PROVENANCE STUDIES THROUGH PETROGRAPHY AND HEAVY MINERAL ANALYSIS OF PART OF AGBAJA-LOKOJA FORMATION, BIDA BASIN, NW NIGERIA

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(Received: 6th Feb., 2015; Accepted: 12th Feb., 2016)

ABSTRACT

Fifty five sandstone samples of Lokoja and Agbaja Formations were collected for textural, geochemical, petrographic and heavy minerals analysis with a view to determining the provenance of the sedimentary rocks.The texture of Lokoja Sandstones reveals poorly sorted sub-arkose immature sandstone with the quartz showing both monocrystalline and polycrystalline crystal forms with more of the undulatory forms which depict its derivation mainly from metamorphic origin. Abundance of feldspathic grains is a reflection of its closeness to the provenance which is perhaps located in the north central basement domain on account of the paleocurrent azimuth trend towards the southeast. The conglomerate and sandstone facies are mostly restricted to the Lokoja area. The ironstone mainly found at Agbaja was identified in Oolitic form. The iron rich sediments must have been derived from the rocks of the northern basements, which had been transported to the environment of deposition, as azimuth of primary structure indicate southwardly direction.

Keyword: Agbaja-Lokoja Formation, Heavy Minerals, Petrography, Sedimentology, Provenance

INTRODUCTION

Sedimentological analysis of basins involve three main aspects: provenance studies, the distribution of facies and paleoenvironment, and the changes in these through time during the basin evolution. Provenance studies are key elements of the basin analysis, as it provides basic information regarding the tectonic origin of a particular basin. Information about the source of sediments may be obtained from the examination of the various clastspresent. (Pettijohn, 1975; Basu,2003). A clast in sediment can be recognized as characteristic of a particular source area through its petrology and chemistry and in some cases; this makes it possible to establish the paleogeographical location of a source area and provides information about the timing and processes of erosion in uplifted areas (Dickinson and Suczek, 1979). Provenance studies are generally relatively easy to carry out in coarser clastic sediments because a pebble or cobble may be readily recognized as being eroded from a particular bedrock lithology. Many rock types may have characteristic texture and compositions that allow them to be identified with confidence. Sedimentary rocks are made up of grains which have their characteristic size, shape, morphology and mineralogy, embeddedin a matrix which is the groundmass particles. There are also cement and voids. These four parameters make up the bulk textural properties of any sedimentary rock. Both grains and matrix are detrital materials which are transported from source into the basin of deposition. The cement which is often authigenic is a component that is formed insitu by precipitation from circulating fluids. The voids are intergranular spaces which may be filled by fluid and matrix materials. Sediment grains vary in sizes and these may be distributed spatially within a basin of deposition. This variation is a reflection of the dynamic of the transporting medium from source to basin. The Bida Basin is a NW- SE trending depression perpendicular to the main axis of the Benue Trough. The basin extends from Kontangora in Niger State to areas slightly beyond Lokoja in the south. The Lokoja sub-basin is the southern flank of the Bida Basin and comprises three formations of varying lithologies (Lokoja, Patti and Agbaja Formation). The study area covers Lokoja and Agbaja town which fall within Latitudes 7° 40′ and 8°00′N and Longitudes 6o 40′ and 6o 55′E (Fig. 1) and the studied sections are basically road side cuts. The stratigraphic succession of the Bida Basin is shown in Figure 2 below:

