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Research Article

GEOCHEMISTRY OF AGBADA FORMATION, NIGER DELTA, SOUTHERN NIGERIA

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ABSTRACT

The major element oxides and petrography were used to understand the geochemistry of the reservoirs of interest from Oloibiri-1 and Akata-2 wells, onshore Niger Delta basin. These Agbada Formation reservoirs showed that the formation had experienced a spectrum of paleotectonic events: Active and Passive Continental Margins; and Oceanic Margin paleotectonic settings sourced from Mafic, Intermediate Igneous and quartzose sedimentary origin during the basement uplift which can be associated to the opening of the Atlantic Ocean. The reservoirs also showed a range of Humid to Semi Humid paleoclimate which corresponds to the moderate to intense paleoweathering conditions in geologic time observed on an average. It was also inferred that the deep reservoirs were more mature and tend towards better reservoir qualities than the shallow ones.

Keywords: Paleotectonics, Provenance, Paleoclimate, Paleoweathering, Sandstone, Agbada Formation, geochemistry, Niger Delta reservoirs

INTRODUCTION

Clastic sedimentary rocks are formed when other pre-existing rocks such as igneous, metamorphic and sedimentary rocks are weathered, eroded, transported and deposited in a basin where most times lithification, cementation and diagenesis, catagenesis and metagenesis take place depending on the depth, temperature, pressure and organic content. These sediments and sedimentary rocks have geochemical signatures that can be used to forward model their geologic history in terms of Paleotectonics, Provenance, Paleoclimate, Paleoweathering, Sandstone chemical classification and sandstone maturity. Whole rock geochemistry has been applied to unravel geological history by many researchers such as Ratcliffe et al, 2010; Ikhane et al, 2014; Madukwe and Bassey, 2015; Zaid and Algahtani, 2015 using discriminatory diagrams of Nesbitt and Young (1982), Bhatia (1983), Dickinson et al (1983), Roser and Korsh (1986), Pettijohn et al (1987), Herron (1988), Roser & Korsch (1988), and Herron (1997).

The aim of the study was to use whole rock geochemistry to unravel the geological history of the selected Agbada Formation reservoirs. This was achieved by carrying out whole rock geochemical analyses using X-Ray Diffractometry (XRD), X-Ray Florescence (XRF) Spectrometry, Atomic Absorption Spectrometry (AAS), and Petrographic microscopy for elemental and mineralogical composition of the subsurface reservoirs in the two wells.

Geology of the Study Area:

The wells used for the study were; Akata-2 and Oloibiri-1 and they geographically lie within the Southern Nigeria (Figure 1). The core and drill cuttings of these wells were retrieved from the core shed of National Geosciences Research Laboratories (NGRL) Kaduna, of Nigerian Geological Survey Agency (NGSA).

