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Paleo environmental Interpretation Of The Exposed Section Of The Benin Formation In Southeastern Part Of The Niger Delta Basin, Nigeria: A Pebble Morphometric Approach

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ABSTRACT

Conglomerate occur in southeastern part of the Niger Delta Basin where they are being quarried for construction purposes. Pebble morphometric analysis was carried out in order to ascertain the environment of deposition of the conglomerate deposits. The pebble morphometric analysis of the conglomerates showed that the mean values of the various morphometric parameters range as follows: flatness ratio (S/L = 45.10 – 71.83), elongation ratio (I/L = 0.5022 – 0.8638), maximum projection sphericity (Ψ P = 0.6867 – 0.8639), oblate prolate index ($\overline{O}\ \overline{P}$ *= -0.4327 – 9.0484***).** *The values fall well above the empirical lower limits established by previous workers to distinguish beach pebbles from fluvial pebbles in modern gravels, thus indicating that the pebbles in southeastern part of the Niger Delta Basin were shaped in fluvial environment. Roundness index determined for the pebbles through simple with Power's (1953) roundness chart averaged 0.254, indicating that the pebbles were deposited in fluvial milieu.*

Keywords: *Conglomerate, pebble, environment, fluvial, roundness*

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I. INTRODUCTION

Conglomerate, a lithified equivalent of gravel may be laid down as marine or continental deposits as a result of wave action on rocky shores and weathering/flow of water respectively (Pettijohn, 1975). Continental conglomerates include those of glacial and fluvial environments while marine conglomerates are conglomerates of beach and turbidity current deposits. Pebble morphometry have been utilized successfully in distinguishing between modern beaches and rivers gravel. It has been used by Dobkin and Folk, 1970, Strattern, 1974, Luttig, 1962, Sneed and Folk, 1958, Nwajide and Hoque, 1982, Sames, 1966, Petters, 1989 as an aid in environmental diagnosis. Griffiths 1967 observed that size of quartz grain measured as individuals is likely to yield the best basis for environmental interpretation. Conglomerate abound in southeastern part of the Niger Delta Basin where they are being quarried for construction purposes. The formation was covered with thick and extensive lateritic deposits which hindered earlier researchers from investigating the deposits. Presently, quarrying and extensive road construction have provided excellent exposures of the units. Therefore, there is a need for this research work to be carried out in the area in order to characterize the deposits. The aim of this research work is to ascertain the environment of deposition of the conglomerate deposits.

