

PALEOENVIRONMENT OF NIGERIA'S AJALI SANDSTONES: A PEBBLE MORPHOMETRIC APPROACH

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ABSTRACT

The Ajali Sandstone is a major clastic formation of Campanian-Maastrichtian age occurring within the Anambra Basin, Southeastern Nigeria. The Sandstones have a high incidence of quartz and feldspar pebbles. Clasts of vein quartz pebbles were selected for morphometric study to decipher the depositional environment of the sandstones.

The three mutually perpendicular axes of each pebble were measured and the roundness estimate with the aid of a roundness image set. Morphometric parameters such as size, flatness ratio, elongation ratio, maximum projection sphericity, form geometry and oblate index were computed. Bivariate scattergrams of roundness versus oblate-prolate index were plotted.

Except for the flatness ratio which is non-diagnostic, all the other results of the morphometric studies indicated a fluvial – dominated depositional environment. The result is in line with earlier conclusions of fluvial or fluviodeltaic depositional environment based on analysis of facies, sedimentary rock which are suitable for morphometrical research: those with isotropic constitution and high resistivity to wear such as cherts, quartz sandstones and some related types.

KEYWORDS: Clastic formation, Fluvial, Fluviodeltaic, Elongation ratio, Oblate index.

INTRODUCTION

The Ajali Sandstone (Formation), referred to as the False Bedded Sandstone in the reports of Nigerian Geological Survey (Bain, 1924, Tattan, 1943; Grove, 1951; Simpson, 1954) is an extensive stratigraphic unit in the Southeastern sedimentary basin of Nigeria. It was formally named the Ajali Sandstone by Reyment (1965).

The formation, Campanian-Maastrichtian in age is present along the Udi Plateau and extends continuously in a thin outcrop of the Southeast of Okigwe (Fig. 1). It is underlain by the Mamu Formation and overlain by the Nsukka Formation both conformably in most of the study area; its stratigraphic relationship with other rock units in the study area is shown in figure 2. The thickest section is present in the Udi Plateau where it has been variously reported to be over 350m to 450m thick (Grove, 1951, Simpson, 1954; Reyment, 1965; Tamfu, 1982). The Formation rapidly thins south of the Oji River and is no more than a few tens of meters over the Okigwe axis.

Most of the Ajali Sandstone is composed of medium to coarse grained sub-angular to sub-rounded quartz arenites (Hoque and Ezepue, 1977; Nwajide and Hoque, 1982) which is pebbly

in places. The pebbles occur as pebble beds, (or sandy conglomerate), conglomerate sandstones, and slightly pebble sandstones. Their thickness ranges between 15 –38cm and consists mostly of the feldspar and quartz pebbles. The quartz pebbles are of two types; quartzite and vein quartz. The former type may be distinguished by their tabular form, and micaceous composition while the vein quartz pebbles have varying shapes, massive and monomineralic.

Several environment interpretations of the Ajali Sandstone have been suggested by many authors (Reyment, 1965; Murat, 1972, Agagu, 1978; Ladipo, 1986) based on the predominant coarse lithology, absence of marine fossils, unimodal palaeocurrent, presence of plant impression and vertical association with coal bearing formation i.e. Mamu and Nsukka Formation. However, as Griffiths (1967) has observed, the size of quartz grain measured as individual is likely to yield the best basis for environmental diagnosis.

The purpose of this study therefore, is to illustrate how morphometric attributes of vein quartz pebbles found in Ajali Sandstones can be utilized for environmental diagnosis. Pebble samples were collected from fifty locations within the formation.

THEORETICAL CONSIDERATIONS

The measurement of pebble axes with Vernier Calipers is based on the method recommended by Folk (1980). In using this method, each pebble is imagined to be placed in a box just capable of accommodating it, and the true magnitude of the long (L), the intermediate (I) and the short (S) axes of the pebble. The estimation of pebble roundness (R) is based on the set of pebble images given by Sames (1966). The images set is based on the proportion of the grain surface that is convex.

For the measurements of pebble axes and roundness (R), the following morphometric parameters – Flatness ratio, Elongation ratio, Maximum projection sphericity and the oblate – prolate index are computed.

The Flatness ratio is the ratio of the short axis to the long axis of the pebble (S/L), while the Elongation ratio is defined as the ratio of the intermediate axis to the long axis (I/L) (Lutig, 1962; Sames, 1996).