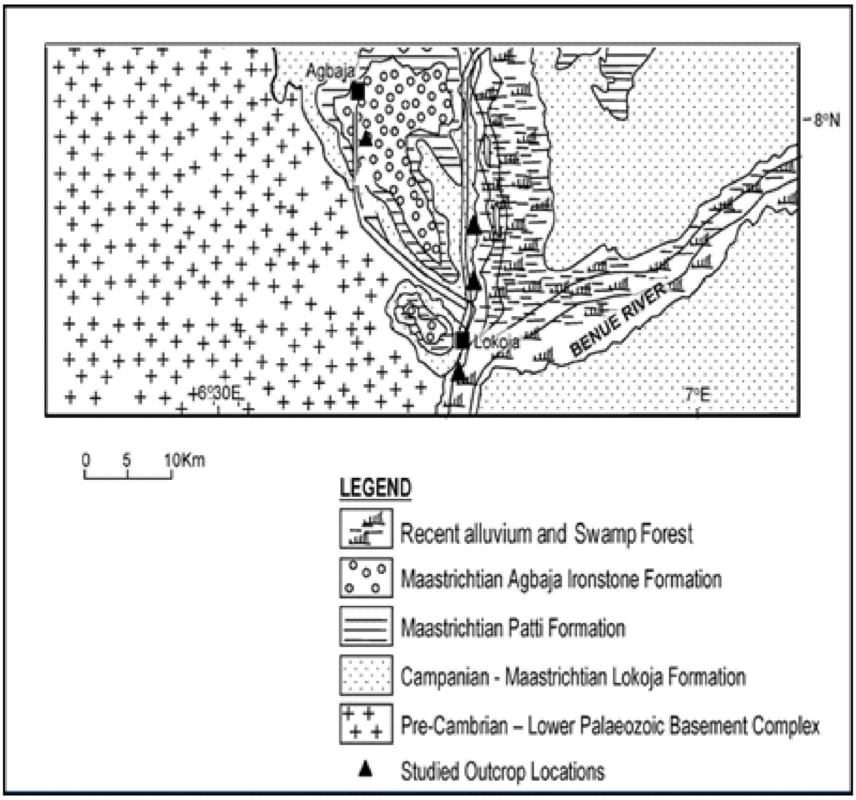


Fig. 1: Sketch of Geological Map of the Study Area, Showing the Different Localities (Extracted from Adeleye, 1976).

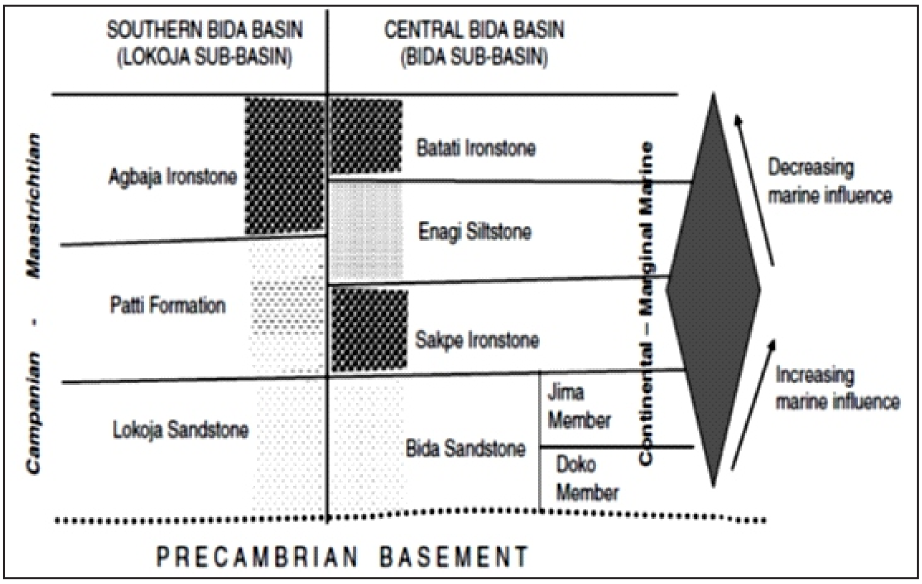


Fig 2: Stratigraphical Succession in the Mid Niger Basin (After Akande, 2005;Obaje, 2009)

METHODS OF STUDY

The methods employed in this research work were field work and laboratory analyses. The field work involved description, logging, measurement and sample collection of various lithologic units. It covers outcrops around Lokoja and Agbaja, where Lokoja and Agbaja Formations were encountered. Most of the outcrops were road cuts which represent the different lithofacies of the formations. Fifty five (55) samples were collected for laboratory analyses. The laboratory work involves textural, geochemical, petrographic and heavy minerals analyses of sandstone samples.

