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Provenance and palaeoenvironment of the lower Kerri-Kerri formation around Biri Fulani, North-Eastern Nigeria

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ABSTRACT: The Kerri-Kerri formation Around Biri Fulani in North-eastern Nigeria is made up of reddish, moderately well sorted, quartz arenites that are large scale cross-bedded. Field studies and laboratory analyses were conducted on these sediments to determine their depositional environments. Sieve analysis of sediments in the area of study showed that the sandstones within the Kerri-Kerri Formation are very leptokurtic and strongly fine-skewed. The sediments are texturally immature and mineralogically mature with angular to subrounded grains thus suggesting a moderate degree of reworking.

Palaeocurrent analysis showed that the Kerri-Kerri Formation were probably originated from the NE and NW basement Complex of Northern Nigeria. This is evidenced by the unimodal direction of the azimuth pointing in southerly and south easterly directions. All these parameters suggest that the sediments of the Kerri-Kerri Formation are products of the fluvial environment.

Keywords: Provenance, Palaeoenvironment, Paleocurrent, Fluvial, Unimodal.

Introduction

The Kerri-Kerri Formation is flat-lying and unconformably overlies eroded and tilted beds of the Gombe Sandstone (Dike, 1995). Dike (1995) reported that the centre of the Kerri-Kerri Formation is occupied by medium to coarse-grained sandstones interbedded with thick clays and about 2-5m thick interbeds of lignite at Dikku and Bara areas, probably representing channel sand and flood plain deposit. In his stratigraphic and structural studies, Dike (1995) interpreted the Kerri-Kerri depocentre as slightly asymmetrical elongate basin bounded to the west and east by closely spaced normal faults which trend between N15°E and N30°E.

Ako and Osundu (1986) as well as Dike and Dan-Hassan (1992) from subsurface studies showed that the formation unconformably overlies the basement complex along its western margin. Odedede (2002) reported that the Lower Kerri-Kerri Formation around Biri Fulani is composed of reddish, moderately well sorted, quartz arenites which are large scale, tabular cross-bedded.

The Palaeocene age attributed to this formation by shell-Bp (Carter *et al.*, 1963) from a *palynoflora* *spinozonocolpites* and *Monocolpites margintes* collected from carbonaceous layers, has been confirmed by

Adegoke *et al.*, (1978). However, little attention has been given to the detailed Sedimentology and palaeocurrent of the Kerri-Kerri Formation, particularly around the present study.

This paper presents the palaeoenvironment and palaeocurrent analysis of the Kerri-Kerri Formation from few outcrops encountered around the Biri Fulani area.

Materials and Methods

The study area lies between Longitudes 11°15' and 11°17'E and Latitudes 10°52' and 10°55'N covering a surface area of about 70km² (Fig. 1).

A stereoscopic examination of aerial photographs covering the area was undertaken and followed by a systematic mapping of the area using a base map of scale 1:25,000. Samples were collected for both sieve and petrographic analysis. A total of six thin sections were prepared and due to the friable nature of the sandstone, they were first impregnated with a mixture of araldite and toluene and were cured before thin sectioning. Photomicrographs of features of interest were taken.

Ten sandstone samples were sampled for sieving and all the samples were friable and were easily disaggregated by using a mortar with a rubber pestle. mechanical analysis was carried out by the convectional sieving method, with screens placed at half-phi ($\frac{1}{2} \phi$) intervals 100grams of material was used for each sample, and a sieving time of 10 minutes was adopted and consistently applied for all samples. The various statistical measures of sand interpretations employed in this study were those of Wentworth (1922), Folk and Ward (1957) and Friedman (1979).

Measurements of cross-bedding forest dips were taken for palaeocurrent analysis and statistical formulae of Potter and Pettijohn (1977) were used to obtain resultant vectors and vector magnitude. However, most of the outcrops have been weathered and the few encountered were noted, described and photographed.

