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Sedimentological and Paleodepositional Studies of Outcropping Sediments in Parts of Southern Middle Niger Basin

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ABSTRACT

The determination of paleodepositional environment within which geologic factors interplayed to create various sedimentary facies and facies associations present in outcropping sediments in parts of the Southern Middle Niger Basin, in order to establish sedimentary architectures through detailed field mapping and laboratory techniques, forms the focus of this study. The Lokoja Formation was mapped on outcrops exposed in Robinson Street, Mount Patti, Banda and Filele in Lokoja area and along the Okene-Lokoja-Abuja express way. The study area lies within latitude N 07^0 81´ and N 08^0 30´; longitude E 006^0 73´ and E 006^0 86´

One main lithofacies, sand, and three sub-lithofacies (fine-grained sand, medium-grained sand, coarse-grained sand) were defined. Sorting ranged from 0.72 – 1.29, indicating poor – moderate sorting for the Lokoja Formation. Depositional environments defined by values of binary plots of skewness versus standard deviation mean versus standard deviation for samples obtained from the Lokoja area, confirmed by binary plot of skewness versus median for same samples indicate that sediments of the Lokoja Formation was deposited in a continental fluvial paleodepositional environment forming a progradational architecture that was generated during relative sea level fall in the adjoining Anambra Basin.

Key words: *Middle Niger Basin, Paleodepositional Environment, Lokoja Formation, Lithofacies, Mount Patti.*

I. INTRODUCTION

Late Cretaceous sediments from surface exposures of the Lokoja sandstone Formation exposed in outcrops along the Okene-Lokoja highway, the base of Mount Patti and in Lokoja town and environs were mapped and analyzed for sedimentological attributes to unravel their paleodepositional history. Outcrop samples were obtained within latitude N 07^0 81´ and N 08^0 30´; and longitude E 006^0 73´ and E 006^0 86´. The dominant lithologies in the area which include sand and ferruginized facies and their characteristic sedimentological attributes indicate deposition in a high energy condition in a continental milieu large coalescing fluvial deposystems. The sandy facies are generally arkosic characterized by poorly sorted very fine to conglomeratic sandstone sequences.

In this paper we report the results of a detailed field and laboratory analysis of outcropping sediments in parts of the Lower Middle Niger Basin, to unravel the paleodepositional environment in which the sediments were formed.

II. GEOLOGICAL AND PHYSIOGRAPHIC SETTING OF THE SOUTHERN MIDDLE NIGER BASIN

The Middle Niger Basin (also known as the Nupe or Bida Basin) is a NW-SE trending intracratonic basin extending from Kotangora (in the North) to just south of Lokoja (in the south). It stretches from south of the confluence of Niger and Benue Rivers to the dam lake of Kainji, where basement rocks separate if from the Sokoto Basin. Generally three physiographic units are recognized in the basin [1]. These are:

a. The Niger River with its flood plain and distributaries,

b. A belt of mesas and buttes, and

c. The plains.

The Niger River runs ESE in the southern marginal area of the basin. Its flood plains are broad and marked in most areas by a series of elongated ponds running parallel to the river. The belt of discontinuous mesas runs from an area about 16 km east of Mokwa to Lokoja and SW Dekina covering about 10% of the basin. The top lies between 260 and 500 meters around the Niger/Benue confluence areas. Flat lying to gently rolling plains covers about 70% of the basin. The plains lie between 60 and 180 meters above sea level in the Lokoja area. Sediment thickness in the Middle Niger Basin is estimated to be between 3000 and 3500 meters [16, 2].

