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Research Article

GRAIN SIZE DISTRIBUTION AND PALEOENVIRONMENTAL STUDIES OF UPPER CRETACEOUS TO PALEOCENE ROCKS IN AUCHI SHEET 266, BENIN FLANK, WESTERN EXTENSION OF THE ANAMBRA BASIN, SOUTHWESTERN NIGERIA

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Abstract

Out crop samples from Mamu, Ajali and Nsuka formation at the different location and ditch cutting samples gotten from Ugbekpe well at different intervals were collected from Benin flank, western extension of the Anambra basin with the aim of identifying their lithofacies and paleoenvironments. Five (5) lithofacies were identified in the Lokoja Basa'Nge' Formation which are cross laminated sandstone, coarse to pebbly grained sand stone, bioturbated sand stone, silty clay, medium to coarse grained sand stone, and sandy clay. Eight (8) lithofacies were identified in Mamu Formation which are parallel laminated grey shale, parallel laminated dark shale, parallel laminated silty clay, ripple bioturbated clayey siltstone, silty clay, parallel laminated clayey siltstone, siltstone, and clayey siltstone. Six (6) lithofacies were identified in Ajali Formation which are fine to medium sandstone, planar cross-bedded sandstone, herring-bone cross-bedded sandstone, medium to coarse sandstone, medium ripple laminated sandstone, and sandy clay. Ten (10) lithofacies were identified in the Nsukka Formation this include dark fissile shale, fine to medium shaly sandstone, coarse poorly sorted sandstone, black fissile sandy shale, clayey sandstone, whitish fine grained sandstone, reddish brown sandstone, granule to pebbly sandstone, grey clay and silty sandstone. Sedimentary structures that characterize these sediments are trough cross bedding, reactivation surfaces, horizontal laminations, low angle cross laminations, herring-bone cross stratifications and planar cross bedding. The depositional environment suggested for the various formations are fluvial to shallow marine environment for Ajali sandstone Formation, fluvial environment for Lokoja Basa'Nge Formation , Near shore to Deltaic environment for Mamu Formation and Open marine, shallow marine, Near shore to Deltaic environment for Nsukka Formation. The Nsukka Formation shows a progradational dominated stacking pattern and a system tract that is basically Highstand systems tract (HST) and one maximum flooding surface.

Keywords: Lithofacies, Paleo-environment, Anambra Basin, Benin Flank, Grain size.

INTRODUCTION

The Anambra Basin is a Cretaceous/ Tertiary basin which is a structural link between the Benue Trough and the Niger- Delta Basin. The evolution of the Benin flank in South Western Nigeria is known to have started with a series of tectonic activities which accompanied the initial opening of the South-American and African plates in late Jurassic to Cretaceous time; (Burke *et al.,* 1972). These events created the interior fracture basin of the Benin flank and part of the Benue Trough Complex and the Benin Basin. The later Santonian-Campanian tectonics which produced the Abakaliki Anticlinorium and the other fold sequence along the Benue Trough Complex also produced the Synclinal basins of the Anambra and Afikpo Syncline. The Niger Delta Basin developed as the Benue Trough feed out sediments, just filling the Anambra Basin and led to the outward growth of the delta; (Burke *et al.,* 1972; Nwajide, 2013). Outcrops available, remain the best and most direct source of information on the rock record, having played a good role in building the primary data set which largely helped in understanding and establishing a stratigraphic architecture in various depositional settings in the flank. Field investigation was used to carry out a detailed field mapping with emphasis on Lithofacies and their palaeoenvironmental significance. Each lithofacies has individual physical characteristics such as grain size, structure and mineral assemblage, sorting variations, which are largely dependent upon depositional processes such as energy conditions and sediment supply source.

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Lithofacies in conjunction with other sedimentologic analyses can enable accurate paleoenvironmental appraisal. This work was carried out with the aim of identifying the paleoenvironment of deposition using lithofacies. It involved sampling of outcrops and subsurface formations from a number of boreholes drilled within the flank.

Location of the Study Area

The study area is geographically located in the Southwestern Nigeria, and defined by Latitudes 07^0 $00^!$ N and 07^0 $15^!$ N and Longitudes 006^0 $00^!$ E and 006^0 $30^!$ E, which constitutes part of the Auchi Sheet 266 (1:100,000). It covers an area of about 2,400km^2. Major access roads into the area include Auchi – Fugar Road, Auchi- Igarra Road, Ayogwiri- Apana Road, Iyora- Uzaire Road, Apana- Iyora Road, Auchi Ukpilla Road, Ugbekpe- Ekperi Road, Ogbonna- Okpekpe Road, Auchi-Ohame Road, as well as Ogbonna- Imiegba Road. The major towns are Auchi, Fugar, Jattu, Imiegba, and Okpekpe; (Fig 1.)

The Stratigraphic Fill of the Anambra Basin

Sedimentation within the Anambra Basin consists of deltaic complexes (2500m thick) ranging from Late Cretaceous to Late Eocene in age. Two major transgressions occurred within the basin resulting in the Nkporo depositional cycle during the Late Campanian to Early Maastrichtian, and the Nsukka depositional cycle during the Late Maastrichtian to Late Paleocene, (Reijers *et al.,* 1997). The formations that make up the Nkporo cycle are the Agbani, Owelli, Mamu and Ajali Formations.

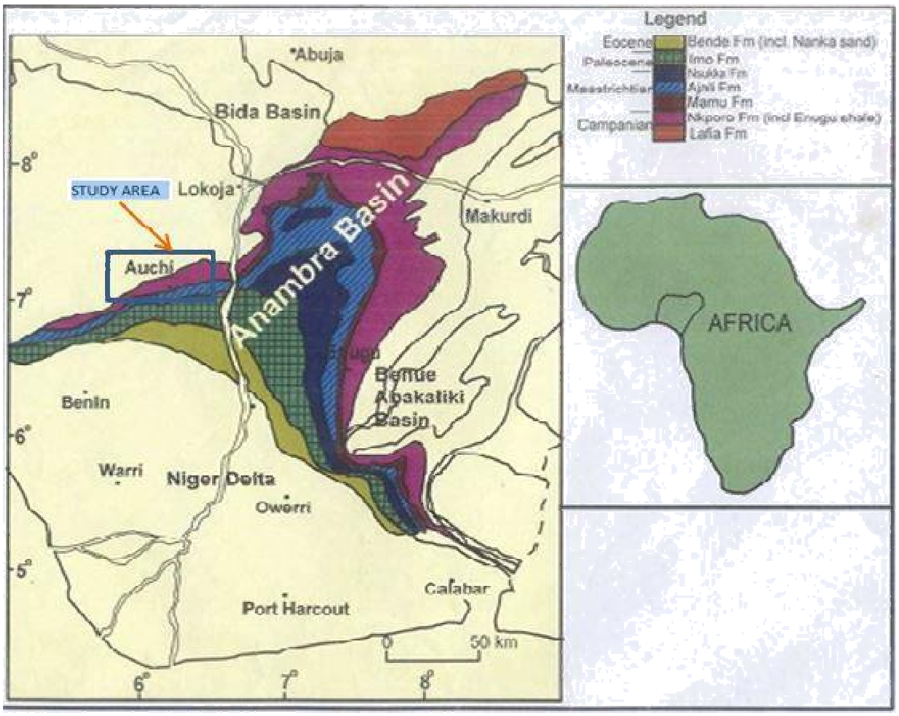


Fig. 1.Map of Anambra Basin showing the location of the study area (Drawn from the Geological Map of Nigeria, GSN 1994)