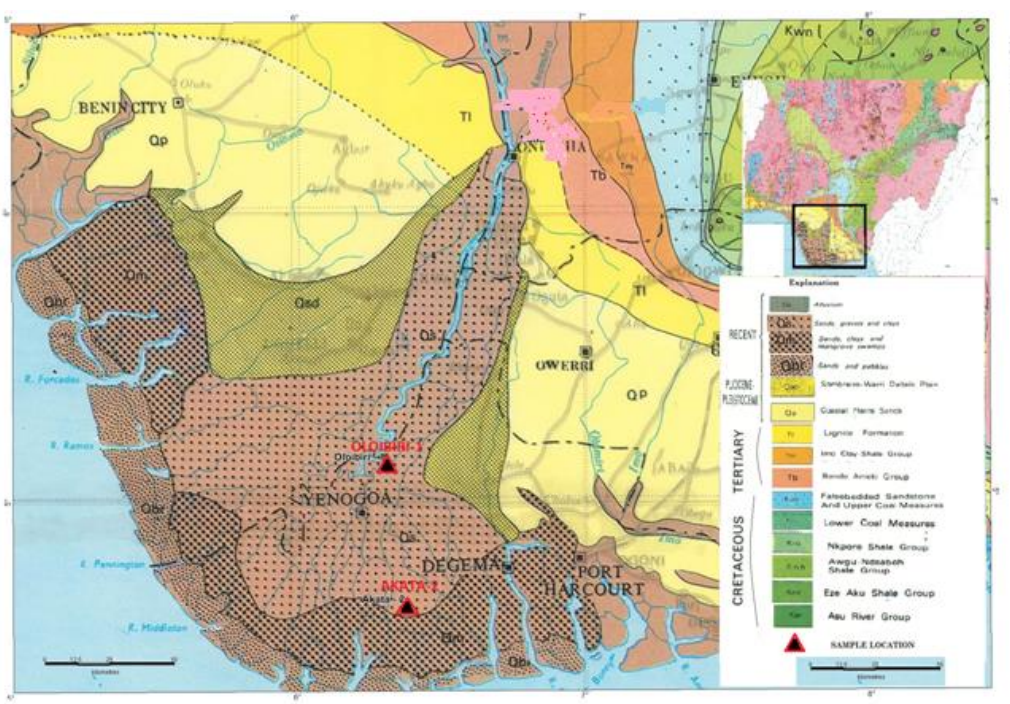


Figure 1: Location map of the study area

The geology of Niger Delta has been well studied due to its vast petroleum resources (Figure 2) by previous workers such Tuttle, 1999; Nwajide, 2013; Brownfield, 2016; using both cores description and analysis of the subsurface Niger Delta (Akata, Agbada and Benin Formations); and outcrop studies of surface formations (the Ameki Group comprising of the Ameki Formation, Nanka Formation and Nsugbe Formation; Ogwashi-Asaba and Imo Formation) in the basin for its sedimentological features. The structural features as well as the tectonic history have been studied using more of geophysical and remote sensing data.

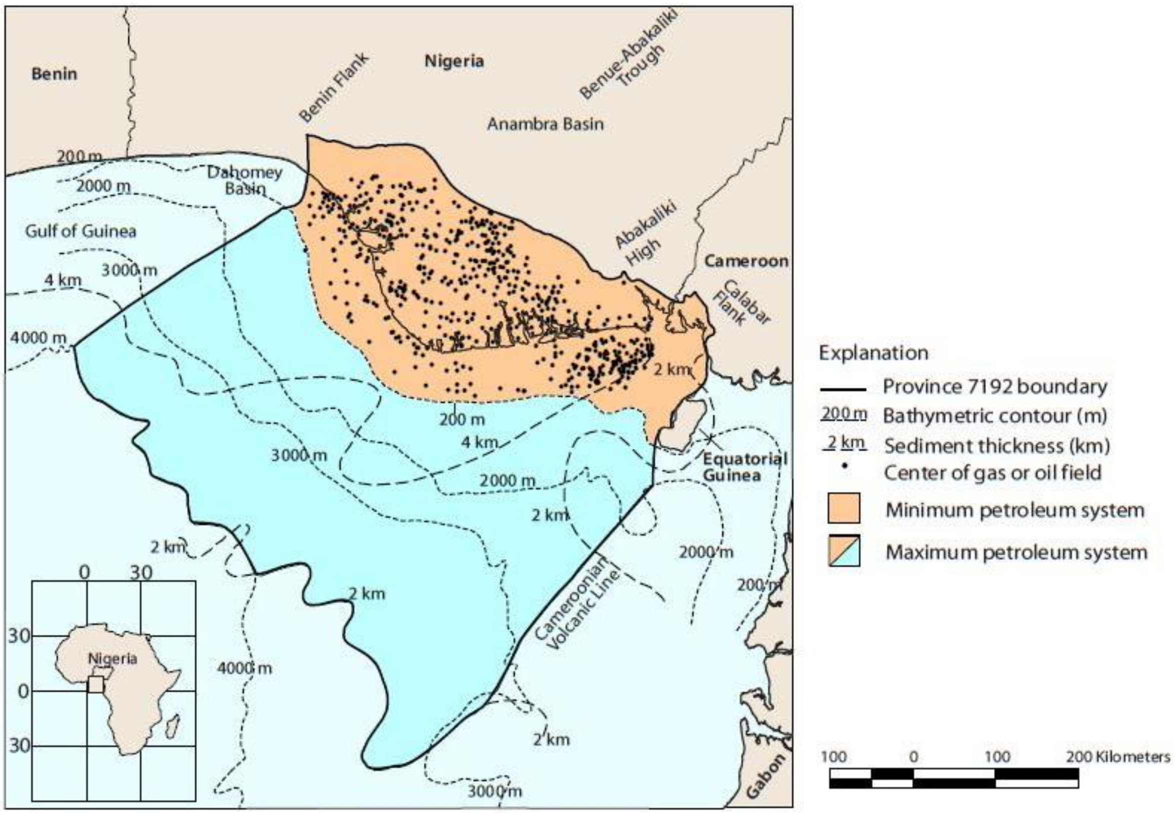


Figure 2: Map of Niger Delta Petroleum province (modified after Tuttle, 1999).

Trenches and ridges of the Cretaceous fracture zones of the West Coast of Equatorial Africa control the tectonic framework of the continental margin. The rifting of South America from Africa started in Early Cretaceous and continued till Late Cretaceous (Genik, 1993; Brownfield, 2016). After this period, gravity became the primary deformational process which ended before the deposition of Benin Formation (Figure 2). These gravity tectonics is displayed in different complex structures that trap hydrocarbons such as shale diapirs, rollover anticlines, collapsed growth faults and back-to-back features and others (Doust and Omatsola, 1990; Stacher, 1995; Brownfield, 2016).