Fig. 3: Field Photograph Showing the Contact Between the Basement and the overlying Sandstone. (Lat. 07°51'17.0"N , Long. E006°41'57.4"E)

Fig. 4: A Conglomeratic Bed Showing various sets of Pebble and Cobble Clasts. (Lat. 07°51'17.0"N , Long. E006°41'57.4"E)

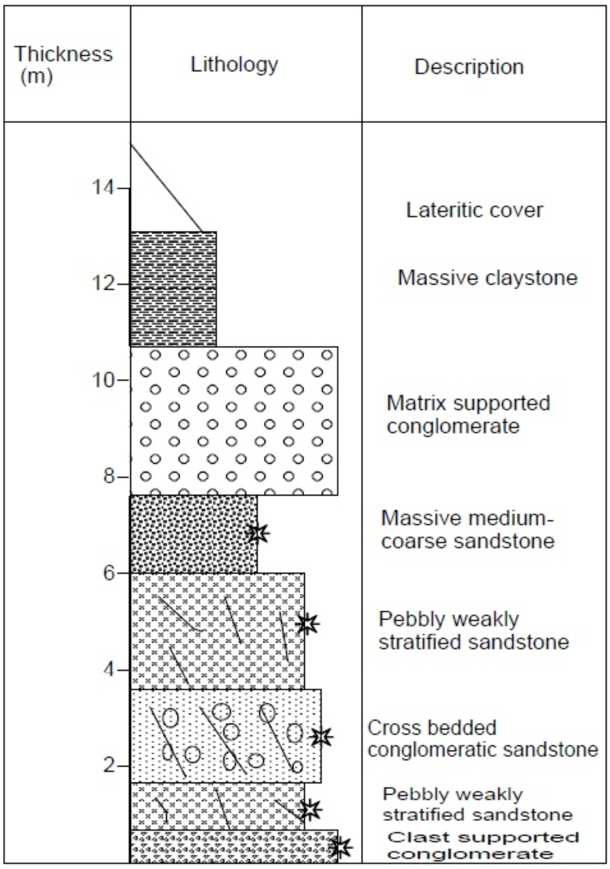


Fig. 5: Lithologic Section of Outcrop at locality 1 in Felele along Lokoja-Okene Road.
★ = Sampling point(Lat. 07°51'17.0"N , long. E006°41'57.4"E)

Fig. 6: Field Photograph of Concretionary Ironstone at Agbaja Plateau, Northwest of Lokoja (Lat. N07° 57' 01.5" Long. 006° 39' 38.5" E)