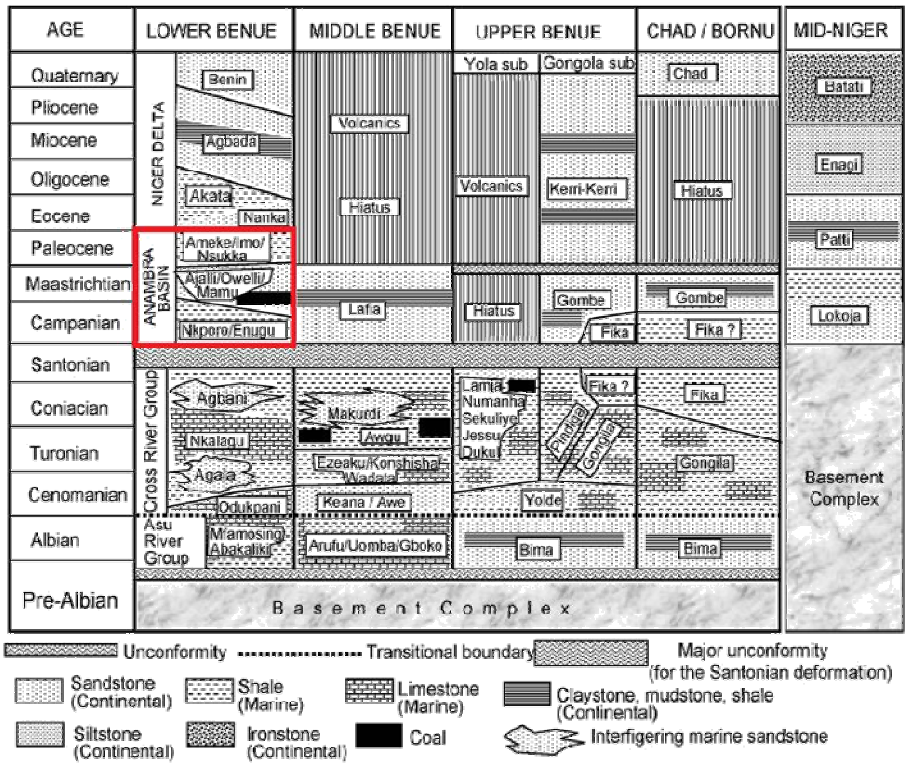


Fig. 2. Stratigraphy of the Anambra basin in relation to the Benue Trough complex (Adapted from Obaje *et al.,* 2006)

The Ajali Formation marks the height of the regression before the beginning of the Nsukka depositional Cycle. The Enugu Shale and Nkporo Shale sequences represent brackish marsh and fossiliferous prodeltaic facies, respectively. The Nsukka Formation marks the beginning of the Nsukka cycle, and is interpreted to be a fluvio-deltaic phase of deposition. This cycle ended with the deposition of the Imo Shale, which is interpreted to be shallow marine shelf sediments. The deposition of the Ameki Group and its laterally equivalent Nanka Formation represents the start of the Eocene regression. The shape, closeness of sediment source areas, transgression and regression cycles, and paleo-circulation patterns are all factors that had major impact on the depositional patterns in the Anambra Basin (Reijers *et al.,* 1997).

MATERIALS AND METHODS

This study involves field investigation and laboratory analysis

Field Investigation

Field mapping and lithologic studies of outcrop sections and ditch cuttings from bore hole samples was used to provide data for lithofacies studies, which will aid in identifying the paleodepositional evironments. Outcrops were studied lithologically with their attributes and characteristics recorded.

Table 1. Lithostratigraphic framework for the Early Cretaceous-Tertiary period in Southeastern Nigeria (after Nwajide, 1990)

m.y	AGE	ABAKALIKI – ANAMBRA BASIN	AFIKPO BASIN
30	Oligocene	Ogwashi-Asaba Formation	Ogwashi-Asaba Formation
54.9	Eocene	Ameki/Nanka Formation/ Nsugbe Sandstone (Ameki Group)	Ameki Formation
65	Palaeocene	Imo Formation Nsukka Formation	Imo Formation Nsukka Formation
73	Maastrichtian	Ajali Formation Mamu Formation	Ajali Formation Mamu Formation
	Campanian	Npkoro Oweli Formation/Enugu Shale	Nkporo Shale/ Afikpo Sandstone
83 87.5	Santonian		Non-deposition/erosion
88.5	Coniacian	Agbani Sandstone/Awgu Shale	
93	Turonian	Eze Aku Group	Eze Aku Group (incl. Amasiri Sandstone)
100 119	Cenomanian – Albian	Asu River Group	Asu River Group
	Aptian Barremian Hauterivian	Unnamed Units	
	Precambrian	Basement Complex	

Sieve Analysis

The grain size analysis was aimed at determining grain size distribution of the sediments. The lithologic logs prepared from lithologic description were used as a guide. This analysis was carried out according to the sieve shaker method of Krumbien and Pettijohn (1938).

The samples were first air dried and twenty (20) samples were selected from both outcrop and ditch cuttings for the sieve analysis. 100g of each sample were disaggregated using a mortar and a pestle. The disaggregated samples were thoroughly mixed and a representative fraction of the sample was obtained by quartering. This was weighed in a sensitive spring balance and 50g of each sample were poured into sets of stacked mesh sieve comprising 4.00, 2.36, 1.70, 1.18, 0.60, 0.30, 0.15, 0.075, and 0.063 mm with a pan at the base fastened very tightly unto an STS- J4 digital high frequency sieve shaker. The machine was set in motion for about 10 minutes, after which the fractions retained in each screen was carefully weighed and recorded against the corresponding size range on a table made for the particular sample. The percentages of these weights, as well as their cumulative weights and cumulative weight percentages were determined and tabulated. Statistical plot of cumulative frequency were done on a log probability paper using excel. A grain size percentile were obtained and was used to calculate the graphic mean, standard deviation (sorting), inclusive graphic skewness and graphic kurtosis for each sample.

RESULTS AND DISCUSSION

Lithofacies Analysis

A lithostratigraphic map identifying the various formations in the study area, their sedimentary structures as well as roads and rivers linking the area was established. The different formations sampled in this study include: Lokoja Basa'Nge Formation, Mamu Formation, Ajali Sandstone and Nsukka Formation. The lithologies consist of Sandstones, Siltstones, Shale, Mudstones, Claystones and clast supported Conglomerate.

