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Sedimentological Characterization of Clastic Sediments of Anambra Basin: Implications for Provenance and Palaeoenvironments Sedimentological

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Abstract

Grain size and heavy mineral studies carried out on eleven samples from sandstone, siltstone and shale beds that are exposed along road cuts and river channels were used to decipher palaeodepositional conditions, provenance and tectonic setting within the Anambra Basin, south-eastern Nigeria. The study revealed three lithofacies belonging to the Lokoja-Basange and Mamu Formations. The sandstones mostly exhibit fining upward sequences with poorly sorted angular to subangular grains that have poor compositional maturity. These are characteristic of short transportation history and fluvial depositional environments. The siltstones and shale display a coarsening upward progradational pattern that is suggestive of deltaic sedimentation. Heavy mineral assemblages observed in the sandstone samples include zircon, rutile, magnetite, topaz and tourmaline which suggest igneous and metamorphic provenance derived from neighbouring rocks of the Precambrian Basement Complex of Nigeria.

Keywords

Anambra Basin · Lithofacies · Provenance · Palaeoenvironment

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1 Introduction

The Anambra Basin (Fig. 1) is one of the inland sedimentary basins in Nigeria known for its economic potential due to the presence of hydrocarbon and other mineral deposits. The westward displacement of depocenters in the Lower Benue Trough (southern part of the trough) led to the deposition of cyclic succession of coals, shales, siltstones and sandstones in the Cretaceous Anambra Basin. Recent studies in Anambra basin (Adeigbe & Salufu, 2009; Obi, 2000; Odunze & Obi, 2013) have led to the reconstruction of the stratigraphic framework within the basin. The present study covers Igarra, Auchi, Sabongida Ora, Uzebba and Ifon areas, showing good exposures of Cretaceous sediments along channels and road cuts. This study aimed at using sedimentological tools to provide geological information on provenance, transportation history and palaeoenvironments of the detrital sediments at different locations.

2 Materials and Methods

The methodology involves field study and laboratory analysis. Field studies were carried out on road cut exposures. Six lithostratigraphic sections which cover Lokoja-Basange Formation and Mamu Formation in the Anambra basin were logged and sampled (Fig. 2) with specific attention paid to differences in lithology, texture, colour, grain size, shape, sorting, bedding, thickness, weathering characteristics and structures. Samples were taken from a few cm below the surface to ensure sampling of in situ materials. A total of eleven rock samples were taken for grain size and heavy mineral analysis using different sieve sizes. In this method, 100 g of each sample was put in the upper sieve, the machine was allowed to shake for ten (10) minutes, and the sediments retained in each of the sieves and the bottom pan was weighed and recorded. Statistical parameters of graphic mean (Mz), graphic standard