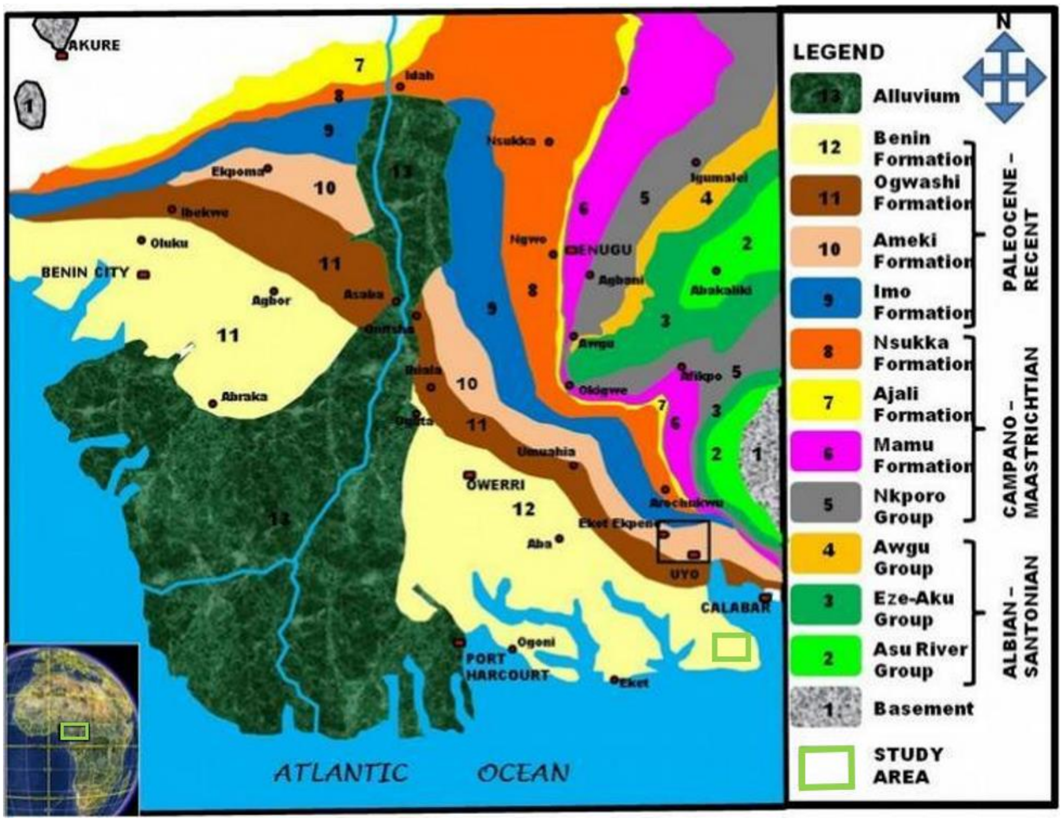


Fig. 1: Geological map showing the study area

II. GEOLOGIC SETTING

The Niger delta complex is a regressive off lap sequence which prograded across the southern Benue Trough and spread out onto cooling and subsiding oceanic crust which was formed as Africa and South America separated. The formation of southern Nigeria sedimentary basins followed the breakup of the south America and Africa continents in the Early Cretaceous (Murat, 1972; Burke, 1996). The separation initiated the opening of the south Atlantic Ocean during the Late Jurassic to Early Cretaceous times and reached Nigeria by Midddle Cretaceous (Fitton, 1980), resulting in the formation of the Benue Trough (Murat, 1972; Hoque and Nwajide, 1984; Reyment, 1965; Nwachulwu, 1972; Olade, 1975; Kogbe, 1976; Petters, 1978; Wright, 1981; Benkhelil, 1982, 1989). The Benue Trough is a continental scale intraplate tectonic megastructure which constitutes part of the Mid- Africa Rift system (Malauski *et al.*, 1995). The tectonics of the Benue Trough is controlled by transcurrent faulting (sinistral wrenging) (Benkhelil, 1989). Genik, 1993 suggested that the Benue Trough is part of the west and central African Rift system that opened as a sinistral wrench complex. The Benue Trough is the failed arm of a Y- shaped triple junction that initiated the opening of the south Atlantic Ocean and is thus regarded as an aulagogen (Hoffman *et al.*, 1975; Olade, 1975; Hoque and Nwajide, 1984). Hoque, 1984 and Benkhelil, 1989 suggested magmatic activity during the opening and closing of the Benue Trough which led to the deposition of Abakaliki pyroclastics. The stratigraphic history of the region is controlled by three sedimentary phases (Short and Stauble, 1967; Murat, 1972; Obi *et al.*, 2001), during which the axis of the sedimentary basin shifted. These three phases were (a) the Abakaliki-Benue phase (Aptian to Santonian) which ended with a mild folding phase in the Santonian. (b) the Anambra-Benin phase (Campanian to Mud Eocene) which included the growth of a proto-Niger Delta during the Late Cretaceous. and (c) the Niger Delta phase (Late Eocene to Recent) which marks the continuous growth of the main Niger Delta. The oldest sediments found in southern Nigeria are non-fossiliferous, arkosic, gravelly, and in general, ill-sorted, commonly cross-bedded sand and quartzitic sandstone. They form the weathering products of the nearby and underlying crystalline and metamorphic basement complex. The first marine incursion in the Middle Cretaceous resulted in the deposition of Asu River Group in the Albian, Eze -Aku Shale in Turonian and Awgu Shale in the Coniacian time. This ended with the onset of a phase of folding, faulting and uplift in early Santonian time, resulting in erosion of Coniacian, Turonian, and even Albian deposits of the uplifted Abakaliki anticlinorium.

The Santonian folding phase was followed by subsidence which initiated a new marine transgression, resulting in the deposition of the Nkporo Shale of Campanian-Maestrichtian age, and its lateral equivalents, the Owelli Sandstone and the Enugu Shale. West of the River Niger, the marine Nkporo Shale ranges in age from Campanian to Maestrichtian. In the east, the Maestrichtian is represented by deltaic deposits (regressive phase) –

the Mamu Formation, the Ajali Formation, and the Nsukka Formation. This regressive period, with the formation of a proto-Niger delta, continued throughout the end of Cretaceous and ended in a major Paleocene marine transgression.

At the beginning of the Tertiary, the sea transgressed the whole of southern Nigeria, terminating the progradation of the Upper Cretaceous Niger delta and separating it stratigraphically from the modern Niger delta which began to form in the Eocene.

The main rock-stratigraphic unit of Paleocene age is the Imo Shale. The Imo Formation consists of blue-grey clays and shales and black shales with bands of calcareous sandstones, marl and limestone (Reyment, 1965). Ostracode and microfauna recovered from the basal limestone unit indicate a Paleocene age for the formation (Adegoke *et al*., 1980). The Imo Formation is the outcrop lithofacies equivalent of the Akata Formation in the subsurface Niger Delta (Short and Stauble, 1967; Avbovbo, 1978).

The Imo Shale ranges into the early Eocene (Stolk, 1963) and is overlain by the sandy Ameki Formation which marks the onset of a regression and the formation of the modern Niger delta. East of the Niger, the Ameki Formation is very heterogeneous, consisting of alternating sandstone and shale, sandy or calcareous shale, marl, and a few fossiliferous shale and limestone beds. These abrupt, irregular alternations indicate deposition in a shallow marine environment with sediment supply from the nearby coast. During the Middle and Late Eocene, the sedimentary rocks became increasingly sandy, marking the onset of a general regression and of deltaic deposition.

In the Middle Eocene, major depocenters initiated in the Paleocene to Eocene in the Anambra basin, Afikpo syncline, and the Ikang Trough were the sites of deltaic outbuilding with the Niger-Benue and the Cross River drainage systems accounting for the bulk of the sediment supply. Both drainage systems merged at the end of the Oligocene and formed the present-day Niger delta. Simple growth faults were initiated in the Oligocene (Whiteman,1982).

During the Miocene, uplift of the Cameroon mountains provided a new and dominant sediment supply through the Cross River, thus constructing the Cross River Delta. The shoreline progressively migrated seaward during deltaic progradation. This was greatly accelerated in Miocene to Pliocene times with attendant increase in growth faulting and large-scale diapiric movement of the Akata Shale. Deltaic growth declined in the Late Pliocene to Pleistocene during a major drop in sea level, with sediments by- passing into deep sea fans. A Late Pleistocene transgression flooded the Plio-Pleistocene upper and lower deltaic plains. As sea level stabilized, a new regressive sequence developed.

Surface evidence of Oligicene and Miocene deposits is limited and much of the evidence for the age determination is inferred. The main rock-stratigraphic unit is the continental Ogwashi-Asaba Formation and its equivalent, the Ijebu Formation in the Lagos area, which contains some sparse marine faunas. Both Formations are predominantly sandy, the sand alternating with lignite seams and a few beds of clay in the Ogwashi-Asaba Formation, or with a few thin clay beds with scarce marine faunas as in the Ijebu Formation (Reyment, 1965).