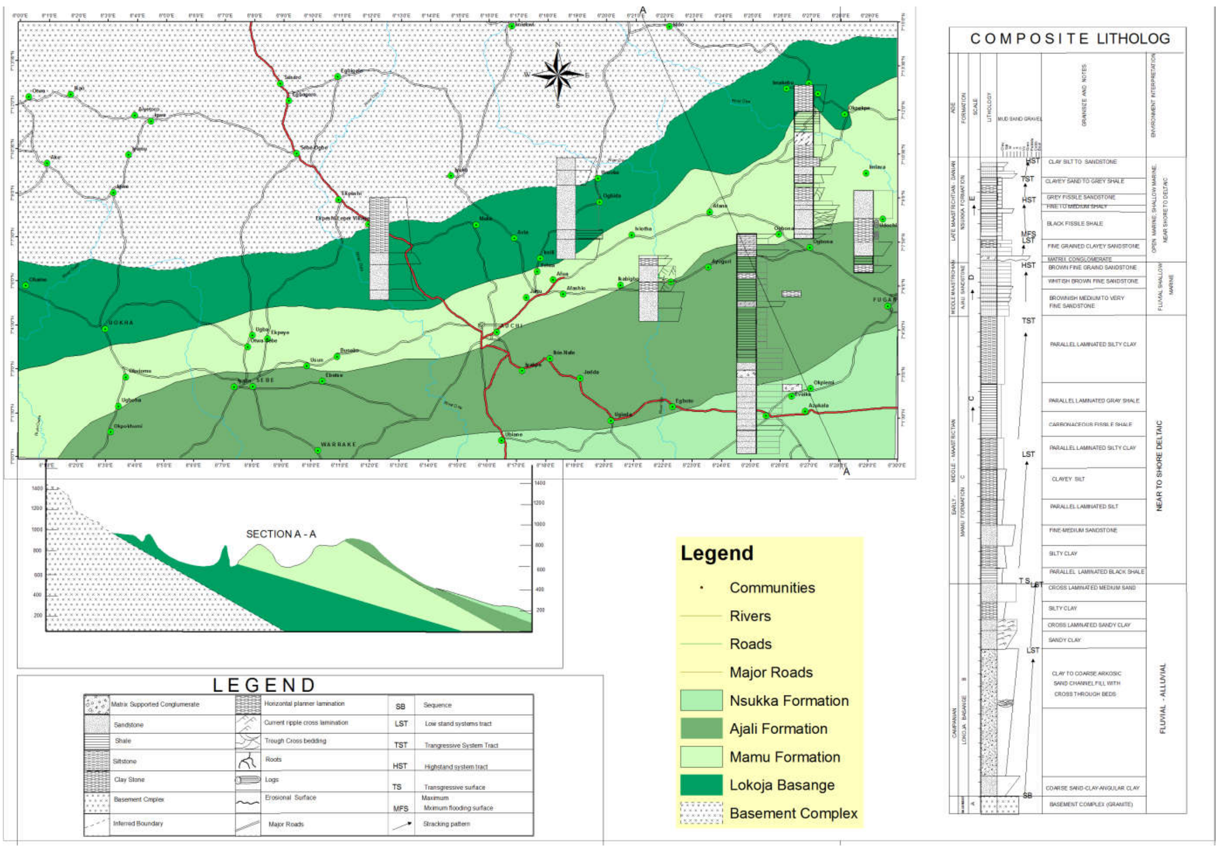


Fig. 3. Lithostratigraphic Map of Auchi sheet 226 Anambra Basin (ONYEACHONAM .N and FREGENE T.J present study)

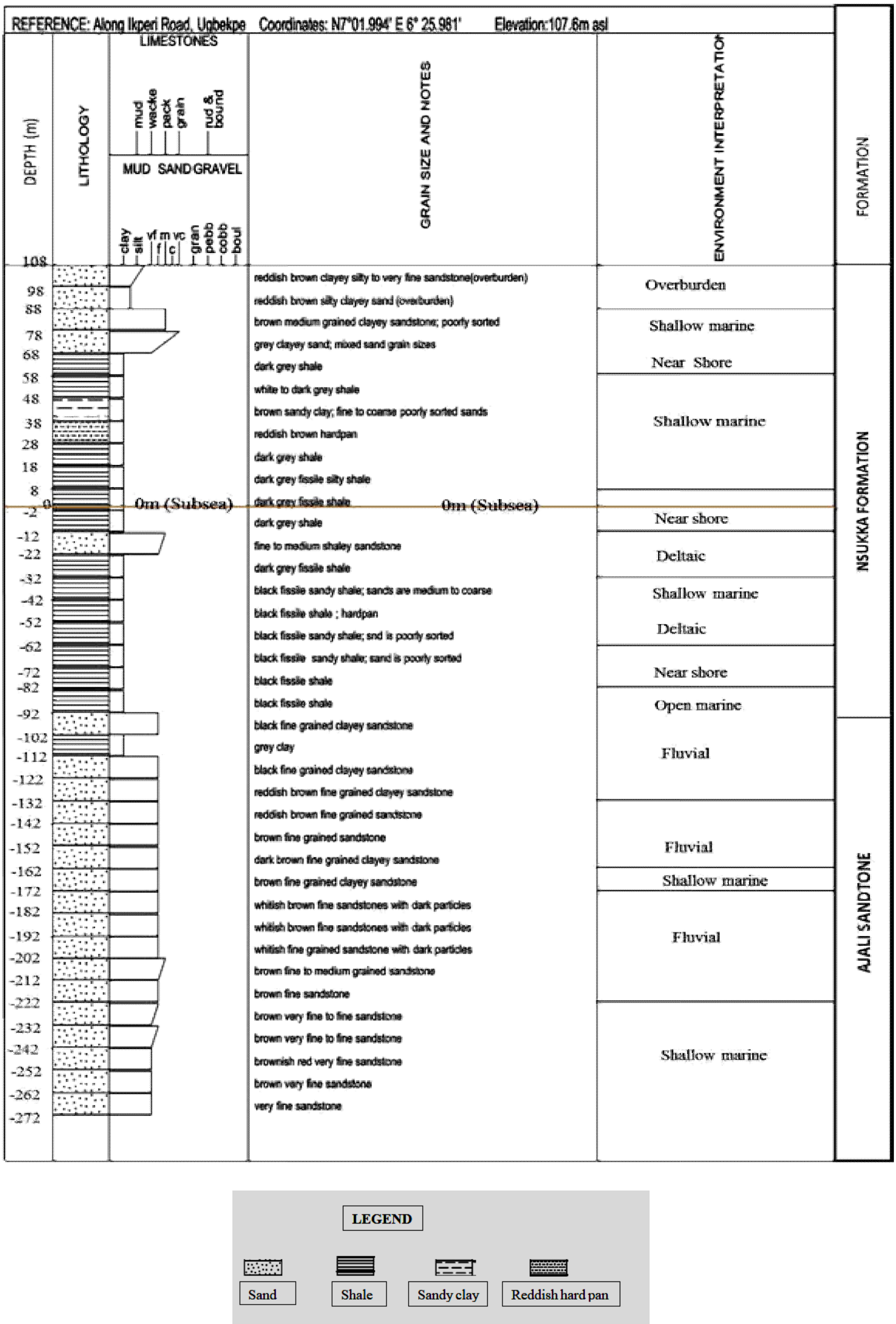


Fig. 4. Litholog of Ugbekpe Well showing the various Lithology penetrated and Depositional environments

Table 2. Cumulative weight percent of the Outcrop samples

Cumulative weight percent of the outcrop samples														
SIEVE SIZE(mm)	PHI(ф)	WT.(%) L1A	WT.(%) L1B	WT.(%) L1C	WT.(%) L1D	WT.(%) L4A1	WT.(%) L4A8	WT.(%) L5E	WT.(%) L6A1	WT.(%) L6B1	WT.(%) L8A	WT.(%) L8H	WT.(%) L11D	WT.(%) L12A
4	-2	—	—	—	—	—	—	—	—	99.7	—	100	0	99.9
2.36	-1.24	—	—	100	—	—	99.6	—	99.99	98.6	100	99.85	0	98.3
1.7	-0.77	—	100	99.36	100	99.99	98.32	100	98.03	92.97	99	98.5	99	90.62
1.18	-0.24	100	99.42	97.58	99.94	99.93	91.91	99.86	94.37	83.88	97.55	96.1	98.68	82.78
0.6	0.74	99.96	97.48	94.14	99.78	99.13	81.64	99.25	84.23	66.1	94.54	90.4	97.92	70.2
0.3	1.74	99.46	86.82	81.09	94.22	84.02	60.35	88.64	39.95	19.52	84.68	68.6	94.24	48.1
0.15	2.74	32.14	44.78	36.69	40.68	30.07	29.53	48.02	12.76	3.04	67.98	33.4	83.05	25.48
0.075	3.74	1.58	2.8	4.88	3.73	13.67	11.72	7.05	5.02	1.3	16.94	5.93	48.42	8.78
0.063	3.99	0.3	0.2	0.96	1.02	4.22	1.86	3.04	0.84	0.6	2.15	0.9	9.89	2.04

Table 3. Cumulative weight percent of the Bore hole samples

Cumulative weight percent of borehole samples								
SIEVE SIZE(mm)	WT.(%) PHI(ф)	WT.(%) BH78-88	WT.(%) BH68-78	WT.(%) BH122-132	WT.(%) BH132-142	WT.(%) BH142-152	WT.(%) BH162-172	WT.(%) BH222-232
4	-2	—	—	—	—	—	—	—
2.36	-1.24	100	—	—	—	—	—	—
1.7	-0.77	99.96	—	100	—	—	—	—
1.18	-0.24	99.92	100	99.74	99.99	100	100	—
0.6	0.74	99.58	99.82	99.3	99.95	99.9	99.87	100
0.3	1.74	62.83	74.93	92.21	91.18	98.8	99.49	99.6
0.15	2.74	21.12	29.25	59.59	29.38	37.79	57.23	55.49
0.075	3.74	5.61	8.78	22.78	3.99	2.65	7.28	3.61
0.063	3.99	2.25	4.24	11.54	0.44	0.17	0.96	0.85

Sedimentary structures that characterize these sediments are trough cross bedding, reactivation surfaces, horizontal laminations, low angle cross laminations, herring-bone cross stratifications and planar cross bedding.