MATERIALS AND METHODS

The following materials were used in the study:

- Reservoir rock samples (cores, drill cuttings and outcrop samples).
- Sample collection tools (these include hand lens, geologic hammer, spoon, sample bags, stationeries such as biro, pencil, ruler and masking tape).
- Personal Protective Equipments (PPEs) such as hand gloves, laboratory coat, eye goggle, safety boots.
- Analyses equipments such as X-Ray Diffractometer, X-Ray Florescence Spectrometer, Atomic Absorption Spectrometer, and Petrographic microscope.
- Others are sample preparation tools which are stated in data analysis below.

Many geochemists have formulated various diagrams for discriminating and classifying sandstones. Ternary diagrams which are one of the oldest, are used to classify sandstones into different chemical groups and the ancient tectonic settings while the more recent discriminating diagrams have been used for provenance, paleoclimate, weathering index, among others; all based on the elemental composition from AAS and XRF results and petrography. These are:

Paleotectonics: The ancient tectonic settings discrimination diagrams by Bhatia (1983), and Roser and Korsh (1986) based on TiO_2, (K_2O+Na_2O, Al_2O_3/SiO_2) or $Al_2O_3/(CaO+Na_2O)$ each versus Fe_2O_3+MgO; and K_2O/Na_2O versus Na_2O/K_2O respectively.

Provenance: Sandstone source discriminated by ternary diagrams after Dickinson et al (1983) based on the Qt, F, L; Qm, F, Lt percentile; A-CN-K (based on Al_2O_3, CaO, Na_2O and K_2O) after Nesbitt and Young (1982); while the discriminant function diagram for the provenance signatures of the studied samples using raw oxides (after Roser & Korsch 1988) is based on the formula below:

- Discriminant Function1= (-1.773*TiO_2) + (0.607*Al_2O_3) + (0.76*Fe_2O_3) + (-1.5*MgO) + (0.616*CaO) + (0.509*Na_2O) + (-1.224*K_2O) + (-9.09).
- Discriminant Function 2= ((0.445*TiO_2) + (0.07*Al_2O_3) + (-0.25*Fe_2O_3) + (-1.142*MgO) + (0.438*CaO) + (1.475*Na_2O) + (1.426*K_2O) + (-6.861)).

Also the discriminant function diagram for the provenance signatures of the samples using ratio of oxides (after Roser & Korsch 1988) is based on the following formula:

- Discriminant Function 1= (30.638*(TiO_2/Al_2O_3) - (12.541*(Fe_2O3/Al_2O_3)) + (7.329*(MgO/Al_2O_3)) + (12.031*(Na_2O/Al_2O_3)) + (35.042*(K_2O/Al_2O_3)) + (-6.382).
- Discriminant Function 2= (56.5*(TiO_2/Al_2O_3) - (10.879*(Fe_2O_3/Al_2O_3)) + (30.875*(MgO/Al_2O_3)) + (5.404*(Na_2O/Al_2O_3)) + (11.112*(K_2O/Al_2O_3)) + (-3.89).

Paleoweathering: This is the ancient weathering conditions and processes undergone by the reservoirs which are expressed by CIA, PIA, CIW and ICV.

- **Chemical Index of Alteration, CIA**= 100 x (Al_2O_3/ (Al_2O_3+CaO+Na_2O+K_2O)) (Nesbitt and Young, 1982).

- **Plagioclase Index of Alteration, PIA**= ((Al_2O_3 – K_2O) / (Al_2O_3+CaO* +Na_2O+K_2O) x100 (Fedo et al, 1995).
- **Chemical Index of Weathering, CIW**= (((Al_2O_3/ (Al_2O_3+CaO*+Na_2O)) X100), Nesbitt and Young, 1982.
- **Index of Compositional Variability, ICV**= (Fe_2O_3 +K_2O +Na_2O +CaO +MgO +MnO +TiO_2)/ Al_2O_3, (Cox et al, 1995).

RESULTS AND DISCUSSION

Based on the analyses of the reservoirs, the figures 4a to d and Tables 1 & 2 are the results of the analysed samples of Oloibiri-1 and Akata-2 wells.

From petrography, the texturally descriptions for Oloibiri-1 shallow reservoir sample of depth 7300feet showed roundness ranging from angular to Subrounded grains. There were a bit of variability in particle sizes as observed in the Photomicrograph (Figures 4a and b) which was indicative of poor sorting. Oloibiri-1 deep reservoir sample was moderately sorted and the particles shape range uniformly from subangular to subrounded. The same minerals were present at both shallow and deep reservoirs depths, they were Quartz, Biotite, Muscovite, Plagioclase Feldspar, Potassium Feldspar, Haematite and rock fragments; and seen in them were mineral inclusion. However, cement exist more in the shallow Oloibiri-1 reservoir than in the deeper ones. The roundness and sorting means that Shallow Agbada Subsurface Formation in Oloibiri-1 well will have less porosity and permeability which translates to less hydrocarbon in place. In addition the increased amount of cement in the shallow reservoir further reduces both porosity and permeability. However, it can act as barriers or baffles that can support reservoir pressure during hydrocarbon production especially if the reservoirs were stacked into a single flow unit.