The youngest rock stratigraphic unit is the Benin Formation of possible Miocene to Recent age. The unit consists predominantly of yellow and white continental sand, alternating with pebbly layers and a few clay beds (Reyment, 1965).

The oldest Formation (Paleocene to Eocene) in the Niger delta form an accurate exposure belt along the delta frame. These are the Paleocene Imo Shale (fossiliferous blue-grey shales with thin sandstone, marl, limestone and locally thick nearshore sandstone); the Eocene Ameki Formation (fossiliferous calcareous clays, coastal sandstone); the late Eocene- Early Oligocene lignite clays and sandstones of Ogwashi-Asaba Formation and the Miocene-Recent Benin Formation (coastal plain sands). These Formations are highly diachronous and extended into the subsurface where they are assigned different Formation names. The Akata, Agbada and Benin Formations are interfingering facies equivalent representing prodelta, delta front and delta top environments respectively. Unconformities, large clay fills of ancient submarine canyons and deep-sea fans occur in the eastern and western delta. These formed mainly during the Early Oligocene and Tertiary low stand of sea level.

Short and Stauble (1967) divided the Niger delta into three stratigraphic sequences, namely: Benin, Agbada and Akata Formations Table 2.

BENIN FORMATION

The Benin Formation has been described as “coastal plain sands” which outcrops in so many places in the Niger delta. It consists mainly of sands and gravels with thickness ranging from 1 to 2,100 meters. The sands and sandstones are coarse grained to very fine grained, pebbly, poorly sorted and unconsolidated to consolidated. The grains are subangular to well rounded. The sand and sandstone are white and yellowish brown in colour. Lignite occurs in thin streaks or finely dispersed fragments. Hematite grains and feldspars are common. Shale is few and thin. The shale is grayish brown, sandy to silty and contains some plant remains and dispersed lignite. Composition, structure, and grain size of the sequence indicate deposition in a continental, probably upper deltaic environment. The shale may be interpreted as backswamp deposits and oxbow fills.

In the eastern part of the Niger delta, the Benin Formation is interrupted by the Afam Clay Member. However, the Formation lacks faunal contents and this makes it uneasy to date although an Oligocene-Recent age is generally accepted. Weber and Daukoru (1976) observed that the Benin Formation consists of fluviatile gravels and sands. The surface Benin Formation has been variously described as yellow and white, sometimes cross bedded sands, clays and sandy clays occurring in lenses (Whiteman, 1982). The Formation is the main source of portable groundwater in the Niger Delta.

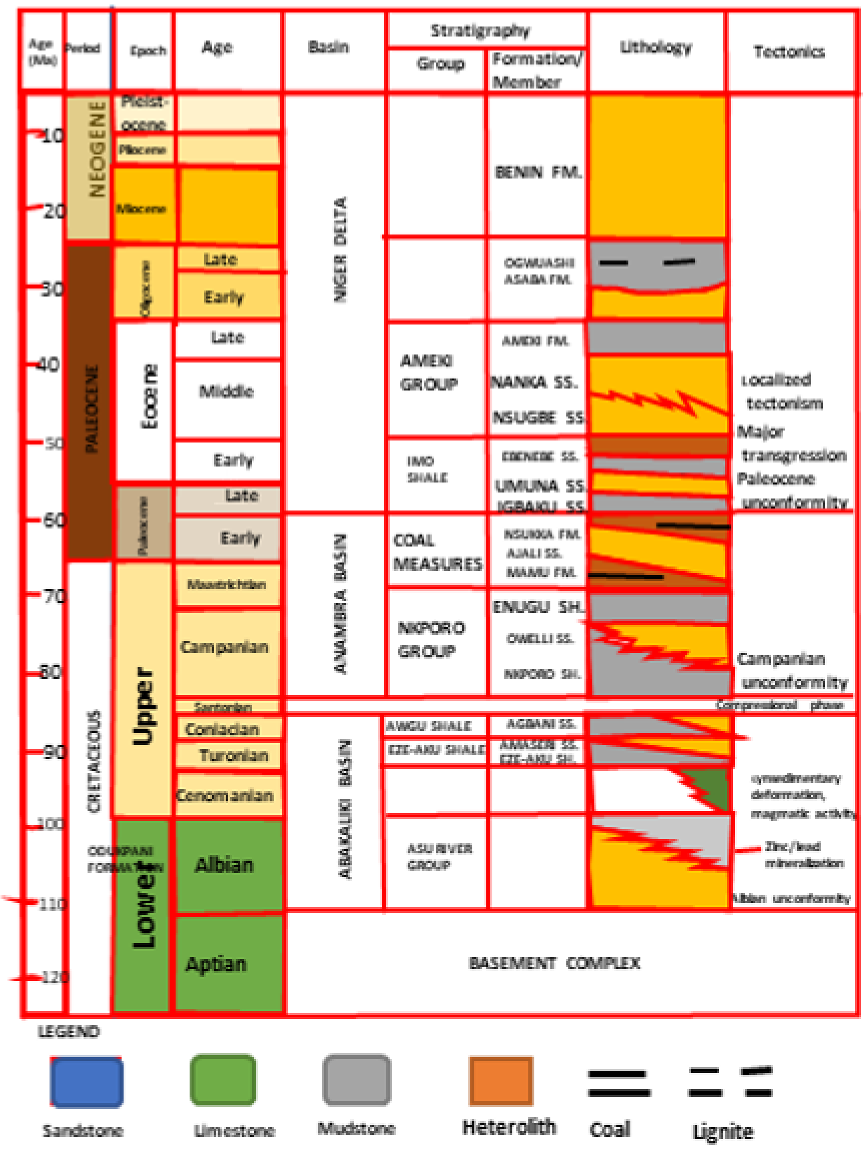


Fig. 2: The stratigraphic succession in the Anambra Basin and outcropping Paleogene Niger Delta Basin (modified after Ekwaenye *et al*., 2014)