The lithofacies association identified through integration of both outcrop and borehole samples revealed:

Lokoja Basa'Nge' Formation: Five (5) lithofacies were identified for the cross laminated sandstone, which are coarse to pebbly grained sand stone ,bioturbated sand stone, silty clay, medium to coarse grained sand stone, and sandy clay.

Mamu Formation: Eight (8) lithofacies were identified in this formation, which are parallel laminated grey shale, parallel laminated dark shale, parallel laminated silty clay, ripple bioturbated clayey siltstone,silty clay, parallel laminated clayey siltstone, siltstone, and clayey siltstone.

Ajali Formation: Six (6) lithofacies were identified in this formation which are fine-medium sandstone, planar cross-bedded sandstone, herring-bone cross-bedded sandstone, medium to coarse sandstone,medium ripple laminated sandstone, and sandy clay.

Nsukka Formation: Ten (10) lithofacies were identified in this formation which are dark fissile shale, fine to medium shaly sandstone, coarse poorly sorted sandstone, black fissile sandy shale, clayey sandstone, whitish fine grained sandstone, reddish brown sandstone, granule to pebbly sandstone, grey clay and silty sandstone.

Grain size characteristics

Calculation of grain size parameters such as mean, median, sorting, skewness and kurtosis was based using Folk and Ward (1957) equations. The results for each section are shown in the tables below:

According to the above tables, it is concluded that:

The Ajali Sandstone are fine to medium grained, poorly sorted to moderately well sorted, nearly symmetrical, fine to coarse skewed and leptokurtic to mesokurtic (Table 4).

The Lokoja Basa'Nge are medium to coarse grained, poorly sorted to moderately sorted, strongly coarse skewed to nearly symmetrical and leptokurtic to mesokurtic (Table 5.).

The Borehole samples are fine to medium grained, poorly sorted to moderately well sorted, strongly coarse skewed to nearly symmetrical and leptokurtic to mesokurtic (Table 6).

Environmental Discrimination

The discriminate functions (Y_1, Y_2 and Y_3 of Sahu, 1964 cited in Alsharhan and El- Sammak, 2004) were applied to the grain size data from the samples in order to characterize the depositional setting.

(a) For the discrimination between Aeolian processes and littoral (intertidal) environments, the discriminate function used is given below:

$$Y_1 = -3.5688 \text{ MZ} + 3.7016\ \delta_1^2 - 2.0766 \text{ SK1} + 3.1135 \text{ KG}$$

Where MZ is the grain size mean, δ1 is inclusive graphic standard deviation (sorting), SK1 is skewness and KG is the graphic kurtosis.

When Y1 is less than -2.7411, Aeolian deposition is indicated whereas if it is greater than - 2.7411, a beach environment is suggested.

(b) For the discrimination between beach (back- shore) and shallow agitated marine (subtidal) environment, the discriminate function used include;

$$Y_2 = 15.6534 \text{ MZ} + 65.7091\ \delta_1^2 + 18.1071 \text{ SK1} + 18.5043 \text{ KG}$$

If the value of Y_2 is less than 65.3650 beach deposition is suggested whereas if it is greater than 65.3650 a shallow agitated marine environment is indicated.

Table 4. Grain size parameters of Ajali Sandstone

Size	Range (ϕ)	Average	Interpretation
Parameter		VALUE (ϕ)	
Mean	1.13-3.04	2.06	Fine to Medium Grained
Sorting	0.52-1.52	0.95	Poorly Sorted to Moderately well Sorted.
Skewness	-0.33- +0.39	0.67	Near Symmetrical, Fine to Coarse Skewed.
Kurtosis	0.80-1.73	1.08	Leptokurtic to Mesokurtic.

Table 5. Grain size parameters of Lokoja Basa'Nge

Size	Range (ϕ)	Average	Interpretation
Parameter		VALUE (ϕ)	
Mean	0.52-2.02	1.3	Medium to Coarse Grained
Sorting	0.94-1.35	1.1	Poorly Sorted to Moderately Sorted
Skewness	-0.42- +0.22	-0.23	Strongly Coarse Skewed to Near Symmetrical.
Kurtosis	0.94-1.47	1.13	Leptokurtic to Mesokurtic.

Table 6. Grain size parameters of Borehole samples

Size	Range (ϕ)	Average	Interpretation
Parameter		Value (ϕ)	
Mean	1.64-2.51	2.12	Fine to Medium Grained
Sorting	0.58-1.54	0.90	Poorly Sorted to Moderately Well Sorted
Skewness	-0.92- +0.05	-0.26	Strongly Coarse Skewed to Near Symmetrical.
KURTOSIS	0.74-1.13	0.90	Platykurtic, Leptokurtic to Mesokurtic.

Table 7. Grain size description at each location

Location	Mean	Sorting	Skewness	Kurtosis
L1A	2.07 Fine Grained.	0.52 Moderately Well Sorted.	-0.33 Strongly Coarse Skewed.	1.03 Mesokurtic.
L1B	2.06 Fine Grained	0.82 Moderately Sorted.	0.12 Fine Skewed.	0.90 Mesokurtic
L1C	1.90 Medium Grained.	0.98 Moderately Sorted.	0.02 Near Symmetrical.	1.16 Leptokurtic.
L1D	2.13 Fine Grained.	0.68 Moderately Well Sorted.	-0.14 Coarse Skewed.	0.98 Mesokurtic.
L5E	2.18 Fine Grained.	0.83 Moderately Sorted.	0.03 Near Symmetrical.	0.80 Platykurtic.
L8A	2.37 Fine Grained.	1.11 Poorly Sorted.	0.39 Strongly Fine Skewed.	1.11 Leptokurtic.
L8H	1.70 Medium Grained.	1.13 Poorly Sorted.	0.17 Fine Skewed	1.14 Leptokurtic