Regional Geological Settings

The Kerri-Kerri Formation records early Tertiary sedimentation of coarse clastic sediments in north eastern Nigeria. The formation is a post-tectonic sequence deposited in continental environment (Adegoke *et al.*, 1986). The origin of the Kerri-Kerri Basin and the structures within its area of deposition are the direct consequence of the folding and uplift of the Cretaceous sediments of the Benue Trough (Adegoke *et al.*, 1986). Folding and uplift probably started during the deposition of the Gombe Sandstone which occupies structurally the same position as the Kerri-Kerri Formation (Adegoke *et al.*, 1986; Dike, 1995). The tectonic phase and associated uplift originated from the axis of the Benue Basin westward toward the margins and uplifting the Gombe Sandstone depositional axis towards the close of the Cretaceous. Thereafter, the compressive stresses were released and a new Kerri-Kerri depocentre was formed (Adegoke *et al.*, 1986; Benkhetil, 1989).

The main structural elements which control the deposition and the structure of the Kerri-Kerri Formation, belong to a group of N-S and NE-SE trending faults (Adegoke *et al.*, 1986; Zaborski *et al.*, 1997). The tectonic regime responsible for the reactivation of those faults is basically extensional.

Geology of Biri-Fulani and Environs

At Biri Bolewa, the lower part of the Kerri-Kerri Formation is exposed and consists of reddish, moderately well sorted (0.89 ϕ), medium-grained (see Table 1), large-scale, tabular cross bedded (Plate 1), quartz arenites (see Table V) with sets 0.6m – 12m thick and foreset on average 2cm thick. The boundary surface between the adjacent cross-bedded units are erosional.

At Koyal-Boni, a large scale cross-bedded quartz arenite is well exposed, poorly sorted, and angular, with clay lenses and sets few mm thick and foresets on average of 1cm thick.

