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Petrographic Characterization of Selected Sidewall Core Samples from NG-1 Well, Niger Delta, Nigeria: Palaeoclimatic Implication

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Abstract

Petrographic investigation of sandstones from Agbada Formation in NG-1 well was undertaken in order to petrographically characterize the sandstones. Petrographic examination of the sandstone shows that the sandstones are mineralogically mature and poorly to moderately sorted quartz arenite. Compositionally, made up of monocrystalline quartz (90-96%), polycrystalline quartz (7-2%), feldspar (2-5%), rock fragments < 3%, silica, hematite cement and clay matrix. Abundant of monocrystalline quartz with marginal undulose extinction over polycrystalline quartz suggest igneous source derivatives. Presence of close packing, point and concavo – convex contacts, weathered plagioclase feldspar, grain dissolution, and fabric imprints indicates intermediate diagenesis. Consideration of petrographic attributes and paleoclimatic discrimination plot inferred semi-humid to humid palaeoclimates.

Keywords: Characterization; Core; Niger delta; Palaeoclimatic; Petrographic.

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1. Introduction

Petrographic study of rocks is primarily hinged on detail examination, identification of minerals, texture, deformation history, paragenesis, and origin of rocks through macroscopic and microscopic examinations. However, petrographic studies of sandstone from Agbada Formation have not burgeoned in the region despite exploration and exploitation of hydrocarbon by various multinational companies operating in the region. It is unexposed at the surface and available outcrops for studies are mainly from subsurface outcrops [1,2]. Paleoclimatic information has been extracted from sandstones and various approaches were adopted by many workers [3,4] among others. The Agbada Formation sandstone encountered in the NG-1 well (Fig. 1) falls within the central swamp depobelt of the Niger Delta. It is compose of sandstone interbedded with shale deposited at the interface between the lower delta plain and marine sediments of the continental shelf

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fronting the delta [1]. Agbada Formation is the main hydrocarbon bearing formation in the Niger Delta. It is composed of alteration of fine and coarse clastics which provide multiple reservoir seal couplets [5,6]. However, various studies have investigated the geology of the formation but have not dwell deeply on the petrographic characterization of the sandstones. This study is intended to use available evidence from petrographic data of the sandstones to unravel the paleoclimatic conditions predominating at the time of deposition.

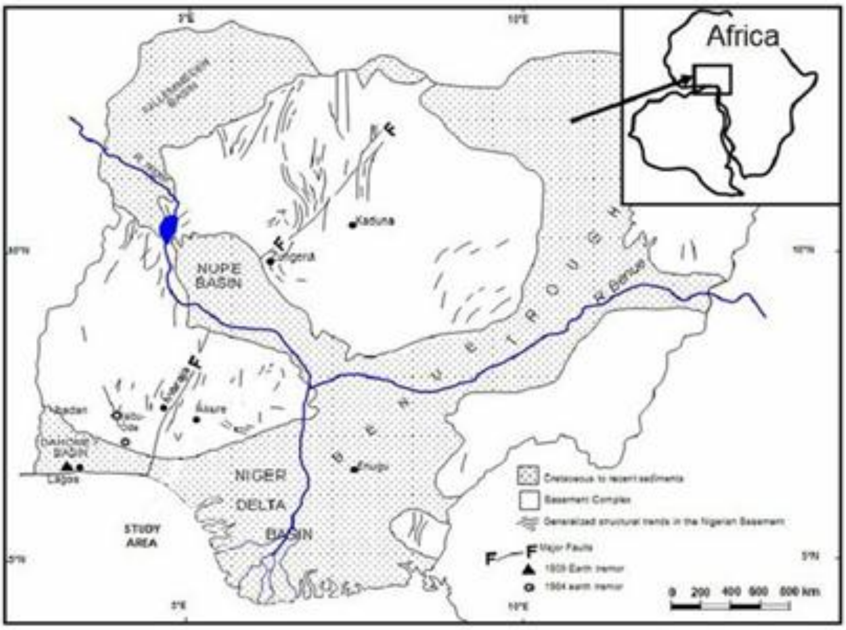

Fig. 1. Geological map of Nigeria showing the location of NG-1 well, Niger Delta [7].