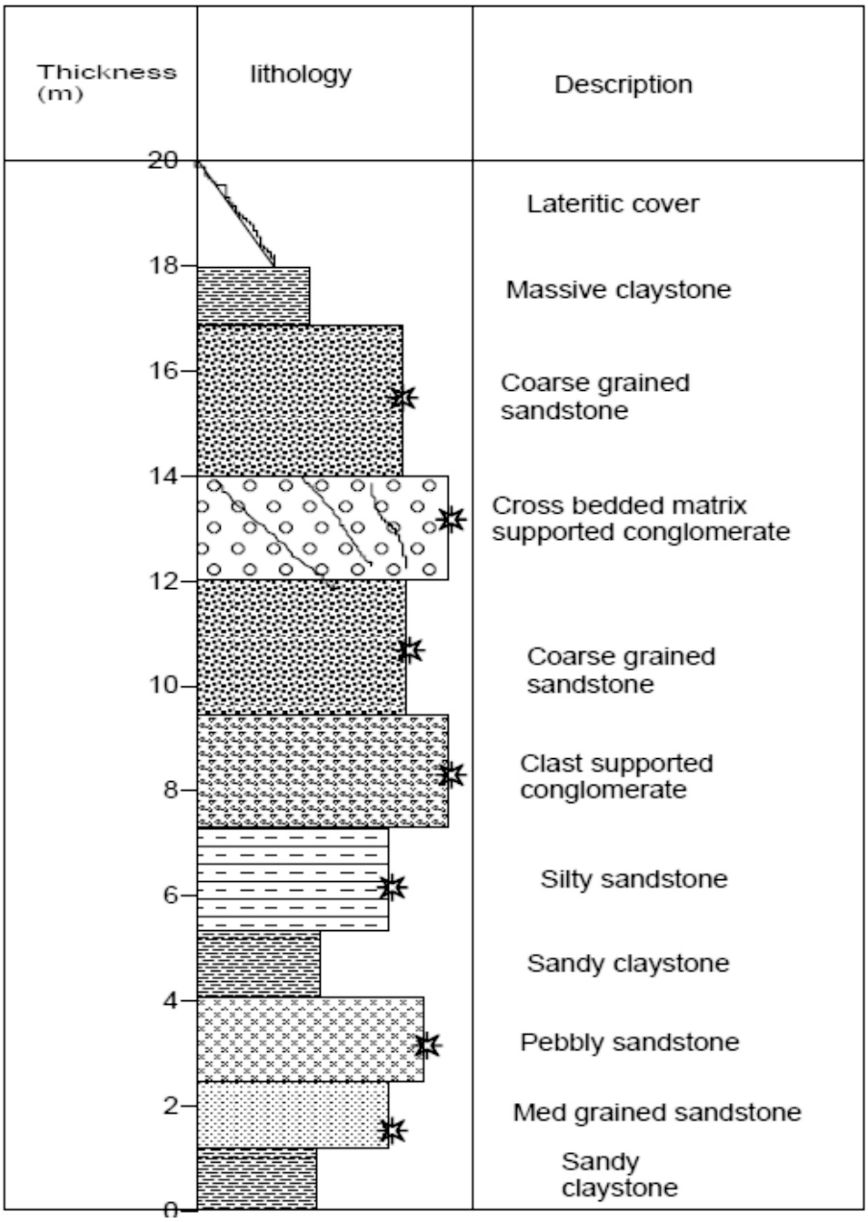


Fig. 7: Lithologic Log Section at Locality 2, Showing the Various Lithologicunits. (Lat. 07^0 51' 10.7" N, Long. 006^0 43' 04.5"E)

RESULTS AND DISCUSSION

Petrographic analysis showed that sandstones from Lokoja and Agbaja Formations are composed of mostly quartz and feldspar. Most of the quartz grains are polycrystalline (Fig. 8) with undulose extinction and few are monocrystalline. The monocrystaline quartz showed mostly straight extinction. The quartz is mostly sub-hedral and anhedral with straight and embayed boundaries (Fig. 9). Most of the grains are equant while others are elongate. Most of the equant grains exhibited straight extinction while elongate grains commonly showed undulose extinction. Undulose extinction is indicative of metamorphic source rock that has been subjected to stress during deformation. Orthoclase feldspar occurs in someof the samples with few from Agbaja. There are few amounts of rock fragments. The rock fragments are mostly metamorphic in origin and are dominated by gneisses and quartzite. The dominant accessory heavy minerals are composed mainly of opaque minerals magnetite and hematite. The non-opaque minerals include rutile, zircon, and chloriteare also present. Some authigenic minerals including silica and clay minerals form coats around the quartz grains.