The Akata-2 subsurface well's shallow reservoir showed a lot more variability in sizes than Oloibiri-1 indicating poorer sorting. At shallow depth of 6611feet, Akata-2 well which is Agbada Formation reservoir displayed a lot of fractured minerals, this may point to the possibility of high pressure effects. This reservoir also showed roundness ranging from angular to subrounded grains. There was a lot of variability in particle sizes as observed in the Photomicrograph (Figures 4c and 4d) which is indicative of very poor sorting. Akata-2 deep reservoir sample also showed various size ranges which could be inferred as ranging from poorly to moderately sorted and the particles shape ranged almost uniformly from subangular to subrounded, the deep reservoirs. Approximately the same minerals were present at both reservoirs depths, they were Quartz, Biotite, Muscovite, Orthoclase Feldspar, Haematite and rock fragments; and seen in them were cement and mineral inclusions. However, Plagioclase Feldspar existed more in the shallow Akata-2 reservoir than in the deeper ones which can be indicative of more maturity for the deep reservoirs. Just as it was in Oloibiri-1 well, the Agbada Formation encountered by Akata-2 well showed better reservoir qualities in greater depths than the shallow ones, this will most likely correspond to greater hydrocarbon in place.

The mineralogical description from petrography result is as follows; the monoclinic Quartz present in Oloibiri-1 samples ranged from 12 to 14 percent, for Akata-2 well samples it was from 20 to 22 percent, The average Polyclinic Quartz for Oloibiri-1 was 44percent, for Akata-2, it was 39. The average total Quartz in Oloibiri-1 and Akata-2 wells, were 57, and 61 percent respectively. This means that in terms of the percentage composition of Quart, Akata-2 is the most mature in the analysed reservoirs. Secondly, the average total Feldspar in Oloibiri-1 is 18percent, Akata-2 15percent. From this result, Feldspar which is indicative of immaturity show that Akata-2 well samples with the lowest value was again the most mature. Also, the average total rock fragment of the samples was 10percent, the average for Akata-2 well was 9 while Oloibiri-1 well was 10, and once more Akata-2 is more mature. Mineral inclusion is lowest in Oloibiri-1 where it is 2 percent on an average and highest in Akata-2 well where it is as high as 6percent (Table 1a). The petrography results show that though there is a general increase in maturity with depth of the analysed Agbada Formation reservoirs, the reservoirs of Akata-2 well which is Southwest of Oloibiri-1 well are mineralogically more mature but texturally less mature compared to those of Oloibiir-1 well. XRF and AAS results show that SiO_2 has a wide range for Oloibiri-1 and Akata-2 being from 54 to 94%; and from 47 to 96% respectively. The highest silicon oxide (SiO_2) is the deepest Akata-2 well reservoir and it corresponds with Petrography result as the reservoir has the highest total Quartz (Table 1b).

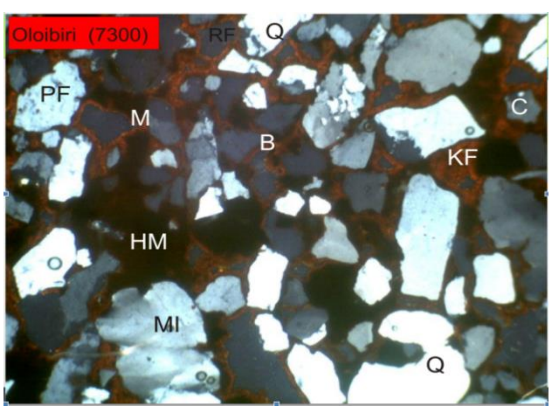
The highest Chemical Index of Alterations CIA value (Table 2) was 92 from Oloibiri-1 at 7300feet, the lowest value is 32 from Oloibiri-1 at 7478feet and the average CIA is 74 is indicative of moderate to intense weathering. The average CIW is 80 is also indicative of an intense weathering although the lowest value is 37 and the highest 95. However, PIA values differ, with an average value of 65, the reservoirs show moderate weathering. The lowest Index of Compositional Variability, ICV value is 0.21 from Oloibiri-1 at 7300feet (Table 2) which means mature sediment while the highest is 4.66 at Akata-2 (6661feet) interpreted as immature. On an average, the reservoir values gave an ICV of 1.44. This is indicative of weak weathering which led to immature clastic sedimentary deposits (Cox et al, 1995). It is important to note that most of the values, more than 65percent of the samples have values below 1.00 which indicate mature reservoir sediments. This is to say that sediments are closer to mature than immature. The ratio of SiO_2 to Al_2O_3 value also tells of the degree of clay in the reservoirs and their maturity, while low values show high clay content, it is indicative of chemically immature sediment, high SiO_2/ Al_2O_3 values are the reverse (Potter, 1978; Maduke and Obasi, 2016). In this study, all the outcrop samples and the shallow Agbada Formation reservoirs have low values of less than 2.8 while the deep subsurface reservoirs have values of at least 20. With lowest value of 1.25 and the highest value of 90.38, the average was 19.93. This means that the outcrop and shallow reservoirs of study are immature while the deep reservoirs are more of mature sediments. In addition, alkali content which is the sum of sodium and potassium oxides concentration gives a clue the degree of chemical maturity. The alkali content in all the reservoirs are less than 2.4, this means that they have very low feldspar content (Maduke and Obasi, 2016).