2. Geological Setting

The evolution of the Niger Delta is tied to southward changing deltaic depocentres well balanced with westward post deformational displacement of depocentres and north directed marine transgression [8]. The drift of Precambrian tectonics triggered the Delta to advance into oceanic crust and repeated subsidence of the oceanic basement created more accommodation for the thick sedimentary pile of the prograding Niger Delta [8]. It is made up of three formations; Akata, Agbada and Benin Formations. Akata Formation is produced during lowstands when terrestrial organic matter and clays were transported to deep water settings as a result of low energy and oxygen deficiency [9,10]. Overlying the Akata Formation (Fig. 2), is Agbada Formation; composed of sandstones, shales and sandstones interbedded with shale [11,12]. Benin Formation topped the sequence and consists mainly of massive continental sandstones [13]. Sedimentation in the Niger Delta begins with the deposition of the Akata Formation. It consists of thick shale, turbidite sand, clay and silt deposited in a marine environment [10]. The sediments encountered in the NG-1 well which form the focal point of this research belong to the Agbada Formation. The Agbada Formation has been the focus of petroleum explorationists because of its vast hydrocarbon potentials. The subsurface outcrops encountered in the NG-1 well is characterized by coarse grained cross bedded quartz arenite to medium grained and parallel bedded quartz arenite (Fig. 2).The upward coarsening upward motifs indicate change of energy regime and high energy of deposition.

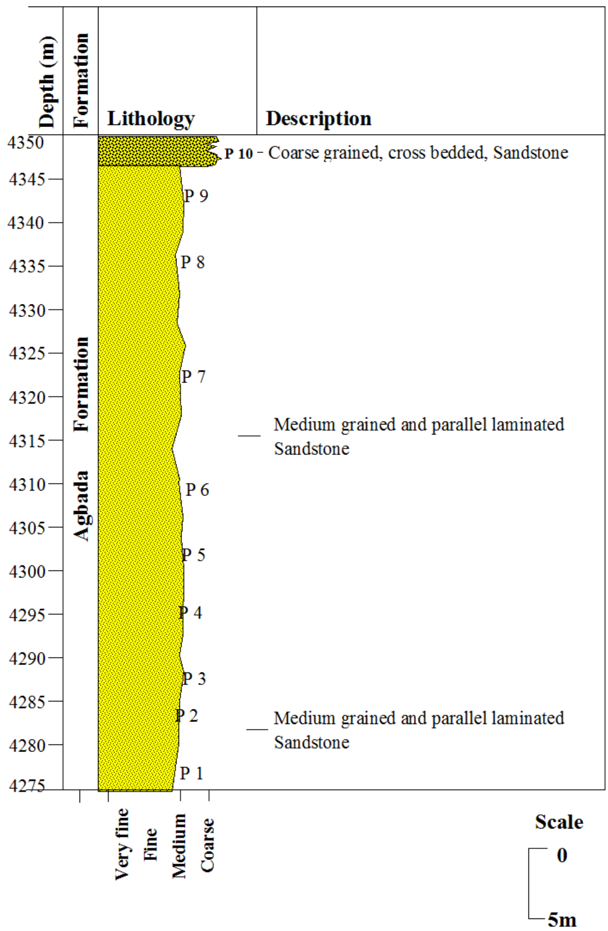

Fig. 2. Lithological log of selected Core intervals, NG-1 well, Niger Delta.

2. Methodology

Petrographic investigation of NG-1 well in the Niger Delta is based on thin section analysis of core intervals from 4275 to 4350 m (Fig. 2). Stratigraphic section was constructed for the core samples and various sedimentary attributes were described. Ten thin sections were prepared and point counting techniques was employed to quantify the various minerals grains. Quantitative estimates of the mineral composition was achieved through points count of 300 grains for each slide. Grain fabric, contact, texture, mineralogy and cements were studied under microscope. Classification scheme of [14,15] was also applied to evaluate palaeoclimatic implications of the sandstones.