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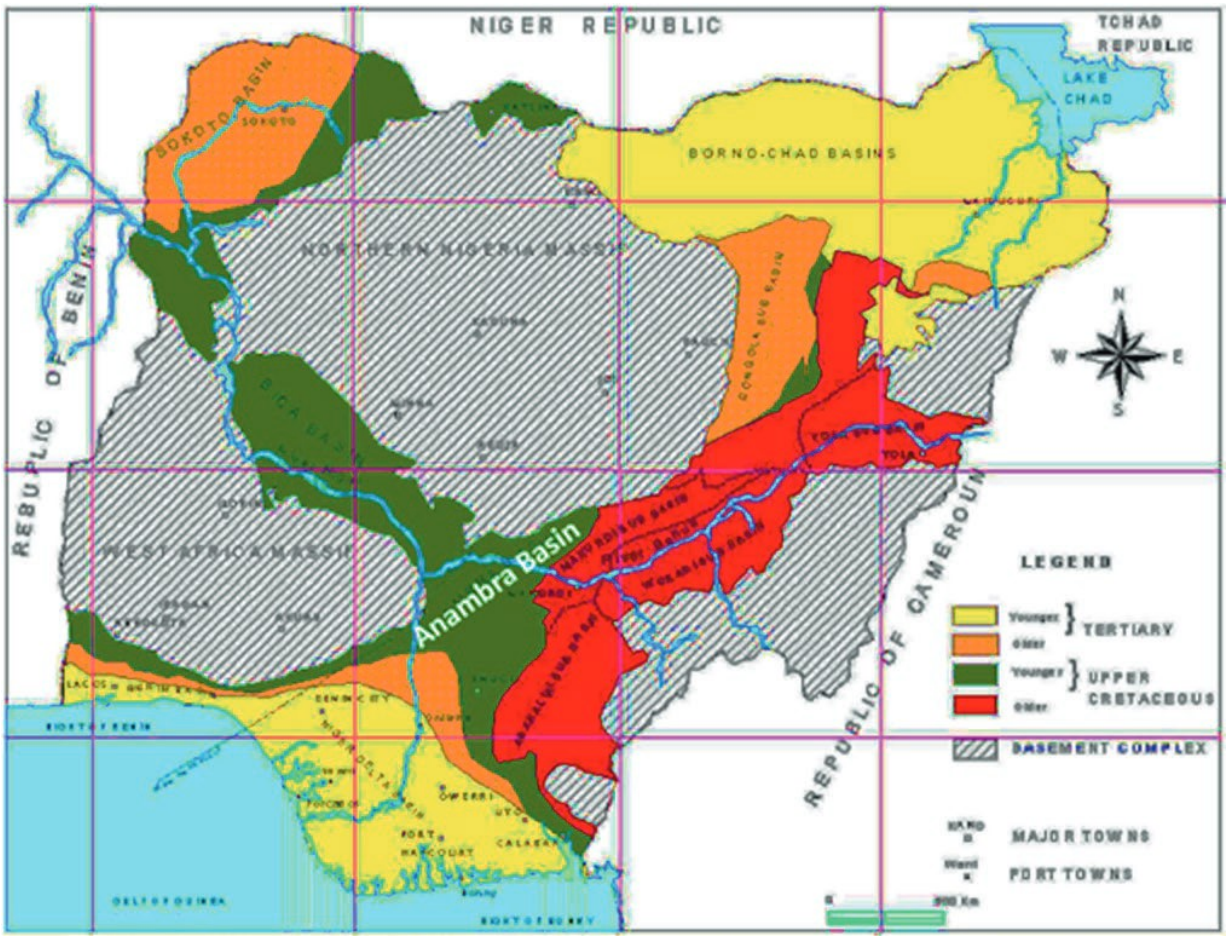


Fig. 1 Geological map of Nigeria showing the sedimentary basin and the study area (after Obaje et al., 2004)

deviation (sorting) (σ1), inclusive graphic skewness (Ski) and graphic kurtosis (KG) of each of the samples are presented in Table 1. Quantitative graphical values of percentiles from various samples obtained from the cumulative frequency curve were plotted for various samples as presented in Fig. 3a. The statistical parameters of the grain size frequency distribution were obtained and computed by the method of Folk and Ward (1957). Eleven samples were subjected to heavy mineral analyses using liquid bromoform (heavy liquid), acetone and filter paper. The disaggregated sample was poured into the bromoform in a separating funnel (with tap locked) and stirred vigorously with the glass rod. The heavy minerals were then drained into the receiving funnel with filter paper, washed with acetone and then dried. The conical flask at the bottom was used to collect the drained bromoform. The identification of minerals was done by using a binocular and polarizing microscope.

3 Results and Discussion

3.1 Lithostratigraphic Description of Outcrop Samples

Six locations were logged and described for facies characteristics. Sandstones, siltstones and shales were observed at various locations (Fig. 2) and each facies having distinct characteristics in terms of texture, structure, mineralogy and colour. The thickness of the sandstone beds varies between 0.3 and 2 m. The sandstones exhibit a fining upward (transgressive) sequence with thin laminations which may suggest fluvial deposition. There were no indications of preservation of fossil, and the grains were subangular to angular, indicating short transportation from the source area. At location 5, the exposure shows medium- to coarse-grained sandstone and form coarsening upward sequences with the underlying siltstone units.