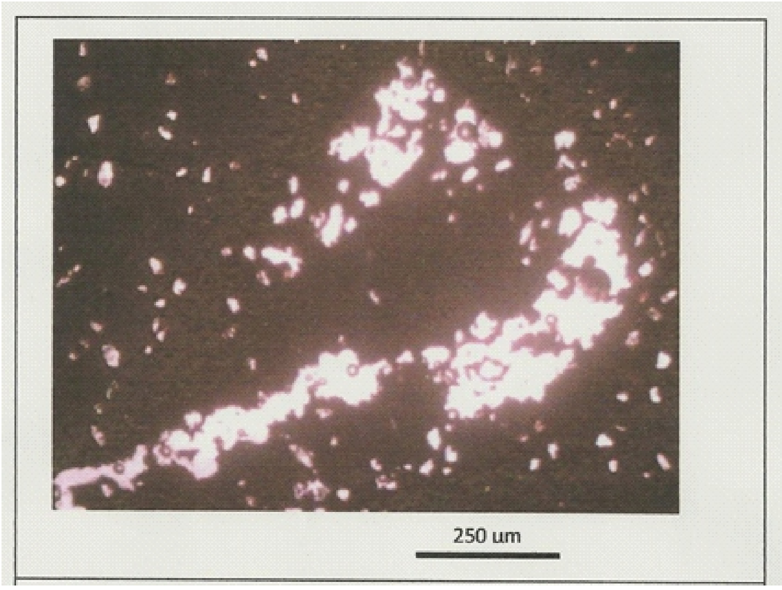
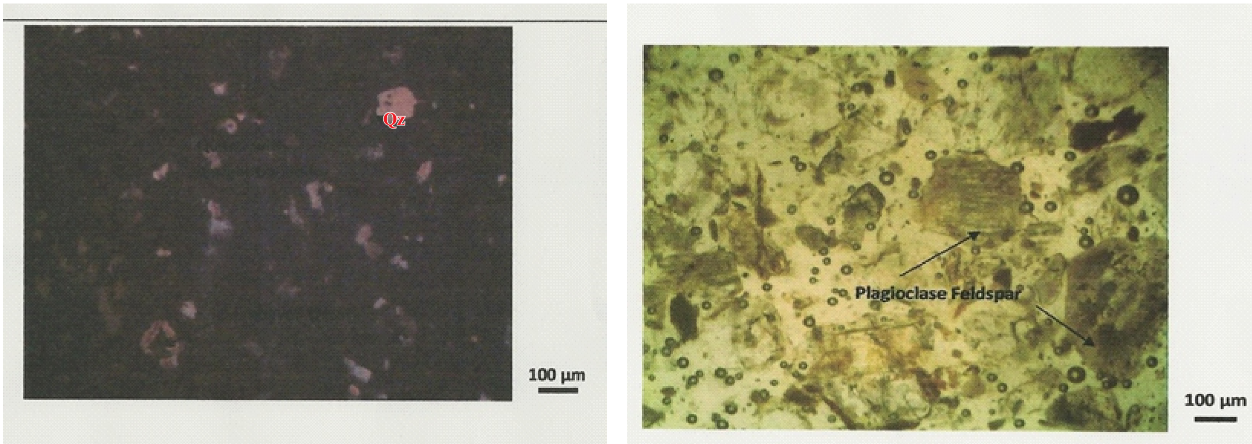


Fig. 8: Photomicrograph Showing Sandstones from Lokoja with Polycrystalline Quartz (PQ).



(a) (b)

Fig.9: Photomicrograph of Sandstone from Felele Showing (a) Subhedral/anhedral quartz(Qz) in Xpl. (b) Sandstone in XplShowingPlagioclase feldspar grains

Generally, the grains showed variation from angular to subangular which suggests different distance of provenance areas for the sediments. The matrix is composed of clay minerals which constitute less than 15% in all the samples observed. The clay matrix could have formed from weathered feldspar grains either in situ or transported into the basin by suspension. The sandstones of Agbaja are mainly composed of quartz with medium grained texture. Some of the quartz minerals occur in polycrystalline forms but their occurrence is subordinate to oolithic iron grains. The detrital mode of the sandstone is composed of an average of 86.25% with a range from 73 to 93% quartz. The feldspar grains range from 2 to 12% with an average of 6.75% while the average for lithic fragment is 4% with a range of 1 to 7% (Table 1). The mineralogical maturity of the sandstone was evaluated using the formulae proposed by Pettijohn (1975) which is based on the Q/(F+L) ratio (Table 2). The maturity indices indicated that the sandstone is immature, due to its high feldspar content. In order to classify the sandstone, detrital mode of Quartz (Q), Feldspar (F) and Lithic fragment (L) was plotted on Folk's (1974) QFR Ternary diagram (Fig. 10). This scheme classifies the sandstone as subarkoses.

Two main mineral groups: the opaque and non-opaque were observed in the sandstone samples analysed. From the modal analysis of detrital grains of heavy minerals carried out on each slide (Table 3), the opaque minerals (magnetite and chromite) account for 15-25 percent in total amount. The non-opaque minerals include zircon, rutile, tourmaline, muscovite, monazite, diopside and garnet. Zircon and rutile are present in significant amount as dominant non opaque, ultrastable minerals. The above association reflects a source area dominated by igneous, metamorphic and sedimentary terrains (Al-Juboury et al. 1994). Tourmaline occurs only in few samples. The low abundance of tourmaline may indicate immaturity. Zircon is recognized in thin section by its high relief, colourless appearance, prismatic habit as well as its very high interference colours (Fig. 11). It forms about 40% of the heavy mineral suite in all the sandstones. Rutile occurs as small reddish- brown prismatic to acicular crystals with very high relief. Tourmaline is identified by its high relief, pleochroic nature and absence of cleavage with good prismatic habit. It is usually black but sometimes green and shows reddish colour on rotation. Garnet occurs as polygonal with colourless to pinkish colour. Mica (muscovite) is present in minor amount in few samples. It occurs as flaky, transparent mineral. The results indicated the dominance of ultra-stable heavy minerals over the metastable and unstable varieties.