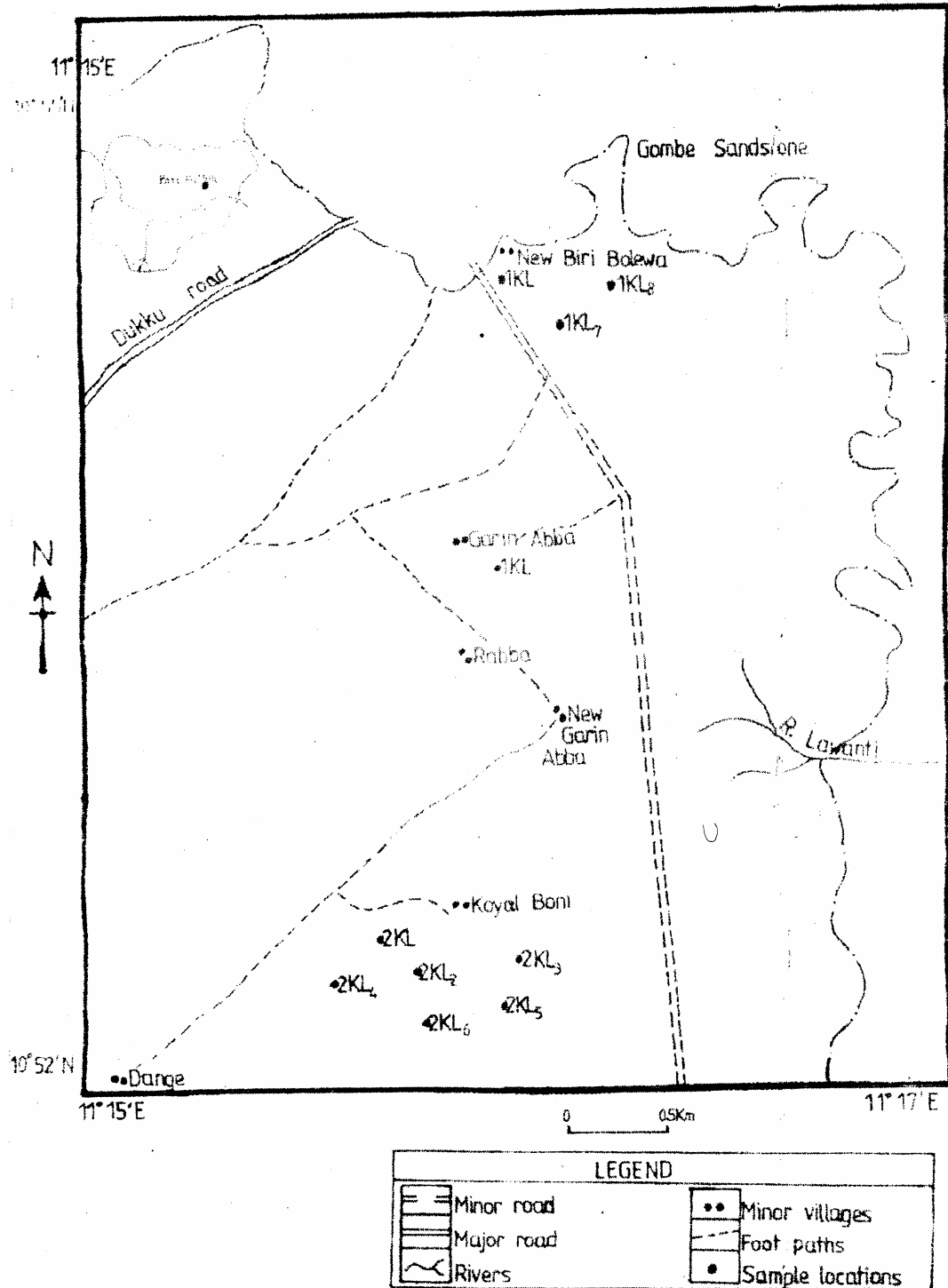


Fig. 1 Location Map of the Study Area, around Biri Fulani

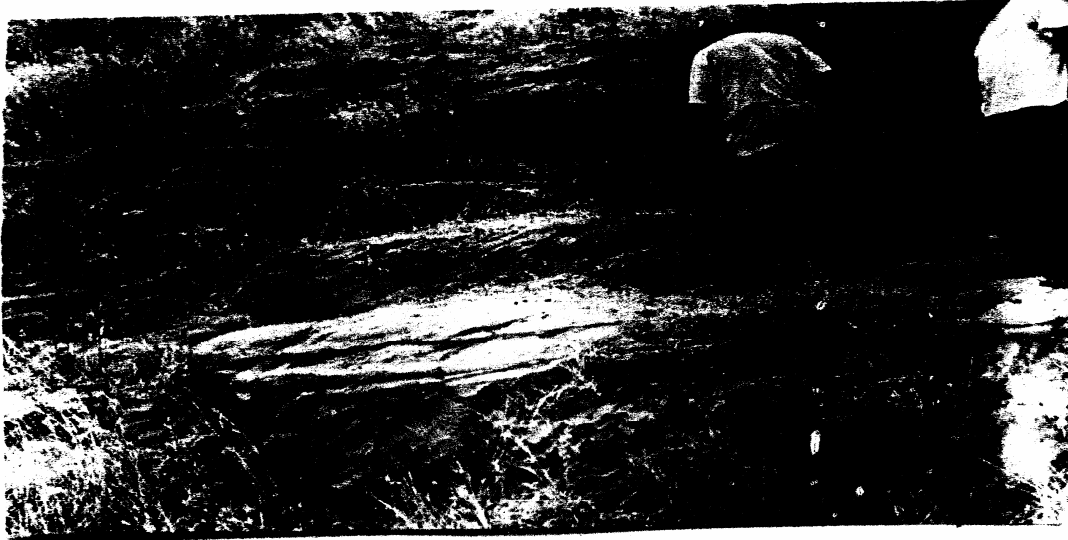


Plate 1: Large-scale, tabular cross-bedded quartz arenite of the Kerri-Keri Formation at Biri, Bolewa.

Results and Discussion

Graphic measures results from sieve analysis to obtain the textural parameters – mean grain, sorting, skewness, kurtosis, simple skewness and simple sorting are shown in Table 1.