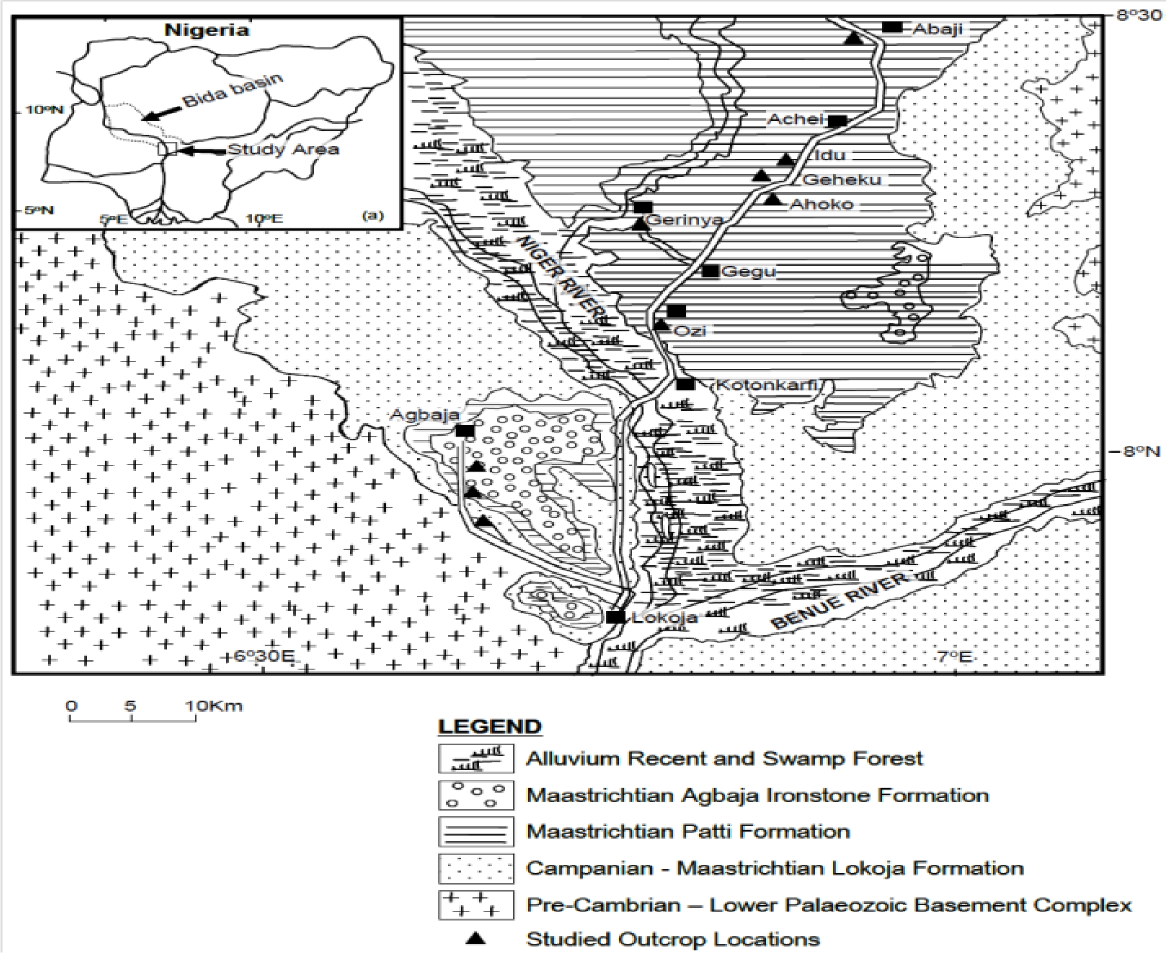

Fig. 1: Map of study area. (Modified from [9])

The basin occupies a gently down warped trough. The epeirogenesis responsible for the basin genesis seems closely connected with the Santonian tectonic crustal movements which mainly affected the Benue Basin and SE Nigeria. The buried basement complex probably has a high relief [6] and the sedimentary formations have been shown to be about 2000 metres thick by gravity survey [11], constituted of post-tectonic molasse facies and thin marine strata, which are all unfolded. Borehole logs, Landsat images interpretation, and Geophysical data across the basin suggest that it is bounded by a NW-SE trending system of linear faults [7]. Gravity studies also confirm central positive anomalies flanked by negative anomalies [10, 12]. This pattern is consistent with rift structures as observed in the adjacent Benue Trough/Basin. A detailed study of the facies indicates rapid basin-wide changes from various alluvial fan facies through flood-basin and deltaic facies to lacustrine facies [2]. Consequently, a simple sag and rift origin earlier suggested may not account for the basin's evolution. According to [2] paleogeographic reconstruction suggests lacustrine environments were widespread and elongate. Lacustrine environments occurred at the basin's axis and close to the margins. This suggests that the depocenter must have migrated during the basin's depositional history and subsided rapidly to accommodate the 3.5 km thick sedimentary fill.

The basin's strata are Late Cretaceous (Campanian – Maastrichtian) in age and were named the Nupe Sandstone by Russ (1930). However, the Sandstone is referred to by [1] as a Group (instead of a formation). [1] (op. cit.) sub-divided the Group into four formations: Bida Sandstone (oldest), Sakpe Ironstone, Enagi Siltstone and Batati Ironstone (youngest). A lateral facies variation occurs in the basin. Around Lokoja, the sequence is usually referred to as the Lokoja Sandstone. However, the Sandstone is only partly equivalent to the Nupe Sandstone [3] and is overlain by Patti Formation [6]. The Bida area and Lokoja area are considered separately as the stratigraphy as different. The Lokoja, Patti and Agbaja Formations occur as the three formational units in the southern Middle Niger basin. The Lokoja Formation consists of pebbly clayey grit and sandstone, coarse-grained cross bedded sandstone, and few thin oolitic iron stones. A basal conglomerate of well-rounded quartz pebbles in a matrix of white clay is rarely exposed. Its thickness depends on the relief of the underlying Basement Complex floor and varies between 100 and 300 metres [3].

