photograph of section showing trough cross beds at Fugar, West of River Niger. This is a ripple mark feature

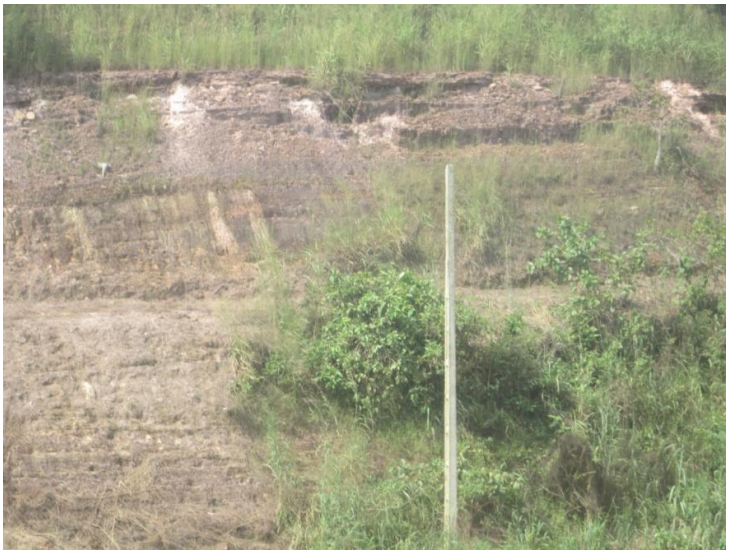


Plate 7. Field Photograph showing the thickness of Ajali Sandstone about 20 m or about two electric poles of the road cut exposure at Umunya

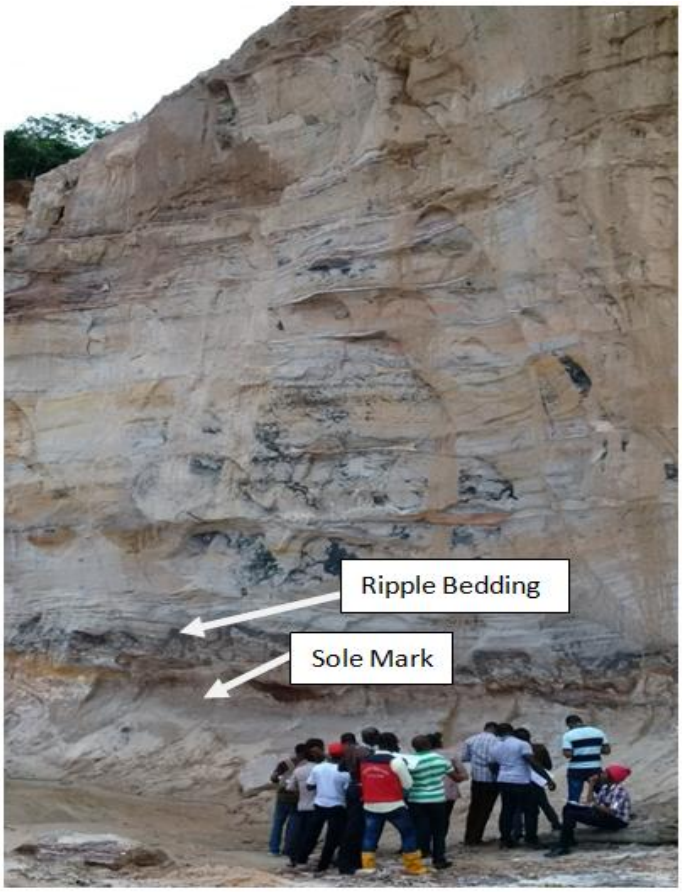


Plate 8. Field photograph of Ajali Sandstone, showing planar and trough cross beds, clay-draped features, lignite, sole mark and ripple bedding features towards the base at Okigwe, east of River Niger

At the Okigwe exposure, clay-draped, white to greyish sandstone and Mamu shale crop out. The ripple marks varies from 2 – 5 cm, while the sole marks from 3 – 7 cm (Plate 8). Directional structures are primary sedimentary features, indicating the depositing current direction. Such structures include cross-bedding, sole marks and grain fabric, and occur in all kinds of sediments but are common in sandstones and important in paleocurrent analysis. Cross-beddings represent the preserved lee-sides of the migrating ripples and dunes, indicating direction of the flow [15,16].