Sphericity is a measure of the equidimensionality, i.e. the approach of a pebble to a sphere (Nwajide and Hoque, 1982). The maximum projection sphericity is the cube root of the ratio between the square of the short axis and the product of the long and intermediate axis i.e. $(S^2/LI)^{1/3}$ (Sneed and Folk, 1958).

The oblate-Prolate Index OP measures how close the intermediate axis (I) of a pebble is to the long axis (L) or to the short axis (S) or to the short axis (S). Dobkins and Folk (1970) who introduced the measure defined it as

$$\bar{OP} = 10 \frac{(L - I - 0.5) / S}{(L - S) / L} \dots \dots \dots (1)$$

Thus, if I exactly half way between L and S, the value of (L-I)/(L-S) is 0.5 and the OP is zero.

Form is a measure of the relation between the three mutually perpendicular dimensions of the pebble and is used to accommodate the fact

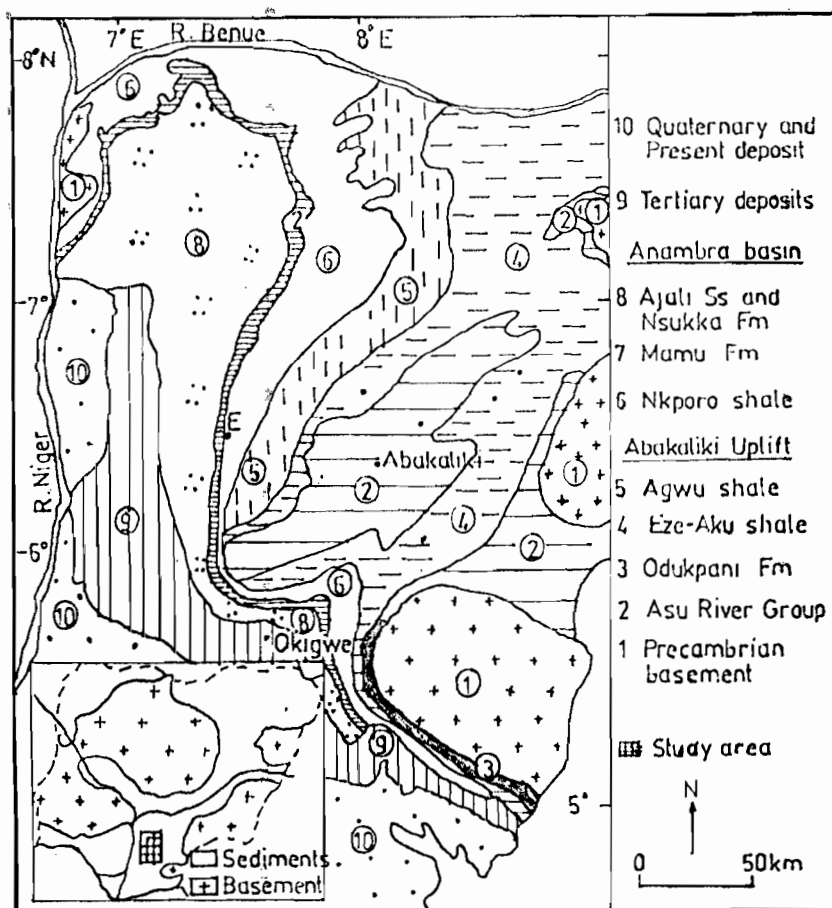


Figure 1. Geological map of south eastern Nigeria (based on published maps of the Geological Survey). The inset shows the position of the study area on sketch map of Nigeria.

AGE		STRATIGRAPHIC SEQUENCE	PETROLOGY OF SANDST. UNITS	BASIN/ PHASE
EOCENE		AMEKI Formation/NANKA SAND	Quartz Arenites	Anambra Basin Second tectonic phase
PALEOCENE		IMO Shale		
Upper Cretaceous	DANIAN	NSURKA Formation		
	MAESTRICHTIAN	AJALI Sandstone		
		MAMU Formation		
	CAMPANIAN	ENUGU Shale/NKPORO Shale		
	CONIACIAN-SANTONIAN	AWGU Shale		
TURONIAN		EZE-AKU Shale	Feldspathic Sandstones	Abakaliki Basin First tectonic phase
CENOMANIAN		O'URKANI Formation		
L. Cretaceous		ASU RIVER Group		
BASEMENT COMPLEX				

Figure 2 Stratigraphic relationship among formations in the study area and petrology of sandstone units (sequence based on Reyment 1965).

that particles having the same numerical value of maximum projection sphericity may have different ratios between their axes (Nwajide and Hoque, 1982).