Table 1: Stratigraphic correlation of Tertiary Formation in the Niger Delta (modified after Reyment, 1965)

Age	**Surface Formation**	**Subsurface Eqivalent**	**Broad Depositional Environment**
Pliocene-Recent	Coastal Plain Sands	Benin Formation, Afam and Qua Iboe Clay Member	Continental
Miocene-Recent	Ogwashi-Asaba Formation	-	-
Eocene-Recent	Ameki Formation	Agbada Formation	Paralic
Paleocene-Recent	Imo Formation	Akata Formation	Marine

III. METHODOLOGY

Pebbles were collected from the pebble's beds in the study area. For each location, thirty pebbles were randomly picked. From these, broken pebbles were discarded and only twenty pebbles of vein quartz were selected for pebble morphometric analysis. This is because only isotropic and monomineralic pebbles are suitable for pebble morphometry. The long (L), intermediate (I) and short axes (S) of each of the twenty pebbles were measured using a vernier caliper and recorded in a chart. The measurement was done by placing the particle on a flat surface and the length of the intermediate, axis, I was determined as the shortest possible diameter. The length of the largest axis, L at right angle to the intermediate axis was next measured, and rotation of the particle by 90 about that revealed the shortest axis, S which was then measured.

From the measurements, the elongation ratio (I/L), flatness ratio (S/L), maximum projection sphericity (Ψ_p), oblate – prolate index (OP) and coefficient of flatness values were computed.

$$\mathrm{OP} = 10\,\frac{\left({}^{L-I}/_{L-S} - 0.5O\right)}{\frac{S}{L}}$$

(After Dobkins and Folk, 1970)

$$\Psi_p = \sqrt[3]{\frac{S^2}{LI}}$$

(After Sneed and Folk, 1958)

$$\text{Coefficient of flatness} = \frac{S}{L} \times 100$$

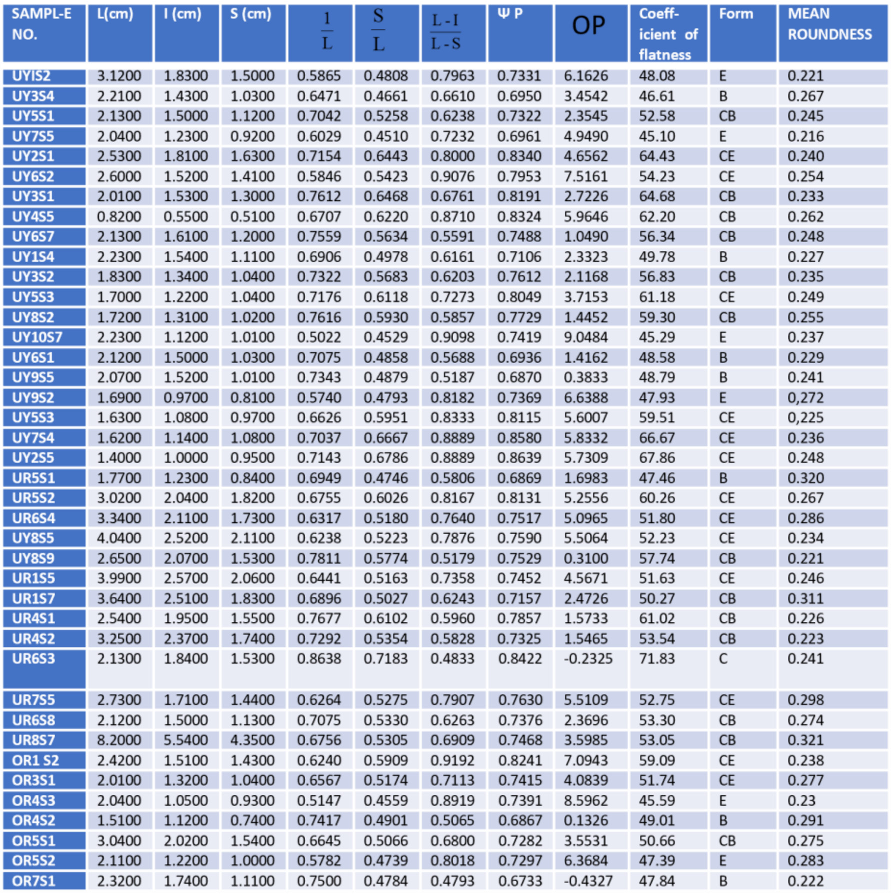
(After Luttig, 1962)

The form of the particles was noted using sphericity form diagram after Sneed and Folk (1958).

Qualitative estimate of the Roundness of the pebbles was noted through simple comparison with Power Roundness chart (After Power,1953). A total of 800 pebbles were analysed.