The Patti Formation is a sequence of fine to medium-grained, grey and white sandstones, carbonaceous siltstone, clay stone, shale and oolitic ironstone. Thin coal seams may be present and white gritty clays are common. The maximum exposed thickness is 70 m [6], while the oolitic ironstones range from 7-16 m thick. The strata yielded a few non-diagnostic plant remains [3]. A Maastrichtian (and possibly Senonian) age was thus assigned to it based mainly on correlation with other formations e.g. the Nupe Sandstone and Enugu Shale of Campano-Maastrichtian age. [5] have recorded a palynomorph assemblage and a foraminifera fauna respectively from the Lokoja area. The micro fauna is considered to be a marsh assemblage.

The palynomorphs are made up mainly of pollen and spores, the assemblage of which is indicative of a Maastrichtian age [5] (op. cit.). [3] indicates that Patti formation yielded fossil plants (from the carbonaceous beds) dates the formation as Campanian to Maastrichtian. More recently, [9] reported a rich and well preserved palynomorph assemblage from the black shale outcrop samples of the Patti Formation collected between Kotonkarfi and Abaji and between Lokoja and Agbaja. The outcrop is constituted by marine dinocyst and the more copious continental sporomorphs. The assemblage is considered to be a confirmation evidence for the Late Cretaceous Tethys – South Atlantic connection through the Nupe Basin. The Agbaja Formation consists of oolitic ironstone and occurs as the topmost stratigraphic sequence in the Agbaja Plateau, on mesas around the southern part of the basin and the Lokoja area.

III. MATERIALS AND METHODS OF STUDY

The southern Middle Niger Basin characteristically lacks exploratory well or well preserved borehole sample, thus leaving us with the option of outcrop samples. Based on lateral and vertical facies changes, and bed thickness a systematic sampling of outcropping sediments was carried out to obtain samples. Thirty seven (37) sand samples obtained from the Lokoja Formation exposed in road cuts in the Lokoja area: Robinson Street Lokoja, Felele, Banda and Mount Patti were used for this study. Samples were lithologically described and subjected to further sedimentological analysis. Thirteen samples were air dried, crushed, and mixed and 50g of each sample was sieved in an automated sieve shaker for 10mins to obtain quantitative data set for further statistical analysis including the Graphic Mean (Mz), Inclusive Graphic Standard Deviation (σ_1), Inclusive Graphic Skewness (SK) and Graphic Kurtosis (K_G)

IV. SEDIMENTOLOGICAL AND PALEOENVIRONMENTAL ANALYSIS

Tables 1 shows summary of the results of sieve analysis carried out on thirteen field samples obtained from parts of the Lokoja Formation, exposed in Robinson Street, Felele, Banda and the basal section of Mount Patti. The graphical presentation of the results for the determination of relevant sedimentological parameters (mean, standard deviation, skewness and kurtosis) is shown in figure 2. Field description of sediments refined by labotaratory analytical results enabled the definition of three sandy subfacies in the area ranging from matrix supported cross bedded cobbly to medium grained poorly sorted arkosic sands with pinkish tint (fig. 3) to grain supported cross bedded pebbly poorly sorted arkosic sands (fig 4). This cobbly conglomeratic and very coarse sand occurs as basal units (fig. 3 and 4**),** while the coarse and medium sand facies occurring at higher levels.

Table 1: Quantitative graphical analytical values of sieve analysis for the Robinson Street, Filele, Banda and Mt. Patti outcrops.

Sample	(Mz)	Grain class	σ_1	Sorting class	SK_I	Skewness
Robinson St. Bed 1	0.64	Coarse sand	1.26	Poorly sorted	0.04	Nearly symmetrical
Robinson St. Bed 2	0.59	Coarse sand	0.72	Moderately sorted	-0.23	Coarse skewed
Robinson St. Bed 3	-0.09	Very coarse sand	1.22	Poorly sorted	-0.09	Coarse skewed
Robinson St. Bed 4	0.73	Coarse sand	1.29	Poorly sorted	-0.17	Coarse skewed
Robinson St. Bed 5	-0.70	Very coarse sand	-	-	-	-
Banda Bed 1	0.75	Coarse sand	0.73	Moderately sorted	0.14	Fined skewed
Banda Bed 2	1.17	Medium sand	1.02	Poorly sorted	0.10	Fined skewed
Banda Bed 3	-0.27	Very coarse sand	-	-	-	-
Filele1 Bed 1	0.93	Coarse sand	0.89	Moderately sorted	-0.07	Nearly symmetrical
Filele 1 Bed 2	0.60	Coarse sand	1.10	Poorly sorted	-0.07	Nearly symmetrical
Filele 2 Bed 1	0.21	Coarse sand	1.11	Poorly sorted	0.14	Fine skewed
Mount P. Bed 1	0.30	Coarse sand	1.26	Poorly sorted	0.17	Fine skewed
Mount P. Bed 4	0.54	Coarse sand	-	-	-	-