Table 1: Sieve analysis result (Derived from graphic measures)

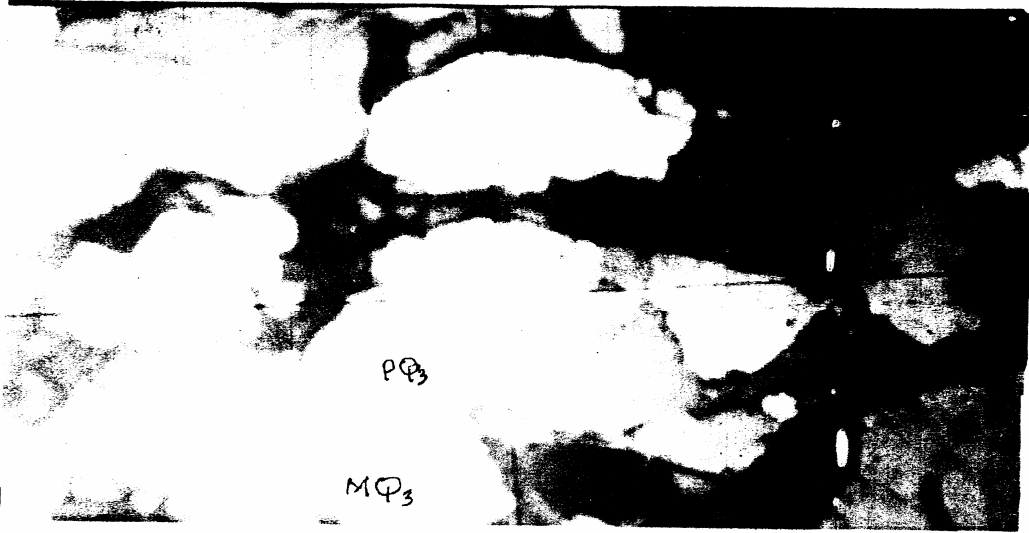
Sample No.	Mean grain size ϕ	Sorting ϕ	Skewness	Kurtosis	Simple skewness	Simple sorting	Interpretation (After Folk & Ward, 1957 & Wentworth, 1922)
1K1	1.24	0.89	0.21	1.75	1.63	2.13	Course grained, moderately sorted, fine skewed and very leptokurtic
2K1	2.37	0.45	2.0	1.54	0	0.95	Medium grained, moderately well sorted, strongly fine-skewed, and very leptokurtic
1K1 ₁	1.20	0.69	1.8	1.53	1.76	1.70	Medium grained moderately well sorted, strongly fine skewed and very leptokurtic
2K1 ₂	1.01	1.00	0.28	1.51	1.42	2.12	Coarse grained, moderately sorted fine-skewed, and very leptokurtic
2K1 ₃	1.21	1.10	0.33	2.00	0.15	1.61	Coarse grained moderately sorted, fine-skewed and very leptokurtic
2K1 ₅	3.23	2.20	0.30	1.49	1.00	1.35	Very fine grained, poorly sorted, strongly fine skewed and very leptokurtic
2K1 ₆	2.70	1.42	0.21	2.11	2.20	2.20	Very fine grained, poorly sorted, strongly fine skewed and very leptokurtic
1K1 ₇	1.00	0.55	0.44	1.70	0.78	0.90	Coarse grained, moderately sorted, fine-skewed and very leptokurtic
1K1 ₈	1.19	0.74	0.42	2.20	1.70	1.55	Medium grained, moderately well sorted, strongly fine skewed and very leptokurtic
2K1 ₄	3.24	1.096	-0.30	1.66	1.56	-2.00	Fine grained, poorly sorted, coarse skewed, and very leptokurtic

Mineralogical composition of Kerri-Kerri Sandstones

Petrographic studies show that quartz is the dominant mineral in all facies studied, and is present as angular to slightly rounded grains of variable size (Table II). Percentage of quartz by volume is about 95% or greater in all the sandstone (Table II) of the study area. Both monocrystalline and polycrystalline quartz grains (Plate 2) occur in the Kerri-Kerri Formation. There is an absence of undulatory extinction, however, indicating an unstrained environment of derivation, because according to Tucker (1988) undulatory extinction is usually a reflection of strain in the crystal lattice.