3. Results and Discussion

3.1. *Petrography*

Petrographic analyses (Table 1) of sandstones in the NG-1 well showed that the studied area is made up of uniform rock suite. The sandstones consist of very fine to coarse grained, poorly to moderately sorted quartz arenite (Fig. 3). Monocrystalline quartz content ranges from 90–96%, polycrystalline quartz (7–2%), feldspar (2–5%), rock fragments <3%, silica, hematite clay cement and clay matrix (Table 1). Petrographic data of NG-1 well were plotted on QFR ternary diagram (Fig. 3) and majority of the samples fall on the domain of quartz arenite. Close packing, point and concavo – convex contacts suggest evidence of compaction (Fig. 4).

Table 1. Petrographic data for NG-1 well Niger Delta.

Sample No	Grain Size	Shape	Sorting	Mono crystalline Quartz (%)	Poly-crystalline Quartz (%)	Feldspar (%)	Rock Frag-ments	Cement	Matrix
P-1	Medium-Coarse grained	Sub angular to rounded	Moderately sorted	93	4	Plagioclase Feldspar <2	-	Hematite	Clay
P-2	Medium grained	Sub angular	Poorly sorted	90	2	Microcline 5%	-	Silica	Clay
P-3	Medium grained – coarse grained	Angular to sub rounded	Moderately sorted	90	5	Microcline 2%	-	Silica	-
P-4	Coarse grained	Angular to sub rounded	Moderately sorted	90	2	Microcline 5%	3	Clay	Clay
P-5	Medium grained	Angular to sub rounded	Moderately sorted	90	7	Traces of plagioclase	-	Silica	Clay
P-6	Medium-Coarse grained	Sub angular to rounded	Moderately sorted	93	4	Plagioclase Feldspar <2	-	Hematite	Clay
P-7	Fine - medium grained	Sub angular	Poorly sorted	90	2	Microcline 5%	-	Silica	Clay
P-8	Medium grained – coarse grained	Angular to sub rounded	Moderately sorted	90	5	Microcline 2%	-	Silica	-
P-9	Coarse grained	Angular to sub rounded	Moderately sorted	90	2	Microcline 5%	3	Clay	Clay
P-10	Coarse - Medium grained	Angular to sub rounded	Moderately sorted	90	7	Traces of plagioclase	-	Silica	Clay

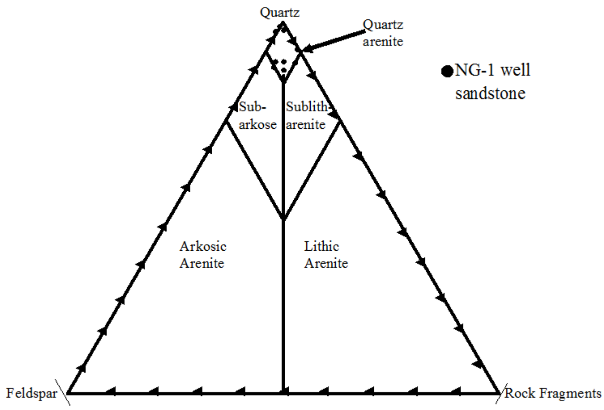

Fig. 3. QFR-triangular plot for the classification of sandstone samples from the NG-1 well [14].