IV. RESULT

TABLE 2: MEAN VALUES OF PEBBLES MEASURED



SAMPL-E NO.	L(cm)	I (cm)	S (cm)	$\frac{I}{L}$	$\frac{S}{L}$	$\frac{L-I}{L-S}$	Ψ P	OP	Coeff-icient of flatness	Form	MEAN ROUNDNESS
UYIS2	3.1200	1.8300	1.5000	0.5865	0.4808	0.7963	0.7331	6.1626	48.08	E	0.221
UY3S4	2.2100	1.4300	1.0300	0.6471	0.4661	0.6610	0.6950	3.4542	46.61	B	0.267
UY5S1	2.1300	1.5000	1.1200	0.7042	0.5258	0.6238	0.7322	2.3545	52.58	CB	0.245
UY7S5	2.0400	1.2300	0.9200	0.6029	0.4510	0.7232	0.6961	4.9490	45.10	E	0.216
UY2S1	2.5300	1.8100	1.6300	0.7154	0.6443	0.8000	0.8340	4.6562	64.43	CE	0.240
UY6S2	2.6000	1.5200	1.4100	0.5846	0.5423	0.9076	0.7953	7.5161	54.23	CE	0.254
UY3S1	2.0100	1.5300	1.3000	0.7612	0.6468	0.6761	0.8191	2.7226	64.68	CB	0.233
UY4S5	0.8200	0.5500	0.5100	0.6707	0.6220	0.8710	0.8324	5.9646	62.20	CB	0.262
UY6S7	2.1300	1.6100	1.2000	0.7559	0.5634	0.5591	0.7488	1.0490	56.34	CB	0.248
UY1S4	2.2300	1.5400	1.1100	0.6906	0.4978	0.6161	0.7106	2.3323	49.78	B	0.227
UY3S2	1.8300	1.3400	1.0400	0.7322	0.5683	0.6203	0.7612	2.1168	56.83	CB	0.235
UY5S3	1.7000	1.2200	1.0400	0.7176	0.6118	0.7273	0.8049	3.7153	61.18	CE	0.249
UY8S2	1.7200	1.3100	1.0200	0.7616	0.5930	0.5857	0.7729	1.4452	59.30	CB	0.255
UY10S7	2.2300	1.1200	1.0100	0.5022	0.4529	0.9098	0.7419	9.0484	45.29	E	0.237
UY6S1	2.1200	1.5000	1.0300	0.7075	0.4858	0.5688	0.6936	1.4162	48.58	B	0.229
UY9S5	2.0700	1.5200	1.0100	0.7343	0.4879	0.5187	0.6870	0.3833	48.79	B	0.241
UY9S2	1.6900	0.9700	0.8100	0.5740	0.4793	0.8182	0.7369	6.6388	47.93	E	0,272
UY5S3	1.6300	1.0800	0.9700	0.6626	0.5951	0.8333	0.8115	5.6007	59.51	CE	0,225
UY7S4	1.6200	1.1400	1.0800	0.7037	0.6667	0.8889	0.8580	5.8332	66.67	CE	0.236
UY2S5	1.4000	1.0000	0.9500	0.7143	0.6786	0.8889	0.8639	5.7309	67.86	CE	0.248
UR5S1	1.7700	1.2300	0.8400	0.6949	0.4746	0.5806	0.6869	1.6983	47.46	B	0.320
UR5S2	3.0200	2.0400	1.8200	0.6755	0.6026	0.8167	0.8131	5.2556	60.26	CE	0.267
UR6S4	3.3400	2.1100	1.7300	0.6317	0.5180	0.7640	0.7517	5.0965	51.80	CE	0.286
UY8S5	4.0400	2.5200	2.1100	0.6238	0.5223	0.7876	0.7590	5.5064	52.23	CE	0.234
UY8S9	2.6500	2.0700	1.5300	0.7811	0.5774	0.5179	0.7529	0.3100	57.74	CB	0.221
UR1S5	3.9900	2.5700	2.0600	0.6441	0.5163	0.7358	0.7452	4.5671	51.63	CE	0.246
UR1S7	3.6400	2.5100	1.8300	0.6896	0.5027	0.6243	0.7157	2.4726	50.27	CB	0.311
UR4S1	2.5400	1.9500	1.5500	0.7677	0.6102	0.5960	0.7857	1.5733	61.02	CB	0.226
UR4S2	3.2500	2.3700	1.7400	0.7292	0.5354	0.5828	0.7325	1.5465	53.54	CB	0.223
UR6S3	2.1300	1.8400	1.5300	0.8638	0.7183	0.4833	0.8422	-0.2325	71.83	C	0.241
UR7S5	2.7300	1.7100	1.4400	0.6264	0.5275	0.7907	0.7630	5.5109	52.75	CE	0.298
UR6S8	2.1200	1.5000	1.1300	0.7075	0.5330	0.6263	0.7376	2.3696	53.30	CB	0.274
UR8S7	8.2000	5.5400	4.3500	0.6756	0.5305	0.6909	0.7468	3.5985	53.05	CB	0.321
OR1 S2	2.4200	1.5100	1.4300	0.6240	0.5909	0.9192	0.8241	7.0943	59.09	CE	0.238
OR3S1	2.0100	1.3200	1.0400	0.6567	0.5174	0.7113	0.7415	4.0839	51.74	CE	0.277
OR4S3	2.0400	1.0500	0.9300	0.5147	0.4559	0.8919	0.7391	8.5962	45.59	E	0.23
OR4S2	1.5100	1.1200	0.7400	0.7417	0.4901	0.5065	0.6867	0.1326	49.01	B	0.291
OR5S1	3.0400	2.0200	1.5400	0.6645	0.5066	0.6800	0.7282	3.5531	50.66	CB	0.275
OR5S2	2.1100	1.2200	1.0000	0.5782	0.4739	0.8018	0.7297	6.3684	47.39	E	0.283
OR7S1	2.3200	1.7400	1.1100	0.7500	0.4784	0.4793	0.6733	-0.4327	47.84	B	0.222