Table 8. Grain size description at each location

Location	Mean	Sorting	Skewness	Kurtosis
L11D	3.04 Very Fine Grained.	0.92 Moderately Sorted.	0.28 Fine Skewed.	1.73 Very Leptokurtic.
L12A	1.13 Medium Grained	1.52 Poorly Sorted.	0.13 Fine Skewed.	0.84 Mesokurtic
L4A1	2.02 Fine Grained.	0.94 Moderately Sorted.	-0.42 Coarse Strongly Skewed.	1.06 Mesokurtic
L4A8	1.53 Medium Grained.	1.35 Poorly Sorted.	0.01 Near Symmetrical.	0.94 Mesokurtic
L6A1	1.13 Medium Grained.	1.09 Poorly Sorted.	-0.13 Coarse Skewed.	1.47 Leptokurtic.
L6B1	0.52 Coarse Grained.	1.02 Poorly Sorted.	0.22 Fine Skewed.	1.03 Leptokurtic.
BH78-88	1.64 Medium Grained.	0.89 Moderately Sorted	-0.13Coarse Skewed	1.06 Mesokurtic.
BH 68-78	1.88 Medium Grained.	0.92 Moderately Sorted.	-0.14 Coarse Skewed.	1.12 Leptokurtic.
BH122-132	2.51 Fine Grained.	0.97Moderately Sorted.	0.05 Near Symmetrical.	0.91 Mesokurtic.
BH132-142	1.99 Medium Grained.	0.68 Moderately Well Sorted.	-0.37 Strongly Coarse Skewed.	1.13 Leptokurtic.
BH142-152	2.13 Fine Grained.	1.54 Poorly Sorted.	-0.22 Coarse Skewed.	1.00 Mesokurtic.
BH162-172	2.38 Fine Grained.	0.64 Moderately Well Sorted.	-0.92Strongly Coarse Skewed.	0.80 Platykurtic
BH222-232	2.33 Fine Grained	0.58Moderately Well Sorted.	-0.07 Near Symmetrical	0.74 Platykurtic

(c) For the discrimination between shallow marine and the fluvial environments, the discriminate function below was used

$$Y_3 = 0.2852\ MZ - 8.7604\ \delta_1^2 - 4.8932\ SK1 + 0.0482\ KG$$

If Y_3 is less than -7.419 the sample is identified as a fluvial (deltaic) deposit, and if greater than -7.41 9 the sample is identified as a shallow marine deposit.

The following classifications are used in order to distinguish the different depositional environments:

Yaeolian:beach > -2.7411 ---beach environment
Yaeolian:beach < -2.7411 ---aeolian environment
Ybeach:marine < 65.3650---beach environment
Ybeach:marine > 65.3650---shallow marine environment
Ymarine:fluvial < -7.4190---fluvial environment
Ymarine:fluvial > -7.4190---shallow marine environment

Paleo-environmental Reconstruction

Lokoja Basa'Nge

Arising from linear discriminant function after Sahu (1964), and bivariate plot of Y_2 vs Y_1 and Y_3 vsY_2 (Fig. 10), it can be deduced that the sediments of Lokoja Basa'Nge were deposited in fluvial environment.