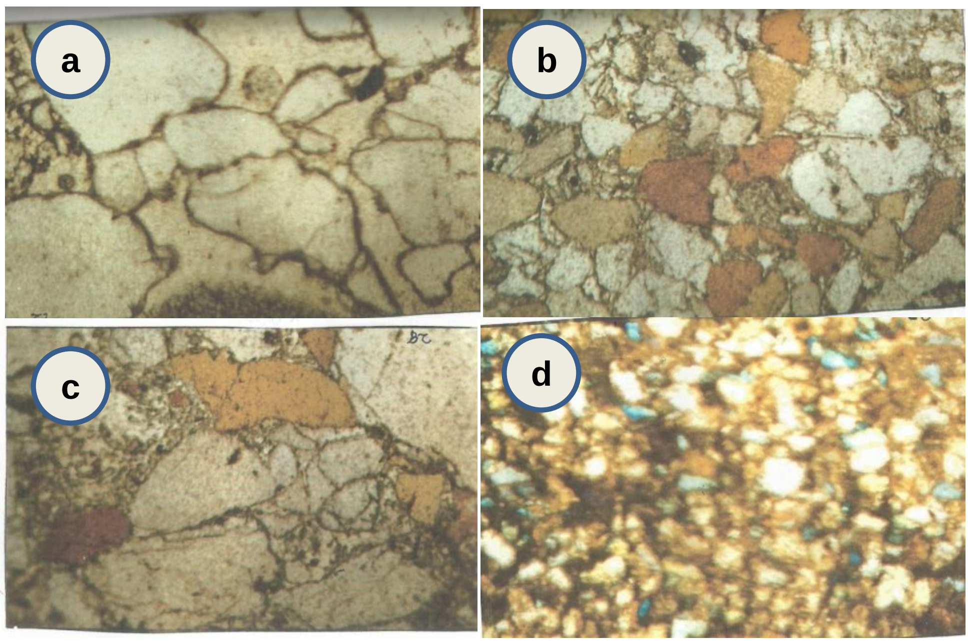

Fig. 4. Photomicrograph of the Agbada sandstones in NG-1 well, Niger Delta.
(a) Hematite and sutured contact, (b) monocrystalline and polycrystalline quartz grained with dislocation structure, (c) decompose plagioclase feldspar and silt size rock fragments and (d) fine grained quartz arenite.

3.2. Paleoclimatic implication

Many workers have attempted to use various geological techniques to decipher the paleoclimatic conditions necessary for sandstones paleo-deposition [15-17]. Sandstones of

NG-1 well plotted on [15] discrimination diagrams (Fig. 5) fall on semi-humid to humid fields and indicate slightly wet to humid paleoclimatic setting. Similarly, Van de Kamp *et al*. [16] asserted that humid tropical climates yield quartz-rich sandstone, and the presence of hematite cements and dearth of feldspars in the studied samples suggest semi-humid to humid climates. The presence of feldspar and matrix almost lacking in the studied samples also indicate that they have passed through phases of diagenetic processes: compaction, cementation and grain dissolution. In addition, the scarcity of feldspars and rock fragments suggest [18,19] that the source area for the sandstone underwent a long period of intensive chemical weathering in a warm humid climate. These claims corroborate the inference from this study based on the petrographic attributes and palaeoclimatic plot.

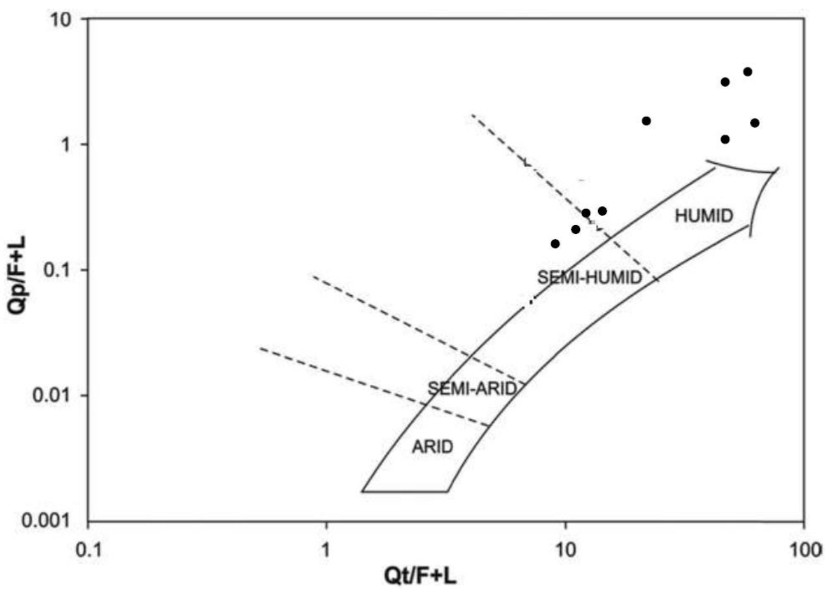

Fig. 5. Paleoclimatic discrimination plot for the NG-1 well [15,17].