LEGEND

B – BLADED CB – COMPACT BLADED CE – COMPACT ELONGATE E – ELONGATE C - COMPACT

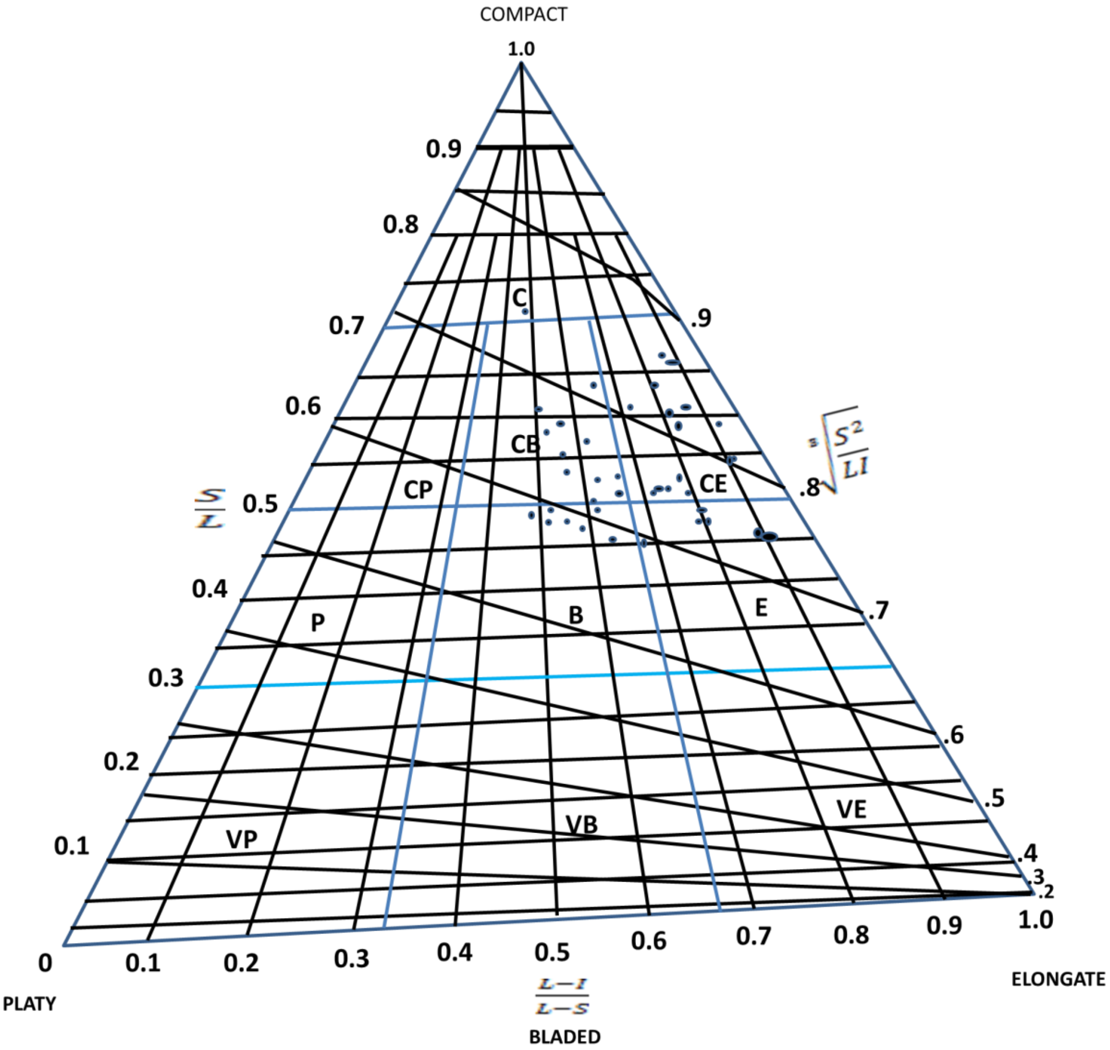


Fig.3: Sphericity form diagram after Sneed and Folk (1958). each point is an average of twenty pebbles.

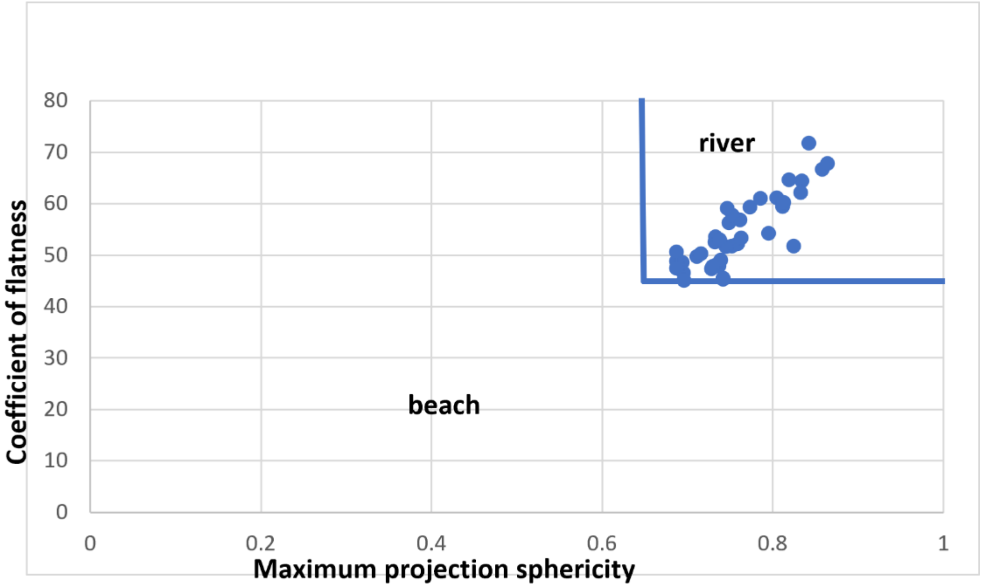


Fig. 4: Bivariate plot of coefficient of flatness versus maximum projection sphericity after Stratten, 1974.