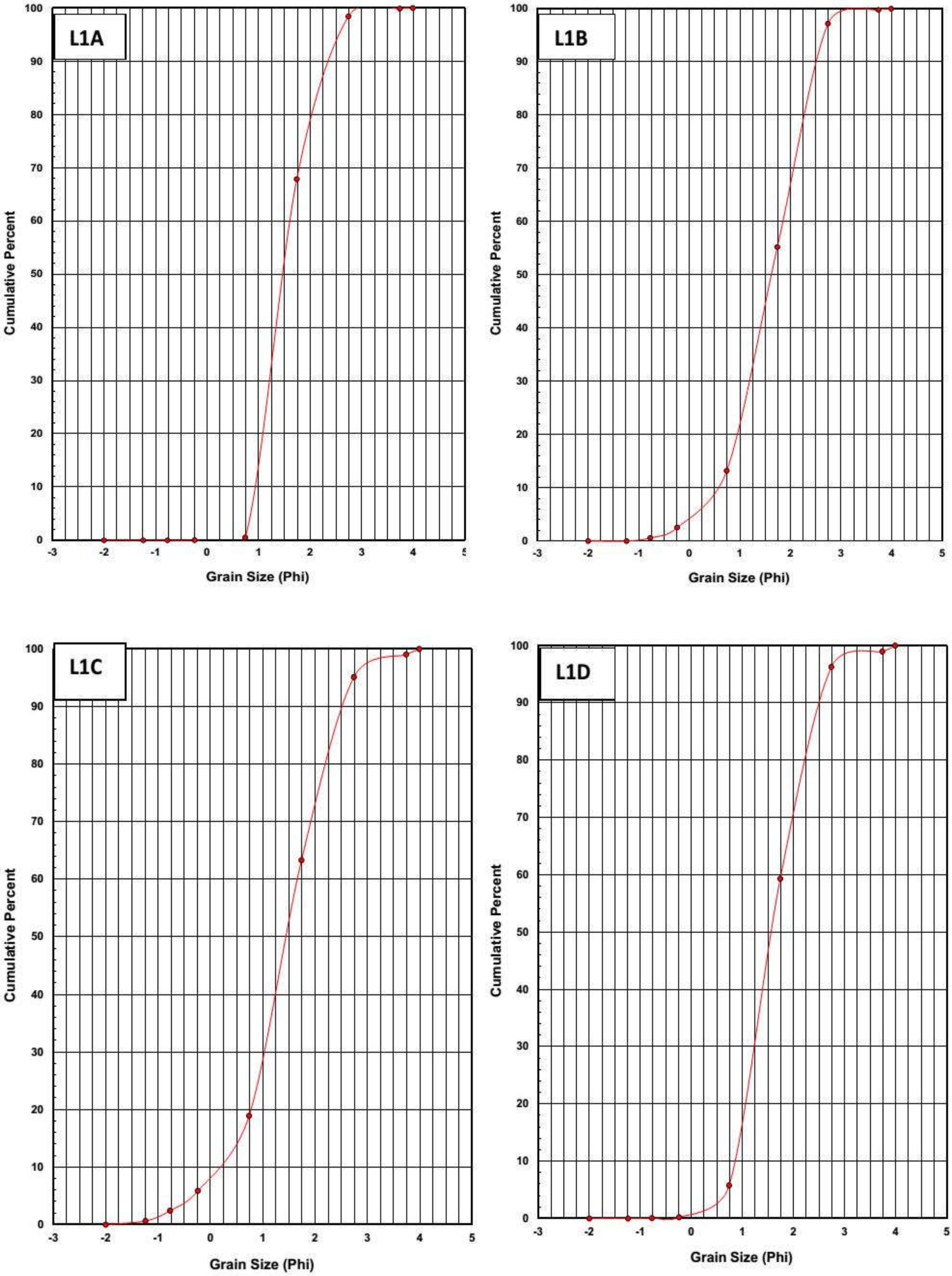


Fig. 5. Grain size distribution curve for location L1A, L1B, L1C,L1D

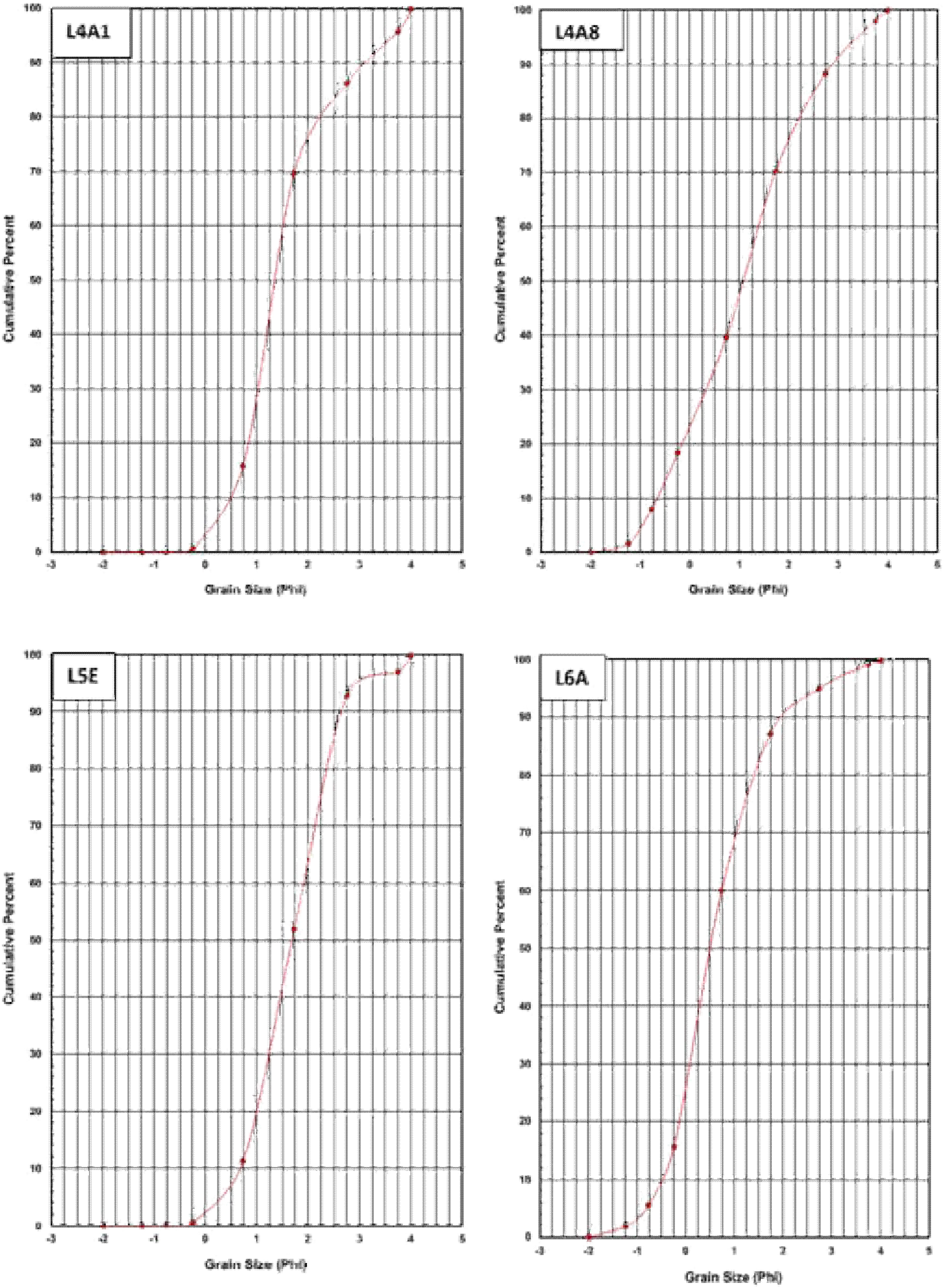


Fig. 6. Grain size distribution curve for location L4A1,L4A8,L5E,L6A

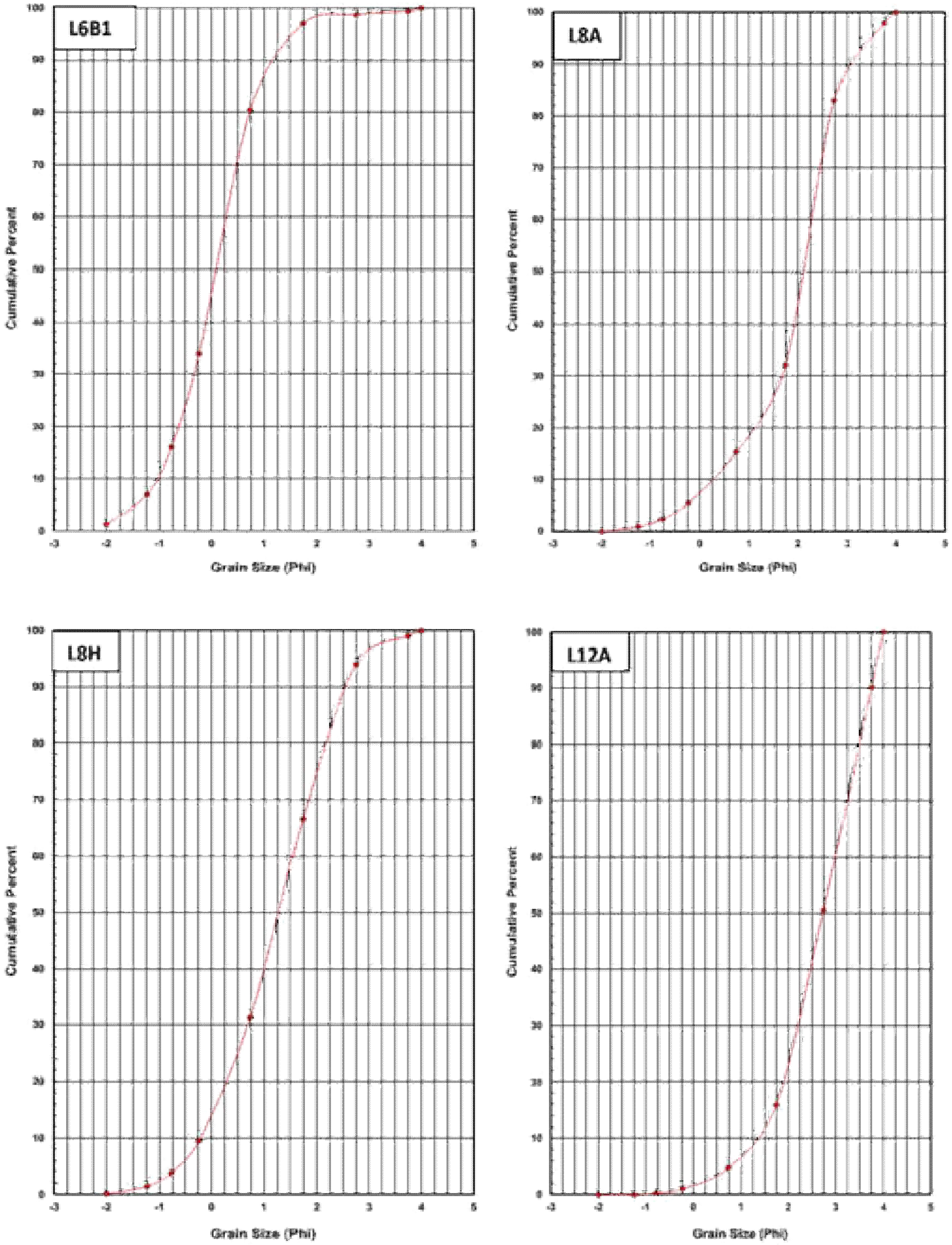


Fig. 7. Grain size distribution curve for location L6B1,L8A,L8H,L12A

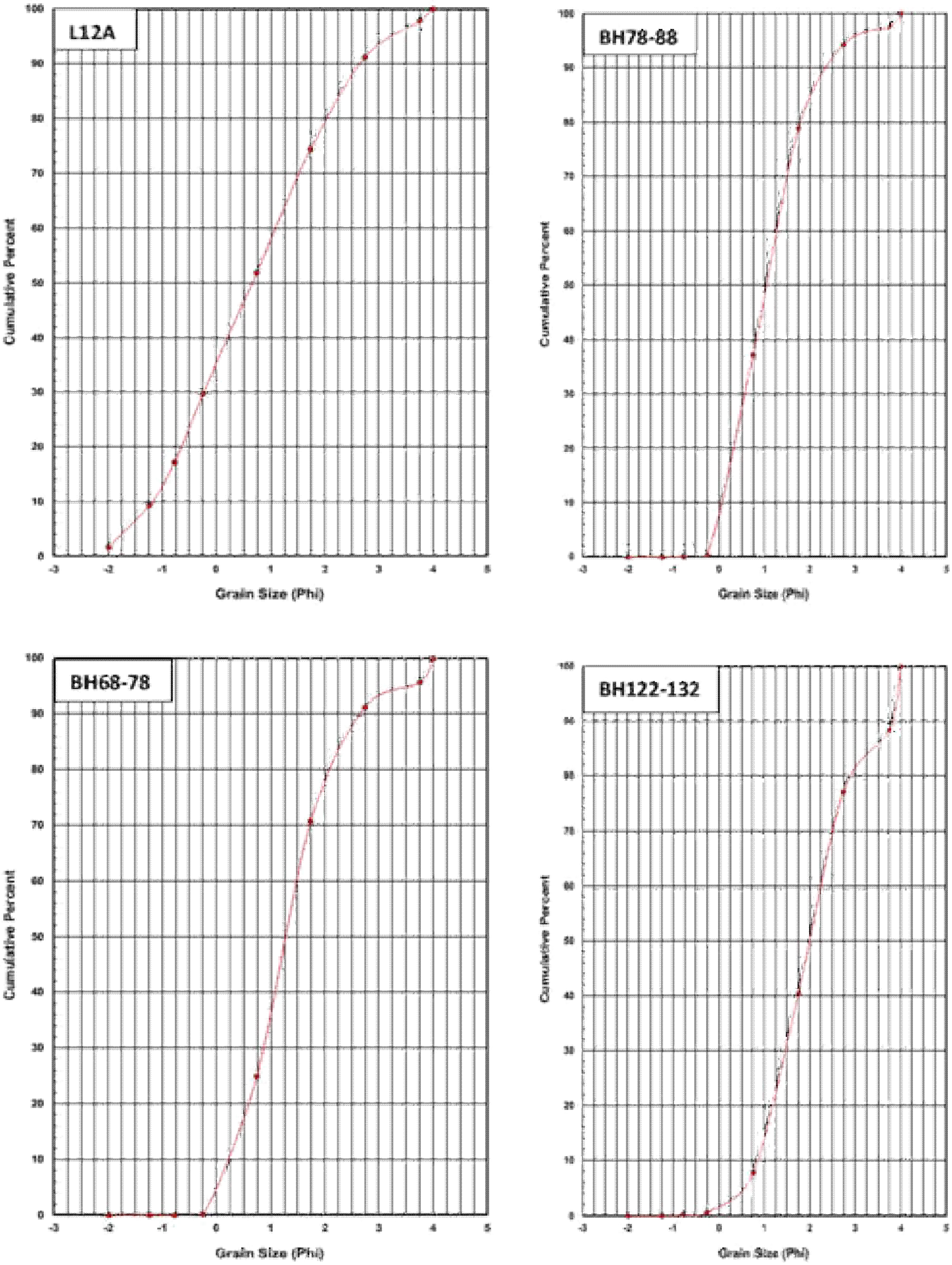