Table 2: Petrographic Analysis Data (Microscopic Examination).

Sample No.	Grain size description	Sorting	Grain shape	Quartz (%)	Feldspar	Mica (%)	Matrix	Cement	Maturity	Remark (Sandstone type)
1k1	Coarse to medium grained	Moderately sorted	Subangular to rounded	97	-	-	-	Hematite	Minerogically & texturally mature	Quartz arenite
2k1	Medium grained	Poorly sorted	Subangular to rounded	96	-	-	< 5% clay	Hematite	Minerogically & texturally mature	Quartz arenite
1k1 ₁	Medium grained	Moderately well sorted	Rounded	95	-	-	-	-	Texturally mature	Quartz arenite
2k1 ₃	Coarse grained	Poorly sorted	Subangular	98	-	-	> 4% clay	-	Texturally submature & mineralogically mature	Quartz arenite
1k1 ₇	Coarse grained	Moderately well sorted	Subangular to round	98	-	-	-	-	Texturally & mineralogically mature	Quartz arenite
2k1 ₈	Medium grained	Moderately sorted	Subangular to rounded	97	-	-	-	-	Texturally & mineralogically mature	Quartz arenite



(Cross-polar x50)

Plate 2: Photomicrograph of Monocrystalline (MQ₃) and Polycrystalline (PQ₃) quartz grains separated by clay matrix at Koyal Boni,



(PLANE POLARIZED) x50.

Plate 3. Photomicrograph of quartz grains in hematite cements observed in sample IKL at Biri-Bolewa.

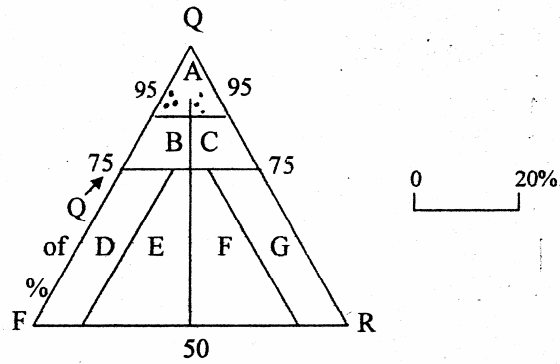


Fig. 2. Classification of sandstone (After Pettijohn *et al.*, 1973).

A = quartz arenite, B= subarkose, C= sublitharenite, D= arkose E = lithic arkose, F = feldspathic litharenite, G=litharenite, Q = quartz F = feldspar, and R=rock fragment.