EXPERIMENTAL WORK

Vein quartz pebbles were used for this morphometric study. They are the most abundant in the Formation and their original shapes and forms have been modified only by attrition. A requirement of grain analysis which should be met by any measurement technique is that, since there may be a relationship between size and mineral species, the technique should be applied

to one mineral only (Griffiths, 1967). The choice of vein quartz pebble is therefore justified by its relative and isotropic properties.

Ten largest unbroken samples were collected from each location where vein quartz pebbles were found. In this manner, fifty batches were collected, totaling five hundred pebbles. The pebbles in each batch were then washed and numbered.

The area of the pebbles were measured in (cm) with a Venier caliper as recommended by Folk (1980). The roundness (R) of each pebble was estimated by noting the proportion of the maximum projection perimeter that is convex in relation to the Sames pebble image set (Sames, 1966). The values of the long (L), the intermediate (I) and the short (S) axes and the roundness (R) of the pebbles in each batch were

then averaged. These averages were then used to compute the morphometric parameters.

RESULT AND DISCUSSIONS

The mean values of morphometric parameters of the Ajali Sandstone pebbles are shown in Table 1. The long axis of the pebbles ranges from 0.68 – 1.71cm with an average 1.15 ± 0.19cm while the intermediate short axes ranges from 0.54 – 1.08cm and 0.43 – 0.90cm with average 0.84 ± 0.12 and 0.66 ± 0.10 respectively. Since the size of pebble is taken as their long axes (Smith, 1966; Griffiths, 1967; Kerumbain, 1983), the pebbles may be regarded as of fine size. The Flatness ratio of the Ajali pebbles ranges from 0.43 – 0.72 with an average of 0.57 ± 0.007. This value is beyond the fluvial range (0.25 – 0.35) and also above the marine range (0.40 – 0.50) proposed by Lutig (1962). The elongation ratio of the pebbles ranges from 0.80 – 0.83 with a mean of 0.73 ± 0.07. The average value of elongation places the pebbles in Lutig's (1962) torrent type flowing water which he thinks evaluate pebbles with elongation values of 0.65 ± 0.75. The sphericity values of the pebbles range from 0.61 – 0.86 with a mean of 0.76 ± 0.053. The Form name of each pebble batch has been determined using the sphericity form diagram (Fig. 3) of Sneed and Folk (1958). The compact-bladed form constitutes 54%, the compact-Elongate 30%, the Elongate-Form 14% and the Bladed-Form 2%.

When compared with those obtained by Dobkins and Folk (1970), the environmental implications of the sphericity values and forms can be better appreciated. They have reported that the 0.66 sphericity line best separates batches and river pebbles, the lower values typifying the beaches while the higher value suggest fluvial origin. The Ajali pebbles are therefore likely to have experienced mainly fluvial transport. The compact-bladed and compact-elongated forms noted by Dokins and Folk (1970) to be dominant in river pebbles are also the most frequent Forms observed in the Ajali pebbles.

The oblate-Prolate index for the pebbles ranges from -3.72 to 5.71 with a means of 1.93 ± 2.12 . This value lies with the range of - 1.00 to + 5.00 which Dobkins and Folk (1970) classed as Fluvial. There are only 9 negative values,

indicating how rare discs are. Also, a plot of maximum projection sphericity values against OP index (Fig. 4) indicate a fluvial environment for the pebbles.

The roundness values of the pebbles in the study area ranges from 23 to 45 with a mean of 33 ± 5.89 . The low roundness value may be indicative of the closeness of the depositional site to the source area (Griffiths, 1967). Figure 5 shows bivariate plot of roundness versus elongation following Sames (1965). The plot indicate a fluvial environment of deposition. It shows that 60% of the pebbles are in the fluvial field, 38% in the transitional field and the remaining 2% in the littoral field.