Plate 9. Field photograph of Ajali Sandstone formation, showing herringbone structure, planar and trough cross beds and skolithos burrows at Uwani-Uboji, about 6km from 9th Mile Corner, near Enugu

Plate 10. Ajali Sandstone (on top), and contact with the dark-colured Mamu formation at the base, dipping 4° SE at Ihube Okigwe area, east of River Niger. The Ajali Sandstone indicates a gradded bedding feature

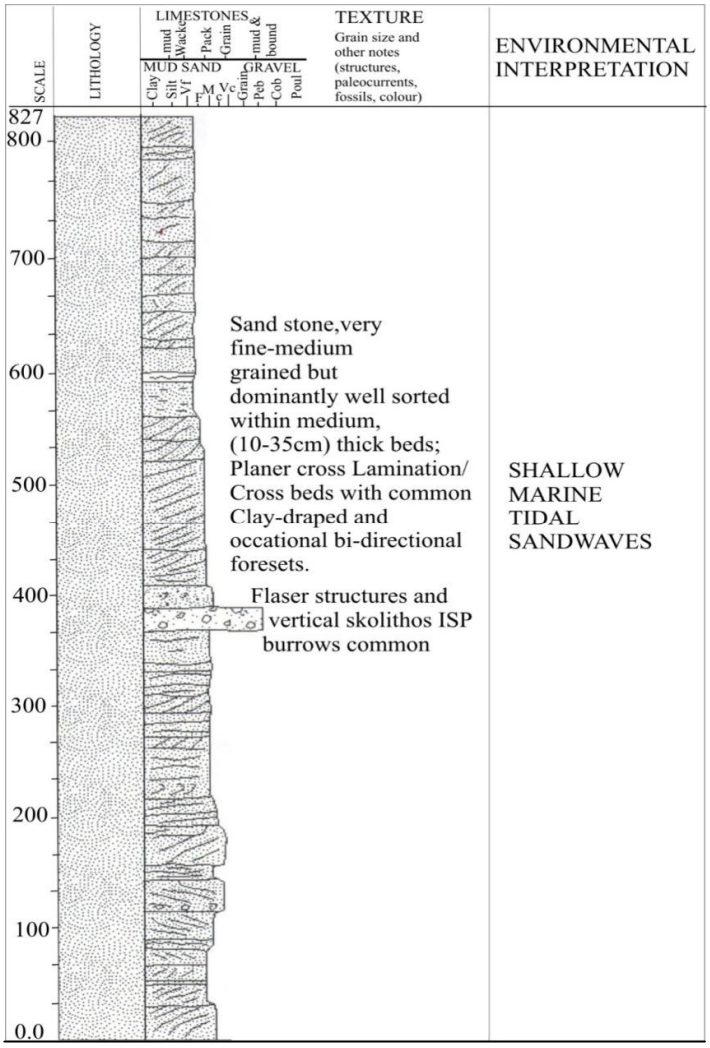


Fig. 6. Ajali Sandstone litholog at Uwani-Uboji

The Uwani-Uboji area is prone to gully erosion (Plate 9 and Fig. 6). The Ajali Sandstone is composed of very fine to medium but dorminantly fine grained, moderately to well sorted, weakly consolidated framework material with clay-draped tabular or planar cross-beds, herringbone cross beds, flasers, and ripples. Skolithos burrows are present and a logged section of the exposure shows that the sandstone was probably deposited as shallow marine subtidal sandwaves [17].

At Ihube Okigwe area (Plate 10), Ajali Sandstone has a sharp contact with Mamu Formation. The top of the Ajali Sandstone Formation is ferroginized and the lower section indicates graded bedding features. The Ajali Sandstone is being mined at several points in Okigwe area for road construction and blocks moudling for house construction [18].

4. CONCLUSION

The small-scale structures identified are original sedimentary structures. The evidence they present would have been different if there were tectonic features related to different tectonic episodes. The structures like tabular or cross beds and burrows of organisms were similar but ripples marks and sole marks were mostly identified east of the River Niger. The paleocurrent was consistently unidirectional to the northeast, an indication that tidal flood flow was far stronger than ebb regime, and effected a net landward shift of subtidal sand-waves. Secondary structures of tectonic origin like

tension gashes, cleavage and schistosity, and drag folding were not observed.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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