Mz = Mean Grain size, σ_1= sorting, SK_I = Skewness

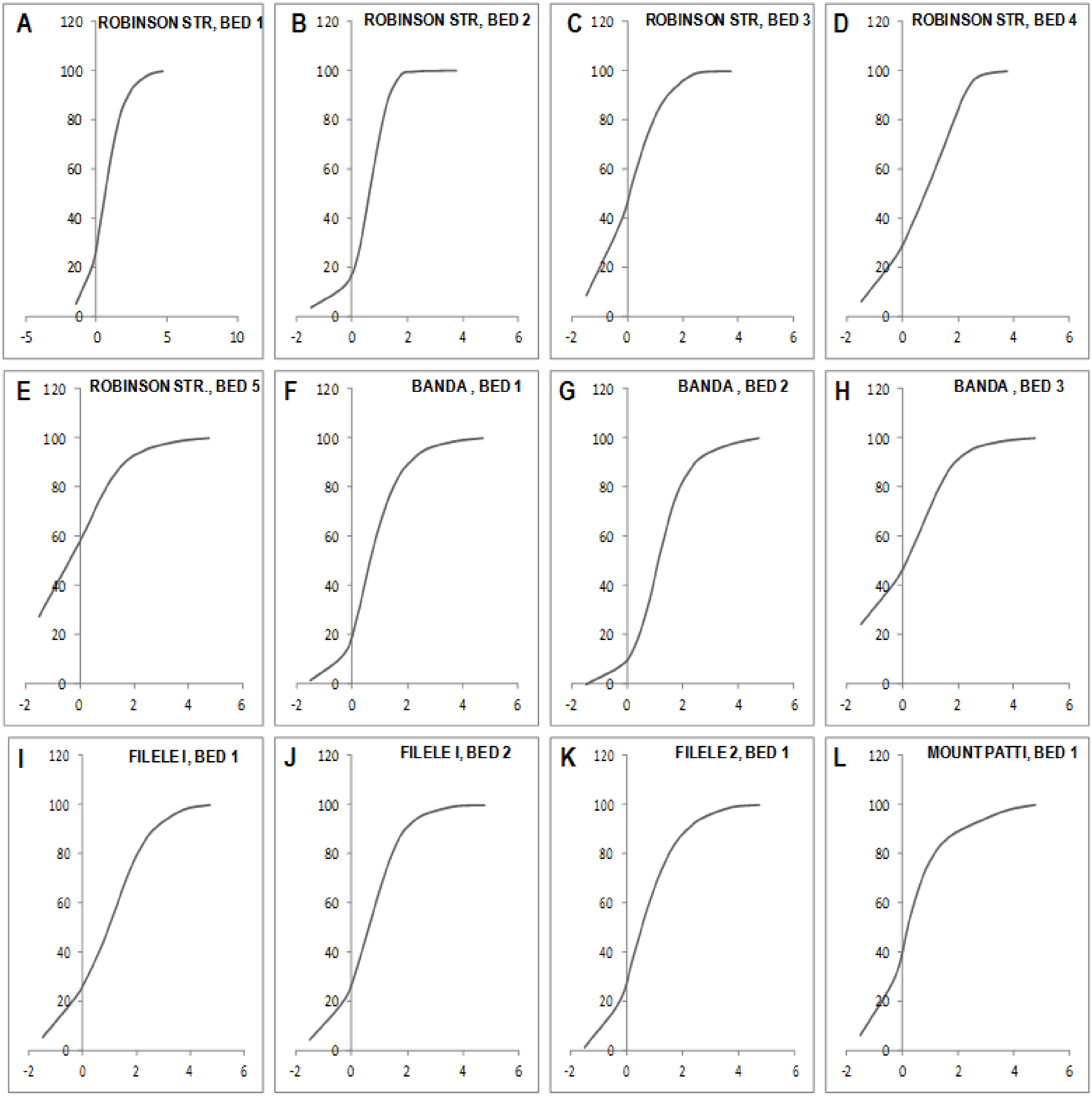

Fig. 2: Graphical presentation of sieve analysis result of samples from various locations. A – E, Robinson str. Samples 1 - 5; F - H, Banda samples 1 – 3; I – J, Filele 1, beds 1 – 2; K, Filele 2, bed 2; L, Mt. Patti bed 1.