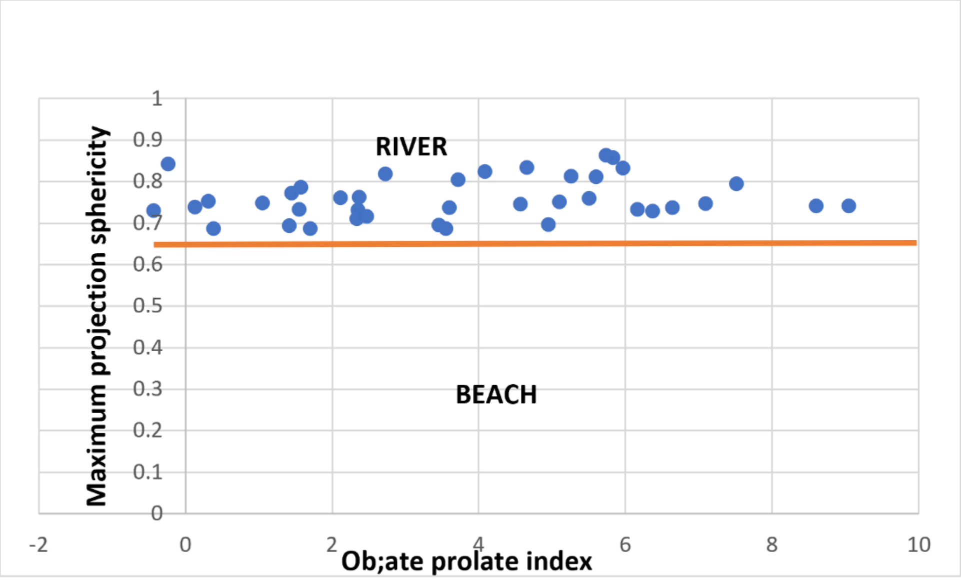


Fig. 5: Bivariate plot of maximum projection sphericity versus oblate prolate index after Dobkin and Folk, 1970.

V. DISCUSSION

The mean values of the various morphometric parameters range as follows: flatness ratio (S/L = 0.4510 – 0.7183), elongation ratio (I/L = 0.5022 – 0.8638), maximum projection sphericity (Ψ P = 0.6867 -0.8639), Oblate Prolate index (Ō P = -4327 -9.0484), coefficient of flatness (45.10 – 71.83), roundness = 0.254 (table 2).

According to Dobkin and Folk (1970), Gale (1990), Udo, (2013), particular gravel clasts shape concentrates in particular environments. For example, disc accumulates on beaches while rollers (elongate clasts) and bladed accumulate in rivers. From the result (table 2, fig. 3), 17.5% of the samples were bladed, 15% were elongate, 32.5% were compact bladed, 32.5% were compact elongate while 2.5% were compact. Since the mean geometric form were bladed, elongate, compact bladed, compact and compact elongate, it means that the environment of deposition is likely to be fluviatile.

In a comperative study of gravels obtained from beaches and rivers in Southern Africa, Stratten (1974) found that fluvial pebbles have mean coefficient of flatness of more than 45 and that their mean sphericities exceed 0.65. Dobkin and Folk (1970), in their study of basalt pebbles in rivers and beaches in Tahiti-Nui, arrived at a lower limit of 0.66 for the mean sphericity of fluvial pebbles, a figure very close to that of stratten (1974). Dobkin and Folk (1970), also found that the mean Oblate-Prolate index of fluvial pebbles exceeds -1.5, whereas the value of beach pebbles is lower. It therefore means that the following values are approximate lower index limits for pebbles shaped in a fluvial environment:

Sphericity = 0.65, Coefficient of flatness = 45, Oblate-Prolate index = -1.5

From the result, the average values of the above three indices for all the localities are well above the lower limits for fluvial pebbles thus lending credence to fluvial origin.

Plot of maximum projection sphericity against coefficient of flatness (fig.4) shows that all the points lie in the fluvial field of Stratten (1974).

Bivariate plot of maximum projection sphericity versus Oblate-Prolate index (fig.5) also shows all the points plotting within the fluvial realm.

Sames (1966) found that roundness values less than 0.350 are typical of river pebbles whereas values more than 0.450 suggest littoral environment. Dobkin and Folk (1970) established for river and beach pebbles, mean roundness values of 0.375 and 0.508 respectively. From these values, it appears that a mean roundness index of 0.380 is the upper limit for pebbles shaped by a river.

The mean roundness value for pebbles in the study area calculated from table 2 is 0.254. This is well below the critical value of 0.380 for river pebbles.

VI. CONCLUSION

In conclusion, the study reveals that the exposed section of the Benin Formation in southeastern part of the Niger Delta Basin is of fluvial origin.

REFERENCES

[1]. Adegoke, O. S., Arua, I., Oyegoke, O., 1980. Two new nautiloids from the Imo shale (Paleocene) and Ameki Formation (Middle Eocene), Anambra Basin, Nigeria. Journal of Mining and

[2]. Geology, v. 17, p. 85-89.

[3]. Avbovbo, A. A., 1978. Tertiary lithosratigraphy of the Niger Delta. American Association of Petroleum Geologists Bulletin, v. 62, p. 295 – 306.

[4]. Benkhelil, J., 1982. Benue Trough and Benue chain. Geol. Mag., v. 119, p. 155 – 168.

[5]. Benkhelil, J., 1989. The origin and evolution of the Cretaceous Benue Trough, Nigeria. Journal of African Earth Sciences, v. 8, p. 251 – 282.

[6]. Burke, K. C., 1996. The African Plate. South African Journal of Geology,

[7]. v. 99, p. 341 – 409.

[8]. Dobkins, J. and R.K. Folk, 1970. Shape Development on Tahiti-Nui. Jour. Sed. Petrol, Vol. 40 (4) pp. 1167-1203.

[9]. Ekwenye, O. C., Nichols, G. J., Collinson, M., Nwajide, C. S., 2014. A paleogeographic model for the sandstone member of the Imo shale, southeastern Nigeria. Jour, Afric. Earth Sci., v. 96, p. 191.