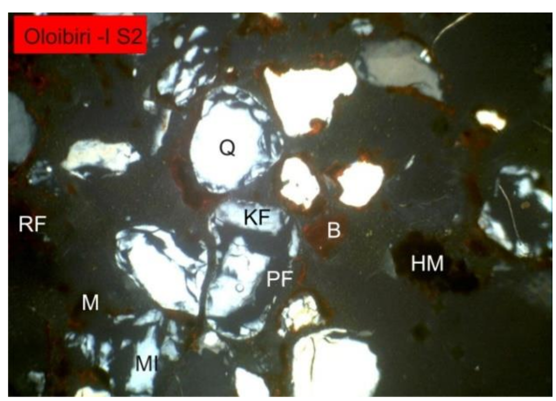
One of the main contributions of Catuneanu (2006) work on Sequence Stratigraphy, is that the main controls on a given sequence are; sea level change, subsidence, uplift, climate, sediment supply, basin physiography, and environmental energy. To highlight these controls as they apply to this study, it is important to note that they are the same as sea level changes, subsidence, paleotectonics, paleoclimate, provenance, and paleoweathering. These are the pre-depositional, depositional and post-depositional processes that led to the formation of the reservoirs of study and they are summarized below:

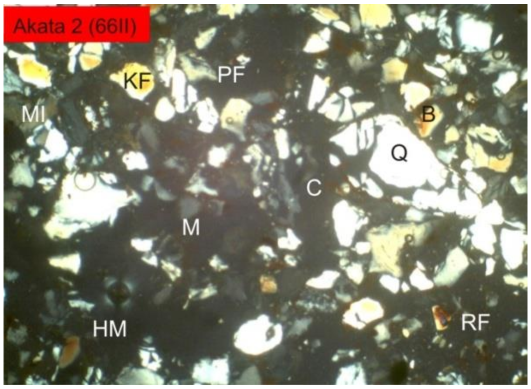
WELL NAME	OLOIBIRI-1	OLOIBIRI-1	AKATA-2	AKATA-2
DEPTH (FT)	7300	7478	6611	7143.5
Monoclinic Quartz (Qm)	14	12	20	22
Polyclinic Quartz (Qp)	46	42	35	40
Total Quartz (Qt)	60	54	57	64
Plagio-Feldspar	10	18	10	10
K-Feldspar	4	3	5	5
Lithic Fragment	2	2	3	2
Metamorphic Rock Fragment	3	2	2	2
Sedimentary Rock Fragment	4	5	4	5
Igneous Rock Fragment	1	1	1	1
Total Rock Fragment	10	10	10	8
Matrix	3	2	3	2
Cement				
Mineral Inclusion	2	2	6	2
Quartz Extinction	1	1	1	1
Total	100	100	100	100

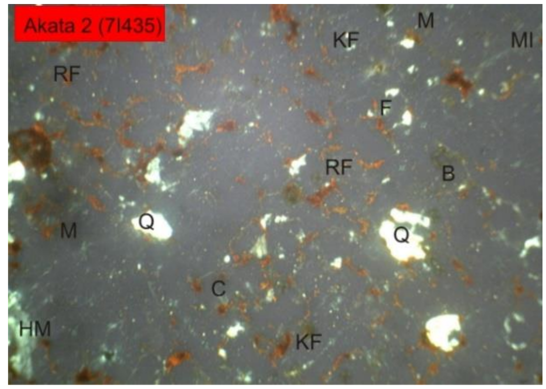
WELL NAME	AKATA-2	AKATA-2	AKATA-2	OLOIBIRI-1	OLOIBIRI-1	OLOIBIRI-1
DEPTH (FT)	6611	6661	7368	7300	7478	7926
CaO (%)	0.03	0.19	0.77	0.1	4.09	0.13
Ba (PPM)	2.269	0.02	0.01	1.26	0.022	0.53
Sr (PPM)	0.04	0.23	0.25	0.08	0.28	0.46
Zn (PPM)	2.24	0	0.01	2.23	0	0
Pb (PPM)	1.384	0	0	1.145	0	0
MgO (%)	0.05	0.28	1.36	0.51	3.9	0.53
Fe2O3 (%)	0.88	0.48	1.24	2.52	0.38	1.12
ZrO2 (%)	N/A	0.01	0.04	N/A	0.01	0.14
Ni2O (%)	N/A	0	0	N/A	0	0
CuO (%)	N/A	0	0	N/A	0	0.02
Ga2O3 (%)	N/A	0	0	N/A	0	0
CeO2 (%)	N/A	0	0.01	N/A	0.01	0.04
Ta2O5 (%)	N/A	0	0	N/A	0	0
WO3 (%)	N/A	-0.05	-0.04	N/A	0	-0.03
SiO2 (%)	46.9	96.36	94	54.97	87.77	93.55
P2O5 (%)	0	0.57	0.64	0.22	0.63	0.8
S (%)	N/A	0.13	0.8	N/A	0.21	1.09
Cl (%)	8.24	0.04	0.22	5.83	0.08	0.06
K2O (%)	1.6	0.66	0.68	0.13	1.02	0.88
TiO2 (%)	0.09	0.06	0.23	0.01	0.06	0.17
V2O5 (%)	N/A	0	0.01	N/A	0	0
Cr2O3 (%)	N/A	0	0	N/A	0	0.01
MnO (%)	N/A	0.01	0.04	0.04	0.05	0.02
As2O3 (%)	N/A	0	0	N/A	0	0
Rb2O (%)	N/A	0	0	N/A	0	0
Y2O3 (%)	N/A	0	0	N/A	0	0
Nb2O5 (%)	N/A	0	0	N/A	0	0
ThO2 (%)	N/A	0	0	N/A	0	0
Al2O3 (%)	37.6	3.04	1.04	25.11	2.74	4.71
Na2O (%)	0.21	0.11	0.53	1.88	0.6	0.43