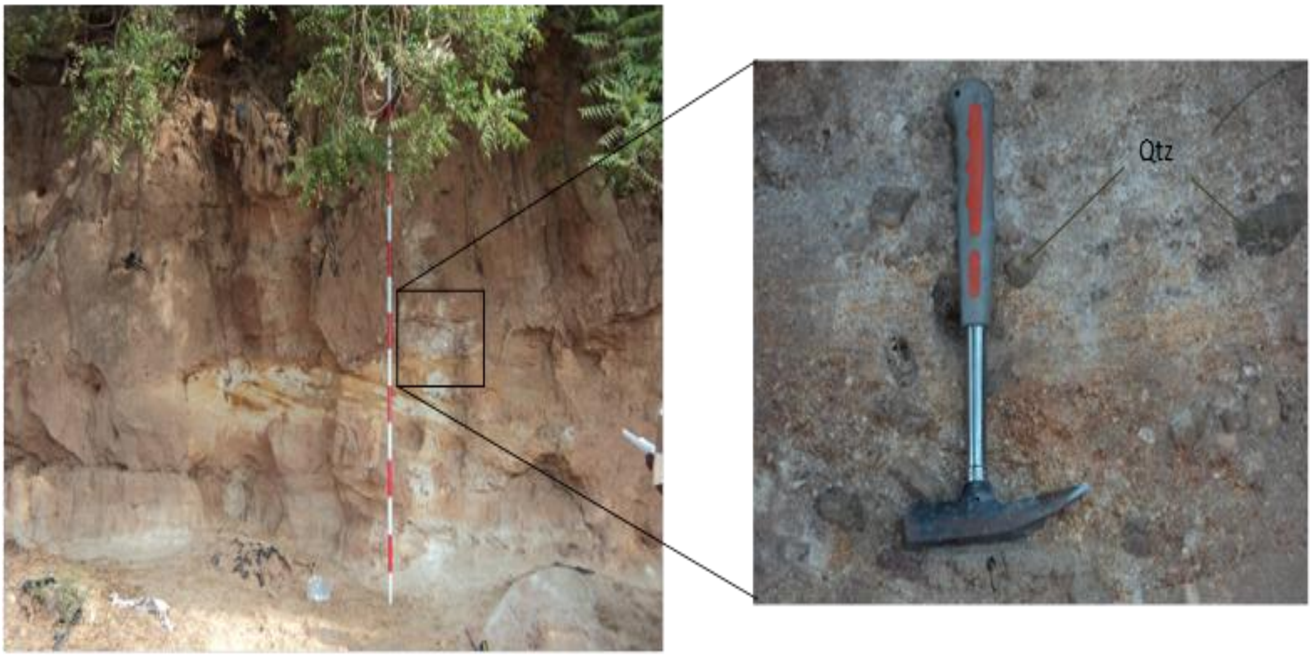

Fig. 3: Matrix supported Cross bedded arkosic very coarse sandstone with large quartzitic conglomerate and breccias fragments exposed along Robinson street road cut section (Qtz = quartzitic breccias fragment).