Table 1: Results of Petrographic Analysis of Representative Sandstones from the Study Area Showing Estimated Mineralogical Composition in Percentages

Samples Number	Qmu	Qpu	Qmn	Qpn	Q	KF	PF	F	Li	Lm	Ls	L
Z1a	40	20	28	5	93	1	1	2	2	3	-	5
Z1b	24	10	42	4	80	2	6	8	2	4	-	6
Z1c	21	7	50	1	79	3	7	10	1	4	-	5
Z1d	34	6	44	3	87	3	5	8	1	1	-	2
Z2a	28	13	42	4	88	3	4	7	1	-	-	1
Z2b	29	5	43	3	80	4	8	12	2	3	-	5
Z3a	29	3	48	2	73	4	7	11	1	4	-	5
Z3b	35	6	48	1	90	2	3	5	1	-	-	1
Z3c	30	5	50	7	92	2	4	6	-	1	-	1
Z3d	31	8	46	2	87	3	4	7	2	3	-	5
Z4a	40	10	40	3	93	1	1	2	2	3	-	5
Z4b	27	13	50	3	93	1	2	3	4	3	-	7

Key for Table 1: Qpu - Polycrystalline undulose quartz, Qpn– Poly-crystalline, undulose quartz, Qmu–Monocrystalline undulose quartz, Qpn–Monocrystalline undulose quartz, Q - Total Quartz, KF - Potassium feldspar, PF - Plagioclase feldspar, F - Total feldspar, L_I - Igneous lithic fragment, Lm – Metamorphic lithic fragment, L_S - Sedimentary lithic fragment, L - Total lithic fragment.

Table 2: Recalculated Sandstones Grain Composition in Percentages.

Sample Number	Q (%)	F (%)	L (%)	Q/ (F+L)
Z1a	93.0	5.0	2.0	13.3
Z1b	85.1	8.5	6.4	5.7
Z1c	84.0	10.6	5.3	5.6
Z1d	89.6	8.3	2.1	23.3
Z2a	91.6	4.2	1.0	18.2
Z2b	84.2	12.6	3.2	5.3
Z3a	82.0	12.4	5.6	4.6
Z3b	93.8	5.2	1.0	15.0
Z3c	92.9	6.1	1.0	13.1
Z3d	87.9	7.1	5.0	7.3
Z4a	86.0	10.0	4.0	6.1
Z4b	90.0	7.0	3.0	9.0

Table 3: Percentage Composition of the Non-opaque and Opaque Heavy Mineral Suites in the Study Area

Sample Numbers	Zi	To	Ru	Di	Ga	Mu	Mn	Ch	Mg	He	Avr
Loc 1a	44	-	4.3	-	-	2.2	26	12	10	-	98.5
Loc 1b	40	-	5.2	-	-	-	13	15	22	-	95.2
Loc 2a	50.2	-	3.1	5.2	7.4	-	4.2	17	12	-	99.1
Loc 2b	35.5	1.3	1.3	-	-	1.3	8.7	25	20	-	93.1
Loc 3a	42.2	-	3.5	5.7	2.9	-	10.4	12	20	-	96.7
Loc 3b	50	-	4.3	3.0	5.1	-	3.5	14	18	-	97.9
Loc 3c	32	-	2.5	2.0	-	-	1.3	25	23	-	85.8
Loc 4a	45	2.0	3.7	-	-	-	5.5	21	11	7	95.2
Loc 4b	33	-	5.0	4.3	-	-	6.0	20	12	5	85.3
Loc 4c	51.2	-	6.1	-	2.5	-	3.5	15	13	7	98.3

Key for Table 3: Zi - zircon, To - tourmaline, Ru - Rutile, Di - Diopside, Ga – Garnet, Mu – Muscovite, Mn – Monazite, Ch – Chromite, Mg – Magnetite.