Tables 1a&b: A summary of the results of petrography and a combination of XRF and AAS respectively









Figures 3a-d: Photomicrographs of the reservoirs

WELLS (Depth in Feet)	SiO2	Al2O3	TiO2	Fe2O3	CaO	Na2O	K2O	MnO	P2O5	MgO	LOI	CIA	PIA	CIW	ICV	Qm	Qt	F	L	RF
Akata-2 (6611)	46.90	37.6	0.09	0.88	0.03	0.21	1.6	N/A	0	0.05	9.75	95.33	91.28	99.37	#N/A	20	57	15	3	10
Akata-2 (6661)	96.36	3.04	0.06	0.48	0.19	0.11	0.66	0.01	0.57	0.28	-	75.82	59.19	90.94	0.595	22	64	15	2	8
Akata-2 (7368)	94.00	1.04	0.23	1.24	0.77	0.53	0.68	0.04	0.64	1.36	-	34.44	11.92	44.44	4.663	-	-	-	-	-
Oloibiri-1 (7300)	54.97	25.11	0.01	2.52	0.1	1.88	0.13	0.04	0.22	0.51	9.75	92.25	91.77	92.69	0.207	14	60	14	2	10
Oloibiri-1 (7478)	87.77	2.74	0.06	0.38	4.07	0.6	1.02	0.05	0.63	3.9	-	32.5	20.4	37	3.679	12	57	21	2	10
Oloibiri-1 (7926)	93.55	4.71	0.17	1.12	0.13	0.43	0.88	0.02	0.8	0.53	-	76.7	62.46	89.43	0.692	-	-	-	-	-

Table 2: A summary of the major elements oxides and some key parameters for defining geologic history of the reservoirs

Paleotectonics:

The ancient tectonic settings of Agbada Formation were inferred using the following discriminatory diagrams. The plots on Roser and Korsch (1986) discriminatory bivariate diagrams based on the ratio of potassium, sodium and silicon oxides (Table 2) and Figure 4a showed that the analysed samples were either Active Continental Margin or Oceanic Island Arc Margin. Whereas the deep reservoirs of both Akata-2 well and Oloibiri-1 well fell in the Active Continental Margin, the shallow reservoirs of these wells were Oceanic Island Arc Margin. Secondly, on Murphy (2000) discriminatory bivariate diagrams based on the ratio of potassium, sodium aluminium and silicon oxides were also used for paleotectonics. In Figure 4b, the deep reservoirs of both Akata-2 well and Oloibiri-1 well fell in the Active Continental Margin while shallow Akata-2 well and Oloibiri-1 well reservoirs were Oceanic Island Arc Margin. Thirdly, the ternary diagram by Dickinson (1983) which is based on petrography has values and plots shown in Figure 4c respectively. Monocrystalline Quartz, Qm; Feldspar, F; and Lithic Fragment, Lt; were the parameters used. From the plots, most of the samples plotted on the Basement Uplift section with only Akata-2 well reservoirs tending towards Transitional Continental.

Provenance:

Using Geochemical discriminatory tools of Dickinson and others (1983) Shallow Agbada Formation reservoirs encountered by Akata-2 well at 6611feet and Oloibiri-1 at 7300feet had analysed had its source from Basement Uplift while in Raw Oxides and Ratio of Oxide of Roser and Korsch (1988), it was Mafic Igneous and Intermediate Igneous while the Deep Agbada Formation reservoir samples in Akata-2 at 6661feet and 7368feet were Transitional Continental in Dickinson and others (1983) tool and they were Quartzose Sedimentary in Roser and Korsch (1988) Raw Oxide discriminatory tool. However at 6661feet, it plotted as Intermediate Igneous in Roser and Korsch (1988) Ratio of Oxides. Agbada Formation Reservoir at Oloibiri-1 well at 7478feet and 7926feet both plotted as Basement Uplift in Dickinson and others (1983) discriminatory tool and both Quartzose Sedimentary based on Raw Oxides by Roser and Korsch (1988) however, for the 7478feet reservoir sample, it was Intermediate Igneous for the Ratio of Oxides, this is similar to the shallow Agbada Formation reservoirs encountered in Akata-2 well at 6611feet and Oloibiri-1 well at 7300feet (Figures 5a and b).