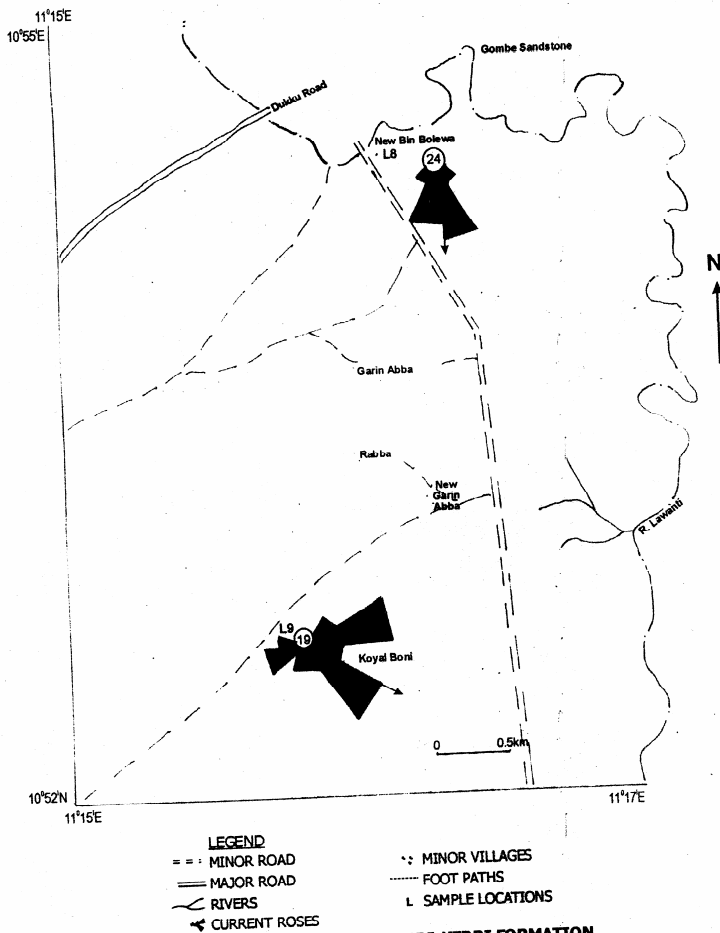


FIG. 3: PALEOCURRENT MAP OF THE KERRI-KERRI FORMATION (AROUND BIRI FULANI)

Clay matrix is a major component (<5%) or totally lacking in the Kerri-Kerri facies studied. The clay has a cloudy appearance, no birefringence and moderate relief. Hematite constitutes the cement (Plate 3) and was identified by its reddish colour and red internal reflections in reflected light.

The method of classification of sandstone proposed by Pettijohn *et al.*, (1973) is utilized in the classification employed in this work. This classification is based on mineralogical composition and percentage of matrix. Based on this classification system, the sandstones examined microscopically, are all quartz arenites (Fig. 2). On maturity, all sandstones studied are mineralogically mature (quartz>95%) and texturally submature to mature (Matrix<55). Compositional and textural maturity basically reflects the weathering processes in the source area, and the degree and extent of reworking and transportation (Tucker, 1988).

All sandstone samples are feldspar-free, and dominantly composed of monocrystalline and polycrystalline quartz grains. Pettijohn (1975) reported that the presence or absence of feldspar is the result of a balance between the rate of decomposition and the rate of erosion. The absence of feldspars in the sediments is therefore considered to be a result of chemical weathering of the parent rock lying to the NE and NW parts of the study area (Fig. 3). Considering the regional geology of Nigeria, it can thus be suggested that the rocks of the basement complex of Northern Nigeria could have sourced sediments during a prolonged period of transportation to the Kerri-Kerri Basin.

Textural Characteristics

An evaluation of sieve analysis in Table 1 shows mean grain sizes ranging from 1.241 ϕ , to 2.57 ϕ with an overall average of 1.90 ϕ , these according to Wentworth (1922), correspond to a range from medium to coarse sandstone. Standard deviation (a measure of sorting) deduced from the sandstones averages 0.69 ϕ indicating moderately well sorted. Skewness values are positive for Kerri-Kerri Formation (averaging 1.11 ϕ), indicating strongly fine skewed. Kurtosis values between 1.59 ϕ and 1.75 ϕ , indicating very leptokurtic.

Discussion

Palaeoenvironment

The ancient sediments of the study area showed that they are very leptokurtic, strongly fine skewed and moderately well-sorted. Positive skewness obtained for Kerri-Kerri Formation is not consistent with beach deposited sands. River sands are generally poorly-sorted and positively skewed, while beach sands are well-sorted and negatively skewed, reflecting in the latter case persistent wave actions (Tucker, 1988). Statistical plotting of the grain size data based on Friedman (1967 and 1979) showed that the Kerri-Kerri sands are of fluvial origin (Fig. 4). Positive skewness values obtained for Kerri-Kerri Formation are also consistent with fluvial setting. The sandstones are moderately well sorted, texturally submature to mature and mineralogically mature, may be due to moderate reworking and were deposited in fluvial environment. The large scale tabular cross-beddings (Plate 1) characterizing the Kerri-Kerri sands and the unimodal azimuthal patterns (Fig. 3) are consistent with fluvial environments (Selley, 1968). The lack of fossils especially marine fossils in the sandstones also suggests a fluvial setting. Inferences from scatter plots, microfacies and sedimentary structure corroborate this evidence.