3.3. Discussion

Sandstones from NG-1 well, Niger Delta are classified as quartz arenite and mineralogically mature. Major composition include monocrystalline quartz (90–96%), polycrystalline quartz (7–2%), feldspar (2–5%), rock fragments < 3%, silica, hematite clay cement and clay matrix (Table 1). The quartz grains are sub-angular to sub-rounded, dirty to pale coloured with signatures of hematite cement (Fig. 4a) and imprints of grain dissolution during diagenesis. Some of the quartz grains exhibit point and concavo – convex contacts and suggest evidence of compaction. Paragenetic sequence observed in the area of study include (1) compaction and interpenetration of grains, (2) clay, silica and hematite cements occurring as coating and lining on grains, and (3) feldspar dissolution.

The coating and lining of the grains by hematite and silica cements occur during early stage of diagensis as a result of compaction. The second abundant mineral in the studied samples is feldspar, whose average is 3.5 %, weathered with cloudy appearance (Fig. 4a and 4c), absence of twining and decomposition towards clay point to early diagenetic stage and a change of paleoenvironmental setting. This scenario may affect the petrophysical quality of the sandstones. Generally, the rock fragments are low (< 3%) and occurs as silt size fragments of pre-existing crystalline rocks. In addition, plotting of petrographic data on source rock derivation plot of [20] indicates a mixture of metamorphic and granitic origin (Fig. 6). Consideration of the paucity of lithic fragments suggests a medium grained source rock of derivation. This inference lends support to [21] findings that the Precambrian felsic metamorphic and granitic rock of southern Nigerian Basement Complex which have undergone weathering and exposed during Late Miocene is a probable potential source rocks of Agbada Formation sandstones. Overall, the entire studied samples from NG-1 well contains mineralogically mature, and poorly to moderately sorted quartz arenite. Semi-humid to humid palaeoclimatic deposition predominate the sediments of the studied area, signatures by the presence of weathered plagioclase feldspar and paleoclimatic discrimination plot (Fig. 5).

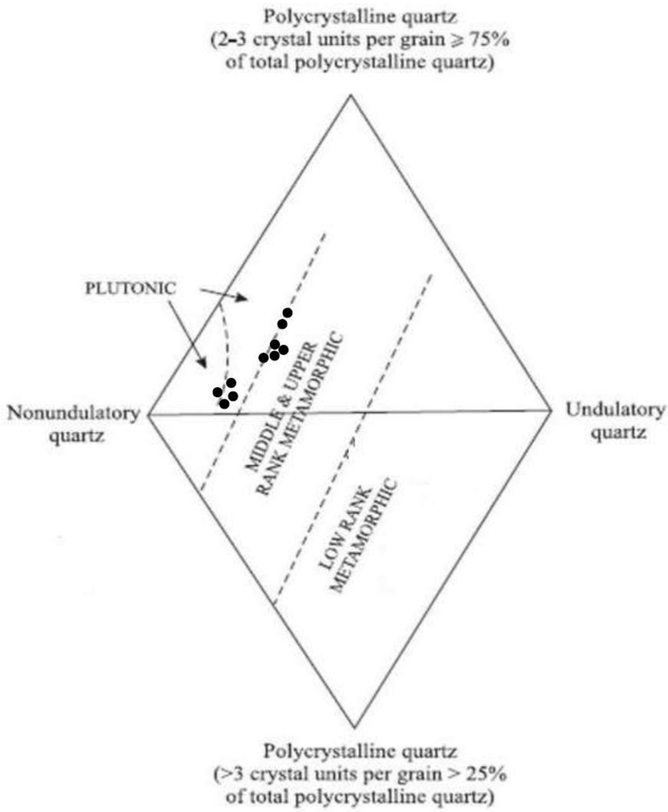

Fig. 6. Derivation source rock plot of Agbada Formation sandstone [20].

4. Conclusion

Petrographic investigations of the sandstones from NG-1 well show that quartz is the main mineral, little microcline, plagioclase feldspar, traces of quartz, clay and hematite cement. It is mineralogically mature and texturally sub-mature. The preponderance of monocrystalline quartz over undulose quartz suggests a combination of metamorphic and plutonic origin. Diagenetic features observed include compaction, dissolution, and quartz and hematite cementation. Diagenetically, close packing, point and concavo-convex grain contacts, and presence of decomposed plagioclase feldspar inferred intermediate diagenesis and semi-humid to humid palaeoclimates of palaeo-deposition.

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