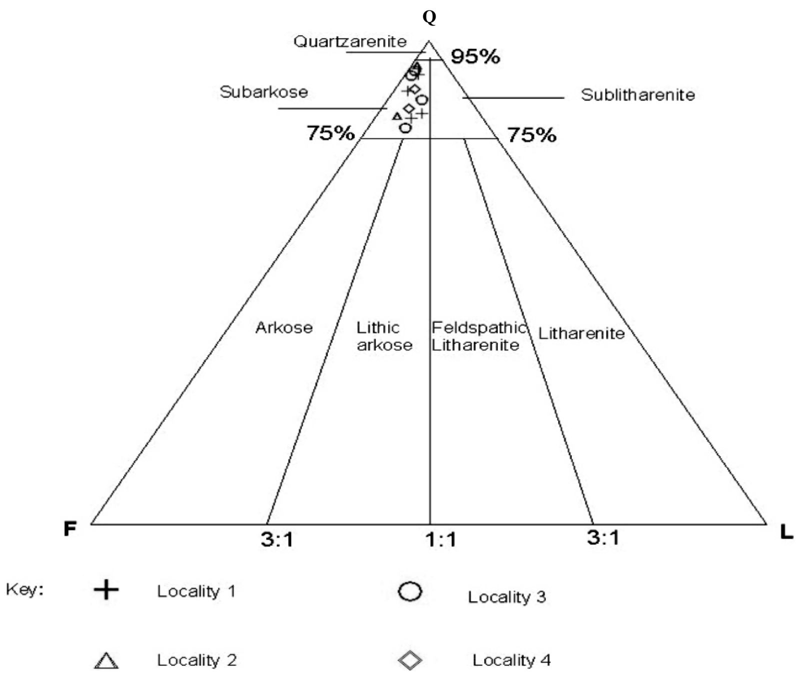


Figure 10: QFL Triangular Plot of Sandstone from all the Locations in the Study Area (After Folks, 1974)

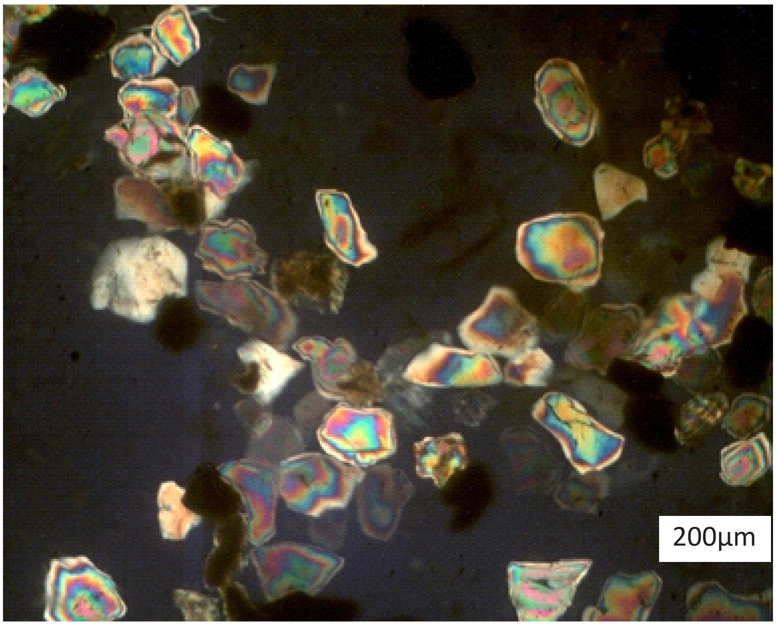


Fig.11: Photomicrograph of Heavy Minerals in xpl, Showing Zircon Grains, mostly Sub-angular to Angular.