Provenance:

Cross-bedding azimuth readings plotted on rose current diagrams for the study area (Fig. 3), suggest a southerly and south-easterly palaeo-flow directions and all locations display a unimodal current direction. This may probably indicate a provenance from NE and NW basement complex of Northern Nigeria. The high proportion of quartz grains in the sandstone suggests a source from a quartz-rich rock such as quartzite, granite, gneiss etc.

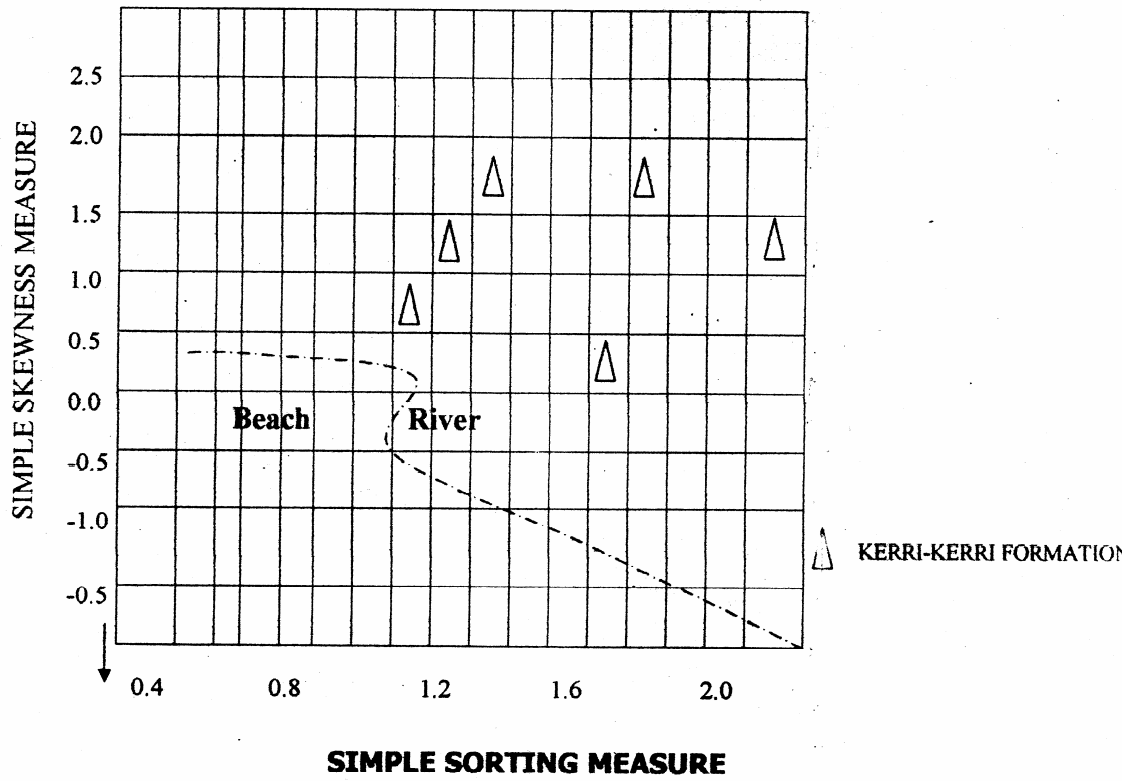


Fig. 4: Scatter plot: simple skewness measure versus simple sorting measure for the study area (Modified After Friedman, 1967).

Conclusion

The kerri-Kerri Formation around Biri Fulani in the Upper Benue Trough of Nigeria is made up of reddish, moderately well-sorted quartz arenites, which are large scale cross-bedded. The sandstones are mineralogically mature and texturally sub-mature to mature, and indicating a moderate degree of reworking. Paleocurrent analysis showed that the Kerri-Kerri sediments were probably deposited by NE and NW trending current suggesting a source area of rocks of the basement complex of Northern Nigeria. This is evidenced by the unimodal direction of the azimuth pointing in southerly and south-easterly directions. A fluvial setting has been assigned to this formation on the basis of the sedimentary structures, textural characteristics and its lack of fossils.

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