Paleoclimate:

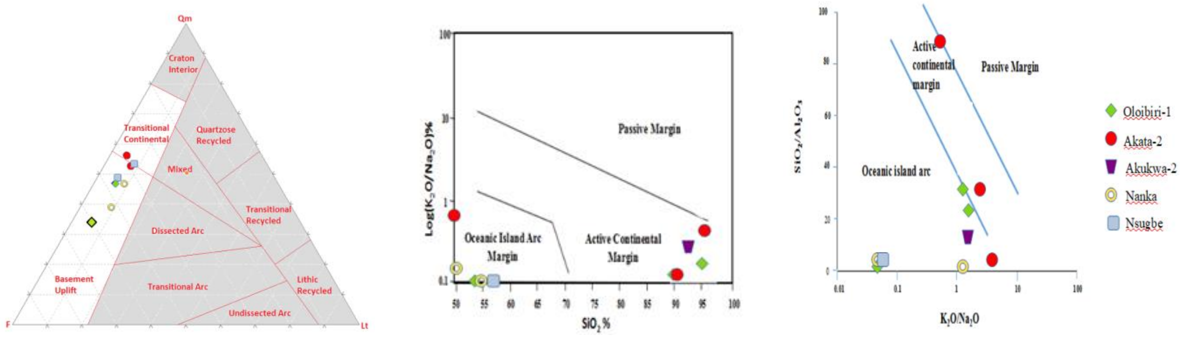
All the analysed reservoir samples from Akata-2 and Oloibiri-1 wells plotted as Plutonic and Humid climate in Suttner and others (1981) discriminatory tool. However, deep Agbada Formation Reservoirs in Akata-2 well at 6661feet and 7368feet and Oloibiri-1 well at 7478feet and 7926feet were Semi-Humid in Suttner and Dutta 1986 ancient climate discriminatory tool. This could indicate better maturity for the deep reservoirs of both wells (Figures 6a and b).

Paleoweathering:

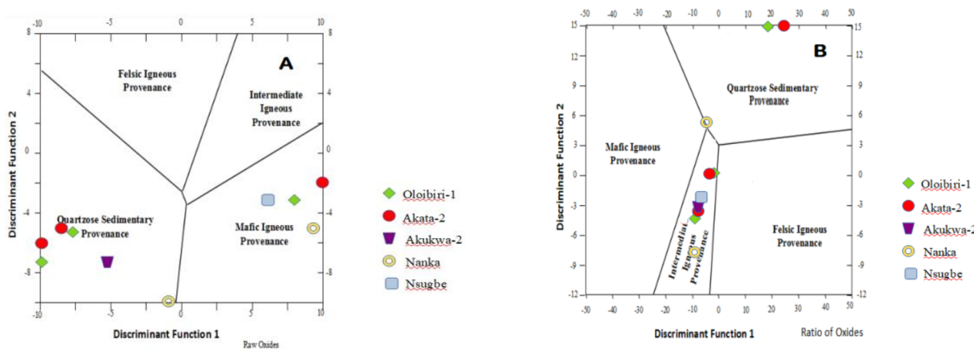
Two discriminatory tools were used for inferring the reservoirs past weathering processes. Both tools show that most of the reservoirs have undergone moderate to intensive weathering. The first is the A-CN-K ternary diagram by Nesbitt and Young (1984) based on chemical index of alteration (CIA); and oxides of aluminium, calcium, sodium and potassium. The trend from shallow to deep series in Akata-2 and Oloibiri-1 wells, the CIA reduces, this means weaker weathering. Minerals such as Kaolinite, Chlorite, Gibbsite, Illite, Smectite, Muscovite and Biotite are abundant in the intensive weathering domain however the deeper reservoirs are expected to have more of Plagioclase, Feldspar, Haematite and clinopyroxene (Figures 7a and b).