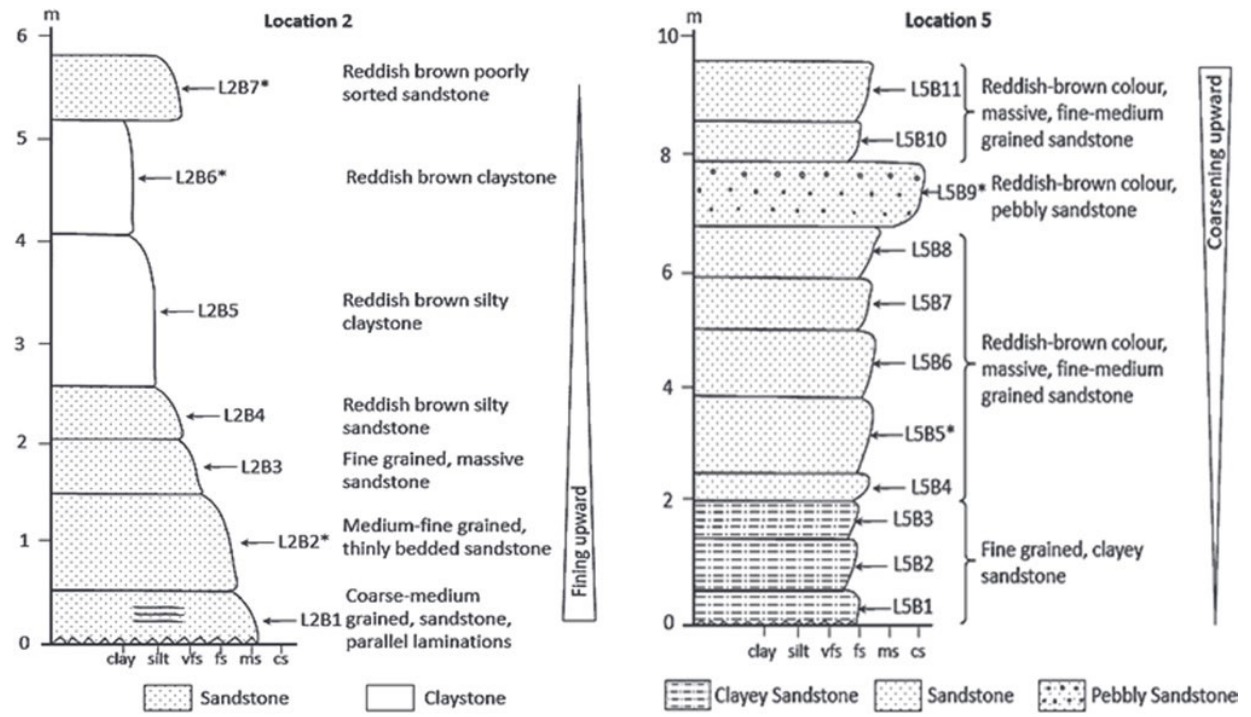


Fig. 2 Lithological succession of Lokoja-Basange Formation exposed at locations 2 and 5

Table 1 Statistical data obtained from grain size analysis (after Folk & Ward, 1957)

Sample	Sample code	Mean value	S.D	Skewness (Sk1)	Kurtosis (KG)
1	L2B2	0.07	1.22	0.38	1.61
2	L2B6	4.3	0.93	−1.18	0.41
3	L2B7	2.83	1.30	0.46	1.17
4	L5B5	2.47	0.78	0.23	4.10
5	L5B9	0.6	1.12	0.77	2.68
6	L7B1	3	1.23	0.40	1.64
7	L8B1	2.57	1.32	0.17	1.76
8	L9B8	3.9	1.06	−0.38	0.94
9	L14B1	1.47	2.20	0.42	0.53
10	L14B2	0.27	1.05	0.51	4.92
11	L15B1	1.53	2.15	0.47	0.48

The sandstone section here shows light to reddish brown coloured, ferruginous pebbly sandstones with a maximum thickness of 9.6 m. This unit exhibits coarsening upward sequences which get progressively pebblier towards the top. Elsewhere, the sandstone shows both cross stratification and flaser laminations. The underlying siltstones in locations 5 and 9 are light brown with beds varying in thicknesses of 0.4–2 m. The siltstone is composed mainly of quartz and clay as matrix and alternates with beds of shale and exhibits coarsening upward sequence (prograding) pattern which may suggest fluvio-deltaic deposition. These outcrops are characteristic of the Mamu Formation. The Mamu Formation is represented here, and the shale is exposed at location 9. The shale is fissile and has a thickness of 4 m. The carbonaceous shale has a dark grey colour due to concentration of organic matter. This suggests high level of biological productivity and low energy condition during deposition. It consists largely of clay minerals and micas. Fossils such as floral remains were present.