[10]. Fitton, J. G., 1980. The Benue Trough and Camerron Line, a migrating rift system in west Africa. Earth Planet Sci. Lett., v. 51, p. 132 – 138.

[11]. Gale, S.J., 1990. The Shape of Beach Gravels. Jour. Sed. Petrol.,Vol. 60, No. 5., pp. 787-789.

[12]. Genik, G. J., 1993. Petroleum geology of Cretaceous Tertiary rift basins in Niger, Chad and Central African Republic. AAPG Bull., v. 77, p. 1405 – 1434.

[13]. Griffiths, J. C., 1967. Scientific Methods in Analysis of Sediments. McGraw-Hill, New York, 508pp.

[14]. Hoffman, P., Dewey, J. F., and Burke, K. C., 1974. Aulacogens and their genetic relations to geosynclines with Proterozoic example from Great Slave Lake, Canada. In: Dot, R. H. Jr. and Shaver, R. H., editors. Modern and ancient geosynclinals sedimentation. SEPM spec. Publ., v. 19, p. 38 -58.

[15]. Hoque, M., and Nwajide, C. S., 1984. Tectono-sedimentological evolution of an elongate intracratonic basin (aulacogen): the case of the Benue Trough of Nigeria. Nigeria Journal of Mining Geol., v. 21, p. 19 – 26.

[16]. Hoque, M., 1984. Pyroclasts from the Lower Benue Trough of Nigeria and their tectonic implications. Jour. Afric. Earth Sc., v. 2, p. 351- 358.

[17]. Kogbe, C.A., 1975. The Cretaceous and Paleogene sediments of Southern Nigeria. Geology of Nigeria. Elizabethan publishing company, Lagos,pp 273-282

[18]. Luttig, G., 1962. The Shape of Pebbles in the Continental, Fluvial and Marine Facies. Int. Assoc. Sc. Hydro. Publ., 59: pp.253-258.

[19]. Malauski, H., Coulon, C., Popoff, M., Boudin, P., 1995. ^{40}/Ar/^{39}Ar chronology, petrology and geodynamic setting of Mesozoic to Early Cenozoic magmatism from the Benue Trough, Nigeria. Jour. Geol. Soc. Lond., v.152, p. 322 – 326.

[20]. Murat, R. C., 1972. Stratigraphy and Paleogeography of the Cretaceous and Lower Tertiary in southern Nigeria. In: Desauvagic, T. F. J., Whiteman, A. J. editors. African Geology, University of Ibadan Press, Nigeria, p. 251 – 266.

[21]. Nwachukwu, S. O., 1972. The tectonic evolution of southern portion of the Benue Trough, NIigeria. Geological Magazine, v. 109, p. 411 – 419.

[22]. Nwajide, C.S. and M. Hoque 1982. Pebble Morphometry as an Aid in Environmental Diagnosis: An example from the Middle Benue Trough. Nig. Jour. Min. Geol., Vol. 19(1), pp. 114-120.

[23]. Olade, M. A., 1975. Evolution of Nigeria Benue Trough (aulacogen): a tectonic model. Geol. Mag., v.112, p. 575 – 583.

[24]. Obi, G. C., Okogbue, C. O. Nwajide, C. S., 1984. Evolution of the Enugu cuester: A tectonically driven erosional process. Global Journal of Pure and Applied Sciences, v. 7, P. 321 – 330.

[25]. Pettijohn, F. J., 1975. Sedimentary Rocks. Harper and Row Publishers, New York, Evanston, San Franscisco and London, pp. 491

[26]. Petters, S. W., 1978. Stratigraphic Evolution of the Benue Trough and its implications for the Upper Cretaceous Paleogeograhy of West Africa. Jour. Geol., v.86, pp.311-322.

[27]. Petters, S.W., 1989. Akwa Ibom State Physical Background, Soils and Land use Ecological Problems. Technical Report of the Task Force on Soil and Land Use Survey, Akwa Ibom State. Government Printers Uyo, 603. pp.

[28]. Power, M.C., 1953. A New roundness Scale for Sedimentary Particles. Jour. Sed.

[29]. Petrol., 23, pp. 117-119.

[30]. Reyment, R.A., 1965. Aspects of the Geology of Nigeria, Ibadan University Press, Ibadan, 143pp.

[31]. Sames, C., 1966. Morphometric Data of Some Recent Pebble. Association. Jour. Sed. Petrol., Vol. 36. pp. 126-142.

[32]. Short, K. C. and A. J. Stauble, 1967. Outline of Geology of Niger Delta. Am. Asso. Petrol. Geol. Bull. 51, pp. 761-781.

[33]. Sneed, E. D. and Folk, R. L., 1958. Pebbles in the lower Colorado river, Texas: A study in particles morphogenesis. Jour. Geol., v. 66, p. 114 – 150.

[34]. Stolk, J., 1963. Contribution à l'ètude des corrèlations microfauniques du Tertiare infèrièur de la Nigeria mèridionale: Colloque Internatl. De Micropalèontologie, pp. 247-275.

[35]. Stratten, T., 1974. Notes on the Apllication of Shape Parameters to Differentiate between Beach and River Deposits in Southern Africa. In: Pebble Morphology of Ancient Conglomerate. The Middlevlei Gold Placer, Witwatersrand, South Africa (ed. B. G. Els). Jour. Of Sedimentary Petrol. Vol. 58: No. 58, pp. 894-901.

[36]. Udo, I. G. and Mpde, A. W., 2013. Use of statistical parameters in the sedimentological study of conglomerate deposits in northeastern part of Akwa Ibom State, Niger Delta Basin, Nigeria. IOSR Journal of Applied Geology and Geophysics, vol. 1 (5), p. 21 -27.

[37]. Whiteman, A. J., 1982. Nigeria: Its petroleum geology, resources and potentials. Graham and Trotman, London, vol. 1, 166pp.