SUMMARY AND CONCLUSION

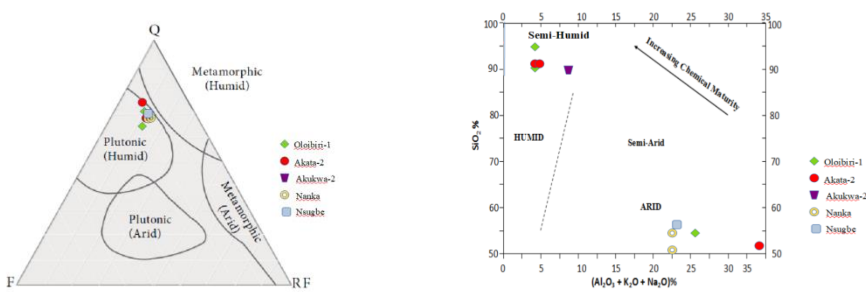
In summary, using Bhatia (1983) Paleotectonics discriminating tool, shallow subsurface Agbada reservoir have the characteristics of Continental Margin; and for Roser and Korsch (1986) and Murphy (2000) tools these reservoirs were Oceanic Island Arc. Whereas deep subsurface Agbada reservoirs were Passive Margin in Bhatia (1983), they were Active Continental Margin in both Roser and Korsch (1986) and Murphy (2000) tools. The provenance of the analysed using Roser and Korsch (1988) discriminant tool, the shallow reservoirs were of Mafic to Intermediate Igneous origin and the deep ones were Quartzose sedimentary in both ratios of oxides and raw oxides; in Dickinson et al (1988) discriminatory tool, both the shallow and the deep subsurface Agbada reservoirs were Basement Uplift, except for deep Akata-2 well reservoirs at 6661feet and 7368feet where they were Transitional Continental. In Suttner et al (1981) all the studied reservoirs paleoclimates were Humid. However, it was a contradictory interpretation in Suttner and Dutter (1986) tool as the subsurface Agbada reservoirs were Semi Arid while the deep Agbada reservoirs were Semi Humid. Nonetheless, in Paleoweathering, using both Nesbitt and Young (1984) and Obasi and Madukwe (2016) discriminants, shallow Agbada reservoirs were strongly weathered while deep Agbada reservoirs showed weak to intense weathering.



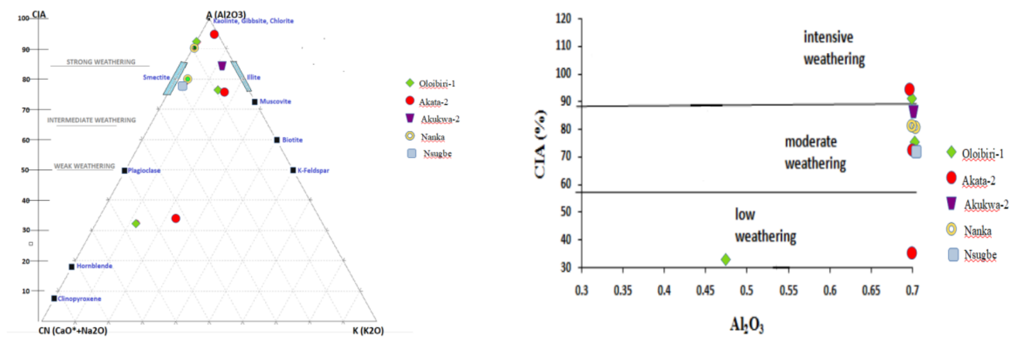
Figures 4a-c: Paleotectonics settings of the reservoirs



Figures 5a & b: Provenance settings of the reservoirs



Figures 6a & b: Paleoclimate settings of the reservoirs



Figures 7 a & b: Paleoweathering settings of the reservoirs

Conclusion:

With the application of geochemistry and petrography of subsurface Agbada Formation using various discriminating tools, the geological history of Agbada Formation reservoirs in Akata-2 and Oloibiri-1 have been inferred. The shallow Agbada reservoirs set have their provenance from Quartzose Sedimentary origin with a tectonic setting of Oceanic Island Arc which were moderately to strongly weathered in ancient times. The deep Agbada reservoirs set showed that the reservoirs are from Intermediate Igneous origin which was in Basement Uplift of the then existing Active Continental Margin paleotectonic settings which was exposed to a Semi-humid climate and was weakly to moderately. In other words, the subsurface Agbada Formation reservoirs were formed in semi humid to semi arid paleoclimatic conditions with a paleotectonics settings ranging from Basement Uplift of the Oceanic Island Arc and Active continental margin after the separation of South America from Africa. And they depict signatures of Intermediate Igneous and Quartzose Sedimentary provenance which have undergone Intermediate to strong (or intense) weathering to form immature to mature, non marine to deltaic sandstones with chemical composition ranging from Lithic Arkose, Sublithic Arenite to Quartz Arenite which host the element and minerals of interest. Thus, the deeper reservoirs are more mature and will tend to better petrophysical qualities than the shallow reservoirs. In conclusion, the most prevalent geological history for Agbada Formation reservoirs are therefore; a paleotectonics of Passive Continental Margin to Active Continental Margin, sourced from partly Intermediate to Mafic Igneous and Quartzose Sedimentary provenance under a mostly Humid to Semi-Humid Paloclimate although there were occasions of Semi-Arid climate in geologic time to produce reservoirs that are classified today as immature to sub-mature Lithic, Sublithic to Quartz Arenites.

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