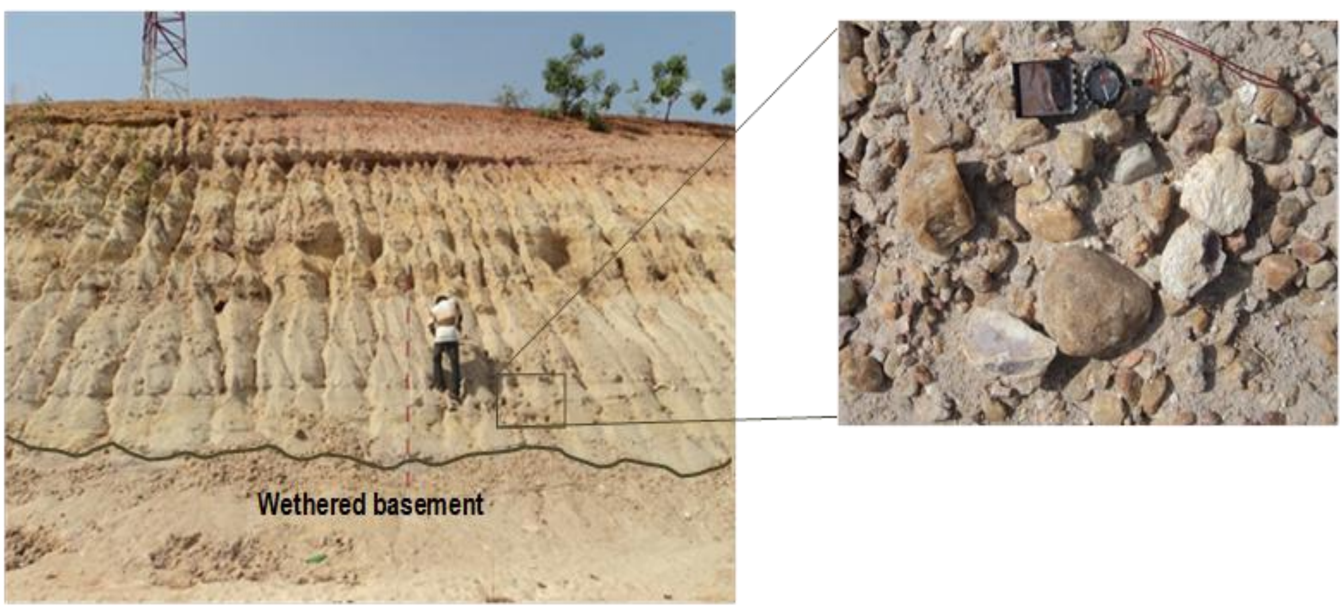

Fig. 4: Thick sequence of very fine to cobbly poorly sorted arkosic sand facies of the Lokoja Formation unconformably overlying the Precambrian basement exposed on a road cut at Filele along the Okene-Lokoja road.

The Lokoja Formation lies unconformably on the Precambrian Basement Complex (fig. 4). The contact between the Lokoja Formation and the basement mapped in this study is visible at Filele (fig. 5) along the Okene-Lokoja express way. The proximity of the sediments to the Precambrian basement in this area accounts for the arkosic components which have been derived from the disintegration of granitic rock fragments plucked from the adjoining basement. High angle cross bedding, fining-upward sequences underlain by very poorly sorted, medium to cobbly conglomeratic sands with large quartzite breccias interpreted as channel lag deposits, characteristic of point bar deposits is commonly exhibited.

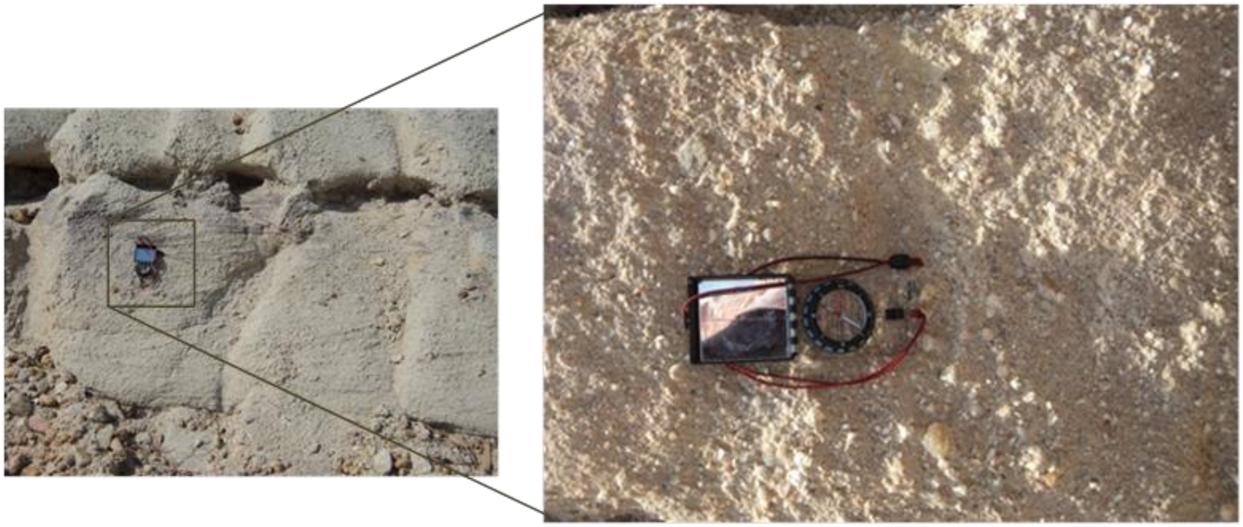

Fig. 5: Grain supported Cross bedded arkosic very coarse sandstone with large pebbly conglomerate fragments exposed along Okene-Lokoja road cut section at Filele.

Thin ferrugenized beds occur discontinuously within the sandstone beds. The deposit gives evidence of a regressive phase in the basin as they completely lacked the characteristics of clastic marine deposits. Sorting values range from 0.72 – 1.29 for the Robinson street, 0.89 – 1.11for Filele, 0.73 – 1.02, for Banda and 1.26, for Mt. Patti outcrop sample s respectively (Table 14). These values are indicative of poor sorting reminiscent of deposition in a fluvial setting, [4], and thus implying deposition during the regressive out-building of continental facies during the Campanian age in the Middle Niger Basin.