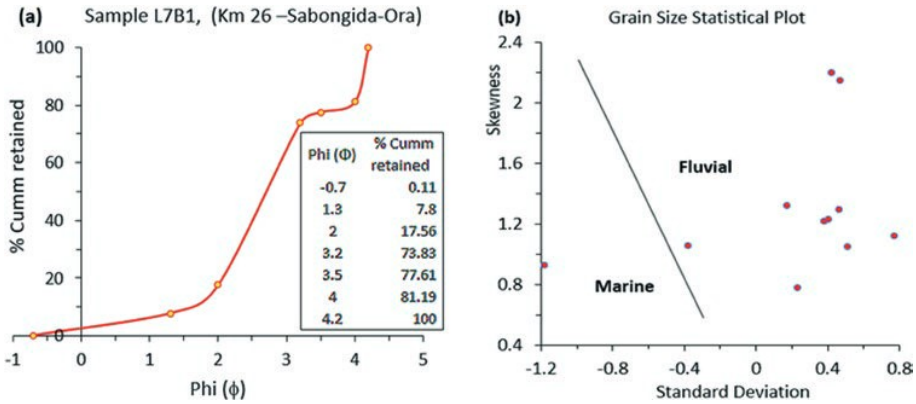


Fig. 3 **a** Cumulative frequency curve for sample L7B1 **b** Bivariate plots of skewness versus standard deviation

3.2 Grain Size Distribution and Palaeoenvironmental Reconstruction

Vischer (1969) and Friedman (1979) indicated the importance of using grain size distributions to deduce palaeoenvironments although it is suggested that particle size distribution for palaeoenvironmental reconstruction should be combined with other sedimentological parameters such as facies association and sedimentary structures (Amaral & Pyrol, 1977; Selley, 1985; Tucker, 1988). The statistical data obtained (Table 1) suggest that the sediments are characterized by fine-grained sand, medium-grained and coarse-grained sandstone whilst sample L2B6 contains silts.

3.3 Sorting and Transportation History

Standard deviation shows the effectiveness of the transporting medium in separating grains of different sizes. The sediments range from moderately to poorly sorted and very poorly sorted, and this is an indication that sediments have not been transported far from the source area before deposition. The poorly sorted sands indicate bedload transport, less winnowing and abrasion. The prevalence of poorly sorted sands and unimodal grain sizes suggest low energy unidirectional fluvial deposition. The skewness of a deposit is sensitive to the depositional environment. The sandstones are characterized by relatively poor sorting and positive skewness/strongly fine skewness which are indicative of river sand (Friedman, 1979). Okoro (1995) reported that negative skewness indicates marine reworking on continental shelf settings. However, in the samples analysed, there was no evidence of marine reworking. Kurtosis revealed that the sediments range from very and extremely leptokurtic to very platykurtic. The leptokurtic nature of the sediments reveals water-laid sediments and low energy conditions.

3.4 Provenance and Palaeoenvironments

Heavy minerals are used for provenance studies, correlation of sedimentary strata of one environment with another and to characterize facies of different localities. The provenance of the sediments is deduced from heavy mineral analyses. The opaque and non-opaque minerals tourmaline, magnetite, zircon, topaz, hematite, sphene, sillimanite and rutile were identified. The heavy minerals occur as detrital grains in the samples which suggests that the sediments are young and were derived from igneous and metamorphic rocks probably from the Basement Complex of south-western and north central Nigeria. The presence of staurolite, rutile, sillimanite and garnet suggests a metamorphic origin. The sediments are thought to have been derived from mixed sources. The presence of hematite suggests oxidation conditions during deposition in a fluvial setting. Palaeoenvironments were deduced from bivariate plots of the mean versus standard deviation and skewness versus standard deviation (sorting) (Fig. 3b) which indicate that the majority of sediments were deposited in a fluvial environment.

4 Conclusions

The grain size parameters (mean, standard deviation, skewness and kurtosis) indicate that the sandstones range from fine grained to coarse grained are poorly sorted, very fine skewed and highly leptokurtic. The angularities of the grains indicate a short transportation history. The range in texture suggests fluctuating energy conditions from low energy regime that deposited fine sand, silts and shale to high energy that deposited medium and coarse sandstone facies. The depositional patterns also suggest fluvio-deltaic sedimentation. The recovery of heavy minerals of zircon, rutile, tourmaline, sphene, sillimanite and staurolite from

the sandstones indicates a mixed igneous and metamorphic sources that are probably derived from neighbouring rocks of the Basement Complex of Nigeria.

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