The foregoing observations based on morphometric study of Ajali pebbles, support earlier conclusions of fluvial and fluvio-deltaic

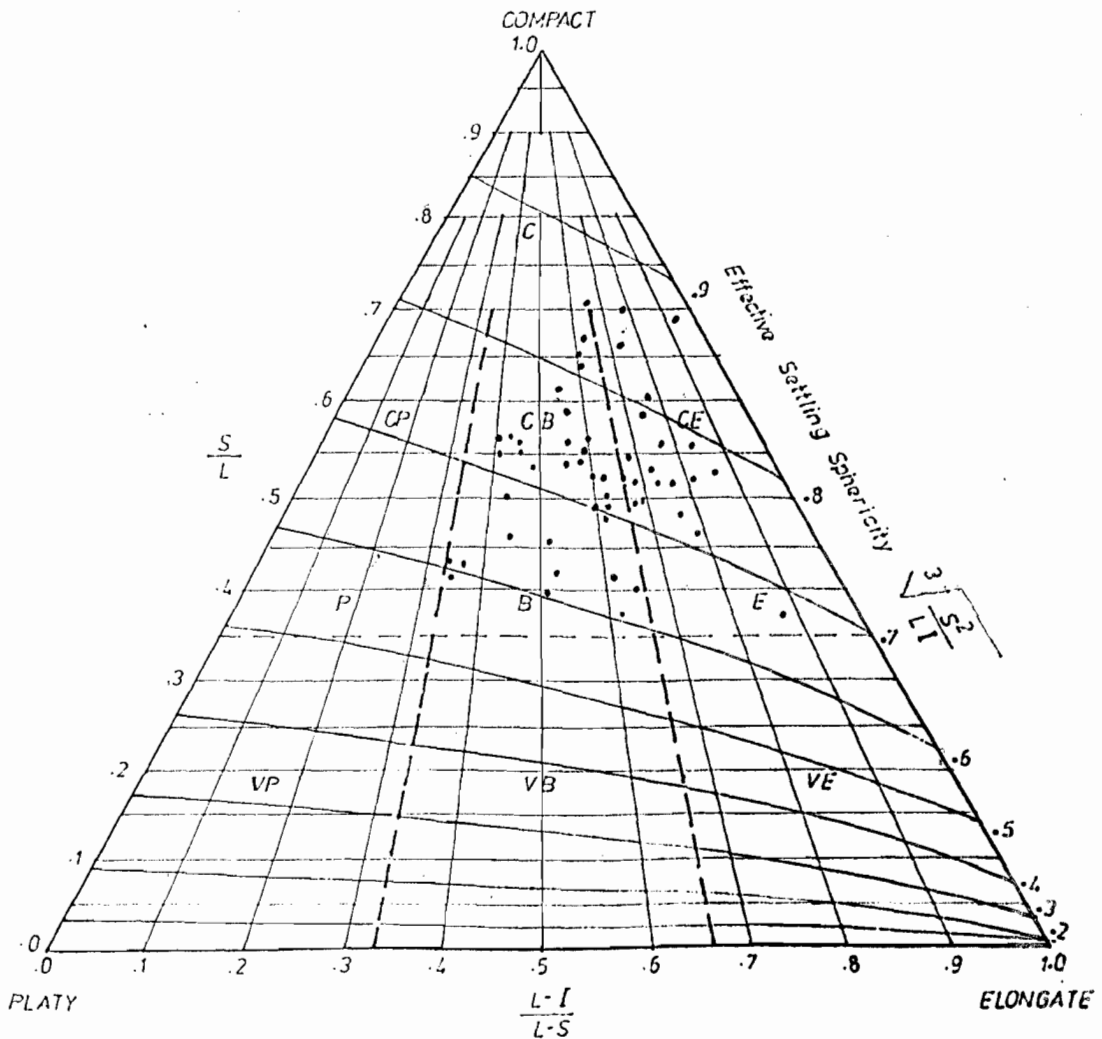


Figure 3 Plot of average pebble shape on Sneed and Folks (1958) Sphericity form diagram each point represents on average of ten pebbles C = compact, P = platy, B = elongate and V = very