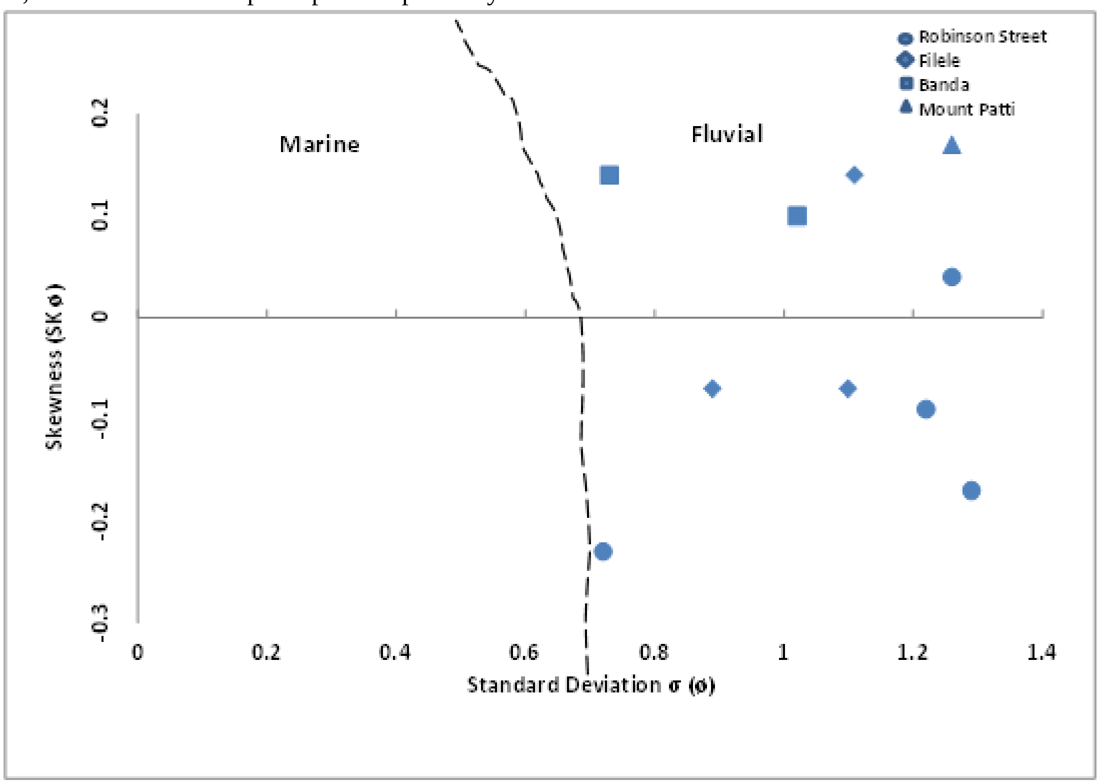

Figure 6: Skewness vs Standard Deviation plots for the Lokoja area (boundary modified after [4])

To further establish the fluvial facies defined for the Lokoja Formation using the sorting values (Table 1), binary plots **(**fig. 6 - 8**)** with boundaries modified after [4], [8], and [15]was done for the samples using the skewness, standard deviation, median and mean values generated from the sedimentological sieve analysis (Table 1). All values plotted falls within the fluvial domains.

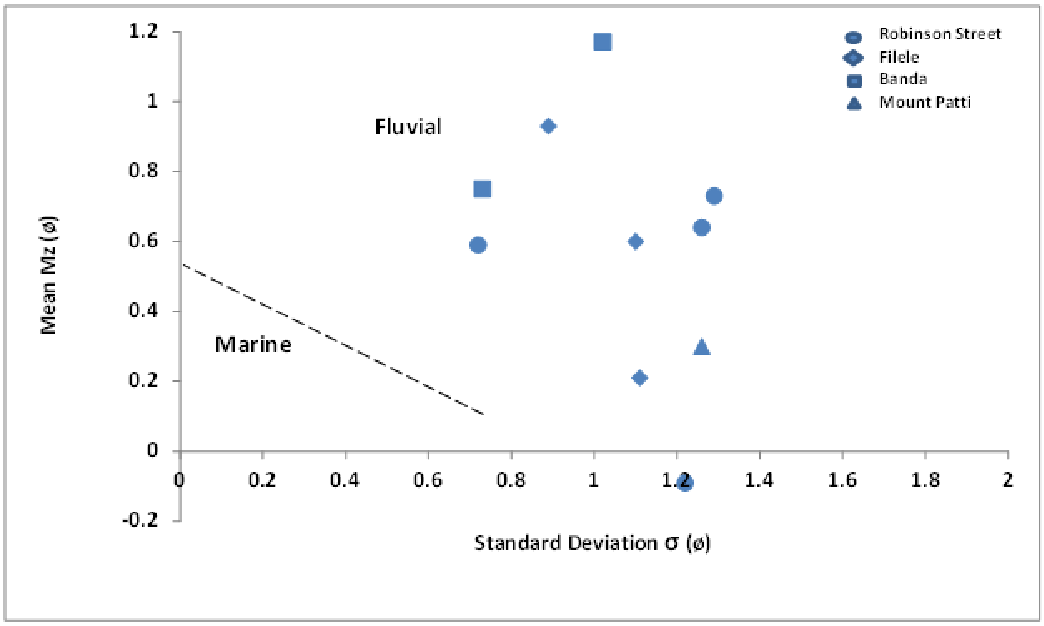

Figure 7: Mean vs Standard Deviation plots for the Lokoja area (boundary after [8])