Fig. 8. Grain size distribution curve for location L12A,BH78-88,BH68-78,BH122-132

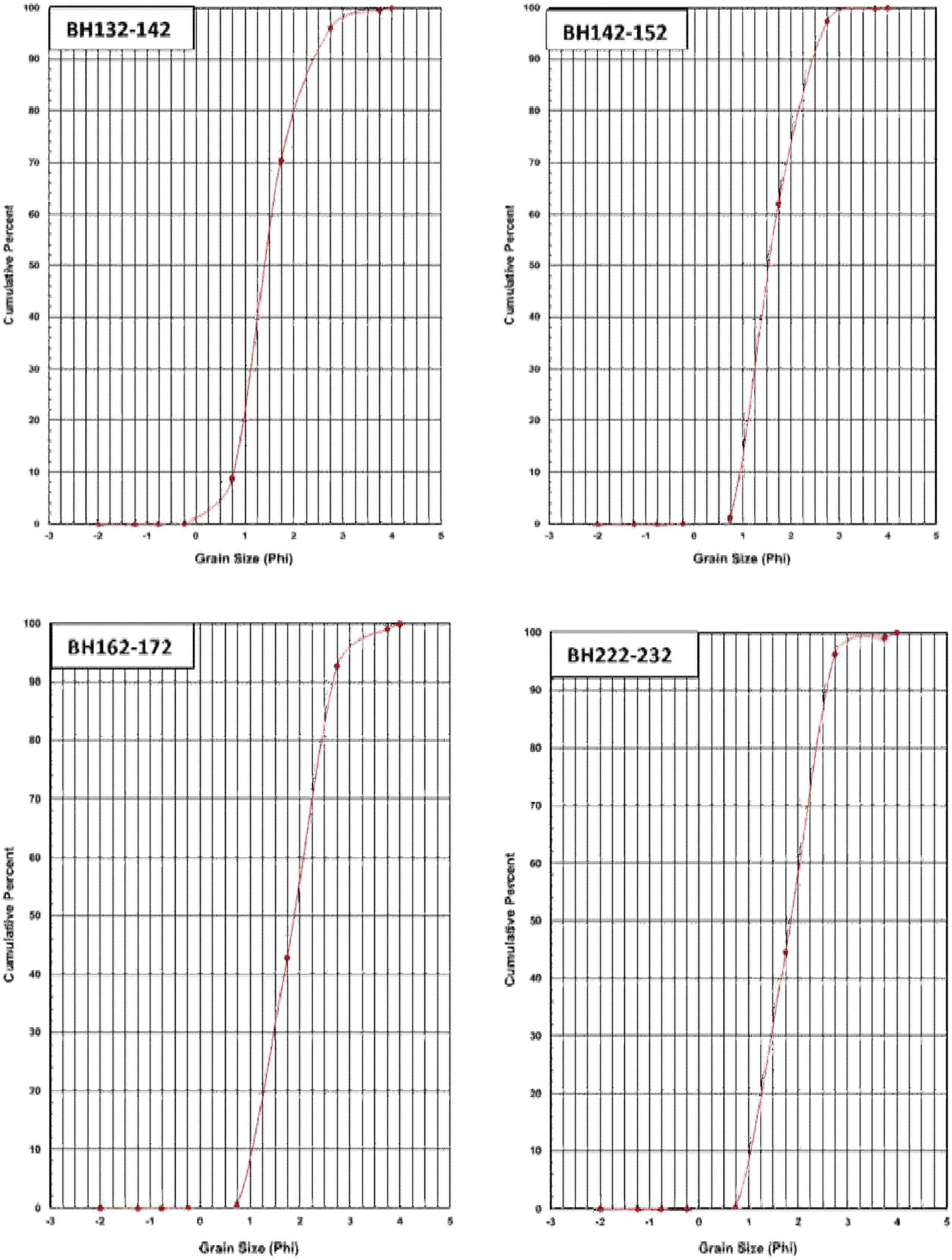


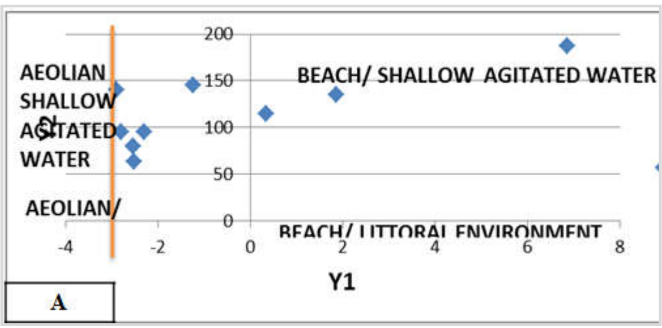
Fig 9: Grain size distribution curve for location BH132-142,BH142-152,BH162-172,BH222-232

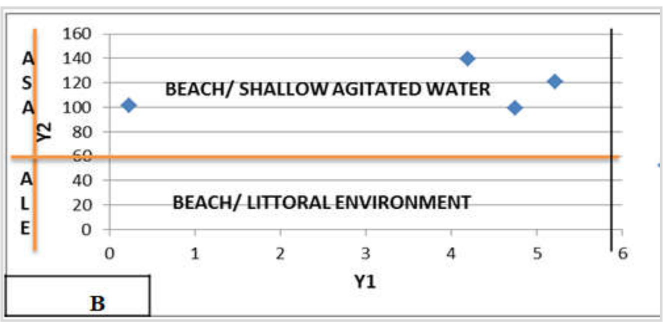
Table 9. Result of the discriminant function analysis