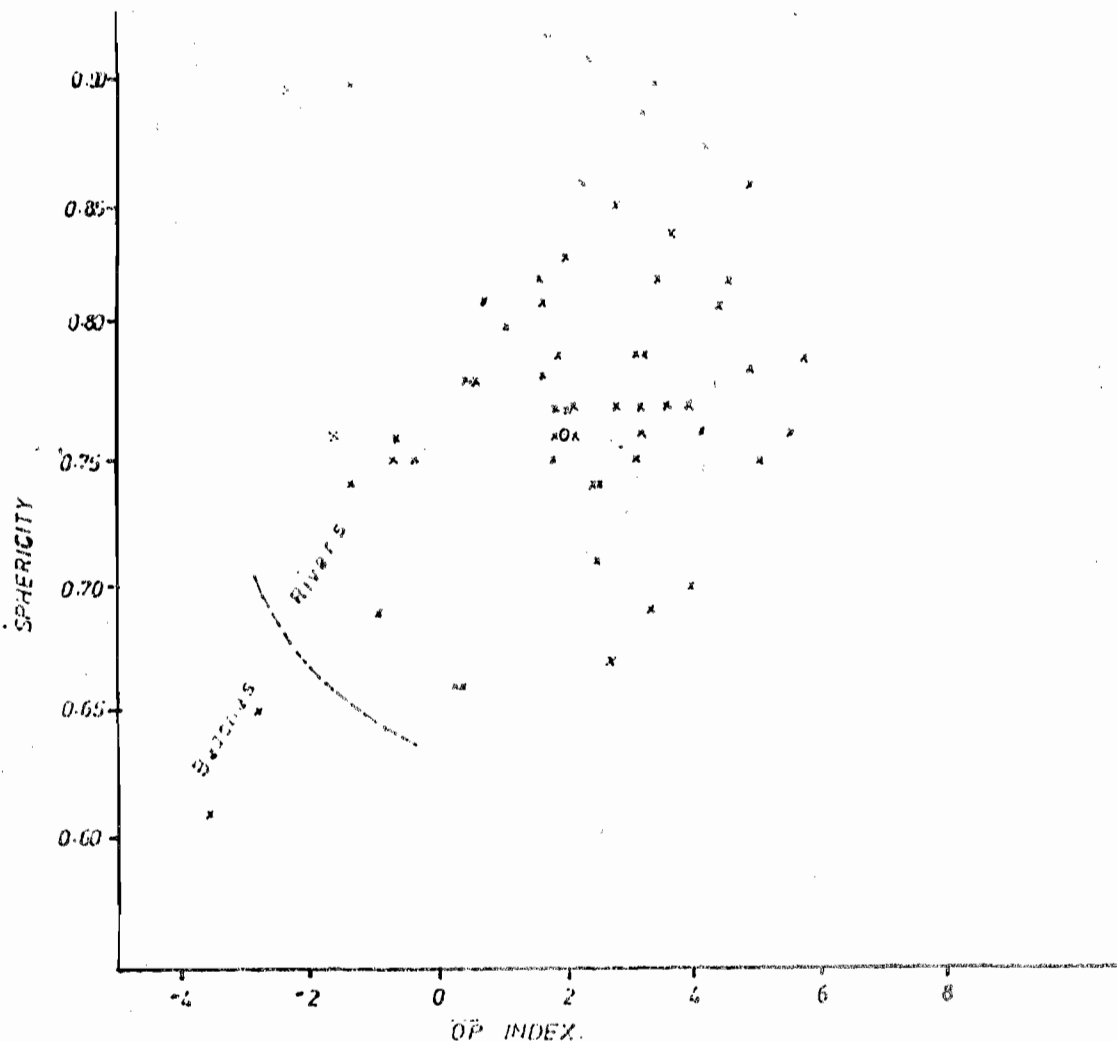


Figure 5 Maximum projection sphericity against oblate-prolate index showing separation of beach and river fields. The average values of the two parameters is shown in solid circle. (After Dobkins and Folk, 1970)

Plot of the mean roundness values of the samples against the mean elongation ratio, and Oblate-prolate index against the maximum projection sphericity strongly indicate fluvial dominated environment. The dominant pebble forms are also the characteristic assemblage observed in fluvial environments. The measurement carried out and the results have shown that littoral, fluvial and detrital pebble associations can be clearly differentiated by morphometrical examination.