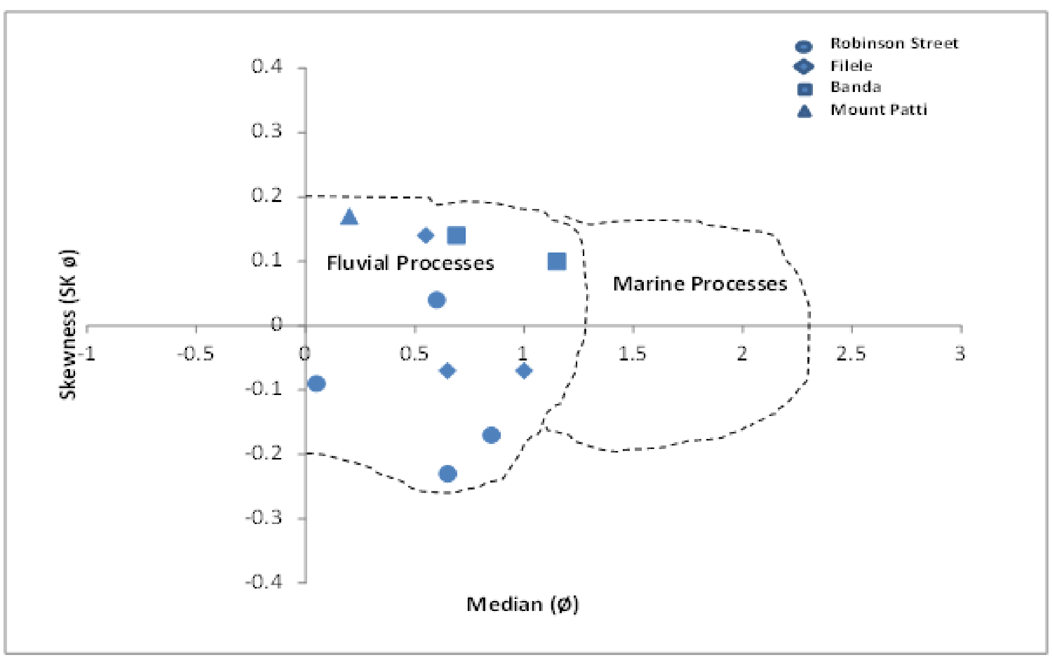

Figure 8: Plot of Skewness against Median plots for the Lokoja area (boundary modified after [15])

V. SEDIMENTARY FACIES OF OUTCROPPING SEDIMENTS IN RELATION TO SEA LEVEL CHANGE.

On bases of environment and processes of deposition which in turn defines the sedimentologic and characteristics of the deposits, fluvial facies is the basic sedimentary facies defined in the outcropping sediments of the study area. A confirmation of the above conclusion on depoenvironment was achieved by values derived from scattered diagram of [4], [8] and [15]. All these reveal and confirm that the outcropping sediments of the Lokoja Formation mapped at Robinson Street, Filele, Banda and Mount Patti are fluvial facies. Field observation and sedimentological analysis as shown in figures 3 - 5 reveals that the sediments are characterized by rapid lateral and vertical change in facies, are poorly sorted, possess very fine to very coarse grains, fining upwards, are texturally and mineralogically immature, displaying sedimentary structures such as cross beddings and lamina; the basic properties of fluvial sediments [13, 14].

The outcrops stand at different elevation, ranging from 47m at Banda to 328m at the base of Mount Patti above sea level, with facies equivalents occurring at lower elevation towards the axis of the basin in a south-eastern direction. The stratigraphic position of the fluvial facies of the Lokoja Formation in this basin is evident of deposition during a regressive out-building phase of basin evolution. Regression is a phenomenon associated with fall in relative sea level, during which period the shoreline moves basinward giving rise to high fluvial activities that is signaled as lowstand progradational sequences or architecture, reminiscent of the Lokoja Sandstone Formation. This trend is adduced to the Late Cretaceous sea level oscillation that affected the adjoining Anambra Basin.

VI. CONCLUSION

The field and laboratory analysis of siliciclastics sediment samples from outcrops of the Lokoja Formation enabled the discrimination of various subfacies formed in continental paleodepositional settings of dominantly fluvial systems during the Late Cretaceous out-building of sedimentary sequences in the Southern Middle Niger Basin and signaled as lowstand systems tract architecture.

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