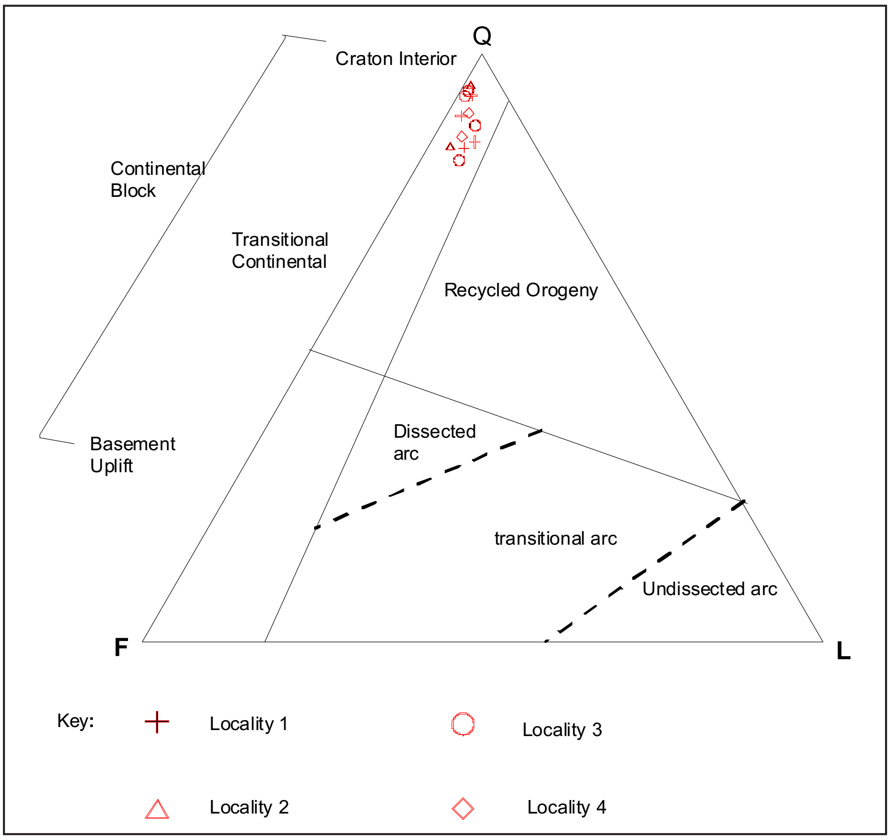


Fig 12: Ternary Diagram Showing Plot of the various Sandstone Clasts (Dikinson *et al.,* 1983)

Ultrastable minerals such as zircon, rutile and tourmaline are resistant tomechanical integration and chemical decomposition compared to the metastable and the unstable types. Unstable heavy minerals often wear away by abrasion during transport from source to basin (Al-Juboury, 2007).

CONCLUSION

The Bida Basin is a NW- SE trending depression perpendicular to the main axis of the Benue Trough. The basin extends from Kontangora in Niger State to areas slightly beyond Lokoja in the south. The Lokoja sub-basin is the southern flank of the Bida Basin and comprises three sedimentary facies assemblages characterised the sediments of Lokoja and Agbaja Formations. They are the conglomerate, sandstone/siltstone and claystone facies. The conglomeratic facies are expressed as massive grain-matrix support conglomerate, graded conglomerate as well as cross stratified to massive sandstones with implications of debris flow, alluvial fan, braided channel and stream deposits respectively. The fine-grained/siltstone as well as the herringbone and bioturbated sandstone sub-facies clearly present the extension of the fluvial sedimentation into the flood plain and shallow marine area where tidal effect held sway.The field work exercise covers places like Lokoja and Agbaja, where Lokoja and Agbaja Formations were encountered. Most of the outcrops were road cuts which represent the different lithofacies of the formations.The laboratory analyses include textural, geochemical, petrographic and heavy minerals analyses for the sandstone samples.

The textural assessment of Lokoja Sandstone revealed poorly sorted sub-arkose immature sandstone with the quartz showing both monocrystalline and polycrystalline crystal forms with more of the undulatory forms which depict its derivation mainly from metamorphic origin. Abundance of feldspathic grains is a reflection of its closeness to the provenance which is perhaps located in the north central basement domain on account of the paleocurrent azimuth trend towards the southeast. The conglomerate and sandstone facies are mostly restricted to the Lokoja area. Plagioclase feldspar occurs in all samples except samples from Agbaja. There are few amounts of rock fragments. The rock fragments are mostly metamorphic in origin and are dominated by gneisses and quartzite. The dominant accessory heavy minerals are composed mainly of opaque minerals magnetite and hematite. The non-opaque minerals include rutile, zircon, and chlorite are also present. The ironstone mainly found at Agbaja was identified as Oolitic form. The iron rich sediments must have been derived from the rocks of the northern basements, which had been transported to the environment of deposition, as azimuth of primary structure indicates southwardly direction.

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