Location	Yaeolian: Beach	Ybeach: Marine	Ymarine: Fluvial	Depositional Environment
L1A	-2.5185	63.2544	-0.1140	Shallow Marine/Beach
L1B	-2.3098	95.2447	-5.8468	Shallow Marine/ Agitated
L1C	0.3444	114.6559	-7.9136	Fluvial/ Agitated
L1D	-2.5479	79.3249	-2.7110	Shallow marine/ Agitated
L5E	-2.8014	94.7381	-5.5215	Shallow marine/ Agitated
L8A	-1.2512	145.6603	-11.9726	Fluvial/ Agitated
L8H	1.8560	134.6878	-10.9994	Fluvial/ Agitated
L11D	-2.9112	140.2849	-7.0458	Shallow marine/ Agitated
L12A	6.8648	187.4002	-20.5134	Fluvial/ Agitated
L4A1	0.2342	101.6900	-5.0583	Shallow marine/ Agitated
L4A8	4.1918	139.7249	-15.5331	Fluvial/ Agitated
L6A1	5.2119	120.6047	-9.3790	Fluvial/ Agitated
L6B1	4.7454	99.5465	-9.9929	Fluvial/ Agitated
BH78-88	0.6495	94.9804	-5.7842	Shallow marine/ Agitated
BH68-78	0.2015	103.2344	-6.1396	Shallow marine/ Agitated
BH122-132	-2.7454	118.8600	-7.7671	Fluvial/ Agitated
BH132-142	-1.1037	75.7544	-1.6183	Shallow marine/ Agitated
BH142-152	4.7475	203.6982	-19.0440	Fluvial/ Agitated
BH162-172	-2.5763	62.3144	1.6308	Shallow marine/ Agitated
BH222-232	-4.6207	71.0027	-1.9043	Shallow marine/ Agitated

Table 10. Deduced depositional environments based on linear discriminant function (After Sahu 1964)

Location	Formation	Calculated Values	Interpretation
L1A		-0.114	Shallow marine
L1B		-5.8468	Shallow marine
L1C		-7.9136	Fluvial
L1D		-2.711	Shallow marine
L5E	AJALI SANDSTONE	-5.5215	Shallow marine
L8A	(OUTCROP)	-11.9726	Fluvial
L8H		-10.9994	Fluvial
L11D		-7.0458	Shallow marine
L12A		-20.5134	Fluvial
L4A1		-5.0583	Fluvial
L4A8	LOKOJA BASANGE	-15.5331	Fluvial
L6A1	(OUTCROP)	-9.379	Fluvial
L6B1		-9.9929	Fluvial
BH78-88		-5.7842	Shallow marine
BH68-78		-6.1396	Shallow marine
BH122-132	AJALI SANDTONE	-7.7671	Fluvial
BH132-142	(BOREHOLE SAMPLES)	-1.6183	Shallow marine
BH142-152		-19.044	Fluvial
BH162-172		1.6308	Shallow marine
BH222-232		-1.9043	Shallow marine





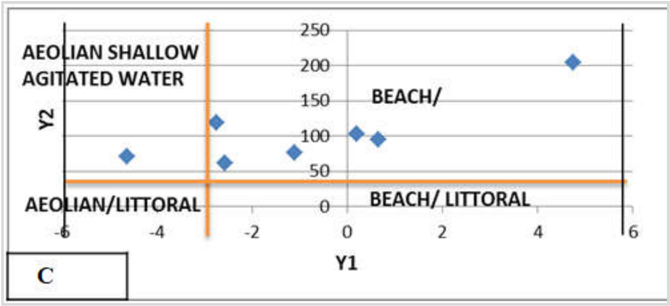


Fig. 10. A, B and C: Bivariate plot of Y_2 vs Y_1 for the Ajali Sandstone, Lokoja Basa'Nge, and Borehole Samples using the template of Alsharhan and El- Sammak (2004)

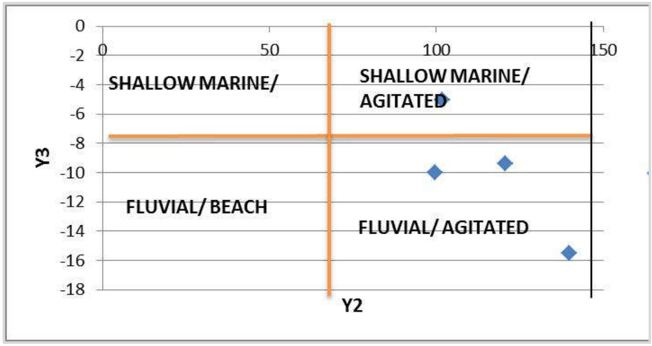


Fig. 11. Bivariate plot of Y_3 vs Y_2 for the Lokoja Basa'Nge, using the template of Alsharhan and El- Sammak (2004)

Ajali Formation

Arising from linear discriminant function after Sahu (1964), and bivariate plot of Y_3 vsY_2 for the Ajali sandstone (outcrop and borehole samples), Fig. 6.4a and b. It can be deduced that the sediments were deposited in shallow marine to fluvial (deltaic) environment.

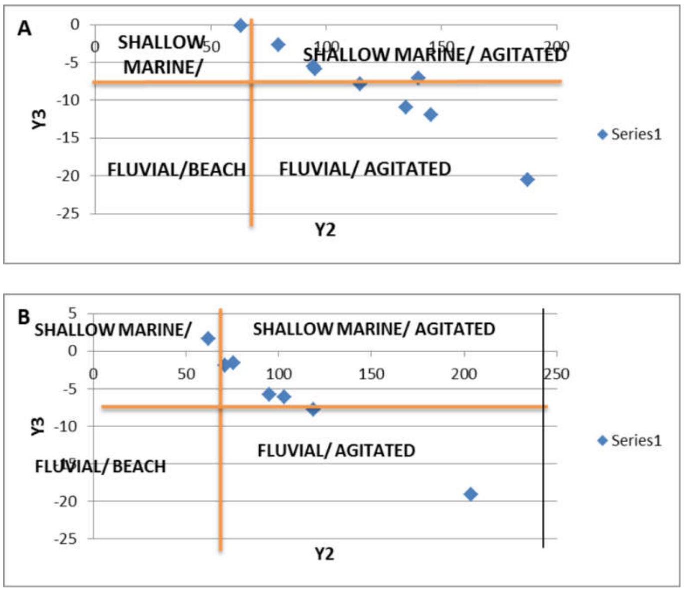


Fig. 12. A and B: Bivariate plot of Y_3 vs Y_2 for the Ajali Sandstone (from borehole and outcrop samples) using template of Alsharhan and El- Sammak (2004)

Conclusion

Field investigation carried out on the sediments outcropping in the Auchi Sheet 266, Benin Flank Southwestern Anambra Basin revealed four formational units overlying the Basement complex. They include: Lokoja Basa'Nge, Mamu Formation, Ajali Sandstone and Nsukka Formation. The lithologies consist of Sandstones, Siltstones, Shale, Mudstones, Claystones and clast supported Conglomerate. Sedimentary structures that characterize these sediments are trough cross bedding, reactivation surfaces, horizontal laminations, low angle cross laminations, herring-bone cross stratifications and planar cross bedding. Five (5) lithofacies were identified in the Lokoja Basa 'Nge' Formation, eight (8) lithofacies in the Mamu Formation, Six (6) lithofacies in the Ajali Formation and ten (10) lithofacies in the Nsukka Formation. The depositional environment suggested for the various formations are fluvial to shallow marine environment for Ajali sandstone Formation, fluvial environment for Lokoja Basa'Nge Formation , Near shore to Deltaic environment for Mamu Formation and Open marine, shallow marine, Near shore to Deltaic environment for Nsukka Formation.

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