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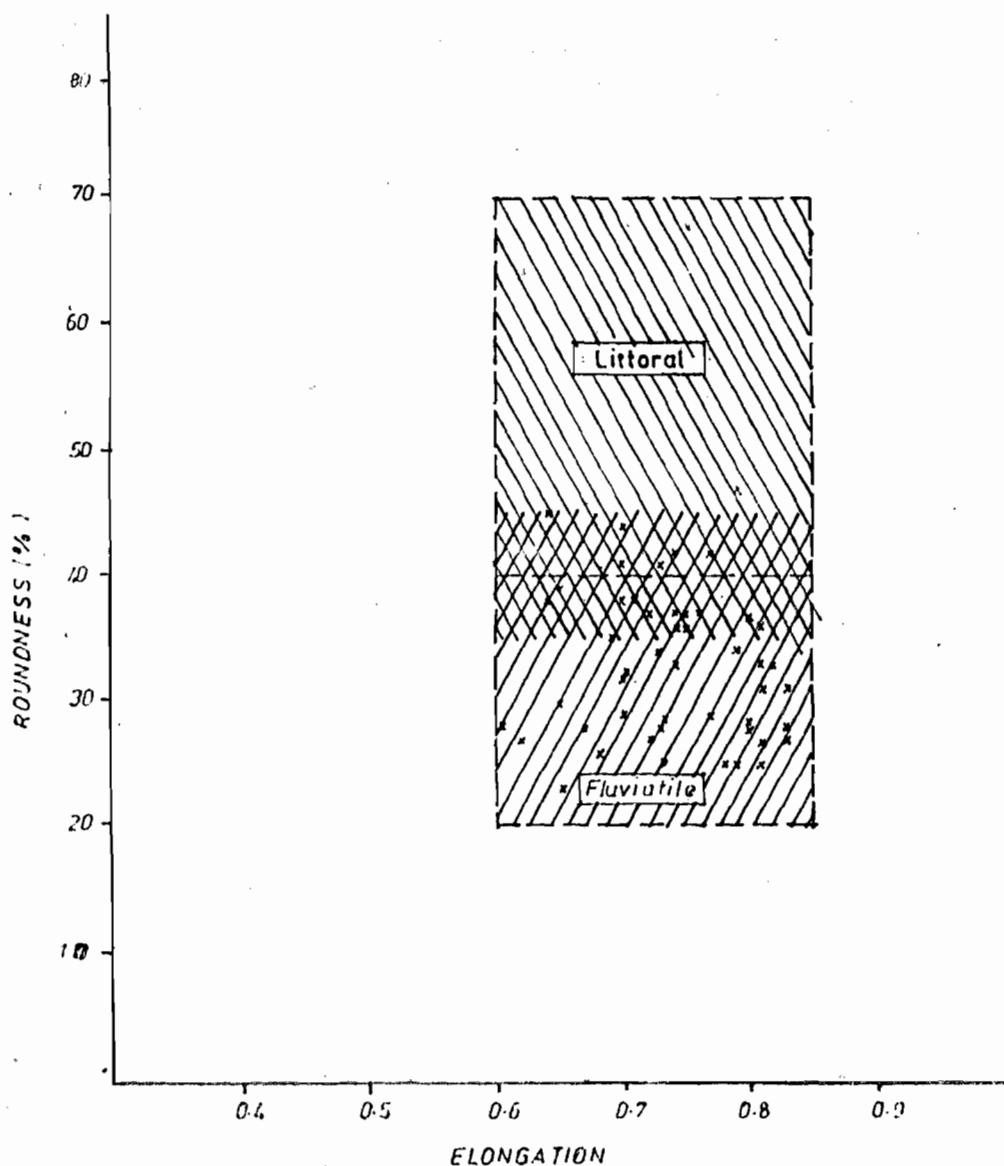


Figure 4 Pebble roundness plotted against elongation ratio, using the Environmental Determination Chart of Sames (1966)

depositional models (Reyments, 1965; Murat, 1972; Hoque and Ezepeue, 1977; Agagu, 1978).

CONCLUSION

The application of morphometry to Ajali Sandstone pebbles has yielded useful results concerning the original source environment of the pebbles. The pebbles average 1.15cm in size mostly subangular to subrounded, and have

mean flatness ratio of 5.57, a mean elongation ratio of 0.73, maximum projection sphericity of 0.76 and Oblate-Prolate index of 1.39. The dominant forms are compact-bladed and compact-elongate.

A comparison of these morphometric parameters with those in published works on large particle morphogenesis shows that the Ajali Sandstone pebbles form part of a fluvial sand body.

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